Gradle User Manual

Version 8.6-milestone-1

Version 8.6-milestone-1

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OVERVIEW

Gradle User Manual

Gradle Build Tool

 Gradle Build Tool is a fast, dependable, and adaptable open-source build automation tool with an elegant and extensible declarative build language.

In this User Manual, Gradle Build Tool is abbreviated **Gradle**.

Why Gradle?

Gradle is a widely used and mature tool with an active community and a strong developer ecosystem.

- Gradle is the most popular build system for the JVM and is the default system for Android and Kotlin Multi-Platform projects. It has a rich community plugin ecosystem.

- Gradle can automate a wide range of software build scenarios using either its built-in functionality, third-party plugins, or custom build logic.

- Gradle provides a high-level, declarative, and expressive build language that makes it easy to read and write build logic.

- Gradle is fast, scalable, and can build projects of any size and complexity.

- Gradle produces dependable results while benefiting from optimizations such as incremental builds, build caching, and parallel execution.

Gradle, Inc. provides a free service called Build Scan® that provides extensive information and insights about your builds. You can view scans to identify problems or share them for debugging help.

Supported Languages and Frameworks

Gradle supports Android, Java, Kotlin Multiplatform, Groovy, Scala, Javascript, and C/C++.

Compatible IDEs

All major IDEs support Gradle, including Android Studio, IntelliJ IDEA, Visual Studio Code, Eclipse,

and NetBeans.

You can also invoke Gradle via its command-line interface (CLI) in your terminal or through your continuous integration (CI) server.

Education

The **Gradle User Manual** is the official documentation for the Gradle Build Tool.

- **Getting Started Tutorial** — Learn Gradle basics and the benefits of building your App with Gradle.
- **Training Courses** — Head over to the courses page to sign up for free Gradle training.

Support

- **Forum** — The fastest way to get help is through the Gradle Forum.
- **Slack** — Community members and core contributors answer questions directly on our Slack Channel.

Licenses

Gradle Build Tool source code is open and licensed under the Apache License 2.0. Gradle user manual and DSL reference manual are licensed under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

The User Manual

Explore our guides and examples to use Gradle.

Releases

Information on Gradle releases and how to install Gradle is found on the Installation page.

Content

The Gradle User Manual is broken down into the following sections:

Running Gradle Builds

Learn Gradle basics and how to use Gradle to build your project.

Authoring Gradle Builds

Develop tasks and plugins to customize your build.

Authoring JVM Builds

Use Gradle with your Java project.

Working with Dependencies

Add dependencies to your build.

Optimizing Builds

Use caches to optimize your build and understand the Gradle daemon, incremental builds and file system watching.

Gradle on CI

Gradle integration with popular continuous integration (CI) servers.

Reference

1. Gradle's API Javadocs

2. Gradle's Groovy DSL

3. Gradle's Kotlin DSL

4. Gradle's Core Plugins

RELEASES

Compatibility Matrix

The sections below describe Gradle's compatibility with several integrations. Versions not listed here may or may not work.

Java

A Java version between 8 and 21 is required to execute Gradle. Java 22 and later versions are not yet supported.

Java 6 and 7 can be used for compilation but are deprecated for use with testing. Testing with Java 6 and 7 will not be supported in Gradle 9.0.

Any fully supported version of Java can be used for compilation or testing. However, the latest Java version may only be supported for compilation or testing, not for running Gradle. Support is achieved using toolchains and applies to all tasks supporting toolchains.

See the table below for the Java version supported by a specific Gradle release:

Table 1. Java Compatibility

Java version	Support for compiling/testing/...	Support for running Gradle
8	N/A	2.0
9	N/A	4.3
10	N/A	4.7
11	N/A	5.0
12	N/A	5.4
13	N/A	6.0
14	N/A	6.3
15	6.7	6.7
16	7.0	7.0
17	7.3	7.3
18	7.5	7.5
19	7.6	7.6
20	8.1	8.3
21	8.4	8.5

Kotlin

Gradle is tested with Kotlin 1.6.10 through 2.0.0-Beta1. Beta and RC versions may or may not work.

Table 2. Embedded Kotlin version

Gradle version	Embedded Kotlin version	Kotlin Language version
5.0	1.3.10	1.3
5.1	1.3.11	1.3
5.2	1.3.20	1.3
5.3	1.3.21	1.3
5.5	1.3.31	1.3
5.6	1.3.41	1.3
6.0	1.3.50	1.3
6.1	1.3.61	1.3
6.3	1.3.70	1.3
6.4	1.3.71	1.3
6.5	1.3.72	1.3
6.8	1.4.20	1.3
7.0	1.4.31	1.4
7.2	1.5.21	1.4
7.3	1.5.31	1.4
7.5	1.6.21	1.4
7.6	1.7.10	1.4
8.0	1.8.10	1.8
8.2	1.8.20	1.8
8.3	1.9.0	1.8
8.4	1.9.10	1.8
8.5	1.9.20	1.8

Groovy

Gradle is tested with Groovy 1.5.8 through 4.0.0.

Gradle plugins written in Groovy must use Groovy 3.x for compatibility with Gradle and Groovy DSL build scripts.

Android

Gradle is tested with Android Gradle Plugin 7.3 through 8.1. Alpha and beta versions may or may not work.

The Feature Lifecycle

Gradle is under constant development. New versions are delivered on a regular and frequent basis (approximately every six weeks) as described in the section on end-of-life support.

Continuous improvement combined with frequent delivery allows new features to be available to users early. Early users provide invaluable feedback, which is incorporated into the development process.

Getting new functionality into the hands of users regularly is a core value of the Gradle platform.

At the same time, API and feature stability are taken very seriously and considered a core value of the Gradle platform. Design choices and automated testing are engineered into the development process and formalized by the section on backward compatibility.

The Gradle *feature lifecycle* has been designed to meet these goals. It also communicates to users of Gradle what the state of a feature is. The term *feature* typically means an API or DSL method or property in this context, but it is not restricted to this definition. Command line arguments and modes of execution (e.g. the Build Daemon) are two examples of other features.

Feature States

Features can be in one of four states:

1. Internal
2. Incubating
3. Public
4. Deprecated

1. Internal

Internal features are not designed for public use and are only intended to be used by Gradle itself. They can change in any way at any point in time without any notice. Therefore, we recommend avoiding the use of such features. *Internal* features are not documented. If it appears in this User Manual, the DSL Reference, or the API Reference, then the feature is not *internal*.

Internal features may evolve into public features.

2. Incubating

Features are introduced in the *incubating* state to allow real-world feedback to be incorporated into the feature before making it public. It also gives users willing to test potential future changes early access.

A feature in an *incubating* state may change in future Gradle versions until it is no longer *incubating*. Changes to *incubating* features for a Gradle release will be highlighted in the release notes for that release. The *incubation* period for new features varies depending on the feature's scope, complexity, and nature.

Features in *incubation* are indicated. In the source code, all methods/properties/classes that are *incubating* are annotated with incubating. This results in a special mark for them in the DSL and API references.

If an *incubating* feature is discussed in this User Manual, it will be explicitly said to be in the *incubating* state.

Feature Preview API

The feature preview API allows certain *incubating* features to be activated by adding `enableFeaturePreview('FEATURE')` in your *settings* file. Individual preview features will be announced in release notes.

When *incubating* features are either promoted to *public* or removed, the feature preview flags for them become obsolete, have no effect, and should be removed from the settings file.

3. Public

The default state for a non-internal feature is *public*. Anything documented in the User Manual, DSL Reference, or API reference that is not explicitly said to be *incubating* or *deprecated* is considered *public*. Features are said to be **promoted** from an *incubating* state to *public*. The release notes for each release indicate which previously *incubating* features are being promoted by the release.

A *public* feature will **never** be removed or intentionally changed without undergoing *deprecation*. All public features are subject to the backward compatibility policy.

4. Deprecated

Some features may be replaced or become irrelevant due to the natural evolution of Gradle. Such features will eventually be removed from Gradle after being *deprecated*. A *deprecated* feature may become stale until it is finally removed according to the backward compatibility policy.

Deprecated features are indicated to be so. In the source code, all methods/properties/classes that are *deprecated* are annotated with "@java.lang.Deprecated" which is reflected in the DSL and API References. In most cases, there is a replacement for the deprecated element, which will be described in the documentation. Using a *deprecated* feature will result in a runtime warning in Gradle's output.

The use of *deprecated* features should be avoided. The release notes for each release indicate any features being *deprecated* by the release.

Backward compatibility policy

Gradle provides backward compatibility across major versions (e.g., `1.x`, `2.x`, etc.). Once a public feature is introduced in a Gradle release, it will remain indefinitely unless deprecated. Once deprecated, it may be removed in the next major release. Deprecated features may be supported across major releases, but this is not guaranteed.

Release end-of-life Policy

Every day, a new nightly build of Gradle is created.

This contains all of the changes made through Gradle's extensive continuous integration tests during that day. Nightly builds may contain new changes that may or may not be stable.

The Gradle team creates a pre-release distribution called a release candidate (RC) for each minor or major release. When no problems are found after a short time (usually a week), the release candidate is promoted to a general availability (GA) release. If a regression is found in the release candidate, a new RC distribution is created, and the process repeats. Release candidates are supported for as long as the release window is open, but they are not intended to be used for production. Bug reports are greatly appreciated during the RC phase.

The Gradle team may create additional patch releases to replace the final release due to critical bug fixes or regressions. For instance, Gradle 5.2.1 replaces the Gradle 5.2 release.

Once a release candidate has been made, all feature development moves on to the next release for the latest major version. As such, each minor Gradle release causes the previous minor releases in the same major version to become end-of-life (EOL). EOL releases do not receive bug fixes or feature backports.

For major versions, Gradle will backport critical fixes and security fixes to the last minor in the previous major version. For example, when Gradle 7 was the latest major version, several releases were made in the 6.x line, including Gradle 6.9 (and subsequent releases).

As such, each major Gradle release causes:

- The previous major version becomes maintenance only. It will only receive critical bug fixes and security fixes.
- The major version before the previous one to become end-of-life (EOL), and that release line will not receive any new fixes.

UPGRADING

Upgrading your build from Gradle 8.x to the latest

This chapter provides the information you need to migrate your Gradle 8.x builds to the latest Gradle release. For migrating from Gradle 4.x, 5.x, 6.x, or 7.x, see the older migration guide first.

We recommend the following steps for all users:

1. Try running `gradle help --scan` and view the deprecations view of the generated build scan.
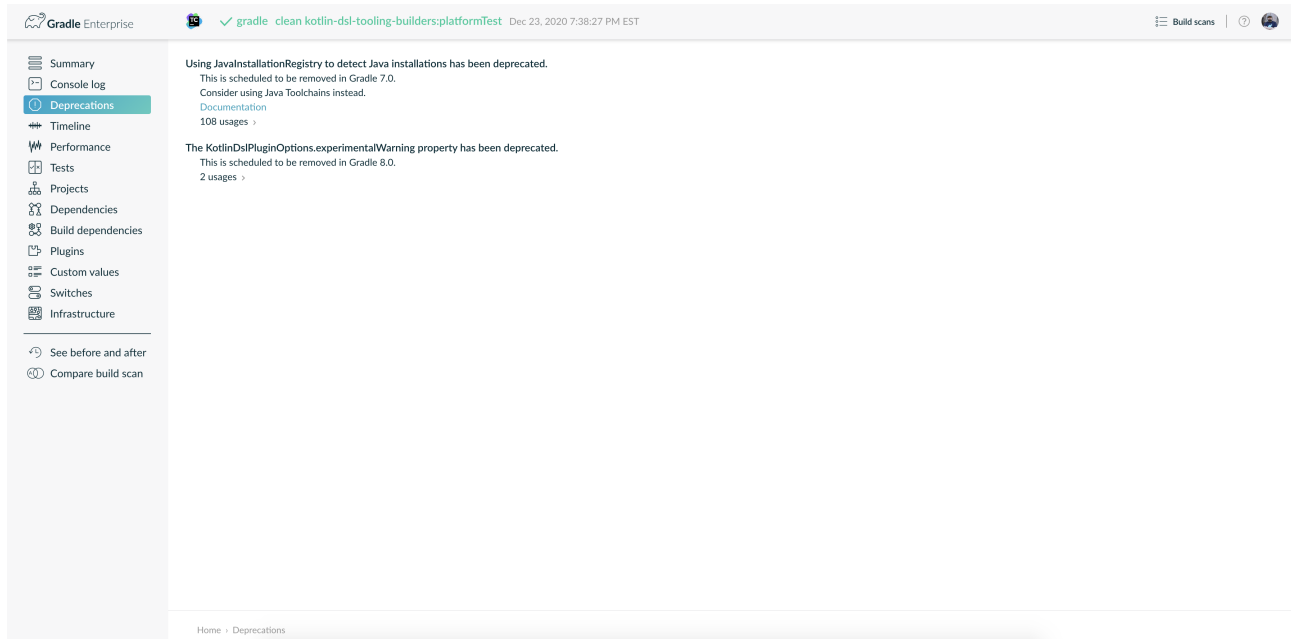
   This is so you can see any deprecation warnings that apply to your build.

   Alternatively, you can run `gradle help --warning-mode=all` to see the deprecations in the console, though it may not report as much detailed information.

2. Update your plugins.

   Some plugins will break with this new version of Gradle, for example because they use internal APIs that have been removed or changed. The previous step will help you identify potential problems by issuing deprecation warnings when a plugin does try to use a deprecated part of the API.

3. Run `gradle wrapper --gradle-version 8.6-milestone-1` to update the project to 8.6-milestone-1.

4. Try to run the project and debug any errors using the Troubleshooting Guide.

Upgrading from 8.5 and earlier

Potential breaking changes

Upgrade to JaCoCo 0.8.11

JaCoCo has been updated to 0.8.11.

Deprecations

Deprecated calling `registerFeature` **using the** `main` **source set**

Calling `registerFeature` on the `java` extension using the `main` source set is deprecated and will change behavior in Gradle 9.0.

Currently, features created while calling `usingSourceSet` with the `main` source set are initialized differently than features created while calling `usingSourceSet` with any other source set. Previously, when using the `main` source set, new `implementation`, `compileOnly`, `runtimeOnly`, `api`, and `compileOnlyApi` configurations were created, and the compile and runtime classpaths of the `main` source set were configured to extend these configurations.

Starting in Gradle 9.0, the `main` source set will be treated like any other source set. With the `java-library` plugin applied (or any other plugin that applies the `java` plugin), calling `usingSourceSet` with the `main` source set will throw an exception. This is because the `java` plugin already configures a main feature. Only if the `java` plugin is not applied will the `main` source set be permitted when calling `usingSourceSet`.

Code that currently registers features with the main source set, like so:

build.gradle.kts

```
plugins {
    id("java-library")
}

java {
    registerFeature("feature") {
        usingSourceSet(sourceSets["main"])
    }
}
```

build.gradle

```
plugins {
    id("java-library")
}

java {
    registerFeature("feature") {
        usingSourceSet(sourceSets.main)
    }
}
```

Should instead create a separate source set for the feature, and register the feature with that source set:

build.gradle.kts

```
plugins {
    id("java-library")
}

sourceSets {
    create("feature")
}

java {
    registerFeature("feature") {
        usingSourceSet(sourceSets["feature"])
    }
}
```

build.gradle

```
plugins {
    id("java-library")
}

sourceSets {
    feature
}

java {
    registerFeature("feature") {
        usingSourceSet(sourceSets.feature)
    }
}
```

Deprecated `ArtifactIdentifier`

The `ArtifactIdentifier` class has been deprecated for removal in Gradle 9.0.

Upgrading from 8.4 and earlier

Potential breaking changes

Upgrade to Kotlin 1.9.20

The embedded Kotlin has been updated to Kotlin 1.9.20.

Changes to Groovy task conventions

The `groovy-base` plugin is now responsible for configuring source and target compatibility version conventions on all `GroovyCompile` tasks.

If you are using this task **without applying `grooy-base`**, you will have to manually set compatibility versions on these tasks. In general, the `groovy-base` plugin should be applied whenever working with Groovy language tasks.

Provider.filter

The type of the argument passed to `Provider.filter` is changed from `Predicate` to `Spec` for a more consistent API. This change should not affect anyone using `Provider.filter` with a lambda expression. However, this might affect plugin authors if they don't use SAM conversions to create a lambda.

Deprecations

Deprecated members of the `org.gradle.util` package now report their deprecation

These members will be removed in Gradle 9.0:

- `VersionNumber.parse(String)`

- `VersionNumber.compareTo(VersionNumber)`

Deprecated depending on resolved configuration

When resolving a `Configuration`, it is sometimes possible to select that same configuration as a variant. Configurations should be used for one purpose (resolution, consumption or dependency declarations), so this can only occur when a configuration is marked as both consumable and resolvable.

This can lead to confusing circular dependency graphs, as the configuration being resolved is used for two different purposes.

To avoid this problem, plugins should mark all resolvable configurations as `canBeConsumed=false` or use the `resolvable(String)` configuration factory method when creating configurations meant for resolution.

In Gradle 9.0, consuming configurations in this manner will no longer be allowed and will result in an error.

Including projects without an existing directory

Gradle will warn if a project is added to the build where the associated `projectDir` does not exist or is not writable. Starting with version 9.0, Gradle will not run builds if a project directory is missing or read-only. If you intend to dynamically synthesize projects make sure to create directories for them as well:

```
include("project-without-directory")
project(":project-without-directory").projectDir.mkdirs()
```

```
include 'project-without-directory'
project(":project-without-directory").projectDir.mkdirs()
```

Upgrading from 8.3 and earlier

Potential breaking changes

Upgrade to Kotlin 1.9.10

The embedded Kotlin has been updated to [Kotlin 1.9.10](#).

XML parsing now requires recent parsers

Gradle 8.4 now configures XML parsers with security features enabled. If your build logic has dependencies on old XML parsers that don't support secure parsing, your build may now fail. If you encounter a failure, check and update or remove any dependency on legacy XML parsers.

If you are unable to upgrade XML parsers coming from your build logic dependencies, you can force the use of the XML parsers built into the JVM. For example, in OpenJDK this can be done by adding the following to `gradle.properties`:

```
systemProp.javax.xml.parsers.SAXParserFactory=com.sun.org.apache.xerces.internal.jaxp.
SAXParserFactoryImpl
systemProp.javax.xml.transform.TransformerFactory=com.sun.org.apache.xalan.internal.xs
ltc.trax.TransformerFactoryImpl
systemProp.javax.xml.parsers.DocumentBuilderFactory=com.sun.org.apache.xerces.internal
.jaxp.DocumentBuilderFactoryImpl
```

See the [CVE-2023-42445](#) advisory for more details and ways to enable secure XML processing on previous Gradle versions.

EAR plugin with customized JEE 1.3 descriptor

Gradle 8.4 forbids external XML entities when parsing XML documents. If you use the EAR plugin and configure the `application.xml` descriptor via the EAR plugin's DSL and customize the descriptor using `withXml {}` and use `asElement{}` in the customization block, then the build will now fail for

security reasons.

build.gradle.kts

```
plugins {
    id("ear")
}
ear {
    deploymentDescriptor {
        version = "1.3"
        withXml {
            asElement()
        }
    }
}
```

build.gradle

```
plugins {
    id("ear")
}
ear {
    deploymentDescriptor {
        version = "1.3"
        withXml {
            asElement()
        }
    }
}
```

If you happen to use `asNode()` instead of `asElement()` then nothing changes given `asNode()` simply ignores external DTDs.

You can work around this by running your build with the `javax.xml.accessExternalDTD` system property set to `http`.

On the command line, add this to your Gradle invocation:

```
-Djavax.xml.accessExternalDTD=http
```

To make this workaround persistent, add the following line to your `gradle.properties`:

```
systemProp.javax.xml.accessExternalDTD=http
```

Note that this will enable HTTP access to external DTDs for the whole build JVM. See the JAXP documentation for more details.

Deprecations

Deprecated `GenerateMavenPom` methods

The following methods on `GenerateMavenPom` are deprecated and will be removed in Gradle 9.0. They were never intended to be public API.

- `getVersionRangeMapper`
- `withCompileScopeAttributes`
- `withRuntimeScopeAttributes`

Upgrading from 8.2 and earlier

Potential breaking changes

Deprecated `Project.buildDir` can cause script compilation failure

With the deprecation of `Project.buildDir`, buildscripts that are compiled with warnings as errors could fail if the deprecated field is used.

See the deprecation entry for details.

`TestLauncher` API no longer ignores build failures

The `TestLauncher` interface is part of the Tooling API, specialized for running tests. It is a logical extension of the `BuildLauncher` that can only launch tasks. A discrepancy has been reported in their behavior: if the same failing test is executed, `BuildLauncher` will report a build failure but `TestLauncher` won't. Originally, this was a design decision in order to continue the execution and run the tests in all test tasks and not stop at the first failure. At the same time, this behavior can be confusing for users as they can experience a failing test in a successful build. To make the two APIs more uniform, we made `TestLauncher` also fail the build, which is a potential breaking change. To continue the test execution even if a test task failed, Tooling API clients should explicitly pass `--continue` to the build.

Fixed variant selection behavior with `ArtifactView` and `ArtifactCollection`

The dependency resolution APIs for selecting different artifacts or files (`Configuration.getIncoming().artifactView { }` and `Configuration.getIncoming().getArtifacts()`) captured immutable copies of the underlying `Configuration`'s attributes to use for variant selection. If the `Configuration`'s attributes were changed after these methods were called, the artifacts selected by these methods could be unexpected.

Consider the case where the set of attributes on a `Configuration` is changed after an `ArtifactView` is created.

```
tasks {
    myTask {
        inputFiles.from(configurations.classpath.incoming.artifactView {
            attributes {
                // Add attributes to select a different type of artifact
            }
        }.files)
    }
}

configurations {
    classpath {
        attributes {
            // Add more attributes to the configuration
        }
    }
}
```

The `inputFiles` property of `myTask` uses an artifact view to select a different type of artifact from the configuration `classpath`. Since the artifact view was created before the attributes were added to the configuration, Gradle was not able to select the correct artifact.

Some builds may have worked around this by also putting the additional attributes into the artifact view. This is no longer necessary.

Upgrade to Kotlin 1.9.0

The embedded Kotlin has been updated from 1.8.20 to Kotlin 1.9.0. The Kotlin language and API levels for the Kotlin DSL are still set to 1.8 for backwards compatibility. See the release notes for Kotlin 1.8.22 and Kotlin 1.8.21.

Kotlin 1.9 dropped support for Kotlin language and API level 1.3. If you build Gradle plugins written in Kotlin with this version of Gradle and need to support Gradle <7.0 you need to stick to using the Kotlin Gradle Plugin <1.9.0 and configure the Kotlin language and API levels to 1.3. See the Compatibility Matrix for details about other versions.

Eager evaluation of `Configuration` attributes

Gradle 8.3 updates the `org.gradle.libraryelements` and `org.gradle.jvm.version` attributes of JVM Configurations to be present at the time of creation, as opposed to previously, where they were only present after the Configuration had been resolved or consumed. In particular, the value for `org.gradle.jvm.version` relies on the project's configured toolchain, meaning that querying the value for this attribute will finalize the value of the project's Java toolchain.

Plugins or build logic that eagerly queries the attributes of JVM configurations may now cause the

project's Java toolchain to be finalized earlier than before. Attempting to modify the toolchain after it has been finalized will result in error messages similar to the following:

```
The value for property 'implementation' is final and cannot be changed any further.
The value for property 'languageVersion' is final and cannot be changed any further.
The value for property 'vendor' is final and cannot be changed any further.
```

This situation may arise when plugins or build logic eagerly queries an existing JVM Configuration's attributes to create a new Configuration with the same attributes. Previously, this logic would have omitted the two above noted attributes entirely, while now the same logic will copy the attributes and finalize the project's Java toolchain. To avoid early toolchain finalization, attribute-copying logic should be updated to query the source Configuration's attributes lazily:

build.gradle.kts

```
fun <T> copyAttribute(attribute: Attribute<T>, from: AttributeContainer, to:
AttributeContainer) =
    to.attributeProvider<T>(attribute, provider {
from.getAttribute(attribute)!! })

val source = configurations["runtimeClasspath"].attributes
configurations {
    create("customRuntimeClasspath") {
        source.keySet().forEach { key ->
            copyAttribute(key, source, attributes)
        }
    }
}
```

build.gradle

```
def source = configurations.runtimeClasspath.attributes
configurations {
    customRuntimeClasspath {
        source.keySet().each { key ->
            attributes.attributeProvider(key, provider { source.getAttribute
(key) })
        }
    }
}
```

Deprecations

Deprecated `Project.buildDir` is to be replaced by `Project.layout.buildDirectory`

The `Project.buildDir` property is deprecated. It uses eager APIs and has ordering issues if the value is read in build logic and then later modified. It could result in outputs ending up in different locations.

It is replaced by a `DirectoryProperty` found at `Project.layout.buildDirectory`. See the `ProjectLayout` interface for details.

Note that, at this stage, Gradle will not print deprecation warnings if you still use `Project.buildDir`. We know this is a big change and want to give time for authors of major plugins to move away from its usage first.

The switch from a `File` to a `DirectoryProperty` requires adaptations in build logic. The main impact is that you cannot use the property inside a `String` to expand it. Instead, you should leverage the `dir` and `file` methods to compute the location you want.

Here is an example for creating a file, where the following:

build.gradle.kts

```
// Returns a java.io.File
file("$buildDir/myOutput.txt")
```

build.gradle

```
// Returns a java.io.File
file("$buildDir/myOutput.txt")
```

should be replaced by:

build.gradle.kts

```kotlin
// Compatible with a number of Gradle lazy APIs that accept also java.io.File
val output: Provider<RegularFile> =
layout.buildDirectory.file("myOutput.txt")

// If you really need the java.io.File for a non lazy API
output.get().asFile

// Or a path for a lazy String based API
output.map { it.asFile.path }
```

build.gradle

```groovy
// Compatible with a number of Gradle lazy APIs that accept also java.io.File
Provider<RegularFile> output = layout.buildDirectory.file("myOutput.txt")

// If you really need the java.io.File for a non lazy API
output.get().asFile

// Or a path for a lazy String based API
output.map { it.asFile.path }
```

Here is another example for creating a directory, where the following:

build.gradle.kts

```kotlin
// Returns a java.io.File
file("$buildDir/outputLocation")
```

build.gradle

```groovy
// Returns a java.io.File
file("$buildDir/outputLocation")
```

should be replaced by:

build.gradle.kts

```kotlin
// Compatible with a number of Gradle APIs that accept a java.io.File
val output: Provider<Directory> = layout.buildDirectory.dir("outputLocation")

// If you really need the java.io.File for a non lazy API
output.get().asFile

// Or a path for a lazy String based API
output.map { it.asFile.path }
```

build.gradle

```groovy
// Compatible with a number of Gradle APIs that accept a java.io.File
Provider<Directory> output = layout.buildDirectory.dir("outputLocation")

// If you really need the java.io.File for a non lazy API
output.get().asFile

// Or a path for a lazy String based API
output.map { it.asFile.path }
```

Deprecated `ClientModule` dependencies

`ClientModule` dependencies are deprecated and will be removed in Gradle 9.0.

Client module dependencies were originally intended to allow builds to override incorrect or missing component metadata of external dependencies by defining the metadata locally. This functionality has since been replaced by Component Metadata Rules.

Consider the following client module dependency example:

build.gradle.kts

```
dependencies {
    implementation(module("org:foo:1.0") {
        dependency("org:bar:1.0")
        module("org:baz:1.0") {
            dependency("com:example:1.0")
        }
    })
}
```

build.gradle

```
dependencies {
    implementation module("org:foo:1.0") {
        dependency "org:bar:1.0"
        module("org:baz:1.0") {
            dependency "com:example:1.0"
        }
    }
}
```

This can be replaced with the following component metadata rule:

build-logic/src/main/kotlin/my-plugin.gradle.kts

```kotlin
@CacheableRule
abstract class AddDependenciesRule @Inject constructor(val dependencies:
List<String>) : ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        listOf("compile", "runtime").forEach { base ->
            context.details.withVariant(base) {
                withDependencies {
                    dependencies.forEach {
                        add(it)
                    }
                }
            }
        }
    }
}
```

build.gradle.kts

```kotlin
dependencies {
    components {
        withModule<AddDependenciesRule>("org:foo") {
            params(listOf(
                "org:bar:1.0",
                "org:baz:1.0"
            ))
        }
        withModule<AddDependenciesRule>("org:baz") {
            params(listOf("com:example:1.0"))
        }
    }

    implementation("org:foo:1.0")
}
```

build-logic/src/main/groovy/my-plugin.gradle

```groovy
@CacheableRule
abstract class AddDependenciesRule implements ComponentMetadataRule {

    List<String> dependencies

    @Inject
    AddDependenciesRule(List<String> dependencies) {
        this.dependencies = dependencies
    }

    @Override
    void execute(ComponentMetadataContext context) {
        ["compile", "runtime"].each { base ->
            context.details.withVariant(base) {
                withDependencies {
                    dependencies.each {
                        add(it)
                    }
                }
            }
        }
    }
}
```

build.gradle

```groovy
dependencies {
    components {
        withModule("org:foo", AddDependenciesRule) {
            params([
                "org:bar:1.0",
                "org:baz:1.0"
            ])
        }
        withModule("org:baz", AddDependenciesRule) {
            params(["com:example:1.0"])
        }
    }

    implementation "org:foo:1.0"
}
```

Earliest supported Develocity plugin version is 3.13.1

Starting in Gradle 9.0, the earliest supported Develocity plugin version is 3.13.1. The plugin versions

from 3.0 up to 3.13 will be ignored when applied.

Upgrade to version 3.13.1 or later of the Develocity plugin. You can find the latest available version on the Gradle Plugin Portal. More information on the compatibility can be found here.

Upgrading from 8.1 and earlier

Potential breaking changes

Upgrade to Kotlin 1.8.20

The embedded Kotlin has been updated to Kotlin 1.8.20. For more information, see What's new in Kotlin 1.8.20.

Note that there is a known issue with Kotlin compilation avoidance that can cause `OutOfMemory` exceptions in `compileKotlin` tasks if the compilation classpath contains very large JAR files. This applies to builds applying the Kotlin plugin v1.8.20 or the `kotlin-dsl` plugin.

You can work around it by disabling Kotlin compilation avoidance in your `gradle.properties` file:

```
kotlin.incremental.useClasspathSnapshot=false
```

See KT-57757 for more information.

Upgrade to Groovy 3.0.17

Groovy has been updated to Groovy 3.0.17.

Since the previous version was 3.0.15, the 3.0.16 changes are also included.

Upgrade to Ant 1.10.13

Ant has been updated to Ant 1.10.13.

Since the previous version was 1.10.11, the 1.10.12 changes are also included.

Upgrade to CodeNarc 3.2.0

The default version of CodeNarc has been updated to CodeNarc 3.2.0.

Upgrade to PMD 6.55.0

PMD has been updated to PMD 6.55.0.

Since the previous version was 6.48.0, all changes since then are included.

Upgrade to JaCoCo 0.8.9

JaCoCo has been updated to 0.8.9.

Plugin compatibility changes

A plugin compiled with Gradle >= 8.2 that makes use of the Kotlin DSL functions `Project.the<T>()`, `Project.the(KClass)` or `Project.configure<T> {}` cannot run on Gradle ⇐ 6.1.

Deferred or avoided configuration of some tasks

When performing dependency resolution, Gradle creates an internal representation of the available Configurations. This requires inspecting all configurations and artifacts. Processing artifacts created by tasks causes those tasks to be realized and configured.

This internal representation is now created more lazily, which can change the order in which tasks are configured. Some tasks may never be configured.

This change may cause code paths that relied on a particular order to no longer function, such as conditionally adding attributes to a configuration based on the presence of certain attributes.

This impacted the bnd plugin and JUnit5 build.

We recommend not modifying domain objects (configurations, source sets, tasks, etc) from configuration blocks for other domain objects that may not be configured.

For example, avoid doing something like this:

```
configurations {
    val myConfig = create("myConfig")
}

tasks.register("myTask") {
        // This is not safe, as the execution of this block may not occur, or may
not occur in the order expected
        configurations["myConfig"].attributes {
            attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage::class.java,
Usage.JAVA_RUNTIME))
        }
    }
```

Deprecations

`CompileOptions` **method deprecations**

The following methods on `CompileOptions` are deprecated:

- `getAnnotationProcessorGeneratedSourcesDirectory()`

- `setAnnotationProcessorGeneratedSourcesDirectory(File)`

- `setAnnotationProcessorGeneratedSourcesDirectory(Provider<File>)`

Current usages of these methods should migrate to `DirectoryProperty` `getGeneratedSourceOutputDirectory()`

Using configurations incorrectly

Gradle will now warn at runtime when methods of Configuration are called inconsistently with the configuration's intended usage.

This change is part of a larger ongoing effort to make the intended behavior of configurations more consistent and predictable, and to unlock further speed and memory improvements.

Currently, the following methods should only be called with these listed allowed usages:

- `resolve()` - RESOLVABLE configurations only
- `files(Closure)`, `files(Spec)`, `files(Dependency…)`, `fileCollection(Spec)`, `fileCollection(Closure)`, `fileCollection(Dependency…)` - RESOLVABLE configurations only
- `getResolvedConfigurations()` - RESOLVABLE configurations only
- `defaultDependencies(Action)` - DECLARABLE configurations only
- `shouldResolveConsistentlyWith(Configuration)` - RESOLVABLE configurations only
- `disableConsistentResolution()` - RESOLVABLE configurations only
- `getDependencyConstraints()` - DECLARABLE configurations only
- `copy()`, `copy(Spec)`, `copy(Closure)`, `copyRecursive()`, `copyRecursive(Spec)`, `copyRecursive(Closure)` - RESOLVABLE configurations only

Intended usage is noted in the `Configuration` interface's Javadoc. This list is likely to grow in future releases.

Starting in Gradle 9.0, using a configuration inconsistently with its intended usage will be prohibited.

Also note that although it is not currently restricted, the `getDependencies()` method is really only intended for use with DECLARABLE configurations. The `getAllDependencies()` method, which retrieves all declared dependencies on a configuration and any superconfigurations, will not be restricted to any particular usage.

Deprecated access to plugin conventions

The concept of conventions is outdated and superseded by extensions to provide custom DSLs.

To reflect this in the Gradle API, the following elements are deprecated:

- org.gradle.api.Project.getConvention()
- org.gradle.api.plugins.Convention
- `org.gradle.api.internal.HasConvention`

Gradle Core plugins still register their conventions in addition to their extensions for backwards compatibility.

It is deprecated to access any of these conventions and their properties. Doing so will now emit a deprecation warning. This will become an error in Gradle 9.0. You should prefer accessing the extensions and their properties instead.

For specific examples see the next sections.

Prominent community plugins already migrated to using extensions to provide custom DSLs. Some of them still registers conventions for backwards compatibility. Registering conventions does not emit a deprecation warning yet to provide a migration window. Future Gradle versions will do.

Also note that Plugins compiled with Gradle ⇐ 8.1 that make use of the Kotlin DSL functions `Project.the<T>()`, `Project.the(KClass)` or `Project.configure<T> {}` will emit a deprecation warning when run on Gradle >= 8.2. To fix this these plugins should be recompiled with Gradle >= 8.2 or changed to access extensions directly using `extensions.getByType<T>()` instead.

Deprecated `base` plugin conventions

The convention properties contributed by the `base` plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The conventions are replaced by the `base { }` configuration block backed by BasePluginExtension. The old convention object defines the `distsDirName`, `libsDirName` and `archivesBaseName` properties with simple getter and setter methods. Those methods are available in the extension only to maintain backwards compatibility. Build scripts should solely use the properties of type `Property`:

build.gradle.kts

```
plugins {
    base
}

base {
    archivesName.set("gradle")
    distsDirectory.set(layout.buildDirectory.dir("custom-dist"))
    libsDirectory.set(layout.buildDirectory.dir("custom-libs"))
}
```

build.gradle

```
plugins {
    id 'base'
}

base {
    archivesName = "gradle"
    distsDirectory = layout.buildDirectory.dir('custom-dist')
    libsDirectory = layout.buildDirectory.dir('custom-libs')
}
```

Deprecated `application` plugin conventions

The convention properties contributed by the `application` plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The following code will now emit deprecation warnings:

build.gradle.kts

```
plugins {
    application
}

applicationDefaultJvmArgs = listOf("-Dgreeting.language=en") // Accessing a
convention
```

build.gradle

```
plugins {
    id 'application'
}

applicationDefaultJvmArgs = ['-Dgreeting.language=en'] // Accessing a
convention
```

This should be changed to use the `application { }` configuration block, backed by JavaApplication, instead:

build.gradle.kts

```kotlin
plugins {
    application
}

application {
    applicationDefaultJvmArgs = listOf("-Dgreeting.language=en")
}
```

build.gradle

```groovy
plugins {
    id 'application'
}

application {
    applicationDefaultJvmArgs = ['-Dgreeting.language=en']
}
```

Deprecated `java` plugin conventions

The convention properties contributed by the `java` plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The following code will now emit deprecation warnings:

build.gradle.kts

```kotlin
plugins {
    id("java")
}

configure<JavaPluginConvention> { // Accessing a convention
    sourceCompatibility = JavaVersion.VERSION_18
}
```

build.gradle

```groovy
plugins {
    id 'java'
}

sourceCompatibility = 18 // Accessing a convention
```

This should be changed to use the `java { }` configuration block, backed by JavaPluginExtension, instead:

build.gradle.kts

```kotlin
plugins {
    id("java")
}

java {
    sourceCompatibility = JavaVersion.VERSION_18
}
```

build.gradle

```groovy
plugins {
    id 'java'
}

java {
    sourceCompatibility = JavaVersion.VERSION_18
}
```

Deprecated `war` plugin conventions

The convention properties contributed by the `war` plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The following code will now emit deprecation warnings:

build.gradle.kts

```kotlin
plugins {
    id("war")
}

configure<WarPluginConvention> { // Accessing a convention
    webAppDirName = "src/main/webapp"
}
```

build.gradle

```groovy
plugins {
    id 'war'
}

webAppDirName = 'src/main/webapp' // Accessing a convention
```

Clients should configure the `war` task directly. Also, [tasks.withType(War.class).configureEach(...)](#) can be used to configure each task of type `War`.

```
plugins {
    id("war")
}

tasks.war {
    webAppDirectory.set(file("src/main/webapp"))
}
```

```
plugins {
    id 'war'
}

war {
    webAppDirectory = file('src/main/webapp')
}
```

Deprecated ear plugin conventions

The convention properties contributed by the ear plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The following code will now emit deprecation warnings:

build.gradle.kts

```kotlin
plugins {
    id("ear")
}

configure<EarPluginConvention> { // Accessing a convention
    appDirName = "src/main/app"
}
```

build.gradle

```groovy
plugins {
    id 'ear'
}

appDirName = 'src/main/app' // Accessing a convention
```

Clients should configure the `ear` task directly. Also, tasks.withType(Ear.class).configureEach(…) can be used to configure each task of type `Ear`.

```kotlin
plugins {
    id("ear")
}

tasks.ear {
    appDirectory.set(file("src/main/app"))
}
```

build.gradle

```groovy
plugins {
    id 'ear'
}

ear {
    appDirectory = file('src/main/app')  // use application metadata found in
    this folder
}
```

Deprecated `project-report` plugin conventions

The convention properties contributed by the `project-reports` plugin have been deprecated and scheduled for removal in Gradle 9.0. For the wider context see the section about plugin convention deprecation.

The following code will now emit deprecation warnings:

build.gradle.kts

```
plugins {
    `project-report`
}

configure<ProjectReportsPluginConvention> {
    projectReportDirName = "custom" // Accessing a convention
}
```

build.gradle

```
plugins {
    id 'project-report'
}

projectReportDirName = "custom" // Accessing a convention
```

Configure your report task instead:

build.gradle.kts

```
plugins {
    `project-report`
}

tasks.withType<HtmlDependencyReportTask>() {

projectReportDirectory.set(project.layout.buildDirectory.dir("reports/custom"
))
}
```

build.gradle

```
plugins {
    id 'project-report'
}

tasks.withType(HtmlDependencyReportTask) {
    projectReportDirectory = project.layout.buildDirectory.dir(
"reports/custom")
}
```

Redundant configuration usage activation

Calling `setCanBeConsumed(boolean)` or `setCanBeResolved(boolean)` on a configuration that already allows that usage is deprecated.

This deprecation is intended to help users identify unnecessary configuration usage modifications.

`Configuration` **method deprecations**

The following method on `Configuration` is deprecated for removal:

- `getAll()`

Obtain the set of all configurations from the project's `configurations` container instead.

Relying on automatic test framework implementation dependencies

In some cases, Gradle will load JVM test framework dependencies from the Gradle distribution in order to execute tests. This existing behavior can lead to test framework dependency version conflicts on the test classpath. To avoid these conflicts, this behavior is deprecated and will be removed in Gradle 9.0. Tests using TestNG are unaffected.

In order to prepare for this change in behavior, either declare the required dependencies explicitly,

or migrate to Test Suites, where these dependencies are managed automatically.

Test Suites

Builds that use test suites will not be affected by this change. Test suites manage the test framework dependencies automatically and do not require dependencies to be explicitly declared. See the user manual for further information on migrating to test suites.

Manually declaring dependencies

In the absence of test suites, dependencies must be manually declared on the test runtime classpath:

- If using JUnit 5, an explicit `runtimeOnly` dependency on `junit-platform-launcher` is required in addition to the existing `implementation` dependency on the test engine.

- If using JUnit 4, only the existing `implementation` dependency on `junit` 4 is required.

- If using JUnit 3, a test `runtimeOnly` dependency on `junit` 4 is required in addition to a `compileOnly` dependency on `junit` 3.

build.gradle.kts

```
dependencies {
    // If using JUnit Jupiter
    testImplementation("org.junit.jupiter:junit-jupiter:5.9.2")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")

    // If using JUnit Vintage
    testCompileOnly("junit:junit:4.13.2")
    testRuntimeOnly("org.junit.vintage:junit-vintage-engine:5.9.2")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")

    // If using JUnit 4
    testImplementation("junit:junit:4.13.2")

    // If using JUnit 3
    testCompileOnly("junit:junit:3.8.2")
    testRuntimeOnly("junit:junit:4.13.2")
}
```

build.gradle

```
dependencies {
    // If using JUnit Jupiter
    testImplementation 'org.junit.jupiter:junit-jupiter:5.9.2'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'

    // If using JUnit Vintage
    testCompileOnly 'junit:junit:4.13.2'
    testRuntimeOnly 'org.junit.vintage:junit-vintage-engine:5.9.2'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'

    // If using JUnit 4
    testImplementation 'junit:junit:4.13.2'

    // If using JUnit 3
    testCompileOnly 'junit:junit:3.8.2'
    testRuntimeOnly 'junit:junit:4.13.2'
}
```

`BuildIdentifier` **and** `ProjectComponentSelector` **method deprecations**

The following methods on `BuildIdentifier` are deprecated:

- `getName()`

- `isCurrentBuild()`

You could use these methods to distinguish between different project components with the same name but from different builds. However, for certain composite build setups, these methods do not provide enough information to guarantee uniqueness.

Current usages of these methods should migrate to `BuildIdentifier.getBuildPath()`.

Similarly, the method `ProjectComponentSelector.getBuildName()` is deprecated. Use `ProjectComponentSelector.getBuildPath()` instead.

Upgrading from 8.0 and earlier

CACHEDIR.TAG files are created in global cache directories

Gradle now emits a `CACHEDIR.TAG` file in some global cache directories, as specified in Cache marking.

This may cause these directories to no longer be searched or backed up by some tools. To disable it, use the following code in an init script in the Gradle User Home:

init.gradle.kts

```
beforeSettings {
    caches {
        // Disable cache marking for all caches
        markingStrategy.set(MarkingStrategy.NONE)
    }
}
```

init.gradle

```
beforeSettings { settings ->
    settings.caches {
        // Disable cache marking for all caches
        markingStrategy = MarkingStrategy.NONE
    }
}
```

Configuration cache options renamed

In this release, the configuration cache feature was promoted from incubating to stable, and as such, all properties originally mentioned in the feature documentation (which had an `unsafe` part in their names, e.g. `org.gradle.unsafe.configuration-cache`) were renamed, in some cases, by just removing the `unsafe` bit.

Incubating property	Finalized property
`org.gradle.unsafe.configuration-cache`	`org.gradle.configuration-cache`
`org.gradle.unsafe.configuration-cache-problems`	`org.gradle.configuration-cache.problems`*
`org.gradle.unsafe.configuration-cache.max-problems`	`org.gradle.configuration-cache.max-problems`

Note that the original `org.gradle.unsafe.configuration-cache`… properties continue to be honored in this release, and no warnings will be produced if they are used, but they will be deprecated and removed in a future release.

Potential breaking changes

Kotlin DSL scripts emit compilation warnings

Compilation warnings from Kotlin DSL scripts are printed to the console output. For example, the use of deprecated APIs in Kotlin DSL will emit warnings each time the script is compiled.

This is a potentially breaking change if you are consuming the console output of Gradle builds.

Configuring Kotlin compiler options with the `kotlin-dsl` plugin applied

If you are configuring custom Kotlin compiler options on a project with the kotlin-dsl plugin applied you might encounter a breaking change.

In previous Gradle versions, the `kotlin-dsl` plugin was adding required compiler arguments on afterEvaluate {}. Now that the Kotlin Gradle Plugin provides lazy configuration properties, our `kotlin-dsl` plugin switched to adding required compiler arguments to the lazy properties directly. As a consequence, if you were setting `freeCompilerArgs` the `kotlin-dsl` plugin is now failing the build because its required compiler arguments are overridden by your configuration.

```
build.gradle.kts

plugins {
    `kotlin-dsl`
}

tasks.withType(KotlinCompile::class).configureEach {
    kotlinOptions { // Deprecated non-lazy configuration options
        freeCompilerArgs = listOf("-Xcontext-receivers")
    }
}
```

With the configuration above you would get the following build failure:

```
* What went wrong
Execution failed for task ':compileKotlin'.
> Kotlin compiler arguments of task ':compileKotlin' do not work for the `kotlin-dsl`
  plugin. The 'freeCompilerArgs' property has been reassigned. It must instead be
  appended to. Please use 'freeCompilerArgs.addAll(\"your\", \"args\")' to fix this.
```

You must change this to adding your custom compiler arguments to the lazy configuration properties of the Kotlin Gradle Plugin in order for them to be appended to the ones required by the kotlin-dsl plugin:

```
build.gradle.kts

plugins {
    `kotlin-dsl`
}

tasks.withType(KotlinCompile::class).configureEach {
    compilerOptions { // New lazy configuration options
        freeCompilerArgs.addAll("-Xcontext-receivers")
    }
}
```

If you were already adding to freeCompilerArgs instead of setting its value, then you should not experience a build failure.

New API introduced may clash with existing Gradle DSL code

When a new property or method is added to an existing type in the Gradle DSL, it may clash with

names already in use in user code.

When a name clash occurs, one solution is to rename the element in user code.

This is a non-exhaustive list of API additions in 8.1 that may cause name collisions with existing user code.

- `JavaExec.getJvmArguments()`
- `JavaExecSpec.getJvmArguments()`

Using unsupported API to start external processes at configuration time is no longer allowed with the configuration cache enabled

Since Gradle 7.5, using `Project.exec`, `Project.javaexec`, and standard Java and Groovy APIs to run external processes at configuration time has been considered an error only if the feature preview `STABLE_CONFIGURATION_CACHE` was enabled. With the configuration cache promotion to a stable feature in Gradle 8.1, this error is detected regardless of the feature preview status. The configuration cache chapter has more details to help with the migration to the new provider-based APIs to execute external processes at configuration time.

Builds that do not use the configuration cache, or only start external processes at execution time are not affected by this change.

Deprecations

Mutating core plugin configuration usage

The allowed usage of a configuration should be immutable after creation. Mutating the allowed usage on a configuration created by a Gradle core plugin is deprecated. This includes calling any of the following `Configuration` methods:

- `setCanBeConsumed(boolean)`
- `setCanBeResolved(boolean)`

These methods now emit deprecation warnings on these configurations, except for certain special cases which make allowances for the existing behavior of popular plugins. This rule does not yet apply to detached configurations or configurations created in buildscripts and third-party plugins. Calling `setCanBeConsumed(false)` on `apiElements` or `runtimeElements` is not yet deprecated in order to avoid warnings that would be otherwise emitted when using select popular third-party plugins.

This change is part of a larger ongoing effort to make the intended behavior of configurations more consistent and predictable, and to unlock further speed and memory improvements in this area of Gradle.

The ability to change the allowed usage of a configuration after creation will be removed in Gradle 9.0.

Reserved configuration names

Configuration names "detachedConfiguration" and "detachedConfigurationX" (where X is any integer) are reserved for internal use when creating detached configurations.

The ability to create non-detached configurations with these names will be removed in Gradle 9.0.

Calling select methods on the `JavaPluginExtension` without the `java` component present

Starting in Gradle 8.1, calling any of the following methods on `JavaPluginExtension` without the presence of the default `java` component is deprecated:

- `withJavadocJar()`
- `withSourcesJar()`
- `consistentResolution(Action)`

This `java` component is added by the `JavaPlugin`, which is applied by any of the Gradle JVM plugins including:

- `java-library`
- `application`
- `groovy`
- `scala`

Starting in Gradle 9.0, calling any of the above listed methods without the presence of the default `java` component will become an error.

`WarPlugin#configureConfiguration(ConfigurationContainer)`

Starting in Gradle 8.1, calling `WarPlugin#configureConfiguration(ConfigurationContainer)` is deprecated. This method was intended for internal use and was never intended to be used as part of the public interface.

Starting in Gradle 9.0, this method will be removed without replacement.

Relying on conventions for custom Test tasks

By default, when applying the `java` plugin, the `testClassesDirs`and `classpath` of all `Test` tasks have the same convention. Unless otherwise changed, the default behavior is to execute the tests from the default `test TestSuite` by configuring the task with the `classpath` and `testClassesDirs` from the `test` suite. This behavior will be removed in Gradle 9.0.

While this existing default behavior is correct for the use case of executing the default unit test suite under a different environment, it does not support the use case of executing an entirely separate set of tests.

If you wish to continue including these tests, use the following code to avoid the deprecation warning in 8.1 and prepare for the behavior change in 9.0. Alternatively, consider migrating to test suites.

```
val test by testing.suites.existing(JvmTestSuite::class)
tasks.named<Test>("myTestTask") {
    testClassesDirs = files(test.map { it.sources.output.classesDirs })
    classpath = files(test.map { it.sources.runtimeClasspath })
}
```

build.gradle

```
tasks.myTestTask {
    testClassesDirs = testing.suites.test.sources.output.classesDirs
    classpath = testing.suites.test.sources.runtimeClasspath
}
```

Modifying Gradle Module Metadata after a publication has been populated

Altering the GMM (e.g., changing a component configuration variants) **after** a Maven or Ivy publication has been populated from their components is now deprecated. This feature will be removed in Gradle 9.0.

Eager population of the publication can happen if the following methods are called:

- Maven

  - MavenPublication.getArtifacts()

- Ivy

  - IvyPublication.getArtifacts()

  - IvyPublication.getConfigurations()

  - IvyPublication.configurations(Action)

Previously, the following code did not generate warnings, but it created inconsistencies between published artifacts:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("maven") {
            from(components["java"])
        }
        create<IvyPublication>("ivy") {
            from(components["java"])
        }
    }
}

// These calls eagerly populate the Maven and Ivy publications

(publishing.publications["maven"] as MavenPublication).artifacts
(publishing.publications["ivy"] as IvyPublication).artifacts

val javaComponent = components["java"] as AdhocComponentWithVariants
javaComponent.withVariantsFromConfiguration(configurations["apiElements"]) {
skip() }
javaComponent.withVariantsFromConfiguration(configurations["runtimeElements"]
) { skip() }
```

```
publishing {
    publications {
        maven(MavenPublication) {
            from components.java
        }
        ivy(IvyPublication) {
            from components.java
        }
    }
}

// These calls eagerly populate the Maven and Ivy publications

publishing.publications.maven.artifacts
publishing.publications.ivy.artifacts

components.java.withVariantsFromConfiguration(configurations.apiElements) {
skip() }
components.java.withVariantsFromConfiguration(configurations.runtimeElements)
{ skip() }
```

In this example, the Maven and Ivy publications will contain the main JAR artifacts for the project, whereas the GMM module file will omit them.

Running tests on JVM versions 6 and 7

Running JVM tests on JVM versions older than 8 is deprecated. Testing on these versions will become an error in Gradle 9.0

Applying Kotlin DSL precompiled scripts published with Gradle < 6.0

Applying Kotlin DSL precompiled scripts published with Gradle < 6.0 is deprecated. Please use a version of the plugin published with Gradle >= 6.0.

Applying the `kotlin-dsl` together with Kotlin Gradle Plugin < 1.8.0

Applying the `kotlin-dsl` together with Kotlin Gradle Plugin < 1.8.0 is deprecated. Please let Gradle control the version of `kotlin-dsl` by removing any explicit `kotlin-dsl` version constraints from your build logic. This will let the `kotlin-dsl` plugin decide which version of the Kotlin Gradle Plugin to use. If you explicitly declare which version of the Kotlin Gradle Plugin to use for your build logic, update it to >= 1.8.0.

Accessing `libraries` or `bundles` from dependency version catalogs in the `plugins {}` block of a Kotlin script

Accessing `libraries` or `bundles` from dependency version catalogs in the `plugins {}` block of a Kotlin script is deprecated. Please only use `versions` or `plugins` from dependency version catalogs in the

`plugins {}` block.

Using `ValidatePlugins` task without a Java Toolchain

Using a task of type [ValidatePlugins](#) without applying the [Java Toolchains](#) plugin is deprecated, and will become an error in Gradle 9.0.

To avoid this warning, please apply the plugin to your project:

build.gradle.kts

```
plugins {
    id("jdk-toolchains")
}
```

build.gradle

```
plugins {
    id 'jdk-toolchains'
}
```

The Java Toolchains plugin is applied automatically by the [Java plugin](#), so you can also apply it to your project and it will fix the warning.

Deprecated members of the `org.gradle.util` package now report their deprecation

These members will be removed in Gradle 9.0.

- `WrapUtil.toDomainObjectSet(…)`
- `GUtil.toCamelCase(…)`
- `GUtil.toLowerCase(…)`
- `ConfigureUtil`

Deprecated JVM vendor IBM Semeru

The enum constant `JvmVendorSpec.IBM_SEMERU` is now deprecated and will be removed in Gradle 9.0.

Please replace it by its equivalent `JvmVendorSpec.IBM` to avoid warnings and potential errors in the next major version release.

Setting custom build layout on `StartParameter` and `GradleBuild`

Following the [related previous deprecation](#) of the behaviour in Gradle 7.1, it is now also deprecated to use related [StartParameter](#) and [GradleBuild](#) properties. These properties will be removed in

Gradle 9.0.

Setting custom build file using buildFile property in GradleBuild task has been deprecated.

Please use the dir property instead to specify the root of the nested build. Alternatively, consider using one of the recommended alternatives for GradleBuild task as suggested in Avoid using the GradleBuild task type section.

Setting custom build layout using StartParameter methods setBuildFile(File) and setSettingsFile(File) as well as the counterpart getters getBuildFile() and getSettingsFile() have been deprecated.

Please use standard locations for settings and build files:

- settings file in the root of the build

- build file in the root of each subproject

Deprecated org.gradle.cache.cleanup property

The `org.gradle.cache.cleanup` property in `gradle.properties` under Gradle User Home has been deprecated. Please use the cache cleanup DSL instead to disable or modify the cleanup configuration.

Since the `org.gradle.cache.cleanup` property may still be needed for older versions of Gradle, this property may still be present and no deprecation warnings will be printed as long as it is also configured via the DSL. The DSL value will always take preference over the `org.gradle.cache.cleanup` property. If the desired configuration is to disable cleanup for older versions of Gradle (using `org.gradle.cache.cleanup`), but to enable cleanup with the default values for Gradle versions at or above Gradle 8, then cleanup should be configured to use Cleanup.DEFAULT:

cache-settings.gradle

```
if (GradleVersion.current() >= GradleVersion.version('8.0')) {
    apply from: "gradle8/cache-settings.gradle"
}
```

cache-settings.gradle.kts

```
if (GradleVersion.current() >= GradleVersion.version("8.0")) {
    apply(from = "gradle8/cache-settings.gradle")
}
```

gradle8/cache-settings.gradle

```
beforeSettings { settings ->
    settings.caches {
        cleanup = Cleanup.DEFAULT
    }
}
```

gradle8/cache-settings.gradle.kts

```
beforeSettings {
    caches {
        cleanup.set(Cleanup.DEFAULT)
    }
}
```

Deprecated using relative paths to specify Java executables

Using relative file paths to point to Java executables is now deprecated and will become an error in Gradle 9. This is done to reduce confusion about what such relative paths should resolve against.

Calling `Task.getConvention()`, `Task.getExtensions()` from a task action

Calling [Task.getConvention()](), [Task.getExtensions()]() from a task action at execution time is now deprecated and will be made an error in Gradle 9.0.

See the [configuration cache chapter]() for details on how to migrate these usages to APIs that are supported by the configuration cache.

Deprecated running test task successfully when no test executed

Running the `Test` task successfully when no test was executed is now deprecated and will become an error in Gradle 9. Note that it is not an error when no test sources are present, in this case the `test` task is simply skipped. It is only an error when test sources are present, but no test was selected for execution. This is changed to avoid accidental successful test runs due to erroneous configuration.

Changes in the IDE integration

Workaround for false positive errors shown in Kotlin DSL `plugins {}` block using version catalog is not needed anymore

Version catalog accessors for plugin aliases in the `plugins {}` block aren't shown as errors in IntelliJ IDEA and Android Studio Kotlin script editor anymore.

If you were using the `@Suppress("DSL_SCOPE_VIOLATION")` annotation as a workaround, you can now remove it.

If you were using the Gradle Libs Error Suppressor IntelliJ IDEA plugin, you can now uninstall it.

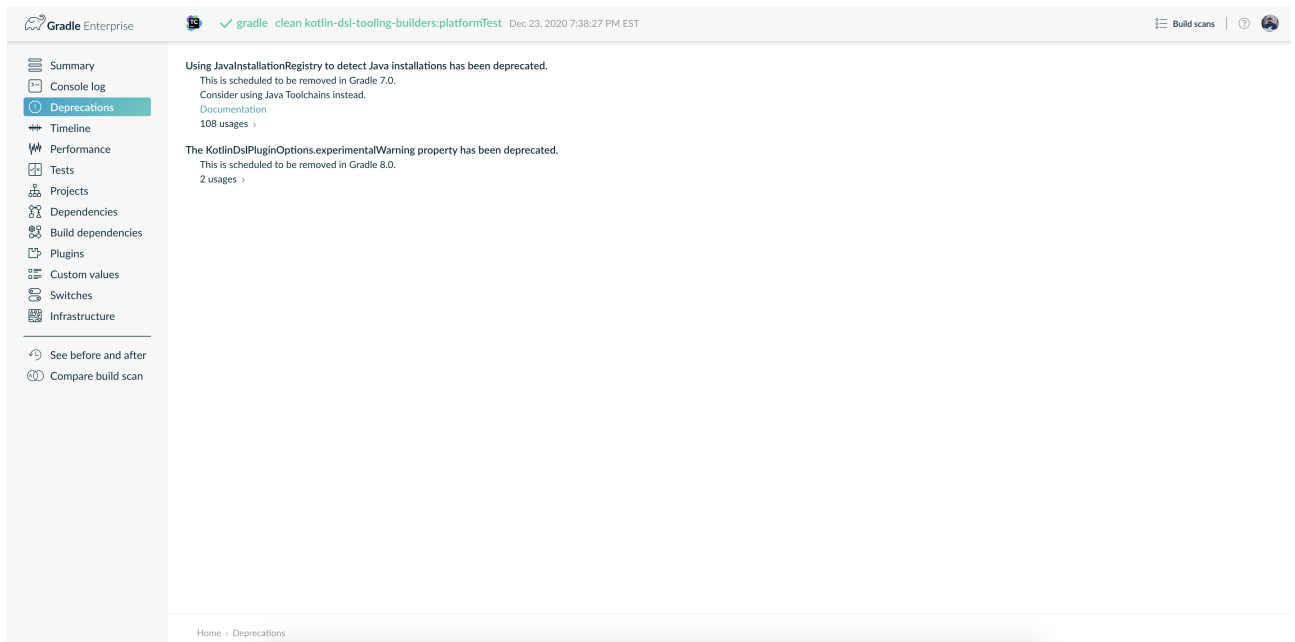After upgrading Gradle to 8.1 you will need to clear the IDE caches and restart.

Also see the deprecated usages of version catalogs in the Kotlin DSL `plugins {}` block above.

Upgrading your build from Gradle 7.x to 8.0

This chapter provides the information you need to migrate your Gradle 7.x builds to Gradle 8.0. For migrating from Gradle 6.x or earlier, complete the older migration guide first.

We recommend the following steps for all users:

1. Try running `gradle help --scan` and view the deprecations view of the generated build scan.

   This is so that you can see any deprecation warnings that apply to your build.

   Alternatively, you can run `gradle help --warning-mode=all` to see the deprecations in the console, though it may not report as much detailed information.

2. Update your plugins.

   Some plugins will break with this new version of Gradle, for example because they use internal APIs that have been removed or changed. The previous step will help you identify potential problems by issuing deprecation warnings when a plugin does try to use a deprecated part of the API.

3. Run `gradle wrapper --gradle-version 8.6-milestone-1` to update the project to 8.6-milestone-1.

4. Try to run the project and debug any errors using the Troubleshooting Guide.

Upgrading from 7.6 and earlier

Warnings that are now errors

Referencing tasks in an included build with `finalizedBy`, `mustRunAfter` or `shouldRunAfter`

Referencing tasks contained in an included build with any of the following methods now results in an execution time error:

- `finalizedBy`

- `mustRunAfter`

- `shouldRunAfter`

Creating TAR trees from resources without backing files

Creating a TAR tree from a resource with no backing file is no longer supported. Instead, convert the resource to a file and use `project.tarTree()` on the file. For more information, see TAR trees from resources without backing files.

Using invalid Java toolchain specifications

Usage of invalid Java toolchain specifications is no longer supported. Related build errors can be avoided by making sure that language version is set on all toolchain specifications. See user manual for more information.

Using automatic toolchain downloading without having a repository configured

Automatic toolchain downloading without explicitly providing repositories to use is no longer supported. See user manual for more information.

Changing test framework after setting test framework options is now an error

When configuring the built-in test task for Java, Groovy, and Scala projects, Gradle no longer allows you to change the test framework used by the `Test` task after configuring options. This was deprecated since it silently discarded configuration in some cases.

The following code example now produces an error:

```
test {
    options {
    }

    useJUnitPlatform()
}
```

Instead, you can:

- set the test framework before configuring options

- migrate to the JVM Test Suite Plugin

```
test {
    // select test framework before configuring options
    useJUnitPlatform()
    options {
    }
}
```

Additionally, setting the test framework multiple times to the *same* framework now accumulates any options that might be set on the framework. Previously, each time the framework was set, it would cause the framework options to be overwritten.

The following code now results in both the "foo" and "bar" tags to be included for the `test` task:

```
test {
    useJUnitPlatform {
        includeTags("foo")
    }
}
tasks.withType(Test).configureEach {
    // previously, this would overwrite the included tags to only include "bar"
    useJUnitPlatform {
        includeTags("bar")
    }
}
```

Removed APIs

Legacy ArtifactTransform API

The legacy `ArtifactTransform` API has been removed. For more information, see Registering artifact transforms extending `ArtifactTransform`.

Legacy IncrementalTaskInputs API

The legacy `IncrementalTaskInputs` API has been removed. For more information, see IncrementalTaskInputs type is deprecated. This change also affects Kotlin Gradle Plugin and Android Gradle Plugin. With Gradle 8.0 you should use Kotlin Gradle Plugin 1.6.10 or later and Android Gradle Plugin 7.3.0 with `android.experimental.legacyTransform.forceNonIncremental=true` property or later.

Legacy AntlrSourceVirtualDirectory API

The legacy `AntlrSourceVirtualDirectory` API has been removed. This change affects the `antlr` plugin. In Gradle 8.0 and above, use the `AntlrSourceDirectorySet` source set extension instead.

JvmPluginsHelper

A deprecated `configureDocumentationVariantWithArtifact` method of the `JvmPluginsHelper` class which did not require a `FileResolver` has been removed. This was an internal API, but may have

been accessed by plugins. Supply a `FileResolver` to the overloaded version of this method instead.

Groovydoc API Cleanup

The deprecated `isIncludePrivate` property of the `Groovydoc` task type has been removed. Use the `access` property along with the `GroovydocAccess#PRIVATE` constant instead.

JavaApplication API Cleanup

The deprecated `mainClassName` property of the `JavaApplication` interface has been removed. Use the `mainClass` property instead.

DefaultDomainObjectSet API Cleanup

The deprecated `DefaultDomainObjectSet(Class)` constructor has been removed. This was an internal API, but may have been used by plugins.

JacocoPluginExtension API Cleanup

The deprecated `reportsDir` property of the `JacocoPluginExtension` has been removed. Use the `reportsDirectory` property instead.

DependencyInsightReportTask API Cleanup

The deprecated `legacyShowSinglePathToDependnecy` property of the `DependencyInsightReportTask` task type has been removed. Use the `showSinglePathToDependency` property instead.

Report and TestReport API Cleanup

The deprecated `destination`, and `enabled` properties of the `Report` type have been removed. Use the `outputLocation` and `required` properties instead.

The deprecated `testResultDirs` property of the `TestReport` task type has been removed. Use the `testResults` property instead.

JacocoMerge Task Removed

The deprecated `JacocoMerge` task type has been removed. The same functionality is also available on the `JacocoReport` task.

JavaExec API Cleanup

The deprecated `main` property of the `JavaExec` task type has been removed. Use the `mainClass` property instead.

AbstractExecTask API Cleanup

The deprecated `execResult` getter property of the `AbstractExecTask` task type has been removed. Use the `executionResult` getter property instead.

AbstractTestTask API Cleanup

The deprecated `binResultsDir` property of the `AbstractTestTask` task type has been removed. Use the `binaryResultsDirectory` property instead.

SourceDirectorySet API Cleanup

The deprecated `outputDir` property of the `SourceDirectorySet` type has been removed. Use the `destinationDirectory` property instead.

VersionCatalog API Cleanup

The deprecated `findDependency(String)` method and `dependencyAliases` property of the `VersionCatalog` type have been removed. Use the `findLibrary(String)` method and `libraryAliases` property instead.

The deprecated `alias(String)` method of the `VersionCatalogBuilder` type has been removed. Use the `library(String, String, String)` or `plugin(String, String)` methods instead.

WorkerExecutor API Cleanup

The deprecated `submit(Class, Action)` method of the `WorkerExecutor` interface has been removed. Instead, obtain a `WorkQueue` via the `noIsolation()`, `classLoaderIsolation()`, and `processIsolation()`, methods and use the `submit(Class, Action)` method on the `WorkQueue` instead.

DependencySubstitution API Cleanup

The deprecated `with(ComponentSelector)` method of the `DependencySubstitution` type's inner `Substitution` type's has been removed. Use the `using(ComponentSelector)` method instead.

AbstractArchiveTask API Cleanup

The deprecated `appendix`, `archiveName`, `archivePath`, `baseName`, `classifier`, `destinationDir`, `extension` and `version` properties of the `AbstractArchiveTask` task type have been removed. Use the `archiveAppendix`, `archiveFileName` , `archiveFile`, `archiveBaseName`, `archiveClassifier`, `destinationDirectory`, `archiveExtension` and `archiveVersion` properties instead.

IdeaModule API Cleanup

The deprecated `testSourceDirs` and `testResourceDirs` properties of the `IdeaModule` type have been removed. This affects the `org.gradle.plugins.ide.idea.model.IdeaModule` type, not the `org.gradle.tooling.model.idea.IdeaModule` type. Use the `testSources` and `testResources` properties instead.

AbstractCompile API Deprecations

The previously deprecated `destinationDir` property of the `AbstractCompile` remains deprecated, and will now emit a deprecation warning upon use. It is now scheduled for removal in Gradle 9.0. Use the `destinationDirectory` property instead.

ResolvedComponentResult API Cleanup

The deprecated `getVariant` method of the `ResolvedComponentResult` interface has been removed. Use the `getVariants` method instead.

Code quality plugins API Cleanup

The deprecated `antBuilder` property of the `Checkstyle`, `CodeNarc` and `Pmd` task types has been removed. Use the `Project` type's `ant` property instead.

Usage API Cleanup

The deprecated public fields `JAVA_API_CLASSES`, `JAVA_API_JARS`, `JAVA_RUNTIME_CLASSES`, `JAVA_RUNTIME_JARS` and `JAVA_RUNTIME_RESOURCES` of the `Usage` type have been removed. The values are available in the **internal** `JavaEcosystemSupport` class for compatibility with previously published modules, but should **not** be used for any new publishing.

ExternalDependency API Cleanup

The deprecated `setForce(boolean)` method of the `ExternalDependency` interface has been removed. Use the `version(Action)` method to configure strict versions instead.

Build-scan method removed from Kotlin DSL

The deprecated `build-scan` plugin application method has been removed from the Kotlin DSL. Use the `gradle-enterprise` method instead.

Configuration extension methods removed from Kotlin DSL

The Kotlin DSL added specialized extension methods for `NamedDomainObjectProvider<Configuration>` that are available when looking up a configuration by name. These extensions allowed builds to access some properties of a `Configuration` when using an instance of `NamedDomainObjectProvider<Configuration>` directly:

```
configurations.compileClasspath.files // equivalent to
configurations.compileClasspath.get().files
configurations.compileClasspath.singleFile // equivalent to
configurations.compileClasspath.get().singleFile
```

All of these extensions have been removed from the API, but the methods are still available for plugins compiled against older versions of Gradle.

- NamedDomainObjectProvider<Configuration>.addToAntBuilder
- NamedDomainObjectProvider<Configuration>.all
- NamedDomainObjectProvider<Configuration>.allArtifacts
- NamedDomainObjectProvider<Configuration>.allDependencies
- NamedDomainObjectProvider<Configuration>.allDependencyConstraints
- NamedDomainObjectProvider<Configuration>.artifacts

- NamedDomainObjectProvider<Configuration>.asFileTree
- NamedDomainObjectProvider<Configuration>.asPath
- NamedDomainObjectProvider<Configuration>.attributes
- NamedDomainObjectProvider<Configuration>.buildDependencies
- NamedDomainObjectProvider<Configuration>.contains
- NamedDomainObjectProvider<Configuration>.copy
- NamedDomainObjectProvider<Configuration>.copyRecursive
- NamedDomainObjectProvider<Configuration>.defaultDependencies
- NamedDomainObjectProvider<Configuration>.dependencies
- NamedDomainObjectProvider<Configuration>.dependencyConstraints
- NamedDomainObjectProvider<Configuration>.description
- NamedDomainObjectProvider<Configuration>.exclude
- NamedDomainObjectProvider<Configuration>.excludeRules
- NamedDomainObjectProvider<Configuration>.extendsFrom
- NamedDomainObjectProvider<Configuration>.fileCollection
- NamedDomainObjectProvider<Configuration>.files
- NamedDomainObjectProvider<Configuration>.filter
- NamedDomainObjectProvider<Configuration>.getTaskDependencyFromProjectDependency
- NamedDomainObjectProvider<Configuration>.hierarchy
- NamedDomainObjectProvider<Configuration>.incoming
- NamedDomainObjectProvider<Configuration>.isCanBeConsumed
- NamedDomainObjectProvider<Configuration>.isCanBeResolved
- NamedDomainObjectProvider<Configuration>.isEmpty
- NamedDomainObjectProvider<Configuration>.isTransitive
- NamedDomainObjectProvider<Configuration>.isVisible
- NamedDomainObjectProvider<Configuration>.minus
- NamedDomainObjectProvider<Configuration>.outgoing
- NamedDomainObjectProvider<Configuration>.plus
- NamedDomainObjectProvider<Configuration>.resolutionStrategy
- NamedDomainObjectProvider<Configuration>.resolve
- NamedDomainObjectProvider<Configuration>.resolvedConfiguration
- NamedDomainObjectProvider<Configuration>.setDescription
- NamedDomainObjectProvider<Configuration>.setExtendsFrom
- NamedDomainObjectProvider<Configuration>.setTransitive
- NamedDomainObjectProvider<Configuration>.singleFile

- NamedDomainObjectProvider<Configuration>.state
- NamedDomainObjectProvider<Configuration>.withDependencies

You should prefer to directly reference the methods from `Configuration`.

Potential breaking changes

`JavaForkOptions getJvmArgs()` and `getAllJvmArgs()` return immutable lists

The lists of JVM arguments retrieved from the `JavaForkOptions` interface are now immutable.

Previously, modifications of the returned list were silently ignored.

Nullable annotations better reflect actual nullability of API

In some APIs, nullability was not correctly annotated and APIs that did allow null or returned null were marked as non-null. In Java or Groovy, this mismatch did not cause problems at compile time. In Kotlin, this mismatch made valid code difficult to write because the language would not allow you to pass null.

One particular example was returning `null` from a `Provider#map` or `Provider#flatMap`. In both APIs, Gradle allows you to return null, but in the Kotlin DSL this was considered illegal.

This correction may cause compilation errors in code that expected non-null.

Plugins, tasks and extension classes are abstract

Most public classes for plugins, tasks and extensions have been made abstract. This was done to make it easier to remove boilerplate from Gradle's implementation.

Plugins that are affected by this change should make their classes abstract as well. Gradle uses runtime class decoration to implement abstract methods as long as the object is instantiated via `ObjectFactory` or some other automatic mechanism (like managed properties). Those methods should never be directly implemented.

Wrapper task configuration

If `gradle-wrapper.properties` contains the `distributionSha256Sum` property, you must specify a sum. You can specify a sum in the wrapped task configuration or with the `--gradle-distribution-sha256-sum` task option.

Changes in the AbstractCodeQualityPlugin class

The deprecated `AbstractCodeQualityPlugin.getJavaPluginConvention()` method was removed in Gradle 8.0. You should use `JavaPluginExtension` instead.

Remove implicit `--add-opens` for Gradle workers

Before Gradle 8.0, Gradle workers on JDK9+ automatically opened JDK modules `java.base/java.util` and `java.base/java.lang` by passing `--add-opens` CLI arguments. This enabled code executed in a Gradle worker to perform deep reflection on JDK internals without warning or failing. Workers no

longer use these implicit arguments.

This affects all internal Gradle workers, which are used for a variety of tasks:

- code-quality plugins (Checkstyle, CodeNarc, Pmd)
- ScalaDoc
- AntlrTask
- JVM compiler daemons
- tasks executed using process isolation via the Worker API

New warnings and errors may appear in any tools, extensions, or plugins that perform deep reflection into JDK internals with the worker API.

These errors can be resolved by updating the violating code or dependency. Updates may include:

- code-quality tools
- annotation processors
- any Gradle plugins which use the worker API

For some examples of possible error or warning outputs which may arise due to this change, see Removes implicit `--add-opens` for test workers.

SourceSet classesDirs no longer depends upon the entire SourceSet as a task dependency

Prior to Gradle 8.0, the task dependencies for `SourceSetOutput.classesDirs` included tasks that did not produce class files. This meant that a task which depends on `classesDirs` would also depend on `classes`, `processResources`, and any other task dependency added to `SourceSetOutput`. This behavior was potentially an error because the `classesDirs` property did not contain the output for `processResources`. Since 8.0, this implicit dependency is removed. Now, depending on `classesDirs` only executes the tasks which directly produce files in the classes directories.

Consider the following buildscript:

```
plugins {
    id 'java-library'
}
// Task lists all files in the given classFiles FileCollection
tasks.register("listClassFiles", ListClassFiles) {
    classFiles.from(java.sourceSets.main.output.classesDirs)
}
```

Previously, the `listClassFiles` task depended on `compileJava`, `processResources`, and `classes`. Now, only `compileJava` is a task dependency of `listClassFiles`.

If a task in your build relied on the previous behavior, you can instead use the entire `SourceSetOutput` as an input, which contains all classes and resources.

If that is not feasible, you can restore the previous behavior by adding more task dependencies to

`classesDirs`:

```
java {
    sourceSets {
        main {
            output.classesDirs.builtBy(output)
        }
    }
}
```

Minimal supported Kotlin Gradle Plugin version changed

Gradle 7.x supports Kotlin Gradle Plugin 1.3.72 and above. Kotlin Gradle Plugin versions above 1.6.21 are not tested with Gradle 7.x. Gradle 8.x supports Kotlin Gradle Plugin 1.6.10 and above. You can use a lower Kotlin language version by modifying the language version and api version setting in the Kotlin compilation tasks.

Minimal supported Android Gradle Plugin version changed

Gradle 7.x supports Android Gradle Plugin (AGP) 4.1 and above. AGP versions above 7.3 are not tested with Gradle 7.x. Gradle 8.x supports AGP 8 and above. Gradle 8.x supports AGP 7.3 and above if you configure the following property:

```
android.experimental.legacyTransform.forceNonIncremental=true
```

Change to `AntBuilder` parent class

Previously, `org.gradle.api.AntBuilder` extended the deprecated `groovy.util.AntBuilder` class. It now extends `groovy.ant.AntBuilder`.

`PluginDeclaration` is not serializable

`org.gradle.plugin.devel.PluginDeclaration` is not serializable anymore. If you need to serialize it, you can convert it into your own, serializable class.

Gradle does not use equals for serialized values in up-to-date checks

Gradle now does not try to use equals when comparing serialized values in up-to-date checks. For more information see Relying on equals for up-to-date checks is deprecated.

Task and transform validation warnings introduced in Gradle 7.x are now errors

Gradle introduced additional task and artifact transform validation warnings in the Gradle 7.x series. Those warnings are now errors in Gradle 8.0 and will fail the build.

Warnings that became errors:

- An input file collection that can't be resolved.
- An input or output file or directory that cannot be read. See Declaring input or output

[directories which contain unreadable content](#).

- Using a `java.io.File` as the `@InputArtifact` of an artifact transform.

- Using an input with an unknown implementation. See [Cannot use an input with an unknown implementation](#).

- Missing dependencies between tasks. See [Implicit dependencies between tasks](#).

- Converting files to a classpath where paths contain file separator.

Gradle does not ignore empty directories for file-trees with `@SkipWhenEmpty`

Previously Gradle used to detect if an input file collection annotated with `@SkipWhenEmpty` consisted only of file trees and then ignored directories automatically. To ignore directories in Gradle 8.0 and later, the input property needs to be explicitly annotated with `@IgnoreEmptyDirectories`. For more information see [File trees and empty directory handling](#).

Format of `JavaVersion` **has changed for Java 9 and Java 10**

The string format of the `JavaVersion` has changed to match the official Java versioning. Starting from Java 9, the language version must not contain the `1.` prefix. This affects the format of the `sourceCompatiblity` and `targetCompatibility` properties on the `JavaCompile` task and `JavaExtension`. The old format is still supported when resolving the `JavaVersion` from a string.

Gradle 7.6	Gradle 8.0
`1.8`	`1.8`
`1.9`	`9`
`1.10`	`10`
`11`	`11`

Precompiled script plugins use strict Kotlin DSL accessor generation by default

In precompiled script plugins, type safe Kotlin DSL accessor generation now fails the build if a plugin fails to apply.

Starting in Gradle 7.6, builds could enable this behavior with the `org.gradle.kotlin.dsl.precompiled.accessors.strict` system property. This behavior is now default. The property has been deprecated and its usage should be removed. You can find more information about this property [below](#).

Init scripts are applied to `buildSrc` **builds**

Init scripts specified using `--init-script` are now applied to `buildSrc` builds. In previous releases these were applied to included builds but not `buildSrc builds.

This behavior is now consistent for `buildSrc` and included builds.

Gradle no longer runs the `build` **task for** `buildSrc` **builds**

When Gradle builds the output of `buildSrc` it runs only the tasks that produce that output, which is typically the `jar` task. In previous releases Gradle would run the `build` task.

This means that the tests of `buildSrc` and its subprojects are not built and executed automatically and must now be explicitly requested.

This behavior is now consistent for `buildSrc` and included builds.

You can run the tests for `buildSrc` in the same way as projects in included builds, for example by running `gradle buildSrc:build`.

`buildFinished { }` **hook for** `buildSrc` **runs after all tasks have executed**

The `buildFinished {}` hook for `buildSrc` now runs after all tasks have completed. In previous releases this hook would run immediately after the tasks for `buildSrc` completed and before any requested tasks started.

This behavior is now consistent for `buildSrc` and included builds.

Changes to paths of included builds

In order to handle conflicts between nested included build names better, Gradle now uses the directory hierarchy of included builds to assign the build path. If you are running tasks from the command line in nested included builds, then you may need to adjust your invocation.

For example, if you have the following hierarchy:

```
.
├─── settings.gradle.kts
└─── nested
     ├─── settings.gradle.kts
     └─── nestedNested
          └─── settings.gradle.kts
```

settings.gradle.kts

```
includeBuild("nested")
```

nested/settings.gradle.kts

```
includeBuild("nestedNested")
```

```
.
├─── settings.gradle
└─── nested
     ├─── settings.gradle
     └─── nestedNested
          └─── settings.gradle
```

settings.gradle

```
includeBuild("nested")
```

nested/settings.gradle

```
includeBuild("nestedNested")
```

Before Gradle 8.0, you ran `gradle :nestedNested:compileJava`. In Gradle 8.0 the invocation changes to `gradle :nested:nestedNested:compileJava`.

Adding `jst.ejb` with the `eclipse wtp` plugin now removes the `jst.utility` facet

The `eclipse wtp` plugin adds the `jst.utility` facet to java projects. Now, adding the `jst.ejb` facet implicitly removes the `jst.utility` facet:

```
eclipse {
    wtp {
        facet {
            facet name: 'jst.ejb', version: '3.2'
        }
    }
}
```

Simplifying PMD custom rules configuration

Previously, you had to explicitly configure PMD to ignore default rules with `ruleSets = []`. In the Gradle 8.0, setting `ruleSetConfig` or `ruleSetFiles` to a non-empty value implicitly ignores default rules.

Report `getOutputLocation` return type changed from Provider to Property

The `outputLocation` property of the Report now returns a value of type `Property<? extends FileSystemLocation>`. Previously, `outputLocation` returned a value of type `Provider<? extends FileSystemLocation>`.

This change makes the Report API more internally consistent, and allows for more idiomatic configuration of reporting tasks.

The former, now `@Deprecated` usage:

```
tasks.named('test') {
    reports.junitXml.setDestination(layout.buildDirectory.file('reports/my-report-old
').get().asFile) // DEPRECATED
}
```

can be replaced with:

```
tasks.named('test') {
    reports.junitXml.outputLocation = layout.buildDirectory.dir('reports/my-report')
}
```

Many built-in and custom reports, such as those used by JUnit, implement this interface. Plugins compiled against an earlier version of Gradle containing the previous method signature may need to be recompiled to be used with newer versions of Gradle containing the new signature.

Removed external plugin validation plugin

The incubating plugin `ExternalPluginValidationPlugin` has been removed. Use the `java-gradle-plugin`'s `validatePlugins` task to validate plugins under development.

Reproducible archives can change compared to past versions

Gradle changes the compression library used for creating archives from an Ant based one to Apache Commons Compress™. As a consequence archives created from the same content, are unlikely to end up identical byte-by-byte to their older versions, created with the old library.

Upgrade to Kotlin 1.8.10

The embedded Kotlin has been updated to Kotlin 1.8.10. Also see Kotlin 1.8.0 release notes. For more information, see the release notes for Kotlin

- 1.7.20
- 1.7.21
- 1.8.0

Updated the Kotlin DSL to Kotlin API Level 1.8

Previously, the Kotlin DSL used Kotlin API level 1.4. Starting with Gradle 8.0, the Kotlin DSL uses Kotlin API level 1.8. This change brings all the improvements made to the Kotlin language and standard library since Kotlin 1.4.0.

For information about breaking and nonbreaking changes in this upgrade, see the following links to the Kotlin documentation:

- Kotlin 1.5 language / standard library
- Kotlin 1.6 language / standard library
- Kotlin 1.7 language / standard library
- Kotlin 1.8 language / standard library

Note that the Kotlin Gradle Plugin 1.8.0 started using Java toolchains. It is recommended you configure a toolchain instead of defining Java `sourceCompatibility`/`targetCompatibility` in Kotlin projects.

Also note that the Kotlin Gradle Plugin 1.8.0 introduced `compilerOptions` with lazy configuration properties as a replacement for `kotlinOptions` which did not support lazy configuration. It is recommended you configure Kotlin compilation using `compilerOptions` instead of `kotlinOptions`.

`kotlinDslPluginOptions.jvmTarget` is deprecated

Previously, you could use `kotlinDslPluginOptions.jvmTarget` to configure which JVM target should be used for compiling code when using the `kotlin-dsl` plugin.

Starting with Gradle 8.0, `kotlinDslPluginOptions.jvmTarget` is deprecated. You should configure a Java Toolchain instead.

If you already have a Java Toolchain configured and `kotlinDslPluginOptions.jvmTarget` unset then Gradle 8.0 will now use the Java Toolchain as the JVM target instead of the previous default target (1.8).

Java Base Plugin now sets Jar, War, and Ear destination directory defaults

Previously, the `base` plugin configured the destinationDirectory of Jar, War, and Ear tasks to the directory specified by BasePluginExtension#getLibsDirectory. In Gradle 8.0, `java-base` handles this configuration. No changes are required for projects that already apply the `java-base` plugin directly or indirectly through the `java`, `application`, `java-library`, or other JVM ecosystem plugins.

Upload Task should not be used

The `Upload` task remains deprecated and is now scheduled for removal in Gradle 9.0. Although this type remains, it is no longer functional and will throw an exception upon running. It is preserved solely to avoid breaking plugins. Use the tasks in the `maven-publish` or `ivy-publish` plugins instead.

Configurations no longer allowed as Dependencies

Adding a Configuration as a dependency in the `dependencies` DSL block, or programmatically using the `DependencyHandler` classes' `doAdd(Configuration, Object, Closure)` method, is no longer allowed and will fail with an exception. To replicate many aspects of this behavior, extend configurations using the `extendsFrom(Configuration)` method on `Configuration` instead.

Deprecated for consumption configurations are now non-consumable

The following configurations were never meant to be consumed:

- The `antlr` configuration created by the `AntlrPlugin`

- The `zinc` configuration created by the `ScalaBasePlugin`

- The `providedCompile` and `providedRuntime` configurations created by the `WarPlugin`

These configurations were deprecated for consumption and are now no longer consumable. Attempting to consume them will result in an error.

Identical consumable configurations are now an error

If a project has multiple consumable configurations that share the same attributes and capabilities declaration, the build will fail when publishing or resolving as a dependency that project. This was previously deprecated.

The `outgoingVariants` report will warn about this for impacted configurations.

Toolchain-based tasks for JVM projects

Starting with Gradle 8.0, all core Java tasks that have toolchain support are now using toolchains unconditionally. If `JavaBasePlugin` is applied, the convention value for tool properties on the task is defined by the toolchain configured on the `java` extension. In case no toolchains are explicitly configured, the toolchain corresponding to the JVM running Gradle is used.

Similarly, tasks from the Groovy and Scala plugins also rely on toolchains to determine on which JVM they are executed.

Scala compilation target

With the toolchain changes described above, Scala compilation tasks are now always provided with a `target` or `release` parameter. The exact parameter and value depend on toolchain usage, or not, and Scala version.

See the Scala plugin documentation for details.

`pluginBundle` dropped in Plugin Publish plugin

Gradle 8 no longer supports the `pluginBundle` extension. Its functionality has been merged into the `gradlePlugin` block. These changes require recent versions of the Plugin Publish plugin (1.0.+). Documentation on configuring plugin publication can be found both on the Portal and in the user manual.

Upgrading from 7.5 and earlier

Updates to Attribute Disambiguation Rules related methods

The `AttributeSchema.setAttributeDisambiguationPrecedence(List)` and `AttributeSchema.getAttributeDisambiguationPrecedence()` methods now accept and return `List` instead of `Collection` to better indicate that the order of the elements in those collection is significant.

Strict Kotlin DSL precompiled script plugins accessors generation

Type safe Kotlin DSL accessors generation for precompiled script plugins does not fail the build by default if a plugin requested in such precompiled scripts fails to be applied. Because the cause could be environmental and for backwards compatibility reasons, this behaviour hasn't changed yet.

Back in Gradle 7.1 the `:generatePrecompiledScriptPluginAccessors` task responsible for the accessors generation has been marked as non-cacheable by default. The `org.gradle.kotlin.dsl.precompiled.accessors.strict` system property was introduced in order to offer an opt-in to a stricter mode of operation that fails the build when a plugin application fails, and enable the build cache for that task.

Starting with Gradle 7.6, non-strict accessors generation for Kotlin DSL precompiled script plugins has been deprecated. This will change in Gradle 8.0. Strict accessor generation will become the default. To opt in to the strict behavior, set the 'org.gradle.kotlin.dsl.precompiled.accessors.strict' system property to `true`.

This can be achieved persistently in the `gradle.properties` file in your build root directory:

```
systemProp.org.gradle.kotlin.dsl.precompiled.accessors.strict=true
```

Potential breaking changes

Upgrade to Kotlin 1.7.10

The embedded Kotlin has been updated to Kotlin 1.7.10.

Gradle doesn't ship with the `kotlin-gradle-plugin` but the upgrade to 1.7.10 can bring the new version. For example when you use the `kotlin-dsl` plugin.

The `kotlin-gradle-plugin` version 1.7.10 changes the type hierarchy of the `KotlinCompile` task type. It doesn't extend from `AbstractCompile` anymore. If you used to select Kotlin compilation tasks by `AbstractCompile` you need to change that to `KotlinCompile`.

For example, this

```
tasks.named<AbstractCompile>("compileKotlin")
```

needs to be changed to

```
tasks.named<KotlinCompile>("compileKotlin")
```

In the same vein, if you used to filter tasks by `AbstractCompile` you won't obtain the Kotlin compilation tasks anymore:

```
tasks.withType<AbstractCompile>().configureEach {
    // ...
}
```

needs to be changed to

```
tasks.withType<AbstractCompile>().configureEach {
    // ...
}
tasks.withType<KotlinCompile>().configureEach {
    // ...
}
```

Upgrade to Groovy 3.0.13

Groovy has been updated to Groovy 3.0.13.

Since the previous version was 3.0.10, the 3.0.11 and 3.0.12 changes are also included.

Upgrade to CodeNarc 3.1.0

The default version of CodeNarc has been updated to 3.1.0.

Upgrade to PMD 6.48.0

PMD has been updated to PMD 6.48.0.

Configuring a non-existing executable now fails

When configuring an executable explicitly for `JavaCompile` or `Test` tasks, Gradle will now emit an error if this executable does not exist. In the past, the task would be executed with the default toolchain or JVM running the build.

Changes to dependency declarations in Test Suites

As part of the ongoing effort to evolve Test Suites, dependency declarations in the Test Suites `dependencies` block are now strongly typed. This will help make this incubating API more discoverable and easier to use in an IDE.

In some cases, this requires syntax changes. For example, build scripts that previously added Test Suite dependencies with the following syntax:

```
testing {
  suites {
    register<JvmTestSuite>("integrationTest") {
      dependencies {
        implementation(project)
      }
    }
  }
}
```

will now fail to compile, with a message like:

```
None of the following functions can be called with the arguments supplied:
public operator fun DependencyAdder.invoke(dependencyNotation: CharSequence): Unit
defined in org.gradle.kotlin.dsl
public operator fun DependencyAdder.invoke(dependency: Dependency): Unit defined in
org.gradle.kotlin.dsl
public operator fun DependencyAdder.invoke(files: FileCollection): Unit defined in
org.gradle.kotlin.dsl
public operator fun DependencyAdder.invoke(dependency: Provider<out Dependency>): Unit
defined in org.gradle.kotlin.dsl
public operator fun DependencyAdder.invoke(externalModule: ProviderConvertible<out
MinimalExternalModuleDependency>): Unit defined in org.gradle.kotlin.dsl
```

To fix this, replace the reference to `project` with a call to `project()`:

```
testing {
  suites {
    register<JvmTestSuite>("integrationTest") {
      dependencies {
        implementation(project())
      }
    }
  }
}
```

Other syntax effected by this change includes:

- You cannot use `Provider<String>` as a dependency declaration.

- You cannot use a `Map` as a dependency declaration for Kotlin or Java.

- You cannot use a bundle as a dependency declaration directly (`implementation(libs.bundles.testing)`). Use `implementation.bundle(libs.bundles.testing)` instead.

For more information, see the updated declare an additional test suite example in the JVM Test Suite Plugin section of the user guide and the `DependencyAdder` page in the DSL reference.

Deprecations

Usage of invalid Java toolchain specifications is now deprecated

Along with the Java language version, the Java toolchain DSL allows configuring other criteria such as specific vendors or VM implementations. Starting with Gradle 7.6, toolchain specifications that configure other properties without specifying the language version are considered *invalid*. Invalid specifications are deprecated and will become build errors in Gradle 8.0.

See more details about toolchain configuration in the user manual.

Deprecated members of the `org.gradle.util` package now report their deprecation

These members will be removed in Gradle 9.0.

- `ClosureBackedAction`
- `CollectionUtils`
- `ConfigureUtil`
- `DistributionLocator`
- `GFileUtils`
- `GradleVersion.getBuildTime()`
- `GradleVersion.getNextMajor()`
- `GradleVersion.getRevision()`
- `GradleVersion.isValid()`

- GUtil

- NameMatcher

- NameValidator

- RelativePathUtil

- TextUtil

- SingleMessageLogger

- VersionNumber

- WrapUtil

Internal DependencyFactory was renamed

The internal `org.gradle.api.internal.artifacts.dsl.dependencies.DependencyFactory` type was renamed to `org.gradle.api.internal.artifacts.dsl.dependencies.DependencyFactoryInternal`. As an internal type, it should not be used, but for compatibility reasons the inner `ClassPathNotation` type is still available. This name for the type is deprecated and will be removed in Gradle 8.0. The public API for this is on `DependencyHandler`, with methods such as `localGroovy()` providing the same functionality.

Replacement collections in `org.gradle.plugins.ide.idea.model.IdeaModule`

The `testResourcesDirs` and `testSourcesDirs` fields and their getters and setters have been deprecated. Replace usages with the now stable `getTestSources()` and `getTestResources()` methods and their respective setters. These new methods return and are backed by `ConfigurableFileCollection` instances for improved flexibility of use. Gradle now warns upon usage of these deprecated methods. They will be removed in a future version of Gradle.

Replacement methods in `org.gradle.api.tasks.testing.TestReport`

The `getDestinationDir()`, `setDestinationDir(File)`, and `getTestResultDirs()` and `setTestResultDirs(Iterable)` methods have been deprecated. Replace usages with the now stable `getDestinationDirectory()` and `getTestResults()` methods and their associated setters. These deprecated elements will be removed in a future version of Gradle.

Deprecated implicit references to outer scope methods in some configuration blocks

Prior to Gradle 7.6, Groovy scripts permitted access to root project configure methods within named container configure methods that throw `MissingMethodException`s. Consider the following snippets for examples of this behavior:

Gradle permits access to the top-level `repositories` block from within the `configurations` block when the provided closure is otherwise an invalid configure closure for a Configuration. In this case, the `repositories` closure executes as if it were called at the script-level, and creates an unconfigured `repositories` Configuration:

```
configurations {
    repositories {
        mavenCentral()
    }
    someConf {
        canBeConsumed = false
        canBeResolved = false
    }
}
```

The behavior also applies to closures which do not immediately execute. In this case, `afterResolve` only executes when the `resolve` task runs. The `distributions` closure is a valid top-level script closure. But it is an invalid configure closure for a Configuration. This example creates the `conf` Configuration immediately. During `resolve` task execution, the `distributions` block executed as if it were declared at the script-level:

```
configurations {
    conf.incoming.afterResolve {
        distributions {
            myDist {
                contents {}
            }
        }
    }
}

task resolve {
    dependsOn configurations.conf
    doFirst {
        configurations.conf.files() // Trigger `afterResolve`
    }
}
```

As of Gradle 7.6, this behavior is deprecated. Starting with Gradle 8.0, this behavior will be removed. Instead, Gradle will throw the underlying `MissingMethodException`. To mitigate this change, consider the following solutions:

```
configurations {
    conf.incoming.afterResolve {
        // Fully qualify the reference.
        project.distributions {
            myDist {
                contents {}
            }
        }
    }
}
```

```
configurations {
    conf
}

// Extract the script-level closure to the script root scope.
configurations.conf.incoming.afterResolve {
    distributions {
        myDist {
            contents {}
        }
    }
}
```

Upgrading from 7.4 and earlier

IncrementalTaskInputs type is deprecated

The `IncrementalTaskInputs` type was used to implement *incremental tasks,* that is to say tasks that can be optimized to run on a subset of changed inputs instead of the whole input. This type had a number of drawbacks. In particular using this type it was not possible to determine what input a change was associated with.

You should now use the `InputChanges` type instead. Please refer to the userguide section about implementing incremental tasks for more details.

Potential breaking changes

Version catalog only accepts a single TOML import file

Only a single file will be accepted when using a `from` import method. This means that notations, which resolve to multiple files (e.g. the Project.files(java.lang.Object…) method, when more then one file is passed) will result in a build failure.

Updates to default tool integration versions

- Checkstyle has been updated to Checkstyle 8.45.1.
- JaCoCo has been updated to 0.8.8.

Classpath file generated by the `eclipse` plugin has changed

Project dependencies defined in test configurations get the `test=true` classpath attribute. All source sets and dependencies defined by the JVM Test Suite plugin are also marked as test code by default. You can now customize test source sets and dependencies via the `eclipse` plugin DSL:

```
eclipse {
    classpath {
        testSourceSets = [sourcesSets.test, sourceSets.myTestSourceSet]
        testConfigurations = [configuration.myTestConfiguration]
    }
}
```

Alternatively, you can adjust or remove classpath attributes in the `eclipse.classpath.file.whenMerged { }` block.

Signing plugin defaults to `gpg` instead of `gpg2` when using the GPG command

The signature plugin's default executable when using the GPG command changed from `gpg2` to `gpg`. The change was motivated as GPG 2.x became stable, and distributions started to migrate by not linking the `gpg2` executable.

In order to set the old default, the executable can be manually defined in `gradle.properties`:

```
signing.gnupg.executable=gpg2
```

`mustRunAfter` constraints no longer violated by `finalizedBy` dependencies

In previous Gradle versions, `mustRunAfter` constraints between regular tasks and finalizer task dependencies would not be honored.

For a concrete example, consider the following task graph definition:

```
tasks {
    register("dockerTest") {
        dependsOn("dockerUp")     // dependsOn createContainer mustRunAfter
removeContainer
        finalizedBy("dockerStop") // dependsOn removeContainer
    }

    register("dockerUp") {
        dependsOn("createContainer")
    }

    register("dockerStop") {
        dependsOn("removeContainer")
    }

    register("createContainer") {
        mustRunAfter("removeContainer")
    }

    register("removeContainer") {
    }
}
```

The relevant constraints are:

- dockerStop is a finalizer of dockerTest so it must be run after dockerTest;

- removeContainer is a dependency of dockerStop so it must be run before dockerStop;

- createContainer must run after removeContainer;

Prior to Gradle 7.5, gradle dockerTest would yield the following order of execution, in violation of the mustRunAfter constraint between :createContainer and :removeContainer:

```
> Task :createContainer UP-TO-DATE
> Task :dockerUp UP-TO-DATE
> Task :dockerTest UP-TO-DATE
> Task :removeContainer UP-TO-DATE
> Task :dockerStop UP-TO-DATE
```

Starting with Gradle 7.5, mustRunAfter constraints are fully honored yielding the following order of execution:

```
> Task :removeContainer UP-TO-DATE
> Task :createContainer UP-TO-DATE
> Task :dockerUp UP-TO-DATE
> Task :dockerTest UP-TO-DATE
> Task :dockerStop UP-TO-DATE
```

Updates to bundled Gradle dependencies

- Groovy has been updated to Groovy 3.0.11.

Scala Zinc version updated to 1.6.1

Zinc is the Scala incremental compiler that allows Gradle to always compile the minimal set of files needed by the current file changes. It takes into account which methods are being used and which have changed, which means it's much more granular than just interfile dependencies.

Zinc version has been updated to the newest available one in order to benefit from all the recent bugfixes. Due to that, if you use `zincVersion` setting it's advised to remove it and only use the default version, because Gradle will only be able to compile Scala code with Zinc versions set to 1.6.x or higher.

Removes implicit `--add-opens` for test workers

Prior to Gradle 7.5, JDK modules `java.base/java.util` and `java.base/java.lang` were automatically opened in test workers on JDK9+ by passing `--add-opens` CLI arguments. This meant any tests were able to perform deep reflection on JDK internals without warning or failing. This caused tests to be unreliable by allowing code to pass when it would otherwise fail in a production environment.

These implicit arguments have been removed and are no longer added by default. If your code or any of your dependencies are performing deep reflection into JDK internals during test execution, you may see the following behavior changes:

Before Java 16, new build warnings are shown. These new warnings are printed to stderr and will not fail the build:

```
WARNING: An illegal reflective access operation has occurred
WARNING: Illegal reflective access by
com.google.inject.internal.cglib.core.ReflectUtils$2 (file:/.../testng-5.12.1.jar) to
<method>
WARNING: Please consider reporting this to the maintainers of
com.google.inject.internal.cglib.core.ReflectUtils$2
WARNING: Use --illegal-access=warn to enable warnings of further illegal reflective
access operations
WARNING: All illegal access operations will be denied in a future release
```

With Java 16 or higher, exceptions are thrown that fail the build:

```
// Thrown by TestNG
java.lang.reflect.InaccessibleObjectException: Unable to make <method> accessible:
module java.base does not "opens java.lang" to unnamed module @1e92bd61
    at
java.base/java.lang.reflect.AccessibleObject.checkCanSetAccessible(AccessibleObject.ja
va:354)
    at
java.base/java.lang.reflect.AccessibleObject.checkCanSetAccessible(AccessibleObject.ja
va:297)
    at java.base/java.lang.reflect.Method.checkCanSetAccessible(Method.java:199)
    at java.base/java.lang.reflect.Method.setAccessible(Method.java:193)
    ...

// Thrown by ProjectBuilder
org.gradle.api.GradleException: Could not inject synthetic classes.
    at
org.gradle.initialization.DefaultLegacyTypesSupport.injectEmptyInterfacesIntoClassLoad
er(DefaultLegacyTypesSupport.java:91)
    at
org.gradle.testfixtures.internal.ProjectBuilderImpl.getGlobalServices(ProjectBuilderIm
pl.java:182)
    at
org.gradle.testfixtures.internal.ProjectBuilderImpl.createProject(ProjectBuilderImpl.j
ava:111)
    at org.gradle.testfixtures.ProjectBuilder.build(ProjectBuilder.java:120)
    ...
Caused by: java.lang.RuntimeException: java.lang.IllegalAccessException: module
java.base does not open java.lang to unnamed module @1e92bd61
```

In most cases, these errors can be resolved by updating the code or dependency performing the
illegal access. If the code-under-test or the newest version of the dependency in question performs
illegal access by design, the old behavior can be restored by opening the java.base/java.lang and
java.base/java.util modules manually with --add-opens:

```
tasks.withType(Test).configureEach {
    jvmArgs(["--add-opens=java.base/java.lang=ALL-UNNAMED",
            "--add-opens=java.base/java.util=ALL-UNNAMED"]
}
```

If you are developing Gradle plugins, ProjectBuilder relies on reflection in the java.base/java.lang
module. Gradle will automatically add the appropriate --add-opens flag to tests when the java-
gradle-plugin plugin is applied.

If you are using TestNG, versions prior to 5.14.6 perform illegal reflection. Updating to at least
5.14.6 should fix the incompatibility.

Checkstyle tasks use toolchains and execute in parallel by default

The Checkstyle plugin now uses the Gradle worker API to run Checkstyle as an external worker process. Multiple Checkstyle tasks may now run in parallel within a project.

Some projects will need to increase the amount of memory available to Checkstyle to avoid out of memory errors. You can increase the maximum memory for the Checkstyle process by setting the `maxHeapSize` for the Checkstyle task. By default, the process will start with a maximum heap size of 512MB.

We also recommend to update Checkstyle to version 9.3 or later.

Missing files specified with relative paths when running Checkstyle

Gradle 7.5 consistently sets the current working directory for the Checkstyle task to `$GRADLE_USER_HOME/workers`. This may cause problems with custom Checkstyle tasks or Checkstyle configuration files that assume a different directory for relative paths.

Previously, Gradle selected the current working directory based on the directory where you ran Gradle. If you ran Gradle in:

- the root directory of a project: Gradle uses the root directory as the current working directory.
- a nested directory of a project: Gradle uses the root directory of the subproject as the current working directory.

In version 7.5 and above, Gradle consistently sets the current working directory for the Checkstyle task to `$GRADLE_USER_HOME/workers`.

Deprecations

Converting files to a classpath where paths contain file separator

Java has the concept of a path separator which is used to separate individual paths in a list of paths, for example in a classpath string. The individual paths must not contain the path separator. Consequently, using `@FileCollection.getAsPath()` for files with paths that contain a path separator has been deprecated, and it will be an error in Gradle 8.0 and later. Using a file collection with paths which contain a path separator may lead to incorrect builds, since Gradle doesn't find the files as inputs, or even to build failures when the path containing the path separator is illegal on the operating system.

`dependencyInsight --singlepath` option is deprecated

For consistency, this was changed to `--single-path`. The API method has remained the same, this only affects the CLI.

Groovydoc `includePrivate` property is deprecated

There is a new access property that allows finer control over what is included in the Groovydoc.

Provider-based API must be used to run external processes at the configuration time

Using `Project.exec`, `Project.javaexec`, and standard Java and Groovy APIs to run external processes at the configuration time is now deprecated when the configuration cache is enabled. It will be an error in Gradle 8.0 and later. Gradle 7.5 introduces configuration cache-compatible ways to execute and obtain output of an external process with the provider-based APIs or a custom implementation of the `ValueSource` interface. The configuration cache chapter has more details to help with the migration to the new APIs.

Upgrading from 7.3 and earlier

Potential breaking changes

Updates to default tool integration versions

- PMD has been updated to PMD 6.39.0.

Deprecations

AdoptOpenJDK toolchain download

Following the move from AdoptOpenJDK to Adoptium, under the Eclipse foundation, it is no longer possible to download an AdoptOpenJDK build from their end point. Instead, an Eclipse Temurin or IBM Semeru build is returned.

Gradle 7.4+ will now emit a deprecation warning when the AdoptOpenJDK vendor is specified in the toolchain specification and it is used by auto provisioning. If you must use AdoptOpenJDK, you should turn off auto-download. If an Eclipse Temurin or IBM Semeru build works for you, specify `JvmVendorSpec.ADOPTIUM` or `JvmVendorSpec.IBM` as the vendor or leave the vendor unspecified.

File trees and empty directory handling

When using `@SkipWhenEmpty` on an input file collection, Gradle skips the task when it determines that the input is empty. If the input file collection consists only of file trees, Gradle ignores directories for the emptiness check. Though when checking for changes to the input file collection, Gradle only ignores directories when the `@IgnoreEmptyDirectories` annotation is present.

Gradle will now ignore directories for both the `@SkipWhenEmpty` check and for determining changes consistently. Until Gradle 8.0, Gradle will detect if an input file collection annotated with `@SkipWhenEmpty` consists only of file trees and then ignore directories automatically. Moreover, Gradle will issue a deprecation warning to advise the user that the behavior will change in Gradle 8.0, and that the input property should be annotated with `@IgnoreEmptyDirectories`. To ignore directories in Gradle 8.0 and later, the input property needs to be annotated with `@IgnoreEmptyDirectories`.

Finally, using `@InputDirectory` implies `@IgnoreEmptyDirectories`, so no changes are necessary when using this annotation. The same is true for `inputs.dir()` when registering an input directory via the runtime API.

Using LazyPublishArtifact without a FileResolver is deprecated

When using a LazyPublishArtifact without a FileResolver, a different file resolution strategy is used, which duplicates some logic in the FileResolver.

To improve consistency, LazyPublishArtifact should be used with a FileResolver, and will require it in the future.

This also affects other internal APIs that use LazyPublishArtifact, which now also have deprecation warnings where needed.

TAR trees from resources without backing files

It is possible to create TAR trees from arbitrary resources. If the resource is not created via `project.resources`, then it may not have a backing file. Creating a TAR tree from a resource with no backing file has been deprecated. Instead, convert the resource to a file and use `project.tarTree()` on the file. To convert the resource to a file you can use a custom task or use dependency management to download the file via a URL. This way, Gradle is able to apply optimizations like up-to-date checks instead of re-running the logic to create the resource every time.

Unique attribute sets

The set of Attributes associated with a *consumable* configuration within a project, must be unique across all other configurations within that project which share the same set of Capabilitys.

This will be checked at the end of configuring variant configurations, as they are locked against further mutation.

If the set of attributes is shared across configurations, consider adding an additional attribute to one of the variants for the sole purpose of disambiguation.

`Provider#forUseAtConfigurationTime()` has been deprecated

Provider#forUseAtConfigurationTime is now deprecated and scheduled for removal in Gradle 9.0. Clients should simply remove the call.

The call was mandatory on providers of external values such as system properties, environment variables, Gradle properties and file contents meant to be used at configuration time together with the configuration cache feature.

Starting with version 7.4 Gradle will implicitly treat an external value used at configuration time as a configuration cache input.

Clients are also free to use standard Java APIs such as `System#getenv` to read environment variables, `System#getProperty` to read system properties as well as Gradle APIs such as `Project#property(String)` and `Project#findProperty(String)` to read Gradle properties at configuration time. The `Provider` based APIs are still the recommended way to connect external values to task inputs for maximum configuration cache reuse.

`ConfigurableReport#setDestination(org.gradle.api.provider.Provider<java.io.File>)` **has been deprecated**

`ConfigurableReport#setDestination(org.gradle.api.provider.Provider<java.io.File>)` is now deprecated and scheduled for removal in Gradle 8.0.

Use `Report#getOutputLocation().set(⋯)` instead.

Task execution listeners and events

The Gradle configuration cache does not support listeners and events that have direct access to `Task` and `Project` instances, which allows Gradle to execute tasks in parallel and to store the minimal amount of data in the configuration cache. In order to move towards an API that is consistent whether the configuration cache is enabled or not, the following APIs are deprecated and will be removed or be made an error in Gradle 8.0:

- Interface TaskExecutionListener
- Interface TaskActionListener
- Method TaskExecutionGraph.addTaskExecutionListener()
- Method TaskExecutionGraph.removeTaskExecutionListener()
- Method TaskExecutionGraph.beforeTask()
- Method TaskExecutionGraph.afterTask()
- Registering TaskExecutionListener, TaskActionListener, TestListener, TestOutputListener via Gradle.addListener()

See the configuration cache chapter for details on how to migrate these usages to APIs that are supported by the configuration cache.

Build finished events

Build finished listeners are not supported by the Gradle configuration cache. And so, the following API are deprecated and will be removed in Gradle 8.0:

- Method Gradle.buildFinished()
- Method BuildListener.buildFinished()

See the configuration cache chapter for details on how to migrate these usages to APIs that are supported by the configuration cache.

Calling `Task.getProject()` from a task action

Calling Task.getProject() from a task action at execution time is now deprecated and will be made an error in Gradle 8.0. This method can be used during configuration time, but it is recommended to avoid doing this.

See the configuration cache chapter for details on how to migrate these usages to APIs that are supported by the configuration cache.

Calling `Task.getTaskDependencies()` from a task action

Calling Task.getTaskDependencies() from a task action at execution time is now deprecated and will be made an error in Gradle 8.0. This method can be used during configuration time, but it is recommended to avoid doing this.

See the configuration cache chapter for details on how to migrate these usages to APIs that are supported by the configuration cache.

Using a build service from a task without the corresponding `Task.usesService` declaration

Gradle needs the information so it can properly honor the build service lifecycle and its usage constraints.

This will become an error in a future Gradle version.

Check the Shared Build Services documentation for more information.

VersionCatalog and VersionCatalogBuilder deprecations

Some methods in VersionCatalog and VersionCatalogBuilder are now deprecated and scheduled for removal in Gradle 8.0. Specific replacements can be found in the JavaDoc of the affected methods.

These methods were changed to improve the consistency between the `libs.versions.toml` file and the API classes.

Upgrading from 7.2 and earlier

Potential breaking changes

Updates to bundled Gradle dependencies

- Kotlin has been updated to Kotlin 1.5.31.
- Groovy has been updated to Groovy 3.0.9.
- Ant has been updated to Ant 1.10.11 to fix CVE-2021-36373 and CVE-2021-36374.
- Commons compress has been updated to Commons-compress 1.21 to fix CVE-2021-35515, CVE-2021-35516, CVE-2021-35517 and CVE-2021-36090.

Application order of plugins in the `plugins` block

The order in which plugins in the `plugins` block were actually applied was inconsistent and depended on how a plugin was added to the class path.

Now the plugins are always applied in the same order they are declared in the `plugins` block which in rare cases might change behavior of existing builds.

Effects of exclusion on substituted dependencies in dependency resolution

Prior to this version, a dependency substitution target could not be excluded from a dependency graph. This was caused by checking for exclusions prior to performing the substitution. Now Gradle will also check for exclusion on the substitution result.

Version catalog

Generated accessors no longer give access to the type unsafe API. You have to use the version catalog extension instead.

Toolchain support in Scala

When using toolchains in Scala, the `-target` option of the Scala compiler will now be set automatically. This means that using a version of Java that cannot be targeted by a version of Scala will result in an error. Providing this flag in the compiler options will disable this behaviour and allow to use a higher Java version to compile for a lower bytecode target.

Declaring input or output directories which contain unreadable content

For up-to-date checks Gradle relies on tracking the state of the inputs and the outputs of a task. Gradle used to ignore unreadable files in the input or outputs to support certain use-cases, although it cannot track their state. Declaring input or output directories on tasks which contain unreadable content has been deprecated and these use-cases are now supported by declaring the task to be untracked. Use the @UntrackedTask annotation or the Task.doNotTrackState() method to declare a task as untracked.

When you are using a `Copy` task for copying single files into a directory which contains unreadable files, use the method Task.doNotTrackState().

Upgrading from 7.1 and earlier

Potential breaking changes

Security changes to application start scripts and Gradle wrapper scripts

Due to CVE-2021-32751, `gradle`, `gradlew` and start scripts generated by Gradle's application plugin have been updated to avoid situations where these scripts could be used for arbitrary code execution when an attacker is able to change environment variables.

You can use the latest version of Gradle to generate a `gradlew` script and use it to execute an older version of Gradle.

This should be transparent for most users; however, there may be changes for Gradle builds that rely on the environment variables `JAVA_OPTS` or `GRADLE_OPTS` to pass parameters with complicated quote escaping. Contact us if you suspect something has broken your build and you cannot find a solution.

Updates to bundled Gradle dependencies

- Groovy has been updated to Groovy 3.0.8.
- Kotlin has been updated to Kotlin 1.5.21.

Updates to default tool integration versions

- PMD has been updated to PMD 6.36.0.

Deprecations

Using Java lambdas as task actions

When using a Java lambda to implement a task action, Gradle cannot track the implementation and the task will never be up-to-date or served from the build cache. Since it is easy to add such a task action, using task actions implemented by Java lambdas is now deprecated. See Validation problems for more details how to fix the issue.

Relying on equals for up-to-date checks is deprecated

When a task input is annotated with `@Input` and is not a type Gradle understand directly (like `String`), then Gradle uses the serialized form of the input for up-to-date checks and the build cache key. Historically, Gradle also loads the serialized value from the last execution and then uses `equals()` to compare it to the current value for up-to-date checks. Doing so is error prone, doesn't work with the build cache and has a performance impact, therefore it has been deprecated. Instead of using `@Input` on a type Gradle doesn't understand directly, use `@Nested` and annotate the properties of the type accordingly.

Upgrading from 7.0 and earlier

Potential breaking changes

Updates to default tool integration versions

- JaCoCo has been updated to 0.8.7.

The `org.gradle.util` package is now a public API

Officially, the `org.gradle.util` package is not part of the public API. But, because this package name doesn't contain the word `internal`, many Gradle plugins already consider as one. Gradle 7.1 addresses the situation and marks the package as public. The classes that were unintentionally exposed are either deprecated or removed, depending on their external usage.

The following classes are now officially recognized as public API:

- `GradleVersion`
- `Path`
- `Configurable`

The following classes have known usages in external plugins and are now deprecated and set for removal in Gradle 8.0:

- `VersionNumber`
- `TextUtil`
- `WrapUtil`
- `RelativePathUtil`
- `DistributionLocator`

- SingleMessageLogger

- ConfigureUtil

ConfigureUtil is being removed without a replacement. Plugins can avoid the need for using ConfigureUtil by following [our example](#).

The following classes have only internal usages and were moved from org.gradle.util to the org.gradle.util.internal package:

- Resources

- RedirectStdOutAndErr

- Swapper

- StdInSwapper

- IncubationLogger

- RedirectStdIn

- MultithreadedTestRule

- DisconnectableInputStream

- BulkReadInputStream

- MockExecutor

- FailsWithMessage

- FailsWithMessageExtension

- TreeVisitor

- AntUtil

- JarUtil

The last set of classes have no external or internal usages and therefore were deleted:

- DiffUtil

- NoopChangeListener

- EnumWithClassBody

- AlwaysTrue

- ReflectionEqualsMatcher

- DynamicDelegate

- IncubationLogger

- NoOpChangeListener

- DeferredUtil

- ChangeListener

The return type of source set extensions have changed

The following source sets are contributed via an extension with a custom type:

- `groovy`: GroovySourceDirectorySet
- `antlr`: AntlrSourceDirectorySet
- `scala`: ScalaSourceDirectorySet

The 'idiomatic' DSL declaration is backward compatible:

```
sourceSets {
    main {
        groovy {
            // ...
        }
    }
}
```

However, the return type of the groovy block has changed to the extension type. This means that the following snippet no longer works in Gradle 7.1:

```
sourceSets {
    main {
        GroovySourceSet sourceSet = groovy {
            // ...
        }
    }
}
```

Start scripts require bash shell

The command used to start Gradle, the Gradle wrapper as well as the scripts generated by the `application` plugin now require `bash` shell.

Deprecations

Using convention mapping with properties with type Provider is deprecated

Convention mapping is an internal feature that is been replaced by the Provider API. When mixing convention mapping with the Provider API, unexpected behavior can occur. Gradle emits a deprecation warning when a property in a task, extension or other domain object uses convention mapping with the Provider API.

To fix this, the plugin that configures the convention mapping for the task, extension or domain object needs to be changed to use the Provider API only.

Setting custom build layout

Command line options:

- `-c`, `--settings-file` for specifying a custom settings file location
- `-b`, `--build-file` for specifying a custom build file location

have been deprecated.

Setting custom build file using buildFile property in GradleBuild task has been deprecated.

Please use the dir property instead to specify the root of the nested build. Alternatively, consider using one of the recommended alternatives for GradleBuild task as suggested in Avoid using the GradleBuild task type section.

Setting custom build layout using StartParameter methods setBuildFile(File) and setSettingsFile(File) as well as the counterpart getters getBuildFile() and getSettingsFile() have been deprecated.

Please use standard locations for settings and build files:

- settings file in the root of the build
- build file in the root of each subproject

For the use case where custom settings or build files are used to model different behavior (similar to Maven profiles), consider using system properties with conditional logic. For example, given a piece of code in either settings or build file:

```
if (System.getProperty("profile") == "custom") {
    println("custom profile")
} else {
    println("default profile")
}
```

You can pass the `profile` system property to Gradle using `gradle -Dprofile=custom` to execute the code in the `custom` profile branch.

Substitution.with replaced with Substitution.using

Dependency substitutions using `with` method have been deprecated and are replaced with `using` method that also allows chaining. For example, a dependency substitution rule `substitute(project(':a')).with(project(':b'))` should be replaced with `substitute(project(':a')).using(project(':b'))`. With chaining you can, for example, add a reason for a substitution like this: `substitute(project(':a')).using(project(':b')).because("a reason")`.

Properties deprecated in JavaExec task

- The main getters and setters in JavaExec task have been deprecated. Use the mainClass property instead.

Deprecated properties in `compile` task

- The JavaCompile.destinationDir property has been deprecated. Use the JavaCompile.destinationDirectory property instead.

- The GroovyCompile.destinationDir property has been deprecated. Use the GroovyCompile.destinationDirectory property instead.

- The ScalaCompile.destinationDir property has been deprecated. Use the ScalaCompile.destinationDirectory property instead.

Non-hierarchical project layouts

Gradle 7.1 deprecated project layouts where subprojects were located outside of the project root. However, based on community feedback we decided to roll back in Gradle 7.4 and removed the deprecation. As a consequence, the Settings.includeFlat() method is deprecated in Gradle 7.1, 7.2, and 7.3 only.

Deprecated `Upload` task

Gradle used to have two ways of publishing artifacts. Now, the situation has been cleared and all build should use the `maven-publish` plugin. The last remaining artifact of the old way of publishing is the `Upload` task that has been deprecated and scheduled for removal in Gradle 8.0. Existing clients should migrate to the `maven-publish` plugin.

Deprecated conventions

The concept of conventions is outdated and superseded by extensions. To reflect this in the Gradle API, the following elements are now deprecated:

- org.gradle.api.Project.getConvention()

- `org.gradle.api.internal.HasConvention` (deprecated)

The internal usages of conventions have been also cleaned up (see the deprecated items below).

Plugin authors migrate to extensions if they replicate the changes we've done internally. Here are some examples:

- Migrate plugin configuration: gradle/gradle#16900.

- Migrate custom source sets: gradle/gradle#17149.

Deprecated consumption of internal plugin configurations

Some core Gradle plugins declare configurations that are used by the plugin itself and are not meant to be published or consumed by another subproject directly. Gradle did not explicitly prohibit this. Gradle 7.1 deprecates consumption of those configurations and this will become an error in Gradle 8.0.

The following plugin configurations have been deprecated for consumption:

plugin	configurations deprecated for consumption
codenarc	codenarc
pmd	pmd
checkstyle	checkstyle
antlr	antlr
jacoco	jacocoAnt, jacocoAgent
scala	zinc
war	providedCompile, providedRuntime

If your use case needs to consume any of the above mentioned configurations in another project, please create a separate consumable configuration that extends from the internal ones. For example:

```
plugins {
    id("codenarc")
}
configurations {
    codenarc {
        // because currently this is consumable until Gradle 8.0 and can clash with
the configuration below depending on the attributes set
        canBeConsumed = false
    }
    codenarcConsumable {
        extendsFrom(codenarc)
        canBeConsumed = true
        canBeResolved = false
        // the attributes below make this configuration consumable by a `java-library`
project using `implementation` configuration
        attributes {
            attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage, Usage.JAVA_RUNTIME))
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.LIBRARY))
            attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
objects.named(LibraryElements, LibraryElements.JAR))
            attribute(Bundling.BUNDLING_ATTRIBUTE, objects.named(Bundling,
Bundling.EXTERNAL))
            attribute(TargetJvmEnvironment.TARGET_JVM_ENVIRONMENT_ATTRIBUTE,
objects.named(TargetJvmEnvironment, TargetJvmEnvironment.STANDARD_JVM));
        }
    }
}
```

Deprecated custom source set interfaces

The following source set interfaces are now deprecated and scheduled for removal in Gradle 8.0:

- GroovySourceSet

- `org.gradle.api.plugins.antlr.AntlrSourceVirtualDirectory` (removed)

- ScalaSourceSet

Clients should configure the sources with their plugin-specific configuration:

- `groovy`: GroovySourceDirectorySet

- `antlr`: AntlrSourceDirectorySet

- `scala`: ScalaSourceDirectorySet

For example, here's how you configure the groovy sources from a plugin:

```
GroovySourceDirectorySet groovySources = sourceSet.getExtensions().getByType
(GroovySourceDirectorySet.class);
groovySources.setSrcDirs(Arrays.asList("sources/groovy"));
```

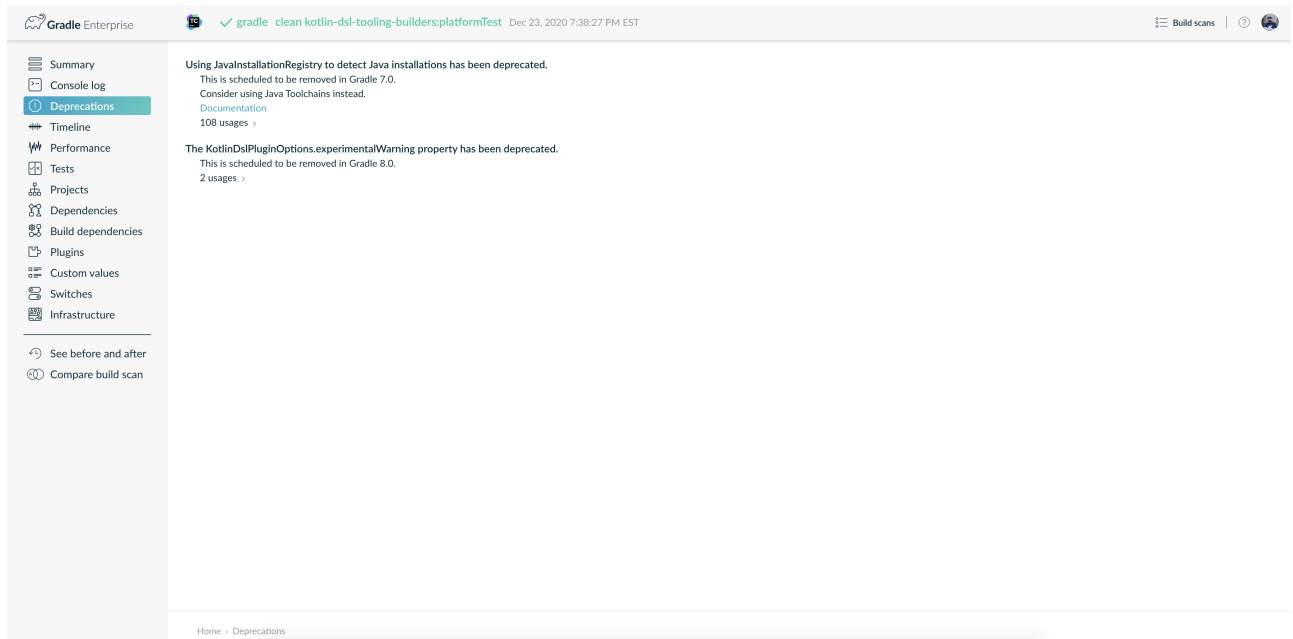**Registering artifact transforms extending `ArtifactTransform`**

When Gradle first introduced artifact transforms, it used the base class `ArtifactTransform` for implementing them. Gradle 5.3 introduced the interface `TransformAction` for implementing artifact transforms, replacing the previous class `ArtifactTransform` and addressing various shortcomings. Using the registration method DependencyHandler.registerTransform(Action) for `ArtifactTransform` has been deprecated. Migrate your artifact transform to use `TransformAction` and use DependencyHandler.registerTransform(Class, Action) instead. See the user manual for more information on implementing `TransformAction`.

Upgrading your build from Gradle 6.x to 7.0

This chapter provides the information you need to migrate your Gradle 6.x builds to Gradle 7.0. For migrating from Gradle 5.x or earlier, complete the older migration guide first.

We recommend the following steps for all users:

1. Try running `gradle help --scan` and view the deprecations view of the generated build scan.

This is so that you can see any deprecation warnings that apply to your build.

Alternatively, you can run `gradle help --warning-mode=all` to see the deprecations in the console, though it may not report as much detailed information.

2. Update your plugins.

   Some plugins will break with this new version of Gradle, for example because they use internal APIs that have been removed or changed. The previous step will help you identify potential problems by issuing deprecation warnings when a plugin does try to use a deprecated part of the API.

3. Run `gradle wrapper --gradle-version 7.0` to update the project to 7.0.

4. Try to run the project and debug any errors using the Troubleshooting Guide.

Upgrading from 6.9 and earlier

Changes in the IDE integration

Changes in the IDEA model

The `getGeneratedSourceDirectories()` and `getGeneratedTestDirectories()` methods are removed from the `IdeaContentRoot` interface. Clients should replace these invocations with `getSourceDirectories()` and `getTestDirectories()` and use the `isGenerated()` method on the returned instances.

Dependency locking now defaults to a single file per project

The format of the dependency lockfile has been changed and as a consequence there is only one file per project instead of one file per configuration per project. This change only affects *writing* lock files. Gradle remains capable of *loading* lock state saved in the older format.

Head over to the documentation to learn how to migrate to the new format. The migration can be

performed per configuration and does not have to be done in a single step. Gradle will automatically clean up previous lock files when migrating them over to the new file format.

Gradle Module Metadata is now reproducible by default

The `buildId` field will not be populated by default to ensure that the produced metadata file remains unchanged when no build inputs are changed. Users can still opt in to have this unique identifier part of the produced metadata if they want to, see the documentation.

The `jcenter()` convenience method is now deprecated

JFrog announced the sunset of the JCenter repository in February 2021. Many Gradle builds rely on JCenter for project dependencies.

No new packages or versions are published to JCenter, but JFrog says they will keep JCenter running in a read-only state indefinitely. We recommend that you consider using `mavenCentral()`, `google()` or a private `maven` repository instead.

Gradle emits a deprecation warning when `jcenter()` is used as a repository and this method is scheduled to be removed in Gradle 8.0.

Potential breaking changes

Updates to bundled Gradle dependencies

- Kotlin has been updated to Kotlin 1.4.31.
- Groovy has been updated to Groovy 3.0.7.

Changes to Groovy and Groovy DSL

Due to the update to the next major version of Groovy, you may experience minor issues when upgrading to Gradle 7.0.

The new version of Groovy has a stricter parser that fails to compile code that may have been accepted in previous Groovy versions. If you encounter syntax errors, check the Groovy issue tracker and Groovy 3 release highlights.

Some very specific regressions have already been fixed in the next minor version of Groovy.

Groovy modularization

Gradle no longer embeds a copy of `groovy-all` that bundles all Groovy modules into a single jar—only the most important modules are distributed in the Gradle distribution.

The `localGroovy()` dependency will include these Groovy modules:

- `groovy`
- `groovy-ant`
- `groovy-astbuilder`
- `groovy-console`

- `groovy-datetime`
- `groovy-dateutil`
- `groovy-groovydoc`
- `groovy-json`
- `groovy-nio`
- `groovy-sql`
- `groovy-templates`
- `groovy-test`
- `groovy-xml`

But the following Groovy modules are **not** included:

- `groovy-cli-picocli`
- `groovy-docgenerator`
- `groovy-groovysh`
- `groovy-jmx`
- `groovy-jsr223`
- `groovy-macro`
- `groovy-servlet`
- `groovy-swing`
- `groovy-test-junit5`
- `groovy-testng`

You can pull these dependencies into your build like any other external dependency.

Building Gradle plugins with Groovy 3

Plugins built with Gradle 7.0 will now have Groovy 3 on their classpath when using `gradleApi()` or `localGroovy()`.

| NOTE | If you use Spock to test your plugins, you will need to use Spock 2.x. There are no compatible versions of Spock 1.x and Groovy 3. |

```
dependencies {
    // Ensure you use the Groovy 3.x variant
    testImplementation('org.spockframework:spock-core:2.0-groovy-3.0') {
        exclude group: 'org.codehaus.groovy'
    }
}

// Spock 2 is based on JUnit Platform which needs to be enabled explicitly.
tasks.withType(Test).configureEach {
    useJUnitPlatform()
}
```

Performance

Depending on the number of subprojects and Groovy DSL build scripts, you may notice a performance regression when compiling build scripts for the first time or when changes are made to the build script's classpath. This is due to the slower performance of the Groovy 3 parser, but the Groovy team is aware of the issue and trying to mitigate the regression.

In general, we are also looking at how we can improve the performance of build script compilation for both Groovy DSL and Kotlin DSL.

Encountering 'Could not find method X for arguments Y on DefaultDependencyHandler'

While the following error initially looks like a compile error, it is actually due to the fact that specific `Configuration`s have been removed. Please refer to Removal of `compile` and `runtime` configurations for more details.

```
Could not find method testCompile() for arguments
[DefaultExternalModuleDependency{group='org.junit', name='junit-bom', version='5.7.0',
configuration='default'}] on object of type
org.gradle.api.internal.artifacts.dsl.dependencies.DefaultDependencyHandler.
```

Updates to default tool integration versions

- PMD has been updated to PMD 6.31.0.
- Groovy and GroovyDoc have been updated to Groovy 3.0.7.

Removal of `compile` and `runtime` configurations

Since its inception, Gradle provided the `compile` and `runtime` configurations to declare dependencies. These however did not support a fine grained scoping of dependencies. Hence, better replacements were introduced in Gradle 3.4:

- The `implementation` configuration should be used to declare dependencies which are *implementation details* of a library: they are not visible to consumers of the library during compilation time.

- The `api` configuration, available only if you apply the `java-library` plugin, should be used to declare dependencies which are part of the API of a library, that need to be exposed to consumers at compilation time.

In Gradle 7, both the `compile` and `runtime` configurations are removed. Therefore, you have to migrate to the `implementation` and `api` configurations above. If you are still using the `java` plugin for a Java library, you will need to apply the `java-library` plugin instead.

Table 3. Common configuration upgrades

Removed Configuration	New Configuration
`compile`	`api` or `implementation`
`runtime`	`runtimeOnly`
`testRuntime`	`testRuntimeOnly`
`testCompile`	`testImplementation`
`<sourceSet>Runtime`	`<sourceSet>RuntimeOnly`
`<sourceSet>Compile`	`<sourceSet>Implementation`

You can find more details about the benefits of the new configurations and which one to use in place of `compile` and `runtime` by reading the Java Library plugin documentation.

When using the Groovy DSL, you need to watch out for a particular upgrade problem when dealing with the removed configurations.

If you were creating custom configurations that extend one of the removed configurations, Gradle may silently create configurations that do not exist.

This looks something like:

```
configurations {
    // This silently creates a configuration called "runtime"
    myConf extendsFrom runtime
}
```

The result of dependency resolution for your custom configuration may not be the same as Gradle 6.x or before. You may notice missing dependencies or artifacts.

Location of temporary project files for `ProjectBuilder`

The `ProjectBuilder` API is used for inspecting Gradle builds in unit tests. This API used to create temporary project files under the system temporary directory as defined by `java.io.tmpdir`.

The API now creates temporary project files under the `Test` task's temporary directory. This path is usually under the project build directory. This may cause test failures when the test expects particular file paths.

If the test uses `ProjectBuilder.withProjectDir(…)`, it is unaffected.

Location of temporary files for TestKit tests

Tests that use the TestKit API used to create temporary files under the system temporary directory as defined by `java.io.tmpdir`. These files were used to store copies of Gradle distributions or another test-only Gradle User Home.

TestKit tests will now create temporary files under the `Test` task's temporary directory. This path is usually under the project build directory. This may cause test failures when the test expects particular file paths.

If the test uses `GradleRunner.withTestKitDir(…)`, it is unaffected.

File system watching with TestKit on Windows

The file system watching implementation on Windows adds a lock to the root project directory in order to watch for changes. This may cause errors when you try to delete the root project directory after running a build with TestKit. For example, tests that use TestKit together with JUnit's `@TempDir` extension, or the `TemporaryFolder` rule can run into this problem. To avoid problems with these file locks, TestKit disables file system watching for builds executed on Windows via `GradleRunner`. If you'd like to override the default behavior, you can enable file system watching by passing `--watch-fs` to `GradleRunner.withArguments()`.

Removal of the legacy `maven` plugin

The `maven` plugin has been removed. You should use the `maven-publish` plugin instead.

Please refer to the [documentation of the Maven Publish plugin](#) for more details.

Removal of the `uploadArchives` task

The `uploadArchives` task was used in combination with the legacy Ivy or Maven publishing mechanisms. It has been removed in Gradle 7. You should migrate to the `maven-publish` or `ivy-publish` plugin instead.

Please refer to the [documentation of the Maven Publish plugin](#) for publishing on Maven repositories. Please refer to the [documentation of the Ivy Publish plugin](#) for publishing on Ivy repositories.

Changes in dependency version sorting

In the context of dependency version sorting, a `-SNAPSHOT` version is now considered to be right before a final release but after any `-RC` version. More special version suffixes are also taken into account. This brings the Gradle algorithm closer to the Maven one for well-known version suffixes.

Have a look at [the documentation](#) for all the rules Gradle applies.

Removal of Play Framework plugins

The deprecated Play plugins have been removed. An external replacement, the [Play Framework plugin](#), is available from the plugin portal.

Removal of deprecated JVM plugins

These unmaintained alternative JVM plugins have been removed: `java-lang`, `scala-lang`, `junit-test-suite`, `jvm-component`, `jvm-resources`.

Please use the stable Java Library and Scala plugins instead.

Removal of experimental JavaScript plugins

The following plugins for experimental JavaScript integration are now removed from the distribution: `coffeescript-base`, `envjs`, `javascript-base`, `jshint`, `rhino`.

If you used these plugins despite their experimental nature, you may find suitable replacements in the Plugin Portal.

Configuring the layout of an Ivy repository

The `layout` method taking a configuration block has been removed and is replaced by patternLayout.

Executing a Gradle build without a settings file is now an error

A Gradle build is defined by its `settings.gradle(.kts)` file found in the current or parent directory. Without a settings file, a Gradle build is undefined and Gradle produces an error when attempting to execute tasks.

To fix this error, create a `settings.gradle(.kts)` file for the build.

Exceptions to this are invoking Gradle with the `init` task or using diagnostic command line flags, such as `--version`.

Calling Project.afterEvaluate() after project evaluation is now an error

Gradle 6.x warns users about the wrong behavior and ignores the target action in this scenario. Starting from 7.0 the same case will produce an error. Plugins and build scripts should be adjusted to call `afterEvaluate` only at configuration time. If you have such a build failure and the related `afterEvaluate` statement is declared in your build sources then you can simply delete it. If `afterEvaluate` is declared in a plugin then report the issue to the plugin maintainers.

Modifying file collections after values finalized is now an error

Calling any mutator methods (i.e. `clear()`, `add()`, `remove()`, etc.) on `ConfigurableFileCollection` after the stored value calculated throws an exception. Users and plugin authors should adjust their code such that all configuration on `ConfigurableFileCollection` happens during configuration time, before the values are read.

Removal of `ProjectLayout#configurableFiles`

Please use `ObjectFactory#fileCollection()` instead.

Removal of `BasePluginConvention.libsDir` **and** `BasePluginConvention.distsDir`

Please use the `libsDirectory` and `distsDirectory` properties instead.

Removal of `UnableToDeleteFileException`

Existing usages should be replaced with `RuntimeException`.

Properties removed in Checkstyle and PMD plugins

- The `configDir` getters and setters have been removed from the Checkstle task and extension. Use the `configDirectory` property instead.
- The `rulePriority` getter and setter have been removed from the Pmd task and extension. Use the `rulesMinimumPriority` property instead.

Removal of `baseName` **property in** `distribution` **plugin**

The `getBaseName()` and `setBaseName()` methods were removed from the `Distribution` class. Clients should replace the usages with the `distributionBaseName` property.

Using `AbstractTask`

Registering a task with the `AbstractTask` type or with a type extending `AbstractTask` was deprecated in Gradle 6.5 and is now an error in Gradle 7.0. You can use DefaultTask instead.

Removal of `BuildListener.buildStarted(Gradle)`

`BuildListener.buildStarted(Gradle)` was deprecated in Gradle 6.0 and is now removed in Gradle 7.0. Please use BuildListener.beforeSettings(Settings) instead.

Removal of unused `StartParameter` **APIs**

The following APIs, which were not usable via command line options anymore since Gradle 5.0, are now removed: `StartParameter.useEmptySettings()`, `StartParameter.isUseEmptySettings()`, `StartParameter.setSearchUpwards(boolean)` and `StartParameter.isSearchUpwards()`.

Removal of searching for settings files in 'master' directories

Gradle no longer supports discovering the settings file in a directory named `master` in a sibling directory. If your build still uses this deprecated feature, consider refactoring the build to have the root directory match the physical root of the project hierarchy. You can find more information about how to structure a Gradle build or a composition of builds in the user manual. Alternatively, you can still run tasks in builds like this by invoking the build from the `master` directory only using a fully qualified path to the task.

`modularity.inferModulePath` **defaults to 'true'**

Compiling, testing and executing now works automatically for any source set that defines a module by containing a `module-info.java` file. Usually, this is the behavior you need. If this is causing issues in cases you manually configure the module path, or use a 3rd party plugin for it, you can still opt out of this by setting `modularity.inferModulePath` to `false` on the java extension or individual tasks.

Removal of `ValidateTaskProperties`

The `ValidateTaskProperties` task has been removed and replaced by the ValidatePlugins task.

Removal of `ImmutableFileCollection`

The `ImmutableFileCollection` type has been removed. Use the factory method instead. A handle to the project layout can be obtained via Project.layout.

Removal of `ComponentSelectionReason.getDescription`

The method `ComponentSelectionReason.getDescription` has been removed. It is replaced by `ComponentSelectionReason.getDescriptions` which returns a list of `ComponentSelectionDescriptor`, each having a `getDescription`.

Removal of domain object collection constructors

The following deprecated constructors were removed:

- DefaultNamedDomainObjectList(Class, Instantiator, Namer)
- DefaultNamedDomainObjectSet(Class, Instantiator)
- DefaultPolymorphicDomainObjectContainer(Class, Instantiator)
- FactoryNamedDomainObjectContainer(Class, Instantiator, NamedDomainObjectFactory)

Removal of arbitrary local cache configuration

The local build cache configuration now needs to be done via BuildCacheConfiguration.local().

Removal of DefaultVersionSelectorScheme constructor

This internal API was used in plugins, amongst other the Nebula plugins, and was deprecated in the Gradle 5.x timeline and is now removed. Latest plugins version should no longer reference it.

Setting the `config_loc` **config property on the** `checkstyle` **plugin is now an error**

The `checkstyle` plugin now fails for the following configuration

```
checkstyle {
    configProperties['config_loc'] = file("path/to/checkstyle-config-dir")
}
```

Builds should declare the checkstyle configuration with the `checkstyle` block:

```
checkstyle {
    configDirectory = file("path/to/checkstyle-config-dir")
}
```

Querying the mapped value of a provider before the producer has completed is now an error

Gradle 6.x warns users about the wrong behavior and then returns a possibly incorrect provider value. Starting with 7.0 the same case will produce an error. Plugins and build scripts should be adjusted to query the mapped value of a provider, for example a task output property, after the task has completed.

Task validation problems are now errors

Gradle 6.0 started warning about problems with task definitions (such as incorrectly defined inputs or outputs). For Gradle 7.0, those warnings are now errors and will fail the build.

Change in behavior when there's a strict version conflict with a local project

Previous Gradle releases had an inconsistent behavior in regard to conflict resolution in a particular configuration: - your project declares a strict dependency on a published module (for example, `com.mycompany:some-module:1.2!!`, where `1.2!!` is the short hand notation for a strict dependency on 1.2) - your build actually provides `com.mycompany:some-module` in a higher version

Previous Gradle releases would succeed, selecting the project dependency despite the strict constraint. Starting from Gradle 7, this will trigger a dependency resolution failure.

See this issue for more context.

Deprecations

Missing dependencies between tasks

Having a task which produces an output in a location and another task consuming that location by referring to it as an input without the consumer task depending on the producer task has been deprecated. A fix for this problem is to add a dependency from the consumer to the producer.

Duplicates strategy

Gradle 7 now fails when a copy operation (or any operation which uses a `org.gradle.api.file.CopySpec`) encounters a duplicate entry, and that the duplicates strategy isn't set. Please look at the CopySpec docs for details.

Upgrading from 6.8 and earlier

No upgrade notes from 6.8 to 6.9, as 6.9 only contains bug fixes.

Upgrading from 6.7 and earlier

Potential breaking changes

Toolchain API is now marked as @NonNull

The API supporting the Java Toolchain feature in `org.gradle.jvm.toolchain` is now marked as `@NonNull`.

This may impact Kotlin consumers where the return types of APIs are no longer nullable.

Updates to default tool integration versions

- JaCoCo has been updated to 0.8.6.
- Checkstyle has been updated to Checkstyle 8.37.
- CodeNarc has been updated to CodeNarc 2.0.0.

Updates to bundled Gradle dependencies

- Kotlin has been updated to Kotlin 1.4.20. Note that Gradle scripts are still using the Kotlin 1.3 language.
- Apache Ant has been updated to 1.10.9 to fix CVE-2020-11979

Projects imported into Eclipse now include custom source set classpaths

Previously, projects imported by Eclipse only included dependencies for the main and test source sets. The compile and runtime classpaths of custom source sets were ignored.

Since Gradle 6.8, projects imported into Eclipse include the compile and runtime classpath for every source set defined by the build.

SourceTask is no longer sensitive to empty directories

Previously, empty directories would be taken into account during up-to-date checks and build cache key calculations for the sources declared in `SourceTask`. This meant that a source tree that contained an empty directory and an otherwise identical source tree that did not contain the empty directory would be considered different sources, even if the task would produce the same outputs. In Gradle 6.8, `SourceTask` now ignores empty directories during doing up-to-date checks and build cache key calculations. In the vast majority of cases, this is the desired behavior, but it is possible that a task may extend `SourceTask` but also produce different outputs when empty directories are present in the sources. For tasks where this is a concern, you can expose a separate property without the `@IgnoreEmptyDirectories` annotation in order to capture those changes:

```
@InputFiles
@SkipWhenEmpty
@PathSensitive(PathSensitivity.ABSOLUTE)
public FileTree getSourcesWithEmptyDirectories() {
    return super.getSource()
}
```

Changes to publications

Publishing a component which has a dependency on an enforced platform now triggers a validation error, preventing accidental publishing of bad metadata: enforced platforms use cases should be limited to applications, not things which can be consumed from another library or an application.

If, for some reason, you still want to publish components with dependencies on enforced platforms,

you can disable the validation following the [documentation](#).

Changing default excludes during the execution phase

Gradle's file trees apply some default exclude patterns for convenience — the same defaults as Ant in fact. See the [user manual](#) for more information. Sometimes, Ant's default excludes prove problematic, for example when you want to include the `.gitignore` in an archive file.

Changing Gradle's default excludes during the execution phase can lead to correctness problems with up-to-date checks. As a consequence, you are only allowed to change Gradle's default excludes in the settings script, see the [user manual](#) for an example.

Deprecations

Referencing tasks from included builds

Direct references to tasks from included builds in `mustRunAfter`, `shouldRunAfter` and `finalizedBy` task methods have been deprecated. Task ordering using `mustRunAfter` and `shouldRunAfter` as well as finalizers specified by `finalizedBy` should be used for task ordering within a build. If you happen to have cross-build task ordering defined using above mentioned methods, consider restructuring such builds and decoupling them from one another.

Searching for settings files in 'master' directories

Gradle will emit a deprecation warning when your build relies on finding the settings file in a directory named `master` in a sibling directory.

If your build uses this feature, consider refactoring the build to have the root directory match the physical root of the project hierarchy.

Alternatively, you can still run tasks in builds like this by invoking the build from the `master` directory only using a [fully qualified path to the task](#).

Using method `NamedDomainObjectContainer<T>.invoke(kotlin.Function1)`

Gradle Kotlin DSL extensions have been changed to favor Gradle's `Action<T>` type over Kotlin function types.

While the change should be transparent to Kotlin clients, Java clients calling Kotlin DSL extensions need to be updated to use the `Action<T>` APIs.

Upgrading from 6.6 and earlier

Potential breaking changes

buildSrc can now see included builds from the root

Previously, `buildSrc` was built in such a way that included builds were ignored from the root build.

Since Gradle 6.7, `buildSrc` can see any included build from the root build. This may cause dependencies to be substituted from an included build in `buildSrc`. This may also change the order

in which some builds are executed if an included build is needed by `buildSrc`.

Updates to default tool integration versions

- PMD has been updated to PMD 6.26.0.
- Checkstyle has been updated to Checkstyle 8.35.
- CodeNarc has been updated to CodeNarc 1.6.1.

Deprecations

Changing default excludes during the execution phase

Gradle's file trees apply some default exclude patterns for convenience — the same defaults as Ant in fact. See the user manual for more information. Sometimes, Ant's default excludes prove problematic, for example when you want to include the `.gitignore` in an archive file.

Changing Gradle's default excludes during the execution phase can lead to correctness problems with up-to-date checks, and is deprecated. You are only allowed to change Gradle's default excludes in the settings script, see the user manual for an example.

Using a Configuration directly as a dependency

Gradle allowed instances of `Configuration` to be used directly as dependencies:

```
dependencies {
    implementation(configurations.myConfiguration)
}
```

This behavior is now deprecated as it is confusing: one could expect the "dependent configuration" to be resolved first and add the result of resolution as dependencies to the including configuration, which is not the case. The deprecated version can be replaced with the actual behavior, which is configuration inheritance:

```
configurations.implementation.extendsFrom(configurations.myConfiguration)
```

Upgrading from 6.5 and earlier

Potential breaking changes

Updates to bundled Gradle dependencies

- Ant has been updated to 1.10.8.
- Groovy has been updated to Groovy 2.5.12.

Dependency substitutions and variant aware dependency resolution

While adding support for expressing variant support in dependency substitutions, a bug fix

introduced a behaviour change that some builds may rely upon. Previously a substituted dependency would still use the [attributes](#) of the original selector instead of the ones from the replacement selector.

With that change, existing substitutions around dependencies with richer selectors, such as for platform dependencies, will no longer work as they did. It becomes mandatory to define the variant aware part in the target selector.

You can be affected by this change if you:

- have dependencies on platforms, like `implementation platform("org:platform:1.0")`
- *or* if you specify attributes on dependencies,
- *and* you use [resolution rules](#) on these dependencies.

See the [documentation](#) for resolving issues if you are impacted.

Deprecations

No deprecations were made in Gradle 6.6.

Upgrading from 6.4 and earlier

Potential breaking changes

Updates to bundled Gradle dependencies

- Kotlin has been updated to [Kotlin 1.3.72](#).
- Groovy has been updated to [Groovy 2.5.11](#).

Updates to default tool integration versions

- PMD has been updated to [PMD 6.23.0](#).

Deprecations

Internal class AbstractTask is deprecated

`AbstractTask` is an internal class which is visible on the public API, as a superclass of public type `DefaultTask`. `AbstractTask` will be removed in Gradle 7.0, and the following are deprecated in Gradle 6.5:

- Registering a task whose type is `AbstractTask` or `TaskInternal`. You can remove the task type from the task registration and Gradle will use `DefaultTask` instead.
- Registering a task whose type is a subclass of `AbstractTask` but not a subclass of `DefaultTask`. You can change the task type to extend `DefaultTask` instead.
- Using the class `AbstractTask` from plugin code or build scripts. You can change the code to use `DefaultTask` instead.

Upgrading from 6.3 and earlier

Potential breaking changes

PMD plugin expects PMD 6.0.0 or higher by default

Gradle 6.4 enabled incremental analysis by default. Incremental analysis is only available in PMD 6.0.0 or higher. If you want to use an older PMD version, you need to disable incremental analysis:

```
pmd {
    incrementalAnalysis = false
}
```

Changes in dependency locking

With Gradle 6.4, the incubating API for dependency locking `LockMode` has changed. The value is now set via a `Property<LockMode>` instead of a direct setter. This means that the notation to set the value has to be updated for the Kotlin DSL:

```
dependencyLocking {
    lockMode.set(LockMode.STRICT)
}
```

Users of the Groovy DSL should not be impacted as the notation `lockMode = LockMode.STRICT` remains valid.

Java versions in published metadata

If a Java library is published with Gradle Module Metadata, the information which Java version it supports is encoded in the `org.gradle.jvm.version` attribute. By default, this attribute was set to what you configured in `java.targetCompatibility`. If that was not configured, it was set to the current Java version running Gradle. Changing the version of a particular compile task, e.g. `javaCompile.targetCompatibility` had no effect on that attribute, leading to wrong information if the attribute was not adjusted manually. This is now fixed and the attribute defaults to the setting of the compile task that is associated with the sources from which the published jar is built.

Ivy repositories with custom layouts

Gradle versions from 6.0 to 6.3.x included could generate bad Gradle Module Metadata when publishing on an Ivy repository which had a custom repository layout. Starting from 6.4, Gradle will no longer publish Gradle Module Metadata if it detects that you are using a custom repository layout.

New properties may shadow variables in build scripts

This release introduces some new properties — `mainClass`, `mainModule`, `modularity` — in different places. Since these are very generic names, there is a chance that you use one of them in your build scripts as variable name. A new property might then shadow one of your variables in an undesired

way, leading to a build failure where the property is accessed instead of the local variable with the same name. You can fix it by renaming the corresponding variable in the build script.

Affected is configuration code inside the `application {}` and `java {}` configuration blocks, inside a java execution setup with `project.javaexec {}`, and inside various task configurations (`JavaExec`, `CreateStartScripts`, `JavaCompile`, `Test`, `Javadoc`).

Updates to bundled Gradle dependencies

- Kotlin has been updated to [Kotlin 1.3.71](#).

Deprecations

There were no deprecations between Gradle 6.3 and 6.4.

Upgrading from 6.2 and earlier

Potential breaking changes

Fewer dependencies available in IDEA

Gradle no longer includes the annotation processor classpath as provided dependencies in IDEA. The dependencies IDEA sees at compile time are the same as what Gradle sees after resolving the compile classpath (configuration named `compileClasspath`). This prevents the leakage of annotation processor dependencies into the project's code.

Before Gradle introduced [incremental annotation processing support](#), IDEA required all annotation processors to be on the compilation classpath to be able to run annotation processing when compiling in IDEA. This is no longer necessary because Gradle has a separate [annotation processor classpath](#). The dependencies for annotation processors are not added to an IDEA module's classpath when a Gradle project with annotation processors is imported.

Updates to bundled Gradle dependencies

- Kotlin has been updated to [Kotlin 1.3.70](#).
- Groovy has been updated to [Groovy 2.5.10](#).

Updates to default tool integration versions

- PMD has been updated to [PMD 6.21.0](#).
- CodeNarc has been updated to [CodeNarc 1.5](#).

Rich console support removed for some 32-bit operating systems

Gradle 6.3 does not support the [rich console](#) for 32-bit Unix systems and for old FreeBSD versions (older than FreeBSD 10). Microsoft Windows 32-bit is unaffected.

Gradle will continue building projects on 32-bit systems but will no longer show the rich console.

Deprecations

Using default and archives configurations

Almost every Gradle project has the *default* and *archives* configurations which are added by the *base* plugin. These configurations are no longer used in modern Gradle builds that use variant aware dependency management and the new publishing plugins.

While the configurations will stay in Gradle for backwards compatibility for now, using them to declare dependencies or to resolve dependencies is now deprecated.

Resolving these configurations was never an intended use case and only possible because in earlier Gradle versions *every* configuration was resolvable. For declaring dependencies, please use the configurations provided by the plugins you use, for example by the Java Library plugin.

Upgrading from 6.1 and earlier

Potential breaking changes

Compile and runtime classpath now request library variants by default

A classpath in a JVM project now explicitly requests the `org.gradle.category=library` attribute. This leads to clearer error messages if a certain library cannot be used. For example, when the library does not support the required Java version. The practical effect is that now all platform dependencies have to be declared as such. Before, platform dependencies also worked, accidentally, when the `platform()` keyword was omitted for local platforms or platforms published with Gradle Module Metadata.

Properties from project root `gradle.properties` leaking into `buildSrc` and included builds

There was a regression in Gradle 6.2 and Gradle 6.2.1 that caused Gradle properties set in the project root `gradle.properties` file to leak into the `buildSrc` build and any builds included by the root.

This could cause your build to start failing if the `buildSrc` build or an included build suddenly found an unexpected or incompatible value for a property coming from the project root `gradle.properties` file.

The regression has been fixed in Gradle 6.2.2.

Deprecations

There were no deprecations between Gradle 6.1 and 6.2.

Upgrading from 6.0 and earlier

Deprecations

Querying a mapped output property of a task before the task has completed

Querying the value of a mapped output property before the task has completed can cause strange

build failures because it indicates stale or non-existent outputs may be used by mistake. This behavior is deprecated and will emit a deprecation warning. This will become an error in Gradle 7.0.

The following example demonstrates this problem where the Producer's output file is parsed before the Producer executes:

```
class Consumer extends DefaultTask {
    @Input
    final Property<Integer> threadPoolSize = ...
}

class Producer extends DefaultTask {
    @OutputFile
    final RegularFileProperty outputFile = ...
}

// threadPoolSize is read from the producer's outputFile
consumer.threadPoolSize = producer.outputFile.map { it.text.toInteger() }

// Emits deprecation warning
println("thread pool size = " + consumer.threadPoolSize.get())
```

Querying the value of `consumer.threadPoolSize` will produce a deprecation warning if done prior to `producer` completing, as the output file has not yet been generated.

Discontinued methods

The following methods have been discontinued and should no longer be used. They will be removed in Gradle 7.0.

- `BasePluginConvention.setProject(ProjectInternal)`
- `BasePluginConvention.getProject()`
- `StartParameter.useEmptySettings()`
- `StartParameter.isUseEmptySettings()`

Alternative JVM plugins (a.k.a "Software Model")

A set of alternative plugins for Java and Scala development were introduced in Gradle 2.x as an experiment based on the "software model". These plugins are now deprecated and will eventually be removed. If you are still using one of these old plugins (`java-lang`, `scala-lang`, `jvm-component`, `jvm-resources`, `junit-test-suite`) please consult the documentation on Building Java & JVM projects to determine which of the stable JVM plugins are appropriate for your project.

Potential breaking changes

`ProjectLayout` **is no longer available to worker actions as a service**

In Gradle 6.0, the `ProjectLayout` service was made available to worker actions via service injection. This service allowed for mutable state to leak into a worker action and introduced a way for dependencies to go undeclared in the worker action.

`ProjectLayout` has been removed from the available services. Worker actions that were using `ProjectLayout` should switch to injecting the `projectDirectory` or `buildDirectory` as a parameter instead.

Updates to bundled Gradle dependencies

- Kotlin has been updated to Kotlin 1.3.61.

Updates to default tool integration versions

- Checkstyle has been updated to Checkstyle 8.27.
- PMD has been updated to PMD 6.20.0.

Publishing Spring Boot applications

Starting from Gradle 6.2, Gradle performs a sanity check before uploading, to make sure you don't upload stale files (files produced by another build). This introduces a problem with Spring Boot applications which are uploaded using the `components.java` component:

```
Artifact my-application-0.0.1-SNAPSHOT.jar wasn't produced by this build.
```

This is caused by the fact that the main `jar` task is disabled by the Spring Boot application, and the component expects it to be present. Because the `bootJar` task uses the *same file* as the main `jar` task by default, previous releases of Gradle would either:

- publish a stale `bootJar` artifact
- or fail if the `bootJar` task hasn't been called previously

A workaround is to tell Gradle what to upload. If you want to upload the `bootJar`, then you need to configure the outgoing configurations to do this:

```
configurations {
    [apiElements, runtimeElements].each {
        it.outgoing.artifacts.removeIf {
it.buildDependencies.getDependencies(null).contains(jar) }
        it.outgoing.artifact(bootJar)
    }
}
```

Alternatively, you might want to re-enable the `jar` task, and add the `bootJar` with a different classifier.
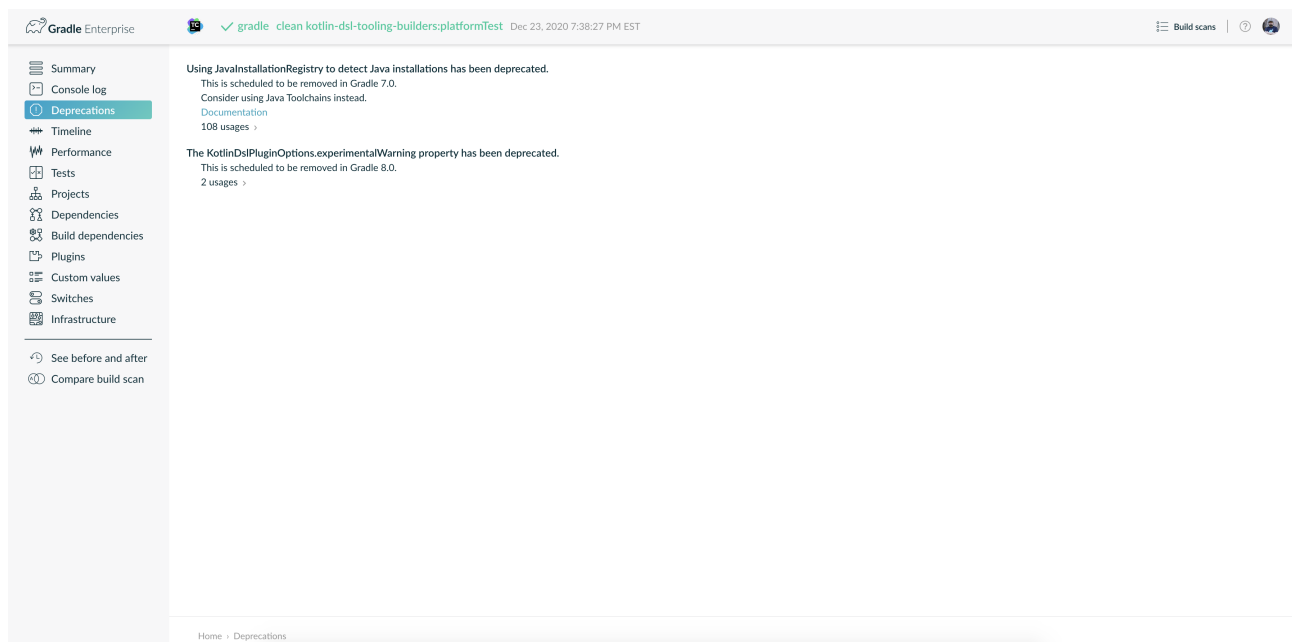
```
jar {
    enabled = true
}

bootJar {
    classifier = 'application'
}
```

Upgrading your build from Gradle 5.x to 6.0

This chapter provides the information you need to migrate your Gradle 5.x builds to Gradle 6.0. For migrating from Gradle 4.x, complete the 4.x to 5.0 guide first.

We recommend the following steps for all users:

1. Try running `gradle help --scan` and view the deprecations view of the generated build scan.

   This is so that you can see any deprecation warnings that apply to your build.

   Alternatively, you can run `gradle help --warning-mode=all` to see the deprecations in the console, though it may not report as much detailed information.

2. Update your plugins.

   Some plugins will break with this new version of Gradle, for example because they use internal APIs that have been removed or changed. The previous step will help you identify potential problems by issuing deprecation warnings when a plugin does try to use a deprecated part of the API.

3. Run `gradle wrapper --gradle-version 6.0` to update the project to 6.0.

4. Try to run the project and debug any errors using the Troubleshooting Guide.

Upgrading from 5.6 and earlier

Deprecations

Dependencies should no longer be declared using the `compile` and `runtime` configurations

The usage of the `compile` and `runtime` configurations in the Java ecosystem plugins has been discouraged since Gradle 3.4.

These configurations are used for compiling and running code from the `main` source set. Other sources sets create similar configurations (e.g. `testCompile` and `testRuntime` for the `test` source set), should not be used either. The `implementation`, `api`, `compileOnly` and `runtimeOnly` configurations should be used to declare dependencies and the `compileClasspath` and `runtimeClasspath` configurations to resolve dependencies. See the relationship of these configurations.

Legacy publication system is deprecated and replaced with the `*-publish` plugins

The `uploadArchives` task and the `maven` plugin are deprecated.

Users should migrate to the publishing system of Gradle by using either the `maven-publish` or `ivy-publish` plugins. These plugins have been stable since Gradle 4.8.

The publishing system is also the only way to ensure the publication of Gradle Module Metadata.

Problems with tasks emit deprecation warnings

When Gradle detects problems with task definitions (such as incorrectly defined inputs or outputs) it will show the following message on the console:

```
Deprecated Gradle features were used in this build, making it incompatible with Gradle
7.0.
Use '--warning-mode all' to show the individual deprecation warnings.
See
https://docs.gradle.org/6.0/userguide/command_line_interface.html#sec:command_line_war
nings
```

The deprecation warnings show up in build scans for every build, regardless of the command-line switches used.

When the build is executed with `--warning-mode all`, the individual warnings will be shown:

```
> Task :myTask
Property 'inputDirectory' is declared without normalization specified. Properties of
cacheable work must declare their normalization via @PathSensitive, @Classpath or
@CompileClasspath. Defaulting to PathSensitivity.ABSOLUTE. This behavior is scheduled
to be removed in Gradle 7.0.
Property 'outputFile' is not annotated with an input or output annotation. This
behavior is scheduled to be removed in Gradle 7.0.
```

If you own the code of the tasks in question, you can fix them by following the suggestions. You can also use `--stacktrace` to see where in the code each warning originates from.

Otherwise, you'll need to report the problems to the maintainer of the relevant task or plugin.

Old API for incremental tasks, `IncrementalTaskInputs`, has been deprecated

In Gradle 5.4 we introduced a new API for implementing incremental tasks: InputChanges. The old API based on `IncrementalTaskInputs` has been deprecated.

Forced dependencies

Forcing dependency versions using `force = true` on a first-level dependency has been deprecated.

Force has both a semantic and ordering issue which can be avoided by using a strict version constraint.

Search upwards related APIs in `StartParameter` have been deprecated

In Gradle 5.0, we removed the `--no-search-upward` CLI parameter.

The related APIs in `StartParameter` (like `isSearchUpwards()`) are now deprecated.

APIs `BuildListener.buildStarted` and `Gradle.buildStarted` have been deprecated

These methods currently do not work as expected since the callbacks will never be called after the build has started.

The methods are being deprecated to avoid confusion.

Implicit duplicate strategy for `Copy` or archive tasks has been deprecated

Archive tasks `Tar` and `Zip` by default allow multiple entries for the same path to exist in the created archive. This can cause "grossly invalid zip files" that can trigger zip bomb detection.

To prevent this from happening accidentally, encountering duplicates while creating an archive now produces a deprecation message and will fail the build starting with Gradle 7.0.

`Copy` tasks also happily copy multiple sources with the same relative path to the destination directory. This behavior has also been deprecated.

If you want to allow duplicates, you can specify that explicitly:

```
task archive(type: Zip) {
    duplicatesStrategy = DuplicatesStrategy.INCLUDE // allow duplicates
    ...
}
```

Executing Gradle without a settings file has been deprecated

A Gradle build is defined by a `settings.gradle[.kts]` file in the current or parent directory. Without

a settings file, a Gradle build is undefined and will emit a deprecation warning.

In Gradle 7.0, Gradle will only allow you to invoke the `init` task or diagnostic command line flags, such as `--version`, with undefined builds.

Calling `Project.afterEvaluate` on an evaluated project has been deprecated

Once a project is evaluated, Gradle ignores all configuration passed to `Project#afterEvaluate` and emits a deprecation warning. This scenario will become an error in Gradle 7.0.

Deprecated plugins

The following bundled plugins were never announced and will be removed in the next major release of Gradle:

- `org.gradle.coffeescript-base`
- `org.gradle.envjs`
- `org.gradle.javascript-base`
- `org.gradle.jshint`
- `org.gradle.rhino`

Some of these plugins may have replacements on the Plugin Portal.

Potential breaking changes

Android Gradle Plugin 3.3 and earlier is no longer supported

Gradle 6.0 supports Android Gradle Plugin versions 3.4 and later.

Build scan plugin 2.x is no longer supported

For Gradle 6, usage of the build scan plugin must be replaced with the Develocity plugin. This also requires changing how the plugin is applied. Please see https://gradle.com/help/gradle-6-build-scan-plugin for more information.

Updates to bundled Gradle dependencies

- Groovy has been updated to Groovy 2.5.8.
- Kotlin has been updated to Kotlin 1.3.50.
- Ant has been updated to Ant 1.10.7.

Updates to default integration versions

- Checkstyle has been updated to Checkstyle 8.24.
- CodeNarc has been updated to CodeNarc 1.4.
- PMD has been updated to PMD 6.17.0.
- JaCoCo has been updated to 0.8.5. Contributed by Evgeny Mandrikov

Changes to build and task names in composite builds

Previously, Gradle used the name of the root project as the build name for an included build. Now, the name of the build's root directory is used and the root project name is not considered if different. A different name for the build can be specified if the build is being included via a settings file.

```
includeBuild("some-other-build") {
    name = "another-name"
}
```

The previous behavior was problematic as it caused different names to be used at different times during the build.

buildSrc is now reserved as a project and subproject build name

Previously, Gradle did not prevent using the name "buildSrc" for a subproject of a multi-project build or as the name of an included build. Now, this is not allowed. The name "buildSrc" is now reserved for the conventional buildSrc project that builds extra build logic.

Typical use of buildSrc is unaffected by this change. You will only be affected if your settings file specifies `include("buildSrc")` or `includeBuild("buildSrc")`.

Scala Zinc compiler

The Zinc compiler has been upgraded to version 1.3.0. Gradle no longer supports building for Scala 2.9.

The minimum Zinc compiler supported by Gradle is 1.2.0 and the maximum tested version is 1.3.0.

To make it easier to select the version of the Zinc compiler, you can now configure a `zincVersion` property:

```
scala {
    zincVersion = "1.2.1"
}
```

Please remove any explicit dependencies you've added to the `zinc` configuration and use this property instead. If you try to use the `com.typesafe.zinc:zinc` dependency, Gradle will switch to the new Zinc implementation.

Changes to Build Cache

Local build cache is always a directory cache

In the past, it was possible to use any build cache implementation as the `local` cache. This is no longer allowed as the local cache must always be a `DirectoryBuildCache`.

Calls to `BuildCacheConfiguration.local(Class)` with anything other than `DirectoryBuildCache` as the

type will fail the build. Calling these methods with the `DirectoryBuildCache` type will produce a deprecation warning.

Use `getLocal()` and `local(Action)` instead.

Failing to pack or unpack cached results will now fail the build

In the past, when Gradle encountered a problem while packing the results of a cached task, Gradle would ignore the problem and continue running the build.

When encountering a corrupt cached artifact, Gradle would remove whatever was already unpacked and re-execute the task to make sure the build had a chance to succeed.

While this behavior was intended to make a build successful, this had the adverse effect of hiding problems and led to reduced cache performance.

In Gradle 6.0, both pack and unpack errors will cause the build to fail, so that these problems will be surfaced more easily.

buildSrc projects automatically use build cache configuration

Previously, in order to use the build cache for the buildSrc build you needed to duplicate your build cache config in the buildSrc build. Now, it automatically uses the build cache configuration defined by the top level settings script.

Changes to Dependency Management

Gradle Module Metadata is always published

Officially introduced in Gradle 5.3, Gradle Module Metadata was created to solve many of the problems that have plagued dependency management for years, in particular, but not exclusively, in the Java ecosystem.

With Gradle 6.0, Gradle Module Metadata is enabled by default.

This means, if you are publishing libraries with Gradle and using the maven-publish or ivy-publish plugin, the Gradle Module Metadata file is always published **in addition** to traditional metadata.

The traditional metadata file will contain a marker so that Gradle knows that there is additional metadata to consume.

Gradle Module Metadata has stricter validation

The following rules are verified when publishing Gradle Module Metadata:

- Variant names must be unique,
- Each variant must have at least one attribute,
- Two variants cannot have the exact same attributes and capabilities,
- If there are dependencies, at least one, across all variants, must carry version information.

These are documented in the specification as well.

Maven or Ivy repositories are no longer queried for artifacts without metadata by default

If Gradle fails to locate the metadata file (`.pom` or `ivy.xml`) of a module in a repository defined in the `repositories { }` section, it now assumes that the module does not exist in that repository.

For dynamic versions, the `maven-metadata.xml` for the corresponding module needs to be present in a Maven repository.

Previously, Gradle would also look for a default artifact (`.jar`). This behavior often caused a large number of unnecessary requests when using multiple repositories that slowed builds down.

You can opt into the old behavior for selected repositories by adding the `artifact()` metadata source.

Changing the pom `packaging` property no longer changes the artifact extension

Previously, if the pom packaging was not *jar, ejb, bundle* or *maven-plugin*, the extension of the main artifact published to a Maven repository was changed during publishing to match the pom packaging.

This behavior led to broken Gradle Module Metadata and was difficult to understand due to handling of different packaging types.

Build authors can change the artifact name when the artifact is created to obtain the same result as before — e.g. by setting `jar.archiveExtension.set(pomPackaging)` explicitly.

An `ivy.xml` published for Java libraries contains more information

A number of fixes were made to produce more correct `ivy.xml` metadata in the `ivy-publish` plugin.

As a consequence, the internal structure of the `ivy.xml` file has changed. The `runtime` configuration now contains more information, which corresponds to the *runtimeElements* variant of a Java library. The `default` configuration should yield the same result as before.

In general, users are advised to migrate from `ivy.xml` to the new Gradle Module Metadata format.

Changes to Plugins and Build scripts

Classes from `buildSrc` are no longer visible to settings scripts

Previously, the buildSrc project was built before applying the project's settings script and its classes were visible within the script. Now, buildSrc is built after the settings script and its classes are not visible to it. The buildSrc classes remain visible to project build scripts and script plugins.

Custom logic can be used from a settings script by declaring external dependencies.

The `pluginManagement` block in settings scripts is now isolated

Previously, any `pluginManagement {}` blocks inside a settings script were executed during the normal execution of the script.

Now, they are executed earlier in a similar manner to `buildscript {}` or `plugins {}`. This means that

code inside such a block cannot reference anything declared elsewhere in the script.

This change has been made so that `pluginManagement` configuration can also be applied when resolving plugins for the settings script itself.

Plugins and classes loaded in settings scripts are visible to project scripts and `buildSrc`

Previously, any classes added to the a settings script by using `buildscript {}` were not visible outside of the script. Now, they are visible to all of the project build scripts.

They are also visible to the `buildSrc` build script and its settings script.

This change has been made so that plugins applied to the settings script can contribute logic to the entire build.

Plugin validation changes

- The `validateTaskProperties` task is now deprecated, use `validatePlugins` instead. The new name better reflects the fact that it also validates artifact transform parameters and other non-property definitions.
- The `ValidateTaskProperties` type is replaced by `ValidatePlugins`.
- The `setClasses()` method is now removed. Use `getClasses().setFrom()` instead.
- The `setClasspath()` method is also removed. use `getClasspath().setFrom()` instead.
- The failOnWarning option is now enabled by default.
- The following task validation errors now fail the build at runtime and are promoted to errors for ValidatePlugins:
  - A task property is annotated with a property annotation not allowed for tasks, like `@InputArtifact`.

Changes to Kotlin DSL

Using the `embedded-kotlin` plugin now requires a repository

Just like when using the `kotlin-dsl` plugin, it is now required to declare a repository where Kotlin dependencies can be found if you apply the `embedded-kotlin` plugin.

```
plugins {
    `embedded-kotlin`
}

repositories {
    mavenCentral()
}
```

Kotlin DSL IDE support now requires Kotlin IntelliJ Plugin >= 1.3.50

With Kotlin IntelliJ plugin versions prior to 1.3.50, Kotlin DSL scripts will be wrongly highlighted

when the *Gradle JVM* is set to a version different from the one in *Project SDK*. Simply upgrade your IDE plugin to a version >= 1.3.50 to restore the correct Kotlin DSL script highlighting behavior.

Kotlin DSL script base types no longer extend `Project`, `Settings` or `Gradle`

In previous versions, Kotlin DSL scripts were compiled to classes that implemented one of the three core Gradle configuration interfaces in order to implicitly expose their APIs to scripts. `org.gradle.api.Project` for project scripts, `org.gradle.api.initialization.Settings` for settings scripts and `org.gradle.api.invocation.Gradle` for init scripts.

Having the script instance implement the core Gradle interface of the model object it was supposed to configure was convenient because it made the model object API immediately available to the body of the script but it was also a lie that could cause all sorts of trouble whenever the script itself was used in place of the model object, a project script **was not** a proper `Project` instance just because it implemented the core `Project` interface and the same was true for settings and init scripts.

In 6.0 all Kotlin DSL scripts are compiled to classes that implement the newly introduced `org.gradle.kotlin.dsl.KotlinScript` interface and the corresponding model objects are now available as *implicit receivers* in the body of the scripts. In other words, a project script behaves as if the body of the script is enclosed within a `with(project) { ⋯ }` block, a settings script as if the body of the script is enclosed within a `with(settings) { ⋯ }` block and an init script as if the body of the script is enclosed within a `with(gradle) { ⋯ }` block. This implies the corresponding model object is also available as a property in the body of the script, the `project` property for project scripts, the `settings` property for settings scripts and the `gradle` property for init scripts.

As part of the change, the `SettingsScriptApi` interface is no longer implemented by settings scripts and the `InitScriptApi` interface is no longer implemented by init scripts. They should be replaced with the corresponding model object interfaces, `Settings` and `Gradle`.

Miscellaneous

Javadoc and Groovydoc don't include timestamps by default

Timestamps in the generated documentation have very limited practical use, however they make it impossible to have repeatable documentation builds. Therefore, the `Javadoc` and `Groovydoc` tasks are now configured to not include timestamps by default any more.

User provided 'config_loc' properties are ignored by Checkstyle

Gradle always uses `configDirectory` as the value for 'config_loc' when running Checkstyle.

New Tooling API progress event

In Gradle 6.0, we introduced a new progress event (org.gradle.tooling.events.test.TestOutputEvent) to expose the output of test execution. This new event breaks the convention of having a `StartEvent`-`FinishEvent` pair to express progress. `TaskOutputEvent` is a simple `ProgressEvent`.

Changes to the task container behavior

The following deprecated methods on the task container now result in errors:

- `TaskContainer.add()`

- `TaskContainer.addAll()`

- `TaskContainer.remove()`

- `TaskContainer.removeAll()`

- `TaskContainer.retainAll()`

- `TaskContainer.clear()`

- `TaskContainer.iterator().remove()`

Additionally, the following deprecated functionality now results in an error:

- Replacing a task that has already been realized.

- Replacing a registered (unrealized) task with an incompatible type. A compatible type is the same type or a sub-type of the registered type.

- Replacing a task that has never been registered.

Replaced and Removed APIs

Methods on `DefaultTask` and `ProjectLayout` replaced with `ObjectFactory`

Use `ObjectFactory.fileProperty()` instead of the following methods that are now removed:

- `DefaultTask.newInputFile()`

- `DefaultTask.newOutputFile()`

- `ProjectLayout.fileProperty()`

Use `ObjectFactory.directoryProperty()` instead of the following methods that are now removed:

- `DefaultTask.newInputDirectory()`

- `DefaultTask.newOutputDirectory()`

- `ProjectLayout.directoryProperty()`

Annotation `@Nullable` has been removed

The `org.gradle.api.Nullable` annotation type has been removed. Use `javax.annotation.Nullable` from JSR-305 instead.

The FindBugs plugin has been removed

The deprecated FindBugs plugin has been removed. As an alternative, you can use the SpotBugs plugin from the Gradle Plugin Portal.

The JDepend plugin has been removed

The deprecated JDepend plugin has been removed. There are a number of community-provided plugins for code and architecture analysis available on the Gradle Plugin Portal.

The OSGI plugin has been removed

The deprecated OSGI plugin has been removed. There are a number of community-provided OSGI plugins available on the Gradle Plugin Portal.

The announce and build-announcements plugins have been removed

The deprecated announce and build-announcements plugins have been removed. There are a number of community-provided plugins for sending out notifications available on the Gradle Plugin Portal.

The Compare Gradle Builds plugin has been removed

The deprecated Compare Gradle Builds plugin has been removed. Please use build scans for build analysis and comparison.

The Play plugins have been removed

The deprecated Play plugin has been removed. An external replacement, the Play Framework plugin, is available from the plugin portal.

Method `AbstractCompile.compile()` method has been removed

The abstract method `compile()` is no longer declared by `AbstractCompile`.

Tasks extending `AbstractCompile` can implement their own `@TaskAction` method with the name of their choosing.

They are also free to add a method annotated with `@TaskAction` using an `InputChanges` parameter without having to implement a parameter-less one as well.

Other Deprecated Behaviors and APIs

- The `org.gradle.util.internal.GUtil.savePropertiesNoDateComment` has been removed. There is no public replacement for this internal method.
- The deprecated class `org.gradle.api.tasks.compile.CompilerArgumentProvider` has been removed. Use org.gradle.process.CommandLineArgumentProvider instead.
- The deprecated class `org.gradle.api.ConventionProperty` has been removed. Use Providers instead of convention properties.
- The deprecated class `org.gradle.reporting.DurationFormatter` has been removed.
- The bridge method `org.gradle.api.tasks.TaskInputs.property(String name, @Nullable Object value)` returning `TaskInputs` has been removed. A plugin using the method must be compiled with Gradle 4.3 to work on Gradle 6.0.
- The following setters have been removed from `JacocoReportBase`:
    - executionData - use `getExecutionData().setFrom()` instead.
    - sourceDirectories - use `getSourceDirectories().setFrom()` instead.
    - classDirectories - use `getClassDirectories().setFrom()` instead.
    - additionalClassDirs - use `getAdditionalClassDirs().setFrom()` instead.

- additionalSourceDirs - use `getAdditionalSourceDirs().setFrom()` instead.

- The `append` property on `JacocoTaskExtension` has been removed. `append` is now always configured to be true for the Jacoco agent.

- The `configureDefaultOutputPathForJacocoMerge` method on `JacocoPlugin` has been removed. The method was never meant to be public.

- File paths in deployment descriptor file name for the ear plugin are not allowed any more. Use a simple name, like `application.xml`, instead.

- The `org.gradle.testfixtures.ProjectBuilder` constructor has been removed. Please use `ProjectBuilder.builder()` instead.

- When incremental Groovy compilation is enabled, a wrong configuration of the source roots or enabling Java annotation for Groovy now fails the build. Disable incremental Groovy compilation when you want to compile in those cases.

- `ComponentSelectionRule` no longer can inject the metadata or ivy descriptor. Use the methods on the `ComponentSelection` parameter instead.

- Declaring an incremental task without declaring outputs is now an error. Declare file outputs or use `TaskOutputs.upToDateWhen()` instead.

- The `getEffectiveAnnotationProcessorPath()` method is removed from the `JavaCompile` and `ScalaCompile` tasks.

- Changing the value of a task property with type `Property<T>` after the task has started execution now results in an error.

- The `isLegacyLayout()` method is removed from `SourceSetOutput`.

- The map returned by `TaskInputs.getProperties()` is now unmodifiable. Trying to modify it will result in an `UnsupportedOperationException` being thrown.

- There are slight changes in the incubating capabilities resolution API, which has been introduced in 5.6, to also allow variant selection based on variant name

Upgrading from 5.5 and earlier

Deprecations

Changing the contents of `ConfigurableFileCollection` task properties after task starts execution

When a task property has type `ConfigurableFileCollection`, then the file collection referenced by the property will ignore changes made to the contents of the collection once the task starts execution. This has two benefits. Firstly, this prevents accidental changes to the property value during task execution which can cause Gradle up-to-date checks and build cache lookup using different values to those used by the task action. Secondly, this improves performance as Gradle can calculate the value once and cache the result.

This will become an error in Gradle 6.0.

Creating `SignOperation` instances

Creating `SignOperation` instances directly is now deprecated. Instead, the methods of

`SigningExtension` should be used to create these instances.

This will become an error in Gradle 6.0.

Declaring an incremental task without outputs

Declaring an incremental task without declaring outputs is now deprecated. Declare file outputs or use TaskOutputs.upToDateWhen() instead.

This will become an error in Gradle 6.0.

Method `WorkerExecutor.submit()` is deprecated

The `WorkerExecutor.submit()` method is now deprecated. The new `noIsolation()`, `classLoaderIsolation()` and `processIsolation()` methods should now be used to submit work. See the section on the Worker API for more information on using these methods.

`WorkerExecutor.submit()` will be removed in Gradle 8.0.

Potential breaking changes

Task dependencies are honored for task `@Input` properties whose value is a `Property`

Previously, task dependencies would be ignored for task `@Input` properties of type `Property<T>`. These are now honored, so that it is possible to attach a task output property to a task `@Input` property.

This may introduce unexpected cycles in the task dependency graph, where the value of an output property is mapped to produce a value for an input property.

Declaring task dependencies using a file `Provider` that does not represent a task output

Previously, it was possible to pass `Task.dependsOn()` a `Provider<File>`, `Provider<RegularFile>` or `Provider<Directory>` instance that did not represent a task output. These providers would be silently ignored.

This is now an error because Gradle does not know how to build files that are not task outputs.

Note that it is still possible to pass `Task.dependsOn()` a `Provider` that returns a file and that represents a task output, for example `myTask.dependsOn(jar.archiveFile)` or `myTask.dependsOn(taskProvider.flatMap { it.outputDirectory })`, when the `Provider` is an annotated `@OutputFile` or `@OutputDirectory` property of a task.

Setting `Property` value to `null` uses the property convention

Previously, calling `Property.set(null)` would always reset the value of the property to 'not defined'. Now, the convention that is associated with the property using the `convention()` method will be used to determine the value of the property.

Enhanced validation of names for `publishing.publications` and `publishing.repositories`

The repository and publication names are used to construct task names for publishing. It was possible to supply a name that would result in an invalid task name. Names for publications and repositories are now restricted to `[A-Za-z0-9_\\-.]+`.

Restricted Worker API classloader and process classpath

Gradle now prevents internal dependencies (like Guava) from leaking into the classpath used by Worker API actions. This fixes an issue where a worker needs to use a dependency that is also used by Gradle internally.

In previous releases, it was possible to rely on these leaked classes. Plugins relying on this behavior will now fail. To fix the plugin, the worker should explicitly include all required dependencies in its classpath.

Default PMD version upgraded to 6.15.0

The PMD plugin has been upgraded to use PMD version 6.15.0 instead of 6.8.0 by default.

Contributed by wreulicke

Configuration copies have unique names

Previously, all copies of a configuration always had the name `<OriginConfigurationName>Copy`. Now when creating multiple copies, each will have a unique name by adding an index starting from the second copy. (e.g. `CompileOnlyCopy2`)

Changed classpath filtering for Eclipse

Gradle 5.6 no longer supplies custom classpath attributes in the Eclipse model. Instead, it provides the attributes for Eclipse test sources. This change requires Buildship version 3.1.1 or later.

Embedded Kotlin upgraded to 1.3.41

Gradle Kotlin DSL scripts and Gradle Plugins authored using the `kotlin-dsl` plugin are now compiled using Kotlin 1.3.41.

Please see the Kotlin blog post and changelog for more information about the included changes.

The minimum supported Kotlin Gradle Plugin version is now 1.2.31. Previously it was 1.2.21.

Automatic capability conflict resolution

Previous versions of Gradle would automatically select, in case of capability conflicts, the module which has the highest capability version. Starting from 5.6, this is an opt-in behavior that can be activated using:

```
configurations.all {
    resolutionStrategy.capabilitiesResolution.all { selectHighestVersion() }
}
```

See [the capabilities section of the documentation](#) for more options.

File removal operations don't follow symlinked directories

When Gradle has to remove the output files of a task for various reasons, it will not follow symlinked directories. The symlink itself will be deleted, but the contents of the linked directory will stay intact.

Disabled debug argument parsing in JavaExec

Gradle 5.6 introduced a new DSL element (`JavaForkOptions.debugOptions(Action<JavaDebugOptions>)`) to configure debug properties for forked Java processes. Due to this change, Gradle no longer parses debug-related JVM arguments. Consequently, `JavaForkOptions.getDebu()` no longer returns `true` if the `-Xrunjdwp:transport=dt_socket,server=y,suspend=y,address=5005` or the `-agentlib:jdwp=transport=dt_socket,server=y,suspend=y,address=5005` argument is specified to the process.

Scala 2.9 and Zinc compiler

Gradle no longer supports building applications using Scala 2.9.

Upgrading from 5.4 and earlier

Deprecations

Play

The built-in [Play plugin](#) has been deprecated and will be replaced by a new [Play Framework plugin](#) available from the plugin portal.

Build Comparison

The *build comparison* plugin has been deprecated and will be removed in the next major version of Gradle.

[Build scans](#) show much deeper insights into your build and you can use [Develocity](#) to directly compare two build's build-scans.

Potential breaking changes

User supplied Eclipse project names may be ignored on conflict

Project names configured via `EclipseProject.setName(…)` were honored by Gradle and Buildship in all cases, even when the names caused conflicts and import/synchronization errors.

Gradle can now deduplicate these names if they conflict with other project names in an Eclipse workspace. This may lead to different Eclipse project names for projects with user-specified names.

The upcoming 3.1.1 version of Buildship is required to take advantage of this behavior.

Contributed by Christian Fränkel

Default JaCoCo version upgraded to 0.8.4

The JaCoCo plugin has been upgraded to use JaCoCo version 0.8.4 instead of 0.8.3 by default.

Contributed by Evgeny Mandrikov

Embedded Ant version upgraded to 1.9.14

The version of Ant distributed with Gradle has been upgraded to 1.9.14 from 1.9.13.

Type `DependencyHandler` now statically exposes `ExtensionAware`

This affects Kotlin DSL build scripts that make use of `ExtensionAware` extension members such as the `extra` properties accessor inside the `dependencies {}` block. The receiver for those members will no longer be the enclosing `Project` instance but the `dependencies` object itself, the innermost `ExtensionAware` conforming receiver. In order to address `Project` extra properties inside `dependencies {}` the receiver must be explicitly qualified i.e. `project.extra` instead of just `extra`. Affected extensions also include `the<T>()` and `configure<T>(T.() → Unit)`.

Improved processing of dependency excludes

Previous versions of Gradle could, in some complex dependency graphs, have a wrong result or a randomized dependency order when lots of excludes were present. To mitigate this, the algorithm that computes exclusions has been rewritten. In some rare cases this may cause some differences in resolution, due to the correctness changes.

Improved classpath separation for worker processes

The system classpath for worker daemons started by the Worker API when using `PROCESS` isolation has been reduced to a minimum set of Gradle infrastructure. User code is still segregated into a separate classloader to isolate it from the Gradle runtime. This should be a transparent change for tasks using the worker API, but previous versions of Gradle mixed user code and Gradle internals in the worker process. Worker actions that rely on things like the `java.class.path` system property may be affected, since `java.class.path` now represents only the classpath of the Gradle internals.

Upgrading from 5.3 and earlier

Deprecations

Using custom local build cache implementations

Using a custom build cache implementation for the local build cache is now deprecated. The only allowed type will be `DirectoryBuildCache` going forward. There is no change in the support for using custom build cache implementations as the remote build cache.

Potential breaking changes

Use HTTPS when configuring Google Hosted Libraries via `googleApis()`

The Google Hosted Libraries URL accessible via `JavaScriptRepositoriesExtension#GOOGLE_APIS_REPO_URL` was changed to use the HTTPS protocol. The change also affect the Ivy repository configured via `googleApis()`.

Upgrading from 5.2 and earlier

Potential breaking changes

Bug fixes in platform resolution

There was a bug from Gradle 5.0 to 5.2.1 (included) where enforced platforms would potentially include dependencies instead of constraints. This would happen whenever a POM file defined both dependencies and "constraints" (via `<dependencyManagement>`) and that you used `enforcedPlatform`. Gradle 5.3 fixes this bug, meaning that you might have differences in the resolution result if you relied on this broken behavior. Similarly, Gradle 5.3 will no longer try to download jars for `platform` and `enforcedPlatform` dependencies (as they should only bring in constraints).

Automatic target JVM version

If you apply any of the Java plugins, Gradle will now do its best to select dependencies which match the target compatibility of the module being compiled. What it means, in practice, is that if you have module A built for Java 8, and module B built for Java 8, then there's no change. However if B is built for Java 9+, then it's not binary compatible anymore, and Gradle would complain with an error message like the following:

```
Unable to find a matching variant of project :producer:
  - Variant 'apiElements' capability test:producer:unspecified:
      - Provides org.gradle.dependency.bundling 'external'
      - Required org.gradle.jvm.version '8' and found incompatible value '9'.
      - Required org.gradle.usage 'java-api' and found value 'java-api-jars'.
  - Variant 'runtimeElements' capability test:producer:unspecified:
      - Provides org.gradle.dependency.bundling 'external'
      - Required org.gradle.jvm.version '8' and found incompatible value '9'.
      - Required org.gradle.usage 'java-api' and found value 'java-runtime-jars'.
```

In general, this is a sign that your project is misconfigured and that your dependencies are not compatible. However, there are cases where you still may want to do this, for example when only a *subset* of classes of your module actually need the Java 9 dependencies, and are not intended to be used on earlier releases. Java in general doesn't encourage you to do this (you should split your module instead), but if you face this problem, you can workaround by disabling this new behavior on the consumer side:

```
java {
    disableAutoTargetJvm()
}
```

Bug fix in Maven / Ivy interoperability with dependency substitution

If you have a Maven dependency pointing to an Ivy dependency where the `default` configuration dependencies do not match the `compile` + `runtime` + `master` ones *and* that Ivy dependency was substituted (using a `resolutionStrategy.force`, `resolutionStrategy.eachDependency` or `resolutionStrategy.dependencySubstitution`) then this fix will impact you. The legacy behaviour of Gradle, prior to 5.0, was still in place instead of being replaced by the changes introduced by improved pom support.

Delete operations correctly handle symbolic links on Windows

Gradle no longer ignores the `followSymlink` option on Windows for the `clean` task, all `Delete` tasks, and `project.delete {}` operations in the presence of junction points and symbolic links.

Fix in publication of additional artifacts

In previous Gradle versions, additional artifacts registered at the project level were not published by `maven-publish` or `ivy-publish` unless they were also added as artifacts in the publication configuration.

With Gradle 5.3, these artifacts are now properly accounted for and published.

This means that artifacts that are registered both on the project *and* the publication, Ivy or Maven, will cause publication to fail since it will create duplicate entries. The fix is to remove these artifacts from the publication configuration.

Upgrading from 5.1 and earlier

Potential breaking changes

Upgrading from 5.0 and earlier

Deprecations

Follow the API links to learn how to deal with these deprecations (if no extra information is provided here):

- Setters for `classes` and `classpath` on `org.gradle.plugin.devel.tasks.ValidateTaskProperties` (removed)

- There should not be setters for lazy properties like `ConfigurableFileCollection`. Use `setFrom` instead. For example,

```
validateTaskProperties.getClasses().setFrom(fileCollection)
validateTaskProperties.getClasspath().setFrom(fileCollection)
```

Potential breaking changes

The following changes were not previously deprecated:

Signing API changes

Input and output files of `Sign` tasks are now tracked via `Signature.getToSign()` and `Signature.getFile()`, respectively.

Collection properties default to empty collection

In Gradle 5.0, the collection property instances created using `ObjectFactory` would have no value defined, requiring plugin authors to explicitly set an initial value. This proved to be awkward and error prone so `ObjectFactory` now returns instances with an empty collection as their initial value.

Worker API: working directory of a worker can no longer be set

Since JDK 11 no longer supports changing the working directory of a running process, setting the working directory of a worker via its fork options is now prohibited. All workers now use the same working directory to enable reuse. Please pass files and directories as arguments instead. See examples in the Worker API documentation.

Changes to native linking tasks

To expand our idiomatic Provider API practices, the install name property from `org.gradle.nativeplatform.tasks.LinkSharedLibrary` is affected by this change.

- `getInstallName()` was changed to return a `Property`.
- `setInstallName(String)` was removed. Use `Property.set()` instead.

Passing arguments to Windows Resource Compiler

To expand our idiomatic Provider API practices, the `WindowsResourceCompile` task has been converted to use the Provider API.

Passing additional compiler arguments now follow the same pattern as the `CppCompile` and other tasks.

Copied configuration no longer shares a list of `beforeResolve` actions with original

The list of `beforeResolve` actions are no longer shared between a copied configuration and the original. Instead, a copied configuration receives a copy of the `beforeResolve` actions at the time the copy is made. Any `beforeResolve` actions added after copying (to either configuration) will not be shared between the original and the copy. This may break plugins that relied on the previous behaviour.

Changes to incubating POM customization types

- The type of `MavenPomDeveloper.properties` has changed from `Property<Map<String, String>>` to `MapProperty<String, String>`.
- The type of `MavenPomContributor.properties` has changed from `Property<Map<String, String>>` to

`MapProperty<String, String>`.

Changes to specifying operating system for native projects

The incubating `operatingSystems` property on native components has been replaced with the `targetMachines` property.

Changes for archive tasks (`Zip`, `Jar`, `War`, `Ear`, `Tar`)

Change in behavior for tasks extending `AbstractArchiveTask`

The `AbstractArchiveTask` has several new properties using the Provider API. Plugins that extend these types and override methods from the base class may no longer behave the same way. Internally, `AbstractArchiveTask` prefers the new properties and methods like `getArchiveName()` are façades over the new properties.

If your plugin/build only uses these types (and does not extend them), nothing has changed.

Upgrading your build from Gradle 4.x to 5.0

This chapter provides the information you need to migrate your older Gradle 4.x builds to Gradle 5.0. In most cases, you will need to apply the changes from all versions that come after the one you're upgrading from. For example, if you're upgrading from Gradle 4.3 to 5.0, you will also need to apply the changes since 4.4, 4.5, etc up to 5.0.

| TIP | If you are using Gradle for Android, you need to move to version 3.3 or higher of both the Android Gradle Plugin and Android Studio. |

For all users

1. If you are not already on the latest 4.10.x release, read the sections below for help upgrading your project to the latest 4.10.x release. We recommend upgrading to the latest 4.10.x release to get the most useful warnings and deprecations information before moving to 5.0. Avoid upgrading Gradle and migrating to Kotlin DSL at the same time in order to ease troubleshooting in case of potential issues.

2. Try running `gradle help --scan` and view the deprecations view of the generated build scan. If there are no warnings, the Deprecations tab will not appear.
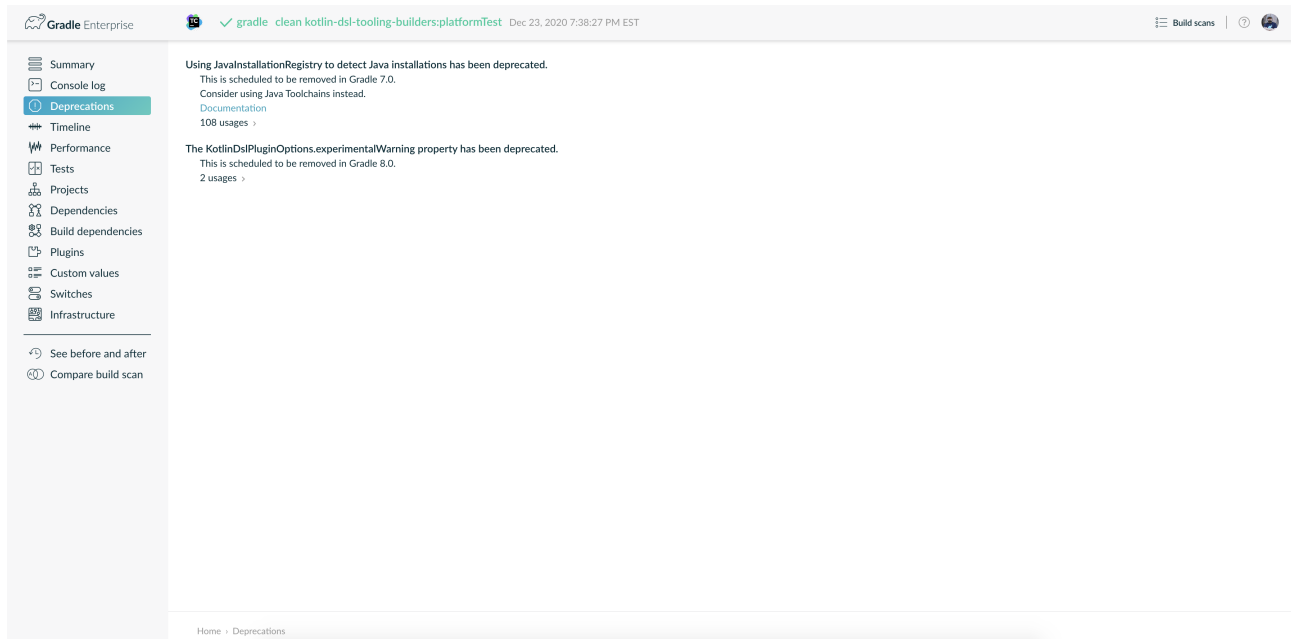
This is so that you can see any deprecation warnings that apply to your build. Gradle 5.x will generate (potentially less obvious) errors if you try to upgrade directly to it.

Alternatively, you can run `gradle help --warning-mode=all` to see the deprecations in the console, though it may not report as much detailed information.

3. Update your plugins.

   Some plugins will break with this new version of Gradle, for example because they use internal APIs that have been removed or changed. The previous step will help you identify potential problems by issuing deprecation warnings when a plugin does try to use a deprecated part of the API.

   In particular, you will need to use at least a 2.x version of the **Shadow Plugin**.

4. Run `gradle wrapper --gradle-version 5.0` to update the project to 5.0

5. Move to Java 8 or higher if you haven't already. Whereas Gradle 4.x requires Java 7, Gradle 5 requires Java 8 to run.

6. Read the Upgrading from 4.10 section and make any necessary changes.

7. Try to run the project and debug any errors using the Troubleshooting Guide.

In addition, Gradle has added several significant new and improved features that you should consider using in your builds:

- Maven Publish and Ivy Publish Plugins that now support digital signatures with the Signing Plugin.

- Use native BOM import in your builds.

- The Worker API for enabling units of work to run in parallel.

- A new API for creating and configuring tasks lazily that can significantly improve your build's configuration time.

Other notable changes to be aware of that may break your build include:

- Separation of compile and runtime dependencies when consuming POMs

- A change that means you should configure existing `wrapper` and `init` tasks rather than defining your own.

- The honoring of implicit wildcards in Maven POM exclusions, which may result in dependencies being excluded that weren't before.

- A change to the way you add Java annotation processors to a project.

- The default memory settings for the command-line client, the Gradle daemon, and all workers including compilers and test executors, have been greatly reduced.

- The default versions of several code quality plugins have been updated.

- Several library versions used by Gradle have been upgraded.

Upgrading from 4.10 and earlier

If you are not already on version 4.10, skip down to the section that applies to your current Gradle version and work your way up until you reach here. Then, apply these changes when moving from Gradle 4.10 to 5.0.

Other changes

- The `enableFeaturePreview('IMPROVED_POM_SUPPORT')` and `enableFeaturePreview('STABLE_PUBLISHING')` flags are no longer necessary. These features are now enabled by default.

- Gradle now bundles JAXB for Java 9 and above. You can remove the `--add-modules java.xml.bind` option from `org.gradle.jvmargs`, if set.

Potential breaking changes

The changes in this section have the potential to break your build, but the vast majority have been deprecated for quite some time and few builds will be affected by a large number of them. We strongly recommend upgrading to Gradle 4.10 first to get a report on what deprecations affect your build.

The following breaking changes are not from deprecations, but the result of changes in behavior:

- Separation of compile and runtime dependencies when consuming POMs

- The evaluation of the `publishing {}` block is no longer deferred until needed but behaves like any other block. Please use `afterEvaluate {}` if you need to defer evaluation.

- The `Javadoc` and `Groovydoc` tasks now delete the destination dir for the documentation before executing. This has been added to remove stale output files from the last task execution.

- The Java Library Distribution Plugin is now based on the Java Library Plugin instead of the Java Plugin.

  While it applies the Java Plugin, it behaves slightly different (e.g. it adds the `api` configuration). Thus, make sure to check whether your build behaves as expected after upgrading.

- The `html` property on `CheckstyleReport` and `FindBugsReport` now returns a `CustomizableHtmlReport` instance that is easier to configure from statically typed languages like Java and Kotlin.
- The Configuration Avoidance API has been updated to prevent the creation and configuration of tasks that are never used.
- The default memory settings for the command-line client, the Gradle daemon, and all workers including compilers and test executors, have been greatly reduced.
- The default versions of several code quality plugins have been updated.
- Several library versions used by Gradle have been upgraded.

The following breaking changes will appear as deprecation warnings with Gradle 4.10:

General

- `<<` for task definitions no longer works. In other words, you can not use the syntax `task myTask << { … }`.

  Use the Task.doLast() method instead, like this:

  ```
  task myTask {
      doLast {
          ...
      }
  }
  ```

- You can no longer use any of the following characters in domain object names, such as project and task names: <space> / \ : < > " ? * | . You should also not use `.` as a leading or trailing character.

Running Gradle & build environment

- As mentioned before, Gradle can no longer be run on Java 7. However, you can still use forked compilation and testing to build and test software for Java 6 and above.
- The `-Dtest.single` command-line option has been removed — use test filtering instead.
- The `-Dtest.debug` command-line option has been removed — use the `--debug-jvm` option instead.
- The `-u/--no-search-upward` command-line option has been removed — make sure all your builds have a *settings.gradle* file.
- The `--recompile-scripts` command-line option has been removed.
- You can no longer have a Gradle build nested in a subdirectory of another Gradle build unless the nested build has a *settings.gradle* file.
- The `DirectoryBuildCache.setTargetSizeInMB(long)` method has been removed — use DirectoryBuildCache.removeUnusedEntriesAfterDays instead.
- The `org.gradle.readLoggingConfigFile` system property no longer does anything — update affected tests to work with your `java.util.logging` settings.

Working with files

- You can no longer cast `FileCollection` objects to other types using the `as` keyword or the `asType()` method.

- You can no longer pass `null` as the configuration action of CopySpec.from(Object, Action).

- For better compatibility with the Kotlin DSL, CopySpec.duplicatesStrategy is no longer nullable. The property setter no longer accepts `null` as a way to reset the property back to its default value. Use `DuplicatesStrategy.INHERIT` instead.

- The `FileCollection.stopExecutionIfEmpty()` method has been removed — use the @SkipWhenEmpty annotation on `FileCollection` task properties instead.

- The `FileCollection.add()` method has been removed — use Project.files() and Project.fileTree() to create configurable file collections/file trees and add to them via ConfigurableFileCollection.from().

- `SimpleFileCollection` has been removed — use Project.files(Object...) instead.

- Don't have your own classes extend `AbstractFileCollection` — use the Project.files() method instead. This problem may exhibit as a missing `getBuildDependencies()` method.

Java builds

- The `CompileOptions.bootClasspath` property has been removed — use CompileOptions.bootstrapClasspath instead.

- You can no longer use `-source-path` as a generic compiler argument — use CompileOptions.sourcepath instead.

- You can no longer use `-processorpath` as a generic compiler argument — use CompileOptions.annotationProcessorPath instead.

- Gradle will no longer automatically apply annotation processors that are on the compile classpath — use CompileOptions.annotationProcessorPath instead.

- The `testClassesDir` property has been removed from the Test task — use testClassesDirs instead.

- The `classesDir` property has been removed from both the *JDepend* task and SourceSetOutput. Use the *JDepend.classesDirs* and SourceSetOutput.classesDirs properties instead.

- The `JavaLibrary(PublishArtifact, DependencySet)` constructor has been removed — this was used by the Shadow Plugin, so make sure you upgrade to at least version 2.x of that plugin.

- The `JavaBasePlugin.configureForSourceSet()` method has been removed.

- You can no longer create your own instances of JavaPluginConvention, ApplicationPluginConvention, WarPluginConvention, EarPluginConvention, BasePluginConvention, and ProjectReportsPluginConvention.

- The `Maven` Plugin used to publish the highly outdated Maven 2 metadata format. This has been changed and it will now publish Maven 3 metadata, just like the `Maven Publish` Plugin.

  With the removal of Maven 2 support, the methods that configure unique snapshot behavior have also been removed. Maven 3 only supports unique snapshots, so we decided to remove them.

Tasks & properties

- The following legacy classes and methods related to lazy properties have been removed — use ObjectFactory.property() to create `Property` instances:

  - `PropertyState`

  - `DirectoryVar`

  - `RegularFileVar`

  - `ProjectLayout.newDirectoryVar()`

  - `ProjectLayout.newFileVar()`

  - `Project.property(Class)`

  - `Script.property(Class)`

  - `ProviderFactory.property(Class)`

- Tasks configured and registered with the task configuration avoidance APIs have more restrictions on the other methods that can be called from a configuration action.

- The internal `@Option` and `@OptionValues` annotations — package `org.gradle.api.internal.tasks.options` — have been removed. Use the public @Option and @OptionValues annotations instead.

- The `Task.deleteAllActions()` method has been removed with no replacement.

- The `Task.dependsOnTaskDidWork()` method has been removed — use declared inputs and outputs instead.

- The following properties and methods of `TaskInternal` have been removed — use task dependencies, task rules, reusable utility methods, or the Worker API in place of executing a task directly.

  - `execute()`

  - `executer`

  - `getValidators()`

  - `addValidator()`

- The TaskInputs.file(Object) method can no longer be called with an argument that resolves to anything other than a single regular file.

- The TaskInputs.dir(Object) method can no longer be called with an argument that resolves to anything other than a single directory.

- You can no longer register invalid inputs and outputs via TaskInputs and TaskOutputs.

- The `TaskDestroyables.file()` and `TaskDestroyables.files()` methods have been removed — use TaskDestroyables.register() instead.

- `SimpleWorkResult` has been removed — use WorkResult.didWork.

- Overriding built-in tasks deprecated in 4.8 now produces an error.

  Attempting to replace a built-in task will produce an error similar to the following:

```
> Cannot add task 'wrapper' as a task with that name already exists.
```

Scala & Play

- Play 2.2 is no longer supported — please upgrade the version of Play you are using.

- The `ScalaDocOptions.styleSheet` property has been removed — the Scaladoc Ant task in Scala 2.11.8 and later no longer supports this property.

Kotlin DSL

- Artifact configuration accessors now have the type `NamedDomainObjectProvider<Configuration>` instead of `Configuration`

- `PluginAware.apply<T>(to)` was renamed `PluginAware.applyTo<T>(target)`.

Both changes could cause script compilation errors. See the Gradle Kotlin DSL release notes for more information and how to fix builds broken by the changes described above.

Miscellaneous

- The `ConfigurableReport.setDestination(Object)` method has been removed — use ConfigurableReport.setDestination(File) instead.

- The `Signature.setFile(File)` method has been removed — Gradle does not support changing the output file for the generated signature.

- The read-only `Signature.toSignArtifact` property has been removed — it should never have been part of the public API.

- The `@DeferredConfigurable` annotation has been removed.

- The method `isDeferredConfigurable()` was removed from `ExtensionSchema`.

- `IdeaPlugin.performPostEvaluationActions()` and `EclipsePlugin.performPostEvaluationActions()` have been removed.

- The `BroadcastingCollectionEventRegister.getAddAction()` method has been removed with no replacement.

- The internal `org.gradle.util` package is no longer imported by default.

  Ideally you shouldn't use classes from this package, but, as a quick fix, you can add explicit imports to your build scripts for those classes.

- The `gradlePluginPortal()` repository no longer looks for JARs without a POM by default.

- The Tooling API can no longer connect to builds using a Gradle version below Gradle 2.6. The same applies to builds run through TestKit.

- Gradle 5.0 requires a minimum Tooling API client version of 3.0. Older client libraries can no longer run builds with Gradle 5.0.

- The IdeaModule Tooling API model element contains methods to retrieve resources and test resources so those elements were removed from the result of `IdeaModule.getSourceDirs()` and `IdeaModule.getTestSourceDirs()`.

- In previous Gradle versions, the `source` field in `SourceTask` was accessible from subclasses.

This is not the case anymore as the `source` field is now declared as `private`.

- In the Worker API, the working directory of a worker can no longer be set.

- A change in behavior related to dependency and version constraints may impact a small number of users.

- There have been several changes to property factory methods on DefaultTask that may impact the creation of custom tasks.

Upgrading from 4.9 and earlier

If you are not already on version 4.9, skip down to the section that applies to your current Gradle version and work your way up until you reach here. Then, apply these changes when upgrading to Gradle 4.10.

Deprecated classes, methods and properties

Follow the API links to learn how to deal with these deprecations (if no extra information is provided here):

- `TaskContainer.add()` and `TaskContainer.addAll()` — use TaskContainer.create() or TaskContainer.register() instead

Potential breaking changes

- There have been several potentially breaking changes in Kotlin DSL — see the *Breaking changes* section of that project's release notes.

- You can no longer use any of the Project.beforeEvaluate() or Project.afterEvaluate() methods with lazy task configuration, for example inside a TaskContainer.register() block.

- Publishing to AWS S3 requires new permissions.

- Both PluginUnderTestMetadata and GeneratePluginDescriptors — classes used by the Java Gradle Plugin Development Plugin — have been updated to use the Provider API.

  Use the Property.set() method to modify their values rather than using standard property assignment syntax, unless you are doing so in a Groovy build script. Standard property assignment still works in that one case.

Upgrading from 4.8 and earlier

- Consider trying the lazy API for task creation and configuration

Potential breaking changes

- You can no longer use GPath syntax with tasks.withType().

  Use Groovy's spread operator instead. For example, you would replace `tasks.withType(JavaCompile).name` with `tasks.withType(JavaCompile)*.name`.

Upgrading from 4.7 and earlier

- Switch to the Maven Publish and Ivy Publish plugins

- Use deferred configuration with the publishing plugins

- Configure existing `wrapper` and `init` tasks rather than defining your own

- Consider migrating to the built-in dependency locking mechanism if you are currently using a plugin or custom solution for this

Potential breaking changes

- Build will now fail if a specified init script is not found.

- `TaskContainer.remove()` now actually removes the given task — some plugins may have accidentally relied on the old behavior.

- Gradle now honors implicit wildcards in Maven POM exclusions.

- The Kotlin DSL now respects JSR-305 package annotations.

  This will lead to some types annotated according to JSR-305 being treated as nullable where they were treated as non-nullable before. This may lead to compilation errors in the build script. See the relevant Kotlin DSL release notes for details.

- Error messages will be directed to standard error rather than standard output now, unless a console is attached to both standard output and standard error. This may affect tools that scrape a build's plain console output. Ignore this change if you're upgrading from an earlier version of Gradle.

Deprecations

Prior to this release, builds were allowed to replace built-in tasks. This feature has been deprecated.

The full list of built-in tasks that should not be replaced is: `wrapper`, `init`, `help`, `tasks`, `projects`, `buildEnvironment`, `components`, `dependencies`, `dependencyInsight`, `dependentComponents`, `model`, `properties`.

Upgrading from 4.6 and earlier

Potential breaking changes

- Gradle will now, by convention, look for Checkstyle configuration files in the root project's *config/checkstyle* directory.

  Checkstyle configuration files in subprojects — the old by-convention location — will be ignored unless you explicitly configure their path via checkstyle.configDir or checkstyle.config.

- The structure of Gradle's plain console output has changed, which may break tools that scrape that output.

- The APIs of many native tasks related to compilation, linking and installation have changed in breaking ways.

- [Kotlin DSL] Delegated properties used to access Gradle's build properties — defined in *gradle.properties* for example — must now be explicitly typed.
- [Kotlin DSL] Declaring a `plugins {}` block inside a nested scope now throws an exception.
- [Kotlin DSL] Only one `pluginManagement {}` block is allowed now.
- The cache control DSL provided by the `org.gradle.api.artifacts.cache.*` interfaces are no longer available.
- `getEnabledDirectoryReportDestinations()`, `getEnabledFileReportDestinations()` and `getEnabledReportNames()` have all been removed from `org.gradle.api.reporting.ReportContainer`.
- StartParameter.projectProperties and StartParameter.systemPropertiesArgs now return immutable maps.

Upgrading from 4.5 and earlier

Deprecations

- You should not put annotation processors on the compile classpath or declare them with the `-processorpath` compiler argument.

  They should be added to the `annotationProcessor` configuration instead. If you don't want any processing, but your compile classpath contains a processor unintentionally (e.g. as part of a library you depend on), use the `-proc:none` compiler argument to ignore it.
- Use CommandLineArgumentProvider in place of CompilerArgumentProvider.

Potential breaking changes

- The Java plugins now add a `sourceSetAnnotationProcessor` configuration for each source set, which might break if any of them match existing configurations you have. We recommend you remove your conflicting configuration declarations.
- The `StartParameter.taskOutputCacheEnabled` property has been replaced by StartParameter.setBuildCacheEnabled(boolean).
- The Visual Studio integration now only configures a single solution for all components in a build.
- Gradle has replaced HttpClient 4.4.1 with version 4.5.5.
- Gradle now bundles the `kotlin-stdlib-jdk8` artifact instead of `kotlin-stdlib-jre8`. This may affect your build. Please see the Kotlin documentation for more details.

Upgrading from 4.4 and earlier

- Make sure you have a *settings.gradle* file: it avoids a performance penalty and allows you to set the root project's name.
- Gradle now ignores the build cache configuration of included builds (composite builds) and instead uses the root build's configuration for all the builds.

Potential breaking changes

- Two overloaded `ValidateTaskProperties.setOutputFile()` methods were removed. They are replaced with auto-generated setters when the task is accessed from a build script, but that won't be the case from plugins and other code outside of the build script.

- The Maven Publish Plugin now produces more complete maven-metadata.xml files, including maintaining a list of `<snapshotVersion>` elements. Some older versions of Maven may not be able to consume this metadata.

- `HttpBuildCache` no longer follows redirects.

- The `Depend` task type has been removed.

- Project.file(Object) no longer normalizes case for file paths on case-insensitive file systems. It now ignores case in such circumstances and does not touch the file system.

- ListProperty no longer extends Property.

Upgrading from 4.3 and earlier

Potential breaking changes

- AbstractTestTask is now extended by non-JVM test tasks as well as Test. Plugins should beware configuring all tasks of type `AbstractTestTask` because of this.

- The default output location for EclipseClasspath.defaultOutputDir has changed from `$projectDir`/*bin* to `$projectDir`/*bin/default*.

- The deprecated `InstallExecutable.setDestinationDir(Provider)` was removed — use InstallExecutable.installDirectory instead.

- The deprecated `InstallExecutable.setExecutable(Provider)` was removed — use InstallExecutable.executableFile instead.

- Gradle will no longer prefer a version of Visual Studio found on the path over other locations. It is now a last resort.

  You can bypass the toolchain discovery by specifying the installation directory of the version of Visual Studio you want via VisualCpp.setInstallDir(Object).

- `pluginManagement.repositories` is now of type RepositoryHandler rather than `PluginRepositoriesSpec`, which has been removed.

- 5xx HTTP errors during dependency resolution will now trigger exceptions in the build.

- The embedded Apache Ant has been upgraded from 1.9.6 to 1.9.9.

- Several third-party libraries used by Gradle have been upgraded to fix security issues.

Upgrading from 4.2 and earlier

- The `plugins {}` block can now be used in subprojects and for plugins in the *buildSrc* directory.

Other deprecations

- You should no longer run Gradle versions older than 2.6 via the Tooling API.

- You should no longer run any version of Gradle via an older version of the Tooling API than 3.0.

- You should no longer chain TaskInputs.property(String,Object) and TaskInputs.properties(Map) methods.

Potential breaking changes

- DefaultTask.newOutputDirectory() now returns a `DirectoryProperty` instead of a `DirectoryVar`.

- DefaultTask.newOutputFile() now returns a `RegularFileProperty` instead of a `RegularFileVar`.

- DefaultTask.newInputFile() now returns a `RegularFileProperty` instead of a `RegularFileVar`.

- ProjectLayout.buildDirectory now returns a `DirectoryProperty` instead of a `DirectoryVar`.

- AbstractNativeCompileTask.compilerArgs is now of type `ListProperty<String>` instead of `List<String>`.

- AbstractNativeCompileTask.objectFileDir is now of type `DirectoryProperty` instead of `File`.

- AbstractLinkTask.linkerArgs is now of type `ListProperty<String>` instead of `List<String>`.

- `TaskDestroyables.getFiles()` is no longer part of the public API.

- Overlapping version ranges for a dependency now result in Gradle picking a version that satisfies all declared ranges.

  For example, if a dependency on `some-module` is found with a version range of `[3,6]` and also transitively with a range of `[4,8]`, Gradle now selects version 6 instead of 8. The prior behavior was to select 8.

- The order of elements in `Iterable` properties marked with either `@OutputFiles` or `@OutputDirectories` now matters. If the order changes, the property is no longer considered up to date.

  Prefer using separate properties with `@OutputFile`/`@OutputDirectory` annotations or use `Map` properties with `@OutputFiles`/`@OutputDirectories` instead.

- Gradle will no longer ignore dependency resolution errors from a repository when there is another repository it can check. Dependency resolution will fail instead. This results in more deterministic behavior with respect to resolution results.

Upgrading from 4.1 and earlier

Potential breaking changes

- The `withPathSensitivity()` methods on TaskFilePropertyBuilder and TaskOutputFilePropertyBuilder have been removed.

- The bundled `bndlib` has been upgraded from 3.2.0 to 3.4.0.

- The FindBugs Plugin no longer renders progress information from its analysis. If you rely on that output in any way, you can enable it with *FindBugs.showProgress*.

Upgrading from 4.0

- Consider using the new Worker API to enable units of work within your build to run in parallel.

Deprecated classes, methods and properties

Follow the API links to learn how to deal with these deprecations (if no extra information is provided here):

- Nullable

Potential breaking changes

- Non-Java projects that have a project dependency on a Java project now consume the `runtimeElements` configuration by default instead of the `default` configuration.

  To override this behavior, you can explicitly declare the configuration to use in the project dependency. For example: `project(path: ':myJavaProject', configuration: 'default')`.

- Default Zinc compiler upgraded from 0.3.13 to 0.3.15.
- [Kotlin DSL] Base package renamed from `org.gradle.script.lang.kotlin` to `org.gradle.kotlin.dsl`.

Changes in detail

[5.0] Default memory settings changed

The command line client now starts with 64MB of heap instead of 1GB. This may affect builds running directly inside the client VM using `--no-daemon` mode. We discourage the use of `--no-daemon`, but if you must use it, you can increase the available memory using the `GRADLE_OPTS` environment variable.

The Gradle daemon now starts with 512MB of heap instead of 1GB. Large projects may have to increase this setting using the `org.gradle.jvmargs` property.

All workers, including compilers and test executors, now start with 512MB of heap. The previous default was 1/4th of physical memory. Large projects may have to increase this setting on the relevant tasks, e.g. `JavaCompile` or `Test`.

[5.0] New default versions for code quality plugins

The default tool versions of the following code quality plugins have been updated:

- The Checkstyle Plugin now uses 8.12 instead of 6.19 by default.
- The CodeNarc Plugin now uses 1.2.1 instead of 1.1 by default.
- The JaCoCo Plugin now uses 0.8.2 instead of 0.8.1 by default.
- The PMD Plugin now uses 6.8.0 instead of 5.6.1 by default.

  In addition, the default ruleset was changed from the now deprecated `java-basic` to

`category/java/errorprone.xml`.

We recommend configuring a ruleset explicitly, though.

[5.0] Library upgrades

Several libraries that are used by Gradle have been upgraded:

- Groovy was upgraded from 2.4.15 to 2.5.4.

- Ant has been upgraded from 1.9.11 to 1.9.13.

- The AWS SDK used to access S3-backed Maven/Ivy repositories has been upgraded from 1.11.267 to 1.11.407.

- The BND library used by the OSGi Plugin has been upgraded from 3.4.0 to 4.0.0.

- The Google Cloud Storage JSON API Client Library used to access Google Cloud Storage backed Maven/Ivy repositories has been upgraded from v1-rev116-1.23.0 to v1-rev136-1.25.0.

- Ivy has been upgraded from 2.2.0 to 2.3.0.

- The JUnit Platform libraries used by the `Test` task have been upgraded from 1.0.3 to 1.3.1.

- The Maven Wagon libraries used to access Maven repositories have been upgraded from 2.4 to 3.0.0.

- SLF4J has been upgraded from 1.7.16 to 1.7.25.

[5.0] Improved support for dependency and version constraints

Through the Gradle 4.x release stream, new `@Incubating` features were added to the dependency resolution engine. These include sophisticated version constraints (`prefer`, `strictly`, `reject`), dependency constraints, and `platform` dependencies.

If you have been using the `IMPROVED_POM_SUPPORT` feature preview, playing with constraints or prefer, reject and other specific version indications, then make sure to take a good look at your dependency resolution results.

[5.0] BOM import

Gradle now provides support for importing bill of materials (BOM) files, which are effectively POM files that use `<dependencyManagement>` sections to control the versions of direct and transitive dependencies. All you need to do is declare the POM as a `platform` dependency.

The following example picks the versions of the `gson` and `dom4j` dependencies from the declared Spring Boot BOM:

```
dependencies {
    // import a BOM
    implementation platform('org.springframework.boot:spring-boot-
dependencies:1.5.8.RELEASE')

    // define dependencies without versions
    implementation 'com.google.code.gson:gson'
    implementation 'dom4j:dom4j'
}
```

[5.0] Separation of compile and runtime dependencies when consuming POMs

Since Gradle 1.0, runtime-scoped dependencies have been included in the Java compilation classpath, which has some drawbacks:

- The compilation classpath is much larger than it needs to be, slowing down compilation.
- The compilation classpath includes runtime-scoped files that do not impact compilation, resulting in unnecessary re-compilation when those files change.

With this new behavior, the Java and Java Library plugins both honor the separation of compile and runtime scopes. This means that the compilation classpath only includes compile-scoped dependencies, while the runtime classpath adds the runtime-scoped dependencies as well. This is particularly useful if you develop and publish Java libraries with Gradle where the separation between `api` and `implementation` dependencies is reflected in the published scopes.

[5.0] Changes to property factory methods on `DefaultTask`

Property factory methods on `DefaultTask` are now final

The property factory methods such as `newInputFile()` are intended to be called from the constructor of a type that extends `DefaultTask`. These methods are now final to avoid subclasses overriding these methods and using state that is not initialized.

Inputs and outputs are not automatically registered

The Property instances that are returned by these methods are no longer automatically registered as inputs or outputs of the task. The Property instances need to be declared as inputs or outputs in the usual ways, such as attaching annotations such as `@OutputFile` or using the runtime API to register the property.

For example, you could previously use the following syntax and have both outputFile instances registered as declared outputs:

build.gradle

```
class MyTask extends DefaultTask {
    // note: no annotation here
    final RegularFileProperty outputFile = newOutputFile()
}

task myOtherTask {
    def outputFile = newOutputFile()
    doLast { ... }
}
```

build.gradle.kts

```
open class MyTask : DefaultTask() {
    // note: no annotation here
    val outputFile: RegularFileProperty = newOutputFile()
}

task("myOtherTask") {
    val outputFile = newOutputFile()
    doLast { ... }
}
```

Now you have to explicitly register `outputFile`, like this:

build.gradle

```groovy
class MyTask extends DefaultTask {
    @OutputFile // property needs an annotation
    final RegularFileProperty outputFile = project.objects.fileProperty()
}

task myOtherTask {
    def outputFile = project.objects.fileProperty()
    outputs.file(outputFile) // or to be registered using the runtime API
    doLast { ... }
}
```

build.gradle.kts

```kotlin
open class MyTask : DefaultTask() {
    @OutputFile // property needs an annotation
    val outputFile: RegularFileProperty = project.objects.fileProperty()
}

task("myOtherTask") {
    val outputFile = project.objects.fileProperty()
    outputs.file(outputFile) // or to be registered using the runtime API
    doLast { ... }
}
```

[5.0] Gradle now bundles JAXB for Java 9 and above

In order to use S3 backed artifact repositories, you previously had to add `--add-modules java.xml.bind` to `org.gradle.jvmargs` when running on Java 9 and above.

Since Java 11 no longer contains the `java.xml.bind` module, Gradle now bundles JAXB 2.3.1 (`com.sun.xml.bind:jaxb-impl`) and uses it on Java 9 and above.

Please remove the `--add-modules java.xml.bind` option from `org.gradle.jvmargs`, if set.

[5.0] The `gradlePluginPortal()` repository no longer looks for JARs without a POM by default

With this new behavior, if a plugin or a transitive dependency of a plugin found in the `gradlePluginPortal()` repository has no Maven POM it will fail to resolve.

Artifacts published to a Maven repository without a POM should be fixed. If you encounter such artifacts, please ask the plugin or library author to publish a new version with proper metadata.

If you are stuck with a bad plugin, you can work around by re-enabling JARs as metadata source for

the `gradlePluginPortal()` repository:

settings.gradle

```
pluginManagement {
    repositories {
        gradlePluginPortal().tap {
            metadataSources {
                mavenPom()
                artifact()
            }
        }
    }
}
```

settings.gradle.kts

```
pluginManagement {
    repositories {
        gradlePluginPortal().apply {
            (this as MavenArtifactRepository).metadataSources {
                mavenPom()
                artifact()
            }
        }
    }
}
```

Java Library Distribution Plugin utilizes Java Library Plugin

The Java Library Distribution Plugin is now based on the Java Library Plugin instead of the Java Plugin.

Additionally, the default distribution created by the plugin will contain all artifacts of the `runtimeClasspath` configuration instead of the deprecated `runtime` configuration.

Configuration Avoidance API disallows common configuration errors

The configuration avoidance API introduced in Gradle 4.9 allows you to avoid creating and configuring tasks that are never used.

With the existing API, this example adds two tasks (`foo` and `bar`):

build.gradle

```
tasks.create("foo") {
    tasks.create("bar")
}
```

build.gradle.kts

```
tasks.create("foo") {
    tasks.create("bar")
}
```

When converting this to use the new API, something surprising happens: bar doesn't exist. The new API only executes configuration actions when necessary, so the register() for task bar only executes when foo is configured.

build.gradle

```
tasks.register("foo") {
    tasks.register("bar") // WRONG
}
```

build.gradle.kts

```
tasks.register("foo") {
    tasks.register("bar") // WRONG
}
```

To avoid this, Gradle now detects this and prevents modification to the underlying container (through create() or register()) when using the new API.

[5.0] Worker API: working directory of a worker can no longer be set

Since JDK 11 no longer supports changing the working directory of a running process, setting the working directory of a worker via its fork options is now prohibited.

All workers now use the same working directory to enable reuse.

Please pass files and directories as arguments instead.

[4.10] Publishing to AWS S3 requires new permissions

The S3 repository transport protocol allows Gradle to publish artifacts to AWS S3 buckets. Starting with this release, every artifact uploaded to an S3 bucket will be equipped with the `bucket-owner-full-control` canned ACL. Make sure that the AWS account used to publish artifacts has the `s3:PutObjectAcl` and `s3:PutObjectVersionAcl` permissions, otherwise the upload will fail.

```
{
    "Version":"2012-10-17",
    "Statement":[
        // ...
        {
            "Effect":"Allow",
            "Action":[
                "s3:PutObject", // necessary for uploading objects
                "s3:PutObjectAcl", // required starting with this release
                "s3:PutObjectVersionAcl" // if S3 bucket versioning is enabled
            ],
            "Resource":"arn:aws:s3:::myCompanyBucket/*"
        }
    ]
}
```

See AWS S3 Cross Account Access for more information.

[4.9] Consider trying the lazy API for task creation and configuration

Gradle 4.9 introduced a new way to create and configure tasks that works lazily. When you use this approach for tasks that are expensive to configure, or when you have many, many tasks, your build configuration time can drop significantly when those tasks don't run.

You can learn more about lazily creating tasks in the Task Configuration Avoidance chapter. You can also read about the background to this new feature in this blog post.

[4.8] Switch to the Maven Publish and Ivy Publish Plugins

Now that the publishing plugins are stable, we recommend that you migrate from the legacy publishing mechanism for standard Java projects, i.e. those based on the Java Plugin. That includes projects that use any one of: Java Library Plugin, Application Plugin or War Plugin.

To use the new approach, simply replace any `upload<Conf>` configuration with a `publishing {}` block. See the publishing overview chapter for more information.

[4.8] Use deferred configuration for publishing plugins

Prior to Gradle 4.8, the `publishing {}` block was implicitly treated as if all the logic inside it was executed after the project was evaluated. This was confusing, because it was the only block that behaved that way. As part of the stabilization effort in Gradle 4.8, we are deprecating this behavior and asking all users to migrate their build.

The new, stable behavior can be switched on by adding the following to your settings file:

settings.gradle

```
enableFeaturePreview('STABLE_PUBLISHING')
```

settings.gradle.kts

```
enableFeaturePreview("STABLE_PUBLISHING")
```

We recommend doing a test run with a local repository to see whether all artifacts still have the expected coordinates. In most cases everything should work as before and you are done. However, your publishing block may rely on the implicit deferred configuration, particularly if it relies on values that may change during the configuration phase of the build.

For example, under the new behavior, the following logic assumes that `jar.archiveBaseName` doesn't change after `artifactId` is set:

build.gradle

```
subprojects {
    publishing {
        publications {
            mavenJava {
                from components.java
                artifactId = jar.archiveBaseName
            }
        }
    }
}
```

build.gradle.kts

```
subprojects {
    publishing {
        publications {
            named<MavenPublication>("mavenJava") {
                from(components["java"])
                artifactId = tasks.jar.get().archiveBaseName.get()
            }
        }
    }
}
```

If that assumption is incorrect or might possibly be incorrect in the future, the `artifactId` must be set within an `afterEvaluate {}` block, like so:

build.gradle

```
subprojects {
    publishing {
        publications {
            mavenJava {
                from components.java
                afterEvaluate {
                    artifactId = jar.archiveBaseName
                }
            }
        }
    }
}
```

build.gradle.kts

```
subprojects {
    publishing {
        publications {
            named<MavenPublication>("mavenJava") {
                from(components["java"])
                afterEvaluate {
                    artifactId = tasks.jar.get().archiveBbaseName.get()
                }
            }
        }
    }
}
```

[4.8] Configure existing `wrapper` and `init` tasks

You should no longer define your own `wrapper` and `init` tasks. Configure the existing tasks instead, for example by converting this:

build.gradle

```
task wrapper(type: Wrapper) {
    ...
}
```

build.gradle.kts

```
task<Wrapper>("wrapper") {
    ...
}
```

to this:

build.gradle

```
wrapper {
    ...
}
```

build.gradle.kts

```
tasks.wrapper {
    ...
}
```

[4.8] Gradle now honors implicit wildcards in Maven POM exclusions

If an exclusion in a Maven POM was missing either a `groupId` or `artifactId`, Gradle used to ignore the exclusion. Now the missing elements are treated as implicit wildcards — e.g. `<groupId>*</groupId>` — which means that some of your dependencies may now be excluded where they weren't before.

You will need to explicitly declare any missing dependencies that you need.

[4.7] Changes to the structure of Gradle's plain console output

The plain console mode now formats output consistently with the rich console, which means that the output format has changed. For example:

- The output produced by a given task is now grouped together, even when other tasks execute in parallel with it.

- Task execution headers are printed with a "> Task" prefix.

- All output produced during build execution is written to the standard output file handle. This includes messages written to System.err unless you are redirecting standard error to a file or any other non-console destination.

This may break tools that scrape details from the plain console output.

[4.6] Changes to the APIs of native tasks related to compilation, linking and installation

Many tasks related to compiling, linking and installing native libraries and applications have been converted to the Provider API so that they support lazy configuration. This conversion has introduced some breaking changes to the APIs of the tasks so that they match the conventions of the Provider API.

The following tasks have been changed:

AbstractLinkTask and its subclasses
- `getDestinationDir()` was replaced by `getDestinationDirectory()`.
- `getBinaryFile()`, `getOutputFile()` was replaced by `getLinkedFile()`.
- `setOutputFile(File)` was removed. Use `Property.set()` instead.
- `setOutputFile(Provider)` was removed. Use `Property.set()` instead.
- `getTargetPlatform()` was changed to return a `Property`.
- `setTargetPlatform(NativePlatform)` was removed. Use `Property.set()` instead.
- `getToolChain()` was changed to return a `Property`.
- `setToolChain(NativeToolChain)` was removed. Use `Property.set()` instead.

CreateStaticLibrary
- `getOutputFile()` was changed to return a `Property`.
- `setOutputFile(File)` was removed. Use `Property.set()` instead.
- `setOutputFile(Provider)` was removed. Use `Property.set()` instead.
- `getTargetPlatform()` was changed to return a `Property`.
- `setTargetPlatform(NativePlatform)` was removed. Use `Property.set()` instead.
- `getToolChain()` was changed to return a `Property`.
- `setToolChain(NativeToolChain)` was removed. Use `Property.set()` instead.
- `getStaticLibArgs()` was changed to return a `ListProperty`.
- `setStaticLibArgs(List)` was removed. Use `ListProperty.set()` instead.

InstallExecutable
- `getSourceFile()` was replaced by `getExecutableFile()`.
- `getPlatform()` was replaced by `getTargetPlatform()`.

- `setTargetPlatform(NativePlatform)` was removed. Use `Property.set()` instead.

- `getToolChain()` was changed to return a `Property`.

- `setToolChain(NativeToolChain)` was removed. Use `Property.set()` instead.

The following have also seen similar changes:

- Assemble

- WindowsResourceCompile

- StripSymbols

- ExtractSymbols

- SwiftCompile

- LinkMachOBundle

[4.6] Visual Studio integration only supports a single solution file for all components of a build

VisualStudioExtension no longer has a `solutions` property. Instead, you configure a single solution via VisualStudioRootExtension in the root project, like so:

build.gradle

```
model {
    visualStudio {
        solution {
            solutionFile.location = "vs/${name}.sln"
        }
    }
}
```

In addition, there are no longer individual tasks to generate the solution files for each component, but rather a single `visualStudio` task that generates a solution file that encompasses all components in the build.

[4.5] `HttpBuildCache` no longer follows redirects

When connecting to an HTTP build cache backend via `HttpBuildCache`, Gradle does not follow redirects any more, treating them as errors instead. Getting a redirect from the build cache backend is mostly a configuration error — using an "http" URL instead of "https" for example — and has negative effects on performance.

[4.4] Third-party dependency upgrades

This version includes several upgrades of third-party dependencies:

- jackson: 2.6.6 → 2.8.9

- plexus-utils: 2.0.6 → 2.1

- xercesImpl: 2.9.1 → 2.11.0

- bsh: 2.0b4 → 2.0b6

- bouncycastle: 1.57 → 1.58

This fix the following security issues:

- CVE-2017-7525 (critical)

- SONATYPE-2017-0359 (critical)

- SONATYPE-2017-0355 (critical)

- SONATYPE-2017-0398 (critical)

- CVE-2013-4002 (critical)

- CVE-2016-2510 (severe)

- SONATYPE-2016-0397 (severe)

- CVE-2009-2625 (severe)

- SONATYPE-2017-0348 (severe)

Gradle does not expose public APIs for these 3rd-party dependencies, but those who customize Gradle will want to be aware.

MIGRATING

Migrating Builds From Apache Maven

Apache Maven is a build tool for Java and other JVM-based projects. It is typical to migrate an existing Maven build to Gradle.

This guide will help with such a migration by explaining the differences and similarities between the two tools and providing steps that you can follow to ease the process.

Converting a build can be scary, but you don't have to do it alone. You can search our documentation, post on our community forums, or reach out on our Slack channel if you get stuck.

Making a case for migration

The primary differences between Gradle and Maven are flexibility, performance, user experience, and dependency management.

A visual overview of these aspects is available in the Maven vs Gradle feature comparison.

Since Gradle 3.0, Gradle has invested heavily in making Gradle builds much faster, with features such as build caching, compile avoidance, and an improved incremental Java compiler. Gradle is now 2-10x faster than Maven for the vast majority of projects, even without using a build cache. In-depth performance comparison and business cases for switching from Maven to Gradle can be found here.

General guidelines

Gradle and Maven have fundamentally different views on how to build a project. Gradle provides a flexible and extensible build model that delegates the actual work to the execution of a graph of tasks. Maven uses a model of fixed, linear phases to which you can attach goals (the things that do the work). This may make migrating between the two seem intimidating, but migrations can be surprisingly easy because Gradle follows many of the same conventions as Maven — such as the standard project structure — and its dependency management works in a similar way.

Here we lay out a series of steps for you to follow that will help facilitate the migration of any Maven build to Gradle:

> **TIP** Keep the old Maven build and new Gradle build side by side. You know the Maven build works, so you should keep it until you are confident that the Gradle build produces all the same artifacts. This also means that users can try the Gradle build without creating a new copy of the source tree.

1. Create a build scan for the Maven build.

    A build scan will make it easier to visualize what's happening in your existing Maven build. For Maven builds, you will be able to see the project structure, what plugins are being used, a timeline of the build steps, and more. Keep this handy so you can compare it to the Gradle build

scans while converting the project.

2. Develop a mechanism to verify that the two builds produce the same artifacts.

   This is a vitally important step to ensure that your deployments and tests don't break. Even small changes, such as the contents of a manifest file in a JAR, can cause problems. If your Gradle build produces the same output as the Maven build, this will give you confidence in switching over and make it easier to implement the changes that will provide the greatest benefits.

   This doesn't mean that you need to verify every artifact at every stage, although doing so can help you quickly identify the source of a problem. You should focus on the critical output such as final reports and the artifacts that are published or deployed.

   You will need to factor in some inherent differences in the build output that Gradle produces compared to Maven. Generated POMs will contain only the information needed for consumption and they will use `<compile>` and `<runtime>` scopes correctly for that scenario. You might also see differences in the order of files in archives and of files on classpaths. Most differences will be minor, but it's worth identifying them and verifying that they are acceptable.

3. Run an automatic conversion.

   This will create all the Gradle build files you need, even for multi-module builds. For simpler Maven projects, the Gradle build will be ready to run!

4. Create a build scan for the Gradle build.

   A build scan will make it easier to visualize what's happening in the build. For Gradle builds, you'll be able to see the project structure, the dependencies (regular and inter-project ones), what plugins are being used and the console output of the build.

   Your build may fail at this point, but that's ok; the scan will still run. Compare the build scan for the Gradle build to the one for the Maven build and continue down this list to troubleshoot the failures.

   We recommend that you regularly generate build scans during the migration to help you identify and troubleshoot problems. If you want, you can also use a Gradle build scan to identify opportunities to improve the performance of the build.

5. Verify your dependencies and fix any problems.

6. Configure integration and functional tests.

   Many tests can simply be migrated by configuring an extra source set. If you are using a third-party library, such as FitNesse, look to see whether there is a suitable community plugin available on the Gradle Plugin Portal.

7. Replace Maven plugins with Gradle equivalents.

   In the case of popular plugins, Gradle often has an equivalent plugin that you can use. You might also find that you can replace a plugin with built-in Gradle functionality. As a last resort, you may need to reimplement a Maven plugin via your own custom plugins and task types.

The rest of this chapter looks in more detail at specific aspects of migrating a build from Maven to Gradle.

Understanding the build lifecycle

Maven builds are based around the concept of *build lifecycles* that consist of a set of fixed phases. This can be a challenge for users migrating to Gradle because the build lifecycle is a new concept. Although it's important to understand how Gradle builds fit into the structure of **initialization**, **configuration**, and **execution** phases, Gradle provides a helper feature that can mimic Maven's phases: *lifecycle tasks*.

This feature allow you to define your own "lifecycles" by creating no-action tasks that simply depend on the tasks you're interested in. And to make the transition to Gradle easier for Maven users, the Base Plugin — applied by all the JVM language plugins like the Java Library Plugin — provides a set of lifecycle tasks that correspond to the main Maven phases.

Here is a list of some of the main Maven phases and the Gradle tasks that they map to:

clean

  Use the `clean` task provided by the Base Plugin.

compile

  Use the `classes` task provided by the Java Plugin and other JVM language plugins. This compiles all classes for all source files of all languages and also performs resource filtering via the `processResources` task.

test

  Use the `test` task provided by the Java Plugin. It runs the unit tests, and more specifically, the tests that make up the `test` source set.

package

  Use the `assemble` task provided by the Base Plugin. This builds whatever is the appropriate package for the project; for example, a JAR for Java libraries or a WAR for traditional Java webapps.

verify

  Use the `check` task provided by the Base Plugin. This runs all verification tasks that are attached to it, which typically includes the unit tests, any static analysis tasks — such as Checkstyle — and others. If you want to include integration tests, you will have to configure these manually.

install

  Use the `publishToMavenLocal` task provided by the Maven Publish Plugin.

  Note that Gradle builds don't require you to "install" artifacts as you have access to more appropriate features like inter-project dependencies and composite builds. You should only use `publishToMavenLocal` for interoperating with Maven builds.

  Gradle also allows you to resolve dependencies against the local Maven cache, as described in the Declaring repositories section.

`deploy`

Use the `publish` task provided by the [Maven Publish Plugin](#) — making sure you switch from the older Maven Plugin (ID: `maven`) if your build is using that one. This will publish your package to all configured publication repositories. There are also tasks that allow you to publish to a single repository even when multiple ones are defined.

Note that the Maven Publish Plugin does not publish **source and Javadoc JARs** *by default*, but this can easily be activated as explained in [the guide for building java projects](#).

Performing an automatic conversion

Gradle's [init](#) [task](#) is typically used to create a new skeleton project, but you can also use it to convert an existing Maven build to Gradle automatically. Once Gradle is [installed on your system](#), all you have to do is run the command

```
> gradle init
```

from the root project directory. This consists of parsing the existing POMs and generating the corresponding Gradle build scripts. Gradle will also create a settings script if you're migrating a [multi-project build](#).

You'll find that the new Gradle build includes the following:

- All the custom repositories that are specified in the POM

- Your external and inter-project dependencies

- The appropriate plugins to build the project (limited to one or more of the [Maven Publish](#), [Java](#) and [War](#) Plugins)

See the [Build Init Plugin chapter](#) for a complete list of the automatic conversion features.

One thing to keep in mind is that assemblies are not automatically converted. This additional conversion will required some manual work. Options include:

- Using the [Distribution Plugin](#)

- Using the [Java Library Distribution Plugin](#)

- Using the [Application Plugin](#)

- [Creating custom archive tasks](#)

- Using a suitable community plugin from the [Gradle Plugin Portal](#)

If your Maven build does not have many plugins or custom steps, you can simply run

```
> gradle build
```

once the migration has completed. This will run the tests and produce the required artifacts automatically.

Migrating dependencies

Gradle's dependency management system is more flexible than Maven's, but it still supports the same concepts of repositories, declared dependencies, scopes (dependency configurations in Gradle), and transitive dependencies. In fact, Gradle works with Maven-compatible repositories which makes it easy to migrate your dependencies.

NOTE	One notable difference between the two tools is in how they manage version conflicts. Maven uses a "closest" match algorithm, whereas Gradle picks the newest. Don't worry though, you have a lot of control over which versions are selected, as documented in Managing Transitive Dependencies.

Over the following sections, we will show you how to migrate the most common elements of a Maven build's dependency management information.

Declaring dependencies

Gradle uses the same dependency identifier components as Maven: group ID, artifact ID and version. It also supports classifiers. All you need to do is substitute the identifier information for a dependency into Gradle's syntax, which is described in the Declaring Dependencies chapter.

For example, consider this Maven-style dependency on Log4J:

```
<dependencies>
    <dependency>
        <groupId>log4j</groupId>
        <artifactId>log4j</artifactId>
        <version>1.2.12</version>
    </dependency>
</dependencies>
```

This dependency would look like the following in a Gradle build script:

Example 1. *Declaring a simple compile-time dependency*

build.gradle.kts

```kotlin
dependencies {
    implementation("log4j:log4j:1.2.12")   ①
}
```

build.gradle

```groovy
dependencies {
    implementation 'log4j:log4j:1.2.12'   ①
}
```

① Attaches version 1.2.12 of Log4J to the `implementation` configuration (scope)

The string identifier takes the Maven values of `groupId`, `artifactId` and `version`, although Gradle refers to them as `group`, `module` and `version`.

The above example raises an obvious question: what is that `implementation` configuration? It's one of the standard dependency configurations provided by the Java Plugin and is often used as a substitute for Maven's default `compile` scope.

Several of the differences between Maven's scopes and Gradle's standard configurations come down to Gradle distinguishing between the dependencies required to build a module and the dependencies required to build a module that depends on it. Maven makes no such distinction, so published POMs typically include dependencies that consumers of a library don't actually need.

Here are the main Maven dependency scopes and how you should deal with their migration:

`compile`

Gradle has two configurations that can be used in place of the `compile` scope: `implementation` and `api`. The former is available to any project that applies the Java Plugin, while `api` is only available to projects that specifically apply the Java Library Plugin.

In most cases you should simply use the `implementation` configuration, particularly if you're building an application or webapp. But if you're building a library, you can learn about which dependencies should be declared using `api` in the section on Building Java libraries. Even more information on the differences between `api` and `implementation` is provided in the Java Library Plugin chapter linked above.

`runtime`

Use the `runtimeOnly` configuration.

test

Gradle distinguishes between those dependencies that are required to *compile* a project's tests and those that are only needed to *run* them.

Dependencies required for test compilation should be declared against the `testImplementation` configuration. Those that are only required for running the tests should use `testRuntimeOnly`.

provided

Use the `compileOnly` configuration.

Note that the War Plugin adds `providedCompile` and `providedRuntime` dependency configurations. These behave slightly differently from `compileOnly` and simply ensure that those dependencies aren't packaged in the WAR file. However, the dependencies are included on runtime and test runtime classpaths, so use these configurations if that's the behavior you need.

import

The `import` scope is mostly used within `<dependencyManagement>` blocks and applies solely to POM-only publications. Read the section on Using bills of materials to learn more about how to replicate this behavior.

You can also specify a regular dependency on a POM-only publication. In this case, the dependencies declared in that POM are treated as normal transitive dependencies of the build.

For example, imagine you want to use the `groovy-all` POM for your tests. It's a POM-only publication that has its own dependencies listed inside a `<dependencies>` block. The appropriate configuration in the Gradle build looks like this:

Example 2. Consuming a POM-only dependency

build.gradle.kts

```
dependencies {
    testImplementation("org.codehaus.groovy:groovy-all:2.5.4")
}
```

build.gradle

```
dependencies {
    testImplementation 'org.codehaus.groovy:groovy-all:2.5.4'
}
```

The result of this will be that all `compile` and `runtime` scope dependencies in the `groovy-all` POM get added to the test runtime classpath, while only the `compile` scope dependencies get added to the test compilation classpath. Dependencies with other scopes will be ignored.

Declaring repositories

Gradle allows you to retrieve declared dependencies from any Maven-compatible or Ivy-compatible repository. Unlike Maven, it has no default repository and so you have to declare at least one. In order to have the same behavior as your Maven build, just configure Maven Central in your Gradle build, like this:

Example 3. Configuring the build to use Maven Central

build.gradle.kts

```
repositories {
    mavenCentral()
}
```

build.gradle

```
repositories {
    mavenCentral()
}
```

You can also use the `repositories {}` block to configure custom repositories, as described in the Repository Types chapter.

Lastly, Gradle allows you to resolve dependencies against the local Maven cache/repository. This helps Gradle builds interoperate with Maven builds, but it shouldn't be a technique that you use if you don't need that interoperability. If you want to share published artifacts via the filesystem, consider configuring a custom Maven repository with a `file://` URL.

You might also be interested in learning about Gradle's own dependency cache, which behaves more reliably than Maven's and can be used safely by multiple concurrent Gradle processes.

Controlling dependency versions

The existence of transitive dependencies means that you can very easily end up with multiple versions of the same dependency in your dependency graph. By default, Gradle will pick the newest version of a dependency in the graph, but that's not always the right solution. That's why it provides several mechanisms for controlling which version of a given dependency is resolved.

On a per-project basis, you can use:

- Dependency constraints
- Bills of materials (Maven BOMs)
- Overriding transitive versions

There are even more, specialized options listed in the controlling transitive dependencies chapter.

If you want to ensure consistency of versions across all projects in a multi-project build, similar to how the `<dependencyManagement>` block in Maven works, you can use the Java Platform Plugin. This allows you declare a set of dependency constraints that can be applied to multiple projects. You can even publish the platform as a Maven BOM or using Gradle's metadata format. See the plugin page for more information on how to do that, and in particular the section on Consuming platforms to see how you can apply a platform to other projects in the same build.

Excluding transitive dependencies

Maven builds use exclusions to keep unwanted dependencies — or unwanted *versions* of dependencies — out of the dependency graph. You can do the same thing with Gradle, but that's not necessarily the *right* thing to do. Gradle provides other options that may be more appropriate for a given situation, so you really need to understand *why* an exclusion is in place to migrate it properly.

If you want to exclude a dependency for reasons unrelated to versions, then check out the section on excluding transitive dependencies. It shows you how to attach an exclusion either to an entire configuration (often the most appropriate solution) or to a dependency. You can even easily apply an exclusion to all configurations.

If you're more interested in controlling which version of a dependency is actually resolved, see the previous section.

Handling optional dependencies

You are likely to encounter two situations regarding optional dependencies:

- Some of your transitive dependencies are declared as optional

- You want to declare some of your direct dependencies as optional in your project's published POM

For the first scenario, Gradle behaves the same way as Maven and simply ignores any transitive dependencies that are declared as optional. They are not resolved and have no impact on the versions selected if the same dependencies appear elsewhere in the dependency graph as non-optional.

As for publishing dependencies as optional, Gradle provides a richer model called feature variants, which will let you declare the "optional features" your library provides.

Using bills of materials (BOMs)

Maven allows you to share dependency constraints by defining dependencies inside a `<dependencyManagement>` section of a POM file that has a packaging type of `pom`. This special type of POM (a BOM) can then be imported into other POMs so that you have consistent library versions across your projects.

Gradle can use such BOMs for the same purpose, using a special dependency syntax based on `platform()` and `enforcedPlatform()` methods. You simply declare the dependency in the normal way, but wrap the dependency identifier in the appropriate method, as shown in this example that

"imports" the Spring Boot Dependencies BOM:

Example 4. Importing a BOM in a Gradle build

build.gradle.kts

```
dependencies {
    implementation(platform("org.springframework.boot:spring-boot-
    dependencies:1.5.8.RELEASE"))   ①

    implementation("com.google.code.gson:gson")   ②
    implementation("dom4j:dom4j")
}
```

build.gradle

```
dependencies {
    implementation platform('org.springframework.boot:spring-boot-
    dependencies:1.5.8.RELEASE') ①

    implementation 'com.google.code.gson:gson' ②
    implementation 'dom4j:dom4j'
}
```

① Applies the Spring Boot Dependencies BOM

② Adds a dependency whose version is defined by that BOM

You can learn more about this feature and the difference between `platform()` and `enforcedPlatform()` in the section on importing version recommendations from a Maven BOM.

NOTE	You can use this feature to apply the `<dependencyManagement>` information from any dependency's POM to the Gradle build, even those that don't have a packaging type of `pom`. Both `platform()` and `enforcedPlatform()` will ignore any dependencies declared in the `<dependencies>` block.

Migrating multi-module builds (project aggregation)

Maven's multi-module builds map nicely to Gradle's multi-project builds. Try the corresponding sample to see how a basic multi-project Gradle build is set up.

To migrate a multi-module Maven build, simply follow these steps:

1. Create a settings script that matches the `<modules>` block of the root POM.

   For example, this `<modules>` block:

```xml
<modules>
    <module>simple-weather</module>
    <module>simple-webapp</module>
</modules>
```

can be migrated by adding the following line to the settings script:

Example 5. Declaring which projects are part of the build

settings.gradle.kts

```kotlin
rootProject.name = "simple-multi-module"  ①

include("simple-weather", "simple-webapp")  ②
```

settings.gradle

```groovy
rootProject.name = 'simple-multi-module'  ①

include 'simple-weather', 'simple-webapp'  ②
```

① Sets the name of the overall project

② Configures two subprojects as part of this build

Output of `gradle projects`

```
> gradle projects

------------------------------------------------------------
Root project 'simple-multi-module'
------------------------------------------------------------

Root project 'simple-multi-module'
+--- Project ':simple-weather'
\--- Project ':simple-webapp'

To see a list of the tasks of a project, run gradle <project-path>:tasks
For example, try running gradle :simple-weather:tasks
```

2. Replace cross-module dependencies with project dependencies.

3. Replicate project inheritance with convention plugins.

   This basically involves creating a root project build script that injects shared configuration into

the appropriate subprojects.

Sharing versions across projects

If you want to replicate the Maven pattern of having dependency versions declared in the `dependencyManagement` section of the root POM file, the best approach is to leverage the `java-platform` plugin. You will need to add a dedicated project for this and consume it in the regular projects of your build. See the documentation for more details on this pattern.

Migrating Maven profiles and properties

Maven allows you parameterize builds using properties of various sorts. Some are read-only properties of the project model, others are user-defined in the POM. It even allows you to treat system properties as project properties.

Gradle has a similar system of project properties, although it differentiates between those and system properties. You can, for example, define properties in:

- the build script
- a `gradle.properties` file in the root project directory
- a `gradle.properties` file in the `$HOME/.gradle` directory

Those aren't the only options, so if you are interested in finding out more about how and where you can define properties, check out the Build Environment chapter.

One important piece of behavior you need to be aware of is what happens when the same property is defined in both the build script and one of the external properties files: the build script value takes precedence. Always. Fortunately, you can mimic the concept of profiles to provide overridable default values.

Which brings us to Maven profiles. These are a way to enable and disable different configurations based on environment, target platform, or any other similar factor. Logically, they are nothing more than limited `if` statements. And since Gradle has much more powerful ways to declare conditions, it does not need to have formal support for profiles (except in the POMs of dependencies). You can easily get the same behavior by combining conditions with secondary build scripts, as you'll see.

Let's say you have different deployment settings depending on the environment: local development (the default), a test environment, and production. To add profile-like behavior, you first create build scripts for each environment in the project root: `profile-default.gradle`, `profile-test.gradle`, and `profile-prod.gradle`. You can then conditionally apply one of those profile scripts based on a project property of your own choice.

The following example demonstrates the basic technique using a project property called `buildProfile` and profile scripts that simply initialize an extra project property called `message`:

Example 6. Mimicking the behavior of Maven profiles in Gradle

build.gradle.kts

```kotlin
val buildProfile: String? by project   ①

apply(from = "profile-${buildProfile ?: "default"}.gradle.kts")   ②

tasks.register("greeting") {
    // Store the message into a variable, because referencing extras from the
task action
    // is not compatible with the configuration cache.
    val message = project.extra["message"]
    doLast {
        println(message)   ③
    }
}
```

profile-default.gradle.kts

```kotlin
val message by extra("foobar")   ④
```

profile-test.gradle.kts

```kotlin
val message by extra("testing 1 2 3")   ④
```

profile-prod.gradle.kts

```kotlin
val message by extra("Hello, world!")   ④
```

```
if (!hasProperty('buildProfile')) ext.buildProfile = 'default'   ①

apply from: "profile-${buildProfile}.gradle"   ②

tasks.register('greeting') {
    // Store the message into a variable, because referencing extras from the
task action
    // is not compatible with the configuration cache.
    def message = project.message
    doLast {
        println message   ③
    }
}
```

profile-default.gradle

```
ext.message = 'foobar'   ④
```

profile-test.gradle

```
ext.message = 'testing 1 2 3'   ④
```

profile-prod.gradle

```
ext.message = 'Hello, world!'   ④
```

① Checks for the existence of (Groovy) or binds (Kotlin) the `buildProfile` project property

② Applies the appropriate profile script, using the value of `buildProfile` in the script filename

③ Prints out the value of the `message` extra project property

④ Initializes the `message` extra project property, whose value can then be used in the main build script

With this setup in place, you can activate one of the profiles by passing a value for the project property you're using — `buildProfile` in this case:

Output of `gradle greeting`

```
> gradle greeting
foobar
```

Output of `gradle -PbuildProfile=test greeting`

```
> gradle -PbuildProfile=test greeting
testing 1 2 3
```

You're not limited to checking project properties. You could also check environment variables, the JDK version, the OS the build is running on, or anything else you can imagine.

One thing to bear in mind is that high level condition statements make builds harder to understand and maintain, similar to the way they complicate object-oriented code. The same applies to profiles. Gradle offers you many better ways to avoid the extensive use of profiles that Maven often requires, for example by configuring multiple tasks that are variants of one another. See the `publishPubNamePublicationToRepoNameRepository` tasks created by the Maven Publish Plugin.

For a lengthier discussion on working with Maven profiles in Gradle, look no further than this blog post.

Filtering resources

Maven has a phase called `process-resources` that has the goal `resources:resources` bound to it by default. This gives the build author an opportunity to perform variable substitution on various files, such as web resources, packaged properties files, etc.

The Java plugin for Gradle provides a `processResources` task to do the same thing. This is a ProcessResources task that copies files from the configured resources directory — `src/main/resources` by default — to an output directory. And as with any `ProcessResources` or `Copy` task, you can configure it to perform file filtering, renaming, and content filtering.

As an example, here's a configuration that treats the source files as `Groovy SimpleTemplateEngine` templates, providing `version` and `buildNumber` properties to those templates:

Example 7. Filtering the content of resources via the `processResources` *task*

build.gradle.kts

```kotlin
tasks {
    processResources {
        expand("version" to version, "buildNumber" to currentBuildNumber)
    }
}
```

build.gradle

```groovy
processResources {
    expand(version: version, buildNumber: currentBuildNumber)
}
```

See the API docs for CopySpec to see all the options available to you.

Configuring integration tests

Many Maven builds incorporate integration tests of some sort, which Maven supports through an extra set of phases: `pre-integration-test`, `integration-test`, `post-integration-test`, and `verify`. It also uses the Failsafe plugin in place of Surefire so that failed integration tests don't automatically fail the build (because you may need to clean up resources, such as a running application server).

This behavior is easy to replicate in Gradle with source sets, as explained in our chapter on Testing in Java & JVM projects. You can then configure a clean-up task, such as one that shuts down a test server for example, to always run after the integration tests regardless of whether they succeed or fail using Task.finalizedBy().

If you really don't want your integration tests to fail the build, then you can use the Test.ignoreFailures setting described in the Test execution section of the Java testing chapter.

Source sets also give you a lot of flexibility on where you place the source files for your integration tests. You can easily keep them in the same directory as the unit tests or, more preferably, in a separate source directory like `src/integTest/java`. To support other types of tests, simple add more source sets and Test tasks.

Migrating common plugins

Maven and Gradle share a common approach of extending the build through plugins. Although the plugin systems are very different beneath the surface, they share many feature-based plugins, such as:

- Shade/Shadow

- Jetty

- Checkstyle

- JaCoCo

- AntRun (see further down)

Why does this matter? Because many plugins rely on standard Java conventions, migration is just a matter of replicating the configuration of the Maven plugin in Gradle. As an example, here's a simple Maven Checkstyle plugin configuration:

```
...
<plugin>
  <groupId>org.apache.maven.plugins</groupId>
  <artifactId>maven-checkstyle-plugin</artifactId>
  <version>2.17</version>
  <executions>
    <execution>
      <id>validate</id>
      <phase>validate</phase>
      <configuration>
        <configLocation>checkstyle.xml</configLocation>
        <encoding>UTF-8</encoding>
        <consoleOutput>true</consoleOutput>
        <failsOnError>true</failsOnError>
        <linkXRef>false</linkXRef>
      </configuration>
      <goals>
        <goal>check</goal>
      </goals>
    </execution>
  </executions>
</plugin>
...
```

Everything outside of the configuration block can safely be ignored when migrating to Gradle. In this case, the corresponding Gradle configuration is as follows:

Example 8. Configuring the Gradle Checkstyle Plugin

build.gradle.kts

```kotlin
checkstyle {
    config = resources.text.fromFile("checkstyle.xml", "UTF-8")
    isShowViolations = true
    isIgnoreFailures = false
}
```

build.gradle

```groovy
checkstyle {
    config = resources.text.fromFile('checkstyle.xml', 'UTF-8')
    showViolations = true
    ignoreFailures = false
}
```

The Checkstyle tasks are automatically added as dependencies of the `check` task, which also includes `test`. If you want to ensure that Checkstyle runs before the tests, then just specify an ordering with the mustRunAfter(…) method:

Example 9. Controlling when the `checkstyle` task runs

build.gradle.kts

```kotlin
tasks {
    test {
        mustRunAfter(checkstyleMain, checkstyleTest)
    }
}
```

build.gradle

```groovy
test.mustRunAfter checkstyleMain, checkstyleTest
```

As you can see, the Gradle configuration is often much shorter than the Maven equivalent. You also have a much more flexible execution model since you are no longer constrained by Maven's fixed phases.

While migrating a project from Maven, don't forget about source sets. These often provide a more elegant solution for handling integration tests or generated sources than Maven can provide, so you should factor them into your migration plans.

Ant goals

Many Maven builds rely on the AntRun plugin to customize the build without the overhead of implementing a custom Maven plugin. Gradle has no equivalent plugin because Ant is a first-class citizen in Gradle builds, via the ant object. For example, you can use Ant's Echo task like this:

Example 10. Invoking Ant tasks

build.gradle.kts

```
tasks.register("sayHello") {
    doLast {
        ant.withGroovyBuilder {
            "echo"("message" to "Hello!")
        }
    }
}
```

build.gradle

```
tasks.register('sayHello') {
    doLast {
        ant.echo message: 'Hello!'
    }
}
```

Even Ant properties and filesets are supported natively. To learn more, see Using Ant from Gradle.

| TIP | It may be simpler and cleaner to just create custom task types to replace the work that Ant is doing for you. You can then more readily benefit from incremental build and other useful Gradle features. |

Understanding which plugins you don't need

It's worth remembering that Gradle builds are typically easier to extend and customize than Maven ones. In this context, that means you may not need a Gradle plugin to replace a Maven one. For example, the Maven Enforcer plugin allows you to control dependency versions and environmental factors, but these things can easily be configured in a normal Gradle build script.

Dealing with uncommon and custom plugins

You may come across Maven plugins that have no counterpart in Gradle, particularly if you or someone in your organisation has written a custom plugin. Such cases rely on you understanding how Gradle (and potentially Maven) works, because you will usually have to write your own plugin.

For the purposes of migration, there are two key types of Maven plugins:

- Those that use the Maven project object.
- Those that don't.

Why is this important? Because if you use one of the latter, you can trivially reimplement it as a custom Gradle task type. Simply define task inputs and outputs that correspond to the mojo parameters and convert the execution logic into a task action.

If a plugin depends on the Maven project, then you will have to rewrite it. Don't start by considering how the Maven plugin works, but look at what problem it is trying to solve. Then try to work out how to solve that problem in Gradle. You will probably find that the two build models are different enough that "transcribing" Maven plugin code into a Gradle plugin just won't be effective. On the plus side, the plugin is likely to be much easier to write than the original Maven one because Gradle has a much richer build model and API.

If you do need to implement custom logic, either via build scripts or plugins, check out the Guides related to plugin development. Also be sure to familiarize yourself with Gradle's Groovy DSL Reference, which provides comprehensive documentation on the API that you'll be working with. It details the standard configuration blocks (and the objects that back them), the core types in the system (`Project`, `Task`, etc.), and the standard set of task types. The main entry point is the Project interface as that's the top-level object that backs the build scripts.

Further reading

This chapter has covered the major topics that are specific to migrating Maven builds to Gradle. All that remain are a few other areas that may be useful during or after a migration:

- Learn how to configure Gradle's build environment, including the JVM settings used to run it
- Learn how to structure your builds effectively
- Configure Gradle's logging and use it from your builds

As a final note, this guide has only touched on a few of Gradle's features and we encourage you to learn about the rest from the other chapters of the user manual and from our step-by-step samples.

Migrating Builds From Apache Ant

Apache Ant is a build tool with a long history in the Java world that is still widely used, albeit by a decreasing number of teams. While flexible, it lacks conventions and many of the powerful features that Gradle provides. Migrating to Gradle is worthwhile so that your builds can become slimmer, simpler, and faster, while still retaining the flexibility you enjoy with Ant. You will also benefit from

robust support for multi-project builds and easy-to-use, flexible dependency management.

The biggest challenge in migrating from Ant to Gradle is that there is no such thing as a standard Ant build. That makes it difficult to provide specific instructions. Fortunately, Gradle has some great integration features with Ant that can make the process relatively smooth. Migrating from Ivy -based dependency management isn't difficult because Gradle has a similar model based on dependency configurations that works with Ivy-compatible repositories.

We will start by outlining the things you should consider when migrating a build from Ant to Gradle and offer some general guidelines on how to proceed.

General guidelines

When you migrate a build from Ant to Gradle, you should keep in mind the nature of what you already have and where you would like to end up. Do you want a Gradle build that mirrors the structure of the existing Ant build? Or do you want to move to something that is more idiomatic to Gradle? What are the main benefits you are looking for?

To better understand, consider the following opposing scenarios:

- An imported build via `ant.importBuild()`

  This approach is quick, simple, and works for many Ant-based builds. You end up with a build that is effectively identical to the original Ant build, except your Ant targets become Gradle tasks. Even the dependencies between targets are retained.

  The downside is that you're still using the Ant build, which you must continue to maintain. You also lose the advantages of Gradle's conventions, many of its plugins, its dependency management, and so on. You can still enhance the build with incremental build information, but it's more effort than would be the case for a normal Gradle build.

- An idiomatic Gradle build

  If you want to future proof your build, this is where you want to end up. Making use of Gradle's conventions and plugins will result in a smaller, easier-to-maintain build, with a structure that is familiar to many Java developers. You will also find it easier to take advantage of Gradle's power features to improve build performance.

  The main downside is the extra work required to perform the migration, particularly if the existing build is complex and has many inter-project dependencies. However, these builds often benefit the most from a switch to idiomatic Gradle. In addition, Gradle provides many features that can ease the migration, such as the ability to use core and custom Ant tasks directly from a Gradle build.

You ideally want to end up somewhere close to the second option in the long term, but you don't have to get there in one fell swoop.

What follows is a series of steps to help you decide the approach you want to take and how to go about it:

1. Keep the old Ant build and new Gradle build side by side.

   You know the Ant build works, so you should keep it until you are confident that the Gradle build produces all the same artifacts and otherwise does what you need. This also means that users can try the Gradle build without creating a new copy of the source tree.

   Don't try to change the directory and file structure of the build until after you're ready to make the switch.

2. Develop a mechanism to verify that the two builds produce the same artifacts.

   This is a vitally important step to ensure that your deployments and tests don't break. Even small changes, such as the contents of a manifest file in a JAR, can cause problems. If your Gradle build produces the same output as the Ant build, this will give you and others confidence in switching over and make it easier to implement the big changes that will provide the greatest benefits.

3. Decide whether you have a multi-project build or not.

   Multi-project builds are generally harder to migrate and require more work than single-project ones. We have provided some dedicated advice to help with the process in the Migrating multi-project builds section.

4. Work out what plugins to use for each project.

   We expect that the vast majority of Ant builds are for JVM-based projects, for which there are a wealth of plugins that provide a lot of the functionality you need. Gradle plugins include core plugins that come packaged with Gradle and useful community plugins on the Plugin Portal.

   Even if the Java Plugin or one of its derivatives (such as the Java Library Plugin) aren't a good match for your build, you should at least consider the Base Plugin for its lifecycle tasks.

5. Import the Ant build or create a Gradle build from scratch.

   This step very much depends on the requirements of your build. If a selection of Gradle plugins can do the vast majority of the work your Ant build does, then it probably makes sense to create a fresh Gradle build script that doesn't depend on the Ant build. You can either implement the missing pieces yourself or use existing Ant tasks.

   The alternative approach is to import the Ant build into the Gradle build script and gradually replace the Ant build functionality. This allows you to have a working Gradle build at each stage, but it requires a bit of work to get the Gradle tasks working properly with the Ant ones. You can learn more about this in Working with an imported build.

6. Configure your build for the existing directory and file structure

   Gradle makes use of conventions to eliminate much of the boilerplate associated with older builds and to make it easier for users to work with new builds once they are familiar with those conventions. But that doesn't mean you have to follow them.

   Gradle provides many configuration options that allow for a good degree of customization.

Those options are typically made available through the plugins that provide the conventions. For example, the standard source directory structure for production Java code — `src/main/java` — is provided by the Java Plugin, which allows you to configure a different source path. Many paths can be modified via properties on the Project object.

7. Migrate to standard Gradle conventions if you wish

   Once you're confident that the Gradle build is producing the same artifacts and other resources as the Ant build, you can consider migrating to the standard conventions, such as for source directory paths. Doing so will allow you to remove the extra configuration that was required to override those conventions. New team members will also find it easier to work with the build after the change.

   It's up to you to decide whether this step is worth the effort and potential disruption, which in turn depends on your specific build and team.

The rest of the chapter covers some common scenarios you will likely deal with during the migration, such as dependency management and working with Ant tasks.

Working with an imported build

WARNING	Importing an Ant build is not supported with the configuration cache. You need to complete the conversion to Gradle to get the benefits of caching.

The first step of many migrations will involve importing an Ant build using `ant.importBuild()`. Then how do you then move towards a standard Gradle build without replacing everything at once?

The important thing to remember is that the Ant targets become real Gradle tasks, meaning you can do things like modify their task dependencies, attach extra task actions, and so on. This allows you to substitute native Gradle tasks for the equivalent Ant ones, maintaining any links to other existing tasks.

As an example, imagine that you have a Java library project that you want to migrate from Ant to Gradle. The Gradle build script has the line that imports the Ant build and now want to use the standard Gradle mechanism for compiling the Java source files. However, you want to keep using the existing `package` task that creates the library's JAR file.

In diagram form, the scenario looks like the following, where each box represents a target/task:
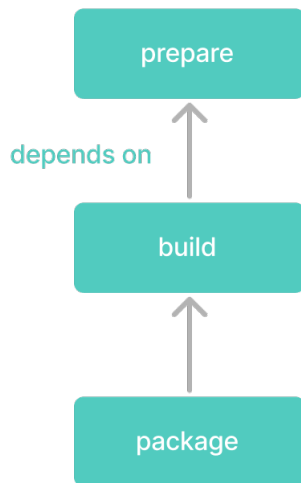
Original Ant build   Updated Gradle build
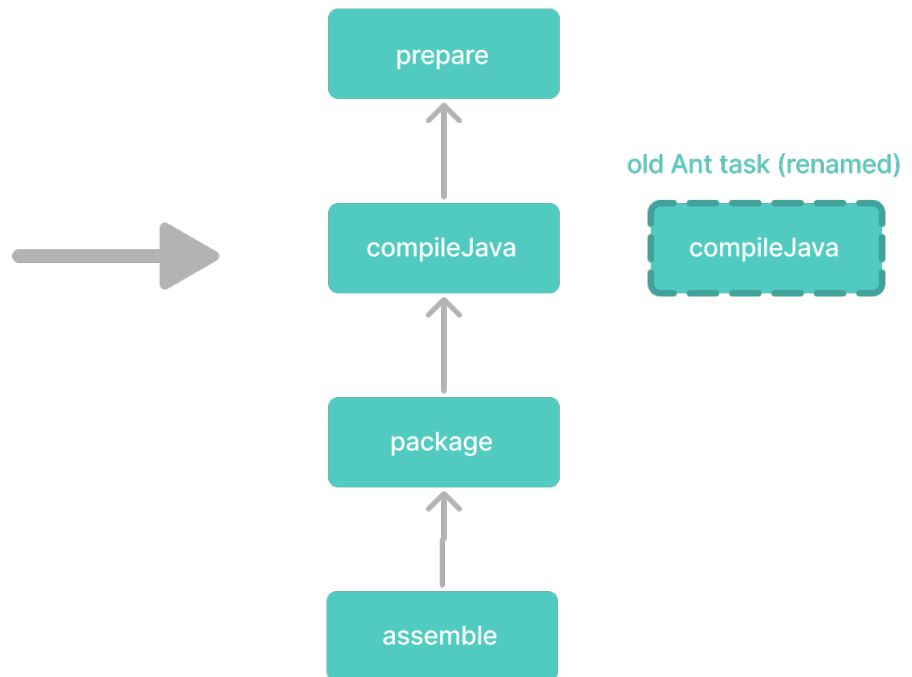
The idea is to substitute the standard Gradle `compileJava` task for the Ant `build` task. There are several steps involved in this substitution:

1. Applying the [Java Library Plugin](#).

   This provides the `compileJava` task shown in the diagram.

2. Renaming the old `build` task.

   The name `build` conflicts with the standard `build` task provided by the [Base Plugin](#) (via the Java Library Plugin).

3. Configuring the compilation to use the existing directory structure.

   There's a good chance the Ant build does not conform to the standard Gradle directory structure, so you need to tell Gradle where to find the source files and where to place the compiled classes so `package` can find them.

4. Updating task dependencies.

   `compileJava` must depend on `prepare`, `package` must depend on `compileJava` rather than `ant_build`, and `assemble` must depend on `package` rather than the standard Gradle `jar` task.

Applying the plugin is as simple as inserting a `plugins {}` block at the beginning of the Gradle build script, i.e. before `ant.importBuild()`. Here's how to apply the Java Library Plugin:

Example 11. Applying the Java Library Plugin

build.gradle.kts

```
plugins {
    `java-library`
}
```

build.gradle

```
plugins {
    id 'java-library'
}
```

To rename the `build` task, use the variant of AntBuilder.importBuild() that accepts a transformer, like this:

Example 12. Renaming targets on import

build.gradle.kts

```
ant.importBuild("build.xml") { oldTargetName ->
    if (oldTargetName == "build") "ant_build" else oldTargetName   ①
}
```

build.gradle

```
ant.importBuild('build.xml') { String oldTargetName ->
    return oldTargetName == 'build' ? 'ant_build' : oldTargetName   ①
}
```

① Renames the `build` target to `ant_build` and leaves all other targets unchanged

Configuring a different path for the sources is described in Building Java & JVM projects. You can change the output directory for the compiled classes in a similar way.

If, for example, the original Ant build stores these paths in Ant properties; `src.dir` for the Java source files and `classes.dir` for the output. Here's how you would configure Gradle to use those paths:

Example 13. Configuring the source sets

build.gradle.kts

```
sourceSets {
    main {
        java.setSrcDirs(listOf(ant.properties["src.dir"]))
        java.destinationDirectory = file(ant.properties["classes.dir"] ?:
layout.buildDirectory.dir("classes"))
    }
}
```

build.gradle

```
sourceSets {
    main {
        java {
            srcDirs = [ ant.properties['src.dir'] ]
            destinationDirectory = file(ant.properties['classes.dir'])
        }
    }
}
```

You should eventually switch to the standard directory structure for your type of project so that you will be able to remove this customization.

The last step is straightforward and involves using the Task.dependsOn property and Task.dependsOn() method to detach and link tasks. The property is appropriate for *replacing* dependencies, while the method is the preferred way to add to the existing dependencies.

Here is the required task dependency configuration for the example scenario, which should come after the Ant build import:

Example 14. Configuring the task dependencies

build.gradle.kts

```
tasks {
    compileJava {
        dependsOn("prepare")   ①
    }
    named("package") {
        setDependsOn(listOf(compileJava))   ②
    }
    assemble {
        setDependsOn(listOf("package"))   ③
    }
}
```

build.gradle

```
compileJava.dependsOn 'prepare'   ①
tasks.named('package') { dependsOn = [ 'compileJava' ] }   ②
assemble.dependsOn = [ 'package' ]   ③
```

① Makes compilation depend on the `prepare` task

② Detaches `package` from the `ant_build` task and makes it depend on `compileJava`

③ Detaches `assemble` from the standard Gradle `jar` task and makes it depend on `package` instead

These four steps will successfully replace the old Ant compilation with the Gradle implementation. Even this small migration will give you the advantage of Gradle's incremental Java compilation for faster builds.

| TIP | This is one example of a staged migration. It may make more sense to include resource processing — such as properties files — and packaging with the compilation in this stage. |

One important question you will have to ask yourself is how many tasks to migrate in each stage. The more you can migrate in one go the better, but risk comes with the number of custom steps within the Ant build that will be affected by the changes.

For example, if the Ant build follows a fairly standard approach for compilation, static resources, packaging and unit tests, then it is probably worth migrating all of those together. But if the build performs some extra processing on the compiled classes, or does something unique when processing the static resources, it is probably worth splitting those tasks into separate stages.

Managing dependencies

Ant builds typically take one of two approaches to dealing with binary dependencies (such as libraries):

- Storing them with the project in a local "lib" directory

- Using Apache Ivy to manage them

They each require a different technique for the migration to Gradle, but you will find the process straightforward in either case. Let's look at each case, in detail, in the following sections.

Serving dependencies from a directory

When you are attempting to migrate a build that stores its dependencies on the filesystem, either locally or on the network, you should consider whether you want to eventually move to managed dependencies using remote repositories. That's because you can incorporate filesystem dependencies into a Gradle build in one of two ways:

- Define a flat-directory repository and use standard dependency declarations

- Attach the files directly to the appropriate dependency configurations (file dependencies)

It's easier to migrate to managed dependencies served from Maven, or Ivy-compatible repositories, if you take the first approach, but doing so requires all your files to conform to the naming convention "<moduleName>-<version>.<extension>".

NOTE	If you store your dependencies in the standard Maven repository layout — `<repoDir>/<group>/<module>/<version>` — then you can define a custom Maven repository with a `file://` URL.

To demonstrate the two techniques, consider a project that has the following library JARs in its `libs` directory:

```
libs
├── our-custom.jar
├── awesome-framework-2.0.jar
└── utility-library-1.0.jar
```

The file `our-custom.jar` has no version number, so it has to be added as a file dependency. The other two JARs match the required naming convention and can be declared as normal module dependencies that are retrieved from a flat-directory repository.

The following sample build script demonstrates how you can incorporate all of these libraries into a build:

Example 15. Declaring dependencies served from the filesystem

build.gradle.kts

```kotlin
repositories {
    flatDir {
        name = "libs dir"
        dir(file("libs"))    ①
    }
}

dependencies {
    implementation(files("libs/our-custom.jar"))    ②
    implementation(":awesome-framework:2.0")    ③
    implementation(":utility-library:1.0")    ③
}
```

build.gradle

```groovy
repositories {
    flatDir {
        name = 'libs dir'
        dir file('libs')    ①
    }
}

dependencies {
    implementation files('libs/our-custom.jar')    ②
    implementation ':awesome-framework:2.0'    ③
    implementation ':utility-library:1.0'    ③
}
```

① Specifies the path to the directory containing the JAR files

② Declares a *file dependency* for the un-versioned JAR

③ Declares dependencies using standard dependency coordinates — note that no group is specified, but each identifier has a leading `:`, implying an empty group

The above sample will add `our-custom.jar`, `awesome-framework-2.0.jar` and `utility-library-1.0.jar` to the `implementation` configuration, which is used to compile the project's code.

NOTE	You can also specify a group in these module dependencies, even though they don't actually have a group. That's because the flat-directory repository simply ignores this information. Then, if you add a normal Maven or Ivy-compatible repository at a later date, Gradle will download the module dependencies that are declared with a group from that repository rather than the flat-directory one.

Migrating Ivy dependencies

Apache Ivy is a standalone dependency management tool that is widely used with Ant. It works similarly to Gradle. In fact, they both allow you to:

- Define your own configurations

- Extend configurations from one another

- Attach dependencies to configurations

- Resolve dependencies from Ivy-compatible repositories

- Publish artifacts to Ivy-compatible repositories

The most notable difference is that Gradle has standard configurations for specific types of projects. For example, the Java Plugin defines configurations like `implementation`, `testImplementation` and `runtimeOnly`. You are able to define your own dependency configurations if needed.

As such, it's typically straightforward to migrate from Ivy to Gradle:

- Transcribe the dependency declarations from your module descriptors into the dependencies {} block of your Gradle build script, ideally using the standard configurations provided by any plugins you apply.

- Transcribe any configuration declarations from your module descriptors into the configurations {} block of the build script for any custom configurations that can't be replaced by Gradle's standard ones.

- Transcribe the resolvers from your Ivy settings file into the repositories {} block of the build script.

See the chapters on Managing Dependency Configurations, Declaring Dependencies and Declaring Repositories for more information.

Ivy provides several Ant tasks that handle Ivy's process for fetching dependencies. The basic steps of that process consist of:

1. *Configure* — applies the configuration defined in the Ivy settings file

2. *Resolve* — locates the declared dependencies and downloads them to the cache if necessary

3. *Retrieve* — copies the cached dependencies to another directory

Gradle's process is similar, but you don't have to explicitly invoke the first two steps as it performs them automatically. The third step doesn't happen at all — unless you create a task to do it — because Gradle typically uses the files in the dependency cache directly in classpaths and as the source for assembling application packages.

Let's look in more detail at how Ivy's steps map to Gradle:

Configuration

Most of Gradle's dependency-related configuration is baked into the build script, as you've seen with elements like the `dependencies {}` block. Another particularly important configuration element is resolutionStrategy, which can be accessed from dependency configurations. This provides many of the features you might get from Ivy's conflict managers and is a powerful way to control transitive dependencies and caching.

Some Ivy configuration options have no equivalent in Gradle. For example, there are no lock strategies because Gradle guarantees that its dependency cache is concurrency safe. There are no "latest strategies" methodology because it's simpler to have a reliable, single strategy for conflict resolution. If the "wrong" version is picked, you can override it using forced versions or other resolution options.

See the chapter on controlling transitive dependencies for more information.

Resolution

At the beginning of the build, Gradle will automatically resolve any dependencies that you have declared and download them to its cache. Gradle searches the repositories for those dependencies, with the search order defined by the order in which the repositories are declared.

It's worth noting that Gradle supports the same dynamic version syntax as Ivy, so you can still use conventions like `1.0.+`. You can also use the special `latest.integration` and `latest.release` labels. If you decide to use such dynamic and changing dependencies, you can configure the caching behavior for them via resolutionStrategy.

You might also want to consider dependency locking if you're using dynamic and/or changing dependencies. It's a way to make the build more reliable and ensures reproducibility.

Retrieval

As mentioned, Gradle does not automatically copy files from the dependency cache. Its standard tasks typically use the files directly. If you want to copy the dependencies to a local directory, you can use a Copy task like this in your build script:

Example 16. *Copying dependencies to a local directory*

build.gradle.kts

```kotlin
tasks.register<Copy>("retrieveRuntimeDependencies") {
    into(layout.buildDirectory.dir("libs"))
    from(configurations.runtimeClasspath)
}
```

build.gradle

```groovy
tasks.register('retrieveRuntimeDependencies', Copy) {
    into layout.buildDirectory.dir('libs')
    from configurations.runtimeClasspath
}
```

A configuration is also a file collection, hence why it can be used in the `from()` configuration. You can use a similar technique to attach a configuration to a compilation task or one that produces documentation. See the chapter on Working with Files for more examples and information on Gradle's file API.

Publishing artifacts

Projects that use Ivy to manage dependencies often also use it for publishing JARs and other artifacts to repositories. If you're migrating such a build, then you'll be glad to know that Gradle has built-in support for publishing artifacts to Ivy-compatible repositories.

Before you attempt to migrate this particular aspect of your build, read the Publishing chapter to learn about Gradle's publishing model. The chapter examples are based on Maven repositories but the same model is used for Ivy repositories.

The basic migration process looks like this:

- Apply the Ivy Publish Plugin to your build

- Configure at least one publication, representing what will be published (including additional artifacts if desired)

- Configure one or more repositories to publish artifacts to

Once that's all done, you will be able to generate an Ivy module descriptor for each publication and publish them to one or more repositories.

Let's say you have defined a publication named "myLibrary" and a repository named "myRepo". Ivy's Ant tasks would then map to the Gradle tasks like this:

- `<deliver>` → `generateDescriptorFileForMyLibraryPublication`

- `<publish>` → `publishMyLibraryPublicationToMyRepoRepository`

There is also a convenient `publish` task that publishes *all* publications to *all* repositories. If you want to limit publications to specific repositories, check out the [relevant section of the Publishing chapter](#).

On dependency versions

Ivy will, by default, automatically replace dynamic versions of dependencies with the resolved "static" versions when it generates the module descriptor. Gradle does *not* mimic this behavior, declared dependency versions are left unchanged.

You can replicate the default Ivy behavior by using the [Nebula Ivy Resolved Plugin](#). Alternatively, you can [customize the descriptor file](#) so that it contains the versions you want.

Dealing with custom Ant tasks

One of the advantages of Ant is that it's fairly easy to create a custom task and incorporate it into a build. If you have such tasks, then there are two main options for migrating them to a Gradle build:

- [Using the custom Ant task](#) from the Gradle build

- Rewriting the task as a [custom Gradle task type](#)

The first option is typically quick and easy. If you want to integrate the task into incremental build, you must use the [incremental build runtime API](#). You also often have to work with Ant paths and filesets, which can be inconvenient.

The second option is preferable long term. Gradle task types tend to be simpler than Ant tasks because they don't have to work with an XML-based interface. You also gain the benefits of Gradle's rich APIs. This approach enables the [type-safe incremental build API](#) based on typed properties.

Working with files

Ant has many tasks for working with files, most of which have Gradle equivalents. As with other areas of the Ant to Gradle migration, you can [use those Ant tasks](#) from within your Gradle build. However, we strongly recommend migrating to native Gradle constructs where possible so that the build benefits from:

- [Incremental build](#)

- Easier integration with other parts of the build, such as dependency configurations

- More idiomatic build scripts

It can be convenient to use Ant tasks that have no direct equivalents, such as `<checksum>` and `<chown>`. However, in the long term, it may be better to convert these to native Gradle task types that make use of standard Java APIs or third-party libraries.

Here are the most common file-related elements used by Ant builds, along with the Gradle equivalents:

- `<copy>` — prefer the Gradle Copy task type
- `<zip>` (plus Java variants) — prefer the Zip task type (plus Jar, War, and Ear)
- `<unzip>` — prefer using the Project.zipTree() method with a Copy task

You can see several examples of Gradle's file API and learn more about it in the Working with Files chapter.

On paths and filesets

Ant makes use of the concepts of path-like structures and filesets to enable users to work with collections of files and directories. Gradle has a simpler, more powerful model based on FileCollections and FileTrees that can be treated as objects from within the build. Both types allow filtering based on Ant's glob syntax, e.g. **/books_*. You can learn more about these types and other aspects of Gradle's file API in the Working with Files chapter.

You can construct Ant paths and filesets from within your build via the ant object if you need to interact with an Ant task that requires them. The chapter on Ant integration has examples that use both `<path>` and `<fileset>`. There is also a method on FileCollection that will convert a file collection to a fileset or similar Ant type.

Migrating Ant properties

Ant makes use of a properties map to store values that can be reused throughout the build. The big downsides to this approach are that property values are all strings and the properties themselves behave like global variables.

Interacting with Ant properties in Gradle

Sometimes you will want to make use of an Ant task directly from your Gradle build and that task requires one or more Ant properties to be set.

If that's the case, you can easily set those properties via the ant object, as described in the Using Ant from Gradle chapter.

Gradle does use something similar in the form of project properties, which are a reasonable way to parameterize a build. These can be set from the command line, in the gradle.properties file, or via specially named system properties and environment variables.

If you have existing Ant properties files, you can copy their contents into the project's gradle.properties file. Just be aware that:

- Properties set in gradle.properties **do not** override extra project properties defined in the build script with the same name
- Imported Ant tasks will not automatically "see" the Gradle project properties — you must copy them into the Ant properties map for that to happen

Another important factor to understand is that a Gradle build script works with an object-oriented API and it's often best to use the properties of tasks, source sets, and other objects where possible. For example, this build script fragment creates tasks for packaging Javadoc documentation as a JAR and unpacking it, linking tasks via their properties:

Example 17. Using task properties in place of project properties

build.gradle.kts

```kotlin
val tmpDistDir = layout.buildDirectory.dir("dist")

tasks.register<Jar>("javadocJarArchive") {
    from(tasks.javadoc)   ①
    archiveClassifier = "javadoc"
}

tasks.register<Copy>("unpackJavadocs") {
    from(zipTree(tasks.named<Jar>("javadocJarArchive").get().archiveFile))
②
    into(tmpDistDir)   ③
}
```

build.gradle

```groovy
def tmpDistDir = layout.buildDirectory.dir('dist')

tasks.register('javadocJarArchive', Jar) {
    from javadoc   ①
    archiveClassifier = 'javadoc'
}

tasks.register('unpackJavadocs', Copy) {
    from zipTree(javadocJarArchive.archiveFile)   ②
    into tmpDistDir   ③
}
```

① Packages all `javadoc`'s output files — equivalent to `from javadoc.destinationDir`

② Uses the location of the Javadoc JAR held by the `javadocJar` task

③ Uses an project property called `tmpDistDir` to define the location of the 'dist' directory

As you can see from the example with `tmpDistDir`, there is often a need to define paths through properties, which is why Gradle also provides extra properties that can be attached to the project, tasks, and some other types of objects.

Migrating multi-project builds

Multi-project builds are a particular challenge to migrate because there is no standard approach in Ant for structuring them or handling inter-project dependencies.

Fortunately, Gradle's multi-project support can handle fairly diverse project structures and it provides much more robust and helpful support than Ant for constructing and maintaining multi-project builds. The `ant.importBuild()` method also handles `<ant>` and `<antcall>` tasks transparently, which allows for a phased migration.

The following steps highlight a suggested method for migrating a multi-project build:

1. Start by learning [how Gradle configures multi-project builds](#).

2. Create a Gradle build script in each project of the build, setting their contents to this line:

   ```
   ant.importBuild 'build.xml'
   ```

   ```
   ant.importBuild("build.xml")
   ```

   Replace `build.xml` with the path to the actual Ant build file that corresponds to the project. If there is no corresponding Ant build file, leave the Gradle build script empty. Even if your build is not be suitable for this migration approach, continue with these steps to see if there is still a way to do a phased migration.

3. Create a settings file that [includes all the projects](#) that now have a Gradle build script.

4. Implement inter-project dependencies.

   Some projects in your multi-project build will depend on artifacts produced by one or more other projects in that build. Such projects need to ensure that the projects they depend on have produced their artifacts and that the paths to those artifacts are known.

   Ensuring the production of the required artifacts typically means calling into other projects' builds via the `<ant>` task. This unfortunately bypasses the Gradle build, negating any changes you make to the Gradle build scripts. You will need to replace targets that use `<ant>` tasks with Gradle [task dependencies](#).

   For example, your web project depends on a "util" library that's part of the same build. The Ant build file for "web" might have a target like this:

   web/build.xml

   ```
   <target name="buildRequiredProjects">
       <ant dir="${root.dir}/util" target="build"/>   ①
   </target>
   ```

   ① `root.dir` would have to be defined by the build

   This can be replaced by an inter-project task dependency in the corresponding Gradle build script, as demonstrated in the following example that assumes the "web" project's "compile"

task is requires "util" to be built beforehand:

web/build.gradle.kts

```kotlin
ant.importBuild("build.xml")

tasks {
    named<Task>("compile") {
        setDependsOn(listOf(":util:build"))
    }
}
```

web/build.gradle

```groovy
ant.importBuild 'build.xml'

compile.dependsOn = [ ':util:build' ]
```

This is not as robust or powerful as Gradle's project dependencies, but it solves the immediate problem without big changes to the build. Just be careful to remove or override any dependencies on tasks that delegate to other subprojects, like the `buildRequiredProjects` task.

5. Identify the projects that have no dependencies on other projects and migrate them to idiomatic Gradle builds scripts.

   Follow the advice in the rest of this guide to migrate individual project builds. As mentioned, you should use Gradle standard plugins where possible. This may mean that you need to add an extra copy task to each build that copies the generated artifacts to the location expected by the rest of the Ant builds.

6. Migrate projects when they depend solely on projects with fully migrated Gradle builds.

   At this point, you should be able to switch to using proper project dependencies attached to the appropriate dependency configurations.

7. Clean up projects once no part of the Ant build depends on them.

   We mentioned in step 5 that you might need to add copy tasks to satisfy the requirements of dependent Ant builds. Once those builds have been migrated, such build logic will no longer be needed and should be removed.

At the end of the process you should have a Gradle build that you are confident works as it should, with much less build logic than before.

Further reading

This chapter has covered the major topics that are specific to migrating Ant builds to Gradle. All that remain are a few other areas that may be useful following a migration:

- Learn how to configure Gradle's build environment, including the JVM settings used to run it
- Learn how to structure your builds effectively
- Configure Gradle's logging and use it from your builds

As a final note, this guide has only touched on a few of Gradle's features and we encourage you to learn about the rest from the other chapters of the User Manual.

GETTING STARTED

Unresolved directive in userguide_single.adoc - include::introduction.adoc[leveloffset=+2]
:leveloffset: +2

Installing Gradle

Gradle Installation

If all you want to do is run an existing Gradle build, then you don't need to install Gradle if the build uses the Gradle Wrapper. This is identifiable by the presence of the `gradlew` or `gradlew.bat` files in the root of the build. You just need to make sure your system satisfies Gradle's prerequisites.

Android Studio comes with a working installation of Gradle, so you don't need to install Gradle separately when only working within that IDE.

You can install Gradle Build Tool on Linux, macOS, or Windows.

The installation can be done manually or using a package manager like SDKMAN! or Homebrew.

Please use the Gradle Wrapper to upgrade Gradle. You can find all Gradle releases and their checksums on the releases page.

Prerequisites

Gradle runs on all major operating systems. It requires [Java Development Kit](#) (JDK) version 8 or higher to run. You can check the [compatibility matrix](#) for more information.

To check, run `java -version`:

```
⬚ java -version
openjdk version "11.0.18" 2023-01-17
OpenJDK Runtime Environment Homebrew (build 11.0.18+0)
OpenJDK 64-Bit Server VM Homebrew (build 11.0.18+0, mixed mode)
```

```
⬚ java version "1.8.0_151"
Java(TM) SE Runtime Environment (build 1.8.0_151-b12)
Java HotSpot(TM) 64-Bit Server VM (build 25.151-b12, mixed mode)
```

Gradle uses the JDK it finds in your path, the JDK used by your IDE, or the JDK specified by your project.

```
echo $PATH
/opt/homebrew/opt/openjdk@17/bin
```

You can also set the `JAVA_HOME` environment variable to point to a specific JDK installation directory.

```
⬚ echo %JAVA_HOME%
C:\Program Files\Java\jdk1.7.0_80
```

```
⬚ echo $JAVA_HOME
/Library/Java/JavaVirtualMachines/jdk-16.jdk/Contents/Home
```

Gradle supports Kotlin and Groovy as the main build languages. Gradle ships with its own Kotlin and Groovy libraries, therefore they do not need to be installed. Existing installations are ignored by Gradle.

[See the full compatibility notes for Java, Groovy, Kotlin and Android.](#)

Linux installation

SDKMAN! is a tool for managing parallel versions of multiple Software Development Kits on most Unix-like systems (macOS, Linux, Cygwin, Solaris and FreeBSD). Gradle is deployed and maintained by SDKMAN!:

```
 sdk install gradle
```

Other package managers are available, but the version of Gradle distributed by them is not controlled by Gradle, Inc. Linux package managers may distribute a modified version of Gradle that is incompatible or incomplete when compared to the official version.

Step 1 - Download the latest Gradle distribution

The distribution ZIP file comes in two flavors:

- Binary-only (bin)

- Complete (all) with docs and sources

We recommend downloading the bin file; it is a smaller file that is quick to download (and the latest documentation is available online).

Step 2 - Unpack the distribution

Unzip the distribution zip file in the directory of your choosing, e.g.:

```
 mkdir /opt/gradle
 unzip -d /opt/gradle gradle-8.6-milestone-1-bin.zip
 ls /opt/gradle/gradle-8.6-milestone-1
LICENSE  NOTICE  bin  README  init.d  lib  media
```

Step 3 - Configure your system environment

To install Gradle, the path to the unpacked files needs to be in your Path. Configure your `PATH` environment variable to include the `bin` directory of the unzipped distribution, e.g.:

```
 export PATH=$PATH:/opt/gradle/gradle-8.6-milestone-1/bin
```

Alternatively, you could also add the environment variable `GRADLE_HOME` and point this to the unzipped distribution. Instead of adding a specific version of Gradle to your `PATH`, you can add `$GRADLE_HOME/bin` to your `PATH`. When upgrading to a different version of Gradle, simply change the `GRADLE_HOME` environment variable.

```
export GRADLE_HOME=/opt/gradle/gradle-8.6-milestone-1
export PATH=${GRADLE_HOME}/bin:${PATH}
```

macOS installation

Installing with a package manager

SDKMAN! is a tool for managing parallel versions of multiple Software Development Kits on most Unix-like systems (macOS, Linux, Cygwin, Solaris and FreeBSD). Gradle is deployed and maintained by SDKMAN!:

```
 sdk install gradle
```

Using Homebrew:

```
 brew install gradle
```

Using MacPorts:

```
 sudo port install gradle
```

Other package managers are available, but the version of Gradle distributed by them is not controlled by Gradle, Inc.

Step 1 - Download the latest Gradle distribution

The distribution ZIP file comes in two flavors:

- Binary-only (bin)

- Complete (all) with docs and sources

We recommend downloading the bin file; it is a smaller file that is quick to download (and the latest documentation is available online).

Step 2 - Unpack the distribution

Unzip the distribution zip file in the directory of your choosing, e.g.:

```
⬡ mkdir /usr/local/gradle
⬡ unzip gradle-8.6-milestone-1-bin.zip -d /usr/local/gradle
⬡ ls /usr/local/gradle/gradle-8.6-milestone-1
LICENSE NOTICE  README  bin init.d  lib
```

Step 3 - Configure your system environment

To install Gradle, the path to the unpacked files needs to be in your Path. Configure your `PATH` environment variable to include the `bin` directory of the unzipped distribution, e.g.:

```
⬡ export PATH=$PATH:/usr/local/gradle/gradle-8.6-milestone-1/bin
```

Alternatively, you could also add the environment variable `GRADLE_HOME` and point this to the unzipped distribution. Instead of adding a specific version of Gradle to your `PATH`, you can add `$GRADLE_HOME/bin` to your `PATH`. When upgrading to a different version of Gradle, simply change the `GRADLE_HOME` environment variable.

It's a good idea to edit `.bash_profile` in your home directory to add `GRADLE_HOME` variable:

```
export GRADLE_HOME=/usr/local/gradle/gradle-8.6-milestone-1
export PATH=$GRADLE_HOME/bin:$PATH
```

Windows installation

Step 1 - **Download** the latest Gradle distribution

The distribution ZIP file comes in two flavors:

- Binary-only (bin)

- Complete (all) with docs and sources

We recommend downloading the bin file.

Step 2 - Unpack the distribution

Create a new directory `C:\Gradle` with **File Explorer**.

Open a second **File Explorer** window and go to the directory where the Gradle distribution was downloaded. Double-click the ZIP archive to expose the content. Drag the content folder `gradle-8.6-milestone-1` to your newly created `C:\Gradle` folder.

Alternatively, you can unpack the Gradle distribution ZIP into `C:\Gradle` using the archiver tool of your choice.

Step 3 - Configure your system environment

To install Gradle, the path to the unpacked files needs to be in your Path.

In **File Explorer** right-click on the `This PC` (or `Computer`) icon, then click `Properties → Advanced System Settings → Environmental Variables`.

Under `System Variables` select `Path`, then click `Edit`. Add an entry for `C:\Gradle\gradle-8.6-milestone-1\bin`. Click `OK` to save.

Alternatively, you can add the environment variable `GRADLE_HOME` and point this to the unzipped distribution. Instead of adding a specific version of Gradle to your `Path`, you can add `%GRADLE_HOME%\bin` to your `Path`. When upgrading to a different version of Gradle, just change the `GRADLE_HOME` environment variable.

Verify the installation

Open a console (or a Windows command prompt) and run `gradle -v` to run gradle and display the version, e.g.:

```
 gradle -v

------------------------------------------------------------
Gradle 8.6-milestone-1
------------------------------------------------------------

Build time:    2023-03-03 16:41:37 UTC
Revision:      7d6581558e226a580d91d399f7dfb9e3095c2b1d

Kotlin:        1.8.10
Groovy:        3.0.13
Ant:           Apache Ant(TM) version 1.10.11 compiled on July 10 2021
JVM:           17.0.6 (Homebrew 17.0.6+0)
OS:            Mac OS X 13.2.1 aarch64
```

If you run into any trouble, see the section on troubleshooting.

You can verify the integrity of the Gradle distribution by downloading the SHA-256 file (available from the releases page) and following these verification instructions.

RUNNING GRADLE BUILDS

Command-Line Interface Reference

The command-line interface is the **primary method of interacting with Gradle**.

The following is a reference for executing and customizing the Gradle command-line. It also serves as a reference when writing scripts or configuring continuous integration.

Use of the Gradle Wrapper is highly encouraged. Substitute `./gradlew` (in macOS / Linux) or `gradlew.bat` (in Windows) for `gradle` in the following examples.

Executing Gradle on the command-line conforms to the following structure:

```
gradle [taskName...] [--option-name...]
```

Options are allowed *before* and *after* task names.

```
gradle [--option-name...] [taskName...]
```

If multiple tasks are specified, you should separate them with a space.

```
gradle [taskName1 taskName2...] [--option-name...]
```

Options that accept values can be specified with or without `=` between the option and argument. The use of `=` is recommended.

```
gradle [...] --console=plain
```

Options that enable behavior have long-form options with inverses specified with `--no-`. The following are opposites.

```
gradle [...] --build-cache
gradle [...] --no-build-cache
```

Many long-form options have short-option equivalents. The following are equivalent:

```
gradle --help
gradle -h
```

| NOTE | Many command-line flags can be specified in `gradle.properties` to avoid needing to be typed. See the Configuring build environment guide for details. |

Command-line usage

The following sections describe the use of the Gradle command-line interface.

Some plugins also add their own command line options. For example, `--tests`, which is added by Java test filtering. For more information on exposing command line options for your own tasks, see Declaring command-line options.

Executing tasks

You can learn about what projects and tasks are available in the project reporting section.

Most builds support a common set of tasks known as *lifecycle tasks*. These include the `build`, `assemble`, and `check` tasks.

To execute a task called `myTask` on the root project, type:

```
$ gradle :myTask
```

This will run the single `myTask` and all of its dependencies.

Specify options for tasks

To pass an option to a task, prefix the option name with `--` after the task name:

```
$ gradle exampleTask --exampleOption=exampleValue
```

Disambiguate task options from built-in options

Gradle does not prevent tasks from registering options that conflict with Gradle's built-in options, like `--profile` or `--help`.

You can fix conflicting task options from Gradle's built-in options with a `--` delimiter before the task name in the command:

```
$ gradle [--built-in-option-name...] -- [taskName...] [--task-option-name...]
```

Consider a task named `mytask` that accepts an option named `profile`:

- In `gradle mytask --profile`, Gradle accepts `--profile` as the built-in Gradle option.
- In `gradle -- mytask --profile=value`, Gradle passes `--profile` as a task option.

Executing tasks in multi-project builds

In a multi-project build, subproject tasks can be executed with `:` separating the subproject name and task name. The following are equivalent when *run from the root project*:

```
$ gradle :subproject:taskName
```

```
$ gradle subproject:taskName
```

You can also run a task for *all* subprojects using a task *selector* that consists of only the task name.

The following command runs the `test` task for all subprojects when invoked from the *root project directory*:

```
$ gradle test
```

| NOTE | Some tasks selectors, like `help` or `dependencies`, will only run the task on the project they are invoked on and not on all the subprojects. |

When invoking Gradle from within a subproject, the project name should be omitted:

```
$ cd subproject
```

```
$ gradle taskName
```

| TIP | When executing the Gradle Wrapper from a subproject directory, reference `gradlew` relatively. For example: `../gradlew taskName`. |

Executing multiple tasks

You can also specify multiple tasks. The tasks' dependencies determine the precise order of execution, and a task having no dependencies may execute earlier than it is listed on the command-line.

For example, the following will execute the `test` and `deploy` tasks in the order that they are listed on the command-line and will also execute the dependencies for each task.

```
$ gradle test deploy
```

Command line order safety

Although Gradle will always attempt to execute the build quickly, command line ordering safety will also be honored.

For example, the following will execute `clean` and `build` along with their dependencies:

```
$ gradle clean build
```

However, the intention implied in the command line order is that `clean` should run first and then `build`. It would be incorrect to execute `clean` *after* `build`, even if doing so would cause the build to execute faster since `clean` would remove what `build` created.

Conversely, if the command line order was `build` followed by `clean`, it would not be correct to execute `clean` before `build`. Although Gradle will execute the build as quickly as possible, it will also respect the safety of the order of tasks specified on the command line and ensure that `clean` runs before `build` when specified in that order.

Note that command line order safety relies on tasks properly declaring what they create, consume, or remove.

Excluding tasks from execution

You can exclude a task from being executed using the `-x` or `--exclude-task` command-line option and providing the name of the task to exclude:

```
$ gradle dist --exclude-task test
```

```
> Task :compile
compiling source

> Task :dist
building the distribution

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```
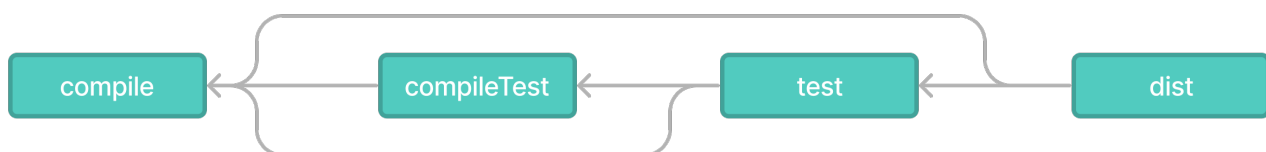

Figure 1. Simple Task Graph

You can see that the `test` task is not executed, even though it depends on the `dist` task. The `test` task's dependencies, such as `compileTest`, are not executed either. Those dependencies of `test` that another task requires, such as `compile`, are still executed.

Forcing tasks to execute

You can force Gradle to execute all tasks ignoring up-to-date checks using the `--rerun-tasks` option:

```
$ gradle test --rerun-tasks
```

This will force `test` and *all* task dependencies of `test` to execute. It is similar to running `gradle clean test`, but without the build's generated output being deleted.

Alternatively, you can tell Gradle to rerun a specific task using the `--rerun` built-in task option.

Continue the build after a task failure

By default, Gradle aborts execution and fails the build when any task fails. This allows the build to complete sooner and prevents cascading failures from obfuscating the root cause of an error.

You can use the `--continue` option to force Gradle to execute every task when a failure occurs:

```
$ gradle test --continue
```

When executed with `--continue`, Gradle executes *every* task in the build if all the dependencies for that task are completed without failure.

For example, tests do not run if there is a compilation error in the code under test because the `test` task depends on the `compilation` task. Gradle outputs each of the encountered failures at the end of the build.

NOTE	If any tests fail, many test suites fail the entire `test` task. Code coverage and reporting tools frequently run after the test task, so "fail fast" behavior may halt execution before those tools run.

Name abbreviation

When you specify tasks on the command-line, you don't have to provide the full name of the task. You can provide enough of the task name to identify the task uniquely. For example, it is likely `gradle che` is enough for Gradle to identify the `check` task.

The same applies to project names. You can execute the `check` task in the `library` subproject with the `gradle lib:che` command.

You can use camel case patterns for more complex abbreviations. These patterns are expanded to match camel case and kebab case names. For example, the pattern `foBa` (or `fB`) matches `fooBar` and `foo-bar`.

More concretely, you can run the `compileTest` task in the `my-awesome-library` subproject with the command `gradle mAL:cT`.

```
$ gradle mAL:cT
```

```
> Task :my-awesome-library:compileTest
compiling unit tests

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

Abbreviations can also be used with the `-x` command-line option.

Tracing name expansion

For complex projects, it might be ambiguous if the intended tasks were executed. When using abbreviated names, a single typo can lead to the execution of unexpected tasks.

When `INFO`, or more [verbose logging](#) is enabled, the output will contain extra information about the project and task name expansion.

For example, when executing the `mAL:cT` command on the previous example, the following log messages will be visible:

```
No exact project with name ':mAL' has been found. Checking for abbreviated names.
Found exactly one project that matches the abbreviated name ':mAL': ':my-awesome-
library'.
No exact task with name ':cT' has been found. Checking for abbreviated names.
Found exactly one task name, that matches the abbreviated name ':cT': ':compileTest'.
```

Common tasks

The following are task conventions applied by built-in and most major Gradle plugins.

Computing all outputs

It is common in Gradle builds for the `build` task to designate assembling all outputs and running all checks:

```
$ gradle build
```

Running applications

It is common for applications to run with the `run` task, which assembles the application and executes some script or binary:

```
$ gradle run
```

Running all checks

It is common for *all* verification tasks, including tests and linting, to be executed using the `check`

task:

```
$ gradle check
```

Cleaning outputs

You can delete the contents of the build directory using the `clean` task. Doing so will cause pre-computed outputs to be lost, causing significant additional build time for the subsequent task execution:

```
$ gradle clean
```

Project reporting

Gradle provides several built-in tasks which show particular details of your build. This can be useful for understanding your build's structure and dependencies, as well as debugging problems.

Listing projects

Running the `projects` task gives you a list of the subprojects of the selected project, displayed in a hierarchy:

```
$ gradle projects
```

You also get a project report within Build Scans.

Listing tasks

Running `gradle tasks` gives you a list of the main tasks of the selected project. This report shows the default tasks for the project, if any, and a description for each task:

```
$ gradle tasks
```

By default, this report shows only those tasks assigned to a task group.

Groups (such as verification, publishing, help, build…) are available as the header of each section when listing tasks:

```
> Task :tasks

Build tasks
-----------
assemble - Assembles the outputs of this project.

Build Setup tasks
-----------------
init - Initializes a new Gradle build.

Distribution tasks
------------------
assembleDist - Assembles the main distributions

Documentation tasks
------------------
javadoc - Generates Javadoc API documentation for the main source code.
```

You can obtain more information in the task listing using the `--all` option:

```
$ gradle tasks --all
```

The option `--no-all` can limit the report to tasks assigned to a task group.

If you need to be more precise, you can display only the tasks from a specific group using the `--group` option:

```
$ gradle tasks --group="build setup"
```

Show task usage details

Running `gradle help --task someTask` gives you detailed information about a specific task:

```
$ gradle -q help --task libs
```

```
Detailed task information for libs

Paths
     :api:libs
     :webapp:libs

Type
     Task (org.gradle.api.Task)

Options
     --rerun     Causes the task to be re-run even if up-to-date.

Description
     Builds the JAR

Group
     build
```

This information includes the full task path, the task type, possible task-specific command line options, and the description of the given task.

You can get detailed information about the task class types using the `--types` option or using `--no-types` to hide this information.

Reporting dependencies

Build Scans give a full, visual report of what dependencies exist on which configurations, transitive dependencies, and dependency version selection. They can be invoked using the `--scan` options:

```
$ gradle myTask --scan
```

This will give you a link to a web-based report, where you can find dependency information like this:

Listing project dependencies

Running the `dependencies` task gives you a list of the dependencies of the selected project, broken down by configuration. For each configuration, the direct and transitive dependencies of that configuration are shown in a tree.

Below is an example of this report:

```
$ gradle dependencies
```

```
> Task :app:dependencies


------------------------------------------------------------
Project ':app'
------------------------------------------------------------

compileClasspath - Compile classpath for source set 'main'.
+--- project :model
|    \--- org.json:json:20220924
+--- com.google.inject:guice:5.1.0
|    +--- javax.inject:javax.inject:1
|    +--- aopalliance:aopalliance:1.0
|    \--- com.google.guava:guava:30.1-jre -> 28.2-jre
|         +--- com.google.guava:failureaccess:1.0.1
|         +--- com.google.guava:listenablefuture:9999.0-empty-to-avoid-conflict-with-
guava
|         +--- com.google.code.findbugs:jsr305:3.0.2
|         +--- org.checkerframework:checker-qual:2.10.0 -> 3.28.0
|         +--- com.google.errorprone:error_prone_annotations:2.3.4
|         \--- com.google.j2objc:j2objc-annotations:1.3
+--- com.google.inject:guice:{strictly 5.1.0} -> 5.1.0 (c)
+--- org.json:json:{strictly 20220924} -> 20220924 (c)
+--- javax.inject:javax.inject:{strictly 1} -> 1 (c)
+--- aopalliance:aopalliance:{strictly 1.0} -> 1.0 (c)
+--- com.google.guava:guava:{strictly [28.0-jre, 28.5-jre]} -> 28.2-jre (c)
+--- com.google.guava:guava:{strictly 28.2-jre} -> 28.2-jre (c)
+--- com.google.guava:failureaccess:{strictly 1.0.1} -> 1.0.1 (c)
+--- com.google.guava:listenablefuture:{strictly 9999.0-empty-to-avoid-conflict-with-
guava} -> 9999.0-empty-to-avoid-conflict-with-guava (c)
+--- com.google.code.findbugs:jsr305:{strictly 3.0.2} -> 3.0.2 (c)
+--- org.checkerframework:checker-qual:{strictly 3.28.0} -> 3.28.0 (c)
+--- com.google.errorprone:error_prone_annotations:{strictly 2.3.4} -> 2.3.4 (c)
\--- com.google.j2objc:j2objc-annotations:{strictly 1.3} -> 1.3 (c)
```

Concrete examples of build scripts and output available in Viewing and debugging dependencies.

Running the `buildEnvironment` task visualises the buildscript dependencies of the selected project, similarly to how `gradle dependencies` visualizes the dependencies of the software being built:

```
$ gradle buildEnvironment
```

Running the `dependencyInsight` task gives you an insight into a particular dependency (or dependencies) that match specified input:

```
$ gradle dependencyInsight --dependency [...] --configuration [...]
```

The `--configuration` parameter restricts the report to a particular configuration such as

`compileClasspath`.

Listing project properties

Running the `properties` task gives you a list of the properties of the selected project:

```
$ gradle -q api:properties
```

```
------------------------------------------------------------
Project ':api' - The shared API for the application
------------------------------------------------------------

allprojects: [project ':api']
ant: org.gradle.api.internal.project.DefaultAntBuilder@12345
antBuilderFactory: org.gradle.api.internal.project.DefaultAntBuilderFactory@12345
artifacts:
org.gradle.api.internal.artifacts.dsl.DefaultArtifactHandler_Decorated@12345
asDynamicObject: DynamicObject for project ':api'
baseClassLoaderScope:
org.gradle.api.internal.initialization.MutableClassLoaderScope@12345
```

You can also query a single property with the optional `--property` argument:

```
$ gradle -q api:properties --property allprojects
```

```
------------------------------------------------------------
Project ':api' - The shared API for the application
------------------------------------------------------------

allprojects: [project ':api']
```

Command-line completion

Gradle provides `bash` and `zsh` tab completion support for tasks, options, and Gradle properties through gradle-completion (installed separately):

[gradle completion 4.0] | *gradle-completion-4.0.gif*

Debugging options

-?, -h, --help

Shows a help message with the built-in CLI options. To show project-contextual options, including help on a specific task, see the `help` task.

-v, --version

Prints Gradle, Groovy, Ant, JVM, and operating system version information and exit without executing any tasks.

-V, --show-version

Prints Gradle, Groovy, Ant, JVM, and operating system version information and continue execution of specified tasks.

-S, --full-stacktrace

Print out the full (very verbose) stacktrace for any exceptions. See also logging options.

-s, --stacktrace

Print out the stacktrace also for user exceptions (e.g. compile error). See also logging options.

--scan

Create a Build Scan with fine-grained information about all aspects of your Gradle build.

-Dorg.gradle.debug=true

Debug Gradle Daemon process. Gradle will wait for you to attach a debugger at `localhost:5005` by default.

-Dorg.gradle.debug.host=(host address)

Specifies the host address to listen on or connect to when debug is enabled. In the server mode on Java 9 and above, passing * for the host will make the server listen on all network interfaces. By default, no host address is passed to JDWP, so on Java 9 and above, the loopback address is used, while earlier versions listen on all interfaces.

-Dorg.gradle.debug.port=(port number)

Specifies the port number to listen on when debug is enabled. *Default is* `5005`.

-Dorg.gradle.debug.server=(true,false)

If set to `true` and debugging is enabled, Gradle will run the build with the socket-attach mode of the debugger. Otherwise, the socket-listen mode is used. *Default is* `true`.

-Dorg.gradle.debug.suspend=(true,false)

When set to `true` and debugging is enabled, the JVM running Gradle will suspend until a debugger is attached. *Default is* `true`.

-Dorg.gradle.daemon.debug=true

Debug Gradle Daemon process. (duplicate of `-Dorg.gradle.debug`)

Performance options

Try these options when optimizing and improving build performance.

Many of these options can be specified in the `gradle.properties` file, so command-line flags are unnecessary.

`--build-cache`, `--no-build-cache`

Toggles the Gradle Build Cache. Gradle will try to reuse outputs from previous builds. *Default is off.*

`--configuration-cache`, `--no-configuration-cache`

Toggles the Configuration Cache. Gradle will try to reuse the build configuration from previous builds. *Default is off.*

`--configuration-cache-problems=(fail,warn)`

Configures how the configuration cache handles problems. Default is `fail`.

Set to `warn` to report problems without failing the build.

Set to `fail` to report problems and fail the build if there are any problems.

`--configure-on-demand`, `--no-configure-on-demand`

Toggles Configure-on-demand. Only relevant projects are configured in this build run. *Default is off.*

`--max-workers`

Sets the maximum number of workers that Gradle may use. *Default is number of processors.*

`--parallel`, `--no-parallel`

Build projects in parallel. For limitations of this option, see Parallel Project Execution. *Default is off.*

`--priority`

Specifies the scheduling priority for the Gradle daemon and all processes launched by it. Values are `normal` or `low`. *Default is normal.*

`--profile`

Generates a high-level performance report in the `layout.buildDirectory.dir("reports/profile")` directory. `--scan` is preferred.

`--scan`

Generate a build scan with detailed performance diagnostics.
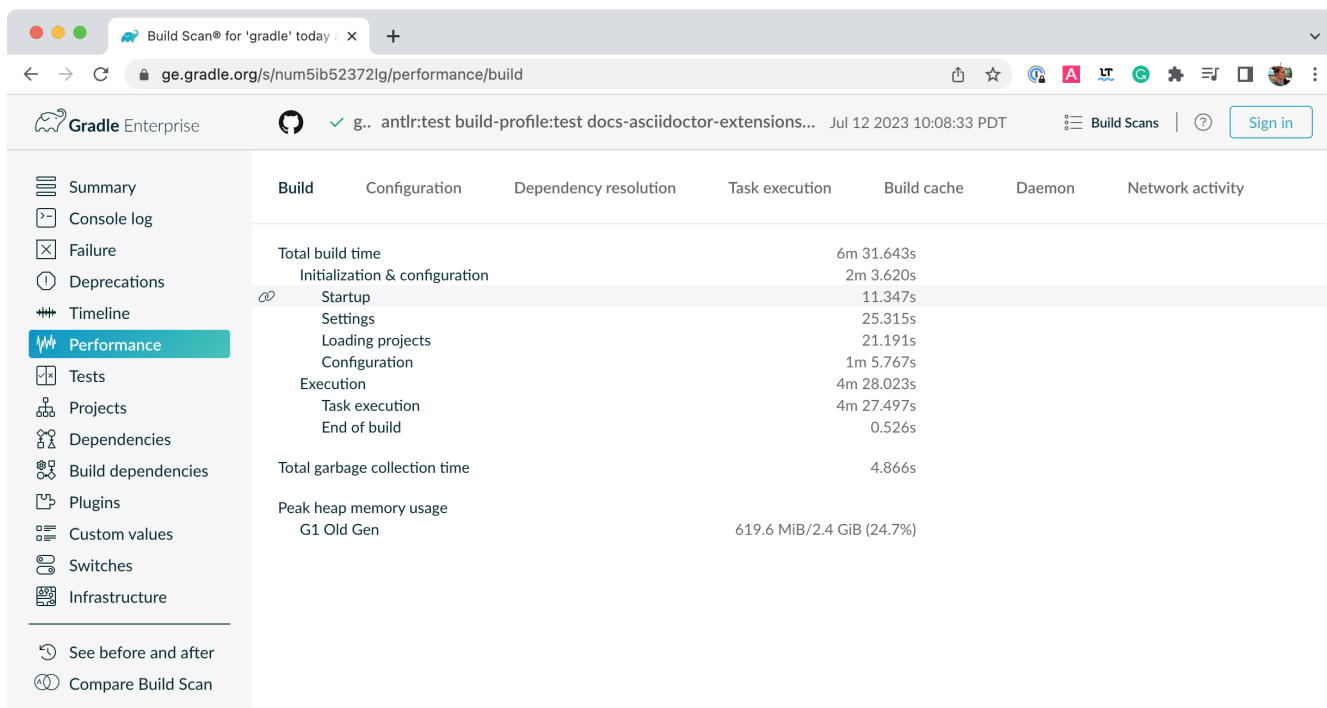
--watch-fs, --no-watch-fs

> Toggles [watching the file system](#). When enabled, Gradle reuses information it collects about the file system between builds. *Enabled by default on operating systems where Gradle supports this feature.*

Gradle daemon options

You can manage the [Gradle Daemon](#) through the following command line options.

--daemon, --no-daemon

> Use the [Gradle Daemon](#) to run the build. Starts the daemon if not running or the existing daemon is busy. *Default is on.*

--foreground

> Starts the Gradle Daemon in a foreground process.

--status (Standalone command)

> Run `gradle --status` to list running and recently stopped Gradle daemons. It only displays daemons of the same Gradle version.

--stop (Standalone command)

> Run `gradle --stop` to stop all Gradle Daemons of the same version.

-Dorg.gradle.daemon.idletimeout=(number of milliseconds)

> Gradle Daemon will stop itself after this number of milliseconds of idle time. *Default is 10800000 (3 hours).*

Logging options

Setting log level

You can customize the verbosity of Gradle logging with the following options, ordered from least verbose to most verbose.

`-Dorg.gradle.logging.level=(quiet,warn,lifecycle,info,debug)`
    Set logging level via Gradle properties.

`-q`, `--quiet`
    Log errors only.

`-w`, `--warn`
    Set log level to warn.

`-i`, `--info`
    Set log level to info.

`-d`, `--debug`
    Log in debug mode (includes normal stacktrace).

Lifecycle is the default log level.

Customizing log format

You can control the use of rich output (colors and font variants) by specifying the console mode in the following ways:

`-Dorg.gradle.console=(auto,plain,rich,verbose)`
    Specify console mode via Gradle properties. Different modes are described immediately below.

`--console=(auto,plain,rich,verbose)`
    Specifies which type of console output to generate.

    Set to `plain` to generate plain text only. This option disables all color and other rich output in the console output. This is the default when Gradle is *not* attached to a terminal.

    Set to `auto` (the default) to enable color and other rich output in the console output when the build process is attached to a console or to generate plain text only when not attached to a console. *This is the default when Gradle is attached to a terminal.*

    Set to `rich` to enable color and other rich output in the console output, regardless of whether the build process is not attached to a console. When not attached to a console, the build output will use ANSI control characters to generate the rich output.

    Set to `verbose` to enable color and other rich output like `rich` with output task names and outcomes at the lifecycle log level, (as is done by default in Gradle 3.5 and earlier).

Showing or hiding warnings

By default, Gradle won't display all warnings (e.g. deprecation warnings). Instead, Gradle will

collect them and render a summary at the end of the build like:

```
Deprecated Gradle features were used in this build, making it incompatible with Gradle
5.0.
```

You can control the verbosity of warnings on the console with the following options:

`-Dorg.gradle.warning.mode=(all,fail,none,summary)`
> Specify warning mode via Gradle properties. Different modes are described immediately below.

`--warning-mode=(all,fail,none,summary)`
> Specifies how to log warnings. Default is `summary`.
>
> Set to `all` to log all warnings.
>
> Set to `fail` to log all warnings and fail the build if there are any warnings.
>
> Set to `summary` to suppress all warnings and log a summary at the end of the build.
>
> Set to `none` to suppress all warnings, including the summary at the end of the build.

Rich console

Gradle's rich console displays extra information while builds are running.

Features:

- Progress bar and timer visually describe the overall status

- Parallel work-in-progress lines below describe what is happening now

- Colors and fonts are used to highlight significant output and errors

Execution options

The following options affect how builds are executed by changing what is built or how dependencies are resolved.

`--include-build`

Run the build as a composite, including the specified build.

`--offline`

Specifies that the build should operate without accessing network resources.

`-U, --refresh-dependencies`

Refresh the state of dependencies.

`--continue`

Continue task execution after a task failure.

`-m, --dry-run`

Run Gradle with all task actions disabled. Use this to show which task would have executed.

`-t, --continuous`

Enables continuous build. Gradle does not exit and will re-execute tasks when task file inputs change.

`--write-locks`

Indicates that all resolved configurations that are *lockable* should have their lock state persisted.

`--update-locks <group:name>[,<group:name>]*`

Indicates that versions for the specified modules have to be updated in the lock file.

This flag also implies `--write-locks`.

`-a, --no-rebuild`

Do not rebuild project dependencies. Useful for debugging and fine-tuning `buildSrc`, but can lead to wrong results. Use with caution!

Dependency verification options

Learn more about this in dependency verification.

`-F=(strict,lenient,off), --dependency-verification=(strict,lenient,off)`

Configures the dependency verification mode.

The default mode is `strict`.

`-M, --write-verification-metadata`

Generates checksums for dependencies used in the project (comma-separated list) for dependency verification.

`--refresh-keys`

Refresh the public keys used for dependency verification.

`--export-keys`

Exports the public keys used for dependency verification.

Environment options

You can [customize](#) many aspects about where build scripts, settings, caches, and so on through the options below.

`-b, --build-file` **(deprecated)**

Specifies the build file. For example: `gradle --build-file=foo.gradle`. The default is `build.gradle`, then `build.gradle.kts`.

`-c, --settings-file` **(deprecated)**

Specifies the settings file. For example: `gradle --settings-file=somewhere/else/settings.gradle`

`-g, --gradle-user-home`

Specifies the Gradle User Home directory. The default is the `.gradle` directory in the user's home directory.

`-p, --project-dir`

Specifies the start directory for Gradle. Defaults to current directory.

`--project-cache-dir`

Specifies the project-specific cache directory. Default value is `.gradle` in the root project directory.

`-D, --system-prop`

Sets a [system property](#) of the JVM, for example `-Dmyprop=myvalue`.

`-I, --init-script`

Specifies an [initialization script](#).

`-P, --project-prop`

Sets a [project property](#) of the root project, for example `-Pmyprop=myvalue`.

`-Dorg.gradle.jvmargs`

Set JVM arguments.

`-Dorg.gradle.java.home`

Set JDK home dir.

Task options

Tasks may define task-specific options which are different from most of the global options described in the sections above (which are interpreted by Gradle itself, can appear anywhere in the

command line, and can be listed using the `--help` option).

Task options:

1. Are consumed and interpreted by the tasks themselves;

2. **Must** be specified immediately after the task in the command-line;

3. May be listed using `gradle help --task someTask` (see Show task usage details).

To learn how to declare command-line options for your own tasks, see Declaring and Using Command Line Options.

Built-in task options

Built-in task options are options available as task options for all tasks. At this time, the following built-in task options exist:

`--rerun`
    Causes the task to be rerun even if up-to-date. Similar to `--rerun-tasks`, but for a specific task.

Bootstrapping new projects

Creating new Gradle builds

Use the built-in `gradle init` task to create a new Gradle build, with new or existing projects.

```
$ gradle init
```

Most of the time, a project type is specified. Available types include `basic` (default), `java-library`, `java-application`, and more. See init plugin documentation for details.

```
$ gradle init --type java-library
```

Standardize and provision Gradle

The built-in `gradle wrapper` task generates a script, `gradlew`, that invokes a declared version of Gradle, downloading it beforehand if necessary.

```
$ gradle wrapper --gradle-version=8.1
```

You can also specify `--distribution-type=(bin|all)`, `--gradle-distribution-url`, `--gradle-distribution-sha256-sum` in addition to `--gradle-version`.
Full details on using these options are documented in the Gradle wrapper section.

Continuous build

Continuous Build allows you to automatically re-execute the requested tasks when file inputs

change. You can execute the build in this mode using the `-t` or `--continuous` command-line option.

For example, you can continuously run the `test` task and all dependent tasks by running:

```
$ gradle test --continuous
```

Gradle will behave as if you ran `gradle test` after a change to sources or tests that contribute to the requested tasks. This means unrelated changes (such as changes to build scripts) will not trigger a rebuild. To incorporate build logic changes, the continuous build must be restarted manually.

Continuous build uses file system watching to detect changes to the inputs. If file system watching does not work on your system, then continuous build won't work either. In particular, continuous build does not work when using `--no-daemon`.

When Gradle detects a change to the inputs, it will not trigger the build immediately. Instead, it will wait until no additional changes are detected for a certain period of time - the quiet period. You can configure the quiet period in milliseconds by the Gradle property `org.gradle.continuous.quietperiod`.

Terminating Continuous Build

If Gradle is attached to an interactive input source, such as a terminal, the continuous build can be exited by pressing `CTRL-D` (On Microsoft Windows, it is required to also press `ENTER` or `RETURN` after `CTRL-D`).

If Gradle is not attached to an interactive input source (e.g. is running as part of a script), the build process must be terminated (e.g. using the `kill` command or similar).

If the build is being executed via the Tooling API, the build can be cancelled using the Tooling API's cancellation mechanism.

Limitations

Under some circumstances, continuous build may not detect changes to inputs.

Creating input directories

Sometimes, creating an input directory that was previously missing does not trigger a build, due to the way file system watching works. For example, creating the `src/main/java` directory may not trigger a build. Similarly, if the input is a filtered file tree and no files are matching the filter, the creation of matching files may not trigger a build.

Inputs of untracked tasks

Changes to the inputs of untracked tasks or tasks that have no outputs may not trigger a build.

Changes to files outside of project directories

Gradle only watches for changes to files inside the project directory. Changes to files outside of the project directory will go undetected and not trigger a build.

Build cycles

Gradle starts watching for changes just before a task executes. If a task modifies its own inputs while executing, Gradle will detect the change and trigger a new build. If every time the task executes, the inputs are modified again, the build will be triggered again. This isn't unique to continuous build. A task that modifies its own inputs will never be considered up-to-date when run "normally" without continuous build.

If your build enters a build cycle like this, you can track down the task by looking at the list of files reported changed by Gradle. After identifying the file(s) that are changed during each build, you should look for a task that has that file as an input. In some cases, it may be obvious (e.g., a Java file is compiled with `compileJava`). In other cases, you can use `--info` logging to find the task that is out-of-date due to the identified files.

Changes to symbolic links

In general, Gradle will not detect changes to symbolic links or to files referenced via symbolic links.

Changes to build logic are not considered

The current implementation does not recalculate the build model on subsequent builds. This means that changes to task configuration, or any other change to the build model, are effectively ignored.

Gradle Wrapper Reference

The **recommended way to execute any Gradle build** is with the help of the Gradle Wrapper (referred to as "Wrapper").

The Wrapper is a script that invokes a declared version of Gradle, downloading it beforehand if necessary. As a result, developers can get up and running with a Gradle project quickly.
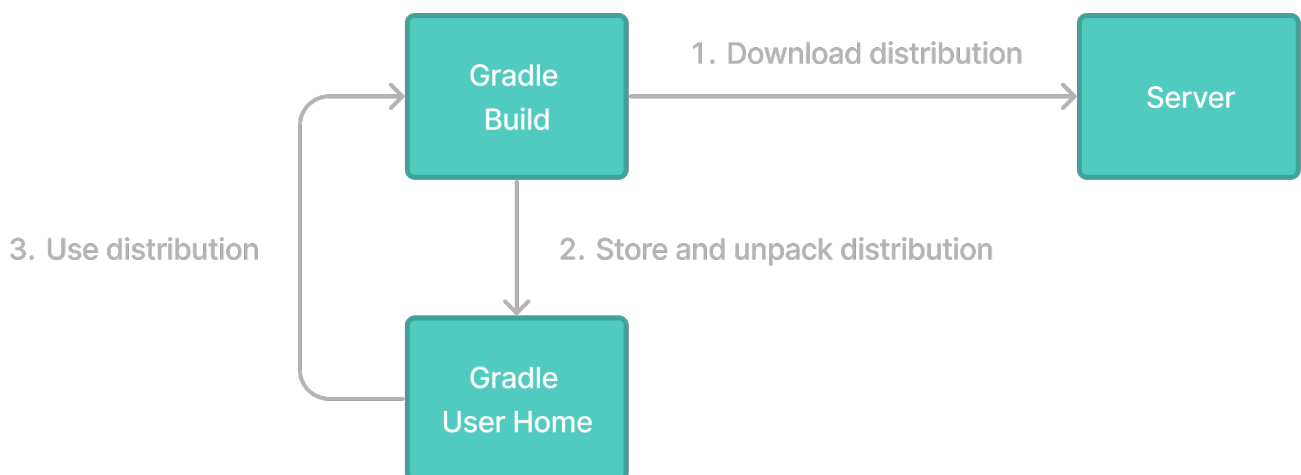
In a nutshell, you gain the following benefits:

- Standardizes a project on a given Gradle version for more reliable and robust builds.
- Provisioning the Gradle version for different users is done with a simple Wrapper definition change.

- Provisioning the Gradle version for different execution environments (e.g., IDEs or Continuous Integration servers) is done with a simple Wrapper definition change.

There are three ways to use the Wrapper:

1. You set up a new Gradle project and add the Wrapper to it.
2. You run a project with the Wrapper that already provides it.
3. You upgrade the Wrapper to a new version of Gradle.

The following sections explain each of these use cases in more detail.

Adding the Gradle Wrapper

Generating the Wrapper files requires an installed version of the Gradle runtime on your machine as described in Installation. Thankfully, generating the initial Wrapper files is a one-time process.

Every vanilla Gradle build comes with a built-in task called `wrapper`. The task is listed under the group "Build Setup tasks" when listing the tasks.

Executing the `wrapper` task generates the necessary Wrapper files in the project directory:

```
$ gradle wrapper
```

```
> Task :wrapper

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

TIP	To make the Wrapper files available to other developers and execution environments, you need to check them into version control. Wrapper files, including the JAR file, are small. Adding the JAR file to version control is expected. Some organizations do not allow projects to submit binary files to version control, and there is no workaround available.

The generated Wrapper properties file, `gradle/wrapper/gradle-wrapper.properties`, stores the information about the Gradle distribution:

- The **server hosting** the Gradle distribution.
- The **type of Gradle distribution**. By default, the `-bin` distribution contains only the runtime but no sample code and documentation.
- The **Gradle version** used for executing the build. By default, the `wrapper` task picks the same Gradle version used to generate the Wrapper files.
- Optionally, a **timeout** in ms used when downloading the Gradle distribution.
- Optionally, a **boolean** to set the **validation of the distribution** URL.

The following is an example of the generated distribution URL in `gradle/wrapper/gradle-wrapper.properties`:

```
distributionUrl=https\://services.gradle.org/distributions/gradle-8.6-milestone-1-bin.zip
```

All of those aspects are configurable at the time of generating the Wrapper files with the help of the following command line options:

`--gradle-version`

The Gradle version used for downloading and executing the Wrapper. The resulting distribution URL is validated before it is written to the properties file.

The following labels are allowed:

- latest
- release-candidate
- nightly
- release-nightly

`--distribution-type`

The Gradle distribution type used for the Wrapper. Available options are `bin` and `all`. The default value is `bin`.

`--gradle-distribution-url`

The full URL pointing to the Gradle distribution ZIP file. This option makes `--gradle-version` and `--distribution-type` obsolete, as the URL already contains this information. This option is valuable if you want to host the Gradle distribution inside your company's network. The URL is validated before it is written to the properties file.

`--gradle-distribution-sha256-sum`

The SHA256 hash sum used for verifying the downloaded Gradle distribution.

`--network-timeout`

The network timeout to use when downloading the Gradle distribution, in ms. The default value is `10000`.

`--no-validate-url`

Disables the validation of the configured distribution URL.

`--validate-url`

Enables the validation of the configured distribution URL. Enabled by default.

If the distribution URL is configured with `--gradle-version` or `--gradle-distribution-url`, the URL is validated by sending a HEAD request in the case of the `https` scheme or by checking the existence of the file in the case of the `file` scheme.

Let's assume the following use-case to illustrate the use of the command line options. You would like to generate the Wrapper with version 8.6-milestone-1 and use the `-all` distribution to enable your IDE to enable code-completion and being able to navigate to the Gradle source code.

The following command-line execution captures those requirements:

```
$ gradle wrapper --gradle-version 8.6-milestone-1 --distribution-type all
> Task :wrapper

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

As a result, you can find the desired information (the generated distribution URL) in the Wrapper properties file:

```
distributionUrl=https\://services.gradle.org/distributions/gradle-8.6-milestone-1-all.zip
```

Let's have a look at the following project layout to illustrate the expected Wrapper files:

```
.
├── a-subproject
│   └── build.gradle.kts
├── settings.gradle.kts
├── gradle
│   └── wrapper
│       ├── gradle-wrapper.jar
│       └── gradle-wrapper.properties
├── gradlew
└── gradlew.bat
```

```
.
├── a-subproject
│   └── build.gradle
├── settings.gradle
├── gradle
│   └── wrapper
│       ├── gradle-wrapper.jar
│       └── gradle-wrapper.properties
├── gradlew
└── gradlew.bat
```

A Gradle project typically provides a `settings.gradle(.kts)` file and one `build.gradle(.kts)` file for each subproject. The Wrapper files live alongside in the `gradle` directory and the root directory of the project.

The following list explains their purpose:

`gradle-wrapper.jar`

The Wrapper JAR file containing code for downloading the Gradle distribution.

`gradle-wrapper.properties`

A properties file responsible for configuring the Wrapper runtime behavior e.g. the Gradle version compatible with this version. Note that more generic settings, like configuring the Wrapper to use a proxy, need to go into a different file.

`gradlew`, `gradlew.bat`

A shell script and a Windows batch script for executing the build with the Wrapper.

You can go ahead and execute the build with the Wrapper without installing the Gradle runtime. If the project you are working on does not contain those Wrapper files, you will need to generate them.

Using the Gradle Wrapper

It is always recommended to execute a build with the Wrapper to ensure a reliable, controlled, and standardized execution of the build. Using the Wrapper looks like running the build with a Gradle installation. Depending on the operating system you either run `gradlew` or `gradlew.bat` instead of the `gradle` command.

The following console output demonstrates the use of the Wrapper on a Windows machine for a Java-based project:

```
$ gradlew.bat build
Downloading https://services.gradle.org/distributions/gradle-5.0-all.zip
.....................................................................
Unzipping C:\Documents and Settings\Claudia\.gradle\wrapper\dists\gradle-5.0-
all\ac27o8rbd0ic8ih41or9l32mv\gradle-5.0-all.zip to C:\Documents and
Settings\Claudia\.gradle\wrapper\dists\gradle-5.0-al\ac27o8rbd0ic8ih41or9l32mv
Set executable permissions for: C:\Documents and
Settings\Claudia\.gradle\wrapper\dists\gradle-5.0-
all\ac27o8rbd0ic8ih41or9l32mv\gradle-5.0\bin\gradle

BUILD SUCCESSFUL in 12s
1 actionable task: 1 executed
```

If the Gradle distribution is unavailable on the machine, the Wrapper will download it and store it in the local file system. Any subsequent build invocation will reuse the existing local distribution as long as the distribution URL in the Gradle properties doesn't change.

NOTE	The Wrapper shell script and batch file reside in the root directory of a single or multi-project Gradle build. You will need to reference the correct path to those files in case you want to execute the build from a subproject directory e.g. `../../gradlew tasks`.

Upgrading the Gradle Wrapper

Projects typically want to keep up with the times and upgrade their Gradle version to benefit from new features and improvements.

One way to upgrade the Gradle version is by manually changing the `distributionUrl` property in the Wrapper's `gradle-wrapper.properties` file.

The better and recommended option is to run the `wrapper` task and provide the target Gradle version as described in [Adding the Gradle Wrapper](). Using the `wrapper` task ensures that any optimizations made to the Wrapper shell script or batch file with that specific Gradle version are applied to the project.

As usual, you should commit the changes to the Wrapper files to version control.

Note that running the wrapper task once will update `gradle-wrapper.properties` only, but leave the wrapper itself in `gradle-wrapper.jar` untouched. This is usually fine as new versions of Gradle can be run even with older wrapper files.

NOTE	If you want **all** the wrapper files to be completely up-to-date, you will need to run the `wrapper` task a second time.

The following command upgrades the Wrapper to the `latest` version:

```
$ ./gradlew wrapper --gradle-version latest

BUILD SUCCESSFUL in 4s
1 actionable task: 1 executed
```

The following command upgrades the Wrapper to a specific version:

```
$ ./gradlew wrapper --gradle-version 8.6-milestone-1

BUILD SUCCESSFUL in 4s
1 actionable task: 1 executed
```

Once you have upgraded the wrapper, you can check that it's the version you expected by executing `./gradlew --version`.

Don't forget to run the `wrapper` task again to download the Gradle distribution binaries (if needed) and update the `gradlew` and `gradle.bat` files.

Customizing the Gradle Wrapper

Most users of Gradle are happy with the default runtime behavior of the Wrapper. However, organizational policies, security constraints or personal preferences might require you to dive deeper into customizing the Wrapper.

Thankfully, the built-in `wrapper` task exposes numerous options to bend the runtime behavior to your needs. Most configuration options are exposed by the underlying task type Wrapper.

Let's assume you grew tired of defining the `-all` distribution type on the command line every time you upgrade the Wrapper. You can save yourself some keyboard strokes by re-configuring the `wrapper` task.

build.gradle.kts

```
tasks.wrapper {
    distributionType = Wrapper.DistributionType.ALL
}
```

build.gradle

```
tasks.named('wrapper') {
    distributionType = Wrapper.DistributionType.ALL
}
```

With the configuration in place, running `./gradlew wrapper --gradle-version 8.6-milestone-1` is enough to produce a `distributionUrl` value in the Wrapper properties file that will request the `-all` distribution:

```
distributionUrl=https\://services.gradle.org/distributions/gradle-8.6-milestone-1-all.zip
```

Check out the API documentation for a more detailed description of the available configuration options. You can also find various samples for configuring the Wrapper in the Gradle distribution.

Authenticated Gradle distribution download

The Gradle `Wrapper` can download Gradle distributions from servers using HTTP Basic Authentication. This enables you to host the Gradle distribution on a private protected server.

You can specify a username and password in two different ways depending on your use case: as system properties or directly embedded in the `distributionUrl`. Credentials in system properties take precedence over the ones embedded in `distributionUrl`.

TIP	HTTP Basic Authentication should only be used with `HTTPS` URLs and not plain `HTTP` ones. With Basic Authentication, the user credentials are sent in clear text.

System properties can be specified in the `.gradle/gradle.properties` file in the user's home directory or by other [means](#).

To specify the HTTP Basic Authentication credentials, add the following lines to the system properties file:

```
systemProp.gradle.wrapperUser=username
systemProp.gradle.wrapperPassword=password
```

Embedding credentials in the `distributionUrl` in the `gradle/wrapper/gradle-wrapper.properties` file also works. Please note that this file is to be committed into your source control system.

TIP	Shared credentials embedded in `distributionUrl` should only be used in a controlled environment.

To specify the HTTP Basic Authentication credentials in `distributionUrl`, add the following line:

```
distributionUrl=https://username:password@somehost/path/to/gradle-distribution.zip
```

This can be used in conjunction with a proxy, authenticated or not. See [Accessing the web via a proxy](#) for more information on how to configure the `Wrapper` to use a proxy.

Verification of downloaded Gradle distributions

The Gradle Wrapper allows for verification of the downloaded Gradle distribution via SHA-256 hash sum comparison. This increases security against targeted attacks by preventing a man-in-the-middle attacker from tampering with the downloaded Gradle distribution.

To enable this feature, download the `.sha256` file associated with the Gradle distribution you want to verify.

Downloading the SHA-256 file

You can download the `.sha256` file from the [stable releases](#) or [release candidate and nightly releases](#). The format of the file is a single line of text that is the SHA-256 hash of the corresponding zip file.

You can also reference the [list of Gradle distribution checksums](#).

Configuring checksum verification

Add the downloaded (SHA-256 checksum) hash sum to `gradle-wrapper.properties` using the `distributionSha256Sum` property or use `--gradle-distribution-sha256-sum` on the command-line:

```
distributionSha256Sum=371cb9fbebbe9880d147f59bab36d61eee122854ef8c9ee1ecf12b82368bcf10
```

Gradle will report a build failure if the configured checksum does not match the checksum found on the server hosting the distribution. Checksum verification is only performed if the configured Wrapper distribution hasn't been downloaded yet.

NOTE	The `Wrapper` task fails if `gradle-wrapper.properties` contains `distributionSha256Sum`, but the task configuration does not define a sum. Executing the `Wrapper` task preserves the `distributionSha256Sum` configuration when the Gradle version does not change.

Verifying the integrity of the Gradle Wrapper JAR

The Wrapper JAR is a binary file that will be executed on the computers of developers and build servers. As with all such files, you should ensure it's trustworthy before executing it.

Since the Wrapper JAR is usually checked into a project's version control system, there is the potential for a malicious actor to replace the original JAR with a modified one by submitting a pull request that only upgrades the Gradle version.

To verify the integrity of the Wrapper JAR, Gradle has created a GitHub Action that automatically checks Wrapper JARs in pull requests against a list of known good checksums.

Gradle also publishes the checksums of all releases (except for version 3.3 to 4.0.2, which did not generate reproducible JARs), so you can manually verify the integrity of the Wrapper JAR.

Automatically verifying the Gradle Wrapper JAR on GitHub

The GitHub Action is released separately from Gradle, so please check its documentation for how to apply it to your project.

Manually verifying the Gradle Wrapper JAR

You can manually verify the checksum of the Wrapper JAR to ensure that it has not been tampered with by running the following commands on one of the major operating systems.

Manually verifying the checksum of the Wrapper JAR on Linux:

```
$ cd gradle/wrapper
```

```
$ curl --location --output gradle-wrapper.jar.sha256 \
       https://services.gradle.org/distributions/gradle-{gradleVersion}-
wrapper.jar.sha256
```

```
$ echo "gradle-wrapper.jar" >> gradle-wrapper.jar.sha256
```

```
$ sha256sum --check gradle-wrapper.jar.sha256
```

```
gradle-wrapper.jar: OK
```

Manually verifying the checksum of the Wrapper JAR on macOS:

```
$ cd gradle/wrapper
```

```
$ curl --location --output gradle-wrapper.jar.sha256 \
        https://services.gradle.org/distributions/gradle-{gradleVersion}-
wrapper.jar.sha256
```

```
$ echo "gradle-wrapper.jar" >> gradle-wrapper.jar.sha256
```

```
$ shasum --check gradle-wrapper.jar.sha256
```

```
gradle-wrapper.jar: OK
```

Manually verifying the checksum of the Wrapper JAR on Windows (using PowerShell):

```
> $expected = Invoke-RestMethod -Uri https://services.gradle.org/distributions/gradle-
8.6-milestone-1-wrapper.jar.sha256
```

```
> $actual = (Get-FileHash gradle\wrapper\gradle-wrapper.jar -Algorithm
SHA256).Hash.ToLower()
```

```
> @{$true = 'OK: Checksum match'; $false = "ERROR: Checksum mismatch!`nExpected:
$expected`nActual:   $actual"}[$actual -eq $expected]
```

```
OK: Checksum match
```

Troubleshooting a checksum mismatch

If the checksum does not match the one you expected, chances are the `wrapper` task wasn't executed with the upgraded Gradle distribution.

You should first check whether the actual checksum matches a different Gradle version.

Here are the commands you can run on the major operating systems to generate the actual checksum of the Wrapper JAR.

Generating the checksum of the Wrapper JAR on Linux:

```
$ sha256sum gradle/wrapper/gradle-wrapper.jar
d81e0f23ade952b35e55333dd5f1821585e887c6d24305aeea2fbc8dad564b95
gradle/wrapper/gradle-wrapper.jar
```

Generating the actual checksum of the Wrapper JAR on macOS:

```
$ shasum --algorithm=256 gradle/wrapper/gradle-wrapper.jar
d81e0f23ade952b35e55333dd5f1821585e887c6d24305aeea2fbc8dad564b95
gradle/wrapper/gradle-wrapper.jar
```

Generating the actual checksum of the Wrapper JAR on Windows (using PowerShell):

```
> (Get-FileHash gradle\wrapper\gradle-wrapper.jar -Algorithm SHA256).Hash.ToLower()
d81e0f23ade952b35e55333dd5f1821585e887c6d24305aeea2fbc8dad564b95
```

Once you know the actual checksum, check whether it's listed on https://gradle.org/release-checksums/. If it is listed, you have verified the integrity of the Wrapper JAR. If the version of Gradle that generated the Wrapper JAR doesn't match the version in `gradle/wrapper/gradle-wrapper.properties`, it's safe to run the `wrapper` task again to update the Wrapper JAR.

If the checksum is not listed on the page, the Wrapper JAR might be from a milestone, release candidate, or nightly build or may have been generated by Gradle 3.3 to 4.0.2. Try to find out how it was generated but treat it as untrustworthy until proven otherwise. If you think the Wrapper JAR was compromised, please let the Gradle team know by sending an email to security@gradle.com.

Multi-Project Build Basics

Gradle supports multi-project builds.
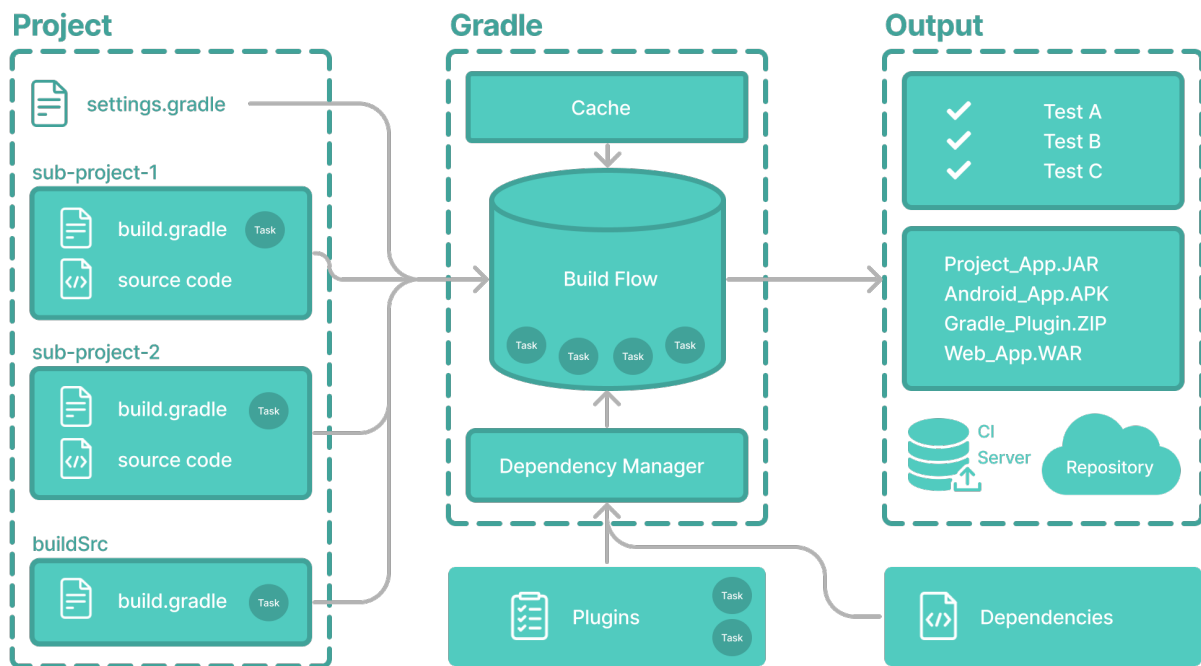
While some small projects and monolithic applications may contain a single build file and source tree, it is often more common for a project to have been split into smaller, interdependent modules. The word "interdependent" is vital, as you typically want to link the many modules together through a single build.
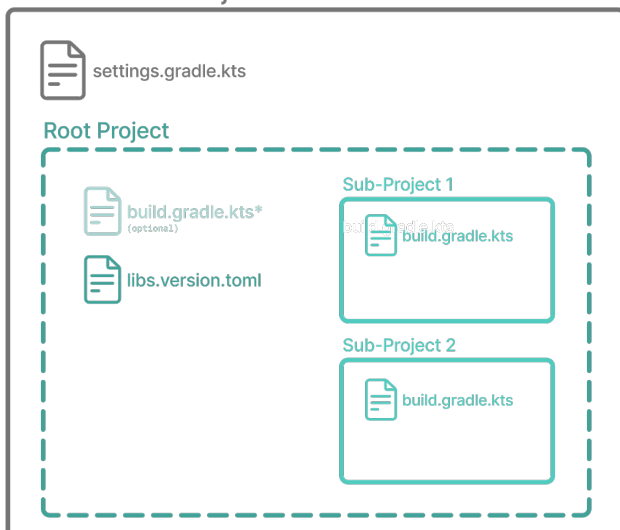
Gradle supports this scenario through *multi-project* builds. This is sometimes referred to as a multi-module project.

A multi-project build consists of one root project and one or more subprojects.

Multi-Project structure

The following represents the structure of a multi-project build that contains two subprojects:

The directory structure should look as follows:

```
├─── .gradle
│    └─── 
├─── gradle
│    ├─── libs.version.toml
│    └─── wrapper
├─── gradlew
├─── gradlew.bat
├─── settings.gradle.kts   ①
├─── sub-project-1
│    └─── build.gradle.kts ②
└─── sub-project-2
     └─── build.gradle.kts ②
```

① The `settings.gradle.kts` file should include all subprojects.

② Each subproject should have its own `build.gradle.kts` file.
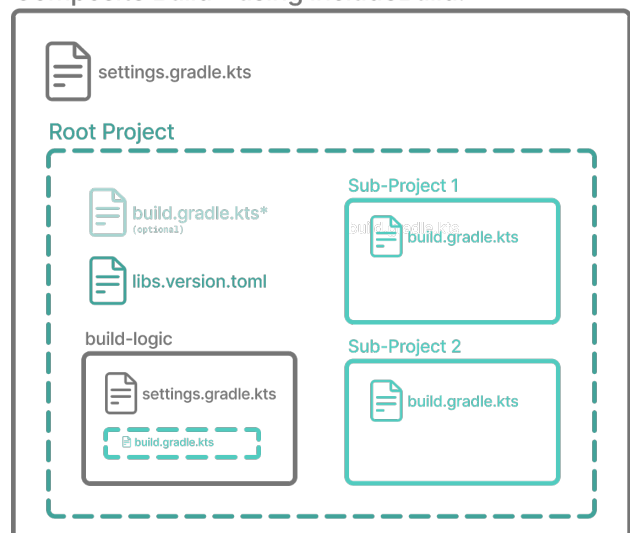
Multi-Project standards

The Gradle community has two standards for multi-project build structures:

- **Multi-Project Builds using buildSrc** - where `buildSrc` is a subproject-like directory at the Gradle project root containing all the build logic.

- **Composite Builds** - a build that includes other builds where `build-logic` is a build directory at the Gradle project root containing all the build logic.

Multi-project Build - using buildSrc:
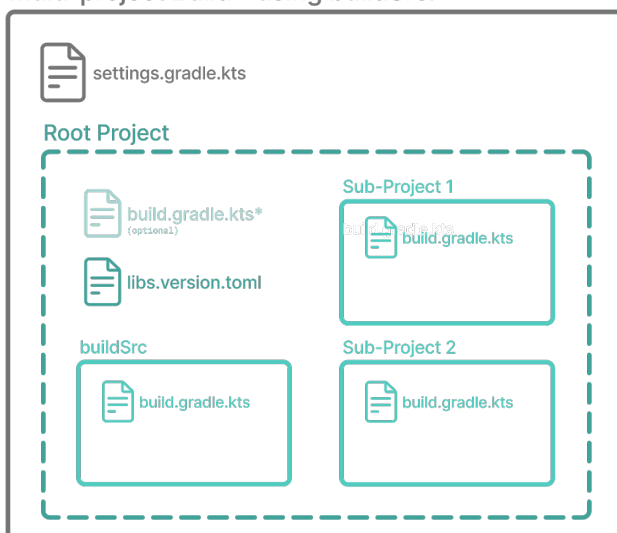
Composite Build - using includeBuild:

See how to declare dependencies between subprojects using `include` and how to create composite builds with `includeBuild`.

Multi-Project path

A project path has the following pattern: it starts with an optional colon, which denotes the root

project.

The root project, `:`, is the only project in a path not specified by its name.

The rest of a project path is a colon-separated sequence of project names, where the next project is a subproject of the previous project:

```
:sub-project-1
```

You can see the project paths when running `gradle projects`:

```
------------------------------------------------------------
Root project 'project'
------------------------------------------------------------

Root project 'project'
+--- Project ':sub-project-1'
\--- Project ':sub-project-2'
```

Project paths usually reflect the filesystem layout, but there are exceptions. Most notably for composite builds.

Identifying project structure

You can use the `gradle projects` command to identify the project structure.

As an example, let's use a multi-project build with the following structure:

```
> gradle -q projects
```

```
------------------------------------------------------------
Root project 'multiproject'
------------------------------------------------------------

Root project 'multiproject'
+--- Project ':api'
+--- Project ':services'
|    +--- Project ':services:shared'
|    \--- Project ':services:webservice'
\--- Project ':shared'

To see a list of the tasks of a project, run gradle <project-path>:tasks
For example, try running gradle :api:tasks
```

Multi-project builds are collections of tasks you can run. The difference is that you may want to control *which* project's tasks get executed.

The following sections will cover your two options for executing tasks in a multi-project build.

Executing tasks by name

The command `gradle test` will execute the `test` task in any subprojects relative to the current working directory that has that task.

If you run the command from the root project directory, you will run `test` in *api*, *shared*, *services:shared* and *services:webservice*.

If you run the command from the *services* project directory, you will only execute the task in *services:shared* and *services:webservice*.

The basic rule behind Gradle's behavior is to **execute all tasks down the hierarchy with *this* name**. And **complain if there is *no* such task found** in any of the subprojects traversed.

NOTE	Some task selectors, like `help` or `dependencies`, will only run the task on the project they are invoked on and not on all the subprojects to reduce the amount of information printed on the screen.

Executing tasks by fully qualified name

You can use a task's fully qualified name to execute a specific task in a particular subproject. For example: `gradle :services:webservice:build` will run the `build` task of the *webservice* subproject.

The fully qualified name of a task is its project path plus the task name.

This approach works for any task, so if you want to know what tasks are in a particular subproject, use the `tasks` task, e.g. `gradle :services:webservice:tasks`.

Multi-Project building and testing

The `build` task is typically used to compile, test, and check a single project.

In multi-project builds, you may often want to do all of these tasks across various projects. The `buildNeeded` and `buildDependents` tasks can help with this.

In this example, the `:services:person-service` project depends on both the `:api` and `:shared` projects. The `:api` project also depends on the `:shared` project.

Assuming you are working on a single project, the `:api` project, you have been making changes but have not built the entire project since performing a `clean`. You want to build any necessary supporting JARs but only perform code quality and unit tests on the parts of the project you have changed.

The `build` task does this:

```
$ gradle :api:build

> Task :shared:compileJava
> Task :shared:processResources
> Task :shared:classes
> Task :shared:jar
> Task :api:compileJava
> Task :api:processResources
> Task :api:classes
> Task :api:jar
> Task :api:assemble
> Task :api:compileTestJava
> Task :api:processTestResources
> Task :api:testClasses
> Task :api:test
> Task :api:check
> Task :api:build

BUILD SUCCESSFUL in 0s
```

If you have just gotten the latest version of the source from your version control system, which included changes in other projects that `:api` depends on, you might want to build all the projects you depend on AND test them too.

The `buildNeeded` task builds AND tests all the projects from the project dependencies of the `testRuntime` configuration:

```
$ gradle :api:buildNeeded

> Task :shared:compileJava
> Task :shared:processResources
> Task :shared:classes
> Task :shared:jar
> Task :api:compileJava
> Task :api:processResources
> Task :api:classes
> Task :api:jar
> Task :api:assemble
> Task :api:compileTestJava
> Task :api:processTestResources
> Task :api:testClasses
> Task :api:test
> Task :api:check
> Task :api:build
> Task :shared:assemble
> Task :shared:compileTestJava
> Task :shared:processTestResources
> Task :shared:testClasses
> Task :shared:test
> Task :shared:check
> Task :shared:build
> Task :shared:buildNeeded
> Task :api:buildNeeded

BUILD SUCCESSFUL in 0s
```

You may want to refactor some part of the `:api` project used in other projects. If you make these changes, testing only the `:api` project is insufficient. You must test all projects that depend on the `:api` project.

The `buildDependents` task tests ALL the projects that have a project dependency (in the testRuntime configuration) on the specified project:

```
$ gradle :api:buildDependents

> Task :shared:compileJava
> Task :shared:processResources
> Task :shared:classes
> Task :shared:jar
> Task :api:compileJava
> Task :api:processResources
> Task :api:classes
> Task :api:jar
> Task :api:assemble
> Task :api:compileTestJava
> Task :api:processTestResources
> Task :api:testClasses
> Task :api:test
> Task :api:check
> Task :api:build
> Task :services:person-service:compileJava
> Task :services:person-service:processResources
> Task :services:person-service:classes
> Task :services:person-service:jar
> Task :services:person-service:assemble
> Task :services:person-service:compileTestJava
> Task :services:person-service:processTestResources
> Task :services:person-service:testClasses
> Task :services:person-service:test
> Task :services:person-service:check
> Task :services:person-service:build
> Task :services:person-service:buildDependents
> Task :api:buildDependents

BUILD SUCCESSFUL in 0s
```

Finally, you can build and test everything in all projects. Any task you run in the root project folder will cause that same-named task to be run on all the children.

You can run `gradle build` to build and test ALL projects.

Consult the Structuring Builds chapter to learn more.

Next Step: Learn about the Gradle Build Lifecycle >>

Troubleshooting builds

The following is a collection of common issues and suggestions for addressing them. You can get other tips and search the Gradle forums and StackOverflow #gradle answers, as well as Gradle

documentation from help.gradle.org.

Troubleshooting Gradle installation

If you followed the installation instructions, and aren't able to execute your Gradle build, here are some tips that may help.

If you installed Gradle outside of just invoking the Gradle Wrapper, you can check your Gradle installation by running `gradle --version` in a terminal.

You should see something like this:

```
❯ gradle --version

------------------------------------------------------------
Gradle 6.5
------------------------------------------------------------

Build time:   2020-06-02 20:46:21 UTC
Revision:     a27f41e4ae5e8a41ab9b19f8dd6d86d7b384dad4

Kotlin:       1.3.72
Groovy:       2.5.11
Ant:          Apache Ant(TM) version 1.10.7 compiled on September 1 2019
JVM:          14 (AdoptOpenJDK 14+36)
OS:           Mac OS X 10.15.2 x86_64
```

If not, here are some things you might see instead.

Command not found: gradle

If you get "command not found: gradle", you need to ensure that Gradle is properly added to your `PATH`.

JAVA_HOME is set to an invalid directory

If you get something like:

```
ERROR: JAVA_HOME is set to an invalid directory

Please set the JAVA_HOME variable in your environment to match the location of your
Java installation.
```

You'll need to ensure that a Java Development Kit version 8 or higher is properly installed, the `JAVA_HOME` environment variable is set, and Java is added to your `PATH`.

Permission denied

If you get "permission denied", that means that Gradle likely exists in the correct place, but it is not executable. You can fix this using `chmod +x path/to/executable` on *nix-based systems.

Other installation failures

If `gradle --version` works, but all of your builds fail with the same error, it is possible there is a problem with one of your Gradle build configuration scripts.

You can verify the problem is with Gradle scripts by running `gradle help` which executes configuration scripts, but no Gradle tasks. If the error persists, build configuration is problematic. If not, then the problem exists within the execution of one or more of the requested tasks (Gradle executes configuration scripts first, and then executes build steps).

Debugging dependency resolution

Common dependency resolution issues such as resolving version conflicts are covered in Troubleshooting Dependency Resolution.

You can see a dependency tree and see which resolved dependency versions differed from what was requested by clicking the *Dependencies* view and using the search functionality, specifying the resolution reason.
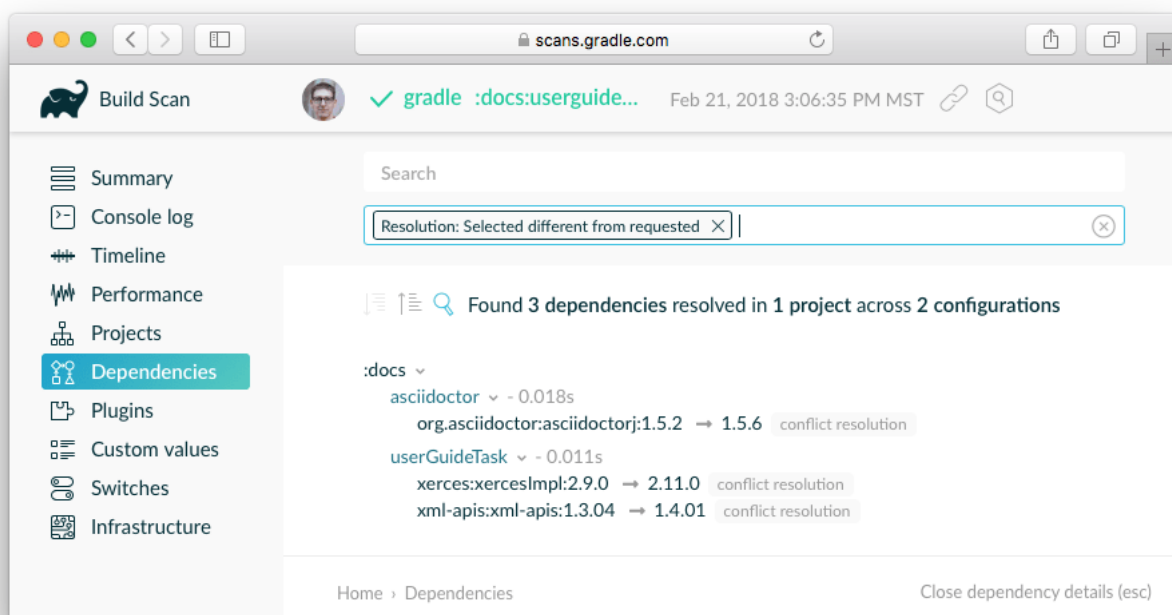

Figure 2. Debugging dependency conflicts with build scans

The actual build scan with filtering criteria is available for exploration.

Troubleshooting slow Gradle builds

For build performance issues (including "slow sync time"), see improving the Performance of Gradle Builds.

Android developers should watch a presentation by the Android SDK Tools team about Speeding Up Your Android Gradle Builds. Many tips are also covered in the Android Studio user guide on optimizing build speed.

Debugging build logic

Attaching a debugger to your build

You can set breakpoints and debug buildSrc and standalone plugins in your Gradle build itself by setting the `org.gradle.debug` property to "true" and then attaching a remote debugger to port 5005. You can change the port number by setting the `org.gradle.debug.port` property to the desired port number.

To attach the debugger remotely via network, you need to set the `org.gradle.debug.host` property to the machine's IP address or `*` (listen on all interfaces).

```
 gradle help -Dorg.gradle.debug=true
```

In addition, if you've adopted the Kotlin DSL, you can also debug build scripts themselves.

The following video demonstrates how to debug an example build using IntelliJ IDEA.

[remote debug gradle] | *remote-debug-gradle.gif*

Figure 3. Interactive debugging of a build script

Adding and changing logging

In addition to controlling logging verbosity, you can also control display of task outcomes (e.g. "UP-TO-DATE") in lifecycle logging using the `--console=verbose` flag.

You can also replace much of Gradle's logging with your own by registering various event listeners. One example of a custom event logger is explained in the logging documentation. You can also control logging from external tools, making them more verbose in order to debug their execution.

NOTE	Additional logs from the Gradle Daemon can be found under `$GRADLE_USER_HOME/daemon/8.6-milestone-1/`.

Task executed when it should have been UP-TO-DATE

`--info` logs explain why a task was executed, though build scans do this in a searchable, visual way by going to the *Timeline* view and clicking on the task you want to inspect.
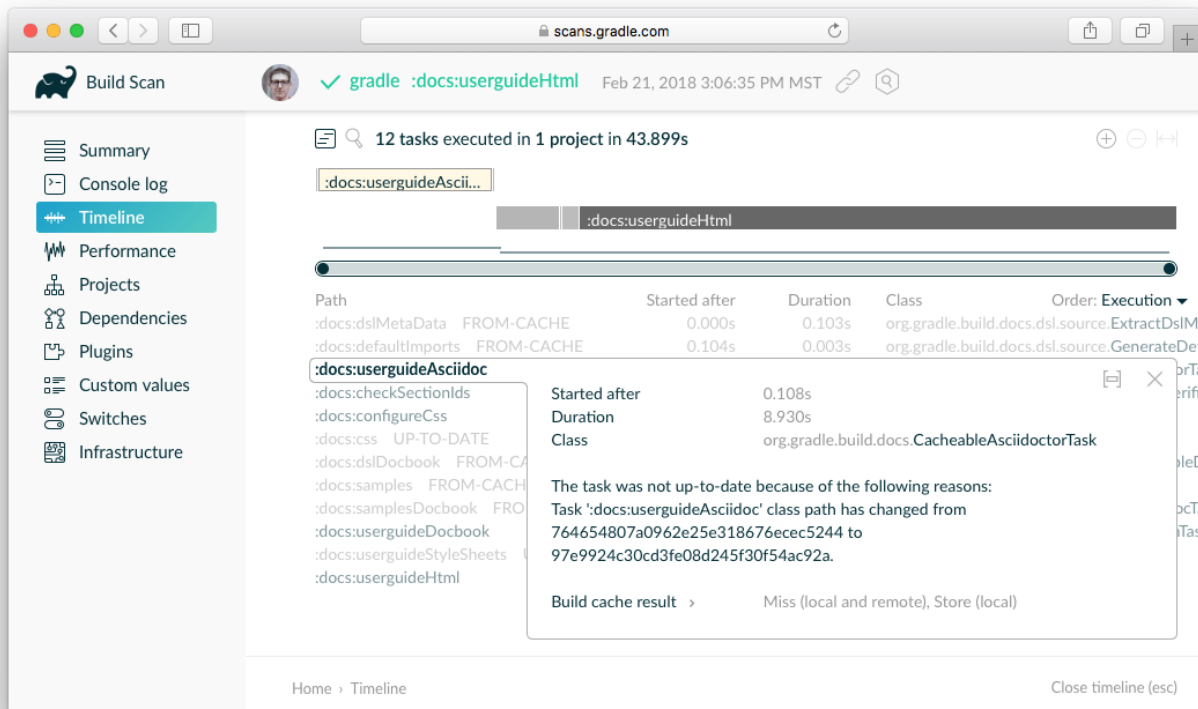
Figure 4. Debugging incremental build with a build scan

You can learn what the task outcomes mean from this listing.

Debugging IDE integration

Many infrequent errors within IDEs can be solved by "refreshing" Gradle. See also more documentation on working with Gradle in IntelliJ IDEA and in Eclipse.

Refreshing IntelliJ IDEA

NOTE This only works for Gradle projects linked to IntelliJ.

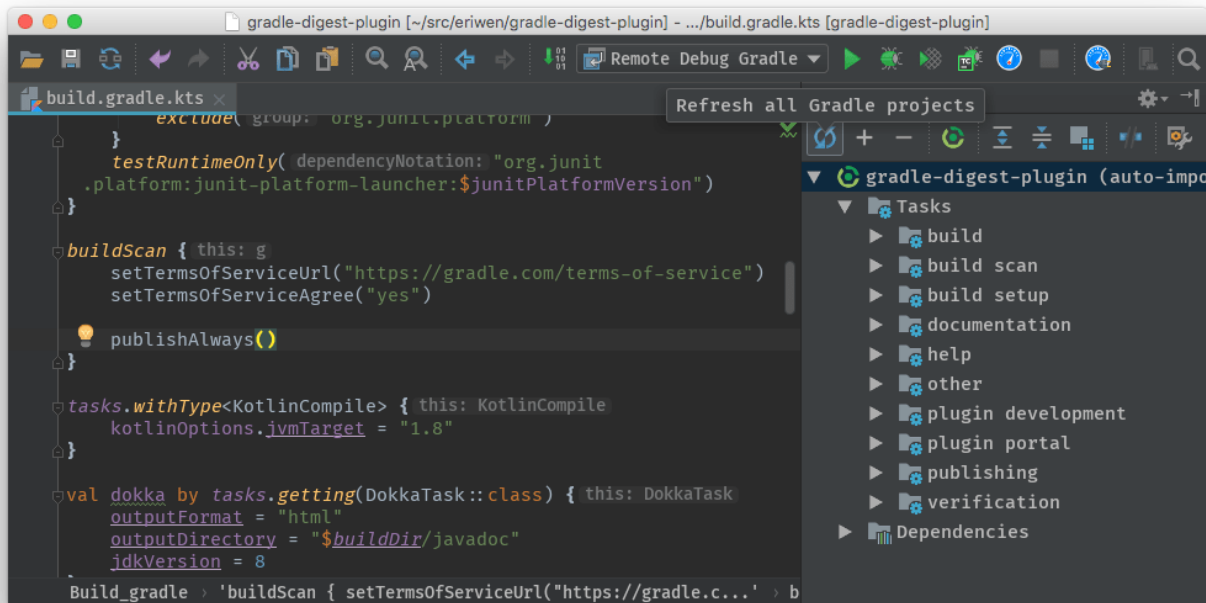From the main menu, go to `View` > `Tool Windows` > `Gradle`. Then click on the *Refresh* icon.

Figure 5. Refreshing a Gradle project in IntelliJ IDEA

Refreshing Eclipse (using Buildship)

If you're using Buildship for the Eclipse IDE, you can re-synchronize your Gradle build by opening the "Gradle Tasks" view and clicking the "Refresh" icon, or by executing the `Gradle` > `Refresh Gradle Project` command from the context menu while editing a Gradle script.
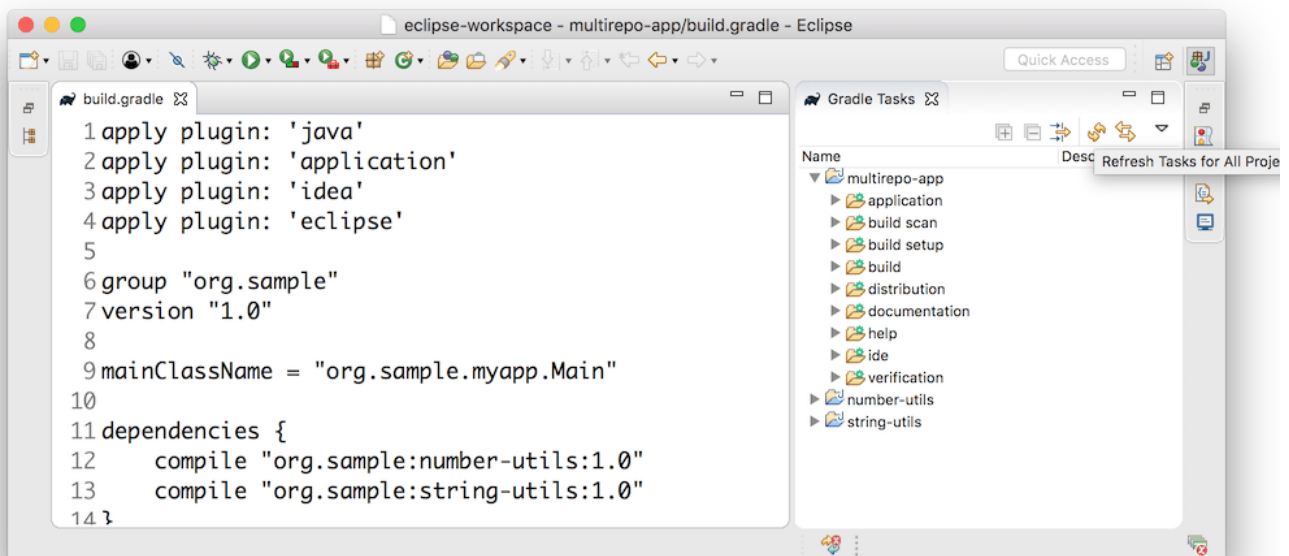

Figure 6. Refreshing a Gradle project in Eclipse Buildship

Troubleshooting daemon connection issues

If your Gradle build fails before running any tasks, you may be encountering problems with your network configuration. When Gradle is unable to communicate with the Gradle daemon process, the build will immediately fail with a message similar to this:

```
$ gradle help

Starting a Gradle Daemon, 1 stopped Daemon could not be reused, use --status for
details

FAILURE: Build failed with an exception.

* What went wrong:
A new daemon was started but could not be connected to: pid=DaemonInfo{pid=55913,
address=[7fb34c82-1907-4c32-afda-888c9b6e2279 port:42751, addresses:[/127.0.0.1]],
state=Busy, ...
```

We have observed this can occur when network address translation (NAT) masquerade is used. When NAT masquerade is enabled, connections that should be considered local to the machine are masked to appear from external IP addresses. Gradle refuses to connect to any external IP address as a security precaution.

The solution to this problem is to adjust your network configuration such that local connections are not modified to appear as from external addresses.

You can monitor the detected network setup and the connection requests in the daemon log file ($GRADLE_USER_HOME/daemon/<Gradle version>/daemon-<PID>.out.log).

```
2021-08-12T12:01:50.755+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding IP addresses for
network interface enp0s3
2021-08-12T12:01:50.759+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Is this a loopback interface?
false
2021-08-12T12:01:50.769+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding remote address
/fe80:0:0:0:85ba:3f3e:1b88:c0e1%enp0s3
2021-08-12T12:01:50.770+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding remote address
/10.0.2.15
2021-08-12T12:01:50.770+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding IP addresses for
network interface lo
2021-08-12T12:01:50.771+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Is this a loopback interface?
true
2021-08-12T12:01:50.771+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding loopback address
/0:0:0:0:0:0:0:1%lo
2021-08-12T12:01:50.771+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.InetAddresses] Adding loopback address
/127.0.0.1
2021-08-12T12:01:50.775+0200 [DEBUG]
[org.gradle.internal.remote.internal.inet.TcpIncomingConnector] Listening on
[7fb34c82-1907-4c32-afda-888c9b6e2279 port:42751, addresses:[localhost/127.0.0.1]].
...
2021-08-12T12:01:50.797+0200 [INFO]
[org.gradle.launcher.daemon.server.DaemonRegistryUpdater] Advertising the daemon
address to the clients: [7fb34c82-1907-4c32-afda-888c9b6e2279 port:42751,
addresses:[localhost/127.0.0.1]]
...
2021-08-12T12:01:50.923+0200 [ERROR]
[org.gradle.internal.remote.internal.inet.TcpIncomingConnector] Cannot accept
connection from remote address /10.0.2.15.
```

Getting additional help

If you didn't find a fix for your issue here, please reach out to the Gradle community on the help forum or search relevant developer resources using help.gradle.org.

If you believe you've found a bug in Gradle, please file an issue on GitHub.

CUSTOMIZING EXECUTION

Configuring the Build Environment

Gradle provides multiple mechanisms for configuring the behavior of Gradle itself and specific projects. The following is a reference for using these mechanisms.

When configuring Gradle behavior, you can use these methods, listed in order of highest to lowest precedence (the first one wins):

Order	Method	Example	Notes
1	Command-line flags	`--build-cache`	These have precedence over properties and environment variables.
2	System properties	`systemProp.http.proxyHost=somehost.org`	Stored in a `gradle.properties` file in a root project directory.
3	Gradle properties	`org.gradle.caching=true`	Stored in a `gradle.properties` file in the `GRADLE_USER_HOME`.
3.1	Gradle properties	`org.gradle.caching=true`	Stored in a `gradle.properties` file in a project directory, then its parent project's directory up to the project's root directory.
3.2	Gradle properties	`org.gradle.caching=true`	Stored in a `gradle.properties` file in the `GRADLE_HOME`.
4	Environment variables	`GRADLE_OPTS`	Sourced by the environment that executes Gradle.

Configuring your build environment

You can configure the build using the same mechanisms.

You can also read information about the environment in the build logic.

1. Command-line flags

The command line interface, along with the available flags, is described in its own section.

2. System properties

Using the `-D` command-line option, you can pass a system property to the JVM, which runs Gradle.

The `-D` option of the `gradle` command has the same effect as the `-D` option of the `java` command.

You can also set system properties in `gradle.properties` files with the prefix `systemProp`:

```
systemProp.gradle.wrapperUser=myuser
systemProp.gradle.wrapperPassword=mypassword
```

The following are *common* system properties:

Gradle Properties

`gradle.wrapperUser=(myuser)`

Specify username to download Gradle distributions [from servers using HTTP Basic Authentication](#).

`gradle.wrapperPassword=(mypassword)`

Specify password for downloading a Gradle distribution using the Gradle wrapper.

`gradle.user.home=(path to directory)`

Specify the `GRADLE_USER_HOME` directory.

The Gradle Properties listed the [section below](#) can also be set as system properties.

Networking Properties

`https.protocols`

Specify the supported TLS versions in a comma-separated format. e.g., `TLSv1.2,TLSv1.3`.

`http.proxyHost`

The hostname, or address, of the proxy server. Default: `none`.

`http.proxyPort`

The port number of the proxy server. Default: `80`.

`http.nonProxyHosts`

Indicates the hosts that should be accessed without going through the proxy. Default: `localhost|127.*|[::1]`.

`https.proxyHost`

The hostname, or address, of the proxy server. Default: `none`.

`https.proxyPort`

The port number of the proxy server. Default: `443`.

`socksProxyHost`

The hostname, or address, of the proxy server. Default: `none`.

`socksProxyPort`

The port number of the proxy server. Default: `1080`.

`socksProxyVersion`

The version of the SOCKS protocol supported by the server. Default: `5` for SOCKS V5.

`java.net.socks.username`

Username to use if the SOCKSv5 server asks for authentication. Default: `none`.

`java.net.socks.password`

Password to use if the SOCKSv5 server asks for authentication. Default: `none`.

Runtime Environment Properties

`java.runtime.version=(string)`

JRE version, e.g. `1.7.0_09-b05`.

`java.version=(string)`

JDK version, e.g., `1.7.0_09`.

`java.home=(string)`

JRE home directory, e.g., `C:\Program Files\Java\jdk1.7.0_09\jre`.

`java.class.path=(string)`

JRE classpath e.g., `.` (dot – used for current working directory).

`java.library.path=(string)`

JRE library search path for search native libraries. Typically taken from the environment variable PATH.

`java.ext.dirs=(string)`

JRE extension library path(s), e.g, `C:\Program Files\Java\jdk1.7.0_09\jre\lib\ext;C:\Windows\Sun\Java\lib\ext`.

Operating System Properties

`os.name=(string)`

The OS's name, e.g., `Windows 7`.

`os.arch=(string)`

The OS's architecture, e.g., `x86`.

`os.version=(string)`

The OS's version, e.g., `6.1`.

File System Properties

`file.separator=(string)`

Symbol for file directory separator such as `d:\test\test.java`. Default is '\' for windows or '/' for Unix/Mac.

`path.separator=(string)`

Symbol for separating path entries, e.g., in PATH or CLASSPATH. Default is ';' for windows or ':' for Unix/Mac.

`line.separator=(string)`

    Symbol for end-of-line (or new line). Default is "\r\n" for windows or "\n" for Unix/Mac OS X.

User Properties

`user.name=(string)`

    The user's name.

`user.home=(string)`

    The user's home directory.

`user.dir=(string)`

    The user's current working directory.

In a multi-project build, `systemProp` properties set in any project except the root will be **ignored**. Only the root project's `gradle.properties` file will be checked for properties that begin with `systemProp`.

The following examples demonstrate how to use System properties.

Example 1: Setting system properties with a `gradle.properties` file:

gradle.properties

```
systemProp.system=gradlePropertiesValue
```

Example 2: Reading system properties at configuration time:

init.gradle.kts

```kotlin
// Using the Java API
println(System.getProperty("system"))
```

settings.gradle.kts

```kotlin
// Using the Java API
println(System.getProperty("system"))

// Using the Gradle API, provides a lazy Provider<String>
println(providers.systemProperty("system").get())
```

build.gradle.kts

```kotlin
// Using the Java API
println(System.getProperty("system"))

// Using the Gradle API, provides a lazy Provider<String>
println(providers.systemProperty("system").get())
```

init.gradle

```groovy
// Using the Java API
println System.getProperty('system')
```

settings.gradle

```groovy
// Using the Java API
println System.getProperty('system')

// Using the Gradle API, provides a lazy Provider<String>
println providers.systemProperty('system').get()
```

build.gradle

```groovy
// Using the Java API
println System.getProperty('system')

// Using the Gradle API, provides a lazy Provider<String>
println providers.systemProperty('system').get()
```

Example 3: Reading system properties for consumption at execution time:

build.gradle.kts

```
tasks.register<PrintValue>("printProperty") {
    // Using the Gradle API, provides a lazy Provider<String> wired to a task
input
    inputValue = providers.systemProperty("system")
}
```

build.gradle

```
tasks.register('printProperty', PrintValue) {
    // Using the Gradle API, provides a lazy Provider<String> wired to a task
input
    inputValue = providers.systemProperty('system')
}
```

Example 4: Setting system properties from the command line `-D gradle.wrapperUser=username`:

```
$ gradle -Dsystem=commandLineValue
```

3. Gradle properties

Gradle provides several options that make it easy to configure the Java process that will be used to execute your build.

While it's possible to configure these in your local environment via `GRADLE_OPTS` or `JAVA_OPTS`, it is useful to be able to store certain settings like JVM memory configuration and `JAVA_HOME` location in version control so that an entire team can work with a consistent environment.

To do so, place these settings into a `gradle.properties` file and commit it to your version control system.

The final configuration taken into account by Gradle is a combination of all Gradle properties set on the command line and your `gradle.properties` files.

If an option is configured in multiple locations, the *first one* found in any of these locations wins:

1. command line, set using `-D`.

2. `gradle.properties` in `GRADLE_USER_HOME` directory.

3. `gradle.properties` in the project's directory, then its parent project's directory up to the build's root directory.

4. `gradle.properties` in the Gradle installation directory.

> **NOTE** The location of the `GRADLE_USER_HOME` may have been changed beforehand via the `-Dgradle.user.home` system property passed on the command line.

The following properties can be used to configure the Gradle build environment:

`org.gradle.caching=(true,false)`

When set to `true`, Gradle will reuse task outputs from any previous build when possible, resulting in much faster builds.

Default is `false`*; the build cache is* **not** *enabled.*

`org.gradle.caching.debug=(true,false)`

When set to `true`, individual input property hashes and the build cache key for each task are logged on the console.

Default is `false`*.*

`org.gradle.configuration-cache=(true,false)`

Enables configuration caching. Gradle will try to reuse the build configuration from previous builds.

Default is `false`*.*

`org.gradle.configuration-cache.inputs.unsafe.ignore.file-system-checks=(file path)`

Used to exclude file system checks on the specified path from configuration cache inputs fingerprinting.

Default is `null`*.*

`org.gradle.configuration-cache.inputs.unsafe.ignore.in-serialization=(true,false)`

Used to ignore inputs in task graph serialization.

Default is `false`*.*

`org.gradle.configuration-cache.problems=(fail,warn)`

Configures how the configuration cache handles problems.

Set to `warn` to report problems without failing the build.

Set to `fail` to report problems and fail the build if there are any problems.

Default is `fail`*.*

`org.gradle.configuration-cache.max-problems=(# of problems)`

Configures the maximum number of configuration cache problems allowed as warnings until

Gradle fails the build.

Default is `512`.

org.gradle.configureondemand=(true,false)

Enables incubating configuration on demand, where Gradle will attempt to configure only necessary projects.

Default is `false`.

org.gradle.console=(auto,plain,rich,verbose)

Customize console output coloring or verbosity.

Default depends on how Gradle is invoked.

org.gradle.continue=(true,false)

If enabled, continue task execution after a task failure, else stop task execution after a task failure.

Default is `false`.

org.gradle.continuous.quietperiod=(# of quiet period millis)

When using continuous build, Gradle will wait for the quiet period to pass before triggering another build. Any additional changes within this quiet period restart the quiet period countdown.

Default is `250` *milliseconds.*

org.gradle.daemon=(true,false)

When set to `true` the Gradle Daemon is used to run the build.

Default is `true`.

org.gradle.daemon.healthcheckinterval=(# of millis)

Gradle Daemon health will be checked after a specified number of milliseconds.

Default is `10000;` *(10 secs).*

org.gradle.daemon.idletimeout=(# of idle millis)

Gradle Daemon will terminate itself after a specified number of idle milliseconds.

Default is `10800000` *(3 hours).*

org.gradle.daemon.registry.base=(directory)

Specify a Daemon registry path where the daemon registry file (addresses of active daemons) and daemon log files reside.

Default is `.` *(local directory).*

org.gradle.debug=(true,false)

When set to `true`, Gradle will run the build with remote debugging enabled, listening on port 5005. Note that this is equivalent to adding `-agentlib:jdwp=transport=dt_socket,server=y,suspend=y,address=5005` to the JVM command line and will suspend the virtual machine until a debugger is attached.

Default is `false`.

org.gradle.debug.host=(host address)

Specifies the host address to listen on or connect to when debug is enabled. In the server mode on Java 9 and above, passing * for the host will make the server listen on all network interfaces.

Default is `null`*; no host address is passed to JDWP (on Java 9 and above, the loopback address is used, while earlier versions listen on all interfaces).*

org.gradle.debug.port=(port number)

Specifies the port number to listen on when debug is enabled.

Default is `5005`.

org.gradle.debug.server=(true,false)

If set to `true` and debugging is enabled, Gradle will run the build with the socket-attach mode of the debugger. Otherwise, the socket-listen mode is used.

Default is `true`.

org.gradle.debug.suspend=(true,false)

When set to `true` and debugging is enabled, the JVM running Gradle will suspend until a debugger is attached.

Default is `true`.

org.gradle.dependency.verification=(strict,lenient,off)

Configures the dependency verification mode where in `strict` mode verification fails as early as possible, in order to avoid the use of compromised dependencies during the build.

Default is `strict`.

org.gradle.internal.instrumentation.agent=(true,false)

Enables the instrumentation Java agent for the daemon.

Default is `true`.

org.gradle.java.home=(path to JDK home)

Specifies the Java home for the Gradle build process. The value can be set to either a `jdk` or `jre` location; however, depending on what your build does, using a JDK is safer. This does not affect the version of Java used to launch the Gradle client VM.

Default is derived from your environment (`JAVA_HOME` *or the path to* `java`*) if the setting is unspecified.*

org.gradle.jvmargs=(JVM arguments)

Specifies the JVM arguments used for the Gradle Daemon. The setting is particularly useful for configuring JVM memory settings for build performance. This does not affect the JVM settings for the Gradle client VM.

Default is `-Xmx512m "-XX:MaxMetaspaceSize=384m"`.

org.gradle.logging.level=(quiet,warn,info,debug)

When set to quiet, warn, info, or debug, Gradle will use this log level. The values are not case-sensitive.

Default is `lifecycle` *level.*

org.gradle.logging.stacktrace=(internal,all,full)

Specifies whether stacktraces should be displayed as part of the build result upon an exception. See the `--stacktrace command-line option` for additional information.

When set to `internal`, a stacktrace is present in the output only in case of internal exceptions.

When set to `all` or `full`, a stacktrace is present in the output for all exceptions and build failures.

Using `full` doesn't truncate the stacktrace, which leads to a much more verbose output.

Default is `internal`.

org.gradle.parallel=(true,false)

When configured, Gradle will fork up to `org.gradle.workers.max` JVMs to execute projects in parallel.

Default is `false`.

org.gradle.priority=(low,normal)

Specifies the scheduling priority for the Gradle daemon and all processes launched by it.

Default is `normal`.

org.gradle.projectcachedir=(directory)

Specify the project-specific cache directory. Defaults to `.gradle` in the root project directory."

Default is `.gradle`.

org.gradle.unsafe.isolated-projects=(true,false)

Enables project isolation which enables configuration caching.

Default is `false`.

org.gradle.vfs.verbose=(true,false)

Configures verbose logging when watching the file system.

Default is `false`.

`org.gradle.vfs.watch=(true,false)`

Toggles [watching the file system](#). When enabled, Gradle reuses information it collects about the file system between builds.

Default is `true` *on operating systems where Gradle supports this feature.*

`org.gradle.vfs.watch.debug=(true,false)`

Enables debug events emitted in `native-platform` to be shown. Events are only shown when `--debug` is enabled or when the daemon is between builds.

Default is `false`.

`org.gradle.warning.mode=(all,fail,summary,none)`

When set to `all`, `summary` or `none`, Gradle will use [different warning type display](#).

Default is `summary`.

`org.gradle.welcome=(never,once)`

Controls whether Gradle should print a welcome message.

If set to `never`, then the welcome message will be suppressed.

If set to `once`, then the message is printed once for each new version of Gradle.

Default is `once`.

`org.gradle.workers.max=(max # of worker processes)`

When configured, Gradle will use a maximum of the [given number of workers](#).

Default is the number of CPU processors.

The following examples demonstrate how to use Gradle properties.

Example 1: Setting Gradle properties with a `gradle.properties` file:

gradle.properties

```
gradlePropertiesProp=gradlePropertiesValue
gradleProperties.with.dots=gradlePropertiesDottedValue
```

Example 2: Reading Gradle properties at configuration time:

settings.gradle.kts

```kotlin
// Using the API, provides a lazy Provider<String>
println(providers.gradleProperty("gradlePropertiesProp").get())

// Using Kotlin delegated properties on `settings`
val gradlePropertiesProp: String by settings
println(gradlePropertiesProp)
```

build.gradle.kts

```kotlin
// Using the API, provides a lazy Provider<String>
println(providers.gradleProperty("gradlePropertiesProp").get())

// Using Kotlin delegated properties on `project`
val gradlePropertiesProp: String by project
println(gradlePropertiesProp)
```

settings.gradle

```groovy
// Using the API, provides a lazy Provider<String>
println providers.gradleProperty('gradlePropertiesProp').get()

// Using Groovy dynamic names
println gradlePropertiesProp
println settings.gradlePropertiesProp

// Using Groovy dynamic array notation on `settings`
println settings['gradlePropertiesProp']
```

build.gradle

```groovy
// Using the API, provides a lazy Provider<String>
println providers.gradleProperty('gradlePropertiesProp').get()

// Using Groovy dynamic names
println gradlePropertiesProp
println project.gradlePropertiesProp

// Using Groovy dynamic array notation on `project`
println project['gradlePropertiesProp']
```

The Kotlin delegated properties are part of the Gradle Kotlin DSL. You need to explicitly specify the type as String. If you need to branch depending on the presence of the property, you can also use

`String?` and check for `null`.

Note that if a Gradle property has a dot in its name, using the dynamic Groovy names is not possible. You have to use the API or the dynamic array notation instead.

Example 3: Reading Gradle properties for consumption at execution time:

build.gradle.kts

```
tasks.register<PrintValue>("printProperty") {
    // Using the API, provides a lazy Provider<String> wired to a task input
    inputValue = providers.gradleProperty("gradlePropertiesProp")
}
```

build.gradle

```
tasks.register('printProperty', PrintValue) {
    // Using the API, provides a lazy Provider<String> wired to a task input
    inputValue = providers.gradleProperty('gradlePropertiesProp')
}
```

Example 4: Setting Gradle properties from the command line:

```
$ gradle -DgradlePropertiesProp=commandLineValue
```

Note that initialization scripts can't read Gradle properties directly. The earliest Gradle properties can be read in initialization scripts is on `settingsEvaluated {}`:

Example 5: Reading Gradle properties from initialization scripts:

init.gradle.kts

```kotlin
settingsEvaluated {
    // Using the API, provides a lazy Provider<String>
    println(providers.gradleProperty("gradlePropertiesProp").get())

    // Using Kotlin delegated properties on `settings`
    val gradlePropertiesProp: String by this
    println(gradlePropertiesProp)
}
```

init.gradle

```groovy
settingsEvaluated { settings ->
    // Using the API, provides a lazy Provider<String>
    println settings.providers.gradleProperty('gradlePropertiesProp').get()

    // Using Groovy dynamic names
    println settings.gradlePropertiesProp

    // Using Groovy dynamic array notation on `settings`
    println settings['gradlePropertiesProp']
}
```

Properties declared in a `gradle.properties` file present in a subproject directory are only available to that project and its children.

4. Environment variables

The following environment variables are available for the `gradle` command.

`GRADLE_HOME`

Installation directory for Gradle.

Can be used to specify a local Gradle version instead of using the wrapper.

You can add `GRADLE_HOME/bin` to your `PATH` for specific applications and use-cases (such as testing an early release for Gradle).

`JAVA_OPTS`

Used to pass JVM options and custom settings to the JVM.

`GRADLE_OPTS`

Specifies JVM arguments to use when starting the Gradle client VM.

The client VM only handles command line input/output, so it is rare that one would need to change its VM options.

The actual build is run by the Gradle daemon, which is not affected by this environment variable.

GRADLE_USER_HOME

Specifies the `GRADLE_USER_HOME` directory for Gradle to store its global configuration properties, initialization scripts, caches, log files and more.

Defaults to `USER_HOME/.gradle` if not set.

JAVA_HOME

Specifies the JDK installation directory to use for the client VM.

This VM is also used for the daemon unless a different one is specified in a Gradle properties file with `org.gradle.java.home`.

GRADLE_LIBS_REPO_OVERRIDE

Overrides for the default Gradle library repository.

Can be used to specify a default Gradle repository URL in `org.gradle.plugins.ide.internal.resolver`.

Useful override to specify an internally hosted repository in case your company uses a firewall/proxy.

The following examples demonstrate how to use environment variables.

Example 1: Reading environment variables at configuration time:

init.gradle.kts

```
// Using the Java API
println(System.getenv("ENVIRONMENTAL"))
```

settings.gradle.kts

```
// Using the Java API
println(System.getenv("ENVIRONMENTAL"))

// Using the Gradle API, provides a lazy Provider<String>
println(providers.environmentVariable("ENVIRONMENTAL").get())
```

build.gradle.kts

```
// Using the Java API
println(System.getenv("ENVIRONMENTAL"))

// Using the Gradle API, provides a lazy Provider<String>
println(providers.environmentVariable("ENVIRONMENTAL").get())
```

init.gradle

```
// Using the Java API
println System.getenv('ENVIRONMENTAL')
```

settings.gradle

```
// Using the Java API
println System.getenv('ENVIRONMENTAL')

// Using the Gradle API, provides a lazy Provider<String>
println providers.environmentVariable('ENVIRONMENTAL').get()
```

build.gradle

```
// Using the Java API
println System.getenv('ENVIRONMENTAL')

// Using the Gradle API, provides a lazy Provider<String>
println providers.environmentVariable('ENVIRONMENTAL').get()
```

Example 2: Reading environment variables for consumption at execution time:

build.gradle.kts

```kotlin
tasks.register<PrintValue>("printValue") {
    // Using the Gradle API, provides a lazy Provider<String> wired to a task
input
    inputValue = providers.environmentVariable("ENVIRONMENTAL")
}
```

build.gradle

```groovy
tasks.register('printValue', PrintValue) {
    // Using the Gradle API, provides a lazy Provider<String> wired to a task
input
    inputValue = providers.environmentVariable('ENVIRONMENTAL')
}
```

Gradle Daemon

A daemon is a computer program that runs as a background process rather than being under the direct control of an interactive user.

Gradle runs on the Java Virtual Machine (JVM) and uses several supporting libraries with non-trivial initialization time. Startups can be slow. The **Gradle Daemon** solves this problem.

The Gradle Daemon is a long-lived background process that reduces the time it takes to run a build.

The Gradle Daemon reduces build times by:

- Caching project information across builds
- Running in the background so every Gradle build doesn't have to wait for JVM startup
- Benefiting from continuous runtime optimization in the JVM
- Watching the file system to calculate exactly what needs to be rebuilt before you run a build

Understanding the Daemon

The Gradle JVM client sends the Daemon build information such as command line arguments, project directories, and environment variables so that it can run the build. The Wrapper is responsible for resolving dependencies, executing build scripts, creating and running tasks; when it is done, it sends the client the output. Communication between the client and the Daemon happens via a local socket connection.

Daemons use the JVM's default minimum heap size.

If the requested build environment does not specify a maximum heap size, the Daemon uses up to 512MB of heap. 512MB is adequate for most builds. Larger builds with hundreds of subprojects, configuration, and source code may benefit from a larger heap size.

Check Daemon status

To get a list of running Daemons and their statuses, use the `--status` command:

```
$ gradle --status
```

```
   PID STATUS   INFO
 28486 IDLE     7.5
 34247 BUSY     7.5
```

Currently, a given Gradle version can only connect to Daemons of the same version. This means the status output only shows Daemons spawned running the same version of Gradle as the current project.

Find Daemons

If you have installed the Java Development Kit (JDK), you can view live daemons with the `jps` command.

```
$ jps
```

```
33920 Jps
27171 GradleDaemon
22792
```

Live Daemons appear under the name `GradleDaemon`. Because this command uses the JDK, you can view Daemons running any version of Gradle.

Enable Deamon

Gradle enables the Daemon by default since Gradle 3.0. If your project doesn't use the Daemon, you can enable it for a single build with the `--daemon` flag when you run a build:

```
$ gradle <task> --daemon
```

This flag overrides any settings that disable the Daemon in your project or user `gradle.properties` files.

To enable the Daemon by default in older Gradle versions, add the following setting to the `gradle.properties` file in the project root or your Gradle User Home (`GRADLE_USER_HOME`:

---

gradle.properties

```
org.gradle.daemon=true
```

Disable Daemon

You can disable the Daemon in multiple ways but there are important considerations:

Single-use Daemon

> If the JVM args of the client process don't match what the build requires, a single-used Daemon (disposable JVM) is created. This means the Daemon is required for the build, so it is created, used, and then stopped at the end of the build.

No Daemon

> If the `JAVA_OPTS` and `GRADLE_OPTS` match `org.gradle.jvmargs`, the Daemon will not be used at all since the build happens in the client JVM.

Disable for a build

To disable the Daemon for a single build, pass the `--no-daemon` flag when you run a build:

```
$ gradle <task> --no-daemon
```

This flag overrides any settings that enable the Daemon in your project including the `gradle.properties` files.

Disable for a project

To disable the Daemon for all builds of a project, add `org.gradle.daemon=false` to the `gradle.properties` file in the project root.

Disable for a user

On Windows, this command disables the Daemon for the current user:

```
(if not exist "%USERPROFILE%/.gradle" mkdir "%USERPROFILE%/.gradle") && (echo. >>
"%USERPROFILE%/.gradle/gradle.properties" && echo org.gradle.daemon=false >>
"%USERPROFILE%/.gradle/gradle.properties")
```

On UNIX-like operating systems, the following Bash shell command disables the Daemon for the current user:

```
mkdir -p ~/.gradle && echo "org.gradle.daemon=false" >> ~/.gradle/gradle.properties
```

Disable globally

There are two recommended ways to disable the Daemon globally across an environment:

- add `org.gradle.daemon=false` to the `$GRADLE_USER_HOME`/gradle.properties` file
- add the flag `-Dorg.gradle.daemon=false` to the `GRADLE_OPTS` environment variable

Don't forget to make sure your JVM arguments and `GRADLE_OPTS` / `JAVA_OPTS` match if you want to completely disable the Daemon and not simply invoke a single-use one.

Stop Daemon

It can be helpful to stop the Daemon when troubleshooting or debugging a failure.

Daemons automatically stop given any of the following conditions:

- Available system memory is low
- Daemon has been idle for 3 hours

To stop running Daemon processes, use the following command:

```
$ gradle --stop
```

This terminates all Daemon processes started with the same version of Gradle used to execute the command.

You can also kill Daemons manually with your operating system. To find the PIDs for all Daemons regardless of Gradle version, see Find Daemons.

Tools & IDEs

The Gradle Tooling API used by IDEs and other tools to integrate with Gradle *always* uses the Gradle Daemon to execute builds. If you execute Gradle builds from within your IDE, you already use the Gradle Daemon. There is no need to enable it for your environment.

Continuous Integration

We recommend using the Daemon for developer machines and Continuous Integration (CI) servers.

Compatibility

Gradle starts a new Daemon if no idle or compatible Daemons exist.

The following values determine compatibility:

- **Requested build environment**, including the following:
  - Java version
  - JVM attributes
  - JVM properties
- Gradle version

Compatibility is based on exact matches of these values. For example:

- If a Daemon is available with a Java 8 runtime, but the requested build environment calls for Java 10, then the Daemon is not compatible.
- If a Daemon is available running Gradle 7.0, but the current build uses Gradle 7.4, then the Daemon is not compatible.

Certain properties of a Java runtime are *immutable*: they cannot be changed once the JVM has started. The following JVM system properties are immutable:

- `file.encoding`
- `user.language`
- `user.country`
- `user.variant`
- `java.io.tmpdir`
- `javax.net.ssl.keyStore`
- `javax.net.ssl.keyStorePassword`
- `javax.net.ssl.keyStoreType`
- `javax.net.ssl.trustStore`
- `javax.net.ssl.trustStorePassword`
- `javax.net.ssl.trustStoreType`
- `com.sun.management.jmxremote`

The following JVM attributes controlled by startup arguments are also immutable:

- The maximum heap size (the `-Xmx` JVM argument)
- The minimum heap size (the `-Xms` JVM argument)
- The boot classpath (the `-Xbootclasspath` argument)
- The "assertion" status (the `-ea` argument)

If the requested build environment requirements for any of these properties and attributes differ from the Daemon's JVM requirements, the Daemon is not compatible.

| NOTE | For more information about build environments, see the build environment documentation. |

Performance Impact

The Daemon can reduce build times by 15-75% when you build the same project repeatedly.

> **TIP** To understand the Daemon's impact on your builds, you can profile your build with `--profile`.

In between builds, the Daemon waits idly for the next build. As a result, your machine only loads Gradle into memory once for multiple builds instead of once per build. This is a significant performance optimization.

Runtime Code Optimizations

The JVM gains significant performance from **runtime code optimization**: optimizations applied to code while it runs.

JVM implementations like OpenJDK's Hotspot progressively optimize code during execution. Consequently, subsequent builds can be faster purely due to this optimization process.

With the Daemon, perceived build times can drop dramatically between a project's 1st and 10th builds.

Memory Caching

The Daemon enables in-memory caching across builds. This includes classes for plugins and build scripts.

Similarly, the Daemon maintains in-memory caches of build data, such as the hashes of task inputs and outputs for incremental builds.

Performance Monitoring

Gradle actively monitors heap usage to detect memory leaks in the Daemon.

When a memory leak exhausts available heap space, the Daemon:

1. Finishes the currently running build.
2. Restarts before running the next build.

Gradle enables this monitoring by default.

To disable this monitoring, set the `org.gradle.daemon.performance.enable-monitoring` Daemon option to `false`.

You can do this on the command line with the following command:

```
$ gradle <task> -Dorg.gradle.daemon.performance.enable-monitoring=false
```

Or you can configure the property in the `gradle.properties` file in the project root or your

GRADLE_USER_HOME (Gradle User Home):

---

gradle.properties

```
org.gradle.daemon.performance.enable-monitoring=false
```

File System Watching

Gradle maintains a Virtual File System (VFS) to calculate what needs to be rebuilt on repeat builds of a project. By watching the file system, Gradle keeps the VFS current between builds.

Enable

Gradle enables file system watching by default for supported operating systems since Gradle 7.

Run the build with the '--watch-fs' flag to force file system watching for a build.

To force file system watching for all builds (unless disabled with `--no-watch-fs`), add the following value to `gradle.properties`:

---

gradle.properties

```
org.gradle.vfs.watch=true
```

Disable

To disable file system watching:

- use the `--no-watch-fs` flag
- set `org.gradle.vfs.watch=false` in `gradle.properties`

Supported Operating Systems

Gradle uses native operating system features to watch the file system. Gradle supports file system watching on the following operating systems:

- Windows 10, version 1709 and later
- Linux, tested on the following distributions:
    - Ubuntu 16.04 or later
    - CentOS 8 or later
    - Red Hat Enterprise Linux (RHEL) 8 or later
    - Amazon Linux 2 or later

- macOS 10.14 (Mojave) or later on Intel and ARM architectures

Supported File Systems

File system watching supports the following file system types:

- APFS
- btrfs
- ext3
- ext4
- XFS
- HFS+
- NTFS

Gradle also supports VirtualBox's shared folders.

Network file systems like Samba and NFS are not supported.

Symlinks

File system watching is not compatible with symlinks. If your project files include symlinks, you must disable `vfs.watch` by setting `org.gradle.vfs.watch=false` in `gradle.properties`.

Unsupported File Systems

When enabled by default, file system watching acts conservatively when it encounters content on unsupported file systems. This can happen if you mount a project directory or subdirectory from a network drive. Gradle doesn't retain information about unsupported file systems between builds when enabled by default. If you explicitly enable file system watching, Gradle retains information about unsupported file systems between builds.

Logging

To view information about Virtual File System (VFS) changes at the beginning and end of a build, enable verbose VFS logging.

Set the `org.gradle.vfs.verbose` Daemon option to `true` to enable verbose logging.

You can do this on the command line with the following command:

```
$ gradle <task> -Dorg.gradle.vfs.verbose=true
```

Or configure the property in the `gradle.properties` file in the project root or your Gradle User Home:

gradle.properties

```
org.gradle.vfs.verbose=true
```

This produces the following output at the start and end of the build:

```
$ gradle assemble --watch-fs -Dorg.gradle.vfs.verbose=true
```

```
Received 3 file system events since last build while watching 1 locations
Virtual file system retained information about 2 files, 2 directories and 0 missing
files since last build
> Task :compileJava NO-SOURCE
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :jar UP-TO-DATE
> Task :assemble UP-TO-DATE

BUILD SUCCESSFUL in 58ms
1 actionable task: 1 up-to-date
Received 5 file system events during the current build while watching 1 locations
Virtual file system retains information about 3 files, 2 directories and 2 missing
files until next build
```

On Windows and macOS, Gradle might report changes received since the last build, even if you haven't changed anything. These are harmless notifications about changes to Gradle's caches and can be safely ignored.

Troubleshooting

Gradle does not detect some changes

Please let us know on the Gradle community Slack. If a build declares its inputs and outputs correctly, this should not happen. So it's either a bug we must fix or your build lacks declaration for some inputs or outputs.

VFS state dropped due to lost state

Did you receive a message that reads `Dropped VFS state due to lost state` during a build? *Please let us know on the Gradle community Slack*. This means that your build cannot benefit from file system watching for one of the following reasons:

- the Daemon received an unknown file system event

- too many changes happened, and the watching API couldn't handle it

Too many open files on macOS

If you receive the `java.io.IOException: Too many open files` error on macOS, raise your open files limit. See this post for more details.

Adjust inotify Limits on Linux

File system watching uses inotify on Linux. Depending on the size of your build, it may be necessary to increase inotify limits. If you are using an IDE, then you probably already had to increase the limits in the past.

File system watching uses one inotify watch per watched directory. You can see the current limit of inotify watches per user by running:

```
cat /proc/sys/fs/inotify/max_user_watches
```

To increase the limit to e.g. 512K watches run the following:

```
echo fs.inotify.max_user_watches=524288 | sudo tee -a /etc/sysctl.conf
```

```
sudo sysctl -p --system
```

Each used inotify watch takes up to 1KB of memory. Assuming inotify uses all the 512K watches then file system watching could use up to 500MB. In a memory-constrained environment, you may want to disable file system watching.

Initialization Scripts

Gradle provides a powerful mechanism for customizing the build based on the current environment.

This mechanism also supports tools that wish to integrate with Gradle.

Basic usage

Initialization scripts (a.k.a. *init scripts*) are similar to other scripts in Gradle. These scripts, however, are run before the build starts.

Here are several possible uses:

- Set up enterprise-wide configuration, such as where to find custom plugins.
- Set up properties based on the current environment, such as a developer's machine vs. a continuous integration server.
- Supply personal information about the user required by the build, such as repository or database authentication credentials.
- Define machine-specific details, such as where JDKs are installed.
- Register build listeners. External tools that wish to listen to Gradle events might find this useful.
- Register build loggers. You could customize how Gradle logs the events that it generates.

One main limitation of init scripts is that they cannot access classes in the `buildSrc` project.

Using an init script

There are several ways to use an init script:

- Specify a file on the command line. The command line option is `-I` or `--init-script` followed by the path to the script.

  The command line option can appear more than once, each time adding another init script. The build will fail if any files specified on the command line do not exist.

- Put a file called `init.gradle` (or `init.gradle.kts` for Kotlin) in the `$GRADLE_USER_HOME/` directory.

- Put a file that ends with `.gradle` (or `.init.gradle.kts` for Kotlin) in the `$GRADLE_USER_HOME/init.d/` directory.

- Put a file that ends with `.gradle` (or `.init.gradle.kts` for Kotlin) in the `$GRADLE_HOME/init.d/` directory, in the Gradle distribution.

  This lets you package a custom Gradle distribution containing custom build logic and plugins. You can combine this with the Gradle wrapper to make custom logic available to all builds in your enterprise.

If more than one init script is found, they will all be executed in the order specified above.

Scripts in a given directory are executed in alphabetical order. For example, a tool can specify an init script on the command line and another in the home directory for defining the environment. Both scripts will run when Gradle is executed.

Writing an init script

Like a Gradle build script, an init script is a Groovy or Kotlin script. Each init script has a Gradle instance associated with it. Any property reference and method call in the init script will delegate to this `Gradle` instance.

Each init script also implements the Script interface.

NOTE	When writing init scripts, pay attention to the scope of the reference you are trying to access. For example, properties loaded from `gradle.properties` are available on `Settings` or `Project` instances but not on the `Gradle` one.

Configuring projects from an init script

You can use an init script to configure the projects in the build. This works similarly to configuring projects in a multi-project build.

The following sample shows how to perform extra configuration from an init script *before* the projects are evaluated:

build.gradle.kts

```kotlin
repositories {
    mavenCentral()
}

tasks.register("showRepos") {
    val repositoryNames = repositories.map { it.name }
    doLast {
        println("All repos:")
        println(repositoryNames)
    }
}
```

init.gradle.kts

```kotlin
allprojects {
    repositories {
        mavenLocal()
    }
}
```

build.gradle

```groovy
repositories {
    mavenCentral()
}

tasks.register('showRepos') {
    def repositoryNames = repositories.collect { it.name }
    doLast {
        println "All repos:"
        println repositoryNames
    }
}
```

init.gradle

```groovy
allprojects {
    repositories {
        mavenLocal()
    }
}
```

This sample uses this feature to configure an additional repository to be used only for specific environments.

Output when applying the init script

```
> gradle --init-script init.gradle.kts -q showRepos
All repos:
[MavenLocal, MavenRepo]
```

```
> gradle --init-script init.gradle -q showRepos
All repos:
[MavenLocal, MavenRepo]
```

External dependencies for the init script

Init scripts can also declare dependencies with the `initscript()` method, passing in a closure that declares the init script classpath.

Declaring external dependencies for an init script:

init.gradle.kts

```
initscript {
    repositories {
        mavenCentral()
    }
    dependencies {
        classpath("org.apache.commons:commons-math:2.0")
    }
}
```

init.gradle

```
initscript {
    repositories {
        mavenCentral()
    }
    dependencies {
        classpath 'org.apache.commons:commons-math:2.0'
    }
}
```

The closure passed to the `initscript()` method configures a ScriptHandler instance. You declare the init script classpath by adding dependencies to the `classpath` configuration.

This is the same way you declare, for example, the Java compilation classpath. You can use any of the dependency types described in Declaring Dependencies, except project dependencies.

Having declared the init script classpath, you can use the classes in your init script as you would any other classes on the classpath. The following example adds to the previous example and uses classes from the init script classpath.

An init script with external dependencies:

init.gradle.kts

```kotlin
import org.apache.commons.math.fraction.Fraction

initscript {
    repositories {
        mavenCentral()
    }
    dependencies {
        classpath("org.apache.commons:commons-math:2.0")
    }
}

println(Fraction.ONE_FIFTH.multiply(2))
```

build.gradle.kts

```kotlin
tasks.register("doNothing")
```

init.gradle

```groovy
import org.apache.commons.math.fraction.Fraction

initscript {
    repositories {
        mavenCentral()
    }
    dependencies {
        classpath 'org.apache.commons:commons-math:2.0'
    }
}

println Fraction.ONE_FIFTH.multiply(2)
```

build.gradle

```groovy
tasks.register('doNothing')
```

Output when applying the init script:

```
> gradle --init-script init.gradle.kts -q doNothing
2 / 5
```

```
> gradle --init-script init.gradle -q doNothing
2 / 5
```

Init script plugins

Like a Gradle build script or a Gradle settings file, plugins can be applied to init scripts.

Using plugins in init scripts:

init.gradle.kts

```kotlin
apply<EnterpriseRepositoryPlugin>()

class EnterpriseRepositoryPlugin : Plugin<Gradle> {
    companion object {
        const val ENTERPRISE_REPOSITORY_URL =
"https://repo.gradle.org/gradle/repo"
    }

    override fun apply(gradle: Gradle) {
        // ONLY USE ENTERPRISE REPO FOR DEPENDENCIES
        gradle.allprojects {
            repositories {

                // Remove all repositories not pointing to the enterprise
repository url
                all {
                    if (this !is MavenArtifactRepository || url.toString() !=
ENTERPRISE_REPOSITORY_URL) {
                        project.logger.lifecycle("Repository ${(this as?
MavenArtifactRepository)?.url ?: name} removed. Only
$ENTERPRISE_REPOSITORY_URL is allowed")
                        remove(this)
                    }
                }

                // add the enterprise repository
                add(maven {
                    name = "STANDARD_ENTERPRISE_REPO"
                    url = uri(ENTERPRISE_REPOSITORY_URL)
                })
            }
        }
    }
}
```

build.gradle.kts

```
repositories{
    mavenCentral()
}

data class RepositoryData(val name: String, val url: URI)

tasks.register("showRepositories") {
    val repositoryData = repositories.withType<MavenArtifactRepository>().map
{ RepositoryData(it.name, it.url) }
    doLast {
        repositoryData.forEach {
            println("repository: ${it.name} ('${it.url}')")
        }
    }
}
```

init.gradle

```
apply plugin: EnterpriseRepositoryPlugin

class EnterpriseRepositoryPlugin implements Plugin<Gradle> {

    private static String ENTERPRISE_REPOSITORY_URL =
"https://repo.gradle.org/gradle/repo"

    void apply(Gradle gradle) {
        // ONLY USE ENTERPRISE REPO FOR DEPENDENCIES
        gradle.allprojects { project ->
            project.repositories {

                // Remove all repositories not pointing to the enterprise
repository url
                all { ArtifactRepository repo ->
                    if (!(repo instanceof MavenArtifactRepository) ||
                        repo.url.toString() != ENTERPRISE_REPOSITORY_URL) {
                        project.logger.lifecycle "Repository ${repo.url}
removed. Only $ENTERPRISE_REPOSITORY_URL is allowed"
                        remove repo
                    }
                }

                // add the enterprise repository
                maven {
                    name "STANDARD_ENTERPRISE_REPO"
                    url ENTERPRISE_REPOSITORY_URL
                }
            }
        }
    }
}
```

```
repositories{
    mavenCentral()
}

@Immutable
class RepositoryData {
    String name
    URI url
}

tasks.register('showRepositories') {
    def repositoryData = repositories.collect { new RepositoryData(it.name,
it.url) }
    doLast {
        repositoryData.each {
            println "repository: ${it.name} ('${it.url}')"
        }
    }
}
```

Output when applying the init script:

```
> gradle --init-script init.gradle.kts -q showRepositories
repository: STANDARD_ENTERPRISE_REPO ('https://repo.gradle.org/gradle/repo')
```

```
> gradle --init-script init.gradle -q showRepositories
repository: STANDARD_ENTERPRISE_REPO ('https://repo.gradle.org/gradle/repo')
```

The plugin in the init script ensures that only a specified repository is used when running the build.

When applying plugins within the init script, Gradle instantiates the plugin and calls the plugin instance's Plugin.apply(T) method.

The `gradle` object is passed as a parameter, which can be used to configure all aspects of a build. Of course, the applied plugin can be resolved as an external dependency as described in External dependencies for the init script

AUTHORING GRADLE BUILDS

LEARNING THE BASICS

Build Lifecycle

As a build author, you define tasks and dependencies between tasks. Gradle guarantees that these tasks will execute in order of their dependencies.

Your build scripts and plugins configure this dependency graph.

For example, if your project tasks include `build`, `assemble`, `createDocs`, your build script(s) can ensure that they are executed in the order `build` → `assemble` → `createDoc`.
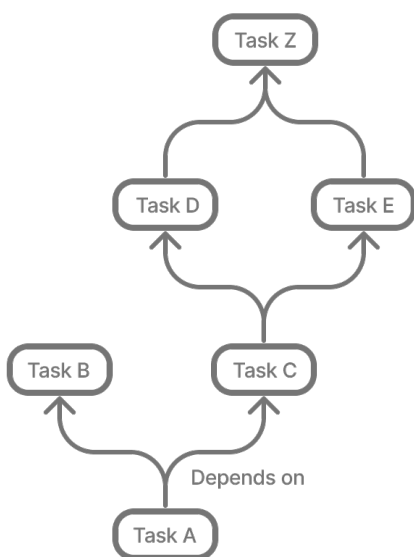
Task Graphs

Gradle builds the task graph **before** executing any task.

Across all projects in the build, tasks form a Directed Acyclic Graph (DAG).

This diagram shows two example task graphs, one abstract and the other concrete, with dependencies between tasks represented as arrows:
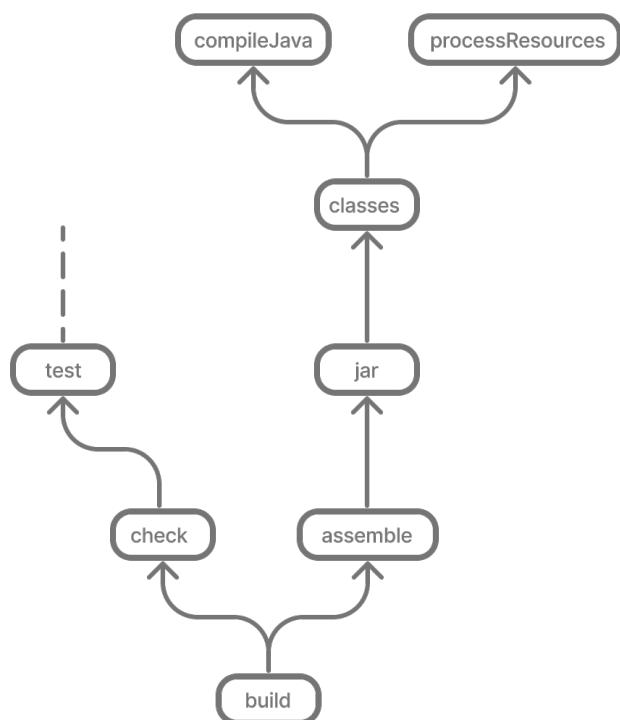
Both plugins and build scripts contribute to the task graph via the task dependency mechanism and annotated inputs/outputs.

Build Phases

A Gradle build has three distinct phases.

1. INITIALIZATION PHASE	→	2. CONFIGURATION PHASE	→	3. EXECUTION PHASE

Gradle runs these phases in order:

Phase 1. Initialization

- Detects the `settings.gradle(.kts)` file.

- Creates a `Settings` instance.

- Evaluates the settings file to determine which projects (and included builds) make up the build.

- Creates a `Project` instance for every project.

Phase 2. Configuration

- Evaluates the build scripts, `build.gradle(.kts)`, of every project participating in the build.

- Creates a task graph for requested tasks.

Phase 3. Execution

- Schedules and executes the selected tasks.

- Dependencies between tasks determine execution order.

- Execution of tasks can occur in parallel.

Build Lifecycle
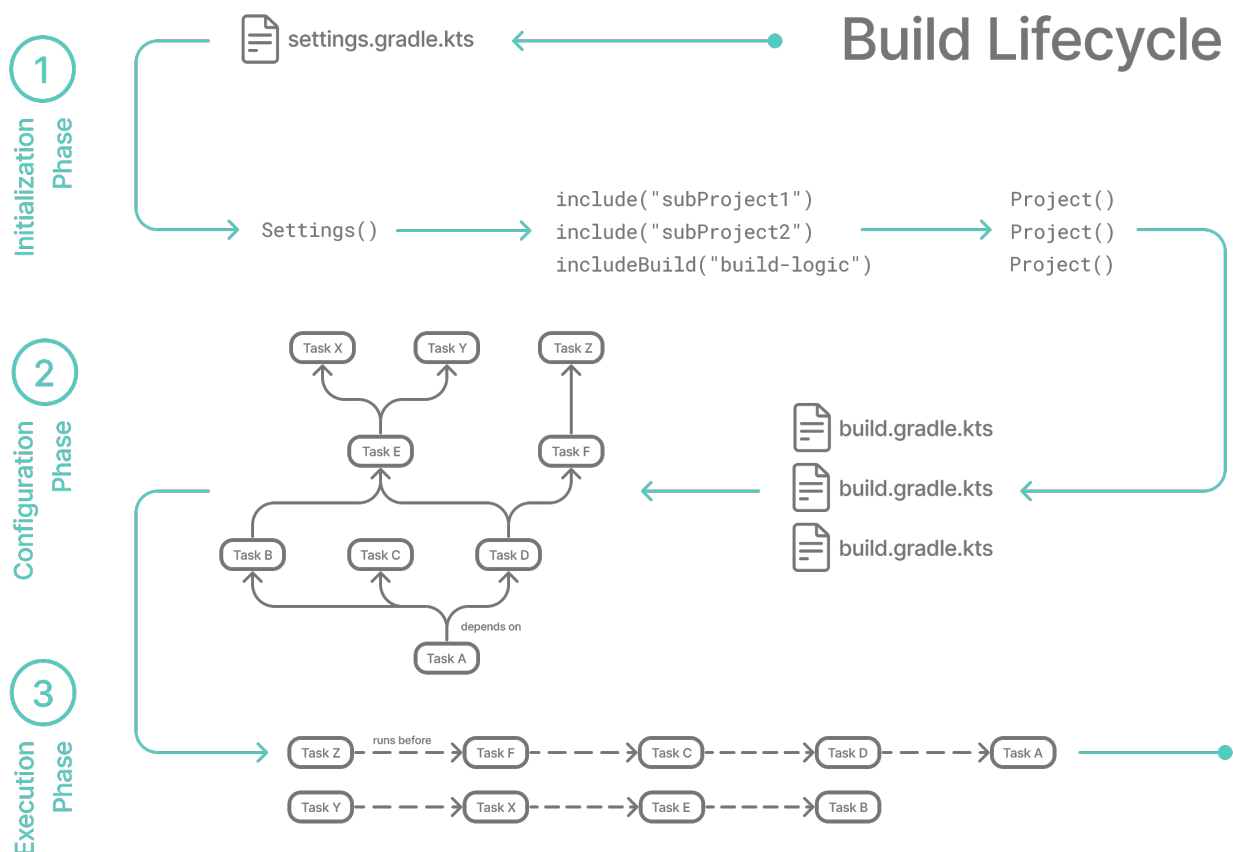
Example

The following example shows which parts of settings and build files correspond to various build phases:

settings.gradle.kts

```
rootProject.name = "basic"
println("This is executed during the initialization phase.")
```

build.gradle.kts

```
println("This is executed during the configuration phase.")

tasks.register("configured") {
    println("This is also executed during the configuration phase, because
:configured is used in the build.")
}

tasks.register("test") {
    doLast {
        println("This is executed during the execution phase.")
    }
}

tasks.register("testBoth") {
    doFirst {
        println("This is executed first during the execution phase.")
    }
    doLast {
        println("This is executed last during the execution phase.")
    }
    println("This is executed during the configuration phase as well, because
:testBoth is used in the build.")
}
```

```
rootProject.name = 'basic'
println 'This is executed during the initialization phase.'
```

build.gradle

```
println 'This is executed during the configuration phase.'

tasks.register('configured') {
    println 'This is also executed during the configuration phase, because
:configured is used in the build.'
}

tasks.register('test') {
    doLast {
        println 'This is executed during the execution phase.'
    }
}

tasks.register('testBoth') {
    doFirst {
      println 'This is executed first during the execution phase.'
    }
    doLast {
      println 'This is executed last during the execution phase.'
    }
    println 'This is executed during the configuration phase as well, because
:testBoth is used in the build.'
}
```

The following command executes the `test` and `testBoth` tasks specified above. Because Gradle only configures requested tasks and their dependencies, the `configured` task never configures:

```
> gradle test testBoth
This is executed during the initialization phase.

> Configure project :
This is executed during the configuration phase.
This is executed during the configuration phase as well, because :testBoth is used in
the build.

> Task :test
This is executed during the execution phase.

> Task :testBoth
This is executed first during the execution phase.
This is executed last during the execution phase.

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

```
> gradle test testBoth
This is executed during the initialization phase.

> Configure project :
This is executed during the configuration phase.
This is executed during the configuration phase as well, because :testBoth is used in
the build.

> Task :test
This is executed during the execution phase.

> Task :testBoth
This is executed first during the execution phase.
This is executed last during the execution phase.

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

Phase 1. Initialization

In the **initialization phase**, Gradle detects the set of projects (root and subprojects) and included builds participating in the build.

Gradle first evaluates the settings file, `settings.gradle(.kts)`, and instantiates a `Settings` object. Then, Gradle instantiates `Project` instances for each project.

Phase 2. Configuration

In the **configuration phase**, Gradle adds tasks and other properties to the projects found by the initialization phase.
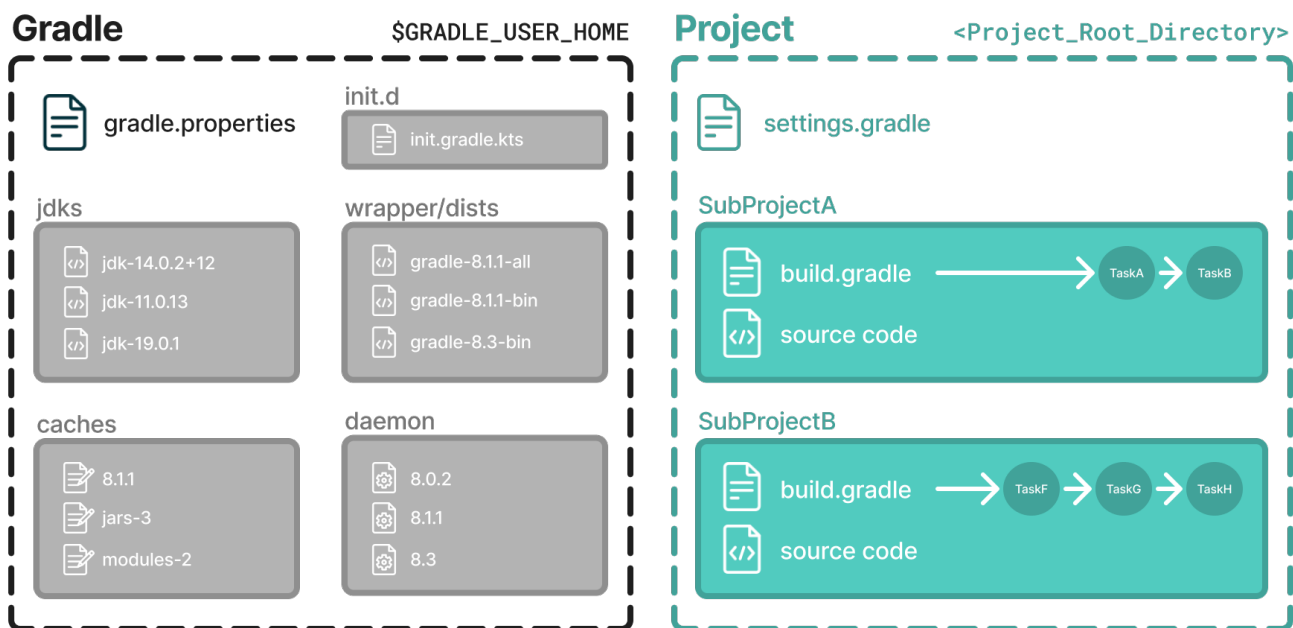
Phase 3. Execution

In the **execution phase**, Gradle runs tasks.

Gradle uses the task execution graphs generated by the configuration phase to determine which tasks to execute.

Gradle Directories

Gradle uses two main directories to perform and manage its work: the Gradle User Home directory and the Project Root directory.
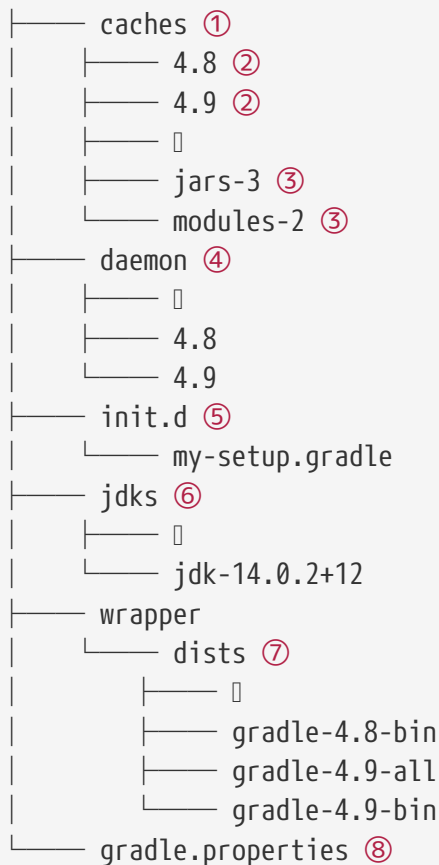

Gradle User Home directory

By default, the Gradle User Home (`~/.gradle` or `C:\Users\<USERNAME>\.gradle`) stores global configuration properties, initialization scripts, caches, and log files.

It can be set with the environment variable `GRADLE_USER_HOME`.

> **TIP** Not to be confused with the `GRADLE_HOME`, the optional installation directory for Gradle.

It is roughly structured as follows:

```
├──── caches ①
│    ├──── 4.8 ②
│    ├──── 4.9 ②
│    ├──── ⬚
│    ├──── jars-3 ③
│    └──── modules-2 ③
├──── daemon ④
│    ├──── ⬚
│    ├──── 4.8
│    └──── 4.9
├──── init.d ⑤
│    └──── my-setup.gradle
├──── jdks ⑥
│    ├──── ⬚
│    └──── jdk-14.0.2+12
├──── wrapper
│    └──── dists ⑦
│          ├──── ⬚
│          ├──── gradle-4.8-bin
│          ├──── gradle-4.9-all
│          └──── gradle-4.9-bin
└──── gradle.properties ⑧
```

① Global cache directory (for everything that is not project-specific).

② Version-specific caches (e.g., to support incremental builds).

③ Shared caches (e.g., for artifacts of dependencies).

④ Registry and logs of the Gradle Daemon.

⑤ Global initialization scripts.

⑥ JDKs downloaded by the toolchain support.

⑦ Distributions downloaded by the Gradle Wrapper.

⑧ Global Gradle configuration properties.

Cleanup of caches and distributions

Gradle automatically cleans its user home directory.

By default, the cleanup runs in the background when the Gradle daemon is stopped or shut down.

If using `--no-daemon`, it runs in the foreground after the build session.

The following cleanup strategies are applied periodically (by default, once every 24 hours):

- Version-specific caches in all `caches/<GRADLE_VERSION>/` directories are checked for whether they are still in use.

  If not, directories for release versions are deleted after 30 days of inactivity, and snapshot versions after 7 days.

- Shared caches in `caches/` (e.g., `jars-*`) are checked for whether they are still in use.

  If no Gradle version still uses them, they are deleted.

- Files in shared caches used by the current Gradle version in `caches/` (e.g., `jars-3` or `modules-2`) are checked for when they were last accessed.

  Depending on whether the file can be recreated locally or downloaded from a remote repository, it will be deleted after 7 or 30 days, respectively.

- Gradle distributions in `wrapper/dists/` are checked for whether they are still in use, i.e., whether there's a corresponding version-specific cache directory.

  Unused distributions are deleted.

Configuring cleanup of caches and distributions

The retention periods of the various caches can be configured.

Caches are classified into four categories:

- **Released wrapper distributions:** Distributions and related version-specific caches corresponding to released versions (e.g., `4.6.2` or `8.0`).

  Default retention for unused versions is 30 days.

- **Snapshot wrapper distributions:** Distributions and related version-specific caches corresponding to snapshot versions (e.g. `7.6-20221130141522+0000`).

  Default retention for unused versions is 7 days.

- **Downloaded resources:** Shared caches downloaded from a remote repository (e.g., cached dependencies).

  Default retention for unused resources is 30 days.

- **Created resources:** Shared caches that Gradle creates during a build (e.g., artifact transforms).

  Default retention for unused resources is 7 days.

The retention period for each category can be configured independently via an init script in Gradle User Home:

gradleUserHome/init.d/cache-settings.gradle.kts

```
beforeSettings {
    caches {
        releasedWrappers.setRemoveUnusedEntriesAfterDays(45)
        snapshotWrappers.setRemoveUnusedEntriesAfterDays(10)
        downloadedResources.setRemoveUnusedEntriesAfterDays(45)
        createdResources.setRemoveUnusedEntriesAfterDays(10)
    }
}
```

gradleUserHome/init.d/cache-settings.gradle

```
beforeSettings { settings ->
    settings.caches {
        releasedWrappers.removeUnusedEntriesAfterDays = 45
        snapshotWrappers.removeUnusedEntriesAfterDays = 10
        downloadedResources.removeUnusedEntriesAfterDays = 45
        createdResources.removeUnusedEntriesAfterDays = 10
    }
}
```

The frequency at which cache cleanup is invoked is also configurable.

There are three possible settings:

- **DEFAULT:** Cleanup is performed periodically in the background (currently once every 24 hours).

- **DISABLED:** Never cleanup Gradle User Home.

  This is useful in cases where Gradle User Home is ephemeral or delaying cleanup is desirable until an explicit point.

- **ALWAYS:** Cleanup is performed at the end of each build session.

  This is useful in cases where it's desirable to ensure that cleanup has occurred before proceeding.

  However, this performs cache cleanup during the build (rather than in the background), which can be expensive, so this option should only be used when necessary.

To disable cache cleanup:

gradleUserHome/init.d/cache-settings.gradle.kts

```
beforeSettings {
    caches {
        cleanup = Cleanup.DISABLED
    }
}
```

gradleUserHome/init.d/cache-settings.gradle

```
beforeSettings { settings ->
    settings.caches {
        cleanup = Cleanup.DISABLED
    }
}
```

NOTE	Cache cleanup settings can only be configured via init scripts and should be placed under the `init.d` directory in Gradle User Home. This effectively couples the configuration of cache cleanup to the Gradle User Home those settings apply to and limits the possibility of different conflicting settings from different projects being applied to the same directory.

Multiple versions of Gradle sharing a Gradle User Home

It is common to share a single Gradle User Home between multiple versions of Gradle.

As stated above, caches in Gradle User Home are version-specific. Different versions of Gradle will perform maintenance on only the version-specific caches associated with each version.

On the other hand, some caches are shared between versions (e.g., the dependency artifact cache or the artifact transform cache).

Beginning with Gradle version 8.0, the cache cleanup settings can be configured to custom retention periods. However, older versions have fixed retention periods (7 or 30 days, depending on the cache). These shared caches could be accessed by versions of Gradle with different settings to retain cache artifacts.

This means that:

- If the retention period is *not* customized, all versions that perform cleanup will have the same retention periods. There will be no effect due to sharing a Gradle User Home with multiple versions.
- If the retention period is customized for Gradle versions greater than or equal to version 8.0 to use retention periods *shorter* than the previously fixed periods, there will also be no effect.

The versions of Gradle aware of these settings will cleanup artifacts earlier than the previously fixed retention periods, and older versions will effectively not participate in the cleanup of shared caches.

- If the retention period is customized for Gradle versions greater than or equal to version 8.0 to use retention periods *longer* than the previously fixed periods, the older versions of Gradle may clean the shared caches earlier than what is configured.

  In this case, if it is desirable to maintain these shared cache entries for newer versions for longer retention periods, they will not be able to share a Gradle User Home with older versions. They will need to use a separate directory.

Another consideration when sharing the Gradle User Home with versions of Gradle before version 8.0 is that the DSL elements to configure the cache retention settings are unavailable in earlier versions, so this must be accounted for in any init script shared between versions. This can easily be handled by conditionally applying a version-compliant script.

NOTE	The version-compliant script should reside somewhere other than the `init.d` directory (such as a sub-directory), so it is not automatically applied.

To configure cache cleanup in a version-safe manner:

gradleUserHome/init.d/cache-settings.gradle.kts

```
if (GradleVersion.current() >= GradleVersion.version("8.0")) {
    apply(from = "gradle8/cache-settings.gradle.kts")
}
```

gradleUserHome/init.d/cache-settings.gradle

```
if (GradleVersion.current() >= GradleVersion.version('8.0')) {
    apply from: "gradle8/cache-settings.gradle"
}
```

Version-compliant cache configuration script:

gradleUserHome/init.d/gradle8/cache-settings.gradle.kts

```
beforeSettings {
    caches {
        releasedWrappers { setRemoveUnusedEntriesAfterDays(45) }
        snapshotWrappers { setRemoveUnusedEntriesAfterDays(10) }
        downloadedResources { setRemoveUnusedEntriesAfterDays(45) }
        createdResources { setRemoveUnusedEntriesAfterDays(10) }
    }
}
```

gradleUserHome/init.d/gradle8/cache-settings.gradle

```
beforeSettings { settings ->
    settings.caches {
        releasedWrappers.removeUnusedEntriesAfterDays = 45
        snapshotWrappers.removeUnusedEntriesAfterDays = 10
        downloadedResources.removeUnusedEntriesAfterDays = 45
        createdResources.removeUnusedEntriesAfterDays = 10
    }
}
```

Cache marking

Beginning with Gradle version 8.1, Gradle supports marking caches with a `CACHEDIR.TAG` file.

It follows the format described in the Cache Directory Tagging Specification. The purpose of this file is to allow tools to identify the directories that do not need to be searched or backed up.

By default, the directories `caches`, `wrapper/dists`, `daemon`, and `jdks` in the Gradle User Home are marked with this file.

Configuring cache marking

The cache marking feature can be configured via an init script in the Gradle User Home:

gradleUserHome/init.d/cache-settings.gradle.kts

```
beforeSettings {
    caches {
        // Disable cache marking for all caches
        markingStrategy = MarkingStrategy.NONE
    }
}
```

gradleUserHome/init.d/cache-settings.gradle

```
beforeSettings { settings ->
    settings.caches {
        // Disable cache marking for all caches
        markingStrategy = MarkingStrategy.NONE
    }
}
```

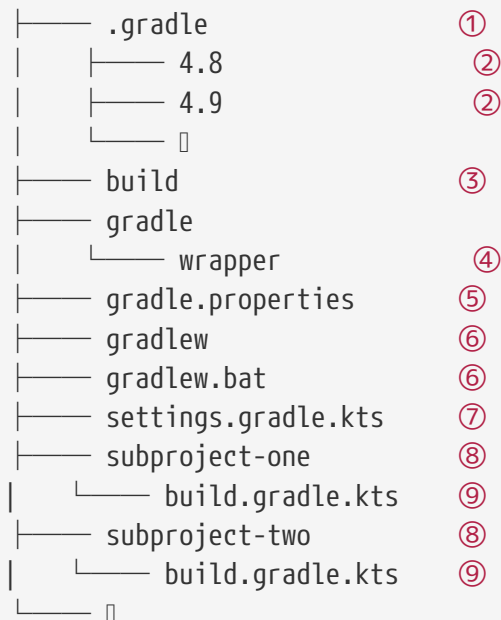| NOTE | Cache marking settings can only be configured via init scripts and should be placed under the `init.d` directory in Gradle User Home. This effectively couples the configuration of cache marking to the Gradle User Home to which those settings apply and limits the possibility of different conflicting settings from different projects being applied to the same directory. |

Project Root directory

The project root directory contains all source files from your project.

It also contains files and directories Gradle generates, such as `.gradle` and `build`.

While the former are usually checked into source control, the latter are transient files Gradle uses to support features like incremental builds.

The anatomy of a typical project root directory looks as follows:

```
├──     .gradle                    ①
│       ├──     4.8                ②
│       ├──     4.9                ②
│       └──     🗀
├──     build                      ③
├──     gradle
│       └──     wrapper            ④
├──     gradle.properties          ⑤
├──     gradlew                    ⑥
├──     gradlew.bat                ⑥
├──     settings.gradle.kts        ⑦
├──     subproject-one             ⑧
│       └──     build.gradle.kts   ⑨
├──     subproject-two             ⑧
│       └──     build.gradle.kts   ⑨
└──     🗀
```

① Project-specific cache directory generated by Gradle.

② Version-specific caches (e.g., to support incremental builds).

③ The build directory of this project into which Gradle generates all build artifacts.

④ Contains the JAR file and configuration of the Gradle Wrapper.

⑤ Project-specific Gradle configuration properties.

⑥ Scripts for executing builds using the Gradle Wrapper.

⑦ The project's settings file where the list of subprojects is defined.

⑧ Usually, a project is organized into one or multiple subprojects.

⑨ Each subproject has its own Gradle build script.

Project cache cleanup

From version 4.10 onwards, Gradle automatically cleans the project-specific cache directory.

After building the project, version-specific cache directories in `.gradle/8.6-milestone-1/` are checked periodically (at most, every 24 hours) to determine whether they are still in use. They are deleted if they haven't been used for 7 days.

Using Tasks

The work that Gradle can do on a project is defined by one or more *tasks*.

SubProjectB

build.gradle

```
                                                                    1. TASK NAME
TaskC   task.register('generateReport', Task) {
            doLast {
                def file = new File("$buildDir/report.txt")       2. TASK REGISTRATION / ACTION
                file.text = ${results}
                println "Generated file: ${file.path}"
            }
            dependsOn tasks.assemble
        }
                                                                    3. TASK GROUP / DESCRIPTION

TaskD   tasks.register('docFilesJar', Jar) {
            group = 'documentation'
            description = 'Generate documentation.'               4. TASK DEPENDENCY
            archiveVersion = null
            archiveFileName = 'doc-files.jar'
            from 'src/main/template'
        }                                                           5. TASK CONFIGURATION

        tasks.named('jar', Jar) {
            from docFilesJar                                      6. TASK TYPE
        }
```

A task represents some independent unit of work that a build performs. This might be compiling some classes, creating a JAR, generating Javadoc, or publishing some archives to a repository.

When a user runs `./gradlew build` in the command line, Gradle will execute the `build` task along with any other tasks it depends on.

List available tasks

Gradle provides several default tasks for a project, which are listed by running `./gradlew tasks`:

```
> Task :tasks

------------------------------------------------------------
Tasks runnable from root project 'myTutorial'
------------------------------------------------------------


Build Setup tasks
-----------------
init - Initializes a new Gradle build.
wrapper - Generates Gradle wrapper files.

Help tasks
----------
buildEnvironment - Displays all buildscript dependencies declared in root project
'myTutorial'.
...
```

Tasks either come from **build scripts** or **plugins**.

Once we apply a plugin to our project, such as the `application` plugin, additional tasks become

available:

build.gradle.kts

```
plugins {
    id("application")
}
```

```
$ ./gradlew tasks

> Task :tasks

------------------------------------------------------------
Tasks runnable from project ':app'
------------------------------------------------------------

Application tasks
-----------------
run - Runs this project as a JVM application

Build tasks
-----------
assemble - Assembles the outputs of this project.
build - Assembles and tests this project.

Documentation tasks
-------------------
javadoc - Generates Javadoc API documentation for the main source code.

Other tasks
-----------
compileJava - Compiles main Java source.

...
```

Many of these tasks, such as `assemble`, `build`, and `run`, should be familiar to a developer.

Task classification

There are two classes of tasks that can be executed:

1. **Actionable tasks** have some action(s) attached to do work in your build: `compileJava`.

2. **Lifecycle tasks** are tasks with no actions attached: `assemble`, `build`.

Typically, a **lifecycle** tasks depends on many **actionable** tasks, and is used to execute many tasks at once.

Task registration and action

Let's take a look at a simple "Hello World" task in a build script:

build.gradle.kts

```
tasks.register("hello") {
    doLast {
        println("Hello world!")
    }
}
```

build.gradle

```
tasks.register('hello') {
    doLast {
        println 'Hello world!'
    }
}
```

In the example, the build script **registers** a single task called `hello` using the TaskContainer API, and adds an **action** to it.

If the tasks in the project are listed, the `hello` task is available to Gradle:

```
$ ./gradlew app:tasks --all

> Task :app:tasks


------------------------------------------------------------
Tasks runnable from project ':app'
------------------------------------------------------------

Other tasks
-----------
compileJava - Compiles main Java source.
compileTestJava - Compiles test Java source.
hello
processResources - Processes main resources.
processTestResources - Processes test resources.
startScripts - Creates OS-specific scripts to run the project as a JVM application.
```

You can execute the task in the build script with `./gradlew hello`:

```
$ ./gradlew hello
Hello world!
```

When Gradle executes the `hello` task, it executes the **action** provided. In this case, the action is simply a block containing some code: `println("Hello world!")`.

Task group and description

The `hello` task from the previous section can be detailed with a **description** and assigned to a **group** with the following update:

build.gradle.kts

```
tasks.register("hello") {
    group = "Custom"
    description = "A lovely greeting task."
    doLast {
        println("Hello world!")
    }
}
```

Once the task is assigned to a group, it will be listed by `./gradlew tasks`:

```
$ ./gradlew tasks

> Task :tasks

Custom tasks
------------------
hello - A lovely greeting task.
```

To view information about a task, use the `help --task <task-name>` command:

```
$./gradlew help --task hello

> Task :help
Detailed task information for hello

Path
:app:hello

Type
Task (org.gradle.api.Task)

Options
--rerun     Causes the task to be re-run even if up-to-date.

Description
A lovely greeting task.

Group
Custom
```

As we can see, the `hello` task belongs to the `custom` group.

Task dependencies

You can declare tasks that depend on other tasks:

```
tasks.register("hello") {
    doLast {
        println("Hello world!")
    }
}
tasks.register("intro") {
    dependsOn("hello")
    doLast {
        println("I'm Gradle")
    }
}
```

```
tasks.register('hello') {
    doLast {
        println 'Hello world!'
    }
}
tasks.register('intro') {
    dependsOn tasks.hello
    doLast {
        println "I'm Gradle"
    }
}
```

```
$ gradle -q intro
Hello world!
I'm Gradle
```

The dependency of `taskX` to `taskY` may be declared before `taskY` is defined:

```kotlin
tasks.register("taskX") {
    dependsOn("taskY")
    doLast {
        println("taskX")
    }
}
tasks.register("taskY") {
    doLast {
        println("taskY")
    }
}
```

```groovy
tasks.register('taskX') {
    dependsOn 'taskY'
    doLast {
        println 'taskX'
    }
}
tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}
```

```
$ gradle -q taskX
taskY
taskX
```

The hello task from the previous example is updated to include a dependency:

build.gradle.kts

```
tasks.register("hello") {
    group = "Custom"
    description = "A lovely greeting task."
    doLast {
        println("Hello world!")
    }
    dependsOn(tasks.assemble)
}
```

The `hello` task now depends on the `assemble` task, which means that Gradle must execute the `assemble` task **before** it can execute the `hello` task:

```
$ ./gradlew :app:hello

> Task :app:compileJava UP-TO-DATE
> Task :app:processResources NO-SOURCE
> Task :app:classes UP-TO-DATE
> Task :app:jar UP-TO-DATE
> Task :app:startScripts UP-TO-DATE
> Task :app:distTar UP-TO-DATE
> Task :app:distZip UP-TO-DATE
> Task :app:assemble UP-TO-DATE

> Task :app:hello
Hello world!
```

Task configuration

Once registered, tasks can be accessed via the TaskProvider API for further configuration.

For instance, you can use this to add dependencies to a task at runtime dynamically:

```kotlin
repeat(4) { counter ->
    tasks.register("task$counter") {
        doLast {
            println("I'm task number $counter")
        }
    }
}
tasks.named("task0") { dependsOn("task2", "task3") }
```

```groovy
4.times { counter ->
    tasks.register("task$counter") {
        doLast {
            println "I'm task number $counter"
        }
    }
}
tasks.named('task0') { dependsOn('task2', 'task3') }
```

```
$ gradle -q task0
I'm task number 2
I'm task number 3
I'm task number 0
```

Or you can add behavior to an existing task:

build.gradle.kts

```kotlin
tasks.register("hello") {
    doLast {
        println("Hello Earth")
    }
}
tasks.named("hello") {
    doFirst {
        println("Hello Venus")
    }
}
tasks.named("hello") {
    doLast {
        println("Hello Mars")
    }
}
tasks.named("hello") {
    doLast {
        println("Hello Jupiter")
    }
}
```

build.gradle

```groovy
tasks.register('hello') {
    doLast {
        println 'Hello Earth'
    }
}
tasks.named('hello') {
    doFirst {
        println 'Hello Venus'
    }
}
tasks.named('hello') {
    doLast {
        println 'Hello Mars'
    }
}
tasks.named('hello') {
    doLast {
        println 'Hello Jupiter'
    }
}
```

```
$ gradle -q hello
Hello Venus
Hello Earth
Hello Mars
Hello Jupiter
```

TIP	The calls `doFirst` and `doLast` can be executed multiple times. They add an action to the beginning or the end of the task's actions list. When the task executes, the actions in the action list are executed in order.

Here is an example of the `named` method being used to configure a task added by a plugin:

```
tasks.named("dokkaHtml") {
    outputDirectory.set(buildDir.resolve("dokka"))
}
```

Task types

Gradle tasks are a subclass of `Task`.

In the build script, the `HelloTask` class is created by extending `DefaultTask`:

build.gradle.kts

```
// Extend the DefaultTask class to create a HelloTask class
abstract class HelloTask : DefaultTask() {
    @TaskAction
    fun hello() {
        println("hello from HelloTask")
    }
}

// Register the hello Task with type HelloTask
tasks.register<HelloTask>("hello") {
    group = "Custom tasks"
    description = "A lovely greeting task."
}
```

The `hello` task is registered with the **type** `HelloTask`.

Executing our new `hello` task:

```
$ ./gradlew hello

> Task :app:hello
hello from HelloTask
```

Now the `hello` task is of type `HelloTask` instead of type `Task`.

The Gradle `help` task reveals the change:

```
$ ./gradlew help --task hello

> Task :help
Detailed task information for hello

Path
:app:hello

Type
HelloTask (Build_gradle$HelloTask)

Options
--rerun     Causes the task to be re-run even if up-to-date.

Description
A lovely greeting task.

Group
Custom tasks
```

Built-in task types

Gradle provides many built-in task types with common and popular functionality, such as copying or deleting files.

This example task copies `*.war` files from the `source` directory to the `target` directory using the `Copy` built-in task:

```
tasks.register("copyTask",Copy) {
    from("source")
    into("target")
    include("*.war")
}
```

There are many task types developers can take advantage of, including `GroovyDoc`, `Zip`, `Jar`, `JacocoReport`, `Sign`, or `Delete`, which are available in the link:DSL.

Next Step: Learn how to write Tasks >>

Writing Build Scripts

The initialization phase in the Gradle Build lifecycle finds the root project and subprojects included in your project root directory using the settings file.
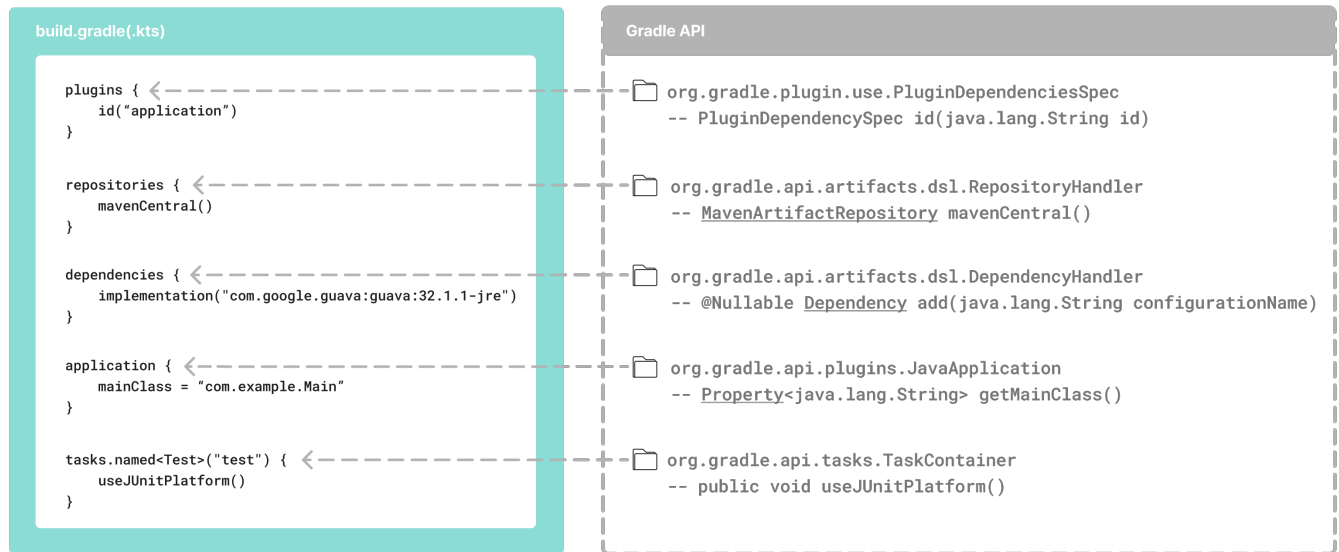
Then, for each project included in the settings file, Gradle creates a `Project` instance.

Gradle then looks for a corresponding build script file, which is used in the configuration phase.

Build Scripts

Every Gradle build comprises one or more **projects**; a *root* project and *subprojects*.

A project typically corresponds to a software component that needs to be built, like a library or an application. It might represent a library JAR, a web application, or a distribution ZIP assembled from the JARs produced by other projects.

On the other hand, it might represent a thing to be done, such as deploying your application to staging or production environments.

Gradle scripts are written in either Groovy DSL or Kotlin DSL (domain-specific language).

A **build script** configures a **project** and is associated with an object of type `Project`.

As the build script executes, it configures `Project`.

The build script is either a `*.gradle` file in Groovy or a `*.gradle.kts` file in Kotlin.

| **IMPORTANT** | *Build scripts* configure `Project` objects and their children. |

The `Project` object

The `Project` object is part of the Gradle API.

- In the Groovy DSL, the `Project` object documentation is found here.
- In the Kotlin DSL, the `Project` object documentation is found here.

Many top-level properties and blocks in a build script are part of the Project API.

For example, the following build script uses the Project.name property to print the name of the project:

build.gradle.kts

```
println(name)
println(project.name)
```

build.gradle

```
println name
println project.name
```

```
$ gradle -q check
project-api
project-api
```

Both `println` statements print out the same property.

The first uses the top-level reference to the `name` property of the `Project` object. The second statement uses the `project` property available to any build script, which returns the associated `Project` object.

Standard project properties

The `Project` object exposes a standard set of properties in your build script.

The following table lists a few commonly used properties:

Name	Type	Description
`name`	`String`	The name of the project directory.
`path`	`String`	The fully qualified name of the project.
`description`	`String`	A description for the project.

Name	Type	Description
dependencies	DependencyHandler	Returns the dependency handler of the project.
repositories	RepositoryHandler	Returns the repository handler of the project.
layout	ProjectLayout	Provides access to several important locations for a project.
group	Object	The group of this project.
version	Object	The version of this project.

The following table lists a few commonly used methods:

Name	Description
uri()	Resolves a file path to a URI, relative to the project directory of this project.
task()	Creates a Task with the given name and adds it to this project.

Build Script structure

The Build script is composed of { ⋯ }, a special object in both Groovy and Kotlin. This object is called a *lambda* in Kotlin or a *closure* in Groovy.

Simply put, the `plugins{ }` block is a method invocation in which a Kotlin *lambda* object or Groovy *closure* object is passed as the argument. It is the short form for:

```
plugins(function() {
    id("plugin")
})
```

Blocks are mapped to Gradle API methods.

The code inside the function is executed against a `this` object called a *receiver* in Kotlin lambda and a *delegate* in Groovy closure. Gradle determines the correct `this` object and invokes the correct corresponding method. The `this` of the method invocation `id("plugin")` object is of type `PluginDependenciesSpec`.

The build script is essentially composed of Gradle API calls built on top of the DSLs. Gradle executes the script line by line, top to bottom.

Let's take a look at an example and break it down:

build.gradle.kts

```
plugins {                                                         ①
    id("org.jetbrains.kotlin.jvm") version "1.9.0"
    id("application")
}

repositories {                                                    ②
    mavenCentral()
}

dependencies {                                                    ③
    testImplementation("org.jetbrains.kotlin:kotlin-test-junit5")
    testImplementation("org.junit.jupiter:junit-jupiter-engine:5.9.3")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
    implementation("com.google.guava:guava:32.1.1-jre")
}

application {                                                     ④
    mainClass = "com.example.Main"
}

tasks.named<Test>("test") {                                      ⑤
    useJUnitPlatform()
}
```

① Apply plugins to the build.

② Define the locations where dependencies can be found.

③ Add dependencies.

④ Set properties.

⑤ Register and configure tasks.

build.gradle

```
plugins {                                                            ①
    id 'org.jetbrains.kotlin.jvm' version '1.9.0'
    id 'application'
}

repositories {                                                       ②
    mavenCentral()
}

dependencies {                                                       ③
    testImplementation 'org.jetbrains.kotlin:kotlin-test-junit5'
    testImplementation 'org.junit.jupiter:junit-jupiter-engine:5.9.3'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'
    implementation 'com.google.guava:guava:32.1.1-jre'
}

application {                                                        ④
    mainClass = 'com.example.Main'
}

tasks.named('test') {                                                ⑤
    useJUnitPlatform()
}
```

① Apply plugins to the build.

② Define the locations where dependencies can be found.

③ Add dependencies.

④ Set properties.

⑤ Register and configure tasks.

1. Apply plugins to the build

Plugins are used to extend Gradle. They are also used to modularize and reuse project configurations.

Plugins can be applied using the `PluginDependenciesSpec` plugins script block.

The plugins block is preferred:

```
plugins {
    id("org.jetbrains.kotlin.jvm") version "1.9.0"
    id("application")
}
```

In the example, the `application` plugin, which is included with Gradle, has been applied, describing our project as a Java application.

The Kotlin gradle plugin, version 1.9.0, has also been applied. This plugin is not included with Gradle and, therefore, has to be described using a `plugin id` and a `plugin version` so that Gradle can find and apply it.

2. Define the locations where dependencies can be found

A project generally has a number of dependencies it needs to do its work. Dependencies include plugins, libraries, or components that Gradle must download for the build to succeed.

The build script lets Gradle know where to look for the binaries of the dependencies. More than one location can be provided:

```
repositories {
    mavenCentral()
    google()
}
```

In the example, the `guava` library and the JetBrains Kotlin plugin (`org.jetbrains.kotlin.jvm`) will be downloaded from the Maven Central Repository.

3. Add dependencies

A project generally has a number of dependencies it needs to do its work. These dependencies are often libraries of precompiled classes that are imported in the project's source code.

Dependencies are managed via configurations and are retrieved from repositories.

Use the `DependencyHandler` returned by `Project.getDependencies()` method to manage the dependencies. Use the `RepositoryHandler` returned by `Project.getRepositories()` method to manage the repositories.

```
dependencies {
    implementation("com.google.guava:guava:32.1.1-jre")
}
```

In the example, the application code uses Google's `guava` libraries. Guava provides utility methods for collections, caching, primitives support, concurrency, common annotations, string processing, I/O, and validations.

4. Set properties

A plugin can add properties and methods to a project using extensions.

The `Project` object has an associated `ExtensionContainer` object that contains all the settings and properties for the plugins that have been applied to the project.

In the example, the `application` plugin added an `application` property, which is used to detail the main class of our Java application:

```
application {
    mainClass = "com.example.Main"
}
```

5. Register and configure tasks

Tasks perform some basic piece of work, such as compiling classes, or running unit tests, or zipping up a WAR file.

While tasks are typically defined in plugins, you may need to register or configure tasks in build scripts.

Registering a task adds the task to your project.

You can register tasks in a project using the `TaskContainer.register(java.lang.String)` method:

```
tasks.register<Zip>("zip-reports") {
    from 'Reports/'
    include '*'
    archiveName 'Reports.zip'
    destinationDir(file('/dir'))
}
```

You may have seen usage of the `TaskContainer.create(java.lang.String)` method **which should be avoided**:

```
tasks.create<Zip>("zip-reports") {
    from 'Reports/'
    include '*'
    archiveName 'Reports.zip'
    destinationDir(file('/dir'))
}
```

> **TIP** `register()`, which enables [task configuration avoidance](), is preferred over `create()`.

You can locate a task to configure it using the `TaskCollection.named(java.lang.String)` method:

```
tasks.named<Test>("test") {
    useJUnitPlatform()
}
```

The example below configures the `Javadoc` task to automatically generate HTML documentation from Java code:

```
tasks.named("javadoc").configure {
    exclude 'app/Internal*.java'
    exclude 'app/internal/*'
    exclude 'app/internal/*'
}
```

Build Scripting

A build script is made up of zero or more statements and script blocks:

```
println(project.layout.projectDirectory);
```

Statements can include method calls, property assignments, and local variable definitions:

```
version = '1.0.0.GA'
```

A script block is a method call which takes a closure/lambda as a parameter:

```
configurations {
}
```

The closure/lambda configures some delegate object as it executes:

```
repositories {
    google()
}
```

A build script is also a Groovy or a Kotlin script:

```kotlin
tasks.register("upper") {
    doLast {
        val someString = "mY_nAmE"
        println("Original: $someString")
        println("Upper case: ${someString.toUpperCase()}")
    }
}
```

```groovy
tasks.register('upper') {
    doLast {
        String someString = 'mY_nAmE'
        println "Original: $someString"
        println "Upper case: ${someString.toUpperCase()}"
    }
}
```

```
$ gradle -q upper
Original: mY_nAmE
Upper case: MY_NAME
```

It can contain elements allowed in a Groovy or Kotlin script, such as method definitions and class definitions:

build.gradle.kts

```
tasks.register("count") {
    doLast {
        repeat(4) { print("$it ") }
    }
}
```

build.gradle

```
tasks.register('count') {
    doLast {
        4.times { print "$it " }
    }
}
```

```
$ gradle -q count
0 1 2 3
```

Flexible task registration

Using the capabilities of the Groovy or Kotlin language, you can register multiple tasks in a loop:

build.gradle

```groovy
4.times { counter ->
    tasks.register("task$counter") {
        doLast {
            println "I'm task number $counter"
        }
    }
}
```

```
$ gradle -q task1
I'm task number 1
```

Declare Variables

Build scripts can declare two variables: **local variables** and **extra properties**.

Local Variables

Declare local variables with the `val` keyword. Local variables are only visible in the scope where they have been declared. They are a feature of the underlying Kotlin language.

Declare local variables with the `def` keyword. Local variables are only visible in the scope where they have been declared. They are a feature of the underlying Groovy language.

build.gradle.kts

```kotlin
val dest = "dest"

tasks.register<Copy>("copy") {
    from("source")
    into(dest)
}
```

build.gradle

```groovy
def dest = 'dest'

tasks.register('copy', Copy) {
    from 'source'
    into dest
}
```

Extra Properties

Gradle's enhanced objects, including projects, tasks, and source sets, can hold user-defined properties.

Add, read, and set extra properties via the owning object's `extra` property. Alternatively, you can access extra properties via Kotlin delegated properties using `by extra`.

Add, read, and set extra properties via the owning object's `ext` property. Alternatively, you can use an `ext` block to add multiple properties simultaneously.

build.gradle.kts

```
plugins {
    id("java-library")
}

val springVersion by extra("3.1.0.RELEASE")
val emailNotification by extra { "build@master.org" }

sourceSets.all { extra["purpose"] = null }

sourceSets {
    main {
        extra["purpose"] = "production"
    }
    test {
        extra["purpose"] = "test"
    }
    create("plugin") {
        extra["purpose"] = "production"
    }
}

tasks.register("printProperties") {
    val springVersion = springVersion
    val emailNotification = emailNotification
    val productionSourceSets = provider {
        sourceSets.matching { it.extra["purpose"] == "production" }.map {
it.name }
    }
    doLast {
        println(springVersion)
        println(emailNotification)
        productionSourceSets.get().forEach { println(it) }
    }
}
```

build.gradle

```
plugins {
    id 'java-library'
}

ext {
    springVersion = "3.1.0.RELEASE"
    emailNotification = "build@master.org"
}

sourceSets.all { ext.purpose = null }

sourceSets {
    main {
        purpose = "production"
    }
    test {
        purpose = "test"
    }
    plugin {
        purpose = "production"
    }
}

tasks.register('printProperties') {
    def springVersion = springVersion
    def emailNotification = emailNotification
    def productionSourceSets = provider {
        sourceSets.matching { it.purpose == "production" }.collect { it.name
    }
    }
    doLast {
        println springVersion
        println emailNotification
        productionSourceSets.get().each { println it }
    }
}
```

```
$ gradle -q printProperties
3.1.0.RELEASE
build@master.org
main
plugin
```

This example adds two extra properties to the `project` object via `by extra`. Additionally, this

example adds a property named `purpose` to each source set by setting `extra["purpose"]` to `null`. Once added, you can read and set these properties via `extra`.

This example adds two extra properties to the `project` object via an `ext` block. Additionally, this example adds a property named `purpose` to each source set by setting `ext.purpose` to `null`. Once added, you can read and set all these properties just like predefined ones.

Gradle requires special syntax for adding a property so that it can fail fast. For example, this allows Gradle to recognize when a script attempts to set a property that does not exist. You can access extra properties anywhere where you can access their owning object. This gives extra properties a wider scope than local variables. Subprojects can access extra properties on their parent projects.

For more information about extra properties, see ExtraPropertiesExtension in the API documentation.

Configure Arbitrary Objects

The example `greet()` task shows an example of arbitrary object configuration:

```kotlin
class UserInfo(
    var name: String? = null,
    var email: String? = null
)

tasks.register("configure") {
    val user = UserInfo().apply {
        name = "Isaac Newton"
        email = "isaac@newton.me"
    }
    doLast {
        println(user.name)
        println(user.email)
    }
}
```

build.gradle

```groovy
class UserInfo {
    String name
    String email
}

tasks.register('configure') {
    def user = configure(new UserInfo()) {
        name = "Isaac Newton"
        email = "isaac@newton.me"
    }
    doLast {
        println user.name
        println user.email
    }
}
```

```
$ gradle -q greet
Isaac Newton
isaac@newton.me
```

Closure Delegates

Each closure has a `delegate` object. Groovy uses this delegate to look up variable and method references to nonlocal variables and closure parameters. Gradle uses this for *configuration closures,*

where the `delegate` object refers to the object being configured.

build.gradle

```gradle
dependencies {
    assert delegate == project.dependencies
    testImplementation('junit:junit:4.13')
    delegate.testImplementation('junit:junit:4.13')
}
```

Default imports

To make build scripts more concise, Gradle automatically adds a set of import statements to scripts.

As a result, instead of writing `throw new org.gradle.api.tasks.StopExecutionException()`, you can write `throw new StopExecutionException()` instead.

Gradle implicitly adds the following imports to each script:

Gradle default imports

```
import org.gradle.*
import org.gradle.api.*
import org.gradle.api.artifacts.*
import org.gradle.api.artifacts.component.*
import org.gradle.api.artifacts.dsl.*
import org.gradle.api.artifacts.ivy.*
import org.gradle.api.artifacts.maven.*
import org.gradle.api.artifacts.query.*
import org.gradle.api.artifacts.repositories.*
import org.gradle.api.artifacts.result.*
import org.gradle.api.artifacts.transform.*
import org.gradle.api.artifacts.type.*
import org.gradle.api.artifacts.verification.*
import org.gradle.api.attributes.*
import org.gradle.api.attributes.java.*
import org.gradle.api.attributes.plugin.*
import org.gradle.api.cache.*
import org.gradle.api.capabilities.*
import org.gradle.api.component.*
import org.gradle.api.configuration.*
import org.gradle.api.credentials.*
import org.gradle.api.distribution.*
import org.gradle.api.distribution.plugins.*
import org.gradle.api.execution.*
import org.gradle.api.file.*
import org.gradle.api.flow.*
```

```
import org.gradle.api.initialization.*
import org.gradle.api.initialization.definition.*
import org.gradle.api.initialization.dsl.*
import org.gradle.api.initialization.resolve.*
import org.gradle.api.invocation.*
import org.gradle.api.java.archives.*
import org.gradle.api.jvm.*
import org.gradle.api.launcher.cli.*
import org.gradle.api.logging.*
import org.gradle.api.logging.configuration.*
import org.gradle.api.model.*
import org.gradle.api.plugins.*
import org.gradle.api.plugins.antlr.*
import org.gradle.api.plugins.catalog.*
import org.gradle.api.plugins.jvm.*
import org.gradle.api.plugins.quality.*
import org.gradle.api.plugins.scala.*
import org.gradle.api.problems.*
import org.gradle.api.provider.*
import org.gradle.api.publish.*
import org.gradle.api.publish.ivy.*
import org.gradle.api.publish.ivy.plugins.*
import org.gradle.api.publish.ivy.tasks.*
import org.gradle.api.publish.maven.*
import org.gradle.api.publish.maven.plugins.*
import org.gradle.api.publish.maven.tasks.*
import org.gradle.api.publish.plugins.*
import org.gradle.api.publish.tasks.*
import org.gradle.api.reflect.*
import org.gradle.api.reporting.*
import org.gradle.api.reporting.components.*
import org.gradle.api.reporting.dependencies.*
import org.gradle.api.reporting.dependents.*
import org.gradle.api.reporting.model.*
import org.gradle.api.reporting.plugins.*
import org.gradle.api.resources.*
import org.gradle.api.services.*
import org.gradle.api.specs.*
import org.gradle.api.tasks.*
import org.gradle.api.tasks.ant.*
import org.gradle.api.tasks.application.*
import org.gradle.api.tasks.bundling.*
import org.gradle.api.tasks.compile.*
import org.gradle.api.tasks.diagnostics.*
import org.gradle.api.tasks.diagnostics.configurations.*
import org.gradle.api.tasks.incremental.*
import org.gradle.api.tasks.javadoc.*
import org.gradle.api.tasks.options.*
import org.gradle.api.tasks.scala.*
import org.gradle.api.tasks.testing.*
import org.gradle.api.tasks.testing.junit.*
```

```
import org.gradle.api.tasks.testing.junitplatform.*
import org.gradle.api.tasks.testing.testng.*
import org.gradle.api.tasks.util.*
import org.gradle.api.tasks.wrapper.*
import org.gradle.api.toolchain.management.*
import org.gradle.authentication.*
import org.gradle.authentication.aws.*
import org.gradle.authentication.http.*
import org.gradle.build.event.*
import org.gradle.buildinit.*
import org.gradle.buildinit.plugins.*
import org.gradle.buildinit.tasks.*
import org.gradle.caching.*
import org.gradle.caching.configuration.*
import org.gradle.caching.http.*
import org.gradle.caching.local.*
import org.gradle.concurrent.*
import org.gradle.external.javadoc.*
import org.gradle.ide.visualstudio.*
import org.gradle.ide.visualstudio.plugins.*
import org.gradle.ide.visualstudio.tasks.*
import org.gradle.ide.xcode.*
import org.gradle.ide.xcode.plugins.*
import org.gradle.ide.xcode.tasks.*
import org.gradle.ivy.*
import org.gradle.jvm.*
import org.gradle.jvm.application.scripts.*
import org.gradle.jvm.application.tasks.*
import org.gradle.jvm.tasks.*
import org.gradle.jvm.toolchain.*
import org.gradle.language.*
import org.gradle.language.assembler.*
import org.gradle.language.assembler.plugins.*
import org.gradle.language.assembler.tasks.*
import org.gradle.language.base.*
import org.gradle.language.base.artifact.*
import org.gradle.language.base.compile.*
import org.gradle.language.base.plugins.*
import org.gradle.language.base.sources.*
import org.gradle.language.c.*
import org.gradle.language.c.plugins.*
import org.gradle.language.c.tasks.*
import org.gradle.language.cpp.*
import org.gradle.language.cpp.plugins.*
import org.gradle.language.cpp.tasks.*
import org.gradle.language.java.artifact.*
import org.gradle.language.jvm.tasks.*
import org.gradle.language.nativeplatform.*
import org.gradle.language.nativeplatform.tasks.*
import org.gradle.language.objectivec.*
import org.gradle.language.objectivec.plugins.*
```

```
import org.gradle.language.objectivec.tasks.*
import org.gradle.language.objectivecpp.*
import org.gradle.language.objectivecpp.plugins.*
import org.gradle.language.objectivecpp.tasks.*
import org.gradle.language.plugins.*
import org.gradle.language.rc.*
import org.gradle.language.rc.plugins.*
import org.gradle.language.rc.tasks.*
import org.gradle.language.scala.tasks.*
import org.gradle.language.swift.*
import org.gradle.language.swift.plugins.*
import org.gradle.language.swift.tasks.*
import org.gradle.maven.*
import org.gradle.model.*
import org.gradle.nativeplatform.*
import org.gradle.nativeplatform.platform.*
import org.gradle.nativeplatform.plugins.*
import org.gradle.nativeplatform.tasks.*
import org.gradle.nativeplatform.test.*
import org.gradle.nativeplatform.test.cpp.*
import org.gradle.nativeplatform.test.cpp.plugins.*
import org.gradle.nativeplatform.test.cunit.*
import org.gradle.nativeplatform.test.cunit.plugins.*
import org.gradle.nativeplatform.test.cunit.tasks.*
import org.gradle.nativeplatform.test.googletest.*
import org.gradle.nativeplatform.test.googletest.plugins.*
import org.gradle.nativeplatform.test.plugins.*
import org.gradle.nativeplatform.test.tasks.*
import org.gradle.nativeplatform.test.xctest.*
import org.gradle.nativeplatform.test.xctest.plugins.*
import org.gradle.nativeplatform.test.xctest.tasks.*
import org.gradle.nativeplatform.toolchain.*
import org.gradle.nativeplatform.toolchain.plugins.*
import org.gradle.normalization.*
import org.gradle.platform.*
import org.gradle.platform.base.*
import org.gradle.platform.base.binary.*
import org.gradle.platform.base.component.*
import org.gradle.platform.base.plugins.*
import org.gradle.plugin.devel.*
import org.gradle.plugin.devel.plugins.*
import org.gradle.plugin.devel.tasks.*
import org.gradle.plugin.management.*
import org.gradle.plugin.use.*
import org.gradle.plugins.ear.*
import org.gradle.plugins.ear.descriptor.*
import org.gradle.plugins.ide.*
import org.gradle.plugins.ide.api.*
import org.gradle.plugins.ide.eclipse.*
import org.gradle.plugins.ide.idea.*
import org.gradle.plugins.signing.*
```

```
import org.gradle.plugins.signing.signatory.*
import org.gradle.plugins.signing.signatory.pgp.*
import org.gradle.plugins.signing.type.*
import org.gradle.plugins.signing.type.pgp.*
import org.gradle.process.*
import org.gradle.swiftpm.*
import org.gradle.swiftpm.plugins.*
import org.gradle.swiftpm.tasks.*
import org.gradle.testing.base.*
import org.gradle.testing.base.plugins.*
import org.gradle.testing.jacoco.plugins.*
import org.gradle.testing.jacoco.tasks.*
import org.gradle.testing.jacoco.tasks.rules.*
import org.gradle.testkit.runner.*
import org.gradle.util.*
import org.gradle.vcs.*
import org.gradle.vcs.git.*
import org.gradle.work.*
import org.gradle.workers.*
```

Using Plugins

Many Gradle features, like the ability to compile Java code, are added by *plugins*.

Plugins add new tasks (e.g., JavaCompile), domain objects (e.g., SourceSet), conventions (e.g., Java source is located at `src/main/java`), and extend core objects or objects from other plugins.

Applying a plugin to a project allows the plugin to extend the project's and Gradle's capabilities.

Plugins can:

- Extend the Gradle model (e.g., add new DSL elements that can be configured).
- Configure the project according to conventions (e.g., add new tasks or configure sensible defaults).
- Apply specific configuration (e.g., add organizational repositories or enforce standards).

There are many advantages to applying plugins over adding logic to the project build script:

- Promotes reuse and reduces the overhead of maintaining similar logic across multiple projects.
- Allows a higher degree of modularization, enhancing comprehensibility and organization.
- Encapsulates imperative logic and allows build scripts to be as declarative as possible.

Plugin distribution

Plugins are available in three ways:

1. **Core plugins** - Gradle develops and maintains a set of [Core Plugins](#).

2. **Community plugins** - Gradle plugins shared in a remote repository such as Maven or the [Gradle Plugin Portal](#).

3. **Local plugins** - Gradle enables users to create **custom** plugins using [APIs](#).

Types of plugins

There are two general types of plugins in Gradle: **binary** plugins and **script** plugins.

Binary plugins are written either programmatically by implementing the `Plugin` interface or through declarations in either Groovy or Kotlin DSL. They can reside within a build script, the project hierarchy, or externally in a plugin jar.

Script plugins are additional build scripts that further configure the build and usually implement a declarative approach to manipulating the build. They are typically used within a build but can be externalized and accessed remotely.

A plugin often starts as a script plugin (because they are easy to write). Then, as the code becomes more valuable, it's migrated to a binary plugin that can be easily tested and shared between multiple projects or organizations.

Using plugins

To use the build logic encapsulated in a plugin, Gradle needs to perform two steps. First, it needs to **resolve** the plugin, and then it needs to **apply** the plugin to the target, usually a `Project`.

Resolving a plugin means finding the correct version of the jar that contains a given plugin and adding it to the script classpath. Once a plugin is resolved, its API can be used in a build script. Script plugins are self-resolving in that they are resolved from the specific file path or URL provided when applying them. Core binary plugins provided as part of the Gradle distribution are automatically resolved.

Applying a plugin means executing the plugin's [Plugin.apply(T)](#) on the Project you want to enhance with the plugin.

The [plugins DSL](#) is recommended to resolve and apply plugins in one step.

Resolving plugins

Gradle provides the **core plugins** (e.g., `JavaPlugin`, `GroovyPlugin`, `MavenPublishPlugin`, etc.) as part of its distribution, which means they are automatically resolved.

```
plugins {
    id("java")
}
```

However, non-core plugins must be resolved before they can be applied. This can be achieved in several ways:

#	Application	Recommended Usage	Where
1	Using the `plugins` block	Applying **community** plugins or **local** plugins in `buildSrc` to a specific project.	Build script or Settings file

		<pre>plugins {
		    id("org.barfuin.gradle.taskinfo") version
		"2.1.0"
		}</pre>	

2	Using the `buildSrc` directory	Applying **community** or **local** plugins to multiple subprojects.	Build script

		<pre>plugins {
		    id("org.barfuin.gradle.taskinfo") version
		"2.1.0"
		}
		repositories {
		    jcenter()
		}
		dependencies {
		    implementation(Libs.Kotlin.coroutines)
		}</pre>	

3	Using the `buildscript` block	Applying **community** plugins to be used specifically in the build script or the build logic.	Build script

		<pre>buildscript {
		  repositories {
		    maven {
		      url =
		uri("https://plugins.gradle.org/m2/")
		    }
		  }
		  dependencies {
		
		classpath("org.barfuin.gradle.taskinfo:gradle-
		taskinfo:2.1.0")
		    }
		}
		plugins {
		  id("org.barfuin.gradle.taskinfo") version
		"2.1.0"
		}</pre>	

4	Using the legacy `apply()` method	Applying **local** script plugins.	Build script

#	Application	Recommended Usage	Where
		```apply(plugin = "org.barfuin.gradle.taskinfo")``` ```apply<MyPlugin>()```	

1. Applying plugins using the `plugins{}` block

The plugin DSL provides a concise and convenient way to declare plugin dependencies.

The plugins block configures an instance of `PluginDependenciesSpec`:

```
plugins {
    application                                // by name
    java                                       // by name
    id("java")                                 // by id - recommended
    id("org.jetbrains.kotlin.jvm") version "1.9.0"  // by id - recommended
}
```

Core Gradle plugins are unique in that they provide short names, such as `java` for the core JavaPlugin.

To apply a core plugin, the short **name** can be used:

build.gradle.kts

```
plugins {
    java
}
```

build.gradle

```
plugins {
    id 'java'
}
```

All other binary plugins must use the fully qualified form of the plugin id (e.g., `com.github.foo.bar`).

To apply a community plugin from Gradle plugin portal, the fully qualified **plugin id**, a globally unique identifier, must be used:

build.gradle.kts

```kotlin
plugins {
    id("com.jfrog.bintray") version "1.8.5"
}
```

build.gradle

```groovy
plugins {
    id 'com.jfrog.bintray' version '1.8.5'
}
```

See `PluginDependenciesSpec` for more information on using the Plugin DSL.

Limitations of the plugins DSL

The plugins DSL provides a convenient syntax for users and the ability for Gradle to determine which plugins are used quickly. This allows Gradle to:

- Optimize the loading and reuse of plugin classes.
- Provide editors with detailed information about the potential properties and values in the build script.

However, the DSL requires that plugins be defined statically.

There are some key differences between the `plugins {}` block mechanism and the "traditional" `apply()` method mechanism. There are also some constraints and possible limitations.

Constrained Syntax

The `plugins {}` block does not support arbitrary code.

It is constrained to be idempotent (produce the same result every time) and side effect-free (safe for Gradle to execute at any time).

The form is:

build.gradle.kts

```
plugins {
    id(«plugin id»)                             ①
    id(«plugin id») version «plugin version»    ②
}
```

① for core Gradle plugins or plugins already available to the build script

② for binary Gradle plugins that need to be resolved

build.gradle

```
plugins {
    id «plugin id»                             ①
    id «plugin id» version «plugin version»    ②
}
```

① for core Gradle plugins or plugins already available to the build script

② for binary Gradle plugins that need to be resolved

Where `«plugin id»` and `«plugin version»` are a string.

Where `«plugin id»` and `«plugin version»` must be constant, literal strings.

The `plugins{}` block must also be a top-level statement in the build script. It cannot be nested inside another construct (e.g., an if-statement or for-loop).

Only in build scripts and settings file

The `plugins{}` block can only be used in a project's build script `build.gradle(.kts)` and the `settings.gradle(.kts)` file. It must appear before any other block. It cannot be used in script plugins or init scripts.

Applying plugins to all subprojects

Suppose you have a multi-project build, you probably want to apply plugins to some or all of the subprojects in your build but not to the `root` project.

While the default behavior of the `plugins{}` block is to immediately `resolve` *and* `apply` the plugins, you can use the `apply false` syntax to tell Gradle not to apply the plugin to the current project. Then, use the `plugins{}` block without the version in subprojects' build scripts:

settings.gradle.kts

```
include("hello-a")
include("hello-b")
include("goodbye-c")
```

build.gradle.kts

```
plugins {
    id("com.example.hello") version "1.0.0" apply false
    id("com.example.goodbye") version "1.0.0" apply false
}
```

hello-a/build.gradle.kts

```
plugins {
    id("com.example.hello")
}
```

hello-b/build.gradle.kts

```
plugins {
    id("com.example.hello")
}
```

goodbye-c/build.gradle.kts

```
plugins {
    id("com.example.goodbye")
}
```

settings.gradle

```
include 'hello-a'
include 'hello-b'
include 'goodbye-c'
```

build.gradle

```
plugins {
    id 'com.example.hello' version '1.0.0' apply false
    id 'com.example.goodbye' version '1.0.0' apply false
}
```

hello-a/build.gradle

```
plugins {
    id 'com.example.hello'
}
```

hello-b/build.gradle

```
plugins {
    id 'com.example.hello'
}
```

goodbye-c/build.gradle

```
plugins {
    id 'com.example.goodbye'
}
```

You can also encapsulate the versions of external plugins by composing the build logic using your own convention plugins.

2. Applying plugins from the `buildSrc` directory

`buildSrc` is an optional directory at the Gradle project root that contains build logic (i.e., plugins) used in building the main project. You can apply plugins that reside in a project's `buildSrc` directory as long as they have a defined id.

The following example shows how to tie the plugin implementation class `my.MyPlugin`, defined in `buildSrc`, to the id "my-plugin":

buildSrc/build.gradle.kts

```kotlin
plugins {
    `java-gradle-plugin`
}

gradlePlugin {
    plugins {
        create("myPlugins") {
            id = "my-plugin"
            implementationClass = "my.MyPlugin"
        }
    }
}
```

buildSrc/build.gradle

```groovy
plugins {
    id 'java-gradle-plugin'
}

gradlePlugin {
    plugins {
        myPlugins {
            id = 'my-plugin'
            implementationClass = 'my.MyPlugin'
        }
    }
}
```

The plugin can then be applied by id:

build.gradle.kts

```
plugins {
    id("my-plugin")
}
```

build.gradle

```
plugins {
    id 'my-plugin'
}
```

3. Applying plugins using the `buildscript{}` block

The `buildscript` block is used for:

1. global `dependencies` and `repositories` required for building the project (applied in the subprojects).
2. declaring which plugins are available for use **in the build script** (in the `build.gradle(.kts)` file itself).

So when you want to use a library in the build script itself, you must add this library on the script classpath using `buildScript`:

```
import org.apache.commons.codec.binary.Base64

buildscript {
    repositories {  // this is where the plugins are located
        mavenCentral()
        google()
    }
    dependencies { // these are the plugins that can be used in subprojects or in the
build file itself
        classpath group: 'commons-codec', name: 'commons-codec', version: '1.2' //
used in the task below
        classpath 'com.android.tools.build:gradle:4.1.0' // used in subproject
    }
}

tasks.register('encode') {
    doLast {
        def byte[] encodedString = new Base64().encode('hello world\n'.getBytes())
        println new String(encodedString)
    }
}
```

And you can apply the globally declared dependencies in the subproject that needs it:

```
plugins {
    id 'com.android.application'
}
```

Binary plugins published as external jar files can be added to a project by adding the plugin to the build script classpath and then applying the plugin.

External jars can be added to the build script classpath using the `buildscript{}` block as described in External dependencies for the build script:

build.gradle.kts

```
buildscript {
    repositories {
        gradlePluginPortal()
    }
    dependencies {
        classpath("com.jfrog.bintray.gradle:gradle-bintray-plugin:1.8.5")
    }
}

apply(plugin = "com.jfrog.bintray")
```

build.gradle

```
buildscript {
    repositories {
        gradlePluginPortal()
    }
    dependencies {
        classpath 'com.jfrog.bintray.gradle:gradle-bintray-plugin:1.8.5'
    }
}

apply plugin: 'com.jfrog.bintray'
```

4. Applying script plugins using the legacy `apply()` method

A script plugin is an ad-hoc plugin, typically written and applied in the same build script. It is applied using the legacy application method:

```
class MyPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        println("Plugin ${this.javaClass.simpleName} applied on ${project.name}")
    }
}

apply<MyPlugin>()
```

Let's take a rudimentary example of a plugin written in a file called `other.gradle` located in the same directory as the `build.gradle` file:

```
public class Other implements Plugin<Project> {
    @Override
    void apply(Project project) {
        // Does something
    }
}
```

First, import the external file using:

```
apply from: 'other.gradle'
```

Then you can apply it:

```
apply plugin: Other
```

Script plugins are automatically resolved and can be applied from a script on the local filesystem or remotely:

build.gradle.kts

```
apply(from = "other.gradle.kts")
```

build.gradle

```
apply from: 'other.gradle'
```

Filesystem locations are relative to the project directory, while remote script locations are specified with an HTTP URL. Multiple script plugins (of either form) can be applied to a given target.

Plugin Management

The `pluginManagement{}` block may only appear in the `settings.gradle(.kts)` file, where it must be the first block in the file or in an Initialization Script:

settings.gradle.kts

```
pluginManagement {
    plugins {
    }
    resolutionStrategy {
    }
    repositories {
    }
}
rootProject.name = "plugin-management"
```

init.gradle.kts

```
settingsEvaluated {
    pluginManagement {
        plugins {
        }
        resolutionStrategy {
        }
        repositories {
        }
    }
}
```

settings.gradle

```
pluginManagement {
    plugins {
    }
    resolutionStrategy {
    }
    repositories {
    }
}
rootProject.name = 'plugin-management'
```

init.gradle

```
settingsEvaluated { settings ->
    settings.pluginManagement {
        plugins {
        }
        resolutionStrategy {
        }
        repositories {
        }
    }
}
```

Custom Plugin Repositories

By default, the `plugins{}` DSL resolves plugins from the public Gradle Plugin Portal.

Many build authors would also like to resolve plugins from private Maven or Ivy repositories because they contain proprietary implementation details or to have more control over what plugins are available to their builds.

To specify custom plugin repositories, use the `repositories{}` block inside `pluginManagement{}`:

settings.gradle.kts

```kotlin
pluginManagement {
    repositories {
        maven(url = "./maven-repo")
        gradlePluginPortal()
        ivy(url = "./ivy-repo")
    }
}
```

settings.gradle

```groovy
pluginManagement {
    repositories {
        maven {
            url './maven-repo'
        }
        gradlePluginPortal()
        ivy {
            url './ivy-repo'
        }
    }
}
```

This tells Gradle to first look in the Maven repository at `../maven-repo` when resolving plugins and then to check the Gradle Plugin Portal if the plugins are not found in the Maven repository. If you don't want the Gradle Plugin Portal to be searched, omit the `gradlePluginPortal()` line. Finally, the Ivy repository at `../ivy-repo` will be checked.

Plugin Version Management

A `plugins{}` block inside `pluginManagement{}` allows all plugin versions for the build to be defined in a single location. Plugins can then be applied by id to any build script via the `plugins{}` block.

One benefit of setting plugin versions this way is that the `pluginManagement.plugins{}` does not have the same constrained syntax as the build script `plugins{}` block. This allows plugin versions to be taken from `gradle.properties`, or loaded via another mechanism.

Managing plugin versions via `pluginManagement`:

settings.gradle.kts

```
pluginManagement {
  val helloPluginVersion: String by settings
  plugins {
    id("com.example.hello") version "${helloPluginVersion}"
  }
}
```

build.gradle.kts

```
plugins {
    id("com.example.hello")
}
```

gradle.properties

```
helloPluginVersion=1.0.0
```

settings.gradle

```
pluginManagement {
  plugins {
      id 'com.example.hello' version "${helloPluginVersion}"
    }
}
```

build.gradle

```
plugins {
    id 'com.example.hello'
}
```

gradle.properties

```
helloPluginVersion=1.0.0
```

The plugin version is loaded from `gradle.properties` and configured in the settings script, allowing the plugin to be added to any project without specifying the version.

Plugin Resolution Rules

Plugin resolution rules allow you to modify plugin requests made in `plugins{}` blocks, e.g., changing the requested version or explicitly specifying the implementation artifact coordinates.

To add resolution rules, use the `resolutionStrategy{}` inside the `pluginManagement{}` block:

```kotlin
pluginManagement {
    resolutionStrategy {
        eachPlugin {
            if (requested.id.namespace == "com.example") {
                useModule("com.example:sample-plugins:1.0.0")
            }
        }
    }
    repositories {
        maven {
            url = uri("./maven-repo")
        }
        gradlePluginPortal()
        ivy {
            url = uri("./ivy-repo")
        }
    }
}
```

settings.gradle

```groovy
pluginManagement {
    resolutionStrategy {
        eachPlugin {
            if (requested.id.namespace == 'com.example') {
                useModule('com.example:sample-plugins:1.0.0')
            }
        }
    }
    repositories {
        maven {
            url './maven-repo'
        }
        gradlePluginPortal()
        ivy {
            url './ivy-repo'
        }
    }
}
```

This tells Gradle to use the specified plugin implementation artifact instead of its built-in default mapping from plugin ID to Maven/Ivy coordinates.

Custom Maven and Ivy plugin repositories must contain plugin marker artifacts and the artifacts that implement the plugin. For more information on publishing plugins to custom repositories, read Gradle Plugin Development Plugin.

See PluginManagementSpec for complete documentation for using the `pluginManagement{}` block.

Plugin Marker Artifacts

Since the `plugins{}` DSL block only allows for declaring plugins by their globally unique plugin `id` and `version` properties, Gradle needs a way to look up the coordinates of the plugin implementation artifact.

To do so, Gradle will look for a Plugin Marker Artifact with the coordinates `plugin.id:plugin.id.gradle.plugin:plugin.version`. This marker needs to have a dependency on the actual plugin implementation. Publishing these markers is automated by the java-gradle-plugin.

For example, the following complete sample from the `sample-plugins` project shows how to publish a `com.example.hello` plugin and a `com.example.goodbye` plugin to both an Ivy and Maven repository using the combination of the java-gradle-plugin, the maven-publish plugin, and the ivy-publish plugin.

build.gradle.kts

```kotlin
plugins {
    `java-gradle-plugin`
    `maven-publish`
    `ivy-publish`
}

group = "com.example"
version = "1.0.0"

gradlePlugin {
    plugins {
        create("hello") {
            id = "com.example.hello"
            implementationClass = "com.example.hello.HelloPlugin"
        }
        create("goodbye") {
            id = "com.example.goodbye"
            implementationClass = "com.example.goodbye.GoodbyePlugin"
        }
    }
}

publishing {
    repositories {
        maven {
            url = uri(layout.buildDirectory.dir("maven-repo"))
        }
        ivy {
            url = uri(layout.buildDirectory.dir("ivy-repo"))
        }
    }
}
```

```gradle
plugins {
    id 'java-gradle-plugin'
    id 'maven-publish'
    id 'ivy-publish'
}

group 'com.example'
version '1.0.0'

gradlePlugin {
    plugins {
        hello {
            id = 'com.example.hello'
            implementationClass = 'com.example.hello.HelloPlugin'
        }
        goodbye {
            id = 'com.example.goodbye'
            implementationClass = 'com.example.goodbye.GoodbyePlugin'
        }
    }
}

publishing {
    repositories {
        maven {
            url layout.buildDirectory.dir("maven-repo")
        }
        ivy {
            url layout.buildDirectory.dir("ivy-repo")
        }
    }
}
```

Running `gradle publish` in the sample directory creates the following Maven repository layout (the Ivy layout is similar):
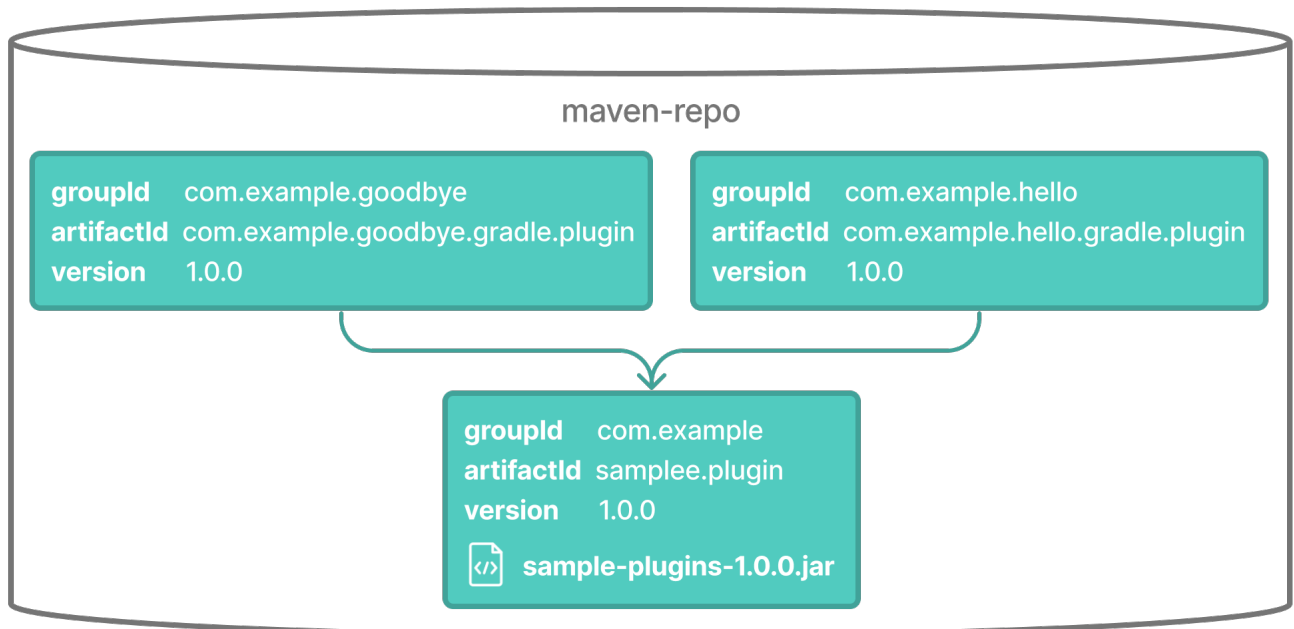
Legacy Plugin Application

With the introduction of the plugins DSL, users should have little reason to use the legacy method of applying plugins. It is documented here in case a build author cannot use the plugin DSL due to restrictions in how it currently works.

build.gradle.kts

```kotlin
apply(plugin = "java")
```

build.gradle

```groovy
apply plugin: 'java'
```

Plugins can be applied using a *plugin id*. In the above case, we are using the short name "java" to apply the JavaPlugin.

Rather than using a plugin id, plugins can also be applied by simply specifying the class of the plugin:

build.gradle.kts

```kotlin
apply<JavaPlugin>()
```

build.gradle

```groovy
apply plugin: JavaPlugin
```

The `JavaPlugin` symbol in the above sample refers to the JavaPlugin. This class does not strictly need to be imported as the `org.gradle.api.plugins` package is automatically imported in all build scripts (see Default imports).

Furthermore, one needs to append the `::class` suffix to identify a class literal in Kotlin instead of `.class` in Java.

Furthermore, it is unnecessary to append `.class` to identify a class literal in Groovy as it is in Java.

Using a Version Catalog

When a project uses a version catalog, plugins can be referenced via aliases when applied.

Let's take a look at a simple Version Catalog:

gradle/libs.versions.toml

```toml
[versions]
intellij-plugin = "1.6"

[plugins]
jetbrains-intellij = { id = "org.jetbrains.intellij", version.ref = "intellij-plugin"
}
```

Then a plugin can be applied to any build script using the `alias` method:

build.gradle.kts

```kotlin
plugins {
    alias(libs.plugins.jetbrains.intellij)
}
```

Working With Files

Almost every Gradle build interacts with files in some way: think source files, file dependencies, reports and so on. That's why Gradle comes with a comprehensive API that makes it simple to perform the file operations you need.

The API has two parts to it:

- Specifying which files and directories to process

- Specifying what to do with them

The File paths in depth section covers the first of these in detail, while subsequent sections, like File copying in depth, cover the second. To begin with, we'll show you examples of the most common scenarios that users encounter.

Copying a single file

You copy a file by creating an instance of Gradle's builtin Copy task and configuring it with the location of the file and where you want to put it. This example mimics copying a generated report into a directory that will be packed into an archive, such as a ZIP or TAR:

Example 18. How to copy a single file

build.gradle.kts

```
tasks.register<Copy>("copyReport") {
    from(layout.buildDirectory.file("reports/my-report.pdf"))
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```
tasks.register('copyReport', Copy) {
    from layout.buildDirectory.file("reports/my-report.pdf")
    into layout.buildDirectory.dir("toArchive")
}
```

The ProjectLayout class is used to find a file or directory path relative to the current project. This is a common way to make build scripts work regardless of the project path. The file and directory paths are then used to specify what file to copy using Copy.from(java.lang.Object...) and which directory to copy it to using Copy.into(java.lang.Object).

Although hard-coded paths make for simple examples, they also make the build brittle. It's better to use a reliable, single source of truth, such as a task or shared project property. In the following

modified example, we use a report task defined elsewhere that has the report's location stored in its `outputFile` property:

Example 19. Prefer task/project properties over hard-coded paths

build.gradle.kts

```kotlin
tasks.register<Copy>("copyReport2") {
    from(myReportTask.flatMap { it.outputFile })
    into(archiveReportsTask.flatMap { it.dirToArchive })
}
```

build.gradle

```groovy
tasks.register('copyReport2', Copy) {
    from myReportTask.outputFile
    into archiveReportsTask.dirToArchive
}
```

We have also assumed that the reports will be archived by `archiveReportsTask`, which provides us with the directory that will be archived and hence where we want to put the copies of the reports.

Copying multiple files

You can extend the previous examples to multiple files very easily by providing multiple arguments to `from()`:

Example 20. Using multiple arguments with from()

build.gradle.kts

```
tasks.register<Copy>("copyReportsForArchiving") {
    from(layout.buildDirectory.file("reports/my-report.pdf"),
layout.projectDirectory.file("src/docs/manual.pdf"))
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```
tasks.register('copyReportsForArchiving', Copy) {
    from layout.buildDirectory.file("reports/my-report.pdf"), layout
.projectDirectory.file("src/docs/manual.pdf")
    into layout.buildDirectory.dir("toArchive")
}
```

Two files are now copied into the archive directory. You can also use multiple `from()` statements to do the same thing, as shown in the first example of the section File copying in depth.

Now consider another example: what if you want to copy all the PDFs in a directory without having to specify each one? To do this, attach inclusion and/or exclusion patterns to the copy specification. Here we use a string pattern to include PDFs only:

Example 21. Using a flat filter

build.gradle.kts

```
tasks.register<Copy>("copyPdfReportsForArchiving") {
    from(layout.buildDirectory.dir("reports"))
    include("*.pdf")
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```
tasks.register('copyPdfReportsForArchiving', Copy) {
    from layout.buildDirectory.dir("reports")
    include "*.pdf"
    into layout.buildDirectory.dir("toArchive")
}
```

One thing to note, as demonstrated in the following diagram, is that only the PDFs that reside directly in the `reports` directory are copied:
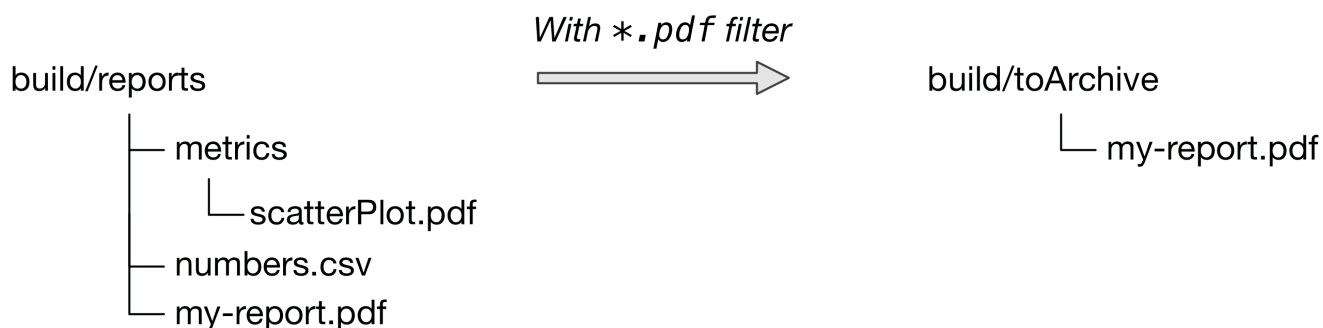
Figure 7. The effect of a flat filter on copying

You can include files in subdirectories by using an Ant-style glob pattern (`**/*`), as done in this updated example:

build.gradle.kts

```kotlin
tasks.register<Copy>("copyAllPdfReportsForArchiving") {
    from(layout.buildDirectory.dir("reports"))
    include("**/*.pdf")
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```groovy
tasks.register('copyAllPdfReportsForArchiving', Copy) {
    from layout.buildDirectory.dir("reports")
    include "**/*.pdf"
    into layout.buildDirectory.dir("toArchive")
}
```

This task has the following effect:
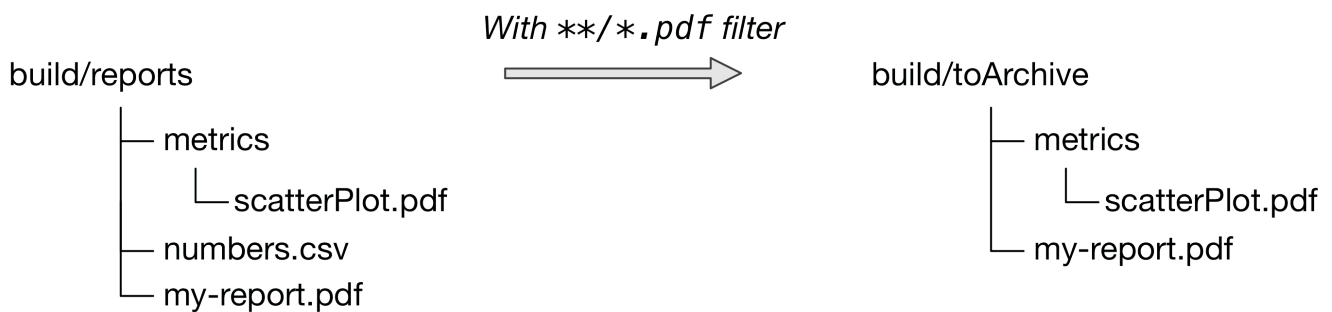
Figure 8. The effect of a deep filter on copying

One thing to bear in mind is that a deep filter like this has the side effect of copying the directory structure below `reports` as well as the files. If you just want to copy the files without the directory structure, you need to use an explicit `fileTree(dir) { includes }.files` expression. We talk more about the difference between file trees and file collections in the File trees section.

This is just one of the variations in behavior you're likely to come across when dealing with file operations in Gradle builds. Fortunately, Gradle provides elegant solutions to almost all those use cases. Read the *in-depth* sections later in the chapter for more detail on how the file operations work in Gradle and what options you have for configuring them.

Copying directory hierarchies

You may have a need to copy not just files, but the directory structure they reside in as well. This is the default behavior when you specify a directory as the `from()` argument, as demonstrated by the following example that copies everything in the `reports` directory, including all its subdirectories, to

the destination:

Example 23. Copying an entire directory

build.gradle.kts

```kotlin
tasks.register<Copy>("copyReportsDirForArchiving") {
    from(layout.buildDirectory.dir("reports"))
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```groovy
tasks.register('copyReportsDirForArchiving', Copy) {
    from layout.buildDirectory.dir("reports")
    into layout.buildDirectory.dir("toArchive")
}
```

The key aspect that users struggle with is controlling how much of the directory structure goes to the destination. In the above example, do you get a `toArchive/reports` directory or does everything in `reports` go straight into `toArchive`? The answer is the latter. If a directory is part of the `from()` path, then it *won't* appear in the destination.

So how do you ensure that `reports` itself is copied across, but not any other directory in `${layout.buildDirectory}`? The answer is to add it as an include pattern:

Example 24. Copying an entire directory, including itself

build.gradle.kts

```kotlin
tasks.register<Copy>("copyReportsDirForArchiving2") {
    from(layout.buildDirectory) {
        include("reports/**")
    }
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```groovy
tasks.register('copyReportsDirForArchiving2', Copy) {
    from(layout.buildDirectory) {
        include "reports/**"
    }
    into layout.buildDirectory.dir("toArchive")
}
```

You'll get the same behavior as before except with one extra level of directory in the destination, i.e. `toArchive/reports`.

One thing to note is how the `include()` directive applies only to the `from()`, whereas the directive in the previous section applied to the whole task. These different levels of granularity in the copy specification allow you to easily handle most requirements that you will come across. You can learn more about this in the section on child specifications.

Creating archives (zip, tar, etc.)

From the perspective of Gradle, packing files into an archive is effectively a copy in which the destination is the archive file rather than a directory on the file system. This means that creating archives looks a lot like copying, with all of the same features!

The simplest case involves archiving the entire contents of a directory, which this example demonstrates by creating a ZIP of the `toArchive` directory:

Example 25. Archiving a directory as a ZIP

build.gradle.kts

```
tasks.register<Zip>("packageDistribution") {
    archiveFileName = "my-distribution.zip"
    destinationDirectory = layout.buildDirectory.dir("dist")

    from(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```
tasks.register('packageDistribution', Zip) {
    archiveFileName = "my-distribution.zip"
    destinationDirectory = layout.buildDirectory.dir('dist')

    from layout.buildDirectory.dir("toArchive")
}
```

Notice how we specify the destination and name of the archive instead of an `into()`: both are required. You often won't see them explicitly set, because most projects apply the Base Plugin. It provides some conventional values for those properties. The next example demonstrates this and you can learn more about the conventions in the archive naming section.

Each type of archive has its own task type, the most common ones being Zip, Tar and Jar. They all share most of the configuration options of `Copy`, including filtering and renaming.

One of the most common scenarios involves copying files into specified subdirectories of the archive. For example, let's say you want to package all PDFs into a `docs` directory in the root of the archive. This `docs` directory doesn't exist in the source location, so you have to create it as part of the archive. You do this by adding an `into()` declaration for just the PDFs:

Example 26. Using the Base Plugin for its archive name convention

build.gradle.kts

```kotlin
plugins {
    base
}

version = "1.0.0"

tasks.register<Zip>("packageDistribution") {
    from(layout.buildDirectory.dir("toArchive")) {
        exclude("**/*.pdf")
    }

    from(layout.buildDirectory.dir("toArchive")) {
        include("**/*.pdf")
        into("docs")
    }
}
```

build.gradle

```groovy
plugins {
    id 'base'
}

version = "1.0.0"

tasks.register('packageDistribution', Zip) {
    from(layout.buildDirectory.dir("toArchive")) {
        exclude "**/*.pdf"
    }

    from(layout.buildDirectory.dir("toArchive")) {
        include "**/*.pdf"
        into "docs"
    }
}
```

As you can see, you can have multiple `from()` declarations in a copy specification, each with its own configuration. See Using child copy specifications for more information on this feature.

Unpacking archives

Archives are effectively self-contained file systems, so unpacking them is a case of copying the files from that file system onto the local file system — or even into another archive. Gradle enables this by providing some wrapper functions that make archives available as hierarchical collections of files (file trees).

The two functions of interest are Project.zipTree(java.lang.Object) and Project.tarTree(java.lang.Object), which produce a FileTree from a corresponding archive file. That file tree can then be used in a `from()` specification, like so:

Example 27. Unpacking a ZIP file

build.gradle.kts

```
tasks.register<Copy>("unpackFiles") {
    from(zipTree("src/resources/thirdPartyResources.zip"))
    into(layout.buildDirectory.dir("resources"))
}
```

build.gradle

```
tasks.register('unpackFiles', Copy) {
    from zipTree("src/resources/thirdPartyResources.zip")
    into layout.buildDirectory.dir("resources")
}
```

As with a normal copy, you can control which files are unpacked via filters and even rename files as they are unpacked.

More advanced processing can be handled by the eachFile() method. For example, you might need to extract different subtrees of the archive into different paths within the destination directory. The following sample uses the method to extract the files within the archive's `libs` directory into the root destination directory, rather than into a `libs` subdirectory:

Example 28. Unpacking a subset of a ZIP file

build.gradle.kts

```kotlin
tasks.register<Copy>("unpackLibsDirectory") {
    from(zipTree("src/resources/thirdPartyResources.zip")) {
        include("libs/**")    ①
        eachFile {
            relativePath = RelativePath(true,
    *relativePath.segments.drop(1).toTypedArray())    ②
        }
        includeEmptyDirs = false    ③
    }
    into(layout.buildDirectory.dir("resources"))
}
```

build.gradle

```groovy
tasks.register('unpackLibsDirectory', Copy) {
    from(zipTree("src/resources/thirdPartyResources.zip")) {
        include "libs/**"    ①
        eachFile { fcd ->
            fcd.relativePath = new RelativePath(true, fcd.relativePath
    .segments.drop(1))    ②
        }
        includeEmptyDirs = false    ③
    }
    into layout.buildDirectory.dir("resources")
}
```

① Extracts only the subset of files that reside in the `libs` directory

② Remaps the path of the extracting files into the destination directory by dropping the `libs` segment from the file path

③ Ignores the empty directories resulting from the remapping, see Caution note below

CAUTION	You can not change the destination path of empty directories with this technique. You can learn more in this issue.

If you're a Java developer and are wondering why there is no `jarTree()` method, that's because `zipTree()` works perfectly well for JARs, WARs and EARs.

Creating "uber" or "fat" JARs

In the Java space, applications and their dependencies typically used to be packaged as separate

JARs within a single distribution archive. That still happens, but there is another approach that is now common: placing the classes and resources of the dependencies directly into the application JAR, creating what is known as an uber or fat JAR.

Gradle makes this approach easy to accomplish. Consider the aim: to copy the contents of other JAR files into the application JAR. All you need for this is the Project.zipTree(java.lang.Object) method and the Jar task, as demonstrated by the `uberJar` task in the following example:

Example 29. Creating a Java uber or fat JAR

build.gradle.kts

```
plugins {
    java
}

version = "1.0.0"

repositories {
    mavenCentral()
}

dependencies {
    implementation("commons-io:commons-io:2.6")
}

tasks.register<Jar>("uberJar") {
    archiveClassifier = "uber"

    from(sourceSets.main.get().output)

    dependsOn(configurations.runtimeClasspath)
    from({
        configurations.runtimeClasspath.get().filter {
it.name.endsWith("jar") }.map { zipTree(it) }
    })
}
```

```
plugins {
    id 'java'
}

version = '1.0.0'

repositories {
    mavenCentral()
}

dependencies {
    implementation 'commons-io:commons-io:2.6'
}

tasks.register('uberJar', Jar) {
    archiveClassifier = 'uber'

    from sourceSets.main.output

    dependsOn configurations.runtimeClasspath
    from {
        configurations.runtimeClasspath.findAll { it.name.endsWith('jar') }
.collect { zipTree(it) }
    }
}
```

In this case, we're taking the runtime dependencies of the project — `configurations.runtimeClasspath.files` — and wrapping each of the JAR files with the `zipTree()` method. The result is a collection of ZIP file trees, the contents of which are copied into the uber JAR alongside the application classes.

Creating directories

Many tasks need to create directories to store the files they generate, which is why Gradle automatically manages this aspect of tasks when they explicitly define file and directory outputs. You can learn about this feature in the incremental build section of the user manual. All core Gradle tasks ensure that any output directories they need are created if necessary using this mechanism.

In cases where you need to create a directory manually, you can use the standard `Files.createDirectories` or `File.mkdirs` methods from within your build scripts or custom task implementations. Here's a simple example that creates a single `images` directory in the project folder:

Example 30. Manually creating a directory

build.gradle.kts

```
tasks.register("ensureDirectory") {
    // Store target directory into a variable to avoid project reference in
the configuration cache
    val directory = file("images")

    doLast {
        Files.createDirectories(directory.toPath())
    }
}
```

build.gradle

```
tasks.register('ensureDirectory') {
    // Store target directory into a variable to avoid project reference in
the configuration cache
    def directory = file("images")

    doLast {
        Files.createDirectories(directory.toPath())
    }
}
```

As described in the Apache Ant manual, the `mkdir` task will automatically create all necessary directories in the given path and will do nothing if the directory already exists.

Moving files and directories

Gradle has no API for moving files and directories around, but you can use the Apache Ant integration to easily do that, as shown in this example:

Example 31. Moving a directory using the Ant task

build.gradle.kts

```kotlin
tasks.register("moveReports") {
    // Store the build directory into a variable to avoid project reference
in the configuration cache
    val dir = buildDir

    doLast {
        ant.withGroovyBuilder {
            "move"("file" to "${dir}/reports", "todir" to "${dir}/toArchive")
        }
    }
}
```

build.gradle

```groovy
tasks.register('moveReports') {
    // Store the build directory into a variable to avoid project reference
in the configuration cache
    def dir = buildDir

    doLast {
        ant.move file: "${dir}/reports",
                 todir: "${dir}/toArchive"
    }
}
```

This is not a common requirement and should be used sparingly as you lose information and can easily break a build. It's generally preferable to copy directories and files instead.

Renaming files on copy

The files used and generated by your builds sometimes don't have names that suit, in which case you want to rename those files as you copy them. Gradle allows you to do this as part of a copy specification using the `rename()` configuration.

The following example removes the "-staging" marker from the names of any files that have it:

Example 32. Renaming files as they are copied

build.gradle.kts

```kotlin
tasks.register<Copy>("copyFromStaging") {
    from("src/main/webapp")
    into(layout.buildDirectory.dir("explodedWar"))

    rename("(.+)-staging(.+)", "$1$2")
}
```

build.gradle

```groovy
tasks.register('copyFromStaging', Copy) {
    from "src/main/webapp"
    into layout.buildDirectory.dir('explodedWar')

    rename '(.+)-staging(.+)', '$1$2'
}
```

You can use regular expressions for this, as in the above example, or closures that use more complex logic to determine the target filename. For example, the following task truncates filenames:

Example 33. Truncating filenames as they are copied

build.gradle.kts

```kotlin
tasks.register<Copy>("copyWithTruncate") {
    from(layout.buildDirectory.dir("reports"))
    rename { filename: String ->
        if (filename.length > 10) {
            filename.slice(0..7) + "~" + filename.length
        }
        else filename
    }
    into(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```groovy
tasks.register('copyWithTruncate', Copy) {
    from layout.buildDirectory.dir("reports")
    rename { String filename ->
        if (filename.size() > 10) {
            return filename[0..7] + "~" + filename.size()
        }
        else return filename
    }
    into layout.buildDirectory.dir("toArchive")
}
```

As with filtering, you can also apply renaming to a subset of files by configuring it as part of a child specification on a `from()`.

Deleting files and directories

You can easily delete files and directories using either the Delete task or the Project.delete(org.gradle.api.Action) method. In both cases, you specify which files and directories to delete in a way supported by the Project.files(java.lang.Object…) method.

For example, the following task deletes the entire contents of a build's output directory:

Example 34. Deleting a directory

build.gradle.kts

```
tasks.register<Delete>("myClean") {
    delete(buildDir)
}
```

build.gradle

```
tasks.register('myClean', Delete) {
    delete buildDir
}
```

If you want more control over which files are deleted, you can't use inclusions and exclusions in the same way as for copying files. Instead, you have to use the builtin filtering mechanisms of `FileCollection` and `FileTree`. The following example does just that to clear out temporary files from a source directory:

Example 35. Deleting files matching a specific pattern

build.gradle.kts

```
tasks.register<Delete>("cleanTempFiles") {
    delete(fileTree("src").matching {
        include("**/*.tmp")
    })
}
```

build.gradle

```
tasks.register('cleanTempFiles', Delete) {
    delete fileTree("src").matching {
        include "**/*.tmp"
    }
}
```

You'll learn more about file collections and file trees in the next section.

File paths in depth

In order to perform some action on a file, you need to know where it is, and that's the information provided by file paths. Gradle builds on the standard Java `File` class, which represents the location of a single file, and provides new APIs for dealing with collections of paths. This section shows you how to use the Gradle APIs to specify file paths for use in tasks and file operations.

But first, an important note on using hard-coded file paths in your builds.

On hard-coded file paths

Many examples in this chapter use hard-coded paths as string literals. This makes them easy to understand, but it's not good practice for real builds. The problem is that paths often change and the more places you need to change them, the more likely you are to miss one and break the build.

Where possible, you should use tasks, task properties, and project properties — in that order of preference — to configure file paths. For example, if you were to create a task that packages the compiled classes of a Java application, you should aim for something like this:

Example 36. How to minimize the number of hard-coded paths in your build

build.gradle.kts

```
val archivesDirPath = layout.buildDirectory.dir("archives")

tasks.register<Zip>("packageClasses") {
    archiveAppendix = "classes"
    destinationDirectory = archivesDirPath

    from(tasks.compileJava)
}
```

build.gradle

```
def archivesDirPath = layout.buildDirectory.dir('archives')

tasks.register('packageClasses', Zip) {
    archiveAppendix = "classes"
    destinationDirectory = archivesDirPath

    from compileJava
}
```

See how we're using the `compileJava` task as the source of the files to package and we've created a project property `archivesDirPath` to store the location where we put archives, on the basis we're

likely to use it elsewhere in the build.

Using a task directly as an argument like this relies on it having defined outputs, so it won't always be possible. In addition, this example could be improved further by relying on the Java plugin's convention for `destinationDirectory` rather than overriding it, but it does demonstrate the use of project properties.

Single files and directories

Gradle provides the Project.file(java.lang.Object) method for specifying the location of a single file or directory. Relative paths are resolved relative to the project directory, while absolute paths remain unchanged.

CAUTION	Never use `new File(relative path)` unless passed to `file()` or `files()` or `from()` or other methods being defined in terms of `file()` or `files()`. Otherwise this creates a path relative to the current working directory (CWD). Gradle can make no guarantees about the location of the CWD, which means builds that rely on it may break at any time.

Here are some examples of using the `file()` method with different types of argument:

Example 37. Locating files

build.gradle.kts

```
// Using a relative path
var configFile = file("src/config.xml")

// Using an absolute path
configFile = file(configFile.absolutePath)

// Using a File object with a relative path
configFile = file(File("src/config.xml"))

// Using a java.nio.file.Path object with a relative path
configFile = file(Paths.get("src", "config.xml"))

// Using an absolute java.nio.file.Path object
configFile = file(Paths.get(System.getProperty("user.home")).resolve("global-
config.xml"))
```

build.gradle

```
// Using a relative path
File configFile = file('src/config.xml')

// Using an absolute path
configFile = file(configFile.absolutePath)

// Using a File object with a relative path
configFile = file(new File('src/config.xml'))

// Using a java.nio.file.Path object with a relative path
configFile = file(Paths.get('src', 'config.xml'))

// Using an absolute java.nio.file.Path object
configFile = file(Paths.get(System.getProperty('user.home')).resolve('global-
config.xml'))
```

As you can see, you can pass strings, `File` instances and `Path` instances to the `file()` method, all of which result in an absolute `File` object. You can find other options for argument types in the reference guide, linked in the previous paragraph.

What happens in the case of multi-project builds? The `file()` method will always turn relative paths into paths that are relative to the current project directory, which may be a child project. If you want to use a path that's relative to the *root project* directory, then you need to use the special

Project.getRootDir() property to construct an absolute path, like so:

Example 38. Creating a path relative to a parent project

build.gradle.kts

```kotlin
val configFile = file("$rootDir/shared/config.xml")
```

build.gradle

```groovy
File configFile = file("$rootDir/shared/config.xml")
```

Let's say you're working on a multi-project build in a `dev/projects/AcmeHealth` directory. You use the above example in the build of the library you're fixing — at `AcmeHealth/subprojects/AcmePatientRecordLib/build.gradle`. The file path will resolve to the absolute version of `dev/projects/AcmeHealth/shared/config.xml`.

The `file()` method can be used to configure any task that has a property of type `File`. Many tasks, though, work on multiple files, so we look at how to specify sets of files next.

File collections

A *file collection* is simply a set of file paths that's represented by the FileCollection interface. *Any* file paths. It's important to understand that the file paths don't have to be related in any way, so they don't have to be in the same directory or even have a shared parent directory. You will also find that many parts of the Gradle API use `FileCollection`, such as the copying API discussed later in this chapter and dependency configurations.

The recommended way to specify a collection of files is to use the ProjectLayout.files(java.lang.Object…) method, which returns a `FileCollection` instance. This method is very flexible and allows you to pass multiple strings, `File` instances, collections of strings, collections of `File`s, and more. You can even pass in tasks as arguments if they have defined outputs. Learn about all the supported argument types in the reference guide.

| **CAUTION** | `files()` properly handle relative paths and `File(relative path)` instances, resolving them relative to the project directory. |

As with the Project.file(java.lang.Object) method covered in the previous section, all relative paths are evaluated relative to the current project directory. The following example demonstrates some of the variety of argument types you can use — strings, `File` instances, a list and a `Path`:

Example 39. Creating a file collection

build.gradle.kts

```kotlin
val collection: FileCollection = layout.files(
    "src/file1.txt",
    File("src/file2.txt"),
    listOf("src/file3.csv", "src/file4.csv"),
    Paths.get("src", "file5.txt")
)
```

build.gradle

```groovy
FileCollection collection = layout.files('src/file1.txt',
                              new File('src/file2.txt'),
                              ['src/file3.csv', 'src/file4.csv'],
                              Paths.get('src', 'file5.txt'))
```

File collections have some important attributes in Gradle. They can be:

- created lazily
- iterated over
- filtered
- combined

Lazy creation of a file collection is useful when you need to evaluate the files that make up a collection at the time a build runs. In the following example, we query the file system to find out what files exist in a particular directory and then make those into a file collection:

Example 40. Implementing a file collection

build.gradle.kts

```kotlin
tasks.register("list") {
    val projectDirectory = layout.projectDirectory
    doLast {
        var srcDir: File? = null

        val collection = projectDirectory.files({
            srcDir?.listFiles()
        })

        srcDir = projectDirectory.file("src").asFile
        println("Contents of ${srcDir.name}")
        collection.map { it.relativeTo(projectDirectory.asFile)
}.sorted().forEach { println(it) }

        srcDir = projectDirectory.file("src2").asFile
        println("Contents of ${srcDir.name}")
        collection.map { it.relativeTo(projectDirectory.asFile)
}.sorted().forEach { println(it) }
    }
}
```

build.gradle

```groovy
tasks.register('list') {
    Directory projectDirectory = layout.projectDirectory
    doLast {
        File srcDir

        // Create a file collection using a closure
        collection = projectDirectory.files { srcDir.listFiles() }

        srcDir = projectDirectory.file('src').asFile
        println "Contents of $srcDir.name"
        collection.collect { projectDirectory.asFile.relativePath(it) }.sort
().each { println it }

        srcDir = projectDirectory.file('src2').asFile
        println "Contents of $srcDir.name"
        collection.collect { projectDirectory.asFile.relativePath(it) }.sort
().each { println it }
    }
}
```

```
> gradle -q list
Contents of src
src/dir1
src/file1.txt
Contents of src2
src2/dir1
src2/dir2
```

The key to lazy creation is passing a closure (in Groovy) or a `Provider` (in Kotlin) to the `files()` method. Your closure/provider simply needs to return a value of a type accepted by `files()`, such as `List<File>`, `String`, `FileCollection`, etc.

Iterating over a file collection can be done through the `each()` method (in Groovy) or `forEach` method (in Kotlin) on the collection or using the collection in a `for` loop. In both approaches, the file collection is treated as a set of `File` instances, i.e. your iteration variable will be of type `File`.

The following example demonstrates such iteration as well as how you can convert file collections to other types using the `as` operator or supported properties:

Example 41. Using a file collection

build.gradle.kts

```kotlin
// Iterate over the files in the collection
collection.forEach { file: File ->
    println(file.name)
}

// Convert the collection to various types
val set: Set<File> = collection.files
val list: List<File> = collection.toList()
val path: String = collection.asPath
val file: File = collection.singleFile

// Add and subtract collections
val union = collection + projectLayout.files("src/file2.txt")
val difference = collection - projectLayout.files("src/file2.txt")
```

build.gradle

```groovy
// Iterate over the files in the collection
collection.each { File file ->
    println file.name
}

// Convert the collection to various types
Set set = collection.files
Set set2 = collection as Set
List list = collection as List
String path = collection.asPath
File file = collection.singleFile

// Add and subtract collections
def union = collection + projectLayout.files('src/file2.txt')
def difference = collection - projectLayout.files('src/file2.txt')
```

You can also see at the end of the example *how to combine file collections* using the `+` and `-` operators to merge and subtract them. An important feature of the resulting file collections is that they are *live*. In other words, when you combine file collections in this way, the result always reflects what's currently in the source file collections, even if they change during the build.

For example, imagine `collection` in the above example gains an extra file or two after `union` is created. As long as you use `union` after those files are added to `collection`, `union` will also contain those additional files. The same goes for the `different` file collection.

Live collections are also important when it comes to *filtering*. If you want to use a subset of a file collection, you can take advantage of the [FileCollection.filter(org.gradle.api.specs.Spec)](#) method to determine which files to "keep". In the following example, we create a new collection that consists of only the files that end with .txt in the source collection:

Example 42. Filtering a file collection

build.gradle.kts

```kotlin
val textFiles: FileCollection = collection.filter { f: File ->
    f.name.endsWith(".txt")
}
```

build.gradle

```groovy
FileCollection textFiles = collection.filter { File f ->
    f.name.endsWith(".txt")
}
```

Output of `gradle -q filterTextFiles`

```
> gradle -q filterTextFiles
src/file1.txt
src/file2.txt
src/file5.txt
```

If `collection` changes at any time, either by adding or removing files from itself, then `textFiles` will immediately reflect the change because it is also a live collection. Note that the closure you pass to `filter()` takes a `File` as an argument and should return a boolean.

File trees

A *file tree* is a file collection that retains the directory structure of the files it contains and has the type [FileTree](#). This means that all the paths in a file tree must have a shared parent directory. The following diagram highlights the distinction between file trees and file collections in the common case of copying files:

File collection

```
src/resources/img/logo.png

src/resources/img/banner.jpg

src/resources/data.txt
```

Copy `src/resources/**`
→
to `build/resources/`

```
build/resources
    ├── logo.png
    ├── banner.jpg
    └── data.txt
```

File tree

```
src/resources
    ├── img
    │   ├── logo.png
    │   └── banner.jpg
    └── data.txt
```

Copy `src/resources/**`
→
to `build/resources/`

```
build/resources
    ├── img
    │   ├── logo.png
    │   └── banner.jpg
    └── data.txt
```
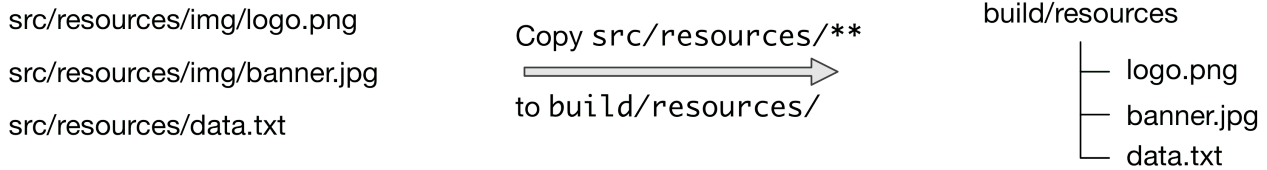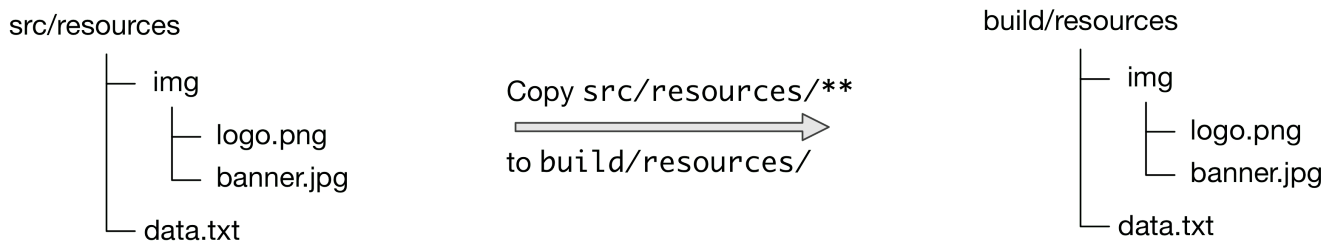
Figure 9. The differences in how file trees and file collections behave when copying files

NOTE	Although `FileTree` extends `FileCollection` (an is-a relationship), their behaviors do differ. In other words, you can use a file tree wherever a file collection is required, but remember: a file collection is a flat list/set of files, while a file tree is a file and directory hierarchy. To convert a file tree to a flat collection, use the FileTree.getFiles() property.

The simplest way to create a file tree is to pass a file or directory path to the Project.fileTree(java.lang.Object) method. This will create a tree of all the files and directories in that base directory (but not the base directory itself). The following example demonstrates how to use the basic method and, in addition, how to filter the files and directories using Ant-style patterns:

Example 43. Creating a file tree

build.gradle.kts

```kotlin
// Create a file tree with a base directory
var tree: ConfigurableFileTree = fileTree("src/main")

// Add include and exclude patterns to the tree
tree.include("**/*.java")
tree.exclude("**/Abstract*")

// Create a tree using closure
tree = fileTree("src") {
    include("**/*.java")
}

// Create a tree using a map
tree = fileTree("dir" to "src", "include" to "**/*.java")
tree = fileTree("dir" to "src", "includes" to listOf("**/*.java",
"**/*.xml"))
tree = fileTree("dir" to "src", "include" to "**/*.java", "exclude" to
"**/*test*/**")
```

build.gradle

```groovy
// Create a file tree with a base directory
ConfigurableFileTree tree = fileTree(dir: 'src/main')

// Add include and exclude patterns to the tree
tree.include '**/*.java'
tree.exclude '**/Abstract*'

// Create a tree using closure
tree = fileTree('src') {
    include '**/*.java'
}

// Create a tree using a map
tree = fileTree(dir: 'src', include: '**/*.java')
tree = fileTree(dir: 'src', includes: ['**/*.java', '**/*.xml'])
tree = fileTree(dir: 'src', include: '**/*.java', exclude: '**/*test*/**')
```

You can see more examples of supported patterns in the API docs for PatternFilterable. Also, see the API documentation for `fileTree()` to see what types you can pass as the base directory.

By default, `fileTree()` returns a `FileTree` instance that applies some default exclude patterns for

convenience — the same defaults as Ant in fact. For the complete default exclude list, see the Ant manual.

If those default excludes prove problematic, you can workaround the issue by changing the default excludes in the settings script:

Example 44. Changing default excludes in the settings script

settings.gradle.kts

```
import org.apache.tools.ant.DirectoryScanner

DirectoryScanner.removeDefaultExclude("**/.git")
DirectoryScanner.removeDefaultExclude("**/.git/**")
```

settings.gradle

```
import org.apache.tools.ant.DirectoryScanner

DirectoryScanner.removeDefaultExclude('**/.git')
DirectoryScanner.removeDefaultExclude('**/.git/**')
```

| NOTE | Currently, Gradle's default excludes are configured via Ant's `DirectoryScanner` class. |

| IMPORTANT | Gradle does not support changing default excludes during the execution phase. |

You can do many of the same things with file trees that you can with file collections:

- iterate over them (depth first)
- filter them (using FileTree.matching(org.gradle.api.Action) and Ant-style patterns)
- merge them

You can also traverse file trees using the FileTree.visit(org.gradle.api.Action) method. All of these techniques are demonstrated in the following example:

Example 45. Using a file tree

build.gradle.kts

```kotlin
// Iterate over the contents of a tree
tree.forEach{ file: File ->
    println(file)
}

// Filter a tree
val filtered: FileTree = tree.matching {
    include("org/gradle/api/**")
}

// Add trees together
val sum: FileTree = tree + fileTree("src/test")

// Visit the elements of the tree
tree.visit {
    println("${this.relativePath} => ${this.file}")
}
```

build.gradle

```groovy
// Iterate over the contents of a tree
tree.each {File file ->
    println file
}

// Filter a tree
FileTree filtered = tree.matching {
    include 'org/gradle/api/**'
}

// Add trees together
FileTree sum = tree + fileTree(dir: 'src/test')

// Visit the elements of the tree
tree.visit {element ->
    println "$element.relativePath => $element.file"
}
```

We've discussed how to create your own file trees and file collections, but it's also worth bearing in mind that many Gradle plugins provide their own instances of file trees, such as Java's source sets. These can be used and manipulated in exactly the same way as the file trees you create yourself.

Another specific type of file tree that users commonly need is the archive, i.e. ZIP files, TAR files, etc. We look at those next.

Using archives as file trees

An archive is a directory and file hierarchy packed into a single file. In other words, it's a special case of a file tree, and that's exactly how Gradle treats archives. Instead of using the `fileTree()` method, which only works on normal file systems, you use the Project.zipTree(java.lang.Object) and Project.tarTree(java.lang.Object) methods to wrap archive files of the corresponding type (note that JAR, WAR and EAR files are ZIPs). Both methods return `FileTree` instances that you can then use in the same way as normal file trees. For example, you can extract some or all of the files of an archive by copying its contents to some directory on the file system. Or you can merge one archive into another.

Here are some simple examples of creating archive-based file trees:

Example 46. Using an archive as a file tree

build.gradle.kts

```
// Create a ZIP file tree using path
val zip: FileTree = zipTree("someFile.zip")

// Create a TAR file tree using path
val tar: FileTree = tarTree("someFile.tar")

// tar tree attempts to guess the compression based on the file extension
// however if you must specify the compression explicitly you can:
val someTar: FileTree = tarTree(resources.gzip("someTar.ext"))
```

build.gradle

```
// Create a ZIP file tree using path
FileTree zip = zipTree('someFile.zip')

// Create a TAR file tree using path
FileTree tar = tarTree('someFile.tar')

//tar tree attempts to guess the compression based on the file extension
//however if you must specify the compression explicitly you can:
FileTree someTar = tarTree(resources.gzip('someTar.ext'))
```

You can see a practical example of extracting an archive file in among the common scenarios we cover.

Understanding implicit conversion to file collections

Many objects in Gradle have properties which accept a set of input files. For example, the JavaCompile task has a `source` property that defines the source files to compile. You can set the value of this property using any of the types supported by the files() method, as mentioned in the API docs. This means you can, for example, set the property to a `File`, `String`, collection, `FileCollection` or even a closure or `Provider`.

This is a feature of specific tasks! That means implicit conversion will not happen for just any task that has a `FileCollection` or `FileTree` property. If you want to know whether implicit conversion happens in a particular situation, you will need to read the relevant documentation, such as the corresponding task's API docs. Alternatively, you can remove all doubt by explicitly using ProjectLayout.files(java.lang.Object...) in your build.

Here are some examples of the different types of arguments that the `source` property can take:

Example 47. Specifying a set of files

build.gradle.kts

```kotlin
tasks.register<JavaCompile>("compile") {
    // Use a File object to specify the source directory
    source = fileTree(file("src/main/java"))

    // Use a String path to specify the source directory
    source = fileTree("src/main/java")

    // Use a collection to specify multiple source directories
    source = fileTree(listOf("src/main/java", "../shared/java"))

    // Use a FileCollection (or FileTree in this case) to specify the source
files
    source = fileTree("src/main/java").matching {
include("org/gradle/api/**") }

    // Using a closure to specify the source files.
    setSource({
        // Use the contents of each zip file in the src dir
        file("src").listFiles().filter { it.name.endsWith(".zip") }.map {
zipTree(it) }
    })
}
```

```
tasks.register('compile', JavaCompile) {

    // Use a File object to specify the source directory
    source = file('src/main/java')

    // Use a String path to specify the source directory
    source = 'src/main/java'

    // Use a collection to specify multiple source directories
    source = ['src/main/java', '../shared/java']

    // Use a FileCollection (or FileTree in this case) to specify the source
files
    source = fileTree(dir: 'src/main/java').matching { include
'org/gradle/api/**' }

    // Using a closure to specify the source files.
    source = {
        // Use the contents of each zip file in the src dir
        file('src').listFiles().findAll {it.name.endsWith('.zip')}.collect {
zipTree(it) }
    }
}
```

One other thing to note is that properties like `source` have corresponding methods in core Gradle tasks. Those methods follow the convention of *appending* to collections of values rather than replacing them. Again, this method accepts any of the types supported by the files() method, as shown here:

Example 48. Appending a set of files

build.gradle.kts

```kotlin
tasks.named<JavaCompile>("compile") {
    // Add some source directories use String paths
    source("src/main/java", "src/main/groovy")

    // Add a source directory using a File object
    source(file("../shared/java"))

    // Add some source directories using a closure
    setSource({ file("src/test/").listFiles() })
}
```

build.gradle

```groovy
compile {
    // Add some source directories use String paths
    source 'src/main/java', 'src/main/groovy'

    // Add a source directory using a File object
    source file('../shared/java')

    // Add some source directories using a closure
    source { file('src/test/').listFiles() }
}
```

As this is a common convention, we recommend that you follow it in your own custom tasks. Specifically, if you plan to add a method to configure a collection-based property, make sure the method appends rather than replaces values.

File copying in depth

The basic process of copying files in Gradle is a simple one:

- Define a task of type Copy
- Specify which files (and potentially directories) to copy
- Specify a destination for the copied files

But this apparent simplicity hides a rich API that allows fine-grained control of which files are copied, where they go, and what happens to them as they are copied — renaming of the files and token substitution of file content are both possibilities, for example.

Let's start with the last two items on the list, which form what is known as a *copy specification*. This is formally based on the CopySpec interface, which the `Copy` task implements, and offers:

- A CopySpec.from(java.lang.Object…) method to define what to copy
- An CopySpec.into(java.lang.Object) method to define the destination

`CopySpec` has several additional methods that allow you to control the copying process, but these two are the only required ones. `into()` is straightforward, requiring a directory path as its argument in any form supported by the Project.file(java.lang.Object) method. The `from()` configuration is far more flexible.

Not only does `from()` accept multiple arguments, it also allows several different types of argument. For example, some of the most common types are:

- A `String` — treated as a file path or, if it starts with "file://", a file URI
- A `File` — used as a file path
- A `FileCollection` or `FileTree` — all files in the collection are included in the copy
- A task — the files or directories that form a task's defined outputs are included

In fact, `from()` accepts all the same arguments as Project.files(java.lang.Object…) so see that method for a more detailed list of acceptable types.

Something else to consider is what type of thing a file path refers to:

- A file — the file is copied as is
- A directory — this is effectively treated as a file tree: everything in it, including subdirectories, is copied. However, the directory itself is not included in the copy.
- A non-existent file — the path is ignored

Here is an example that uses multiple `from()` specifications, each with a different argument type. You will probably also notice that `into()` is configured lazily using a closure (in Groovy) or a Provider (in Kotlin) — a technique that also works with `from()`:

Example 49. Specifying copy task source files and destination directory

build.gradle.kts

```
tasks.register<Copy>("anotherCopyTask") {
    // Copy everything under src/main/webapp
    from("src/main/webapp")
    // Copy a single file
    from("src/staging/index.html")
    // Copy the output of a task
    from(copyTask)
    // Copy the output of a task using Task outputs explicitly.
    from(tasks["copyTaskWithPatterns"].outputs)
    // Copy the contents of a Zip file
    from(zipTree("src/main/assets.zip"))
    // Determine the destination directory later
    into({ getDestDir() })
}
```

build.gradle

```
tasks.register('anotherCopyTask', Copy) {
    // Copy everything under src/main/webapp
    from 'src/main/webapp'
    // Copy a single file
    from 'src/staging/index.html'
    // Copy the output of a task
    from copyTask
    // Copy the output of a task using Task outputs explicitly.
    from copyTaskWithPatterns.outputs
    // Copy the contents of a Zip file
    from zipTree('src/main/assets.zip')
    // Determine the destination directory later
    into { getDestDir() }
}
```

Note that the lazy configuration of `into()` is different from a child specification, even though the syntax is similar. Keep an eye on the number of arguments to distinguish between them.

Filtering files

You've already seen that you can filter file collections and file trees directly in a `Copy` task, but you can also apply filtering in any copy specification through the CopySpec.include(java.lang.String…) and CopySpec.exclude(java.lang.String…) methods.

Both of these methods are normally used with Ant-style include or exclude patterns, as described in

PatternFilterable. You can also perform more complex logic by using a closure that takes a FileTreeElement and returns `true` if the file should be included or `false` otherwise. The following example demonstrates both forms, ensuring that only .html and .jsp files are copied, except for those .html files with the word "DRAFT" in their content:

Example 50. Selecting the files to copy

build.gradle.kts

```
tasks.register<Copy>("copyTaskWithPatterns") {
    from("src/main/webapp")
    into(layout.buildDirectory.dir("explodedWar"))
    include("**/*.html")
    include("**/*.jsp")
    exclude { details: FileTreeElement ->
        details.file.name.endsWith(".html") &&
            details.file.readText().contains("DRAFT")
    }
}
```

build.gradle

```
tasks.register('copyTaskWithPatterns', Copy) {
    from 'src/main/webapp'
    into layout.buildDirectory.dir('explodedWar')
    include '**/*.html'
    include '**/*.jsp'
    exclude { FileTreeElement details ->
        details.file.name.endsWith('.html') &&
            details.file.text.contains('DRAFT')
    }
}
```

A question you may ask yourself at this point is what happens when inclusion and exclusion patterns overlap? Which pattern wins? Here are the basic rules:

- If there are no explicit inclusions or exclusions, everything is included

- If at least one inclusion is specified, only files and directories matching the patterns are included

- Any exclusion pattern overrides any inclusions, so if a file or directory matches at least one exclusion pattern, it won't be included, regardless of the inclusion patterns

Bear these rules in mind when creating combined inclusion and exclusion specifications so that you end up with the exact behavior you want.

Note that the inclusions and exclusions in the above example will apply to *all* `from()` configurations. If you want to apply filtering to a subset of the copied files, you'll need to use child specifications.

Renaming files

The example of how to rename files on copy gives you most of the information you need to perform this operation. It demonstrates the two options for renaming:

- Using a regular expression
- Using a closure

Regular expressions are a flexible approach to renaming, particularly as Gradle supports regex groups that allow you to remove and replaces parts of the source filename. The following example shows how you can remove the string "-staging" from any filename that contains it using a simple regular expression:

Example 51. Renaming files as they are copied

build.gradle.kts

```
tasks.register<Copy>("rename") {
    from("src/main/webapp")
    into(layout.buildDirectory.dir("explodedWar"))
    // Use a regular expression to map the file name
    rename("(.+)-staging(.+)", "$1$2")
    rename("(.+)-staging(.+)".toRegex().pattern, "$1$2")
    // Use a closure to convert all file names to upper case
    rename { fileName: String ->
        fileName.toUpperCase()
    }
}
```

build.gradle

```
tasks.register('rename', Copy) {
    from 'src/main/webapp'
    into layout.buildDirectory.dir('explodedWar')
    // Use a regular expression to map the file name
    rename '(.+)-staging(.+)', '$1$2'
    rename(/(.+)-staging(.+)/, '$1$2')
    // Use a closure to convert all file names to upper case
    rename { String fileName ->
        fileName.toUpperCase()
    }
}
```

You can use any regular expression supported by the Java `Pattern` class and the substitution string (the second argument of `rename()` works on the same principles as the `Matcher.appendReplacement()` method.

Regular expressions in Groovy build scripts

There are two common issues people come across when using regular expressions in this context:

1. If you use a slashy string (those delimited by '/') for the first argument, you *must* include the parentheses for `rename()` as shown in the above example.

2. It's safest to use single quotes for the second argument, otherwise you need to escape the '$' in group substitutions, i.e. `"\$1\$2"`.

The first is a minor inconvenience, but slashy strings have the advantage that you don't have to escape backslash ('\') characters in the regular expression. The second issue stems from Groovy's support for embedded expressions using `${ }` syntax in double-quoted and slashy strings.

The closure syntax for `rename()` is straightforward and can be used for any requirements that simple regular expressions can't handle. You're given the name of a file and you return a new name for that file, or `null` if you don't want to change the name. Do be aware that the closure will be executed for every file that's copied, so try to avoid expensive operations where possible.

Filtering file content (token substitution, templating, etc.)

Not to be confused with filtering which files are copied, *file content filtering* allows you to transform the content of files while they are being copied. This can involve basic templating that uses token substitution, removal of lines of text, or even more complex filtering using a full-blown template engine.

The following example demonstrates several forms of filtering, including token substitution using the CopySpec.expand(java.util.Map) method and another using CopySpec.filter(java.lang.Class) with an Ant filter:

Example 52. Filtering files as they are copied

build.gradle.kts

```
import org.apache.tools.ant.filters.FixCrLfFilter
import org.apache.tools.ant.filters.ReplaceTokens
tasks.register<Copy>("filter") {
    from("src/main/webapp")
    into(layout.buildDirectory.dir("explodedWar"))
    // Substitute property tokens in files
    expand("copyright" to "2009", "version" to "2.3.1")
    // Use some of the filters provided by Ant
    filter(FixCrLfFilter::class)
    filter(ReplaceTokens::class, "tokens" to mapOf("copyright" to "2009",
"version" to "2.3.1"))
    // Use a closure to filter each line
    filter { line: String ->
        "[$line]"
    }
    // Use a closure to remove lines
    filter { line: String ->
        if (line.startsWith('-')) null else line
    }
    filteringCharset = "UTF-8"
}
```

```
import org.apache.tools.ant.filters.FixCrLfFilter
import org.apache.tools.ant.filters.ReplaceTokens

tasks.register('filter', Copy) {
    from 'src/main/webapp'
    into layout.buildDirectory.dir('explodedWar')
    // Substitute property tokens in files
    expand(copyright: '2009', version: '2.3.1')
    // Use some of the filters provided by Ant
    filter(FixCrLfFilter)
    filter(ReplaceTokens, tokens: [copyright: '2009', version: '2.3.1'])
    // Use a closure to filter each line
    filter { String line ->
        "[$line]"
    }
    // Use a closure to remove lines
    filter { String line ->
        line.startsWith('-') ? null : line
    }
    filteringCharset = 'UTF-8'
}
```

The `filter()` method has two variants, which behave differently:

- one takes a `FilterReader` and is designed to work with Ant filters, such as `ReplaceTokens`

- one takes a closure or `Transformer` that defines the transformation for each line of the source file

Note that both variants assume the source files are text based. When you use the `ReplaceTokens` class with `filter()`, the result is a template engine that replaces tokens of the form `@tokenName@` (the Ant-style token) with values that you define.

The `expand()` method treats the source files as Groovy templates, which evaluate and expand expressions of the form `${expression}`. You can pass in property names and values that are then expanded in the source files. `expand()` allows for more than basic token substitution as the embedded expressions are full-blown Groovy expressions.

NOTE	It's good practice to specify the character set when reading and writing the file, otherwise the transformations won't work properly for non-ASCII text. You configure the character set with the CopySpec.setFilteringCharset(String) property. If it's not specified, the JVM default character set is used, which is likely to be different from the one you want.

Setting file permissions

For any `CopySpec` involved in copying files, may it be the `Copy` task itself, or any child specifications, you can explicitly set the permissions the destination files will have, via the `CopySpec.filePermissions {}` configurations block. You can do the same for directories too, independently of files, via the `CopySpec.dirPermissions {}` configurations block.

NOTE	Not setting permissions explicitly will preserve the permissions of the original files or directories.

Example 53. Setting permissions for destination files

build.gradle.kts

```
tasks.register<Copy>("permissions") {
    from("src/main/webapp")
    into(layout.buildDirectory.dir("explodedWar"))
    filePermissions {
        user {
            read = true
            execute = true
        }
        other.execute = false
    }
    dirPermissions {
        unix("r-xr-x---")
    }
}
```

build.gradle

```
tasks.register('permissions', Copy) {
    from 'src/main/webapp'
    into layout.buildDirectory.dir('explodedWar')
    filePermissions {
        user {
            read = true
            execute = true
        }
        other.execute = false
    }
    dirPermissions {
        unix('r-xr-x---')
    }
}
```

For a detailed description of file permissions see FilePermissions and UserClassFilePermissions. For details on the convenience method used in the samples see ConfigurableFilePermissions.unix(String).

Using empty configuration blocks for file or directory permissions still sets them explicitly, just to fixed default values. In fact everything that's inside one of these configurations blocks is relative to the default values. Default permissions differ for files and directories:

- **file**: read & write for **owner**, read for **group**, read for **other** (**0644, rw-r—r--**)
- **directory**: read, write & execute for **owner**, read & execute for **group**, read & execute for **other** (**0755, rwxr-xr-x**)

Using the `CopySpec` class

A copy specification (or copy spec for short) determines what gets copied to where, and what happens to files during the copy. You've alread seen many examples in the form of configuration for `Copy` and archiving tasks. But copy specs have two attributes that are worth covering in more detail:

1. They can be independent of tasks
2. They are hierarchical

The first of these attributes allows you to *share copy specs within a build*. The second provides fine-grained control within the overall copy specification.

Sharing copy specs

Consider a build that has several tasks that copy a project's static website resources or add them to an archive. One task might copy the resources to a folder for a local HTTP server and another might package them into a distribution. You could manually specify the file locations and appropriate inclusions each time they are needed, but human error is more likely to creep in, resulting in inconsistencies between tasks.

One solution Gradle provides is the Project.copySpec(org.gradle.api.Action) method. This allows you to create a copy spec outside of a task, which can then be attached to an appropriate task using the CopySpec.with(org.gradle.api.file.CopySpec…) method. The following example demonstrates how this is done:

Example 54. Sharing copy specifications

build.gradle.kts

```kotlin
val webAssetsSpec: CopySpec = copySpec {
    from("src/main/webapp")
    include("**/*.html", "**/*.png", "**/*.jpg")
    rename("(.+)-staging(.+)", "$1$2")
}

tasks.register<Copy>("copyAssets") {
    into(layout.buildDirectory.dir("inPlaceApp"))
    with(webAssetsSpec)
}

tasks.register<Zip>("distApp") {
    archiveFileName = "my-app-dist.zip"
    destinationDirectory = layout.buildDirectory.dir("dists")

    from(appClasses)
    with(webAssetsSpec)
}
```

build.gradle

```groovy
CopySpec webAssetsSpec = copySpec {
    from 'src/main/webapp'
    include '**/*.html', '**/*.png', '**/*.jpg'
    rename '(.+)-staging(.+)', '$1$2'
}

tasks.register('copyAssets', Copy) {
    into layout.buildDirectory.dir("inPlaceApp")
    with webAssetsSpec
}

tasks.register('distApp', Zip) {
    archiveFileName = 'my-app-dist.zip'
    destinationDirectory = layout.buildDirectory.dir('dists')

    from appClasses
    with webAssetsSpec
}
```

Both the `copyAssets` and `distApp` tasks will process the static resources under `src/main/webapp`, as

specified by `webAssetsSpec`.

> **NOTE**
>
> The configuration defined by `webAssetsSpec` will *not* apply to the app classes included by the `distApp` task. That's because `from appClasses` is its own child specification independent of `with webAssetsSpec`.
>
> This can be confusing to understand, so it's probably best to treat `with()` as an extra `from()` specification in the task. Hence it doesn't make sense to define a standalone copy spec without at least one `from()` defined.

If you encounter a scenario in which you want to apply the same copy configuration to *different* sets of files, then you can share the configuration block directly without using `copySpec()`. Here's an example that has two independent tasks that happen to want to process image files only:

Example 55. Sharing copy patterns only

build.gradle.kts

```kotlin
val webAssetPatterns = Action<CopySpec> {
    include("**/*.html", "**/*.png", "**/*.jpg")
}

tasks.register<Copy>("copyAppAssets") {
    into(layout.buildDirectory.dir("inPlaceApp"))
    from("src/main/webapp", webAssetPatterns)
}

tasks.register<Zip>("archiveDistAssets") {
    archiveFileName = "distribution-assets.zip"
    destinationDirectory = layout.buildDirectory.dir("dists")

    from("distResources", webAssetPatterns)
}
```

build.gradle

```groovy
def webAssetPatterns = {
    include '**/*.html', '**/*.png', '**/*.jpg'
}

tasks.register('copyAppAssets', Copy) {
    into layout.buildDirectory.dir("inPlaceApp")
    from 'src/main/webapp', webAssetPatterns
}

tasks.register('archiveDistAssets', Zip) {
    archiveFileName = 'distribution-assets.zip'
    destinationDirectory = layout.buildDirectory.dir('dists')

    from 'distResources', webAssetPatterns
}
```

In this case, we assign the copy configuration to its own variable and apply it to whatever `from()` specification we want. This doesn't just work for inclusions, but also exclusions, file renaming, and file content filtering.

Using child specifications

If you only use a single copy spec, the file filtering and renaming will apply to *all* the files that are copied. Sometimes this is what you want, but not always. Consider the following example that

copies files into a directory structure that can be used by a Java Servlet container to deliver a website:

Copy HTML and image files here

build/explodedWar

Copy runtime
dependencies (JARs) here

WEB-INF

lib/

classes/

Copy compiled app classes here

js/

Copy JavaScript files here
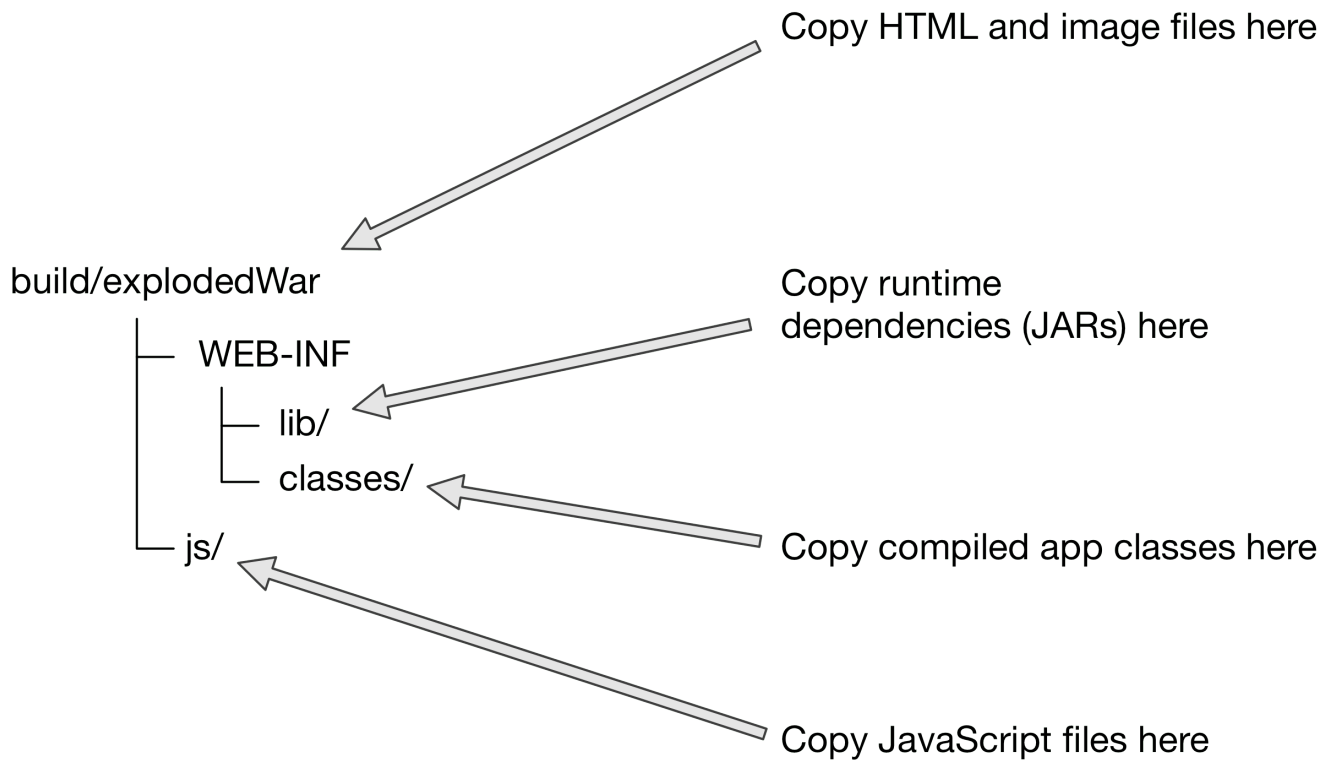
Figure 10. Creating an exploded WAR for a Servlet container

This is not a straightforward copy as the `WEB-INF` directory and its subdirectories don't exist within the project, so they must be created during the copy. In addition, we only want HTML and image files going directly into the root folder — `build/explodedWar` — and only JavaScript files going into the `js` directory. So we need separate filter patterns for those two sets of files.

The solution is to use *child specifications*, which can be applied to both `from()` and `into()` declarations. The following task definition does the necessary work:

Example 56. Nested copy specs

build.gradle.kts

```kotlin
tasks.register<Copy>("nestedSpecs") {
    into(layout.buildDirectory.dir("explodedWar"))
    exclude("**/*staging*")
    from("src/dist") {
        include("**/*.html", "**/*.png", "**/*.jpg")
    }
    from(sourceSets.main.get().output) {
        into("WEB-INF/classes")
    }
    into("WEB-INF/lib") {
        from(configurations.runtimeClasspath)
    }
}
```

build.gradle

```groovy
tasks.register('nestedSpecs', Copy) {
    into layout.buildDirectory.dir("explodedWar")
    exclude '**/*staging*'
    from('src/dist') {
        include '**/*.html', '**/*.png', '**/*.jpg'
    }
    from(sourceSets.main.output) {
        into 'WEB-INF/classes'
    }
    into('WEB-INF/lib') {
        from configurations.runtimeClasspath
    }
}
```

Notice how the `src/dist` configuration has a nested inclusion specification: that's the child copy spec. You can of course add content filtering and renaming here as required. A child copy spec is still a copy spec.

The above example also demonstrates how you can copy files into a subdirectory of the destination either by using a child `into()` on a `from()` or a child `from()` on an `into()`. Both approaches are acceptable, but you may want to create and follow a convention to ensure consistency across your build files.

One final thing to be aware of is that a child copy spec inherits its destination path, include patterns, exclude patterns, copy actions, name mappings and filters from its parent. So be careful where you place your configuration.

Copying files in your own tasks

There might be occasions when you want to copy files or directories as *part* of a task. For example, a custom archiving task based on an unsupported archive format might want to copy files to a temporary directory before they are then archived. You still want to take advantage of Gradle's copy API, but without introducing an extra `Copy` task.

The solution is to use the Project.copy(org.gradle.api.Action) method. It works the same way as the `Copy` task by configuring it with a copy spec. Here's a trivial example:

Example 57. Copying files using the copy() method without up-to-date check

build.gradle.kts

```kotlin
tasks.register("copyMethod") {
    doLast {
        copy {
            from("src/main/webapp")
            into(layout.buildDirectory.dir("explodedWar"))
            include("**/*.html")
            include("**/*.jsp")
        }
    }
}
```

build.gradle

```groovy
tasks.register('copyMethod') {
    doLast {
        copy {
            from 'src/main/webapp'
            into layout.buildDirectory.dir('explodedWar')
            include '**/*.html'
            include '**/*.jsp'
        }
    }
}
```

The above example demonstrates the basic syntax and also highlights two major limitations of using the `copy()` method:

1. The `copy()` method is not incremental. The example's `copyMethod` task will *always* execute because it has no information about what files make up the task's inputs. You have to manually define the task inputs and outputs.

2. Using a task as a copy source, i.e. as an argument to `from()`, won't set up an automatic task dependency between your task and that copy source. As such, if you are using the `copy()` method as part of a task action, you must explicitly declare all inputs and outputs in order to get the correct behavior.

The following example shows you how to workaround these limitations by using the dynamic API for task inputs and outputs:

Example 58. Copying files using the copy() method with up-to-date check

build.gradle.kts

```kotlin
tasks.register("copyMethodWithExplicitDependencies") {
    // up-to-date check for inputs, plus add copyTask as dependency
    inputs.files(copyTask)
        .withPropertyName("inputs")
        .withPathSensitivity(PathSensitivity.RELATIVE)
    outputs.dir("some-dir") // up-to-date check for outputs
        .withPropertyName("outputDir")
    doLast {
        copy {
            // Copy the output of copyTask
            from(copyTask)
            into("some-dir")
        }
    }
}
```

build.gradle

```groovy
tasks.register('copyMethodWithExplicitDependencies') {
    // up-to-date check for inputs, plus add copyTask as dependency
    inputs.files(copyTask)
        .withPropertyName("inputs")
        .withPathSensitivity(PathSensitivity.RELATIVE)
    outputs.dir('some-dir') // up-to-date check for outputs
        .withPropertyName("outputDir")
    doLast {
        copy {
            // Copy the output of copyTask
            from copyTask
            into 'some-dir'
        }
    }
}
```

These limitations make it preferable to use the `Copy` task wherever possible, because of its builtin support for incremental building and task dependency inference. That is why the `copy()` method is intended for use by custom tasks that need to copy files as part of their function. Custom tasks that use the `copy()` method should declare the necessary inputs and outputs relevant to the copy action.

Mirroring directories and file collections with the Sync task

The Sync task, which extends the Copy task, copies the source files into the destination directory and then removes any files from the destination directory which it did not copy. In other words, it synchronizes the contents of a directory with its source. This can be useful for doing things such as installing your application, creating an exploded copy of your archives, or maintaining a copy of the project's dependencies.

Here is an example which maintains a copy of the project's runtime dependencies in the `build/libs` directory.

Example 59. Using the Sync task to copy dependencies

build.gradle.kts

```
tasks.register<Sync>("libs") {
    from(configurations["runtime"])
    into(layout.buildDirectory.dir("libs"))
}
```

build.gradle

```
tasks.register('libs', Sync) {
    from configurations.runtime
    into layout.buildDirectory.dir('libs')
}
```

You can also perform the same function in your own tasks with the Project.sync(org.gradle.api.Action) method.

Deploying single files into application servers

When working with application servers, you can use a Copy task to deploy the application archive (e.g. a WAR file). Since you are deploying a single file, the destination directory of the Copy is the whole deployment directory. The deployment directory sometimes does contain unreadable files like named pipes, so Gradle may have problems doing up-to-date checks. In order to support this use-case, you can use Task.doNotTrackState().

Example 60. Using Copy to deploy a WAR file

build.gradle.kts

```kotlin
plugins {
    war
}

tasks.register<Copy>("deployToTomcat") {
    from(tasks.war)
    into(layout.projectDirectory.dir("tomcat/webapps"))
    doNotTrackState("Deployment directory contains unreadable files")
}
```

build.gradle

```groovy
plugins {
    id 'war'
}

tasks.register("deployToTomcat", Copy) {
    from war
    into layout.projectDirectory.dir('tomcat/webapps')
    doNotTrackState("Deployment directory contains unreadable files")
}
```

Installing executables

When you are building a standalone executable, you may want to install this file on your system, so it ends up in your path. You can use a `Copy` task to install the executable into shared directories like `/usr/local/bin`. The installation directory probably contains many other executables, some of which may even be unreadable by Gradle. To support the unreadable files in the `Copy` task's destination directory and to avoid time consuming up-to-date checks, you can use Task.doNotTrackState().

Example 61. Using Copy to install an executable

build.gradle.kts

```
tasks.register<Copy>("installExecutable") {
    from("build/my-binary")
    into("/usr/local/bin")
    doNotTrackState("Installation directory contains unrelated files")
}
```

build.gradle

```
tasks.register("installExecutable", Copy) {
    from "build/my-binary"
    into "/usr/local/bin"
    doNotTrackState("Installation directory contains unrelated files")
}
```

Archive creation in depth

Archives are essentially self-contained file systems and Gradle treats them as such. This is why working with archives is very similar to working with files and directories, including such things as file permissions.

Out of the box, Gradle supports creation of both ZIP and TAR archives, and by extension Java's JAR, WAR and EAR formats — Java's archive formats are all ZIPs. Each of these formats has a corresponding task type to create them: Zip, Tar, Jar, War, and Ear. These all work the same way and are based on copy specifications, just like the Copy task.

Creating an archive file is essentially a file copy in which the destination is implicit, i.e. the archive file itself. Here's a basic example that specifies the path and name of the target archive file:

Example 62. Archiving a directory as a ZIP

build.gradle.kts

```kotlin
tasks.register<Zip>("packageDistribution") {
    archiveFileName = "my-distribution.zip"
    destinationDirectory = layout.buildDirectory.dir("dist")

    from(layout.buildDirectory.dir("toArchive"))
}
```

build.gradle

```groovy
tasks.register('packageDistribution', Zip) {
    archiveFileName = "my-distribution.zip"
    destinationDirectory = layout.buildDirectory.dir('dist')

    from layout.buildDirectory.dir("toArchive")
}
```

In the next section you'll learn about convention-based archive names, which can save you from always configuring the destination directory and archive name.

The full power of copy specifications are available to you when creating archives, which means you can do content filtering, file renaming or anything else that is covered in the previous section. A particularly common requirement is copying files into subdirectories of the archive that don't exist in the source folders, something that can be achieved with `into()` child specifications.

Gradle does of course allow you create as many archive tasks as you want, but it's worth bearing in mind that many convention-based plugins provide their own. For example, the Java plugin adds a `jar` task for packaging a project's compiled classes and resources in a JAR. Many of these plugins provide sensible conventions for the names of archives as well as the copy specifications used. We recommend you use these tasks wherever you can, rather than overriding them with your own.

Archive naming

Gradle has several conventions around the naming of archives and where they are created based on the plugins your project uses. The main convention is provided by the Base Plugin, which defaults to creating archives in the `layout.buildDirectory.dir("distributions")` directory and typically uses archive names of the form *[projectName]-[version].[type]*.

The following example comes from a project named `archive-naming`, hence the `myZip` task creates an archive named `archive-naming-1.0.zip`:

Example 63. Creation of ZIP archive

build.gradle.kts

```
plugins {
    base
}

version = "1.0"

tasks.register<Zip>("myZip") {
    from("somedir")
    val projectDir = layout.projectDirectory.asFile
    doLast {
        println(archiveFileName.get())
        println(destinationDirectory.get().asFile.relativeTo(projectDir))
        println(archiveFile.get().asFile.relativeTo(projectDir))
    }
}
```

build.gradle

```
plugins {
    id 'base'
}

version = 1.0

tasks.register('myZip', Zip) {
    from 'somedir'
    File projectDir = layout.projectDirectory.asFile
    doLast {
        println archiveFileName.get()
        println projectDir.relativePath(destinationDirectory.get().asFile)
        println projectDir.relativePath(archiveFile.get().asFile)
    }
}
```

Output of `gradle -q myZip`

```
> gradle -q myZip
archive-naming-1.0.zip
build/distributions
build/distributions/archive-naming-1.0.zip
```

Note that the name of the archive does *not* derive from the name of the task that creates it.

If you want to change the name and location of a generated archive file, you can provide values for the `archiveFileName` and `destinationDirectory` properties of the corresponding task. These override any conventions that would otherwise apply.

Alternatively, you can make use of the default archive name pattern provided by AbstractArchiveTask.getArchiveFileName(): *[archiveBaseName]-[archiveAppendix]-[archiveVersion]-[archiveClassifier].[archiveExtension]*. You can set each of these properties on the task separately if you wish. Note that the Base Plugin uses the convention of project name for *archiveBaseName*, project version for *archiveVersion* and the archive type for *archiveExtension*. It does not provide values for the other properties.

This example — from the same project as the one above — configures just the `archiveBaseName` property, overriding the default value of the project name:

Example 64. Configuration of archive task - custom archive name

build.gradle.kts

```
tasks.register<Zip>("myCustomZip") {
    archiveBaseName = "customName"
    from("somedir")

    doLast {
        println(archiveFileName.get())
    }
}
```

build.gradle

```
tasks.register('myCustomZip', Zip) {
    archiveBaseName = 'customName'
    from 'somedir'

    doLast {
        println archiveFileName.get()
    }
}
```

Output of `gradle -q myCustomZip`

```
> gradle -q myCustomZip
customName-1.0.zip
```

You can also override the default `archiveBaseName` value for *all* the archive tasks in your build by using the *project* property `archivesBaseName`, as demonstrated by the following example:

Example 65. Configuration of archive task - appendix & classifier

build.gradle.kts

```
plugins {
    base
}

version = "1.0"

base {
    archivesName = "gradle"
    distsDirectory = layout.buildDirectory.dir("custom-dist")
    libsDirectory = layout.buildDirectory.dir("custom-libs")
}

val myZip by tasks.registering(Zip::class) {
    from("somedir")
}

val myOtherZip by tasks.registering(Zip::class) {
    archiveAppendix = "wrapper"
    archiveClassifier = "src"
    from("somedir")
}

tasks.register("echoNames") {
    val projectNameString = project.name
    val archiveFileName = myZip.flatMap { it.archiveFileName }
    val myOtherArchiveFileName = myOtherZip.flatMap { it.archiveFileName }
    doLast {
        println("Project name: $projectNameString")
        println(archiveFileName.get())
        println(myOtherArchiveFileName.get())
    }
}
```

```
plugins {
    id 'base'
}

version = 1.0
base {
    archivesName = "gradle"
    distsDirectory = layout.buildDirectory.dir('custom-dist')
    libsDirectory = layout.buildDirectory.dir('custom-libs')
}

def myZip = tasks.register('myZip', Zip) {
    from 'somedir'
}

def myOtherZip = tasks.register('myOtherZip', Zip) {
    archiveAppendix = 'wrapper'
    archiveClassifier = 'src'
    from 'somedir'
}

tasks.register('echoNames') {
    def projectNameString = project.name
    def archiveFileName = myZip.flatMap { it.archiveFileName }
    def myOtherArchiveFileName = myOtherZip.flatMap { it.archiveFileName }
    doLast {
        println "Project name: $projectNameString"
        println archiveFileName.get()
        println myOtherArchiveFileName.get()
    }
}
```

Output of `gradle -q echoNames`

```
> gradle -q echoNames
Project name: archives-changed-base-name
gradle-1.0.zip
gradle-wrapper-1.0-src.zip
```

You can find all the possible archive task properties in the API documentation for AbstractArchiveTask, but we have also summarized the main ones here:

`archiveFileName` — `Property<String>`, **default:** `archiveBaseName-archiveAppendix-archiveVersion-archiveClassifier.archiveExtension`

The complete file name of the generated archive. If any of the properties in the default value are

empty, their '-' separator is dropped.

archiveFile — **Provider<RegularFile>**, *read-only*, **default: destinationDirectory/archiveFileName**

The absolute file path of the generated archive.

destinationDirectory — **DirectoryProperty**, **default: depends on archive type**

The target directory in which to put the generated archive. By default, JARs and WARs go into `layout.buildDirectory.dir("libs")`. ZIPs and TARs go into `layout.buildDirectory.dir("distributions")`.

archiveBaseName — **Property<String>**, **default: project.name**

The base name portion of the archive file name, typically a project name or some other descriptive name for what it contains.

archiveAppendix — **Property<String>**, **default: null**

The appendix portion of the archive file name that comes immediately after the base name. It is typically used to distinguish between different forms of content, such as code and docs, or a minimal distribution versus a full or complete one.

archiveVersion — **Property<String>**, **default: project.version**

The version portion of the archive file name, typically in the form of a normal project or product version.

archiveClassifier — **Property<String>**, **default: null**

The classifier portion of the archive file name. Often used to distinguish between archives that target different platforms.

archiveExtension — **Property<String>**, **default: depends on archive type and compression type**

The filename extension for the archive. By default, this is set based on the archive task type and the compression type (if you're creating a TAR). Will be one of: `zip`, `jar`, `war`, `tar`, `tgz` or `tbz2`. You can of course set this to a custom extension if you wish.

Sharing content between multiple archives

As described earlier, you can use the Project.copySpec(org.gradle.api.Action) method to share content between archives.

Reproducible builds

Sometimes it's desirable to recreate archives exactly the same, byte for byte, on different machines. You want to be sure that building an artifact from source code produces the same result no matter when and where it is built. This is necessary for projects like reproducible-builds.org.

Reproducing the same byte-for-byte archive poses some challenges since the order of the files in an archive is influenced by the underlying file system. Each time a ZIP, TAR, JAR, WAR or EAR is built from source, the order of the files inside the archive may change. Files that only have a different timestamp also causes differences in archives from build to build. All AbstractArchiveTask (e.g. Jar, Zip) tasks shipped with Gradle include support for producing reproducible archives.

For example, to make a `Zip` task reproducible you need to set Zip.isReproducibleFileOrder() to `true` and Zip.isPreserveFileTimestamps() to `false`. In order to make all archive tasks in your build reproducible, consider adding the following configuration to your build file:

Example 66. Activating reproducible archives

build.gradle.kts

```
tasks.withType<AbstractArchiveTask>().configureEach {
    isPreserveFileTimestamps = false
    isReproducibleFileOrder = true
}
```

build.gradle

```
tasks.withType(AbstractArchiveTask).configureEach {
    preserveFileTimestamps = false
    reproducibleFileOrder = true
}
```

Often you will want to publish an archive, so that it is usable from another project. This process is described in Cross-Project publications.

Logging

The log is the main 'UI' of a build tool. If it is too verbose, real warnings and problems are easily hidden by this. On the other hand you need relevant information for figuring out if things have gone wrong. Gradle defines 6 log levels, as shown in Log levels. There are two Gradle-specific log levels, in addition to the ones you might normally see. Those levels are *QUIET* and *LIFECYCLE*. The latter is the default, and is used to report build progress.

Log levels

ERROR   Error messages

QUIET   Important information messages

WARNING   Warning messages

LIFECYCLE   Progress information messages

INFO   Information messages

DEBUG	Debug messages

NOTE	The rich components of the console (build status and work in progress area) are displayed regardless of the log level used. Before Gradle 4.0 those rich components were only displayed at log level `LIFECYCLE` or below.

Choosing a log level

You can use the command line switches shown in Log level command-line options to choose different log levels. You can also configure the log level using `gradle.properties`, see Gradle properties. In Stacktrace command-line options you find the command line switches which affect stacktrace logging.

Table 4. Log level command-line options

Option	Outputs Log Levels
`-q` or `--quiet`	QUIET and higher
`-w` or `--warn`	WARN and higher
no logging options	LIFECYCLE and higher
`-i` or `--info`	INFO and higher
`-d` or `--debug`	DEBUG and higher (that is, all log messages)

CAUTION	The `DEBUG` log level can expose security sensitive information to the console.

Stacktrace command-line options

`-s` or `--stacktrace`

Truncated stacktraces are printed. We recommend this over full stacktraces. Groovy full stacktraces are extremely verbose (Due to the underlying dynamic invocation mechanisms. Yet they usually do not contain relevant information for what has gone wrong in *your* code.) This option renders stacktraces for deprecation warnings.

`-S` or `--full-stacktrace`

The full stacktraces are printed out. This option renders stacktraces for deprecation warnings.

<No stacktrace options>

No stacktraces are printed to the console in case of a build error (e.g. a compile error). Only in case of internal exceptions will stacktraces be printed. If the `DEBUG` log level is chosen, truncated stacktraces are always printed.

Logging Sensitive Information

Running Gradle with the `DEBUG` log level can expose security sensitive information to the console and build log.

This information can include but is not limited to:

- Environment variables

- Private repository credentials

- Build cache & Develocity Credentials

- [Plugin Portal](#) publishing credentials

The DEBUG log level should **not** be used when running on public Continuous Integration services. Build logs for public Continuous Integration services are world-viewable and can expose this sensitive information. Depending upon your organization's threat model, logging sensitive credentials in private CI may also be a vulnerability. Please discuss this with your organization's security team.

Some CI providers attempt to scrub sensitive credentials from logs; however, this will be imperfect and usually only scrubs exact-matches of pre-configured secrets.

If you believe a Gradle Plugin may be exposing sensitive information, please contact security@gradle.com for disclosure assistance.

Writing your own log messages

A simple option for logging in your build file is to write messages to standard output. Gradle redirects anything written to standard output to its logging system at the `QUIET` log level.

Example 67. Using stdout to write log messages

build.gradle.kts

```
println("A message which is logged at QUIET level")
```

build.gradle

```
println 'A message which is logged at QUIET level'
```

Gradle also provides a `logger` property to a build script, which is an instance of [Logger](#). This interface extends the SLF4J `Logger` interface and adds a few Gradle specific methods to it. Below is an example of how this is used in the build script:

Example 68. Writing your own log messages

build.gradle.kts

```
logger.quiet("An info log message which is always logged.")
logger.error("An error log message.")
logger.warn("A warning log message.")
logger.lifecycle("A lifecycle info log message.")
logger.info("An info log message.")
logger.debug("A debug log message.")
logger.trace("A trace log message.") // Gradle never logs TRACE level logs
```

build.gradle

```
logger.quiet('An info log message which is always logged.')
logger.error('An error log message.')
logger.warn('A warning log message.')
logger.lifecycle('A lifecycle info log message.')
logger.info('An info log message.')
logger.debug('A debug log message.')
logger.trace('A trace log message.') // Gradle never logs TRACE level logs
```

Use the typical SLF4J pattern to replace a placeholder with an actual value as part of the log message.

Example 69. Writing a log message with placeholder

build.gradle.kts

```
logger.info("A {} log message", "info")
```

build.gradle

```
logger.info('A {} log message', 'info')
```

You can also hook into Gradle's logging system from within other classes used in the build (classes from the `buildSrc` directory for example). Simply use an SLF4J logger. You can use this logger the same way as you use the provided logger in the build script.

Example 70. Using SLF4J to write log messages

build.gradle.kts

```kotlin
import org.slf4j.LoggerFactory

val slf4jLogger = LoggerFactory.getLogger("some-logger")
slf4jLogger.info("An info log message logged using SLF4j")
```

build.gradle

```groovy
import org.slf4j.LoggerFactory

def slf4jLogger = LoggerFactory.getLogger('some-logger')
slf4jLogger.info('An info log message logged using SLF4j')
```

Logging from external tools and libraries

Internally, Gradle uses Ant and Ivy. Both have their own logging system. Gradle redirects their logging output into the Gradle logging system. There is a 1:1 mapping from the Ant/Ivy log levels to the Gradle log levels, except the Ant/Ivy `TRACE` log level, which is mapped to Gradle `DEBUG` log level. This means the default Gradle log level will not show any Ant/Ivy output unless it is an error or a warning.

There are many tools out there which still use standard output for logging. By default, Gradle redirects standard output to the `QUIET` log level and standard error to the `ERROR` level. This behavior is configurable. The project object provides a LoggingManager, which allows you to change the log levels that standard out or error are redirected to when your build script is evaluated.

Example 71. Configuring standard output capture

build.gradle.kts

```
logging.captureStandardOutput(LogLevel.INFO)
println("A message which is logged at INFO level")
```

build.gradle

```
logging.captureStandardOutput LogLevel.INFO
println 'A message which is logged at INFO level'
```

To change the log level for standard out or error during task execution, tasks also provide a LoggingManager.

Example 72. Configuring standard output capture for a task

build.gradle.kts

```
tasks.register("logInfo") {
    logging.captureStandardOutput(LogLevel.INFO)
    doFirst {
        println("A task message which is logged at INFO level")
    }
}
```

build.gradle

```
tasks.register('logInfo') {
    logging.captureStandardOutput LogLevel.INFO
    doFirst {
        println 'A task message which is logged at INFO level'
    }
}
```

Gradle also provides integration with the Java Util Logging, Jakarta Commons Logging and Log4j logging toolkits. Any log messages which your build classes write using these logging toolkits will be redirected to Gradle's logging system.

Changing what Gradle logs

WARNING	The configuration cache limits the ability to customize Gradle's logging UI. The custom logger can only implement supported listener interfaces. These interfaces do not receive events when the configuration cache entry is reused, because the whole configuration phase is skipped.

You can replace much of Gradle's logging UI with your own. You might do this, for example, if you want to customize the UI in some way - to log more or less information, or to change the formatting. You replace the logging using the Gradle.useLogger(java.lang.Object) method. This is accessible from a build script, or an init script, or via the embedding API. Note that this completely disables Gradle's default output. Below is an example init script which changes how task execution and build completion is logged.

Example 73. Customizing what Gradle logs

customLogger.init.gradle.kts

```
useLogger(CustomEventLogger())

@Suppress("deprecation")
class CustomEventLogger() : BuildAdapter(), TaskExecutionListener {

    override fun beforeExecute(task: Task) {
        println("[${task.name}]")
    }

    override fun afterExecute(task: Task, state: TaskState) {
        println()
    }

    override fun buildFinished(result: BuildResult) {
        println("build completed")
        if (result.failure != null) {
            (result.failure as Throwable).printStackTrace()
        }
    }
}
```

customLogger.init.gradle

```
useLogger(new CustomEventLogger())

@SuppressWarnings("deprecation")
class CustomEventLogger extends BuildAdapter implements TaskExecutionListener
{

    void beforeExecute(Task task) {
        println "[$task.name]"
    }

    void afterExecute(Task task, TaskState state) {
        println()
    }

    void buildFinished(BuildResult result) {
        println 'build completed'
        if (result.failure != null) {
            result.failure.printStackTrace()
        }
    }
}
```

```
$ gradle -I customLogger.init.gradle.kts build

> Task :compile
[compile]
compiling source

> Task :testCompile
[testCompile]
compiling test source

> Task :test
[test]
running unit tests

> Task :build
[build]

build completed
3 actionable tasks: 3 executed
```

```
$ gradle -I customLogger.init.gradle build

> Task :compile
[compile]
compiling source

> Task :testCompile
[testCompile]
compiling test source

> Task :test
[test]
running unit tests

> Task :build
[build]

build completed
3 actionable tasks: 3 executed
```

Your logger can implement any of the listener interfaces listed below. When you register a logger, only the logging for the interfaces that it implements is replaced. Logging for the other interfaces is left untouched. You can find out more about the listener interfaces in Build lifecycle events.

- BuildListener[1]

- ProjectEvaluationListener

- TaskExecutionGraphListener

- TaskExecutionListener[1]

- TaskActionListener[1]

Avoiding traps

Groovy script variables

For users of the Groovy DSL it is important to understand how Groovy deals with script variables. Groovy has two types of script variables. One with a local scope and one with a script-wide scope.

Example: Variables scope: local and script wide

scope.groovy

```groovy
String localScope1 = 'localScope1'
def localScope2 = 'localScope2'
scriptScope = 'scriptScope'

println localScope1
println localScope2
println scriptScope

closure = {
    println localScope1
    println localScope2
    println scriptScope
}

def method() {
    try {
        localScope1
    } catch (MissingPropertyException e) {
        println 'localScope1NotAvailable'
    }
    try {
        localScope2
    } catch(MissingPropertyException e) {
        println 'localScope2NotAvailable'
    }
    println scriptScope
}

closure.call()
method()
```

Output of `groovy scope.groovy`

```
> groovy scope.groovy
localScope1
localScope2
scriptScope
localScope1
localScope2
scriptScope
localScope1NotAvailable
localScope2NotAvailable
scriptScope
```

Variables which are declared with a type modifier are visible within closures but not visible within methods.

Configuration and execution phase

It is important to keep in mind that Gradle has a distinct configuration and execution phase (see Build Lifecycle).

Example 74. Distinct configuration and execution phase

build.gradle.kts

```kotlin
val classesDir = file("build/classes")
classesDir.mkdirs()
tasks.register<Delete>("clean") {
    delete("build")
}
tasks.register("compile") {
    dependsOn("clean")
    val classesDir = classesDir
    doLast {
        if (!classesDir.isDirectory) {
            println("The class directory does not exist. I can not operate")
            // do something
        }
        // do something
    }
}
```

build.gradle

```groovy
def classesDir = file('build/classes')
classesDir.mkdirs()
tasks.register('clean', Delete) {
    delete 'build'
}
tasks.register('compile') {
    dependsOn 'clean'
    def localClassesDir = classesDir
    doLast {
        if (!localClassesDir.isDirectory()) {
            println 'The class directory does not exist. I can not operate'
            // do something
        }
        // do something
    }
}
```

Output of `gradle -q compile`

```
> gradle -q compile
The class directory does not exist. I can not operate
```

As the creation of the directory happens during the configuration phase, the `clean` task removes the directory during the execution phase.

[1] Not compatible with the configuration cache.

STRUCTURING INDIVIDUAL BUILDS

Structuring and Building a Software Component with Gradle

If you are building a software of a certain size with Gradle, you have two basic structuring mechanisms. First, this chapter describes how to structure your software project using a Gradle multi-project. In this documentation, we consider this to be a single *software component* which is structured internally. Second, you may regard your software as a *software product* that is composed of multiple *software components* where each component is represented by a separate Gradle build. This is described in detail in the chapter on structuring software products with Gradle

Creating a multi-project build

A multi-project build in Gradle consists of one root project, and one or more subprojects.

A basic multi-project build contains a root project and a single subproject. This is a structure of a multi-project build that contains a single subproject called app:

Example 75. Basic multi-project build

Project layout

```
.
├── app
|   ...
|   └── build.gradle.kts
└── settings.gradle.kts
```

Project layout

```
.
├── app
|   ...
|   └── build.gradle
└── settings.gradle
```

This is the recommended project structure for starting any Gradle project. The build init plugin also generates skeleton projects that follow this structure - a root project with a single subproject.

Note that the root project does not have a Gradle build file, only a settings file that defines the subprojects to include.

settings.gradle.kts

```
rootProject.name = "basic-multiproject"
include("app")
```

settings.gradle

```
rootProject.name = 'basic-multiproject'
include 'app'
```

In this case, Gradle will look for a build file in the `app` directory.

We can view the structure of a multi-project build by running the `gradle projects` command.

```
> gradle -q projects

------------------------------------------------------------
Root project 'basic-multiproject'
------------------------------------------------------------

Root project 'basic-multiproject'
\--- Project ':app'

To see a list of the tasks of a project, run gradle <project-path>:tasks
For example, try running gradle :app:tasks
```

Let's say the `app` subproject is a Java application by applying the application plugin and configuring the main class:

app/build.gradle.kts

```kotlin
plugins {
    id("application")
}

application {
    mainClass = "com.example.Hello"
}
```

app/build.gradle

```groovy
plugins {
    id 'application'
}

application {
    mainClass = 'com.example.Hello'
}
```

app/src/main/java/com/example/Hello.java

```java
package com.example;

public class Hello {
    public static void main(String[] args) {
        System.out.println("Hello, world!");
    }
}
```

We can then run the application by executing the `run` task from the application plugin.

```
> gradle -q run
Hello, world!
```

And that's how simple it is to create a basic multi-project build.

Adding subprojects

Let's say we want to add another subproject called `lib` to the previously created project. All we need to do is add another `include` statement in the root settings file:

settings.gradle.kts

```
rootProject.name = "basic-multiproject"
include("app")
include("lib")
```

settings.gradle

```
rootProject.name = 'basic-multiproject'
include 'app'
include 'lib'
```

Gradle will then look for the build file for the new subproject in the `lib/` subdirectory of the project:

Example 76. Multi-project build with two subprojects

Project layout

```
.
├── app
│   ...
│   └── build.gradle.kts
├── lib
│   ...
│   └── build.gradle.kts
└── settings.gradle.kts
```

Project layout

```
.
├── app
│   ...
│   └── build.gradle
├── lib
│   ...
│   └── build.gradle
└── settings.gradle
```

Next, will explore how build logic can be [shared between subprojects](#) and how subprojects can [depend on one another](#).

Naming recommendations

As your project grows, naming and consistency gets increasingly more important. To keep your builds maintainable, we recommend the following:

1. *Keep default project names for subprojects*: It is possible to configure custom project names in the settings file. However, it's an unnecessary extra effort for the developers to keep track of which project belongs to what folders.

2. *Use kebab case formatting for all project names*: A kebab case formatting is when all letters lowercase, words separated with a dash ('-') character (e.g.`kebab-case-formatting`). This is already the de-facto pattern for many large projects. Besides, Gradle supports [name abbreviation for kebab case names](#).

3. *Define the root project name in the settings file*: The ´rootProject.name´ effectively assigns a name to the build as a whole, which is used in reports like build scans. If the root project name is not set, the name will be the container directory name, which can be unstable (i.e. you can check out your project to any directory). If the root project name is not set and it is checked out to a root of a file system (e.g. `/` or `C:\`), the name will be generated randomly.

Declaring Dependencies between Subprojects

Project dependencies

What if one project needs the jar produced by another project on its compile classpath? What if it also requires the transitive dependencies of the other project? Obviously this is a very common use case for Java multi-project builds. As mentioned in [Project dependencies](#), Gradle offers project dependencies for this.

Example 77. Project dependencies

Project layout

```
.
├── buildSrc
│   ...
├── api
│   ├── src
│   │   └── ...
│   └── build.gradle.kts
├── services
│   └── person-service
│       ├── src
│       │   └── ...
│       └── build.gradle.kts
├── shared
│   ├── src
│   │   └── ...
│   └── build.gradle.kts
└── settings.gradle.kts
```

Project layout

```
.
├── buildSrc
│   ...
├── api
│   ├── src
│   │   └── ...
│   └── build.gradle
├── services
│   └── person-service
│       ├── src
│       │   └── ...
│       └── build.gradle
├── shared
│   ├── src
│   │   └── ...
│   └── build.gradle
└── settings.gradle
```

We have the projects `shared`, `api` and `person-service`. The `person-service` project has a dependency on the other two projects. The `api` project has a dependency on the `shared` project. It has no build script and gets nothing injected by another build script. We use the `:` separator to define a project

path. Consult the DSL documentation of Settings.include(java.lang.String[]) for more information about defining project paths.

settings.gradle.kts

```
rootProject.name = "dependencies-java"
include("api", "shared", "services:person-service")
```

buildSrc/src/main/kotlin/myproject.java-conventions.gradle.kts

```
plugins {
    id("java")
}

group = "com.example"
version = "1.0"

repositories {
    mavenCentral()
}

dependencies {
    testImplementation("junit:junit:4.13")
}
```

api/build.gradle.kts

```
plugins {
    id("myproject.java-conventions")
}

dependencies {
    implementation(project(":shared"))
}
```

shared/build.gradle.kts

```
plugins {
    id("myproject.java-conventions")
}
```

services/person-service/build.gradle.kts

```
plugins {
    id("myproject.java-conventions")
}

dependencies {
    implementation(project(":shared"))
    implementation(project(":api"))
}
```

```
plugins {
    id("myproject.java-conventions")
}
```

settings.gradle

```
rootProject.name = 'dependencies-java'
include 'api', 'shared', 'services:person-service'
```

buildSrc/src/main/groovy/myproject.java-conventions.gradle

```
plugins {
    id 'java'
}

group = 'com.example'
version = '1.0'

repositories {
    mavenCentral()
}

dependencies {
    testImplementation "junit:junit:4.13"
}
```

api/build.gradle

```
plugins {
    id 'myproject.java-conventions'
}

dependencies {
    implementation project(':shared')
}
```

shared/build.gradle

```
plugins {
    id 'myproject.java-conventions'
}
```

services/person-service/build.gradle

```groovy
plugins {
    id 'myproject.java-conventions'
}

dependencies {
    implementation project(':shared')
    implementation project(':api')
}
```

Shared build logic is extracted into a *convention plugin* that is applied in the subprojects' build scripts that also define project dependencies. A project dependency is a special form of an execution dependency. It causes the other project to be built first and adds the jar with the classes of the other project to the classpath. It also adds the dependencies of the other project to the classpath. You can trigger a `gradle :api:compile`. First the `shared` project is built and then the `api` project is built. Project dependencies enable partial multi-project builds.

Depending on artifacts produced by another project

Project dependencies model dependencies between modules. Effectively, you are saying that you depend on the main output of another project. In a Java-based project that's usually a JAR file.

Sometimes you may want to depend on an output produced by another task. In turn, you'll want to make sure that the task is executed beforehand to produce that very output. Declaring a task dependency from one project to another is a poor way to model this kind of relationship and introduces unnecessary coupling. The recommended way to model such a dependency is to produce the output, mark it as an "outgoing" artifact or add it to the output of the `main` source set which you can depend on in the consuming project.

Let's say you are working in a multi-project build with the two subprojects `producer` and `consumer`. The subproject `producer` defines a task named `buildInfo` that generates a properties file containing build information e.g. the project version. You can then map the task provider to its output file and Gradle will automatically establish a task dependency.

Example 78. Task generating a property file containing build information

build.gradle.kts

```kotlin
plugins {
    id("java-library")
}

version = "1.0"

val buildInfo by tasks.registering(BuildInfo::class) {
    version = project.version.toString()
    outputFile = layout.buildDirectory.file("generated-resources/build-
info.properties")
}

sourceSets {
    main {
        output.dir(buildInfo.map { it.outputFile.asFile.get().parentFile })
    }
}
```

build.gradle

```groovy
plugins {
    id 'java-library'
}

version = '1.0'

def buildInfo = tasks.register("buildInfo", BuildInfo) {
    version = project.version
    outputFile = layout.buildDirectory.file('generated-resources/build-
info.properties')
}

sourceSets {
    main {
        output.dir(buildInfo.map { it.outputFile.asFile.get().parentFile })
    }
}
```

buildSrc/src/main/java/BuildInfo.java

```java
public abstract class BuildInfo extends DefaultTask {

    @Input
    public abstract Property<String> getVersion();

    @OutputFile
    public abstract RegularFileProperty getOutputFile();

    @TaskAction
    public void create() throws IOException {
        Properties prop = new Properties();
        prop.setProperty("version", getVersion().get());
        try (OutputStream output = new FileOutputStream(getOutputFile().getAsFile
().get())) {
            prop.store(output, null);
        }
    }
}
```

The consuming project is supposed to be able to read the properties file at runtime. Declaring a project dependency on the producing project takes care of creating the properties beforehand and making it available to the runtime classpath.

Example 79. Declaring a project dependency on the project producing the properties file

build.gradle.kts

```kotlin
dependencies {
    runtimeOnly(project(":producer"))
}
```

build.gradle

```groovy
dependencies {
    runtimeOnly project(':producer')
}
```

In the example above, the consumer now declares a dependency on the outputs of the `producer` project.

Depending on the main output artifact from another project is only one example. Gradle has one of the most powerful dependency management engines that allows you to share arbitrary artifacts

between projects and let Gradle build them on demand. For more details see the section on sharing outputs between projects.

Sharing Build Logic between Subprojects

Convention Plugins

Usually, subprojects in a multi-project build share some common traits. For example, several subprojects may contain *code* in a particular programming language while another subproject may be dedicated for *documentation*. Code quality rules apply to all of the *code* subprojects but not the *documentation* subproject. At the same time, the subprojects that share one common trait may serve different purposes - they may produce different *artifact types* that further differentiate them, for example:

- *public libraries* - libraries that are published to some repository
- *internal libraries* - libraries on which other subprojects depend on internally within the project
- *command line applications* - applications with specific packaging requirements
- *web services* - applications with specific packaging requirements that are different from above
- etc

Some other *code* subprojects may be dedicated for *testing purposes* and so on.

The traits above identify a subproject's *type*. Or in other words, a subproject's *type* tells us what traits the project has.

Gradle's recommended way of organizing build logic is to use its plugin system. A plugin should define the *type* of a subproject. In fact, Gradle core plugins are modeled in the same way - for example, the Java Plugin configures a generic `java` project, while Java Library Plugin internally applies the Java Plugin and configures aspects specific to a Java library in addition. Similarly, the Application Plugin applies and configures the Java Plugin and the Distribution Plugin.

You can compose custom build logic by applying and configuring both core and external plugins and create custom plugins that define new project *types* and configure conventions specific to your project or organization. For each of the example traits from the beginning of this section, we can write a plugin that encapsulates the logic common to the subproject of a given *type*.

We recommend putting source code and tests for the convention plugins in the special `buildSrc` directory in the root directory of the project. For more information about `buildSrc`, consult Using buildSrc to organize build logic.

Have a look at the sample that demonstrates a multi-project build that models the build logic using convention plugins.

Another, more complex and real-world example of a multi-project build that composes build logic using convention plugins is the build of the Gradle Build Tool itself.

Cross project configuration

Another, discouraged, way to share build logic between subprojects is *cross project configuration* via the `subprojects {}` and `allprojects {}` DSL constructs. With cross configuration, build logic can be injected into a subproject and this is not obvious when looking at the subproject's build script, making it harder to understand the logic of a particular subproject. In the long run, cross configuration usually grows complex with more and more conditional logic and a higher maintenance burden. Cross configuration can also introduce configuration-time coupling between projects, which can prevent optimizations like configuration-on-demand from working properly.

There are two most common uses of cross-configuration that can be better modelled using convention plugins:

- Applying plugins or other configuration to subprojects of certain type. Often the cross-configuration section will do `if subproject is of type X, then configure Y`. This is equivalent to applying `X-conventions` plugin directly to a subproject.

- Extracting information from subprojects of a certain type. This use case can be modelled using outgoing configuration variants.

Fine Tuning the Project Layout

A multi-project build is a build where you build more than one project during a single execution of Gradle. You have to declare the projects taking part in the multi-project build in the settings file.

Project locations

Multi-project builds are always represented by a tree with a single root. Each element in the tree represents a project. A project has a path which denotes the position of the project in the multi-project build tree. In most cases the project path is consistent with the physical location of the project in the file system. However, this behavior is configurable. The project tree is created in the `settings.gradle` file. The location of the settings file is also the location of the root project.

Building the tree

In the settings file you can use the `include` method to build the project tree.

Example 80. Project layout

settings.gradle.kts

```kotlin
include("project1", "project2:child", "project3:child1")
```

settings.gradle

```groovy
include 'project1', 'project2:child', 'project3:child1'
```

The `include` method takes project paths as arguments. The project path is assumed to be equal to the relative physical file system path. For example, a path 'services:api' is mapped by default to a folder 'services/api' (relative from the project root). You only need to specify the leaves of the tree. This means that the inclusion of the path 'services:hotels:api' will result in creating 3 projects: 'services', 'services:hotels' and 'services:hotels:api'. More examples of how to work with the project path can be found in the DSL documentation of Settings.include(java.lang.String[]).

Modifying elements of the project tree

The multi-project tree created in the settings file is made up of so called *project descriptors*. You can modify these descriptors in the settings file at any time. To access a descriptor you can do:

Example 81. Lookup of elements of the project tree

settings.gradle.kts

```kotlin
include("project-a")
println(rootProject.name)
println(project(":project-a").name)
```

settings.gradle

```groovy
include('project-a')
println rootProject.name
println project(':project-a').name
```

Using this descriptor you can change the name, project directory and build file of a project.

Example 82. Modification of elements of the project tree

settings.gradle.kts

```kotlin
rootProject.name = "main"
include("project-a")
project(":project-a").projectDir = file("custom/my-project-a")
project(":project-a").buildFileName = "project-a.gradle.kts"
```

settings.gradle

```groovy
rootProject.name = 'main'
include('project-a')
project(':project-a').projectDir = file('custom/my-project-a')
project(':project-a').buildFileName = 'project-a.gradle'
```

Look at the ProjectDescriptor class in the API documentation for more information.

Configuration time and execution time

Build phases describes the phases of every Gradle build. Let's zoom into the configuration and execution phases of a multi-project build. Configuration here means evaluating the build script file of a project, which includes downloading all plugins and build script dependencies. By default, the configuration of all projects happens before any task is executed. This means that when a single task, from a single project is requested, *all* projects of a multi-project build are configured first. The reason every project needs to be configured is to support the flexibility of accessing and changing any part of the Gradle project model.

Parallel project execution

With more and more CPU cores available on developer desktops and CI servers, it is important that Gradle is able to fully utilise these processing resources. More specifically, parallel execution attempts to:

- Reduce total build time for a multi-project build where execution is IO bound or otherwise does not consume all available CPU resources.

- Provide faster feedback for execution of small projects without awaiting completion of other projects.

Although Gradle already offers parallel test execution via Test.setMaxParallelForks(int) the feature described in this section is parallel execution at a project level.

Parallel project execution allows the separate projects in a decoupled multi-project build to be executed in parallel (see also Decoupled projects). While parallel execution does not strictly require

decoupling at configuration time, the long-term goal is to provide a powerful set of features that will be available for fully decoupled projects. Such features include:

- Configuration on-demand.

- Configuration of projects in parallel.

- Re-use of configuration for unchanged projects.

- Project-level up-to-date checks.

- Using pre-built artifacts in the place of building dependent projects.

How does parallel execution work? First, you need to tell Gradle to use parallel mode. You can use the `--parallel` command line argument or configure your build environment (Gradle properties). Unless you provide a specific number of parallel threads, Gradle attempts to choose the right number based on available CPU cores. Every parallel worker exclusively owns a given project while executing a task. Task dependencies are fully supported and parallel workers will start executing upstream tasks first. Bear in mind that the alphabetical ordering of decoupled tasks, as can be seen during sequential execution, is not guaranteed in parallel mode. In other words, in parallel mode tasks will run as soon as their dependencies complete *and a task worker is available to run them*, which may be earlier than they would start during a sequential build. You should make sure that task dependencies and task inputs/outputs are declared correctly to avoid ordering issues.

Decoupled Projects

Gradle allows any project to access any other project during both the configuration and execution phases. While this provides a great deal of power and flexibility to the build author, it also limits the flexibility that Gradle has when building those projects. For instance, this effectively prevents Gradle from correctly building multiple projects in parallel, configuring only a subset of projects, or from substituting a pre-built artifact in place of a project dependency.

Two projects are said to be *decoupled* if they do not directly access each other's project model. Decoupled projects may only interact in terms of declared dependencies: project dependencies and/or task dependencies. Any other form of project interaction (i.e. by modifying another project object or by reading a value from another project object) causes the projects to be coupled. The consequence of coupling during the configuration phase is that if gradle is invoked with the 'configuration on demand' option, the result of the build can be flawed in several ways. The consequence of coupling during execution phase is that if gradle is invoked with the parallel option, one project task runs too late to influence a task of a project building in parallel. Gradle does not attempt to detect coupling and warn the user, as there are too many possibilities to introduce coupling.

A very common way for projects to be coupled is by using configuration injection. It may not be immediately apparent, but using key Gradle features like the `allprojects` and `subprojects` keywords automatically cause your projects to be coupled. This is because these keywords are used in a `build.gradle` file, which defines a project. Often this is a "root project" that does nothing more than define common configuration, but as far as Gradle is concerned this root project is still a fully-fledged project, and by using `allprojects` that project is effectively coupled to all other projects. Coupling of the root project to subprojects does not impact configuration on-demand, but using the `allprojects` and `subprojects` in any subproject's `build.gradle` file will have an impact.

This means that using any form of shared build script logic or configuration injection (`allprojects`, `subprojects`, etc.) will cause your projects to be coupled. As we extend the concept of project decoupling and provide features that take advantage of decoupled projects, we will also introduce new features to help you to solve common use cases (like configuration injection) without causing your projects to be coupled.

In order to make good use of cross project configuration without running into issues for parallel and 'configuration on demand' options, follow these recommendations:

- Avoid a subproject's build script referencing other subprojects; preferring cross configuration from the root project.

- Avoid changing the configuration of other projects at execution time.

Configuration on demand

The *Configuration injection* feature and access to the complete project model are possible because every project is configured before the execution phase. Yet, this approach may not be the most efficient in a very large multi-project build. There are Gradle builds with a hierarchy of hundreds of subprojects. The configuration time of huge multi-project builds may become noticeable.

Configuration on demand attempts to configure only projects that are relevant for requested tasks, i.e. it only executes the build script file of projects that are participating in the build. This way, the configuration time of a large multi-project build can be reduced.

The configuration on demand feature is incubating, so not every build is guaranteed to work correctly. The feature should work very well for multi-project builds that have decoupled projects. In "configuration on demand" mode, projects are configured as follows:

- The root project is always configured.

- The project in the directory where the build is executed is also configured, but only when Gradle is executed without any tasks. This way the default tasks behave correctly when projects are configured on demand.

- The standard project dependencies are supported and makes relevant projects configured. If project A has a compile dependency on project B then building A causes configuration of both projects.

- The task dependencies declared via task path are supported and cause relevant projects to be configured. Example: `someTask.dependsOn(":some-other-project:someOtherTask")`

- A task requested via task path from the command line (or Tooling API) causes the relevant project to be configured. For example, building 'project-a:project-b:someTask' causes configuration of project-b.

To configure on demand with every build run see Gradle properties. To configure on demand just for a given build, see command-line performance-oriented options.

STRUCTURING SOFTWARE PRODUCTS

Structuring Large Projects

As software projects grow, it is common to organize large systems into components that are connected following a certain software architecture. Usually, it makes sense to also organize the artifacts (source code etc.) that make up the software in repositories and folder structures that reflect component boundaries and architecture. If Gradle is used to build such a software system, it can help you to perform this organisation and enforce boundaries between components.

You can look at Gradle as a modelling tool for your software: It allows you to describe the coarse grained structure and architecture of your software in a model written in Gradle's DSLs. The build tool Gradle can then interpret this model to build the software.

An example

How you architect your software and how you divide it into components depends on what you are building. There is no one-fits-all solution. Hence, Gradle does not enforce a particular structure on you, but rather offers the tools to model your individual setup.

Still, to exemplify these features, we explore a sample project with the following architecture:
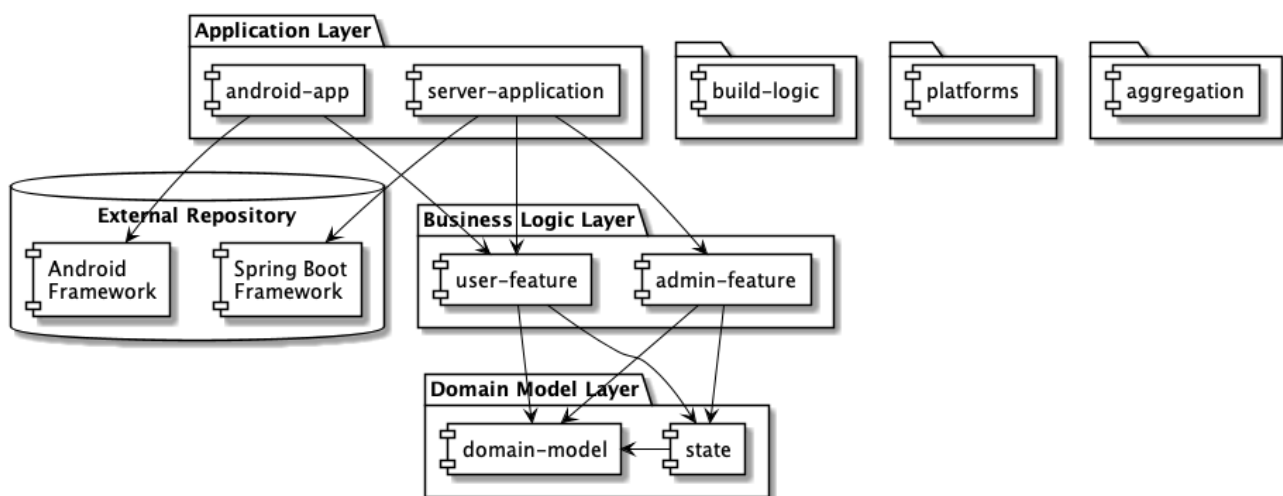
| NOTE | You can download the full sample to explore, build and run it. |

The structure follows a typical setup that can be found in similar form in many commonly used software architectures.

- At the bottom we define our domain model. There are two components: a *domain-model* component contains the model definition (i.e. a set of data classes) and a *state* component is responsible for managing a modifiable state of the model during application runtime.

- On top of the model, business logic for different features is implemented independently of each other and independently of a concrete application technology. In this example, we have two features: *user* and *admin*.

- At the top, we have concrete applications users use to interact with the features. In the example, we build a Spring Boot application that supports both features via a web browser. And an Android app that only supports the *user* feature.

Our components may rely on existing components that are retrieved from binary repositories. For example, the Spring Boot and Android frameworks.

Apart from the production code, there are also components that deal with building and delivering the product:

- The *build-logic* component contains the configuration details about building the software. For example, defining a Java version to use or configuring a test framework. It may also contain additional build logic for Gradle (custom plugins with custom tasks) that is not covered by commonly available Gradle plugins.

- The *platforms* component is a central place to define which versions of external components are to be used in all of our own components. By that, it defines the constraints for the environments – that is, *the platforms* – to build, test and run the software product.

- The *aggregation* component contains the setup of the delivery pipeline that is required to push the product to production and doing automated end-to-end testing as part of that. Basically, this is the part of the build that is not required on local development machines.

NOTE	The domain of our example is to build a tool to inform people about Gradle Build Tool releases. Concretely, the application lists Gradle releases with links to release notes (*user* feature) and offers an administration interface for the range of releases to be listed (*admin* feature).

Reflecting software architecture in project structure

Let's look at how to implement the architecture of the sample with Gradle. We can represent each of our *components* as a separate *Gradle build*. We'll get to the details of what that means and how components are connected in a bit.

Each Gradle build has its own folder. The minimum to make these folders Gradle builds is to add an empty `settings.gradle(.kts)` file to each of them. Let's do this for all the components we have in our software:

```
├──── android-app
|     └──── settings.gradle.kts
├──── server-application
|     └──── settings.gradle.kts
|
├──── admin-feature
|     └──── settings.gradle.kts
├──── user-feature
|     └──── settings.gradle.kts
|
├──── state
|     └──── settings.gradle.kts
|
├──── domain-model
|     └──── settings.gradle.kts
|
├──── build-logic
|     └──── settings.gradle.kts
|
├──── platforms
|     └──── settings.gradle.kts
|
└──── aggregation
      └──── settings.gradle.kts
```

```
├──── android-app
│       └──── settings.gradle
├──── server-application
│       └──── settings.gradle
│
├──── admin-feature
│       └──── settings.gradle
├──── user-feature
│       └──── settings.gradle
│
├──── state
│       └──── settings.gradle
│
├──── domain-model
│       └──── settings.gradle
│
├──── build-logic
│       └──── settings.gradle
│
├──── platforms
│       └──── settings.gradle
│
└──── aggregation
        └──── settings.gradle
```

In the listing, each component lives in a separate folder. Here we arrange them as a flat list in a root folder. This root folder can be used as root of a Git repository for example.

This is only the setup of the sample. You can freely choose where to physically locate your components. For instance, you can group all components that live in one "layer" in a common subfolder. Or, since these are all independent Gradle builds, you can have each component live in a separate repository. It's up to you to decide what works best for you, the software you are building, and the teams working on it.

Defining an inner structure for components

Before we get to the topic of connecting the components, let's first look at them individually.

So far, each component is just an empty folder with an empty `settings.gradle(.kts)` file indicating that this is a component Gradle can work with in some form. To fill the component with content, you should define at least one project (referred to as subproject in Gradle's DSLs) in it.

You can start with components consisting of a single project each, but introduce additional projects later to structure a single component more internally. In our sample, we start with a single project in each component.

A project is added by using the `include()` construct in the settings file.

Example 83. Use include() to add a project to a component

domain-model/settings.gradle.kts

```
include("release") // a project for data classes that represent software
releases
```

domain-model/settings.gradle

```
include('release') // a project for data classes that represent software
releases
```

Once included, you may create a folder matching the project name and create a `build.gradle(.kts)` file in it to configure that part of the component. You can find more information in the chapter about structuring Gradle builds for a single software component.

Assigning types to components

Let's zoom into the *domain-model* component:

```
└──── domain-model               <-- component
     ├──── settings.gradle.kts   <-- define inner structure of component and where to
locate other components
     └──── release               <-- project in component
        └──── build.gradle.kts   <-- defines type of the project and its dependencies
```

```
└──── domain-model               <-- component
     ├──── settings.gradle       <-- define inner structure of component and where to
locate other components
     └──── release               <-- project in component
        └──── build.gradle       <-- defines type of the project and its dependencies
```

Initially, `release/build.gradle(.kts)` is empty. The project is of no specific type and does not offer any useful content. If we add more files to the `domain-model/release` folder now, for example Java source files, Gradle won't know what to do with these files and will just ignore them. We need to assign a type to the project to make Gradle aware of the purpose of such files.

In Gradle, you assign a type to a project by applying a plugin. The simplest thing you can do is to apply one of Gradle's core plugins, like `base` or `java-library`.

However, usually you have additional configuration to do in the context of the product you are building. For example, if your project should be a "Java Library", it would not only apply the `java-library` plugin but also configure details such as setting the Java version to 11. You can add details

like that directly in `release/build.gradle(.kts)` but than you would have to repeat them in other components that also contain "Java Library" projects.

Thus, the recommendation is to start using custom project types right away:

Example 84. Assign the custom type `com.example.java-library` to a project in the `user-feature` component

user-feature/data/build.gradle.kts

```
plugins {
    id("com.example.java-library")
}
```

user-feature/data/build.gradle

```
plugins {
    id('com.example.java-library')
}
```

Example 85. Assign the custom type `com.example.kotlin-library` to a project in the `domain-model` component

domain-model/release/build.gradle.kts

```
plugins {
    id("com.example.kotlin-library")
}
```

domain-model/release/build.gradle

```
plugins {
    id('com.example.kotlin-library')
}
```

As stated above, a project type is represented by a plugin in Gradle. We thus define custom project types, such as `com.example.java-library` and `com.example.kotlin-library`, as plugins. The next section explains how to define such plugins.

Defining custom project types as convention plugins

Where do we get `com.example.kotlin-library` plugin from? This is what our `build-logic` component

is for.

The `build-logic` component contains project types that Gradle itself understands as build configuration. That is, Gradle plugins for your specific needs, which we call *convention plugins*.

Currently, there are different project types you can use to define *convention plugins* depending on which tools and languages you prefer. In general, any JVM language (Java, Groovy, Kotlin, Scala) can be used to write Gradle plugins as classes that implement the `Plugin<Project>` interface. The most compact way however, is to write them as scripts in Gradle's Groovy or Kotlin DSL.

Which method you choose is up to you. If you are familiar with one of Gradle's DSLs you may choose that, as it is the most compact way to write *convention plugins*. If you are new to Gradle (and also new to Groovy and Kotlin) you may prefer to write the *convention plugins* in Java or another language like Scala. Then you reduce the interaction with Gradle's Groovy or Kotlin DSL to a minimum.

You need to use one of the following project types (i.e. Gradle core plugins) in projects of your `build-logic` component:

- `kotlin-dsl` – Build logic projects with this type (i.e., that apply the `kotlin-dsl` plugin) allow you to write convention plugins as `.gradle.kts` files in `src/main/kotlin`.

- `groovy-gradle-plugin` – Build logic projects with this type (i.e., that apply the `groovy-gradle-plugin` plugin) allow you to write convention plugins as `.gradle` files in `src/main/groovy`.

- `java-gradle-plugin` – Build logic projects with this type (i.e., that apply the `java-gradle-plugin` plugin) allow you to write convention plugins as `.java` classes that implement the `Plugin<Project>` interface in `src/main/java`. If you apply other JVM language plugins on top, like `groovy`, `scala` or `org.jetbrains.kotlin.jvm`, you can also write the plugin class in the corresponding language.

In our sample, we choose the option of using Gradle's DSLs for the convention plugins. The `build-logic` component has several projects that each define a project type through a convention plugin - one of: `java-library`, `kotlin-library`, `spring-application`, `android-application`. Also, there is a project called `commons` for build configuration shared by all our project types.

Example 86. Assign a custom type to a component's project by applying a convention plugin

build-logic/spring-boot-application/build.gradle.kts

```
plugins {
    `kotlin-dsl` ①
}

dependencies {
    implementation(platform("com.example.platform:plugins-platform")) ②

    implementation(project(":commons")) ③

    implementation("org.springframework.boot:org.springframework.boot.gradle.plug
    in") ④
}
```

build-logic/spring-boot-application/build.gradle

```
plugins {
    id('groovy-gradle-plugin') ①
}

dependencies {
    implementation(platform('com.example.platform:plugins-platform')) ②

    implementation(project(':commons')) ③

    implementation(
'org.springframework.boot:org.springframework.boot.gradle.plugin') ④
}
```

Looking at the `build.gradle(.kts)` of the `build-logic` project for spring boot applications, we see:

① That it is of type `groovy-gradle-plugin` or `kotlin-dsl` to allow convention plugins written in the corresponding DSL

② It depends on our own `plugins-platform` from the `platforms` component

③ It depends on the `commons` project from `build-logic` to have access to our own commons convention plugin

④ It depends on the Spring Boot Gradle plugin from the Gradle Plugin Portal so that we may apply that plugin to our Spring Boot projects

Now, we can write the convention plugin for Spring application like this:

Example 87. Defining a custom project type as convention plugin

build-logic/spring-boot-application/src/main/kotlin/com.example.spring-boot-application.gradle.kts

```kotlin
plugins {
    id("com.example.commons")
    id("org.springframework.boot")
}

dependencies {
    implementation("org.springframework.boot:spring-boot-starter-web")
    implementation("org.springframework.boot:spring-boot-starter-thymeleaf")
}
```

build-logic/spring-boot-application/src/main/groovy/com.example.spring-boot-application.gradle

```groovy
plugins {
    id('com.example.commons')
    id('org.springframework.boot')
}

dependencies {
    implementation('org.springframework.boot:spring-boot-starter-web')
    implementation('org.springframework.boot:spring-boot-starter-thymeleaf')
}
```

We see that we apply our own `com.example.commons` plugin which is another convention plugin that, among other things, configures the Java version we are targeting and adds a dependency to a platform (`com.example.platform:product-platform` from our `platforms` component). And we apply the spring boot plugin. Furthermore, we add two dependencies that Spring Boot projects should always have in our context.

Similarly, we define convention plugins for "Java Libraries", "Kotlin Libraries" and "Android Applications". With that, we have four different project types defined that we assign to the projects of our production code components.

You can find more information about writing convention plugins in section on sharing build logic and the associated sample. For using classes to implement plugins, and for writing more advanced custom build logic, consult the chapter on Gradle plugin development.

Connecting components

As demonstrated in the architecture figure, our production code components depend on each other. Above, we already saw that the `platforms` component is used in the `build-logic` component. We also

said that we want to use the `build-logic` component, which declares project types through convention plugins, to assign those types to the projects in our production code components.

How do you define these dependencies? There are two distinct things to do:

1. *Make components (builds) known to each other.* This is done by adding `includeBuild(⋯)` statements to `settings.gradle(.kts)`. This is *not* adding a dependency between (projects of) components. It just makes the physical location of one component known to another. In that sense it is similar to repository declarations to discover binary components. Consult the section on defining composite builds for more information about how to include builds.

2. *Declare dependencies between (projects of) components.* This is done similarly to declaring dependencies to binary components by using GA (*group* and *artifact*) coordinates in the `dependencies { }` block of a `build.gradle(.kts)` file: `implementation("com.example.platform:product-platform")`. Or, if the included component provides a plugin, you apply the plugin by ID similar to how you would apply a plugin from the plugin portal: `plugins { id("com.example.java-library") }`

As another example, consider the setup of our `server-application` component:

Example 88. Defining component locations and inner structure of the `server-application` *component*

server-application/settings.gradle.kts

```
// == Define locations for build logic ==
pluginManagement {
    repositories {
        gradlePluginPortal()
    }
    includeBuild("../build-logic")
}

// == Define locations for components ==
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
includeBuild("../platforms")
includeBuild("../user-feature")
includeBuild("../admin-feature")

// == Define the inner structure of this component ==
rootProject.name = "server-application" // the component name
include("app")
```

server-application/settings.gradle

```
// == Define locations for build logic ==
pluginManagement {
    repositories {
        gradlePluginPortal()
    }
    includeBuild('../build-logic')
}

// == Define locations for components ==
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
includeBuild('../platforms')
includeBuild('../user-feature')
includeBuild('../admin-feature')

// == Define the inner structure of this component ==
rootProject.name = 'server-application' // the component name
include('app')
```

We see that the `settings.gradle(.kts)` file only defines location for build logic components, other production code components and the inner structure of the component. Only the `build.gradle(.kts)` file in the `app` project then defines actual dependencies by applying a convention plugin and utilizing the *dependencies* block.

Example 89. Configuring type and dependencies of the `app` *project inside the* `server-application` *component*

server-application/app/build.gradle.kts

```kotlin
plugins {
    id("com.example.spring-boot-application")
}

group = "${group}.server-application"

dependencies {
    implementation("com.example.myproduct.user-feature:table")
    implementation("com.example.myproduct.admin-feature:config")

    implementation("org.apache.juneau:juneau-marshall")
}
```

server-application/app/build.gradle

```groovy
plugins {
    id('com.example.spring-boot-application')
}

group = "${group}.server-application"

dependencies {
    implementation('com.example.myproduct.user-feature:table')
    implementation('com.example.myproduct.admin-feature:config')

    implementation('org.apache.juneau:juneau-marshall')
}
```

The model of your software

That's it. This chapter gave an overview of which techniques to use to structure a software project into components with Gradle by following a sample. Download the full sample to explore further details. The next chapter covers more details about how to work with and evolve this kind of project structure. The chapter on composite builds gives you more technical background about the capabilities build composition offers.

To summarize, if you follow the suggestions from this chapter, your setup should clearly separate the following concerns to give you a flexible and clean model of your software product:

1. *Write compact* `build.gradle(.kts)` *files.* While in traditional Gradle builds these files tend to grow and mix a lot of different concerns, the structure presented here keeps these files

compact. In most cases they only declare a project type by applying a single convention plugin and dependencies in the `dependencies {}` block. They might include minimal project-specific configuration, but these should be kept as minimal as possible. This also makes builds less dependent on Gradle's DSLs: If you put your build logic into convention plugins, you can write it directly in Java if you like.

2. *Isolate cross-cutting technical concerns into project types.* Technically motivated build configuration often cuts across the entire software architecture. Whether or not a project is a "Java Library" or "Kotlin Library" may be totally independent of where it is located in the hierarchy of your components. If you use convention plugins, this allows you to isolate the definition of such project types in a central place, while still reusing them wherever needed. (This is a huge advantage over so called cross project configuration, which has been popular with older Gradle versions, but is bound to the hierarchy of your project.)

3. *Declare the origins of components in a central place.* In this structure, the places where a build can find other components, independent of whether they are located in a binary repository or are available locally as other Gradle builds, are defined centrally in the `settings.gradle(.kts)` file. This makes it easy to change the origin of a component and move from a binary to a from-source version of a component. Note that there are different strategies to avoid duplicating this information in each `settings.gradle(.kts)` of each of your components.

4. *Declare platforms in a central place.* Having a platform component as in the example is optional. You could do things without one of these, e.g. by declaring dependency constraints directly in your convention plugins. However, platforms are a good option to ensure all the boundaries for the environment in which your software operates defined in a central place.

Tweaking Project Structure

This chapter covers more details on selected topics related to structuring and building a software product with Gradle.

Working with the software project

You have several options to interact with a build that is a composition of multiple builds.

Using an umbrella build

If all your builds are located in one folder structure, you can have an umbrella build in a root folder that includes all builds. You can then call tasks from the root project by addressing one of the builds. Usually, you would then put the Gradle wrapper into the root as well. The sample on structuring software projects contains such an umbrella build in the root. You can address tasks from there:

```
$ ./gradlew :server-application:app:bootRun

$ ./gradlew :android-app:app:installDebug
```

The umbrella build is a good place to define cross-build lifecycle tasks. For example, you can define a `checkFeatures` task for conveniently running all checks in selected components by adding a

`build.gradle(.kts)` file to your umbrella build.

build.gradle.kts

```
// This is an example of a lifecycle task that crosses build boundaries
defined in the umbrella build.
tasks.register("checkFeatures") {
    group = "verification"
    description = "Run all feature tests"
    dependsOn(gradle.includedBuild("admin-feature").task(":config:check"))
    dependsOn(gradle.includedBuild("user-feature").task(":data:check"))
    dependsOn(gradle.includedBuild("user-feature").task(":table:check"))
}
```

build.gradle

```
// This is an example of a lifecycle task that crosses build boundaries
defined in the umbrella build.
tasks.register('checkFeatures') {
    group = 'verification'
    description = 'Run all feature tests'
    dependsOn(gradle.includedBuild('admin-feature').task(':config:check'))
    dependsOn(gradle.includedBuild('user-feature').task(':data:check'))
    dependsOn(gradle.includedBuild('user-feature').task(':table:check'))
}
```

In your IDE, you can import the umbrella build and then will have all Gradle builds as projects/modules visible in the workspace.

Working with components in isolation

Independent of whether you have an umbrella build or not, you can work with each component independently. That is, you can pick any component build and build it individually.

In the sample, the umbrella build is a convenience. The whole project can also be used without it, if you work with the components independently.

```
$ cd server-application
$ ../gradlew :app:bootRun

$ cd android-app
$ ../gradlew :app:installDebug

$ cd user-feature
$ ../gradlew check
```

You can also import components independently in the IDE. This allows you to focus only on the parts important for the component you work on in your IDE's workspace. It might also speed up the IDE performance in the case of a very large code base.

NOTE	If all components live in the same repository, you should only have one Gradle wrapper in the root of the repository. If you have an umbrella build there, you can use that to manage the wrapper.

However, if you import an individual component in an IDE, it might have issues finding the wrapper and you might need to configure a Gradle installation manually.

If your components are scattered over multiple repositories, each should have its own wrapper, but you should ensure that you upgrade them simultaneously.

Using multiple source repositories

Multi-repo development is a well known alternative to mono-repo development. Both have advantages and disadvantages. It depends on many different factors which setup works best for the development of your product.

Gradle aims to support both setups equally well. When you split your product into components, each represented by an independent build, switching a Gradle build between mono- and multi-repo development is simple. In mono-repo development, you put all builds under a common root. In multi-repo development, you place each build into a separate source repository.

Multi-repo development possibly needs some additional guidlines and tooling, so that builds can still find each other. A simple solution is that users who want to build a certain component need to clone all repositories of dependent components next to each other in a file hierarchy. If you follow this pattern, builds can find each other with `includeBuild("../other-component")` statements. If locations are more flexible, you can also invoke Gradle with `--include-build` flags to provide locations dynamically.

Another more evolved setup can involve versioning all components and, instead of including the source versions of all components, depend on published versions of them from binary repositories. This is described next.

Publishing and using binary components

You can also decide to publish your components to a binary repository. If you make the decision to do so at some point and you want to work with binary versions of certain components instead of the source versions, you can do that by adding the repository to which you published instead of the corresponding `includeBuild("···")` statements in your `settings.gradle(.kts)` file. If the components keep their coordinates, you do not need to adjust any dependencies. You just need to define versions for the components, ideally in a platform project.

Publishing components with convention plugins

Note that when publishing build logic components, the `maven-publish` will also publish so called plugin markers that allow Gradle to find plugins by ID – even if they are located in a repository. For that you only need to declare the repositories you want to publish to in your build the same way you do it for other components.

Sharing repository and included build declarations between builds

Each component build has its own `settings.gradle(.kts)` file to describe the location of other components. Which is done by declaring repositories with binary components and by declaring file system locations of included builds.

If components are developed independently, it often makes sense to define these individually for each one. Then it is individually controlled where the other components originate from. Furthermore, the declarations might vary from build to build. For example, you might only

include the builds that are needed to build a certain component and not all builds that make up the product.

However, it may also lead to redundancy as you declare the same repositories and included builds in each `settings.gradle(.kts)` file again. In particular, if all builds live in the same repository.

Similar as for build scripts, you can define *settings convention plugins* for the `settings.gradle(.kts)` file to reuse configuration. For that, you should create a separate build. *Settings convention plugins* can be written in Groovy DSL or Kotlin DSL similar to other convention plugins. The script file name has to end with `.settings.gradle(.kts)`. A build providing a settings plugin needs to be included as plugin builds in the `pluginManagement {}` block.

= Composing builds

== What is a composite build?

A composite build is simply a build that includes other builds. In many ways a composite build is similar to a Gradle multi-project build, except that instead of including single `projects`, complete `builds` are included.

Composite builds allow you to:

- combine builds that are usually developed independently, for instance when trying out a bug fix in a library that your application uses
- decompose a large multi-project build into smaller, more isolated chunks that can be worked in independently or together as needed

A build that is included in a composite build is referred to, naturally enough, as an "included build". Included builds do not share any configuration with the composite build, or the other included builds. Each included build is configured and executed in isolation.

Included builds interact with other builds via *dependency substitution*. If any build in the composite has a dependency that can be satisfied by the included build, then that dependency will be replaced by a project dependency on the included build. *Because of the reliance on dependency substitution, composite builds may force configurations to be resolved earlier, when composing the task execution graph. This can have a negative impact on overall build performance, because these configurations are not resolved in parallel.*

By default, Gradle will attempt to determine the dependencies that can be substituted by an included build. However for more flexibility, it is possible to explicitly declare these substitutions if the default ones determined by Gradle are not correct for the composite. See Declaring substitutions.

As well as consuming outputs via project dependencies, a composite build can directly declare task dependencies on included builds. Included builds are isolated, and are not able to declare task dependencies on the composite build or on other included builds. See Depending on tasks in an included build.

== Defining a composite build

The following examples demonstrate the various ways that 2 Gradle builds that are normally developed separately can be combined into a composite build. For these examples, the `my-utils` multi-project build produces 2 different java libraries (`number-utils` and `string-utils`), and the `my-app` build produces an executable using functions from those libraries.

The `my-app` build does not have direct dependencies on `my-utils`. Instead, it declares binary dependencies on the libraries produced by `my-utils`.

my-app/app/build.gradle.kts

```
plugins {
    id("application")
}

application {
    mainClass = "org.sample.myapp.Main"
}

dependencies {
    implementation("org.sample:number-utils:1.0")
    implementation("org.sample:string-utils:1.0")
}
```

my-app/app/build.gradle

```
plugins {
    id 'application'
}

application {
    mainClass = 'org.sample.myapp.Main'
}

dependencies {
    implementation 'org.sample:number-utils:1.0'
    implementation 'org.sample:string-utils:1.0'
}
```

Defining a composite build via `--include-build`

The `--include-build` command-line argument turns the executed build into a composite, substituting dependencies from the included build into the executed build.

Output of `gradle --include-build ../my-utils run`

```
> gradle --include-build ../my-utils run
link:https://docs.gradle.org/8.6-milestone-1/samples/build-organization/composite-
builds/basic/tests/basicCli.out[]
```

Defining a composite build via the settings file

It's possible to make the above arrangement persistent, by using Settings.includeBuild(java.lang.Object) to declare the included build in the `settings.gradle` (or `settings.gradle.kts` in Kotlin) file. The settings file can be used to add subprojects and included builds at the same time. Included builds are added by location. See the examples below for more details.

Defining a separate composite build

One downside of the above approach is that it requires you to modify an existing build, rendering it less useful as a standalone build. One way to avoid this is to define a separate composite build, whose only purpose is to combine otherwise separate builds.

settings.gradle.kts

```
rootProject.name = "my-composite"

includeBuild("my-app")
includeBuild("my-utils")
```

settings.gradle

```
rootProject.name = 'my-composite'

includeBuild 'my-app'
includeBuild 'my-utils'
```

In this scenario, the 'main' build that is executed is the composite, and it doesn't define any useful tasks to execute itself. In order to execute the 'run' task in the 'my-app' build, the composite build must define a delegating task.

build.gradle.kts

```
tasks.register("run") {
    dependsOn(gradle.includedBuild("my-app").task(":app:run"))
}
```

build.gradle

```
tasks.register('run') {
    dependsOn gradle.includedBuild('my-app').task(':app:run')
}
```

More details about tasks that depend on included build tasks are below.

=== Including builds that define Gradle plugins

A special case of included builds are builds that define Gradle plugins. These builds should be included using the `includeBuild` statement inside the `pluginManagement` `{}` block of the settings file. Using this mechanism, the included build may also contribute a settings plugin that can be applied in the settings file itself.

settings.gradle.kts

```
pluginManagement {
    includeBuild("../url-verifier-plugin")
}
```

settings.gradle

```
pluginManagement {
    includeBuild '../url-verifier-plugin'
}
```

You may also use the `includeBuild` mechanism outside `pluginManagement` to include plugin builds. However, this does not support all use cases and including plugin builds like that might be deprecated in a future Gradle version.

=== Restrictions on included builds

Most builds can be included into a composite, including other composite builds. However there are some restrictions.

Every included build:

- must not have a `rootProject.name` the same as another included build.

- must not have a `rootProject.name` the same as a top-level project of the composite build.

- must not have a `rootProject.name` the same as the composite build `rootProject.name`.

When a composite build is included into another composite build, then both included builds would have the same parent. In other words, nested composite build structure is flattened.

== Interacting with a composite build

In general, interacting with a composite build is much the same as a regular multi-project build. Tasks can be executed, tests can be run, and builds can be imported into the IDE.

=== Executing tasks

Tasks from an included build can be executed from the command-line or from your IDE in the same way as tasks from a regular multi-project build. Executing a task will result in task dependencies being executed, as well as those tasks required to build dependency artifacts from other included builds.

You can call a task in an included build using a fully qualified path, for example `:included-build-name:project-name:taskName`. Project and task names can be abbreviated.

```
$ ./gradlew :included-build:subproject-a:compileJava
> Task :included-build:subproject-a:compileJava

$ ./gradlew :i-b:sA:cJ
> Task :included-build:subproject-a:compileJava
```

To exclude a task from the command line, you also need to provide the fully qualified path to the task.

| NOTE | Included build tasks are automatically executed in order to generate required dependency artifacts, or the including build can declare a dependency on a task from an included build. |

=== Importing into the IDE

One of the most useful features of composite builds is IDE integration. By applying the idea or eclipse plugin to your build, it is possible to generate a single IDEA or Eclipse project that permits all builds in the composite to be developed together.

In addition to these Gradle plugins, recent versions of IntelliJ IDEA and Eclipse Buildship support direct import of a composite build.

Importing a composite build permits sources from separate Gradle builds to be easily developed together. For every included build, each sub-project is included as an IDEA Module or Eclipse Project. Source dependencies are configured, providing cross-build navigation and refactoring.

== Declaring the dependencies substituted by an included build

By default, Gradle will configure each included build in order to determine the dependencies it can provide. The algorithm for doing this is very simple: Gradle will inspect the group and name for the projects in the included build, and substitute project dependencies for any external dependency matching `${project.group}:${project.name}`.

By default, substitutions are not registered for the *main* build.

To make the (sub)projects of the main build addressable by `${project.group}:${project.name}`, you can tell Gradle to treat the main build like an included build by self-including it: `includeBuild(".")`.

> There are cases when the default substitutions determined by Gradle are not sufficient, or they are not correct for a particular composite. For these cases it is possible to explicitly declare the substitutions for an included build. Take for example a single-project build 'anonymous-library', that produces a java utility library but does not declare a value for the group attribute:

build.gradle.kts

```
plugins {
    java
}
```

build.gradle

```
plugins {
    id 'java'
}
```

> When this build is included in a composite, it will attempt to substitute for the dependency module "undefined:anonymous-library" ("undefined" being the default value for `project.group`, and "anonymous-library" being the root project name). Clearly this isn't going to be very useful in a composite build. To use the unpublished library unmodified in a composite build, the composing build can explicitly declare the substitutions that it provides:

settings.gradle.kts

```
includeBuild("anonymous-library") {
    dependencySubstitution {
        substitute(module("org.sample:number-utils")).using(project(":"))
    }
}
```

settings.gradle

```
includeBuild('anonymous-library') {
    dependencySubstitution {
        substitute module('org.sample:number-utils') using project(':')
    }
}
```

With this configuration, the "my-app" composite build will substitute any dependency on `org.sample:number-utils` with a dependency on the root project of "anonymous-library".

=== Deactivate included build substitutions for a Configuration

If you need to resolve a published version of a module that is also available as part of an included build, you can deactivate the included build substitution rules on the ResolutionStrategy of the Configuration that is resolved. This is necessary, because the rules are globally applied in the build and Gradle does not consider published versions during resolution by default.

build.gradle.kts

```
configurations.create("publishedRuntimeClasspath") {
    resolutionStrategy.useGlobalDependencySubstitutionRules = false

    extendsFrom(configurations.runtimeClasspath.get())
    isCanBeConsumed = false
    attributes.attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage.JAVA_RUNTIME))
}
```

build.gradle

```
configurations.create('publishedRuntimeClasspath') {
    resolutionStrategy.useGlobalDependencySubstitutionRules = false

    extendsFrom(configurations.runtimeClasspath)
    canBeConsumed = false
    attributes.attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage, Usage
.JAVA_RUNTIME))
}
```

In this example, we create a separate `publishedRuntimeClasspath` configuration that gets resolve to the published versions of modules that also exist in one of the local builds. This can be used, for example, to compare published and locally built Jar files.

=== Cases where included build substitutions must be declared

Many builds will function automatically as an included build, without declared substitutions. Here are some common cases where declared substitutions are required:

- When the `archivesBaseName` property is used to set the name of the published artifact.

- When a configuration other than `default` is published.

- When the `MavenPom.addFilter()` is used to publish artifacts that don't match the project name.

- When the `maven-publish` or `ivy-publish` plugins are used for publishing, and the publication coordinates don't match `${project.group}:${project.name}`.

=== Cases where composite build substitutions won't work

Some builds won't function correctly when included in a composite, even when dependency substitutions are explicitly declared. This limitation is due to the fact that a project dependency that is substituted will always point to the `default` configuration of the target project. Any time that the artifacts and dependencies specified for the default configuration of a project don't match what is actually published to a repository, then the composite build may exhibit different behaviour.

Here are some cases where the publish module metadata may be different from the project default configuration:

- When a configuration other than `default` is published.

- When the `maven-publish` or `ivy-publish` plugins are used.

- When the `POM` or `ivy.xml` file is tweaked as part of publication.

Builds using these features function incorrectly when included in a composite build. We plan to improve this in the future.

== Depending on tasks in an included build

While included builds are isolated from one another and cannot declare direct dependencies, a composite build is able to declare task dependencies on its included builds. The included builds are accessed using Gradle.getIncludedBuilds() or Gradle.includedBuild(java.lang.String), and a task reference is obtained via the IncludedBuild.task(java.lang.String) method.

Using these APIs, it is possible to declare a dependency on a task in a particular included build, or tasks with a certain path in all or some of the included builds.

build.gradle.kts

```
tasks.register("run") {
    dependsOn(gradle.includedBuild("my-app").task(":app:run"))
}
```

build.gradle

```
tasks.register('run') {
    dependsOn gradle.includedBuild('my-app').task(':app:run')
}
```

build.gradle.kts

```
tasks.register("publishDeps") {
    dependsOn(gradle.includedBuilds.map {
it.task(":publishMavenPublicationToMavenRepository") })
}
```

build.gradle

```
tasks.register('publishDeps') {
    dependsOn gradle.includedBuilds*.task(
':publishMavenPublicationToMavenRepository')
}
```

== Current limitations and future plans for composite builds

Limitations of the current implementation include:

- No support for included builds that have publications that don't mirror the project default configuration. See Cases where composite builds won't work.
- Multiple composite builds may conflict when run in parallel, if more than one includes the same build. Gradle does not share the project lock of a shared composite build to between Gradle invocation to prevent concurrent execution.

== AUTHORING SUSTAINABLE BUILDS

= Organizing Gradle Projects

Source code and build logic of every software project should be organized in a meaningful way. This page lays out the best practices that lead to readable, maintainable projects. The following sections also touch on common problems and how to avoid them.

== Separate language-specific source files

Gradle's language plugins establish conventions for discovering and compiling source code. For example, a project applying the Java plugin will automatically compile the code in the directory `src/main/java`. Other language plugins follow the same pattern. The last portion of the directory path usually indicates the expected language of the source files.

Some compilers are capable of cross-compiling multiple languages in the same source directory. The Groovy compiler can handle the scenario of mixing Java and Groovy source files located in `src/main/groovy`. Gradle recommends that you place sources in directories according to their language, because builds are more performant and both the user and build can make stronger assumptions.

The following source tree contains Java and Kotlin source files. Java source files live in `src/main/java`, whereas Kotlin source files live in `src/main/kotlin`.

```
.
├── build.gradle.kts
└── src
    └── main
        ├── java
        │   └── HelloWorld.java
        └── kotlin
            └── Utils.kt
```

```
.
├── build.gradle
└── src
    └── main
        ├── java
        │   └── HelloWorld.java
        └── kotlin
            └── Utils.kt
```

Separate source files per test type

It's very common that a project defines and executes different types of tests e.g. unit tests, integration tests, functional tests or smoke tests. Optimally, the test source code for each test type should be stored in dedicated source directories. Separated test source code has a positive impact on maintainability and separation of concerns as you can run test types independent from each other.

Have a look at the sample that demonstrates how a separate integration tests configuration can be added to a Java-based project.

Use standard conventions as much as possible

All Gradle core plugins follow the software engineering paradigm convention over configuration. The plugin logic provides users with sensible defaults and standards, the conventions, in a certain context. Let's take the Java plugin as an example.

- It defines the directory `src/main/java` as the default source directory for compilation.
- The output directory for compiled source code and other artifacts (like the JAR file) is `build`.

By sticking to the default conventions, new developers to the project immediately know how to find their way around. While those conventions can be reconfigured, it makes it harder to build script users and authors to manage the build logic and its outcome. Try to stick to the default conventions as much as possible except if you need to adapt to the layout of a legacy project. Refer to the reference page of the relevant plugin to learn about its default conventions.

Always define a settings file

Gradle tries to locate a `settings.gradle` (Groovy DSL) or a `settings.gradle.kts` (Kotlin DSL) file with every invocation of the build. For that purpose, the runtime walks the hierarchy of the directory tree up to the root directory. The algorithm stops searching as soon as it finds the settings file.

Always add a `settings.gradle` to the root directory of your build to avoid the initial performance impact. The file can either be empty or define the desired name of the project.

A multi-project build must have a `settings.gradle(.kts)` file in the root project of the multi-project hierarchy. It is required because the settings file defines which projects are taking part in a multi-project build. Besides defining included projects, you might need it to add libraries to your build script classpath.

The following example shows a standard Gradle project layout:

```
.
├── settings.gradle.kts
├── subproject-one
│   └── build.gradle.kts
└── subproject-two
    └── build.gradle.kts
```

```
.
├── settings.gradle
├── subproject-one
│   └── build.gradle
└── subproject-two
    └── build.gradle
```

Use `buildSrc` to abstract imperative logic

Complex build logic is usually a good candidate for being encapsulated either as custom task or binary plugin. Custom task and plugin implementations should not live in the build script. It is very convenient to use `buildSrc` for that purpose as long as the code does not need to be shared among multiple, independent projects.

The directory `buildSrc` is treated as an included build. Upon discovery of the directory, Gradle automatically compiles and tests this code and puts it in the classpath of your build script. For multi-project builds there can be only one `buildSrc` directory, which has to sit in the root project directory. `buildSrc` should be preferred over script plugins as it is easier to maintain, refactor and test the code.

`buildSrc` uses the same source code conventions applicable to Java and Groovy projects. It also provides direct access to the Gradle API. Additional dependencies can be declared in a dedicated `build.gradle` under `buildSrc`.

buildSrc/build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    testImplementation("junit:junit:4.13")
}
```

buildSrc/build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    testImplementation 'junit:junit:4.13'
}
```

A typical project including `buildSrc` has the following layout. Any code under `buildSrc` should use a package similar to application code. Optionally, the `buildSrc` directory can host a build script if additional configuration is needed (e.g. to apply plugins or to declare dependencies).

```
.
├── buildSrc
│   ├── build.gradle.kts
│   └── src
│       ├── main
│       │   └── java
│       │       └── com
│       │           └── enterprise
│       │               ├── Deploy.java
│       │               └── DeploymentPlugin.java
│       └── test
│           └── java
│               └── com
│                   └── enterprise
│                       └── DeploymentPluginTest.java
├── settings.gradle.kts
├── subproject-one
│   └── build.gradle.kts
└── subproject-two
    └── build.gradle.kts
```

```
.
├── buildSrc
│    ├── build.gradle
│    └── src
│         ├── main
│         │    └── java
│         │         └── com
│         │              └── enterprise
│         │                   ├── Deploy.java
│         │                   └── DeploymentPlugin.java
│         └── test
│              └── java
│                   └── com
│                        └── enterprise
│                             └── DeploymentPluginTest.java
├── settings.gradle
├── subproject-one
│    └── build.gradle
└── subproject-two
     └── build.gradle
```
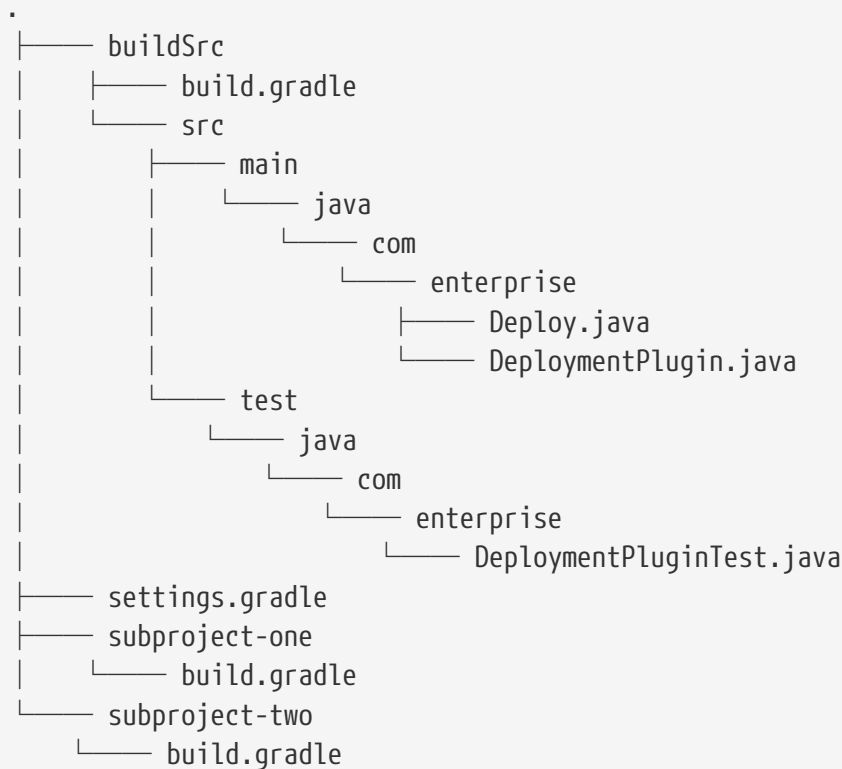
A change in `buildSrc` causes the whole project to become out-of-date.

Thus, when making small incremental changes, the `--no-rebuild` command-line option is often helpful to get faster feedback. Remember to run a full build regularly.

== Declare properties in `gradle.properties` file

In Gradle, properties can be defined in the build script, in a `gradle.properties` file or as parameters on the command line.

It's common to declare properties on the command line for ad-hoc scenarios. For example you may want to pass in a specific property value to control runtime behavior just for this one invocation of the build. Properties in a build script can easily become a maintenance headache and convolute the build script logic. The `gradle.properties` helps with keeping properties separate from the build script and should be explored as viable option. It's a good location for placing properties that control the build environment.

A typical project setup places the `gradle.properties` file in the root directory of the build. Alternatively, the file can also live in the `GRADLE_USER_HOME` directory if you want it to apply to all builds on your machine.

```
.
├── gradle.properties
└── settings.gradle.kts
├── subproject-a
│   └── build.gradle.kts
└── subproject-b
    └── build.gradle.kts
```

```
.
├── gradle.properties
└── settings.gradle
├── subproject-a
│   └── build.gradle
└── subproject-b
    └── build.gradle
```

Avoid overlapping task outputs

Tasks should define inputs and outputs to get the performance benefits of incremental build functionality. When declaring the outputs of a task, make sure that the directory for writing outputs is unique among all the tasks in your project.

Intermingling or overwriting output files produced by different tasks compromises up-to-date checking causing slower builds. In turn, these filesystem changes may prevent Gradle's build cache from properly identifying and caching what would otherwise be cacheable tasks.

Standardizing builds with a custom Gradle distribution

Often enterprises want to standardize the build platform for all projects in the organization by defining common conventions or rules. You can achieve that with the help of initialization scripts. Initialization scripts make it extremely easy to apply build logic across all projects on a single machine. For example, to declare a in-house repository and its credentials.

There are some drawbacks to the approach. First of all, you will have to communicate the setup process across all developers in the company. Furthermore, updating the initialization script logic uniformly can prove challenging.

Custom Gradle distributions are a practical solution to this very problem. A custom Gradle distribution is comprised of the standard Gradle distribution plus one or many custom initialization scripts. The initialization scripts come bundled with the distribution and are applied every time the build is run. Developers only need to point their checked-in Wrapper files to the URL of the custom Gradle distribution.

Custom Gradle distributions may also contain a `gradle.properties` file in the root of the distribution, which provide an organization-wide set of properties that control the build environment.

The following steps are typical for creating a custom Gradle distribution:

1. Implement logic for downloading and repackaging a Gradle distribution.

2. Define one or many initialization scripts with the desired logic.

3. Bundle the initialization scripts with the Gradle distribution.

4. Upload the Gradle distribution archive to a HTTP server.

5. Change the Wrapper files of all projects to point to the URL of the custom Gradle distribution.

build.gradle

```gradle
plugins {
    id 'base'
}

// This is defined in buildSrc
import org.gradle.distribution.DownloadGradle

version = '0.1'

tasks.register('downloadGradle', DownloadGradle) {
    description = 'Downloads the Gradle distribution with a given version.'
    gradleVersion = '4.6'
}

tasks.register('createCustomGradleDistribution', Zip) {
    description = 'Builds custom Gradle distribution and bundles initialization
scripts.'

    dependsOn downloadGradle

    def projectVersion = project.version
    archiveFileName = downloadGradle.gradleVersion.map { gradleVersion ->
        "mycompany-gradle-${gradleVersion}-${projectVersion}-bin.zip"
    }

    from zipTree(downloadGradle.destinationFile)

    from('src/init.d') {
        into "${downloadGradle.distributionNameBase.get()}/init.d"
    }
}
```

Best practices for authoring maintainable builds

Gradle has a rich API with several approaches to creating build logic. The associated flexibility can easily lead to unnecessarily complex builds with custom code commonly added directly to build scripts. In this chapter, we present several best practices that will help you develop expressive and maintainable builds that are easy to use.

> **NOTE** The third-party Gradle lint plugin helps with enforcing a desired code style in build scripts if that's something that would interest you.

Avoid using imperative logic in scripts

The Gradle runtime does not enforce a specific style for build logic. For that very reason, it's easy to end up with a build script that mixes declarative DSL elements with imperative, procedural code. Let's talk about some concrete examples.

- *Declarative code:* Built-in, language-agnostic DSL elements (e.g. Project.dependencies{} or Project.repositories{}) or DSLs exposed by plugins
- *Imperative code:* Conditional logic or very complex task action implementations

The end goal of every build script should be to only contain declarative language elements which makes the code easier to understand and maintain. Imperative logic should live in binary plugins and which in turn is applied to the build script. As a side product, you automatically enable your team to reuse the plugin logic in other projects if you publish the artifact to a binary repository.

The following sample build shows a negative example of using conditional logic directly in the build script. While this code snippet is small, it is easy to imagine a full-blown build script using numerous procedural statements and the impact it would have on readability and maintainability. By moving the code into a class, it can also be tested individually.

build.gradle.kts

```
if (project.findProperty("releaseEngineer") != null) {
    tasks.register("release") {
        doLast {
            logger.quiet("Releasing to production...")

            // release the artifact to production
        }
    }
}
```

build.gradle

```
if (project.findProperty('releaseEngineer') != null) {
    tasks.register('release') {
        doLast {
            logger.quiet 'Releasing to production...'

            // release the artifact to production
        }
    }
}
```

Let's compare the build script with the same logic implemented as a binary plugin. The code might look more involved at first but clearly looks more like typical application code. This particular plugin class lives in the buildSrc directory which makes it available to the build script automatically.

ReleasePlugin.java

```java
package com.enterprise;

import org.gradle.api.Action;
import org.gradle.api.Plugin;
import org.gradle.api.Project;
import org.gradle.api.Task;
import org.gradle.api.tasks.TaskProvider;

public class ReleasePlugin implements Plugin<Project> {
    private static final String RELEASE_ENG_ROLE_PROP = "releaseEngineer";
    private static final String RELEASE_TASK_NAME = "release";

    @Override
    public void apply(Project project) {
        if (project.findProperty(RELEASE_ENG_ROLE_PROP) != null) {
            Task task = project.getTasks().create(RELEASE_TASK_NAME);

            task.doLast(new Action<Task>() {
                @Override
                public void execute(Task task) {
                    task.getLogger().quiet("Releasing to production...");

                    // release the artifact to production
                }
            });
        }
    }
}
```

Now that the build logic has been translated into a plugin, you can apply it in the build script. The build script has been shrunk from 8 lines of code to a one liner.

build.gradle.kts

```kotlin
plugins {
    id("com.enterprise.release")
}
```

build.gradle

```
plugins {
    id 'com.enterprise.release'
}
```

Avoid using internal Gradle APIs

Use of Gradle internal APIs in plugins and build scripts has the potential to break builds when either Gradle or plugins change.

The following packages are listed in the Gradle public API definition and the Kotlin DSL API definition, except any subpackage with `internal` in the name.

Gradle API packages

```
org.gradle
org.gradle.api.*
org.gradle.authentication.*
org.gradle.build.*
org.gradle.buildinit.*
org.gradle.caching.*
org.gradle.concurrent.*
org.gradle.deployment.*
org.gradle.external.javadoc.*
org.gradle.ide.*
org.gradle.ivy.*
org.gradle.jvm.*
org.gradle.language.*
org.gradle.maven.*
org.gradle.nativeplatform.*
org.gradle.normalization.*
org.gradle.platform.*
org.gradle.plugin.devel.*
org.gradle.plugin.use
org.gradle.plugin.management
org.gradle.plugins.*
org.gradle.process.*
org.gradle.testfixtures.*
org.gradle.testing.jacoco.*
org.gradle.tooling.*
org.gradle.swiftpm.*
org.gradle.model.*
org.gradle.testkit.*
org.gradle.testing.*
org.gradle.vcs.*
org.gradle.work.*
org.gradle.workers.*
org.gradle.util.*
```

Kotlin DSL API packages

```
org.gradle.kotlin.dsl
org.gradle.kotlin.dsl.precompile
```

=== Alternatives for oft-used internal APIs

To provide a nested DSL for your custom task, don't use `org.gradle.internal.reflect.Instantiator`; use ObjectFactory instead. It may also be helpful to read the chapter on lazy configuration.

Don't use `org.gradle.api.internal.ConventionMapping`. Use Provider and/or Property. You can find an example for capturing user input to configure runtime behavior in the implementing plugins section.

Instead of `org.gradle.internal.os.OperatingSystem`, use another method to detect operating system, such as Apache commons-lang SystemUtils or `System.getProperty("os.name")`.

Use other collections or I/O frameworks instead of `org.gradle.util.CollectionUtils`, `org.gradle.util.internal.GFileUtils`, and other classes under `org.gradle.util.*`.

Gradle plugin authors may find the Designing Gradle Plugins subsection on restricting the plugin implementation to Gradle's public API helpful.

== Follow conventions when declaring tasks

The task API gives a build author a lot of flexibility to declare tasks in a build script. For optimal readability and maintainability follow these rules:

- The task type should be the only key-value pair within the parentheses after the task name.

- Other configuration should be done within the task's configuration block.

- Task actions added when declaring a task should only be declared with the methods Task.doFirst{} or Task.doLast{}.

- When declaring an ad-hoc task — one that doesn't have an explicit type — you should use Task.doLast{} if you're only declaring a single action.

- A task should define a group and description.

build.gradle.kts

```kotlin
import com.enterprise.DocsGenerate

tasks.register<DocsGenerate>("generateHtmlDocs") {
    group = JavaBasePlugin.DOCUMENTATION_GROUP
    description = "Generates the HTML documentation for this project."
    title = "Project docs"
    outputDir = layout.buildDirectory.dir("docs")
}

tasks.register("allDocs") {
    group = JavaBasePlugin.DOCUMENTATION_GROUP
    description = "Generates all documentation for this project."
    dependsOn("generateHtmlDocs")

    doLast {
        logger.quiet("Generating all documentation...")
    }
}
```

build.gradle

```groovy
import com.enterprise.DocsGenerate

def generateHtmlDocs = tasks.register('generateHtmlDocs', DocsGenerate) {
    group = JavaBasePlugin.DOCUMENTATION_GROUP
    description = 'Generates the HTML documentation for this project.'
    title = 'Project docs'
    outputDir = layout.buildDirectory.dir('docs')
}

tasks.register('allDocs') {
    group = JavaBasePlugin.DOCUMENTATION_GROUP
    description = 'Generates all documentation for this project.'
    dependsOn generateHtmlDocs

    doLast {
        logger.quiet('Generating all documentation...')
    }
}
```

== Improve task discoverability

Even new users to a build should to be able to find crucial information quickly and effortlessly. In Gradle you can declare a group and a description for any task of the build. The tasks report uses the assigned values to organize and render the task for easy discoverability. Assigning a group and description is most helpful for any task that you expect build users to invoke.

The example task `generateDocs` generates documentation for a project in the form of HTML pages. The task should be organized underneath the bucket `Documentation`. The description should express its intent.

build.gradle.kts

```
tasks.register("generateDocs") {
    group = "Documentation"
    description = "Generates the HTML documentation for this project."

    doLast {
        // action implementation
    }
}
```

build.gradle

```
tasks.register('generateDocs') {
    group = 'Documentation'
    description = 'Generates the HTML documentation for this project.'

    doLast {
        // action implementation
    }
}
```

The output of the tasks report reflects the assigned values.

```
> gradle tasks

> Task :tasks

Documentation tasks
-------------------
generateDocs - Generates the HTML documentation for this project.
```

== Minimize logic executed during the configuration phase

It's important for every build script developer to understand the different phases of the build lifecycle and their implications on performance and evaluation order of build logic. During the configuration phase the project and its domain objects should be *configured*, whereas the execution phase only executes the actions of the task(s) requested on the command line plus their dependencies. Be aware that any code that is not part of a task action will be executed with *every single run* of the build. A build scan can help you with identifying the time spent during each of the lifecycle phases. It's an invaluable tool for diagnosing common performance issues.

Let's consider the following incantation of the anti-pattern described above. In the build script you can see that the dependencies assigned to the configuration `printArtifactNames` are resolved outside of the task action.

build.gradle.kts

```
dependencies {
    implementation("log4j:log4j:1.2.17")
}

tasks.register("printArtifactNames") {
    // always executed
    val libraryNames = configurations.compileClasspath.get().map { it.name }

    doLast {
        logger.quiet(libraryNames.joinToString())
    }
}
```

build.gradle

```
dependencies {
    implementation 'log4j:log4j:1.2.17'
}

tasks.register('printArtifactNames') {
    // always executed
    def libraryNames = configurations.compileClasspath.collect { it.name }

    doLast {
        logger.quiet libraryNames
    }
}
```

The code for resolving the dependencies should be moved into the task action to avoid the performance impact of resolving the dependencies before they are actually needed.

build.gradle.kts

```
dependencies {
    implementation("log4j:log4j:1.2.17")
}

tasks.register("printArtifactNames") {
    val compileClasspath: FileCollection = configurations.compileClasspath.get()
    doLast {
        val libraryNames = compileClasspath.map { it.name }
        logger.quiet(libraryNames.joinToString())
    }
}
```

build.gradle

```
dependencies {
    implementation 'log4j:log4j:1.2.17'
}

tasks.register('printArtifactNames') {
    FileCollection compileClasspath = configurations.compileClasspath
    doLast {
        def libraryNames = compileClasspath.collect { it.name }
        logger.quiet libraryNames
    }
}
```

== Avoid using the `GradleBuild` task type

The GradleBuild task type allows a build script to define a task that invokes another Gradle build. The use of this type is generally discouraged. There are some corner cases where the invoked build doesn't expose the same runtime behavior as from the command line or through the Tooling API leading to unexpected results.

Usually, there's a better way to model the requirement. The appropriate approach depends on the problem at hand. Here're some options:

- Model the build as multi-project build if the intention is to execute tasks from different modules as unified build.
- Use composite builds for projects that are physically separated but should occasionally be built as a single unit.

== Avoid inter-project configuration

Gradle does not restrict build script authors from reaching into the domain model from one project into another one in a multi-project build. Strongly-coupled projects hurts build execution performance as well as readability and maintainability of code.

The following practices should be avoided:

- Explicitly depending on a task from another project via Task.dependsOn(java.lang.Object…).
- Setting property values or calling methods on domain objects from another project.
- Executing another portion of the build with GradleBuild.
- Declaring unnecessary project dependencies.

== Externalize and encrypt your passwords

Most builds need to consume one or many passwords. The reasons for this need may vary. Some builds need a password for publishing artifacts to a secured binary repository, other builds need a password for downloading binary files. Passwords should always kept safe to prevent fraud. Under no circumstance should you add the password to the build script in plain text or declare it in `gradle.properties` file in the project's directory. Those files usually live in a version control repository and can be viewed by anyone that has access to it.

Passwords together with any other sensitive data should be kept external from the version controlled project files. Gradle exposes an API for providing credentials in ProviderFactory as well as Artifact Repositories that allows to supply credential values using Gradle properties when they are needed by the build. This way the credentials can be stored in the `gradle.properties` file that resides in the user's home directory or be injected to the build using command line arguments or environment variables.

If you store sensitive credentials in user home's `gradle.properties`, consider encrypting them. At the moment Gradle does not provide a built-in mechanism for encrypting, storing and accessing passwords. A good solution for solving this problem is the Gradle Credentials plugin.

Don't anticipate configuration creation

Gradle will create certain configurations, such as `default` or `archives`, using a "check if needed" strategy. That means it will only create these configurations if they **do not** already exist.

You should **not** ever create these configurations yourself. Names such as these, and the names of configurations associated with source sets, should be considered implicitly "reserved". The exact list of reserved names depends on which plugins are applied and how your build is configured.

This situation will be announced with the following deprecation warnings:

```
Configuration customCompileClasspath already exists with permitted usage(s):
    Consumable - this configuration can be selected by another project as a
dependency
    Resolvable - this configuration can be resolved by this project to a set of
files
    Declarable - this configuration can have dependencies added to it
Yet Gradle expected to create it with the usage(s):
    Resolvable - this configuration can be resolved by this project to a set of
files
```

Gradle will then attempt to mutate the allowed usage to match the expected usage and will emit a second warning:

```
Gradle will mutate the usage of this configuration to match the expected usage.
This may cause unexpected behavior. Creating configurations with reserved names
has been deprecated. This is scheduled to be removed in Gradle 9.0. Create source
sets prior to creating or accessing the configurations associated with them.
```

Some configurations may have their usage locked against mutation. In this case your build will fail and this warning will be immediately followed by an exception with the message:

```
Gradle cannot mutate the usage of configuration 'customCompileClasspath' because
it is locked.
```

If you encounter this error you must either:

1. Change the name of your configuration to avoid the conflict.
2. If changing the name is not possible, ensure the allowed usage (consumable, resolvable, declarable against) for your configuration is aligned with Gradle's expectations.

As a best practice, you should not "anticipate" configuration creation - let Gradle create the configuration first and then adjust it. Or, if possible, use non-conflicting names for your custom configurations by renaming them when you see this warning.

DEVELOPING GRADLE TASKS

Authoring Tasks

In the introductory tutorial you learned how to create simple tasks. You also learned how to add additional behavior to these tasks later on, and you learned how to create dependencies between tasks. This was all about simple tasks, but Gradle takes the concept of tasks further. Gradle supports tasks that have their own properties and methods. Such tasks are either provided by you or built into Gradle.

Task outcomes

When Gradle executes a task, it can label the task with different outcomes in the console UI and via the Tooling API. These labels are based on if a task has actions to execute, if it should execute those actions, if it did execute those actions and if those actions made any changes.

`(no label)` **or** `EXECUTED`

Task executed its actions.

- Task has actions and Gradle has determined they should be executed as part of a build.
- Task has no actions and some dependencies, and any of the dependencies are executed. See also Lifecycle Tasks.

`UP-TO-DATE`

Task's outputs did not change.

- Task has outputs and inputs and they have not changed. See Incremental Build.
- Task has actions, but the task tells Gradle it did not change its outputs.
- Task has no actions and some dependencies, but all of the dependencies are up-to-date, skipped or from cache. See also Lifecycle Tasks.
- Task has no actions and no dependencies.

`FROM-CACHE`

Task's outputs could be found from a previous execution.

- Task has outputs restored from the build cache. See Build Cache.

`SKIPPED`

Task did not execute its actions.

- Task has been explicitly excluded from the command-line. See Excluding tasks from execution.
- Task has an `onlyIf` predicate return false. See Using a predicate.

`NO-SOURCE`

Task did not need to execute its actions.

- Task has inputs and outputs, but no sources. For example, source files are `.java` files for JavaCompile.

Defining tasks

We have already seen how to define tasks using strings for task names in this chapter. There are a few variations on this style, which you may need to use in certain situations.

NOTE	The task configuration APIs are described in more detail in the task configuration avoidance chapter.

build.gradle.kts

```kotlin
tasks.register("hello") {
    doLast {
        println("hello")
    }
}

tasks.register<Copy>("copy") {
    from(file("srcDir"))
    into(buildDir)
}
```

build.gradle

```groovy
tasks.register('hello') {
    doLast {
        println 'hello'
    }
}

tasks.register('copy', Copy) {
    from(file('srcDir'))
    into(buildDir)
}
```

We add the tasks to the `tasks` collection. Have a look at TaskContainer for more variations of the `register()` method.

In the Kotlin DSL there is also a specific delegated properties syntax that is useful if you need the registered task for further reference.

build.gradle.kts

```kotlin
// Using Kotlin delegated properties

val hello by tasks.registering {
    doLast {
        println("hello")
    }
}

val copy by tasks.registering(Copy::class) {
    from(file("srcDir"))
    into(buildDir)
}
```

build.gradle

```groovy
// Assigning registered tasks to a variable in Groovy

def hello = tasks.register('hello') {
    doLast {
        println 'hello'
    }
}

def copy = tasks.register('copy', Copy) {
    from(file('srcDir'))
    into(buildDir)
}
```

If you look at the API of the *tasks* container you may notice that there are additional methods to *create* tasks. The use of these methods is discouraged and will be deprecated in future versions.

These methods only exist for backward compatibility as they were introduced before task configuration avoidance was added to Gradle.

== Locating tasks

You often need to locate the tasks that you have defined in the build file, for example, to configure them or use them for dependencies. There are a number of ways of doing this. Firstly, just like with defining tasks there are language specific syntaxes for the Groovy and Kotlin DSL:

In general, tasks are available through the `tasks` collection. You should use the methods that return a *task provider* – `register()` or `named()` – to make sure you do not break task configuration avoidance.

build.gradle.kts

```
tasks.register("hello")
tasks.register<Copy>("copy")

println(tasks.named("hello").get().name) // or just 'tasks.hello' if the task was
added by a plugin

println(tasks.named<Copy>("copy").get().destinationDir)
```

build.gradle

```
tasks.register('hello')
tasks.register('copy', Copy)

println tasks.named('hello').get().name

println tasks.named('copy').get().destinationDir
```

Tasks of a specific type can also be accessed by using the `tasks.withType()` method. This enables to easily avoid duplication of code and reduce redundancy.

```
tasks.withType<Tar>().configureEach {
    enabled = false
}

tasks.register("test") {
    dependsOn(tasks.withType<Copy>())
}
```

build.gradle

```
tasks.withType(Tar).configureEach {
    enabled = false
}

tasks.register('test') {
    dependsOn tasks.withType(Copy)
}
```

WARNING	The following shows how to access a task by path. This is not a recommended practice anymore as it breaks task configuration avoidance and project isolation. Dependencies between projects should be declared as dependencies.

You can access tasks from any project using the task's path using the `tasks.getByPath()` method. You can call the `getByPath()` method with a task name, or a relative path, or an absolute path.

project-a/build.gradle.kts

```
tasks.register("hello")
```

build.gradle.kts

```
tasks.register("hello")

println(tasks.getByPath("hello").path)
println(tasks.getByPath(":hello").path)
println(tasks.getByPath("project-a:hello").path)
println(tasks.getByPath(":project-a:hello").path)
```

project-a/build.gradle

```
tasks.register('hello')
```

build.gradle

```
tasks.register('hello')

println tasks.getByPath('hello').path
println tasks.getByPath(':hello').path
println tasks.getByPath('project-a:hello').path
println tasks.getByPath(':project-a:hello').path
```

Output of `gradle -q hello`

```
> gradle -q hello
:hello
:hello
:project-a:hello
:project-a:hello
```

Have a look at TaskContainer for more options for locating tasks.

== Configuring tasks

As an example, let's look at the `Copy` task provided by Gradle. To register a `Copy` task for your build, you can declare in your build script:

build.gradle.kts

```
tasks.register<Copy>("myCopy")
```

build.gradle

```
tasks.register('myCopy', Copy)
```

This registers a copy task with no default behavior. The task can be configured using its API (see Copy). The following examples show several different ways to achieve the same configuration.

Just to be clear, realize that the name of this task is myCopy, but it is of *type* Copy. You can have multiple tasks of the same *type*, but with different names. You'll find this gives you a lot of power to implement cross-cutting concerns across all tasks of a particular type.

build.gradle.kts

```
tasks.named<Copy>("myCopy") {
    from("resources")
    into("target")
    include("**/*.txt", "**/*.xml", "**/*.properties")
}
```

build.gradle

```
tasks.named('myCopy') {
    from 'resources'
    into 'target'
    include('**/*.txt', '**/*.xml', '**/*.properties')
}
```

You can also store the task reference in a variable and use to configure the task further at a later point in the script.

build.gradle.kts

```
// Configure task using Kotlin delegated properties and a lambda
val myCopy by tasks.existing(Copy::class) {
    from("resources")
    into("target")
}
myCopy {
    include("**/*.txt", "**/*.xml", "**/*.properties")
}
```

build.gradle

```groovy
// Configure task through a task provider
def myCopy = tasks.named('myCopy')  {
    from 'resources'
    into 'target'
}
myCopy.configure {
    include('**/*.txt', '**/*.xml', '**/*.properties')
}
```

Have a look at TaskContainer for more options for configuring tasks.

If you use the *Kotlin DSL* and the task you want to configure was added by a plugin, you can use a convenient accessor for the task. That is, instead of `tasks.named("test")` you can just write `tasks.test`.

You can also use a configuration block when you define a task.

build.gradle.kts

```kotlin
tasks.register<Copy>("copy") {
    from("resources")
    into("target")
    include("**/*.txt", "**/*.xml", "**/*.properties")
}
```

build.gradle

```groovy
tasks.register('copy', Copy) {
    from 'resources'
    into 'target'
    include('**/*.txt', '**/*.xml', '**/*.properties')
}
```

Don't forget about the build phases

A task has both configuration and actions. When using the `doLast`, you are simply using a shortcut to define an action. Code defined in the configuration section of your task will get executed during the configuration phase of the build regardless of what task was targeted. See Build Lifecycle for more details about the build lifecycle.

== Passing arguments to a task constructor

As opposed to configuring the mutable properties of a `Task` after creation, you can pass argument values to the `Task` class's constructor. In order to pass values to the `Task` constructor, you must annotate the relevant constructor with `@javax.inject.Inject`.

build.gradle.kts

```kotlin
abstract class CustomTask @Inject constructor(
    private val message: String,
    private val number: Int
) : DefaultTask()
```

build.gradle

```groovy
abstract class CustomTask extends DefaultTask {
    private final String message
    private final int number

    @Inject
    CustomTask(String message, int number) {
        this.message = message
        this.number = number
    }
}
```

You can then create a task, passing the constructor arguments at the end of the parameter list.

build.gradle.kts

```kotlin
tasks.register<CustomTask>("myTask", "hello", 42)
```

build.gradle

```
tasks.register('myTask', CustomTask, 'hello', 42)
```

NOTE	It's recommended to use the Task Configuration Avoidance APIs to improve configuration time.

In all circumstances, the values passed as constructor arguments must be non-null. If you attempt to pass a `null` value, Gradle will throw a `NullPointerException` indicating which runtime value is `null`.

== Adding dependencies to a task

There are several ways you can define the dependencies of a task. In Task dependencies you were introduced to defining dependencies using task names. Task names can refer to tasks in the same project as the task, or to tasks in other projects. To refer to a task in another project, you prefix the name of the task with the path of the project it belongs to. The following is an example which adds a dependency from `project-a:taskX` to `project-b:taskY`:

project-a/build.gradle.kts

```
tasks.register("taskX") {
    dependsOn(":project-b:taskY")
    doLast {
        println("taskX")
    }
}
```

project-b/build.gradle.kts

```
tasks.register("taskY") {
    doLast {
        println("taskY")
    }
}
```

project-a/build.gradle

```
tasks.register('taskX')  {
    dependsOn ':project-b:taskY'
    doLast {
        println 'taskX'
    }
}
```

project-b/build.gradle

```
tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}
```

Output of `gradle -q taskX`

```
> gradle -q taskX
taskY
taskX
```

Instead of using a task name, you can define a dependency using a `TaskProvider` object, as shown in this example:

build.gradle.kts

```
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}

val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}

taskX {
    dependsOn(taskY)
}
```

```
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}

def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}

taskX.configure {
    dependsOn taskY
}
```

Output of `gradle -q taskX`

```
> gradle -q taskX
taskY
taskX
```

For more advanced uses, you can define a task dependency using a lazy block. When evaluated, the block is passed the task whose dependencies are being calculated. The lazy block should return a single `Task` or collection of `Task` objects, which are then treated as dependencies of the task. The following example adds a dependency from `taskX` to all the tasks in the project whose name starts with `lib`:

build.gradle.kts

```
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}

// Using a Gradle Provider
taskX {
    dependsOn(provider {
        tasks.filter { task -> task.name.startsWith("lib") }
    })
}

tasks.register("lib1") {
    doLast {
        println("lib1")
    }
}

tasks.register("lib2") {
    doLast {
        println("lib2")
    }
}

tasks.register("notALib") {
    doLast {
        println("notALib")
    }
}
```

build.gradle

```groovy
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}

// Using a Gradle Provider
taskX.configure {
    dependsOn(provider {
        tasks.findAll { task -> task.name.startsWith('lib') }
    })
}

tasks.register('lib1') {
    doLast {
        println('lib1')
    }
}

tasks.register('lib2') {
    doLast {
        println('lib2')
    }
}

tasks.register('notALib') {
    doLast {
        println('notALib')
    }
}
```

Output of `gradle -q taskX`

```
> gradle -q taskX
lib1
lib2
taskX
```

For more information about task dependencies, see the Task API.

== Ordering tasks

In some cases it is useful to control the *order* in which 2 tasks will execute, without introducing an explicit dependency between those tasks. The primary difference between a task *ordering* and a task *dependency* is that an ordering rule does not influence which tasks will be executed, only the order in which they will be executed.

Task ordering can be useful in a number of scenarios:

- Enforce sequential ordering of tasks: e.g. 'build' never runs before 'clean'.
- Run build validations early in the build: e.g. validate I have the correct credentials before starting the work for a release build.
- Get feedback faster by running quick verification tasks before long verification tasks: e.g. unit tests should run before integration tests.
- A task that aggregates the results of all tasks of a particular type: e.g. test report task combines the outputs of all executed test tasks.

There are two ordering rules available: "*must run after*" and "*should run after*".

When you use the "must run after" ordering rule you specify that `taskB` must always run after `taskA`, whenever both `taskA` and `taskB` will be run. This is expressed as `taskB.mustRunAfter(taskA)`. The "should run after" ordering rule is similar but less strict as it will be ignored in two situations. Firstly if using that rule introduces an ordering cycle. Secondly when using parallel execution and all dependencies of a task have been satisfied apart from the "should run after" task, then this task will be run regardless of whether its "should run after" dependencies have been run or not. You should use "should run after" where the ordering is helpful but not strictly required.

With these rules present it is still possible to execute `taskA` without `taskB` and vice-versa.

build.gradle.kts

```kotlin
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}
val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}
taskY {
    mustRunAfter(taskX)
}
```

build.gradle

```groovy
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}
def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}
taskY.configure {
    mustRunAfter taskX
}
```

Output of `gradle -q taskY taskX`

```
> gradle -q taskY taskX
taskX
taskY
```

```kotlin
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}
val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}
taskY {
    shouldRunAfter(taskX)
}
```

build.gradle

```groovy
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}
def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}
taskY.configure {
    shouldRunAfter taskX
}
```

Output of `gradle -q taskY taskX`

```
> gradle -q taskY taskX
taskX
taskY
```

In the examples above, it is still possible to execute taskY without causing taskX to run:

Output of `gradle -q taskY`

```
> gradle -q taskY
taskY
```

To specify a "must run after" or "should run after" ordering between 2 tasks, you use the Task.mustRunAfter(java.lang.Object…) and Task.shouldRunAfter(java.lang.Object…) methods. These methods accept a task instance, a task name or any other input accepted by Task.dependsOn(java.lang.Object…).

Note that "`B.mustRunAfter(A)`" or "`B.shouldRunAfter(A)`" does not imply any execution dependency between the tasks:

- It is possible to execute tasks `A` and `B` independently. The ordering rule only has an effect when both tasks are scheduled for execution.

- When run with `--continue`, it is possible for `B` to execute in the event that `A` fails.

As mentioned before, the "should run after" ordering rule will be ignored if it introduces an ordering cycle:

build.gradle.kts

```
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}
val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}
val taskZ by tasks.registering {
    doLast {
        println("taskZ")
    }
}
taskX { dependsOn(taskY) }
taskY { dependsOn(taskZ) }
taskZ { shouldRunAfter(taskX) }
```

build.gradle

```
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}
def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}
def taskZ = tasks.register('taskZ') {
    doLast {
        println 'taskZ'
    }
}
taskX.configure { dependsOn(taskY) }
taskY.configure { dependsOn(taskZ) }
taskZ.configure { shouldRunAfter(taskX) }
```

Output of `gradle -q taskX`

```
> gradle -q taskX
taskZ
taskY
taskX
```

== Adding a description to a task

You can add a description to your task. This description is displayed when executing `gradle tasks`.

build.gradle.kts

```
tasks.register<Copy>("copy") {
    description = "Copies the resource directory to the target directory."
    from("resources")
    into("target")
    include("**/*.txt", "**/*.xml", "**/*.properties")
}
```

build.gradle

```
tasks.register('copy', Copy) {
    description 'Copies the resource directory to the target directory.'
    from 'resources'
    into 'target'
    include('**/*.txt', '**/*.xml', '**/*.properties')
}
```

== Skipping tasks

Gradle offers multiple ways to skip the execution of a task.

=== Using a predicate

You can use `Task.onlyIf` to attach a predicate to a task. The task's actions are only executed if the predicate evaluates to true. The predicate is passed the task as a parameter, and should return true if the task should execute and false if the task should be skipped. The predicate is evaluated just before the task is executed. Passing an optional reason string to `onlyIf()` is useful for explaining why the task is skipped.

build.gradle.kts

```
val hello by tasks.registering {
    doLast {
        println("hello world")
    }
}

hello {
    val skipProvider = providers.gradleProperty("skipHello")
    onlyIf("there is no property skipHello") {
        !skipProvider.isPresent()
    }
}
```

```
def hello = tasks.register('hello') {
    doLast {
        println 'hello world'
    }
}

hello.configure {
    def skipProvider = providers.gradleProperty("skipHello")
    onlyIf("there is no property skipHello") {
        !skipProvider.present
    }
}
```

Output of `gradle hello -PskipHello`

```
> gradle hello -PskipHello
> Task :hello SKIPPED

BUILD SUCCESSFUL in 0s
```

It is possible to find the reason for a task being skipped by running the build with the `--info` logging level.

Output of `gradle hello -PskipHello --hello`

```
> gradle hello -PskipHello --info
...

> Task :hello SKIPPED
Skipping task ':hello' as task onlyIf 'there is no property skipHello' is false.
:hello (Thread[included builds,5,main]) completed. Took 0.018 secs.

BUILD SUCCESSFUL in 13s
```

=== Using StopExecutionException

If the logic for skipping a task can't be expressed with a predicate, you can use the StopExecutionException. If this exception is thrown by an action, the further execution of this action as well as the execution of any following action of this task is skipped. The build continues with executing the next task.

build.gradle.kts

```
val compile by tasks.registering {
    doLast {
        println("We are doing the compile.")
    }
}

compile {
    doFirst {
        // Here you would put arbitrary conditions in real life.
        if (true) {
            throw StopExecutionException()
        }
    }
}
tasks.register("myTask") {
    dependsOn(compile)
    doLast {
        println("I am not affected")
    }
}
```

build.gradle

```
def compile = tasks.register('compile') {
    doLast {
        println 'We are doing the compile.'
    }
}

compile.configure {
    doFirst {
        // Here you would put arbitrary conditions in real life.
        if (true) {
            throw new StopExecutionException()
        }
    }
}
tasks.register('myTask') {
    dependsOn('compile')
    doLast {
        println 'I am not affected'
    }
}
```

Output of `gradle -q myTask`

```
> gradle -q myTask
I am not affected
```

This feature is helpful if you work with tasks provided by Gradle. It allows you to add *conditional* execution of the built-in actions of such a task.[2]

=== Enabling and disabling tasks

Every task has an `enabled` flag which defaults to `true`. Setting it to `false` prevents the execution of any of the task's actions. A disabled task will be labelled SKIPPED.

build.gradle.kts

```
val disableMe by tasks.registering {
    doLast {
        println("This should not be printed if the task is disabled.")
    }
}

disableMe {
    enabled = false
}
```

build.gradle

```
def disableMe = tasks.register('disableMe') {
    doLast {
        println 'This should not be printed if the task is disabled.'
    }
}

disableMe.configure {
    enabled = false
}
```

Output of `gradle disableMe`

```
> gradle disableMe
> Task :disableMe SKIPPED

BUILD SUCCESSFUL in 0s
```

Task timeouts

Every task has a `timeout` property which can be used to limit its execution time. When a task reaches its timeout, its task execution thread is interrupted. The task will be marked as failed. Finalizer tasks will still be run. If `--continue` is used, other tasks can continue running after it. Tasks that don't respond to interrupts can't be timed out. All of Gradle's built-in tasks respond to timeouts in a timely manner.

build.gradle.kts

```
tasks.register("hangingTask") {
    doLast {
        Thread.sleep(100000)
    }
    timeout = Duration.ofMillis(500)
}
```

build.gradle

```
tasks.register("hangingTask") {
    doLast {
        Thread.sleep(100000)
    }
    timeout = Duration.ofMillis(500)
}
```

Task rules

Sometimes you want to have a task whose behavior depends on a large or infinite number value range of parameters. A very nice and expressive way to provide such tasks are task rules:

build.gradle.kts

```kotlin
tasks.addRule("Pattern: ping<ID>") {
    val taskName = this
    if (startsWith("ping")) {
        task(taskName) {
            doLast {
                println("Pinging: " + (taskName.replace("ping", "")))
            }
        }
    }
}
```

build.gradle

```groovy
tasks.addRule("Pattern: ping<ID>") { String taskName ->

    if (taskName.startsWith("ping")) {
        task(taskName) {
            doLast {
                println "Pinging: " + (taskName - 'ping')
            }
        }
    }
}
```

Output of `gradle -q pingServer1`

```
> gradle -q pingServer1
Pinging: Server1
```

The String parameter is used as a description for the rule, which is shown with `gradle tasks`.

Rules are not only used when calling tasks from the command line. You can also create dependsOn relations on rule based tasks:

build.gradle.kts

```kotlin
tasks.addRule("Pattern: ping<ID>") {
    val taskName = this
    if (startsWith("ping")) {
        task(taskName) {
            doLast {
                println("Pinging: " + (taskName.replace("ping", "")))
            }
        }
    }
}

tasks.register("groupPing") {
    dependsOn("pingServer1", "pingServer2")
}
```

build.gradle

```groovy
tasks.addRule("Pattern: ping<ID>") { String taskName ->

    if (taskName.startsWith("ping")) {
        task(taskName) {
            doLast {
                println "Pinging: " + (taskName - 'ping')
            }
        }
    }
}

tasks.register('groupPing') {
    dependsOn 'pingServer1', 'pingServer2'
}
```

Output of `gradle -q groupPing`

```
> gradle -q groupPing
Pinging: Server1
Pinging: Server2
```

If you run `gradle -q tasks` you won't find a task named `pingServer1` or `pingServer2`, but this script is executing logic based on the request to run those tasks.

== Finalizer tasks

Finalizer tasks are automatically added to the task graph when the finalized task is scheduled to run.

build.gradle.kts

```kotlin
val taskX by tasks.registering {
    doLast {
        println("taskX")
    }
}
val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}

taskX { finalizedBy(taskY) }
```

build.gradle

```groovy
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
    }
}
def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}

taskX.configure { finalizedBy taskY }
```

Output of `gradle -q taskX`

```
> gradle -q taskX
taskX
taskY
```

Finalizer tasks will be executed even if the finalized task fails or if the finalized task is considered up to date.

build.gradle.kts

```kotlin
val taskX by tasks.registering {
    doLast {
        println("taskX")
        throw RuntimeException()
    }
}
val taskY by tasks.registering {
    doLast {
        println("taskY")
    }
}

taskX { finalizedBy(taskY) }
```

build.gradle

```groovy
def taskX = tasks.register('taskX') {
    doLast {
        println 'taskX'
        throw new RuntimeException()
    }
}
def taskY = tasks.register('taskY') {
    doLast {
        println 'taskY'
    }
}

taskX.configure { finalizedBy taskY }
```

Output of `gradle -q taskX`

```
> gradle -q taskX
taskX
taskY

FAILURE: Build failed with an exception.

* Where:
Build file '/home/user/gradle/samples/build.gradle' line: 4

* What went wrong:
Execution failed for task ':taskX'.
> java.lang.RuntimeException (no error message)

* Try:
> Run with --stacktrace option to get the stack trace.
> Run with --info or --debug option to get more log output.
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

BUILD FAILED in 0s
```

Finalizer tasks are useful in situations where the build creates a resource that has to be cleaned up regardless of the build failing or succeeding. An example of such a resource is a web container that is started before an integration test task and which should be always shut down, even if some of the tests fail.

To specify a finalizer task you use the Task.finalizedBy(java.lang.Object…) method. This method accepts a task instance, a task name, or any other input accepted by Task.dependsOn(java.lang.Object…).

== Lifecycle tasks

Lifecycle tasks are tasks that do not do work themselves. They typically do not have any task actions. Lifecycle tasks can represent several concepts:

- a work-flow step (e.g., run all checks with `check`)

- a buildable thing (e.g., create a debug 32-bit executable for native components with `debug32MainExecutable`)

- a convenience task to execute many of the same logical tasks (e.g., run all compilation tasks with `compileAll`)

The Base Plugin defines several standard lifecycle tasks, such as `build`, `assemble`, and `check`. All the core language plugins, like the Java Plugin, apply the Base Plugin and hence have the same base set of lifecycle tasks.

Unless a lifecycle task has actions, its outcome is determined by its task dependencies. If any of those dependencies are executed, the lifecycle task will be considered `EXECUTED`. If all of the task dependencies are up to date, skipped or from cache, the lifecycle task will be considered `UP-TO-DATE`.

== Summary

If you are coming from Ant, an enhanced Gradle task like *Copy* seems like a cross between an Ant target and an Ant task. Although Ant's tasks and targets are really different entities, Gradle combines these notions into a single entity. Simple Gradle tasks are like Ant's targets, but enhanced Gradle tasks also include aspects of Ant tasks. All of Gradle's tasks share a common API and you can create dependencies between them. These tasks are much easier to configure than an Ant task. They make full use of the type system, and are more expressive and easier to maintain.

=== Moved documentation

Some documentation previously appearing in this chapter has been moved to the Incremental Build chapter.

==== Up-to-date checks (AKA Incremental Build)

Moved to the Incremental Build chapter.

==== Task inputs and outputs

Moved to a [section under Incremental Build](#).

Custom task types

Moved to a [section under Incremental Build](#).

Using dependency resolution results

Moved to a [section under Incremental Build](#).

Using the classpath annotations

Moved to a [section under Incremental Build](#).

Nested inputs

Moved to a [section under Incremental Build](#).

Runtime validation

Moved to a [section under Incremental Build](#).

Runtime API

Moved to a [section under Incremental Build](#).

Using it for ad-hoc tasks

Moved to a [section under Incremental Build](#).

Fine-grained configuration

Moved to a [section under Incremental Build](#).

Using it for custom task types

Moved to a [section under Incremental Build](#).

Important beneficial side effects

Moved to a [section under Incremental Build](#).

Inferred task dependencies

Moved to a [section under Incremental Build](#).

Input and output validation

Moved to a [section under Incremental Build](#).

Continuous build

Moved to a [section under Incremental Build](#).

==== Task parallelism

Moved to a [section under Incremental Build](#).

==== How does it work?

Moved to a [section under Incremental Build](#).

==== Advanced techniques

Moved to a [section under Incremental Build](#).

==== Adding your own cached input/output methods

Moved to a [section under Incremental Build](#).

==== Linking an `@OutputDirectory` to an `@InputFiles`

Moved to a [section under Incremental Build](#).

==== Disabling up-to-date checks

Moved to a [section under Incremental Build](#).

==== Integrate an external tool which does its own up-to-date checking

Moved to a [section under Incremental Build](#).

==== Configure input normalization

Moved to a [section under Incremental Build](#).

==== Properties file normalization

Moved to a [section under Incremental Build](#).

==== Java `META-INF` normalization

Moved to a [section under Incremental Build](#).

==== Providing custom up-to-date logic

Moved to a [section under Incremental Build](#).

==== Stale task outputs

Moved to a [section under Incremental Build](#).

= Incremental build

An important part of any build tool is the ability to avoid doing work that has already been done. Consider the process of compilation. Once your source files have been compiled, there should be no need to recompile them unless something has changed that affects the output, such as the modification of a source file or the removal of an output file. And compilation can

take a significant amount of time, so skipping the step when it's not needed saves a lot of time.

Gradle supports this behavior out of the box through a feature called **incremental build**. You have almost certainly already seen it in action. When you run a task and the task is marked with `UP-TO-DATE` in the console output, this means incremental build is at work.

How does an incremental build work? How can you make sure your tasks support running incrementally? Let's take a look.

== Task inputs and outputs

In the most common case, a task takes some inputs and generates some outputs. We can consider the process of Java compilation as an example of a task. The Java source files act as inputs of the task, while the generated class files, i.e. the result of the compilation, are the outputs of the task.
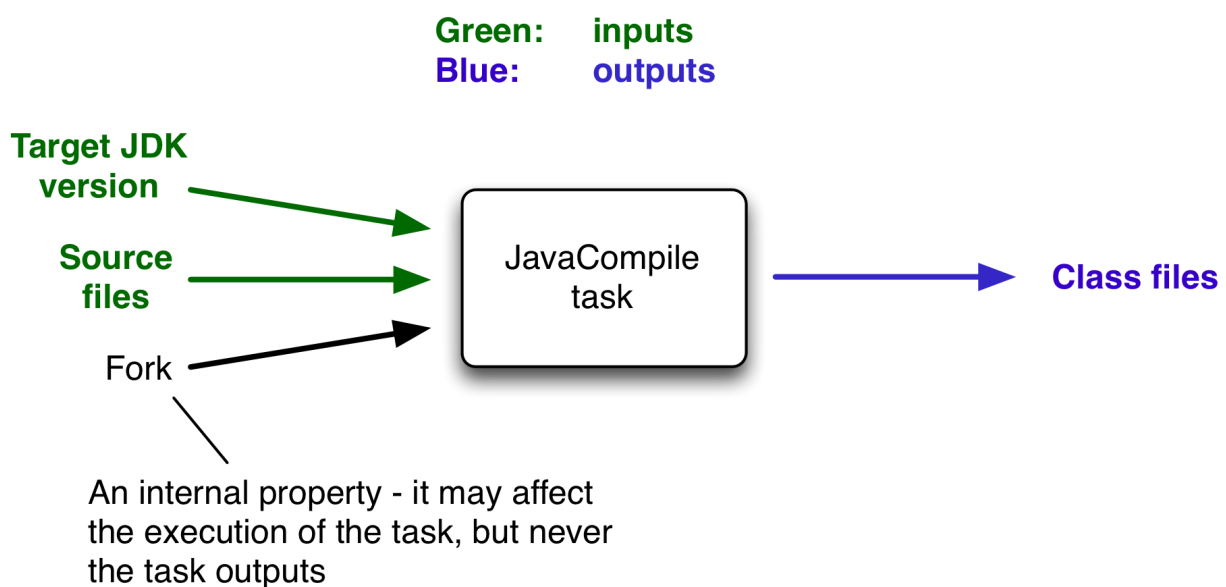
Figure 11. Example task inputs and outputs

An important characteristic of an input is that it affects one or more outputs, as you can see from the previous figure. Different bytecode is generated depending on the content of the source files and the minimum version of the Java runtime you want to run the code on. That makes them task inputs. But whether compilation has 500MB or 600MB of maximum memory available, determined by the `memoryMaximumSize` property, has no impact on what bytecode gets generated. In Gradle terminology, `memoryMaximumSize` is just an internal task property.

As part of incremental build, Gradle tests whether any of the task inputs or outputs has changed since the last build. If they haven't, Gradle can consider the task up to date and therefore skip executing its actions. Also note that incremental build won't work unless a task has at least one task output, although tasks usually have at least one input as well.

What this means for build authors is simple: you need to tell Gradle which task properties are inputs and which are outputs. If a task property affects the output, be sure to register it as an input, otherwise the task will be considered up to date when it's not. Conversely, don't register properties as inputs if they don't affect the output, otherwise the task will potentially execute

when it doesn't need to. Also be careful of non-deterministic tasks that may generate different output for exactly the same inputs: these should not be configured for incremental build as the up-to-date checks won't work.

Let's now look at how you can register task properties as inputs and outputs.

Declaring inputs and outputs via annotations

If you're implementing a custom task as a class, then it takes just two steps to make it work with incremental build:

1. Create typed properties (via getter methods) for each of your task inputs and outputs

2. Add the appropriate annotation to each of those properties

> **NOTE** Annotations must be placed on getters or on Groovy properties. Annotations placed on setters, or on a Java field without a corresponding annotated getter, are ignored.

Gradle supports four main categories of inputs and outputs:

- Simple values

  Things like strings and numbers. More generally, a simple value can have any type that implements `Serializable`.

- Filesystem types

  These consist of `RegularFile`, `Directory` and the standard `File` class but also derivatives of Gradle's [FileCollection](#) type and anything else that can be passed to either the [Project.file(java.lang.Object)](#) method — for single file/directory properties — or the [Project.files(java.lang.Object...)](#) method.

- Dependency resolution results

  This includes the [ResolvedArtifactResult](#) type for artifact metadata and the [ResolvedComponentResult](#) type for dependency graphs. Note that they are only supported wrapped in a `Provider`.

- Nested values

  Custom types that don't conform to the other two categories but have their own properties that are inputs or outputs. In effect, the task inputs or outputs are nested inside these custom types.

As an example, imagine you have a task that processes templates of varying types, such as FreeMarker, Velocity, Moustache, etc. It takes template source files and combines them with some model data to generate populated versions of the template files.

This task will have three inputs and one output:

- Template source files

- Model data

- Template engine

- Where the output files are written

When you're writing a custom task class, it's easy to register properties as inputs or outputs via annotations. To demonstrate, here is a skeleton task implementation with some suitable inputs and outputs, along with their annotations:

buildSrc/src/main/java/org/example/ProcessTemplates.java

```java
package org.example;

import java.util.HashMap;
import org.gradle.api.DefaultTask;
import org.gradle.api.file.ConfigurableFileCollection;
import org.gradle.api.file.DirectoryProperty;
import org.gradle.api.file.FileSystemOperations;
import org.gradle.api.provider.Property;
import org.gradle.api.tasks.*;

import javax.inject.Inject;

public abstract class ProcessTemplates extends DefaultTask {

    @Input
    public abstract Property<TemplateEngineType> getTemplateEngine();

    @InputFiles
    public abstract ConfigurableFileCollection getSourceFiles();

    @Nested
    public abstract TemplateData getTemplateData();

    @OutputDirectory
    public abstract DirectoryProperty getOutputDir();

    @Inject
    public abstract FileSystemOperations getFs();

    @TaskAction
    public void processTemplates() {
        // ...
    }
}
```

buildSrc/src/main/java/org/example/TemplateData.java

```java
package org.example;

import org.gradle.api.provider.MapProperty;
import org.gradle.api.provider.Property;
import org.gradle.api.tasks.Input;

public abstract class TemplateData {

    @Input
    public abstract Property<String> getName();

    @Input
    public abstract MapProperty<String, String> getVariables();
}
```

Output of `gradle processTemplates`

```
> gradle processTemplates
> Task :processTemplates

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 up-to-date
```

Output of `gradle processTemplates` *(run again)*

```
> gradle processTemplates
> Task :processTemplates UP-TO-DATE

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 up-to-date
```

There's plenty to talk about in this example, so let's work through each of the input and output properties in turn:

- **templateEngine**

  Represents which engine to use when processing the source templates, e.g. FreeMarker, Velocity, etc. You could implement this as a string, but in this case we have gone for a custom enum as it provides greater type information and safety. Since enums implement `Serializable` automatically, we can treat this as a simple value and use the `@Input` annotation, just as we would with a `String` property.

- **sourceFiles**

  The source templates that the task will be processing. Single files and collections of files need their own special annotations. In this case, we're dealing with a collection of input files and so we use the `@InputFiles` annotation. You'll see more file-oriented annotations in a table later.

- **templateData**

  For this example, we're using a custom class to represent the model data. However, it does not implement `Serializable`, so we can't use the `@Input` annotation. That's not a problem as the properties within `TemplateData` — a string and a hash map with serializable type parameters — are serializable and can be annotated with `@Input`. We use `@Nested` on `templateData` to let Gradle know that this is a value with nested input properties.

- **outputDir**

  The directory where the generated files go. As with input files, there are several annotations for output files and directories. A property representing a single directory requires `@OutputDirectory`. You'll learn about the others soon.

These annotated properties mean that Gradle will skip the task if none of the source files, template engine, model data or generated files has changed since the previous time Gradle executed the task. This will often save a significant amount of time. You can learn how Gradle detects changes later.

This example is particularly interesting because it works with collections of source files. What happens if only one source file changes? Does the task process all the source files again or just the modified one? That depends on the task implementation. If the latter, then the task itself is incremental, but that's a different feature to the one we're discussing here. Gradle does help task implementers with this via its incremental task inputs feature.

Now that you have seen some of the input and output annotations in practice, let's take a look at all the annotations available to you and when you should use them. The table below lists the available annotations and the corresponding property type you can use with each one.

Table 5. Incremental build property type annotations

Annotation	Expected property type	Description
@Input	Any `Serializable` type or dependency resolution result types	A simple input value or dependency resolution results
@InputFile	`File`*	A single input file (not directory)
@InputDirectory	`File`*	A single input directory (not file)
@InputFiles	`Iterable<File>`*	An iterable of input files and directories
@Classpath	`Iterable<File>`*	An iterable of input files and directories that represent a Java classpath. This allows the task to ignore irrelevant changes to the property, such as different names for the same files. It is similar to annotating the property `@PathSensitive(RELATIVE)` but it will ignore the names of JAR files directly added to the classpath, and it will consider changes in the order of the files as a change in the classpath. Gradle will inspect the contents of jar files on the classpath and ignore changes that do not affect the semantics of the classpath (such as file dates and entry order). See also Using the classpath annotations. **Note:** The `@Classpath` annotation was introduced in Gradle 3.2. To stay compatible with earlier Gradle versions, classpath properties should also be annotated with `@InputFiles`.

Annotation	Expected property type	Description
@CompileClasspath	Iterable<File>*	An iterable of input files and directories that represent a Java compile classpath. This allows the task to ignore irrelevant changes that do not affect the API of the classes in classpath. See also Using the classpath annotations.

The following kinds of changes to the classpath will be ignored:

- Changes to the path of jar or top level directories.
- Changes to timestamps and the order of entries in Jars.
- Changes to resources and Jar manifests, including adding or removing resources.
- Changes to private class elements, such as private fields, methods and inner classes.
- Changes to code, such as method bodies, static initializers and field initializers (except for constants).
- Changes to debug information, for example when a change to a comment affects the line numbers in class debug information.
- Changes to directories, including directory entries in Jars.

NOTE - The @CompileClasspath annotation was introduced in Gradle 3.4. To stay compatible with Gradle 3.3 and 3.2, compile classpath properties should also be annotated with |

Annotation	Expected property type	Description
@OutputFile	File*	A single output file (not directory)
@OutputDirectory	File*	A single output directory (not file)
@OutputFiles	Map<String, File>** or Iterable<File>*	An iterable or map of output files. Using a file tree turns caching off for the task.
@OutputDirectories	Map<String, File>** or Iterable<File>*	An iterable of output directories. Using a file tree turns caching off for the task.
@Destroys	File or Iterable<File>*	Specifies one or more files that are removed by this task. Note that a task can define either inputs/outputs or destroyables, but not both.
@LocalState	File or Iterable<File>*	Specifies one or more files that represent the local state of the task. These files are removed when the task is loaded from cache.
@Nested	Any custom type	A custom type that may not implement Serializable but does have at least one field or property marked with one of the annotations in this table. It could even be another @Nested.
@Console	Any type	Indicates that the property is neither an input nor an output. It simply affects the console output of the task in some way, such as increasing or decreasing the verbosity of the task.

Annotation	Expected property type	Description
@Internal	Any type	Indicates that the property is used internally but is neither an input nor an output.
@ReplacedBy	Any type	Indicates that the property has been replaced by another and should be ignored as an input or output.
@SkipWhenEmpty	`File` or `Iterable<File>`*	Used with `@InputFiles` or `@InputDirectory` to tell Gradle to skip the task if the corresponding files or directory are empty, along with all other input files declared with this annotation. Tasks that have been skipped due to all of their input files that were declared with this annotation being empty will result in a distinct "no source" outcome. For example, `NO-SOURCE` will be emitted in the console output. Implies @Incremental.
@Incremental	`Provider<FileSystemLocation>` or `FileCollection`	Used with `@InputFiles` or `@InputDirectory` to instruct Gradle to track changes to the annotated file property, so the changes can be queried via `@InputChanges.getFileChanges()`. Required for incremental tasks.
@Optional	Any type	Used with any of the property type annotations listed in the Optional API documentation. This annotation disables validation checks on the corresponding property. See the section on validation for more details.

Annotation	Expected property type	Description
`@PathSensitive`	`File` or `Iterable<File>`*	Used with any input file property to tell Gradle to only consider the given part of the file paths as important. For example, if a property is annotated with `@PathSensitive(PathSensitivity.NAME_ONLY)`, then moving the files around without changing their contents will not make the task out-of-date.
`@IgnoreEmptyDirectories`	`File` or `Iterable<File>`*	Used with `@InputFiles` or `@InputDirectory` to instruct Gradle to track only changes to the contents of directories and not differences in the directories themselves. For example, removing, renaming or adding an empty directory somewhere in the directory structure will not make the task out-of-date.
`@NormalizeLineEndings`	`File` or `Iterable<File>`*	Used with `@InputFiles`, `@InputDirectory` or `@Classpath` to instruct Gradle to normalize line endings when calculating up-to-date checks or build cache keys. For example, switching a file between Unix line endings and Windows line endings (or vice-versa) will not make the task out-of-date.

`File` can be any type accepted by Project.file(java.lang.Object) and `Iterable<File>` can be any type accepted by Project.files(java.lang.Object...). This includes instances of `Callable`, such as closures, allowing for lazy evaluation of the property values. Be aware that the types `FileCollection` and `FileTree` are `Iterable<File>`s.

Similar to the above, `File` can be any type accepted by Project.file(java.lang.Object). The `Map` itself can be wrapped in `Callable`s, such as closures.

Annotations are inherited from all parent types including implemented interfaces. Property type annotations override any other property type annotation declared in a parent type. This way an `@InputFile` property can be turned into an `@InputDirectory` property in a child task type.

Annotations on a property declared in a type override similar annotations declared by the superclass and in any implemented interfaces. Superclass annotations take precedence over annotations declared in implemented interfaces.

The Console and Internal annotations in the table are special cases as they don't declare either task inputs or task outputs. So why use them? It's so that you can take advantage of the Java Gradle Plugin Development plugin to help you develop and publish your own plugins. This plugin checks whether any properties of your custom task classes lack an incremental build annotation. This protects you from forgetting to add an appropriate annotation during development.

=== Using dependency resolution results

Dependency resolution results can be consumed as task inputs in two ways. First by consuming the graph of the resolved metadata using ResolvedComponentResult. Second by consuming the flat set of the resolved artifacts using ResolvedArtifactResult.

A resolved graph can be obtained lazily from the incoming resolution result of a `Configuration` and wired to an `@Input` property:

Task declaration

```
link:https://docs.gradle.org/8.6-milestone-1/samples/writing-tasks/tasks-with-
dependency-resolution-result-inputs/common/dependency-
reports/src/main/java/com/example/GraphResolvedComponents.java[tag=inputs]
```

Task configuration

```
link:https://docs.gradle.org/8.6-milestone-1/samples/writing-tasks/tasks-with-
dependency-resolution-result-inputs/common/dependency-
reports/src/main/java/com/example/DependencyReportsPlugin.java[tag=graphResolvedCompon
ents]
```

The resolved set of artifacts can be obtained lazily from the incoming artifacts of a `Configuration`. Given the `ResolvedArtifactResult` type contains both metadata and file information, instances need to be transformed to metadata only before being wired to an `@Input` property:

Task declaration

```
link:https://docs.gradle.org/8.6-milestone-1/samples/writing-tasks/tasks-with-
dependency-resolution-result-inputs/common/dependency-
reports/src/main/java/com/example/ListResolvedArtifacts.java[tag=inputs]
```

Task configuration

```
link:https://docs.gradle.org/8.6-milestone-1/samples/writing-tasks/tasks-with-
dependency-resolution-result-inputs/common/dependency-
reports/src/main/java/com/example/DependencyReportsPlugin.java[tag=listResolvedArtifac
ts]
```

Both graph and flat results can be combined and augmented with resolved file information. This is all demonstrated in the Tasks with dependency resolution result inputs sample.

=== Using the classpath annotations

Besides `@InputFiles`, for JVM-related tasks Gradle understands the concept of classpath inputs. Both runtime and compile classpaths are treated differently when Gradle is looking for changes.

As opposed to input properties annotated with `@InputFiles`, for classpath properties the order of the entries in the file collection matter. On the other hand, the names and paths of the directories and jar files on the classpath itself are ignored. Timestamps and the order of class files and resources inside jar files on a classpath are ignored, too, thus recreating a jar file with different file dates will not make the task out of date.

Runtime classpaths are marked with `@Classpath`, and they offer further customization via classpath normalization.

Input properties annotated with `@CompileClasspath` are considered Java compile classpaths. Additionally to the aforementioned general classpath rules, compile classpaths ignore changes to everything but class files. Gradle uses the same class analysis described in Java compile avoidance to further filter changes that don't affect the class' ABIs. This means that changes which only touch the implementation of classes do not make the task out of date.

=== Nested inputs

When analyzing `@Nested` task properties for declared input and output sub-properties Gradle uses the type of the actual value. Hence it can discover all sub-properties declared by a runtime sub-type.

When adding `@Nested` to a `Provider`, the value of the `Provider` is treated as a nested input.

When adding `@Nested` to an iterable, each element is treated as a separate nested input. Each nested input in the iterable is assigned a name, which by default is the dollar sign followed by the index in the iterable, e.g. `$2`. If an element of the iterable implements `Named`, then the name is used as property name. The ordering of the elements in the iterable is crucial for reliable up-to-date checks and caching if not all of the elements implement `Named`. Multiple elements which have the same name are not allowed.

When adding `@Nested` to a map, then for each value a nested input is added, using the key as name.

The type and classpath of nested inputs is tracked, too. This ensures that changes to the implementation of a nested input causes the build to be out of date. By this it is also possible to add user provided code as an input, e.g. by annotating an `@Action` property with `@Nested`. Note that any inputs to such actions should be tracked, either by annotated properties on the action or by manually registering them with the task.

Using nested inputs allows richer modeling and extensibility for tasks, as e.g. shown by Test.getJvmArgumentProviders().

This allows us to model the JaCoCo Java agent, thus declaring the necessary JVM arguments and providing the inputs and outputs to Gradle:

JacocoAgent.java

```java
class JacocoAgent implements CommandLineArgumentProvider {
    private final JacocoTaskExtension jacoco;

    public JacocoAgent(JacocoTaskExtension jacoco) {
        this.jacoco = jacoco;
    }

    @Nested
    @Optional
    public JacocoTaskExtension getJacoco() {
        return jacoco.isEnabled() ? jacoco : null;
    }

    @Override
    public Iterable<String> asArguments() {
        return jacoco.isEnabled() ? ImmutableList.of(jacoco.getAsJvmArg()) :
Collections.<String>emptyList();
    }
}

test.getJvmArgumentProviders().add(new JacocoAgent(extension));
```

For this to work, `JacocoTaskExtension` needs to have the correct input and output annotations.

The approach works for Test JVM arguments, since `Test.getJvmArgumentProviders()` is an `Iterable` annotated with `@Nested`.

There are other task types where this kind of nested inputs are available:

- JavaExec.getArgumentProviders() - model e.g. custom tools

- JavaExec.getJvmArgumentProviders() - used for Jacoco Java agent

- CompileOptions.getCompilerArgumentProviders() - model e.g. annotation processors

- Exec.getArgumentProviders() - model e.g. custom tools

- JavaCompile.getOptions().getForkOptions().getJvmArgumentProviders() - model Java compiler daemon command line arguments

- GroovyCompile.getGroovyOptions().getForkOptions().getJvmArgumentProviders() - model Groovy compiler daemon command line arguments

- ScalaCompile.getScalaOptions().getForkOptions().getJvmArgumentProviders() - model Scala compiler daemon command line arguments

In the same way, this kind of modelling is available to custom tasks.

=== Validation at runtime

When executing the build Gradle checks if task types are declared with the proper annotations. It tries to identify problems where e.g. annotations are used on incompatible types, or on setters etc. Any getter not annotated with an input/output annotation is also flagged. These problems then fail the build or are turned into deprecation warnings when the task is executed.

Tasks that have a validation warning are executed **without any optimizations**. Specifically, they never can be:

- up-to-date,

- loaded from or stored in the build cache,

- executed in parallel with other tasks, even if parallel execution is enabled,

- executed incrementally.

The in-memory representation of the file system state (*Virtual File System)* is also invalidated before an invalid task is executed.

== Declaring inputs and outputs via the runtime API

Custom task classes are an easy way to bring your own build logic into the arena of incremental build, but you don't always have that option. That's why Gradle also provides an alternative API that can be used with any tasks, which we look at next.

When you don't have access to the source for a custom task class, there is no way to add any of

the annotations we covered in the previous section. Fortunately, Gradle provides a runtime API for scenarios just like that. It can also be used for ad-hoc tasks, as you'll see next.

=== Declaring inputs and outputs of ad-hoc tasks

This runtime API is provided through a couple of aptly named properties that are available on every Gradle task:

- Task.getInputs() of type TaskInputs
- Task.getOutputs() of type TaskOutputs
- Task.getDestroyables() of type TaskDestroyables

These objects have methods that allow you to specify files, directories and values which constitute the task's inputs and outputs. In fact, the runtime API has almost feature parity with the annotations.

It lacks equivalents for

- @Nested
- @Classpath
- @CompileClasspath
- @LocalState
- @ReplacedBy
- @Internal

Let's take the template processing example from before and see how it would look as an ad-hoc task that uses the runtime API:

build.gradle.kts

```
tasks.register("processTemplatesAdHoc") {
    inputs.property("engine", TemplateEngineType.FREEMARKER)
    inputs.files(fileTree("src/templates"))
        .withPropertyName("sourceFiles")
        .withPathSensitivity(PathSensitivity.RELATIVE)
    inputs.property("templateData.name", "docs")
    inputs.property("templateData.variables", mapOf("year" to "2013"))
    outputs.dir(layout.buildDirectory.dir("genOutput2"))
        .withPropertyName("outputDir")

    doLast {
        // Process the templates here
    }
}
```

```
tasks.register('processTemplatesAdHoc') {
    inputs.property('engine', TemplateEngineType.FREEMARKER)
    inputs.files(fileTree('src/templates'))
        .withPropertyName('sourceFiles')
        .withPathSensitivity(PathSensitivity.RELATIVE)
    inputs.property('templateData.name', 'docs')
    inputs.property('templateData.variables', [year: '2013'])
    outputs.dir(layout.buildDirectory.dir('genOutput2'))
        .withPropertyName('outputDir')

    doLast {
        // Process the templates here
    }
}
```

Output of `gradle processTemplatesAdHoc`

```
> gradle processTemplatesAdHoc
> Task :processTemplatesAdHoc

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

As before, there's much to talk about. To begin with, you should really write a custom task class for this as it's a non-trivial implementation that has several configuration options. In this case, there are no task properties to store the root source folder, the location of the output directory or any of the other settings. That's deliberate to highlight the fact that the runtime API doesn't require the task to have any state. In terms of incremental build, the above ad-hoc task will behave the same as the custom task class.

All the input and output definitions are done through the methods on `inputs` and `outputs`, such as `property()`, `files()`, and `dir()`. Gradle performs up-to-date checks on the argument values to determine whether the task needs to run again or not. Each method corresponds to one of the incremental build annotations, for example `inputs.property()` maps to `@Input` and `outputs.dir()` maps to `@OutputDirectory`.

The files that a task removes can be specified through `destroyables.register()`.

build.gradle.kts

```
tasks.register("removeTempDir") {
    val tmpDir = layout.projectDirectory.dir("tmpDir")
    destroyables.register(tmpDir)
    doLast {
        tmpDir.asFile.deleteRecursively()
    }
}
```

build.gradle

```
tasks.register('removeTempDir') {
    def tempDir = layout.projectDirectory.dir('tmpDir')
    destroyables.register(tempDir)
    doLast {
        tempDir.asFile.deleteDir()
    }
}
```

One notable difference between the runtime API and the annotations is the lack of a method that corresponds directly to `@Nested`. That's why the example uses two `property()` declarations for the template data, one for each `TemplateData` property. You should utilize the same technique when using the runtime API with nested values. Any given task can either declare destroyables or inputs/outputs, but cannot declare both.

=== Fine-grained configuration

The runtime API methods only allow you to declare your inputs and outputs in themselves. However, the file-oriented ones return a builder — of type TaskInputFilePropertyBuilder — that lets you provide additional information about those inputs and outputs.

You can learn about all the options provided by the builder in its API documentation, but we'll show you a simple example here to give you an idea of what you can do.

Let's say we don't want to run the `processTemplates` task if there are no source files, regardless of whether it's a clean build or not. After all, if there are no source files, there's nothing for the task to do. The builder allows us to configure this like so:

build.gradle.kts

```kotlin
tasks.register("processTemplatesAdHocSkipWhenEmpty") {
    // ...

    inputs.files(fileTree("src/templates") {
            include("**/*.fm")
        })
        .skipWhenEmpty()
        .withPropertyName("sourceFiles")
        .withPathSensitivity(PathSensitivity.RELATIVE)
        .ignoreEmptyDirectories()

    // ...
}
```

build.gradle

```groovy
tasks.register('processTemplatesAdHocSkipWhenEmpty') {
    // ...

    inputs.files(fileTree('src/templates') {
            include '**/*.fm'
        })
        .skipWhenEmpty()
        .withPropertyName('sourceFiles')
        .withPathSensitivity(PathSensitivity.RELATIVE)
        .ignoreEmptyDirectories()

    // ...
}
```

Output of `gradle clean processTemplatesAdHocSkipWhenEmpty`

```
> gradle clean processTemplatesAdHocSkipWhenEmpty
> Task :processTemplatesAdHocSkipWhenEmpty NO-SOURCE

BUILD SUCCESSFUL in 0s
3 actionable tasks: 2 executed, 1 up-to-date
```

The `TaskInputs.files()` method returns a builder that has a `skipWhenEmpty()` method. Invoking this method is equivalent to annotating to the property with `@SkipWhenEmpty`.

Now that you have seen both the annotations and the runtime API, you may be wondering which API you should be using. Our recommendation is to use the annotations wherever possible, and it's sometimes worth creating a custom task class just so that you can make use of them. The runtime API is more for situations in which you can't use the annotations.

=== Declaring inputs and outputs for custom task types

Another type of example involves registering additional inputs and outputs for instances of a custom task class. For example, imagine that the `ProcessTemplates` task also needs to read `src/headers/headers.txt` (e.g. because it is included from one of the sources). You'd want Gradle to know about this input file, so that it can re-execute the task whenever the contents of this file change. With the runtime API you can do just that:

build.gradle.kts

```
tasks.register<ProcessTemplates>("processTemplatesWithExtraInputs") {
    // ...

    inputs.file("src/headers/headers.txt")
        .withPropertyName("headers")
        .withPathSensitivity(PathSensitivity.NONE)
}
```

build.gradle

```
tasks.register('processTemplatesWithExtraInputs', ProcessTemplates) {
    // ...

    inputs.file('src/headers/headers.txt')
        .withPropertyName('headers')
        .withPathSensitivity(PathSensitivity.NONE)
}
```

Using the runtime API like this is a little like using `doLast()` and `doFirst()` to attach extra actions to a task, except in this case we're attaching information about inputs and outputs.

> **WARNING**   If the task type is already using the incremental build annotations, registering inputs or outputs with the same property names will result in an error.

== Benefits of declaring task inputs and outputs

Once you declare a task's formal inputs and outputs, Gradle can then infer things about those properties. For example, if an input of one task is set to the output of another, that means the first task depends on the second, right? Gradle knows this and can act upon it.

We'll look at this feature next and also some other features that come from Gradle knowing things about inputs and outputs.

=== Inferred task dependencies

Consider an archive task that packages the output of the `processTemplates` task. A build author will see that the archive task obviously requires `processTemplates` to run first and so may add an explicit `dependsOn`. However, if you define the archive task like so:

build.gradle.kts

```
tasks.register<Zip>("packageFiles") {
    from(processTemplates.map { it.outputDir })
}
```

build.gradle

```
tasks.register('packageFiles', Zip) {
    from processTemplates.map { it.outputDir }
}
```

Output of `gradle clean packageFiles`

```
> gradle clean packageFiles
> Task :processTemplates
> Task :packageFiles

BUILD SUCCESSFUL in 0s
5 actionable tasks: 4 executed, 1 up-to-date
```

Gradle will automatically make `packageFiles` depend on `processTemplates`. It can do this because it's aware that one of the inputs of packageFiles requires the output of the processTemplates task. We call this an inferred task dependency.

The above example can also be written as

build.gradle.kts

```
tasks.register<Zip>("packageFiles2") {
    from(processTemplates)
}
```

build.gradle

```
tasks.register('packageFiles2', Zip) {
    from processTemplates
}
```

Output of `gradle clean packageFiles2`

```
> gradle clean packageFiles2
> Task :processTemplates
> Task :packageFiles2

BUILD SUCCESSFUL in 0s
5 actionable tasks: 4 executed, 1 up-to-date
```

This is because the `from()` method can accept a task object as an argument. Behind the scenes, `from()` uses the `project.files()` method to wrap the argument, which in turn exposes the task's formal outputs as a file collection. In other words, it's a special case!

=== Input and output validation

The incremental build annotations provide enough information for Gradle to perform some basic validation on the annotated properties. In particular, it does the following for each property before the task executes:

- `@InputFile` - verifies that the property has a value and that the path corresponds to a file (not a directory) that exists.

- `@InputDirectory` - same as for `@InputFile`, except the path must correspond to a directory.

- `@OutputDirectory` - verifies that the path doesn't match a file and also creates the directory if it doesn't already exist.

If one task produces an output in a location and another task consumes that location by referring to it as an input, then Gradle checks that the consumer task depends on the producer task. When the producer and the consumer tasks are executing at the same time, the build fails to avoid capturing an incorrect state.

Such validation improves the robustness of the build, allowing you to identify issues related to inputs and outputs quickly.

You will occasionally want to disable some of this validation, specifically when an input file may validly not exist. That's why Gradle provides the `@Optional` annotation: you use it to tell Gradle that a particular input is optional and therefore the build should not fail if the corresponding file or directory doesn't exist.

=== Continuous build

Another benefit of defining task inputs and outputs is continuous build. Since Gradle knows what files a task depends on, it can automatically run a task again if any of its inputs change. By activating continuous build when you run Gradle — through the `--continuous` or `-t` options — you will put Gradle into a state in which it continually checks for changes and executes the requested tasks when it encounters such changes.

You can find out more about this feature in Continuous build.

=== Task parallelism

One last benefit of defining task inputs and outputs is that Gradle can use this information to make decisions about how to run tasks when the "--parallel" option is used. For instance, Gradle will inspect the outputs of tasks when selecting the next task to run and will avoid concurrent execution of tasks that write to the same output directory. Similarly, Gradle will use the information about what files a task destroys (e.g. specified by the `Destroys` annotation) and avoid running a task that removes a set of files while another task is running that consumes or creates those same files (and vice versa). It can also determine that a task that creates a set of files has already run and that a task that consumes those files has yet to run and will avoid

running a task that removes those files in between. By providing task input and output information in this way, Gradle can infer creation/consumption/destruction relationships between tasks and can ensure that task execution does not violate those relationships.

== How does it work?

Before a task is executed for the first time, Gradle takes a fingerprint of the inputs. This fingerprint contains the paths of input files and a hash of the contents of each file. Gradle then executes the task. If the task completes successfully, Gradle takes a fingerprint of the outputs. This fingerprint contains the set of output files and a hash of the contents of each file. Gradle persists both fingerprints for the next time the task is executed.

Each time after that, before the task is executed, Gradle takes a new fingerprint of the inputs and outputs. If the new fingerprints are the same as the previous fingerprints, Gradle assumes that the outputs are up to date and skips the task. If they are not the same, Gradle executes the task. Gradle persists both fingerprints for the next time the task is executed.

If the stats of a file (i.e. `lastModified` and `size`) did not change, Gradle will reuse the file's fingerprint from the previous run. That means that Gradle does not detect changes when the stats of a file did not change.

Gradle also considers the *code* of the task as part of the inputs to the task. When a task, its actions, or its dependencies change between executions, Gradle considers the task as out-of-date.

Gradle understands if a file property (e.g. one holding a Java classpath) is order-sensitive. When comparing the fingerprint of such a property, even a change in the order of the files will result in the task becoming out-of-date.

Note that if a task has an output directory specified, any files added to that directory since the last time it was executed are ignored and will NOT cause the task to be out of date. This is so unrelated tasks may share an output directory without interfering with each other. If this is not the behaviour you want for some reason, consider using TaskOutputs.upToDateWhen(groovy.lang.Closure)

Note also that changing the availability of an unavailable file (e.g. modifying the target of a broken symlink to a valid file, or vice versa), will be detected and handled by up-to-date check.

The inputs for the task are also used to calculate the build cache key used to load task outputs when enabled. For more details see Task output caching.

For tracking the implementation of tasks, task actions and nested inputs, Gradle uses the class name and an identifier for the classpath which contains the implementation. There are some situations when Gradle is not able to track the implementation precisely:

Unknown classloader

When the classloader which loaded the implementation has not been created by Gradle, the classpath cannot be determined.

Java lambda

> Java lambda classes are created at runtime with a non-deterministic classname. Therefore, the class name does not identify the implementation of the lambda and changes between different Gradle runs.

When the implementation of a task, task action or a nested input cannot be tracked precisely, Gradle disables any caching for the task. That means that the task will never be up-to-date or loaded from the build cache.

== Advanced techniques

Everything you've seen so far in this section will cover most of the use cases you'll encounter, but there are some scenarios that need special treatment. We'll present a few of those next with the appropriate solutions.

=== Adding your own cached input/output methods

Have you ever wondered how the `from()` method of the `Copy` task works? It's not annotated with `@InputFiles` and yet any files passed to it are treated as formal inputs of the task. What's happening?

The implementation is quite simple and you can use the same technique for your own tasks to improve their APIs. Write your methods so that they add files directly to the appropriate annotated property. As an example, here's how to add a `sources()` method to the custom `ProcessTemplates` class we introduced earlier:

build.gradle.kts

```
tasks.register<ProcessTemplates>("processTemplates") {
    templateEngine = TemplateEngineType.FREEMARKER
    templateData.name = "test"
    templateData.variables = mapOf("year" to "2012")
    outputDir = layout.buildDirectory.dir("genOutput")

    sources(fileTree("src/templates"))
}
```

```
tasks.register('processTemplates', ProcessTemplates) {
    templateEngine = TemplateEngineType.FREEMARKER
    templateData.name = 'test'
    templateData.variables = [year: '2012']
    outputDir = file(layout.buildDirectory.dir('genOutput'))

    sources fileTree('src/templates')
}
```

ProcessTemplates.java

```java
public abstract class ProcessTemplates extends DefaultTask {
    // ...
    @SkipWhenEmpty
    @InputFiles
    @PathSensitive(PathSensitivity.NONE)
    public abstract ConfigurableFileCollection getSourceFiles();

    public void sources(FileCollection sourceFiles) {
        getSourceFiles().from(sourceFiles);
    }

    // ...
}
```

Output of `gradle processTemplates`

```
> gradle processTemplates
> Task :processTemplates

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

In other words, as long as you add values and files to formal task inputs and outputs during the configuration phase, they will be treated as such regardless from where in the build you add them.

If we want to support tasks as arguments as well and treat their outputs as the inputs, we can use the `TaskProvider` directly like so:

build.gradle.kts

```kotlin
val copyTemplates by tasks.registering(Copy::class) {
    into(file(layout.buildDirectory.dir("tmp")))
    from("src/templates")
}

tasks.register<ProcessTemplates>("processTemplates2") {
    // ...
    sources(copyTemplates)
}
```

build.gradle

```groovy
def copyTemplates = tasks.register('copyTemplates', Copy) {
    into file(layout.buildDirectory.dir('tmp'))
    from 'src/templates'
}

tasks.register('processTemplates2', ProcessTemplates) {
    // ...
    sources copyTemplates
}
```

ProcessTemplates.java

```java
    // ...
    public void sources(TaskProvider<?> inputTask) {
        getSourceFiles().from(inputTask);
    }
    // ...
```

Output of `gradle processTemplates2`

```
> gradle processTemplates2
> Task :copyTemplates
> Task :processTemplates2

BUILD SUCCESSFUL in 0s
4 actionable tasks: 4 executed
```

This technique can make your custom task easier to use and result in cleaner build files. As an added benefit, our use of `TaskProvider` means that our custom method can set up an inferred task dependency.

One last thing to note: if you are developing a task that takes collections of source files as inputs, like this example, consider using the built-in SourceTask. It will save you having to implement some of the plumbing that we put into `ProcessTemplates`.

=== Linking an `@OutputDirectory` to an `@InputFiles`

When you want to link the output of one task to the input of another, the types often match and a simple property assignment will provide that link. For example, a `File` output property can be assigned to a `File` input.

Unfortunately, this approach breaks down when you want the files in a task's `@OutputDirectory` (of type `File`) to become the source for another task's `@InputFiles` property (of type `FileCollection`). Since the two have different types, property assignment won't work.

As an example, imagine you want to use the output of a Java compilation task — via the `destinationDir` property — as the input of a custom task that instruments a set of files containing Java bytecode. This custom task, which we'll call `Instrument`, has a `classFiles` property annotated with `@InputFiles`. You might initially try to configure the task like so:

build.gradle.kts

```
plugins {
    id("java-library")
}

tasks.register<Instrument>("badInstrumentClasses") {
    classFiles.from(fileTree(tasks.compileJava.flatMap { it.destinationDirectory
}))
    destinationDir = layout.buildDirectory.dir("instrumented")
}
```

build.gradle

```
plugins {
    id 'java-library'
}

tasks.register('badInstrumentClasses', Instrument) {
    classFiles.from fileTree(tasks.named('compileJava').flatMap { it
.destinationDirectory }) {}
    destinationDir = file(layout.buildDirectory.dir('instrumented'))
}
```

Output of `gradle clean badInstrumentClasses`

```
> gradle clean badInstrumentClasses
> Task :clean UP-TO-DATE
> Task :badInstrumentClasses NO-SOURCE

BUILD SUCCESSFUL in 0s
3 actionable tasks: 2 executed, 1 up-to-date
```

There's nothing obviously wrong with this code, but you can see from the console output that the compilation task is missing. In this case you would need to add an explicit task dependency between `instrumentClasses` and `compileJava` via `dependsOn`. The use of `fileTree()` means that Gradle can't infer the task dependency itself.

One solution is to use the `TaskOutputs.files` property, as demonstrated by the following example:

build.gradle.kts

```
tasks.register<Instrument>("instrumentClasses") {
    classFiles.from(tasks.compileJava.map { it.outputs.files })
    destinationDir = layout.buildDirectory.dir("instrumented")
}
```

build.gradle

```
tasks.register('instrumentClasses', Instrument) {
    classFiles.from tasks.named('compileJava').map { it.outputs.files }
    destinationDir = file(layout.buildDirectory.dir('instrumented'))
}
```

Output of `gradle clean instrumentClasses`

```
> gradle clean instrumentClasses
> Task :clean UP-TO-DATE
> Task :compileJava
> Task :instrumentClasses

BUILD SUCCESSFUL in 0s
5 actionable tasks: 4 executed, 1 up-to-date
```

Alternatively, you can get Gradle to access the appropriate property itself by using one of `project.files()`, `project.layout.files()` or `project.objects.fileCollection()` in place of `project.fileTree()`:

build.gradle.kts

```kotlin
tasks.register<Instrument>("instrumentClasses2") {
    classFiles.from(layout.files(tasks.compileJava))
    destinationDir = layout.buildDirectory.dir("instrumented")
}
```

build.gradle

```groovy
tasks.register('instrumentClasses2', Instrument) {
    classFiles.from layout.files(tasks.named('compileJava'))
    destinationDir = file(layout.buildDirectory.dir('instrumented'))
}
```

Output of `gradle clean instrumentClasses2`

```
> gradle clean instrumentClasses2
> Task :clean UP-TO-DATE
> Task :compileJava
> Task :instrumentClasses2

BUILD SUCCESSFUL in 0s
5 actionable tasks: 4 executed, 1 up-to-date
```

Remember that `files()`, `layout.files()` and `objects.fileCollection()` can take tasks as arguments, whereas `fileTree()` cannot.

The downside of this approach is that all file outputs of the source task become the input files of the target — `instrumentClasses` in this case. That's fine as long as the source task only has a single file-based output, like the `JavaCompile` task. But if you have to link just one output property among several, then you need to explicitly tell Gradle which task generates the input files using the `builtBy` method:

build.gradle.kts

```
tasks.register<Instrument>("instrumentClassesBuiltBy") {
    classFiles.from(fileTree(tasks.compileJava.flatMap { it.destinationDirectory
}) {
        builtBy(tasks.compileJava)
    })
    destinationDir = layout.buildDirectory.dir("instrumented")
}
```

build.gradle

```
tasks.register('instrumentClassesBuiltBy', Instrument) {
    classFiles.from fileTree(tasks.named('compileJava').flatMap { it
.destinationDirectory }) {
        builtBy tasks.named('compileJava')
    }
    destinationDir = file(layout.buildDirectory.dir('instrumented'))
}
```

Output of `gradle clean instrumentClassesBuiltBy`

```
> gradle clean instrumentClassesBuiltBy
> Task :clean UP-TO-DATE
> Task :compileJava
> Task :instrumentClassesBuiltBy

BUILD SUCCESSFUL in 0s
5 actionable tasks: 4 executed, 1 up-to-date
```

You can of course just add an explicit task dependency via `dependsOn`, but the above approach provides more semantic meaning, explaining why `compileJava` has to run beforehand.

=== Disabling up-to-date checks

Gradle automatically handles up-to-date checks for output files and directories, but what if the task output is something else entirely? Perhaps it's an update to a web service or a database table. Or sometimes you have a task which should always run.

That's where the `doNotTrackState()` method on `Task` comes in. One can use this to disable up-to-date checks completely for a task, like so:

build.gradle.kts

```
tasks.register<Instrument>("alwaysInstrumentClasses") {
    classFiles.from(layout.files(tasks.compileJava))
    destinationDir = layout.buildDirectory.dir("instrumented")
    doNotTrackState("Instrumentation needs to re-run every time")
}
```

build.gradle

```
tasks.register('alwaysInstrumentClasses', Instrument) {
    classFiles.from layout.files(tasks.named('compileJava'))
    destinationDir = file(layout.buildDirectory.dir('instrumented'))
    doNotTrackState("Instrumentation needs to re-run every time")
}
```

Output of `gradle clean alwaysInstrumentClasses`

```
> gradle clean alwaysInstrumentClasses
> Task :compileJava
> Task :alwaysInstrumentClasses

BUILD SUCCESSFUL in 0s
4 actionable tasks: 1 executed, 3 up-to-date
```

```
> gradle alwaysInstrumentClasses
> Task :compileJava UP-TO-DATE
> Task :alwaysInstrumentClasses

BUILD SUCCESSFUL in 0s
4 actionable tasks: 1 executed, 3 up-to-date
```

If you are writing your own task that always should run, then you can also use the `@UntrackedTask` annotation on the task class instead of calling `Task.doNotTrackState()`.

=== Integrate an external tool which does its own up-to-date checking

Sometimes you want to integrate an external tool like Git or Npm, both of which do their own up-to-date checking. In that case it doesn't make much sense for Gradle to also do up-to-date checks. You can disable Gradle's up-to-date checks by using the `@UntrackedTask` annotation on the task wrapping the tool. Alternatively, you can use the runtime API method `Task.doNotTrackState()`.

For example, let's say you want to implement a task which clones a Git repository.

buildSrc/src/main/java/org/example/GitClone.java

```java
@UntrackedTask(because = "Git tracks the state") ①
public abstract class GitClone extends DefaultTask {

    @Input
    public abstract Property<String> getRemoteUri();

    @Input
    public abstract Property<String> getCommitId();

    @OutputDirectory
    public abstract DirectoryProperty getDestinationDir();

    @TaskAction
    public void gitClone() throws IOException {
        File destinationDir = getDestinationDir().get().getAsFile().getAbsoluteFile();
②
        String remoteUri = getRemoteUri().get();
        // Fetch origin or clone and checkout
        // ...
    }

}
```

build.gradle.kts

```
tasks.register<GitClone>("cloneGradleProfiler") {
    destinationDir = layout.buildDirectory.dir("gradle-profiler") // <3
    remoteUri = "https://github.com/gradle/gradle-profiler.git"
    commitId = "d6c18a21ca6c45fd8a9db321de4478948bdf801b"
}
```

build.gradle

```
tasks.register("cloneGradleProfiler", GitClone) {
    destinationDir = layout.buildDirectory.dir("gradle-profiler") ③
    remoteUri = "https://github.com/gradle/gradle-profiler.git"
    commitId = "d6c18a21ca6c45fd8a9db321de4478948bdf801b"
}
```

① Declare the task as untracked.

② Use the output directory to run the external tool.

③ Add the task and configure the output directory in your build.

=== Configure input normalization

For up to date checks and the build cache Gradle needs to determine if two task input properties have the same value. In order to do so, Gradle first normalizes both inputs and then compares the result. For example, for a compile classpath, Gradle extracts the ABI signature from the classes on the classpath and then compares signatures between the last Gradle run and the current Gradle run as described in Java compile avoidance.

Normalization applies to all zip files on the classpath (e.g. jars, wars, aars, apks, etc). This allows Gradle to recognize when two zip files are functionally the same, even though the zip files themselves might be slightly different due to metadata (such as timestamps or file order). Normalization applies not only to zip files directly on the classpath, but also to zip files nested inside directories or inside other zip files on the classpath.

It is possible to customize Gradle's built-in strategy for runtime classpath normalization. All inputs annotated with `@Classpath` are considered to be runtime classpaths.

Let's say you want to add a file `build-info.properties` to all your produced jar files which contains information about the build, e.g. the timestamp when the build started or some ID to identify the CI job that published the artifact. This file is only for auditing purposes, and has no effect on the outcome of running tests. Nonetheless, this file is part of the runtime classpath for the `test` task and changes on every build invocation. Therefore, the `test` would be never up-to-date or pulled from the build cache. In order to benefit from incremental builds again, you are able tell Gradle to ignore this file on the runtime classpath at the project level by using Project.normalization(org.gradle.api.Action) (in the *consuming* project):

build.gradle.kts

```
normalization {
    runtimeClasspath {
        ignore("build-info.properties")
    }
}
```

build.gradle

```
normalization {
    runtimeClasspath {
        ignore 'build-info.properties'
    }
}
```

If adding such a file to your jar files is something you do for all of the projects in your build, and you want to filter this file for all consumers, you should consider configuring such normalization in a convention plugin to share it between subprojects.

The effect of this configuration would be that changes to `build-info.properties` would be ignored for up-to-date checks and build cache key calculations. Note that this will not change the runtime behavior of the `test` task — i.e. any test is still able to load `build-info.properties` and the runtime classpath is still the same as before.

==== Properties file normalization

By default, properties files (i.e. files that end in a `.properties` extension) will be normalized to ignore differences in comments, whitespace and the order of properties. Gradle does this by loading the properties files and only considering the individual properties during up-to-date checks or build cache key calculations.

It is sometimes the case, though, that certain properties have a runtime impact, while others do not. If a property is changing that does not have an impact on the runtime classpath, it may be desirable to exclude it from up-to-date checks and build cache key calculations. However, excluding the entire file would also exclude the properties that do have a runtime impact. In this case, properties can be excluded selectively from any or all properties files on the runtime classpath.

A rule for ignoring properties can be applied to a specific set of files using the patterns described in RuntimeClasspathNormalization. In the event that a file matches a rule, but cannot be loaded as a properties file (e.g. because it is not formatted properly or uses a non-standard encoding), it will be incorporated into the up-to-date or build cache key calculation as a normal file. In other words, if the file cannot be loaded as a properties file, any changes to whitespace, property order, or comments may cause the task to become out-of-date or cause a cache miss.

build.gradle.kts

```kotlin
normalization {
    runtimeClasspath {
        properties("**/build-info.properties") {
            ignoreProperty("timestamp")
        }
    }
}
```

build.gradle

```groovy
normalization {
    runtimeClasspath {
        properties('**/build-info.properties') {
            ignoreProperty 'timestamp'
        }
    }
}
```

build.gradle.kts

```kotlin
normalization {
    runtimeClasspath {
        properties {
            ignoreProperty("timestamp")
        }
    }
}
```

build.gradle

```groovy
normalization {
    runtimeClasspath {
        properties {
            ignoreProperty 'timestamp'
        }
    }
}
```

==== Java `META-INF` normalization

For files in the `META-INF` directory of jar archives it's not always possible to ignore files completely due to their runtime impact.

Manifest files within `META-INF` are normalized to ignore comments, whitespace and order differences. Manifest attribute names are compared case-and-order insensitively. Manifest properties files are normalized according to Properties File Normalization.

build.gradle.kts

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreAttribute("Implementation-Version")
        }
    }
}
```

build.gradle

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreAttribute("Implementation-Version")
        }
    }
}
```

build.gradle.kts

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreProperty("app.version")
        }
    }
}
```

build.gradle

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreProperty("app.version")
        }
    }
}
```

build.gradle.kts

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreManifest()
        }
    }
}
```

build.gradle

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreManifest()
        }
    }
}
```

build.gradle.kts

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreCompletely()
        }
    }
}
```

build.gradle

```
normalization {
    runtimeClasspath {
        metaInf {
            ignoreCompletely()
        }
    }
}
```

=== Providing custom up-to-date logic

Gradle automatically handles up-to-date checks for output files and directories, but what if the task output is something else entirely? Perhaps it's an update to a web service or a database table. Gradle has no way of knowing how to check whether the task is up to date in such cases.

That's where the `upToDateWhen()` method on `TaskOutputs` comes in. This takes a predicate function that is used to determine whether a task is up to date or not. For example, you could read the version number of your database schema from the database. Or, you could check whether a particular record in a database table exists or has changed for example.

Just be aware that up-to-date checks should *save* you time. Don't add checks that cost as much or more time than the standard execution of the task. In fact, if a task ends up running frequently anyway, because it's rarely up to date, then it may not be worth having no up-to-date checks at all as described in [sec:disable-state-tracking]. Remember that your checks will always run if the task is in the execution task graph.

One common mistake is to use `upToDateWhen()` instead of `Task.onlyIf()`. If you want to skip a task on the basis of some condition unrelated to the task inputs and outputs, then you should use `onlyIf()`. For example, in cases where you want to skip a task when a particular property is set or not set.

== Stale task outputs

When the Gradle version changes, Gradle detects that outputs from tasks that ran with older versions of Gradle need to be removed to ensure that the newest version of the tasks are starting from a known clean state.

> **NOTE** Automatic clean-up of stale output directories has only been implemented for the output of source sets (Java/Groovy/Scala compilation).

= Developing Custom Gradle Task Types

Gradle supports two types of task. One such type is the simple task, where you define the task with an action closure. We have seen these in Build Script Basics. For this type of task, the action closure determines the behaviour of the task. This type of task is good for implementing one-off tasks in your build script.

The other type of task is the enhanced task, where the behaviour is built into the task, and the task provides some properties which you can use to configure the behaviour. We have seen these in Authoring Tasks. Most Gradle plugins use enhanced tasks. With enhanced tasks, you don't need to implement the task behaviour as you do with simple tasks. You simply declare the task and configure the task using its properties. In this way, enhanced tasks let you reuse a piece of behaviour in many different places, possibly across different builds.

The behaviour and properties of an enhanced task are defined by the task's class. When you declare an enhanced task, you specify the type, or class of the task.

Implementing your own custom task class in Gradle is easy. You can implement a custom task

class in pretty much any language you like, provided it ends up compiled to JVM bytecode. In our examples, we are going to use Groovy as the implementation language. Groovy, Java or Kotlin are all good choices as the language to use to implement a task class, as the Gradle API has been designed to work well with these languages. In general, a task implemented using Java or Kotlin, which are statically typed, will perform better than the same task implemented using Groovy.

Packaging a task class

There are several places where you can put the source for the task class.

Build script

> You can include the task class directly in the build script. This has the benefit that the task class is automatically compiled and included in the classpath of the build script without you having to do anything. However, the task class is not visible outside the build script, and so you cannot reuse the task class outside the build script it is defined in.

`buildSrc` **project**

> You can put the source for the task class in the `rootProjectDir/buildSrc/src/main/groovy` directory (or `rootProjectDir/buildSrc/src/main/java` or `rootProjectDir/buildSrc/src/main/kotlin` depending on which language you prefer). Gradle will take care of compiling and testing the task class and making it available on the classpath of the build script. The task class is visible to every build script used by the build. However, it is not visible outside the build, and so you cannot reuse the task class outside the build it is defined in. Using the `buildSrc` project approach separates the task declaration — that is, what the task should do — from the task implementation — that is, how the task does it.
>
> See Organizing Gradle Projects for more details about the `buildSrc` project.

Standalone project

> You can create a separate project for your task class. This project produces and publishes a JAR which you can then use in multiple builds and share with others. Generally, this JAR might include some custom plugins, or bundle several related task classes into a single library. Or some combination of the two.

In our examples, we will start with the task class in the build script, to keep things simple. Then we will look at creating a standalone project.

Writing a simple task class

To implement a custom task class, you extend DefaultTask.

build.gradle.kts

```kotlin
abstract class GreetingTask : DefaultTask() {
}
```

build.gradle

```
abstract class GreetingTask extends DefaultTask {
}
```

This task doesn't do anything useful, so let's add some behaviour. To do so, we add a method to the task and mark it with the TaskAction annotation. Gradle will call the method when the task executes. You don't have to use a method to define the behaviour for the task. You could, for instance, call `doFirst()` or `doLast()` with a closure in the task constructor to add behaviour.

build.gradle.kts

```
abstract class GreetingTask : DefaultTask() {
    @TaskAction
    fun greet() {
        println("hello from GreetingTask")
    }
}

// Create a task using the task type
tasks.register<GreetingTask>("hello")
```

build.gradle

```
abstract class GreetingTask extends DefaultTask {
    @TaskAction
    def greet() {
        println 'hello from GreetingTask'
    }
}

// Create a task using the task type
tasks.register('hello', GreetingTask)
```

```
> gradle -q hello
hello from GreetingTask
```

Let's add a property to the task, so we can customize it. Tasks are objects, and when you declare a task, you can set the properties or call methods on the task object. Here we add a `greeting` property, and set the value when we declare the `greeting` task.

build.gradle.kts

```
abstract class GreetingTask : DefaultTask() {
    @get:Input
    abstract val greeting: Property<String>

    init {
        greeting.convention("hello from GreetingTask")
    }

    @TaskAction
    fun greet() {
        println(greeting.get())
    }
}

// Use the default greeting
tasks.register<GreetingTask>("hello")

// Customize the greeting
tasks.register<GreetingTask>("greeting") {
    greeting = "greetings from GreetingTask"
}
```

build.gradle

```
abstract class GreetingTask extends DefaultTask {
    @Input
    abstract Property<String> getGreeting()

    GreetingTask() {
        greeting.convention('hello from GreetingTask')
    }

    @TaskAction
    def greet() {
        println greeting.get()
    }
}

// Use the default greeting
tasks.register('hello', GreetingTask)

// Customize the greeting
tasks.register('greeting',GreetingTask) {
    greeting = 'greetings from GreetingTask'
}
```

Output of `gradle -q hello greeting`

```
> gradle -q hello greeting
hello from GreetingTask
greetings from GreetingTask
```

== A standalone project

Now we will move our task to a standalone project, so we can publish it and share it with others. This project is simply a Groovy project that produces a JAR containing the task class. Here is a simple build script for the project. It applies the Groovy plugin, and adds the Gradle API as a compile-time dependency.

build.gradle.kts

```kotlin
plugins {
    groovy
}

dependencies {
    implementation(gradleApi())
}
```

build.gradle

```groovy
plugins {
    id 'groovy'
}

dependencies {
    implementation gradleApi()
}
```

We just follow the convention for where the source for the task class should go.

=== Example: A custom task

src/main/groovy/org/gradle/GreetingTask.groovy

```groovy
package org.gradle

import org.gradle.api.DefaultTask
import org.gradle.api.tasks.TaskAction
import org.gradle.api.tasks.Input

class GreetingTask extends DefaultTask {

    @Input
    String greeting = 'hello from GreetingTask'

    @TaskAction
    def greet() {
        println greeting
    }
}
```

=== Using your task class in another project

To use a task class in a build script, you need to add the class to the build script's classpath. To do this, you use a `buildscript { }` block, as described in External dependencies for the build script. The following example shows how you might do this when the JAR containing the task class has been published to a local repository:

build.gradle.kts

```kotlin
buildscript {
    repositories {
        maven {
            url = uri(repoLocation)
        }
    }
    dependencies {
        classpath("org.gradle:task:1.0-SNAPSHOT")
    }
}

tasks.register<org.gradle.GreetingTask>("greeting") {
    greeting = "howdy!"
}
```

build.gradle

```
buildscript {
    repositories {
        maven {
            url = uri(repoLocation)
        }
    }
    dependencies {
        classpath 'org.gradle:task:1.0-SNAPSHOT'
    }
}

tasks.register('greeting', org.gradle.GreetingTask) {
    greeting = 'howdy!'
}
```

=== Writing tests for your task class

You can use the ProjectBuilder class to create Project instances to use when you test your task class.

=== Example: Testing a custom task

src/test/groovy/org/gradle/GreetingTaskTest.groovy

```groovy
class GreetingTaskTest {
    @Test
    void canAddTaskToProject() {
        Project project = ProjectBuilder.builder().build()
        def task = project.task('greeting', type: GreetingTask)
        assertTrue(task instanceof GreetingTask)
    }
}
```

== Incremental tasks

With Gradle, it's very simple to implement a task that is skipped when all of its inputs and outputs are up to date (see Incremental Build). However, there are times when only a few input files have changed since the last execution, and you'd like to avoid reprocessing all of the unchanged inputs. This can be particularly useful for a transformer task that converts input files to output files on a 1:1 basis.

If you'd like to optimize your build so that only out-of-date input files are processed, you can do so with an *incremental task*.

=== Implementing an incremental task

For a task to process inputs incrementally, that task must contain an *incremental task action*. This is a task action method that has a single InputChanges parameter. That parameter tells Gradle that the action only wants to process the changed inputs. In addition, the task needs to declare at least one incremental file input property by using either @Incremental or @SkipWhenEmpty.

To query incremental changes for an input file property, that property always needs to return the same instance. The easiest way to accomplish this is to use one of the following types for such properties: RegularFileProperty, DirectoryProperty or ConfigurableFileCollection.

You can learn more about `RegularFileProperty` and `DirectoryProperty` in the Lazy Configuration chapter, especially the sections on using read-only and configurable properties and lazy file properties.

The incremental task action can use InputChanges.getFileChanges() to find out what files have changed for a given file-based input property, be it of type `RegularFileProperty`, `DirectoryProperty` or `ConfigurableFileCollection`. The method returns an `Iterable` of type FileChanges, which in turn can be queried for the following:

- the affected file
- the change type (`ADDED`, `REMOVED` or `MODIFIED`)
- the normalized path of the changed file
- the file type of the changed file

The following example demonstrates an incremental task that has a directory input. It assumes that the directory contains a collection of text files and copies them to an output directory, reversing the text within each file. The key things to note are the type of the `inputDir` property, its annotations, and how the action (`execute()`) uses `getFileChanges()` to process the subset of files that have actually changed since the last build. You can also see how the action deletes a target file if the corresponding input file has been removed:

```
abstract class IncrementalReverseTask : DefaultTask() {
    @get:Incremental
    @get:PathSensitive(PathSensitivity.NAME_ONLY)
    @get:InputDirectory
    abstract val inputDir: DirectoryProperty

    @get:OutputDirectory
    abstract val outputDir: DirectoryProperty

    @get:Input
    abstract val inputProperty: Property<String>

    @TaskAction
    fun execute(inputChanges: InputChanges) {
        println(
            if (inputChanges.isIncremental) "Executing incrementally"
            else "Executing non-incrementally"
        )

        inputChanges.getFileChanges(inputDir).forEach { change ->
            if (change.fileType == FileType.DIRECTORY) return@forEach

            println("${change.changeType}: ${change.normalizedPath}")
            val targetFile = outputDir.file(change.normalizedPath).get().asFile
            if (change.changeType == ChangeType.REMOVED) {
                targetFile.delete()
            } else {
                targetFile.writeText(change.file.readText().reversed())
            }
        }
    }
}
```

```groovy
abstract class IncrementalReverseTask extends DefaultTask {
    @Incremental
    @PathSensitive(PathSensitivity.NAME_ONLY)
    @InputDirectory
    abstract DirectoryProperty getInputDir()

    @OutputDirectory
    abstract DirectoryProperty getOutputDir()

    @Input
    abstract Property<String> getInputProperty()

    @TaskAction
    void execute(InputChanges inputChanges) {
        println(inputChanges.incremental
            ? 'Executing incrementally'
            : 'Executing non-incrementally'
        )

        inputChanges.getFileChanges(inputDir).each { change ->
            if (change.fileType == FileType.DIRECTORY) return

            println "${change.changeType}: ${change.normalizedPath}"
            def targetFile = outputDir.file(change.normalizedPath).get().asFile
            if (change.changeType == ChangeType.REMOVED) {
                targetFile.delete()
            } else {
                targetFile.text = change.file.text.reverse()
            }
        }
    }
}
```

If for some reason the task is executed non-incrementally, for example by running with `--rerun-tasks`, all files are reported as `ADDED`, irrespective of the previous state. In this case, Gradle automatically removes the previous outputs, so the incremental task only needs to process the given files.

For a simple transformer task like the above example, the task action simply needs to generate output files for any out-of-date inputs and delete output files for any removed inputs.

| **IMPORTANT** | A task may only contain a single incremental task action. |

=== Which inputs are considered out of date?

When there is a previous execution of the task, and the only changes since that execution are to incremental input file properties, then Gradle is able to determine which input files need to be processed (incremental execution). In this case, the InputChanges.getFileChanges() method returns details for all input files for the given property that were *added, modified* or *removed*.

However, there are many cases where Gradle is unable to determine which input files need to be processed (non-incremental execution). Examples include:

- There is no history available from a previous execution.
- You are building with a different version of Gradle. Currently, Gradle does not use task history from a different version.
- An `upToDateWhen` criterion added to the task returns `false`.
- An input property has changed since the previous execution.
- A non-incremental input file property has changed since the previous execution.
- One or more output files have changed since the previous execution.

In all of these cases, Gradle will report all input files as `ADDED` and the `getFileChanges()` method will return details for all the files that comprise the given input property.

You can check if the task execution is incremental or not with the InputChanges.isIncremental() method.

=== An incremental task in action

Given the example incremental task implementation above, let's walk through some scenarios based on it.

First, consider an instance of `IncrementalReverseTask` that is executed against a set of inputs for the first time. In this case, all inputs will be considered added, as shown here:

```
tasks.register<IncrementalReverseTask>("incrementalReverse") {
    inputDir = file("inputs")
    outputDir = layout.buildDirectory.dir("outputs")
    inputProperty = project.findProperty("taskInputProperty") as String? ?:
"original"
}
```

build.gradle

```
tasks.register('incrementalReverse', IncrementalReverseTask) {
    inputDir = file('inputs')
    outputDir = layout.buildDirectory.dir("outputs")
    inputProperty = project.properties['taskInputProperty'] ?: 'original'
}
```

Build layout

```
.
├── build.gradle
└── inputs
    ├── 1.txt
    ├── 2.txt
    └── 3.txt
```

Output of `gradle -q incrementalReverse`

```
> gradle -q incrementalReverse
Executing non-incrementally
ADDED: 1.txt
ADDED: 2.txt
ADDED: 3.txt
```

Naturally when the task is executed again with no changes, then the entire task is up to date
and the task action is not executed:

```
> gradle incrementalReverse
> Task :incrementalReverse UP-TO-DATE

BUILD SUCCESSFUL in 0s
1 actionable task: 1 up-to-date
```

When an input file is modified in some way or a new input file is added, then re-executing the task results in those files being returned by InputChanges.getFileChanges(). The following example modifies the content of one file and adds another before running the incremental task:

build.gradle.kts

```
tasks.register("updateInputs") {
    val inputsDir = layout.projectDirectory.dir("inputs")
    outputs.dir(inputsDir)
    doLast {
        inputsDir.file("1.txt").asFile.writeText("Changed content for existing
file 1.")
        inputsDir.file("4.txt").asFile.writeText("Content for new file 4.")
    }
}
```

build.gradle

```
tasks.register('updateInputs') {
    def inputsDir = layout.projectDirectory.dir('inputs')
    outputs.dir(inputsDir)
    doLast {
        inputsDir.file('1.txt').asFile.text = 'Changed content for existing file
1.'
        inputsDir.file('4.txt').asFile.text = 'Content for new file 4.'
    }
}
```

Output of `gradle -q updateInputs incrementalReverse`

```
> gradle -q updateInputs incrementalReverse
Executing incrementally
MODIFIED: 1.txt
ADDED: 4.txt
```

When an existing input file is removed, then re-executing the task results in that file being returned by InputChanges.getFileChanges() as `REMOVED`. The following example removes one of the existing files before executing the incremental task:

build.gradle.kts

```kotlin
tasks.register<Delete>("removeInput") {
    delete("inputs/3.txt")
}
```

build.gradle

```groovy
tasks.register('removeInput', Delete) {
    delete 'inputs/3.txt'
}
```

Output of `gradle -q removeInput incrementalReverse`

```
> gradle -q removeInput incrementalReverse
Executing incrementally
REMOVED: 3.txt
```

When an *output* file is deleted (or modified), then Gradle is unable to determine which input files are out of date. In this case, details for *all* the input files for the given property are returned by InputChanges.getFileChanges(). The following example removes just one of the output files from the build directory, but notice how all the input files are considered to be `ADDED`:

build.gradle.kts

```kotlin
tasks.register<Delete>("removeOutput") {
    delete(layout.buildDirectory.file("outputs/1.txt"))
}
```

```
tasks.register('removeOutput', Delete) {
    delete layout.buildDirectory.file("outputs/1.txt")
}
```

Output of `gradle -q removeOutput incrementalReverse`

```
> gradle -q removeOutput incrementalReverse
Executing non-incrementally
ADDED: 1.txt
ADDED: 2.txt
ADDED: 3.txt
```

The last scenario we want to cover concerns what happens when a non-file-based input property is modified. In such cases, Gradle is unable to determine how the property impacts the task outputs, so the task is executed non-incrementally. This means that *all* input files for the given property are returned by InputChanges.getFileChanges() and they are all treated as ADDED. The following example sets the project property `taskInputProperty` to a new value when running the `incrementalReverse` task and that project property is used to initialize the task's `inputProperty` property, as you can see in the first example of this section. Here's the output you can expect in this case:

Output of `gradle -q -PtaskInputProperty=changed incrementalReverse`

```
> gradle -q -PtaskInputProperty=changed incrementalReverse
Executing non-incrementally
ADDED: 1.txt
ADDED: 2.txt
ADDED: 3.txt
```

Storing incremental state for cached tasks

Using Gradle's `InputChanges` is not the only way to create tasks that only work on changes since the last execution. Tools like the Kotlin compiler provide incrementality as a built-in feature. The way this is typically implemented is that the tool stores some analysis data about the state of the previous execution in some file. If such state files are relocatable, then they can be declared as outputs of the task. This way when the task's results are loaded from cache, the next execution can already use the analysis data loaded from cache, too.

However, if the state files are non-relocatable, then they can't be shared via the build cache. Indeed, when the task is loaded from cache, any such state files must be cleaned up to prevent stale state from confusing the tool during the next execution. Gradle can ensure such stale files are removed if they are declared via task.localState.register() or if a property is marked with the @LocalState annotation.

Declaring and Using Command Line Options

Sometimes a user wants to declare the value of an exposed task property on the command line instead of the build script. Being able to pass in property values on the command line is particularly helpful if they change more frequently. The task API supports a mechanism for marking a property to automatically generate a corresponding command line parameter with a specific name at runtime.

Declaring a command-line option

Exposing a new command line option for a task property is straightforward. You just have to annotate the corresponding setter method of a property with Option. An option requires a mandatory identifier. Additionally, you can provide an optional description. A task can expose as many command line options as properties available in the class.

Options may be declared in superinterfaces of the task class as well. If multiple interfaces declare the same property, but with different option flags, they will both work to set the property.

Let's have a look at an example to illustrate the functionality. The custom task `UrlVerify` verifies whether a given URL can be resolved by making a HTTP call and checking the response code. The URL to be verified is configurable through the property `url`. The setter method for the property is annotated with @Option.

Example: Declaring a command line option

```java
import org.gradle.api.tasks.options.Option;

public class UrlVerify extends DefaultTask {
    private String url;

    @Option(option = "url", description = "Configures the URL to be verified.")
    public void setUrl(String url) {
        this.url = url;
    }

    @Input
    public String getUrl() {
        return url;
    }

    @TaskAction
    public void verify() {
        getLogger().quiet("Verifying URL '{}'", url);

        // verify URL by making a HTTP call
    }
}
```

All options declared for a task can be rendered as console output by running the `help` task and the `--task` option.

=== Using an option on the command line

Using an option on the command line has to adhere to the following rules:

- The option uses a double-dash as prefix e.g. `--url`. A single dash does not qualify as valid syntax for a task option.
- The option argument follows directly after the task declaration e.g. `verifyUrl --url=http://www.google.com/`.
- Multiple options of a task can be declared in any order on the command line following the task name.

Getting back to the previous example, the build script creates a task instance of type `UrlVerify` and provides a value from the command line through the exposed option.

build.gradle.kts

```kotlin
tasks.register<UrlVerify>("verifyUrl")
```

build.gradle

```
tasks.register('verifyUrl', UrlVerify)
```

Output of `gradle -q verifyUrl --url=http://www.google.com/`

```
> gradle -q verifyUrl --url=http://www.google.com/
Verifying URL 'http://www.google.com/'
```

=== Supported data types for options

Gradle limits the set of data types that can be used for declaring command line options. The use on the command line differ per type.

`boolean`, `Boolean`, `Property<Boolean>`

Describes an option with the value `true` or `false`. Passing the option on the command line treats the value as `true`, for example `--foo` equates to `true`. The absence of the option uses the default value of the property. For each boolean option, an opposite option is created automatically. For example, `--no-foo` is created for the provided option `--foo` and `--bar` is created for `--no-bar`. Options whose name starts with `--no` are disable options and set the option value to `false`. An opposite option is only created if no option with the same name already exists for the task.

`Double`, `Property<Double>`

Describes an option with a double value. Passing the option on the command line also requires a value e.g. `--factor=2.2` or `--factor 2.2`.

`Integer`, `Property<Integer>`

Describes an option with an integer value. Passing the option on the command line also requires a value e.g. `--network-timeout=5000` or `--network-timeout 5000`.

`Long`, `Property<Long>`

Describes an option with a long value. Passing the option on the command line also requires a value e.g. `--threshold=2147483648` or `--threshold 2147483648`.

`String`, `Property<String>`

Describes an option with an arbitrary String value. Passing the option on the command line also requires a value e.g. `--container-id=2x94held` or `--container-id 2x94held`.

`enum`, `Property<enum>`

Describes an option as an enumerated type. Passing the option on the command line also requires a value e.g. `--log-level=DEBUG` or `--log-level debug`. The value is not case sensitive.

`List<T>` **where** `T` **is** `Double`, `Integer`, `Long`, `String`, `enum`

Describes an option that can takes multiple values of a given type. The values for the option have to be provided as multiple declarations e.g. `--image-id=123 --image-id=456`. Other notations such as comma-separated lists or multiple values separated by a space character are currently not supported.

`ListProperty<T>`, `SetProperty<T>` **where** `T` **is** `Double`, `Integer`, `Long`, `String`, `enum`

Describes an option that can takes multiple values of a given type. The values for the option

have to be provided as multiple declarations e.g. `--image-id=123 --image-id=456`. Other notations such as comma-separated lists or multiple values separated by a space character are currently not supported.

`DirectoryProperty`, `RegularFileProperty`

Describes an option with a file system element. Passing the option on the command line also requires a value that represents a path, e.g. `--output-file=file.txt` or `--output-dir outputDir`. Relative paths are resolved relative to the project directory of the project that owns this property instance, see FileSystemLocationProperty.set().

=== Documenting available values for an option

In theory, an option for a property type `String` or `List<String>` can accept any arbitrary value. Expected values for such an option can be documented programmatically with the help of the annotation OptionValues. This annotation may be assigned to any method that returns a `List` of one of the supported data types. In addition, you have to provide the option identifier to indicate the relationship between option and available values.

NOTE	Passing a value on the command line that is not supported by the option does not fail the build or throw an exception. You'll have to implement custom logic for such behavior in the task action.

This example demonstrates the use of multiple options for a single task. The task implementation provides a list of available values for the option `output-type`.

=== Example: Declaring available values for an option

UrlProcess.java

```java
import org.gradle.api.tasks.options.Option;
import org.gradle.api.tasks.options.OptionValues;

public abstract class UrlProcess extends DefaultTask {
    private String url;
    private OutputType outputType;

    @Input
    @Option(option = "http", description = "Configures the http protocol to be allowed.")
    public abstract Property<Boolean> getHttp();

    @Option(option = "url", description = "Configures the URL to send the request to.")
    public void setUrl(String url) {
        if (!getHttp().getOrElse(true) && url.startsWith("http://")) {
            throw new IllegalArgumentException("HTTP is not allowed");
        } else {
            this.url = url;
        }
    }
}
```

```java
    @Input
    public String getUrl() {
        return url;
    }

    @Option(option = "output-type", description = "Configures the output type.")
    public void setOutputType(OutputType outputType) {
        this.outputType = outputType;
    }

    @OptionValues("output-type")
    public List<OutputType> getAvailableOutputTypes() {
        return new ArrayList<OutputType>(Arrays.asList(OutputType.values()));
    }

    @Input
    public OutputType getOutputType() {
        return outputType;
    }

    @TaskAction
    public void process() {
        getLogger().quiet("Writing out the URL response from '{}' to '{}'", url,
outputType);

        // retrieve content from URL and write to output
    }

    private static enum OutputType {
        CONSOLE, FILE
    }
}
```

=== Listing command line options

Command line options using the annotations Option and OptionValues are self-documenting.
You will see declared options and their available values reflected in the console output of the
help task. The output renders options in alphabetical order, except for boolean disable options
which appear following the enable option.

=== Example: Listing available values for option

Output of `gradle -q help --task processUrl`

```
> gradle -q help --task processUrl
Detailed task information for processUrl

Path
     :processUrl

Type
     UrlProcess (UrlProcess)

Options
     --http     Configures the http protocol to be allowed.

     --no-http     Disables option --http.

     --output-type     Configures the output type.
                       Available values are:
                              CONSOLE
                              FILE

     --url     Configures the URL to send the request to.

     --rerun     Causes the task to be re-run even if up-to-date.

Description
     -

Group
     -
```

=== Limitations

Support for declaring command line options currently comes with a few limitations.

- Command line options can only be declared for custom tasks via annotation. There's no programmatic equivalent for defining options.

- Options cannot be declared globally e.g. on a project-level or as part of a plugin.

- When assigning an option on the command line then the task exposing the option needs to be spelled out explicitly e.g. `gradle check --tests abc` does not work even though the `check` task depends on the `test` task.

- If you specify a task option name that conflicts with the name of a built-in Gradle option, use the `--` delimiter before calling your task to reference that option. For more information, see Disambiguate Task Options from Built-in Options.

== The Worker API

As can be seen from the discussion of incremental tasks, the work that a task performs can be viewed as discrete units (i.e. a subset of inputs that are transformed to a certain subset of

outputs). Many times, these units of work are highly independent of each other, meaning they can be performed in any order and simply aggregated together to form the overall action of the task. In a single threaded execution, these units of work would execute in sequence, however if we have multiple processors, it would be desirable to perform independent units of work concurrently. By doing so, we can fully utilize the available resources at build time and complete the activity of the task faster.

The Worker API provides a mechanism for doing exactly this. It allows for safe, concurrent execution of multiple items of work during a task action. But the benefits of the Worker API are not confined to parallelizing the work of a task. You can also configure a desired level of isolation such that work can be executed in an isolated classloader or even in an isolated process. Furthermore, the benefits extend beyond even the execution of a single task. Using the Worker API, Gradle can begin to execute tasks in parallel by default. In other words, once a task has submitted its work to be executed asynchronously, and has exited the task action, Gradle can then begin the execution of other independent tasks in parallel, even if those tasks are in the same project.

=== Using the Worker API

| NOTE | A step-by-step description of converting a normal task action to use the worker API can be found in the section on developing parallel tasks. |

In order to submit work to the Worker API, two things must be provided: an implementation of the unit of work, and the parameters for the unit of work.

The parameters for the unit of work are defined as an interface or abstract class that implements WorkParameters. The parameters type must be a managed type.

You can find out more about implementing work parameters in Developing Custom Gradle Types.

The implementation is a class that extends WorkAction. This class should be abstract and should not implement the getParameters() method. Gradle will inject an implementation of this method at runtime with the parameters object for each unit of work.

```kotlin
// The parameters for a single unit of work
interface ReverseParameters : WorkParameters {
    val fileToReverse : RegularFileProperty
    val destinationDir : DirectoryProperty
}

// The implementation of a single unit of work
abstract class ReverseFile @Inject constructor(val fileSystemOperations:
FileSystemOperations) : WorkAction<ReverseParameters> {
    override fun execute() {
        fileSystemOperations.copy {
            from(parameters.fileToReverse)
            into(parameters.destinationDir)
            filter { line: String -> line.reversed() }
        }
    }
}
```

```groovy
// The parameters for a single unit of work
interface ReverseParameters extends WorkParameters {
    RegularFileProperty getFileToReverse()
    DirectoryProperty getDestinationDir()
}

// The implementation of a single unit of work.
abstract class ReverseFile implements WorkAction<ReverseParameters> {
    private final FileSystemOperations fileSystemOperations

    @Inject
    public ReverseFile(FileSystemOperations fileSystemOperations) {
        this.fileSystemOperations = fileSystemOperations
    }

    @Override
    void execute() {
        fileSystemOperations.copy {
            from parameters.fileToReverse
            into parameters.destinationDir
            filter { String line -> line.reverse() }
        }
    }
}
```

A `WorkAction` implementation can inject services that provide capabilities during work execution, such as the FileSystemOperations service in the example above. See Service Injection for further information on injecting service types.

In order to submit the unit of work, it is necessary to first acquire the WorkerExecutor. To do this, a task should have a constructor annotated with `javax.inject.Inject` that accepts a WorkerExecutor parameter. Gradle will inject the instance of WorkerExecutor at runtime when the task is created. Then a WorkQueue object can be created and individual items of work can be submitted.

build.gradle.kts

```kotlin
// The WorkerExecutor will be injected by Gradle at runtime
abstract class ReverseFiles @Inject constructor(private val workerExecutor:
WorkerExecutor) : SourceTask() {
    @get:OutputDirectory
    abstract val outputDir: DirectoryProperty

    @TaskAction
    fun reverseFiles() {
        // Create a WorkQueue to submit work items
        val workQueue = workerExecutor.noIsolation()

        // Create and submit a unit of work for each file
        source.forEach { file ->
            workQueue.submit(ReverseFile::class) {
                fileToReverse = file
                destinationDir = outputDir
            }
        }
    }
}
```

build.gradle

```
abstract class ReverseFiles extends SourceTask {
    private final WorkerExecutor workerExecutor

    @OutputDirectory
    abstract DirectoryProperty getOutputDir()

    // The WorkerExecutor will be injected by Gradle at runtime
    @Inject
    ReverseFiles(WorkerExecutor workerExecutor) {
        this.workerExecutor = workerExecutor
    }

    @TaskAction
    void reverseFiles() {
        // Create a WorkQueue to submit work items
        WorkQueue workQueue = workerExecutor.noIsolation()

        // Create and submit a unit of work for each file
        source.each { file ->
            workQueue.submit(ReverseFile.class) { ReverseParameters parameters ->
                parameters.fileToReverse = file
                parameters.destinationDir = outputDir
            }
        }
    }
}
```

Once all of the work for a task action has been submitted, it is safe to exit the task action. The work will be executed asynchronously and in parallel (up to the setting of `max-workers`). Of course, any tasks that are dependent on this task (and any subsequent task actions of this task) will not begin executing until all of the asynchronous work completes. However, other independent tasks that have no relationship to this task can begin executing immediately.

If any failures occur while executing the asynchronous work, the task will fail and a WorkerExecutionException will be thrown detailing the failure for each failed work item. This will be treated like any failure during task execution and will prevent any dependent tasks from executing.

In some cases, however, it might be desirable to wait for work to complete before exiting the task action. This is possible using the WorkQueue.await() method. As in the case of allowing the work to complete asynchronously, any failures that occur while executing an item of work will be surfaced as a WorkerExecutionException thrown from the WorkQueue.await() method.

Note that Gradle will only begin running other independent tasks in parallel when a task has exited a task action and returned control of execution to Gradle. When WorkQueue.await() is used,

execution does not leave the task action. This means that Gradle will not allow other tasks to begin executing and will wait for the task action to complete before doing so.

build.gradle.kts

```kotlin
// Create a WorkQueue to submit work items
val workQueue = workerExecutor.noIsolation()

// Create and submit a unit of work for each file
source.forEach { file ->
    workQueue.submit(ReverseFile::class) {
        fileToReverse = file
        destinationDir = outputDir
    }
}

// Wait for all asynchronous work submitted to this queue to complete before
continuing
workQueue.await()
logger.lifecycle("Created ${outputDir.get().asFile.listFiles().size} reversed
files in
${outputDir.get().asFile.toRelativeString(projectLayout.projectDirectory.asFile)}"
)
```

build.gradle

```groovy
// Create a WorkQueue to submit work items
WorkQueue workQueue = workerExecutor.noIsolation()

// Create and submit a unit of work for each file
source.each { file ->
    workQueue.submit(ReverseFile.class) { ReverseParameters parameters ->
        parameters.fileToReverse = file
        parameters.destinationDir = outputDir
    }
}

// Wait for all asynchronous work submitted to this queue to complete before
continuing
workQueue.await()
logger.lifecycle("Created ${outputDir.get().asFile.listFiles().length} reversed
files in ${projectLayout.projectDirectory.asFile.relativePath(outputDir.get()
.asFile)}")
```

=== Isolation Modes

Gradle provides three isolation modes that can be configured when creating a WorkQueue and are specified using the one of the following methods on WorkerExecutor:

WorkerExecutor.noIsolation()

    This states that the work should be run in a thread with a minimum of isolation. For instance, it will share the same classloader that the task is loaded from. This is the fastest level of isolation.

WorkerExecutor.classLoaderIsolation()

    This states that the work should be run in a thread with an isolated classloader. The classloader will have the classpath from the classloader that the unit of work implementation class was loaded from as well as any additional classpath entries added through ClassLoaderWorkerSpec.getClasspath().

WorkerExecutor.processIsolation()

    This states that the work should be run with a maximum level of isolation by executing the work in a separate process. The classloader of the process will use the classpath from the classloader that the unit of work was loaded from as well as any additional classpath entries added through ClassLoaderWorkerSpec.getClasspath(). Furthermore, the process will be a *Worker Daemon* which will stay alive and can be reused for future work items that may have the same requirements. This process can be configured with different settings than the Gradle JVM using ProcessWorkerSpec.forkOptions(org.gradle.api.Action).

=== Worker Daemons

When using `processIsolation()`, gradle will start a long-lived *Worker Daemon* process that can be reused for future work items.

build.gradle.kts

```kotlin
// Create a WorkQueue with process isolation
val workQueue = workerExecutor.processIsolation() {
    // Configure the options for the forked process
    forkOptions {
        maxHeapSize = "512m"
        systemProperty("org.gradle.sample.showFileSize", "true")
    }
}

// Create and submit a unit of work for each file
source.forEach { file ->
    workQueue.submit(ReverseFile::class) {
        fileToReverse = file
        destinationDir = outputDir
    }
}
```

build.gradle

```groovy
// Create a WorkQueue with process isolation
WorkQueue workQueue = workerExecutor.processIsolation() { ProcessWorkerSpec spec
->
    // Configure the options for the forked process
    forkOptions { JavaForkOptions options ->
        options.maxHeapSize = "512m"
        options.systemProperty "org.gradle.sample.showFileSize", "true"
    }
}

// Create and submit a unit of work for each file
source.each { file ->
    workQueue.submit(ReverseFile.class) { ReverseParameters parameters ->
        parameters.fileToReverse = file
        parameters.destinationDir = outputDir
    }
}
```

When a unit of work for a Worker Daemon is submitted, Gradle will first look to see if a compatible, idle daemon already exists. If so, it will send the unit of work to the idle daemon, marking it as busy. If not, it will start a new daemon. When evaluating compatibility, Gradle looks at a number of criteria, all of which can be controlled through ProcessWorkerSpec.forkOptions(org.gradle.api.Action).

By default, a worker daemon starts with a maximum heap of 512MB. This can be changed by adjusting the workers fork options.

executable

A daemon is considered compatible only if it uses the same java executable.

classpath

A daemon is considered compatible if its classpath contains all of the classpath entries requested. Note that a daemon is considered compatible only if the classpath exactly matches the requested classpath.

heap settings

A daemon is considered compatible if it has at least the same heap size settings as requested. In other words, a daemon that has higher heap settings than requested would be considered compatible.

jvm arguments

A daemon is considered compatible if it has set all of the jvm arguments requested. Note that a daemon is considered compatible if it has additional jvm arguments beyond those requested (except for arguments treated specially such as heap settings, assertions, debug, etc).

system properties

A daemon is considered compatible if it has set all of the system properties requested with the same values. Note that a daemon is considered compatible if it has additional system properties beyond those requested.

environment variables

A daemon is considered compatible if it has set all of the environment variables requested with the same values. Note that a daemon is considered compatible if it has more environment variables in addition to those requested.

bootstrap classpath

A daemon is considered compatible if it contains all of the bootstrap classpath entries requested. Note that a daemon is considered compatible if it has more bootstrap classpath entries in addition to those requested.

debug

A daemon is considered compatible only if debug is set to the same value as requested (true or false).

enable assertions

> A daemon is considered compatible only if enable assertions is set to the same value as requested (true or false).

default character encoding

> A daemon is considered compatible only if the default character encoding is set to the same value as requested.

Worker daemons will remain running until either the build daemon that started them is stopped, or system memory becomes scarce. When available system memory is low, Gradle will begin stopping worker daemons in an attempt to minimize memory consumption.

== Cancellation and timeouts

In order to support cancellation (e.g. when the user stops the build with CTRL+C) and task timeouts, custom tasks should react to their executing thread being interrupted. The same is true for work items submitted via the worker API. If a task does not respond to an interrupt within 10s, the daemon will shut down in order to free up system resources.

== More details

It's often a good approach to package custom task types in a custom Gradle plugin. The plugin can provide useful defaults and conventions for the task type, and provides a convenient way to use the task type from a build script or another plugin. Please see Developing Custom Gradle Plugins for more details.

Gradle provides a number of features that are helpful when developing Gradle types, including tasks. Please see Developing Custom Gradle Types for more details.

= Lazy Configuration

As a build grows in complexity, knowing when and where a particular value is configured can become difficult to reason about. Gradle provides several ways to manage this complexity using *lazy configuration.*

== Lazy properties

Gradle provides lazy properties, which delay the calculation of a property's value until it's actually required. These provide three main benefits to build script and plugin authors:

1. Build authors can wire together Gradle models without worrying when a particular property's value will be known. For example, you may want to set the input source files of a task based on the source directories property of an extension but the extension property value isn't known until the build script or some other plugin configures them.

2. Build authors can wire an output property of a task into an input property of some other task and Gradle automatically determines the task dependencies based on this connection. Property instances carry information about which task, if any, produces their value. Build authors do not need to worry about keeping task dependencies in sync with configuration changes.

3. Build authors can avoid resource intensive work during the configuration phase, which can have a large impact on build performance. For example, when a configuration value comes from parsing a file but is only used when functional tests are run, using a property instance to capture this means that the file is parsed only when the functional tests are run, but not when, for example, `clean` is run.

Gradle represents lazy properties with two interfaces:

- Provider represents a value that can only be queried and cannot be changed.

  - Properties with these types are read-only.

  - The method Provider.get() returns the current value of the property.

  - A `Provider` can be created from another `Provider` using Provider.map(Transformer).

  - Many other types extend `Provider` and can be used where-ever a `Provider` is required.

- Property represents a value that can be queried and also changed.

  - Properties with these types are configurable.

  - `Property` extends the `Provider` interface.

  - The method Property.set(T) specifies a value for the property, overwriting whatever value may have been present.

  - The method Property.set(Provider) specifies a `Provider` for the value for the property, overwriting whatever value may have been present. This allows you to wire together `Provider` and `Property` instances before the values are configured.

  - A `Property` can be created by the factory method ObjectFactory.property(Class).

Lazy properties are intended to be passed around and only queried when required. Usually, this will happen during the execution phase. For more information about the Gradle build phases, please see Build Lifecycle.

The following demonstrates a task with a configurable `greeting` property and a read-only `message` property that is derived from this:

```kotlin
abstract class Greeting : DefaultTask() { ①
    @get:Input
    abstract val greeting: Property<String> ②

    @Internal
    val message: Provider<String> = greeting.map { it + " from Gradle" } ③

    @TaskAction
    fun printMessage() {
        logger.quiet(message.get())
    }
}

tasks.register<Greeting>("greeting") {
    greeting.set("Hi") ④
    greeting = "Hi" ⑤
}
```

```groovy
abstract class Greeting extends DefaultTask { ①
    @Input
    abstract Property<String> getGreeting() ②

    @Internal
    final Provider<String> message = greeting.map { it + ' from Gradle' } ③

    @TaskAction
    void printMessage() {
        logger.quiet(message.get())
    }
}

tasks.register("greeting", Greeting) {
    greeting.set('Hi') ④
    greeting = 'Hi' ⑤
}
```

① A task that displays a greeting

② A configurable greeting

③ Read-only property calculated from the greeting

④ Configure the greeting

⑤ Alternative notation to calling Property.set() (incubating for Kotlin, see Kotlin DSL Primer)

Output of `gradle greeting`

```
$ gradle greeting

> Task :greeting
Hi from Gradle

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

The `Greeting` task has a property of type `Property<String>` to represent the configurable greeting and a property of type `Provider<String>` to represent the calculated, read-only, message. The message `Provider` is created from the greeting `Property` using the `map()` method, and so its value is kept up-to-date as the value of the greeting property changes.

Note that Gradle Groovy DSL generates setter methods for each `Property`-typed property in a task implementation. These setter methods allow you to configure the property using the assignment (`=`) operator as a convenience.

In Kotlin DSL, the `set()` method on the property needs to be used instead of `=`.

== Creating a Property or Provider instance

Neither `Provider` nor its subtypes such as `Property` are intended to be implemented by a build script or plugin author. Gradle provides factory methods to create instances of these types instead. See the Quick Reference for all of the types and factories available. In the previous example, we have seen 2 factory methods:

- ObjectFactory.property(Class) create a new `Property` instance. An instance of the ObjectFactory can be referenced from Project.getObjects() or by injecting `ObjectFactory` through a constructor or method.

- Provider.map(Transformer) creates a new `Provider` from an existing `Provider` or `Property` instance.

A `Provider` can also be created by the factory method ProviderFactory.provider(Callable). You should prefer using `map()` instead, as this has some useful benefits, which we will see later.

There are no specific methods create a provider using a `groovy.lang.Closure`. When writing a plugin or build script with Groovy, you can use the `map(Transformer)` method with a closure and Groovy

will take care of converting the closure to a `Transformer`. You can see this in action in the previous example.

Similarly, when writing a plugin or build script with Kotlin, the Kotlin compiler will take care of converting a Kotlin function into a `Transformer`.

> == Connecting properties together
>
> An important feature of lazy properties is that they can be connected together so that changes to one property are automatically reflected in other properties. Here's an example where the property of a task is connected to a property of a project extension:

build.gradle.kts

```kotlin
// A project extension
interface MessageExtension {
    // A configurable greeting
    abstract val greeting: Property<String>
}

// A task that displays a greeting
abstract class Greeting : DefaultTask() {
    // Configurable by the user
    @get:Input
    abstract val greeting: Property<String>

    // Read-only property calculated from the greeting
    @Internal
    val message: Provider<String> = greeting.map { it + " from Gradle" }

    @TaskAction
    fun printMessage() {
        logger.quiet(message.get())
    }
}

// Create the project extension
val messages = project.extensions.create<MessageExtension>("messages")

// Create the greeting task
tasks.register<Greeting>("greeting") {
    // Attach the greeting from the project extension
    // Note that the values of the project extension have not been configured yet
    greeting = messages.greeting
}

messages.apply {
    // Configure the greeting on the extension
    // Note that there is no need to reconfigure the task's `greeting` property.
This is automatically updated as the extension property changes
    greeting = "Hi"
}
```

build.gradle

```gradle
// A project extension
interface MessageExtension {
    // A configurable greeting
    Property<String> getGreeting()
}

// A task that displays a greeting
abstract class Greeting extends DefaultTask {
    // Configurable by the user
    @Input
    abstract Property<String> getGreeting()

    // Read-only property calculated from the greeting
    @Internal
    final Provider<String> message = greeting.map { it + ' from Gradle' }

    @TaskAction
    void printMessage() {
        logger.quiet(message.get())
    }
}

// Create the project extension
project.extensions.create('messages', MessageExtension)

// Create the greeting task
tasks.register("greeting", Greeting) {
    // Attach the greeting from the project extension
    // Note that the values of the project extension have not been configured yet
    greeting = messages.greeting
}

messages {
    // Configure the greeting on the extension
    // Note that there is no need to reconfigure the task's `greeting` property.
This is automatically updated as the extension property changes
    greeting = 'Hi'
}
```

```
$ gradle greeting

> Task :greeting
Hi from Gradle

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

This example calls the Property.set(Provider) method to attach a `Provider` to a `Property` to supply the value of the property. In this case, the `Provider` happens to be a `Property` as well, but you can connect any `Provider` implementation, for example one created using `Provider.map()`

== Working with files

In Working with Files, we introduced four collection types for `File`-like objects:

Table 6. Collection of files recap

Read-only Type	Configurable Type
FileCollection	ConfigurableFileCollection
FileTree	ConfigurableFileTree

All of these types are also considered lazy types.

In this section, we are going to introduce more strongly typed models types to represent elements of the file system: Directory and RegularFile. These types shouldn't be confused with the standard Java File type as they are used to tell Gradle, and other people, that you expect more specific values such as a directory or a non-directory, regular file.

Gradle provides two specialized `Property` subtypes for dealing with values of these types: RegularFileProperty and DirectoryProperty. ObjectFactory has methods to create these: ObjectFactory.fileProperty() and ObjectFactory.directoryProperty().

A `DirectoryProperty` can also be used to create a lazily evaluated `Provider` for a `Directory` and `RegularFile` via DirectoryProperty.dir(String) and DirectoryProperty.file(String) respectively. These methods create providers whose values are calculated relative to the location for the `DirectoryProperty` they were created from. The values returned from these providers will reflect changes to the `DirectoryProperty`.

```kotlin
// A task that generates a source file and writes the result to an output
directory
abstract class GenerateSource : DefaultTask() {
    // The configuration file to use to generate the source file
    @get:InputFile
    abstract val configFile: RegularFileProperty

    // The directory to write source files to
    @get:OutputDirectory
    abstract val outputDir: DirectoryProperty

    @TaskAction
    fun compile() {
        val inFile = configFile.get().asFile
        logger.quiet("configuration file = $inFile")
        val dir = outputDir.get().asFile
        logger.quiet("output dir = $dir")
        val className = inFile.readText().trim()
        val srcFile = File(dir, "${className}.java")
        srcFile.writeText("public class ${className} { }")
    }
}

// Create the source generation task
tasks.register<GenerateSource>("generate") {
    // Configure the locations, relative to the project and build directories
    configFile = layout.projectDirectory.file("src/config.txt")
    outputDir = layout.buildDirectory.dir("generated-source")
}

// Change the build directory
// Don't need to reconfigure the task properties. These are automatically updated
as the build directory changes
layout.buildDirectory = layout.projectDirectory.dir("output")
```

build.gradle

```groovy
// A task that generates a source file and writes the result to an output
directory
abstract class GenerateSource extends DefaultTask {
    // The configuration file to use to generate the source file
    @InputFile
    abstract RegularFileProperty getConfigFile()

    // The directory to write source files to
    @OutputDirectory
    abstract DirectoryProperty getOutputDir()

    @TaskAction
    def compile() {
        def inFile = configFile.get().asFile
        logger.quiet("configuration file = $inFile")
        def dir = outputDir.get().asFile
        logger.quiet("output dir = $dir")
        def className = inFile.text.trim()
        def srcFile = new File(dir, "${className}.java")
        srcFile.text = "public class ${className} { ... }"
    }
}

// Create the source generation task
tasks.register('generate', GenerateSource) {
    // Configure the locations, relative to the project and build directories
    configFile = layout.projectDirectory.file('src/config.txt')
    outputDir = layout.buildDirectory.dir('generated-source')
}

// Change the build directory
// Don't need to reconfigure the task properties. These are automatically updated
as the build directory changes
layout.buildDirectory = layout.projectDirectory.dir('output')
```

```
$ gradle generate

> Task :generate
configuration file = /home/user/gradle/samples/src/config.txt
output dir = /home/user/gradle/samples/output/generated-source

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

```
$ gradle generate

> Task :generate
configuration file = /home/user/gradle/samples/kotlin/src/config.txt
output dir = /home/user/gradle/samples/kotlin/output/generated-source

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

This example creates providers that represent locations in the project and build directories through Project.getLayout() with ProjectLayout.getBuildDirectory() and ProjectLayout.getProjectDirectory().

To close the loop, note that a `DirectoryProperty`, or a simple `Directory`, can be turned into a `FileTree` that allows the files and directories contained in the directory to be queried with DirectoryProperty.getAsFileTree() or Directory.getAsFileTree(). Moreover, from a `DirectoryProperty`, or a `Directory`, you can also create `FileCollection` instances containing a set of the files contained in the directory with DirectoryProperty.files(Object…) or Directory.files(Object…).

== Working with task inputs and outputs

Many builds have several tasks connected together, where one task consumes the outputs of another task as an input. To make this work, we would need to configure each task to know where to look for its inputs and place its outputs, make sure that the producing and consuming tasks are configured with the same location, and attach task dependencies between the tasks. This can be cumbersome and brittle if any of these values are configurable by a user or configured by multiple plugins, as task properties need to be configured in the correct order and locations and task dependencies kept in sync as values change.

The `Property` API makes this easier by keeping track of not just the value for a property, which we have seen already, but also the task that produces the value, so that you don't have to specify it as well. As an example consider the following plugin with a producer and consumer task which are wired together:

build.gradle.kts

```kotlin
abstract class Producer : DefaultTask() {
    @get:OutputFile
    abstract val outputFile: RegularFileProperty

    @TaskAction
    fun produce() {
        val message = "Hello, World!"
        val output = outputFile.get().asFile
        output.writeText( message)
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer : DefaultTask() {
    @get:InputFile
    abstract val inputFile: RegularFileProperty

    @TaskAction
    fun consume() {
        val input = inputFile.get().asFile
        val message = input.readText()
        logger.quiet("Read '${message}' from ${input}")
    }
}

val producer = tasks.register<Producer>("producer")
val consumer = tasks.register<Consumer>("consumer")

consumer {
    // Connect the producer task output to the consumer task input
    // Don't need to add a task dependency to the consumer task. This is
automatically added
    inputFile = producer.flatMap { it.outputFile }
}

producer {
    // Set values for the producer lazily
    // Don't need to update the consumer.inputFile property. This is automatically
updated as producer.outputFile changes
    outputFile = layout.buildDirectory.file("file.txt")
}

// Change the build directory.
// Don't need to update producer.outputFile and consumer.inputFile. These are
automatically updated as the build directory changes
layout.buildDirectory = layout.projectDirectory.dir("output")
```

build.gradle

```groovy
abstract class Producer extends DefaultTask {
    @OutputFile
    abstract RegularFileProperty getOutputFile()

    @TaskAction
    void produce() {
        String message = 'Hello, World!'
        def output = outputFile.get().asFile
        output.text = message
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer extends DefaultTask {
    @InputFile
    abstract RegularFileProperty getInputFile()

    @TaskAction
    void consume() {
        def input = inputFile.get().asFile
        def message = input.text
        logger.quiet("Read '${message}' from ${input}")
    }
}

def producer = tasks.register("producer", Producer)
def consumer = tasks.register("consumer", Consumer)

consumer.configure {
    // Connect the producer task output to the consumer task input
    // Don't need to add a task dependency to the consumer task. This is
automatically added
    inputFile = producer.flatMap { it.outputFile }
}

producer.configure {
    // Set values for the producer lazily
    // Don't need to update the consumer.inputFile property. This is automatically
updated as producer.outputFile changes
    outputFile = layout.buildDirectory.file('file.txt')
}

// Change the build directory.
// Don't need to update producer.outputFile and consumer.inputFile. These are
automatically updated as the build directory changes
layout.buildDirectory = layout.projectDirectory.dir('output')
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producer
Wrote 'Hello, World!' to /home/user/gradle/samples/output/file.txt

> Task :consumer
Read 'Hello, World!' from /home/user/gradle/samples/output/file.txt

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producer
Wrote 'Hello, World!' to /home/user/gradle/samples/kotlin/output/file.txt

> Task :consumer
Read 'Hello, World!' from /home/user/gradle/samples/kotlin/output/file.txt

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

In the example above, the task outputs and inputs are connected before any location is defined. The setters can be called at any time before the task is executed and the change will automatically affect all related input and output properties.

Another important thing to note in this example is the absence of any explicit task dependency. Task outputs represented using `Providers` keep track of which task produces their value, and using them as task inputs will implicitly add the correct task dependencies.

Implicit task dependencies also works for input properties that are not files.

build.gradle.kts

```kotlin
abstract class Producer : DefaultTask() {
    @get:OutputFile
    abstract val outputFile: RegularFileProperty

    @TaskAction
    fun produce() {
        val message = "Hello, World!"
        val output = outputFile.get().asFile
        output.writeText( message)
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer : DefaultTask() {
    @get:Input
    abstract val message: Property<String>

    @TaskAction
    fun consume() {
        logger.quiet(message.get())
    }
}

val producer = tasks.register<Producer>("producer") {
    // Set values for the producer lazily
    // Don't need to update the consumer.inputFile property. This is automatically
updated as producer.outputFile changes
    outputFile = layout.buildDirectory.file("file.txt")
}
tasks.register<Consumer>("consumer") {
    // Connect the producer task output to the consumer task input
    // Don't need to add a task dependency to the consumer task. This is
automatically added
    message = producer.flatMap { it.outputFile }.map { it.asFile.readText() }
}
```

build.gradle

```
abstract class Producer extends DefaultTask {
    @OutputFile
    abstract RegularFileProperty getOutputFile()

    @TaskAction
    void produce() {
        String message = 'Hello, World!'
        def output = outputFile.get().asFile
        output.text = message
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer extends DefaultTask {
    @Input
    abstract Property<String> getMessage()

    @TaskAction
    void consume() {
        logger.quiet(message.get())
    }
}

def producer = tasks.register('producer', Producer) {
    // Set values for the producer lazily
    // Don't need to update the consumer.inputFile property. This is automatically
updated as producer.outputFile changes
    outputFile = layout.buildDirectory.file('file.txt')
}
tasks.register('consumer', Consumer) {
    // Connect the producer task output to the consumer task input
    // Don't need to add a task dependency to the consumer task. This is
automatically added
    message = producer.flatMap { it.outputFile }.map { it.asFile.text }
}
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producer
Wrote 'Hello, World!' to /home/user/gradle/samples/build/file.txt

> Task :consumer
Hello, World!

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producer
Wrote 'Hello, World!' to /home/user/gradle/samples/kotlin/build/file.txt

> Task :consumer
Hello, World!

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

== Working with collections

Gradle provides two lazy property types to help configure `Collection` properties. These work exactly like any other `Provider` and, just like file providers, they have additional modeling around them:

- For `List` values the interface is called ListProperty. You can create a new `ListProperty` using ObjectFactory.listProperty(Class) and specifying the element type.

- For `Set` values the interface is called SetProperty. You can create a new `SetProperty` using ObjectFactory.setProperty(Class) and specifying the element type.

This type of property allows you to overwrite the entire collection value with HasMultipleValues.set(Iterable) and HasMultipleValues.set(Provider) or add new elements through the various `add` methods:

- HasMultipleValues.add(T): Add a single element to the collection

- HasMultipleValues.add(Provider): Add a lazily calculated element to the collection

- HasMultipleValues.addAll(Provider): Add a lazily calculated collection of elements to the list

Just like every `Provider`, the collection is calculated when Provider.get() is called. The following

example shows the ListProperty in action:

build.gradle.kts

```
abstract class Producer : DefaultTask() {
    @get:OutputFile
    abstract val outputFile: RegularFileProperty

    @TaskAction
    fun produce() {
        val message = "Hello, World!"
        val output = outputFile.get().asFile
        output.writeText( message)
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer : DefaultTask() {
    @get:InputFiles
    abstract val inputFiles: ListProperty<RegularFile>

    @TaskAction
    fun consume() {
        inputFiles.get().forEach { inputFile ->
            val input = inputFile.asFile
            val message = input.readText()
            logger.quiet("Read '${message}' from ${input}")
        }
    }
}

val producerOne = tasks.register<Producer>("producerOne")
val producerTwo = tasks.register<Producer>("producerTwo")
tasks.register<Consumer>("consumer") {
    // Connect the producer task outputs to the consumer task input
    // Don't need to add task dependencies to the consumer task. These are
automatically added
    inputFiles.add(producerOne.get().outputFile)
    inputFiles.add(producerTwo.get().outputFile)
}

// Set values for the producer tasks lazily
// Don't need to update the consumer.inputFiles property. This is automatically
updated as producer.outputFile changes
producerOne { outputFile = layout.buildDirectory.file("one.txt") }
producerTwo { outputFile = layout.buildDirectory.file("two.txt") }

// Change the build directory.
// Don't need to update the task properties. These are automatically updated as
the build directory changes
layout.buildDirectory = layout.projectDirectory.dir("output")
```

```groovy
abstract class Producer extends DefaultTask {
    @OutputFile
    abstract RegularFileProperty getOutputFile()

    @TaskAction
    void produce() {
        String message = 'Hello, World!'
        def output = outputFile.get().asFile
        output.text = message
        logger.quiet("Wrote '${message}' to ${output}")
    }
}

abstract class Consumer extends DefaultTask {
    @InputFiles
    abstract ListProperty<RegularFile> getInputFiles()

    @TaskAction
    void consume() {
        inputFiles.get().each { inputFile ->
            def input = inputFile.asFile
            def message = input.text
            logger.quiet("Read '${message}' from ${input}")
        }
    }
}

def producerOne = tasks.register('producerOne', Producer)
def producerTwo = tasks.register('producerTwo', Producer)
tasks.register('consumer', Consumer) {
    // Connect the producer task outputs to the consumer task input
    // Don't need to add task dependencies to the consumer task. These are
automatically added
    inputFiles.add(producerOne.get().outputFile)
    inputFiles.add(producerTwo.get().outputFile)
}

// Set values for the producer tasks lazily
// Don't need to update the consumer.inputFiles property. This is automatically
updated as producer.outputFile changes
producerOne.configure { outputFile = layout.buildDirectory.file('one.txt') }
producerTwo.configure { outputFile = layout.buildDirectory.file('two.txt') }

// Change the build directory.
// Don't need to update the task properties. These are automatically updated as
the build directory changes
layout.buildDirectory = layout.projectDirectory.dir('output')
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producerOne
Wrote 'Hello, World!' to /home/user/gradle/samples/output/one.txt

> Task :producerTwo
Wrote 'Hello, World!' to /home/user/gradle/samples/output/two.txt

> Task :consumer
Read 'Hello, World!' from /home/user/gradle/samples/output/one.txt
Read 'Hello, World!' from /home/user/gradle/samples/output/two.txt

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

Output of `gradle consumer`

```
$ gradle consumer

> Task :producerOne
Wrote 'Hello, World!' to /home/user/gradle/samples/kotlin/output/one.txt

> Task :producerTwo
Wrote 'Hello, World!' to /home/user/gradle/samples/kotlin/output/two.txt

> Task :consumer
Read 'Hello, World!' from /home/user/gradle/samples/kotlin/output/one.txt
Read 'Hello, World!' from /home/user/gradle/samples/kotlin/output/two.txt

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

== Working with maps

Gradle provides a lazy MapProperty type to allow Map values to be configured. You can create a MapProperty instance using ObjectFactory.mapProperty(Class, Class).

Similar to other property types, a MapProperty has a set() method that you can use to specify the value for the property. There are some additional methods to allow entries with lazy values to be added to the map.

build.gradle.kts

```kotlin
abstract class Generator: DefaultTask() {
    @get:Input
    abstract val properties: MapProperty<String, Int>

    @TaskAction
    fun generate() {
        properties.get().forEach { entry ->
            logger.quiet("${entry.key} = ${entry.value}")
        }
    }
}

// Some values to be configured later
var b = 0
var c = 0

tasks.register<Generator>("generate") {
    properties.put("a", 1)
    // Values have not been configured yet
    properties.put("b", providers.provider { b })
    properties.putAll(providers.provider { mapOf("c" to c, "d" to c + 1) })
}

// Configure the values. There is no need to reconfigure the task
b = 2
c = 3
```

build.gradle

```groovy
abstract class Generator extends DefaultTask {
    @Input
    abstract MapProperty<String, Integer> getProperties()

    @TaskAction
    void generate() {
        properties.get().each { key, value ->
            logger.quiet("${key} = ${value}")
        }
    }
}

// Some values to be configured later
def b = 0
def c = 0

tasks.register('generate', Generator) {
    properties.put("a", 1)
    // Values have not been configured yet
    properties.put("b", providers.provider { b })
    properties.putAll(providers.provider { [c: c, d: c + 1] })
}

// Configure the values. There is no need to reconfigure the task
b = 2
c = 3
```

```
$ gradle generate

> Task :generate
a = 1
b = 2
c = 3
d = 4

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

== Applying a convention to a property

Often you want to apply some *convention,* or default value, to a property to be used if no value has been configured for the property. You can use the `convention()` method for this. This method accepts either a value or a `Provider` and this will be used as the value until some other value is configured.

build.gradle.kts

```
tasks.register("show") {
    val property = objects.property(String::class)

    // Set a convention
    property.convention("convention 1")

    println("value = " + property.get())

    // Can replace the convention
    property.convention("convention 2")
    println("value = " + property.get())

    property.set("explicit value")

    // Once a value is set, the convention is ignored
    property.convention("ignored convention")

    doLast {
        println("value = " + property.get())
    }
}
```

build.gradle

```
tasks.register("show") {
    def property = objects.property(String)

    // Set a convention
    property.convention("convention 1")

    println("value = " + property.get())

    // Can replace the convention
    property.convention("convention 2")
    println("value = " + property.get())

    property.set("explicit value")

    // Once a value is set, the convention is ignored
    property.convention("ignored convention")

    doLast {
        println("value = " + property.get())
    }
}
```

```
$ gradle show
value = convention 1
value = convention 2

> Task :show
value = explicit value

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

== Making a property unmodifiable

Most properties of a task or project are intended to be configured by plugins or build scripts and then the resulting value used to do something useful. For example, a property that specifies the output directory for a compilation task may start off with a value specified by a plugin, then a build script might change the value to some custom location, then this value is used by the task when it runs. However, once the task starts to run, we want to prevent any further change to the property. This way we avoid errors that result from different consumers, such as the task action or Gradle's up-to-date checks or build caching or other tasks, using different values for the property.

Lazy properties provide several methods that you can use to disallow changes to their value once the value has been configured. The finalizeValue() method calculates the *final* value for the property and prevents further changes to the property. When the value of the property comes from a `Provider`, the provider is queried for its current value and the result becomes the final value for the property. This final value replaces the provider and the property no longer tracks the value of the provider. Calling this method also makes a property instance unmodifiable and any further attempts to change the value of the property will fail. Gradle automatically makes the properties of a task final when the task starts execution.

The finalizeValueOnRead() method is similar, except that the property's final value is not calculated until the value of the property is queried. In other words, this method calculates the final value lazily as required, whereas `finalizeValue()` calculates the final value eagerly. This method can be used when the value may be expensive to calculate or may not have been configured yet, but you also want to ensure that all consumers of the property see the same value when they query the value.

== Guidelines

This section will introduce guidelines to be successful with the Provider API. To see those guidelines in action, have a look at gradle-site-plugin, a Gradle plugin demonstrating established techniques and practices for plugin development.

- The Property and Provider types have all of the overloads you need to query or configure a value. For this reason, you should follow the following guidelines:
  - For configurable properties, expose the Property directly through a single getter.

- For non-configurable properties, expose an Provider directly through a single getter.
- Avoid simplifying calls like `obj.getProperty().get()` and `obj.getProperty().set(T)` in your code by introducing additional getters and setters.
- When migrating your plugin to use providers, follow these guidelines:
  - If it's a new property, expose it as a Property or Provider using a single getter.
  - If it's incubating, change it to use a Property or Provider using a single getter.
  - If it's a stable property, add a new Property or Provider and deprecate the old one. You should wire the old getter/setters into the new property as appropriate.

== Future development

Going forward, new properties will use the Provider API. The Groovy Gradle DSL adds convenience methods to make the use of Providers mostly transparent in build scripts. Existing tasks will have their existing "raw" properties replaced by Providers as needed and in a backwards compatible way. New tasks will be designed with the Provider API.

== Provider Files API Reference

Use these types for *read-only* values:

Provider<RegularFile>

File on disk

Factories

- Provider.map(Transformer).
- Provider.flatMap(Transformer).
- DirectoryProperty.file(String)

Provider<Directory>

Directory on disk

Factories

- Provider.map(Transformer).
- Provider.flatMap(Transformer).
- DirectoryProperty.dir(String)

FileCollection

Unstructured collection of files

Factories

- Project.files(Object[])
- ProjectLayout.files(Object...)
- DirectoryProperty.files(Object...)

FileTree

Hierarchy of files

Factories

- Project.fileTree(Object) will produce a ConfigurableFileTree, or you can use Project.zipTree(Object) and Project.tarTree(Object)
- DirectoryProperty.getAsFileTree()

== Property Files API Reference

Use these types for *mutable* values:

RegularFileProperty

File on disk

Factories

- ObjectFactory.fileProperty()

DirectoryProperty

Directory on disk

Factories

- ObjectFactory.directoryProperty()

ConfigurableFileCollection

Unstructured collection of files

Factories

- ObjectFactory.fileCollection()

ConfigurableFileTree

Hierarchy of files

Factories

- ObjectFactory.fileTree()

SourceDirectorySet

Hierarchy of source directories

Factories

- ObjectFactory.sourceDirectorySet(String, String)

== Lazy Collections API Reference

Use these types for *mutable* values:

ListProperty<T>

a property whose value is `List<T>`

Factories

- ObjectFactory.listProperty(Class)

SetProperty<T>

a property whose value is Set<T>

Factories

- ObjectFactory.setProperty(Class)

Lazy Objects API Reference

Use these types for *read only* values:

Provider<T>

a property whose value is an instance of T

Factories

- Provider.map(Transformer).

- Provider.flatMap(Transformer).

- ProviderFactory.provider(Callable). Always prefer one of the other factory methods over this method.

Use these types for *mutable* values:

Property<T>

a property whose value is an instance of T

Factories

- ObjectFactory.property(Class)

Developing Parallel Tasks using the Worker API

The Worker API provides the ability to break up the execution of a task action into discrete units of work and then to execute that work concurrently and asynchronously. This allows Gradle to fully utilize the resources available and complete builds faster. This section will walk you through the process of converting an existing custom task to use the Worker API.

This section assumes that you understand the basics of writing Gradle custom tasks. For more information on that topic, consult the section on custom tasks.

You'll start by creating a custom task class that generates MD5 hashes for a configurable set of files. Then, you'll convert this custom task to use the Worker API. Then we'll explore running the task with different levels of isolation. In the process, you'll learn about the basics of the Worker API and the capabilities it provides.

Create a custom task class

First, you'll need to create a custom task that generates MD5 hashes of a configurable set of files.

In a new directory, create a `buildSrc/build.gradle(.kts)` file.

buildSrc/build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    implementation("commons-io:commons-io:2.5")
    implementation("commons-codec:commons-codec:1.9")  ①
}
```

buildSrc/build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    implementation 'commons-io:commons-io:2.5'
    implementation 'commons-codec:commons-codec:1.9'  ①
}
```

① Your custom task class will use Apache Commons Codec to generate MD5 hashes.

| TIP | If you are not familiar with `buildSrc`, this is a special directory that allows you to define and build custom classes that should be available for use in your build script. See the section on organizing build logic for further information. |

Now, create a custom task class in your `buildSrc/src/main/java` directory. You should name this class `CreateMD5`.

buildSrc/src/main/java/CreateMD5.java

```java
import org.apache.commons.codec.digest.DigestUtils;
import org.apache.commons.io.FileUtils;
import org.gradle.api.file.DirectoryProperty;
import org.gradle.api.file.RegularFile;
import org.gradle.api.provider.Provider;
import org.gradle.api.tasks.OutputDirectory;
import org.gradle.api.tasks.SourceTask;
import org.gradle.api.tasks.TaskAction;
import org.gradle.workers.WorkerExecutor;

import java.io.File;
import java.io.FileInputStream;
import java.io.InputStream;

abstract public class CreateMD5 extends SourceTask { ①

    @OutputDirectory
    abstract public DirectoryProperty getDestinationDirectory(); ②

    @TaskAction
    public void createHashes() {
        for (File sourceFile : getSource().getFiles()) { ③
            try {
                InputStream stream = new FileInputStream(sourceFile);
                System.out.println("Generating MD5 for " + sourceFile.getName() +
"...");
                // Artificially make this task slower.
                Thread.sleep(3000); ④
                Provider<RegularFile> md5File = getDestinationDirectory().file
(sourceFile.getName() + ".md5");   ⑤
                FileUtils.writeStringToFile(md5File.get().getAsFile(),
DigestUtils.md5Hex(stream), (String) null);
            } catch (Exception e) {
                throw new RuntimeException(e);
            }
        }
    }
}
```

① **SourceTask** is a convenience type for tasks that operate on a set of source files.

② The output of the task will go into a configured directory.

③ The task iterates over all of the files defined as "source files" and creates an MD5 hash of each.

④ Insert an artificial sleep to simulate hashing a large file (the sample files won't be that large).

⑤ The MD5 hash of each file is written to the output directory into a file of the same name with an "md5" extension.

Next, create a `build.gradle(.kts)` that registers your new `CreateMD5` task.

build.gradle.kts

```
plugins { id("base") } ①

tasks.register<CreateMD5>("md5") {
    destinationDirectory = project.layout.buildDirectory.dir("md5") ②
    source(project.layout.projectDirectory.file("src")) ③
}
```

build.gradle

```
plugins { id 'base' } ①

tasks.register("md5", CreateMD5) {
    destinationDirectory = project.layout.buildDirectory.dir("md5") ②
    source(project.layout.projectDirectory.file('src')) ③
}
```

① Apply the `base` plugin so that you'll have a `clean` task to use to remove the output.

② MD5 hash files will be written to `build/md5`.

③ This task will generate MD5 hash files for every file in the `src` directory.

Now, you'll need some source to generate MD5 hashes from. Create 3 files in the src directory:

src/einstein.txt

```
Intellectual growth should commence at birth and cease only at death.
```

src/feynman.txt

```
I was born not knowing and have had only a little time to change that here and
there.
```

src/oppenheimer.txt

```
No man should escape our universities without knowing how little he knows.
```

At this point, you can give your task a try:

```
$ gradle md5
```

You should see output similar to:

```
> Task :md5
Generating MD5 for einstein.txt...
Generating MD5 for feynman.txt...
Generating MD5 for oppenheimer.txt...

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

In the `build/md5` directory, you should now see corresponding files with an `md5` extension containing MD5 hashes of the files from the `src` directory. Notice that the task takes at least 9 seconds to run because it hashes each file one at a time (i.e. 3 files at ~3 seconds a piece).

== Converting to the Worker API

Although this task processes each file in sequence, the processing of each file is independent of any other file. It would be really nice if this work was done in parallel and could take advantage of multiple processors. This is where the Worker API can help.

First, you'll need to define an interface that represents the parameters of each unit of work and extends `org.gradle.workers.WorkParameters`. For the generation of MD5 hash files, the unit

of work will require two parameters: the file to be hashed and the file to write the hash to. There is no need to create a concrete implementation, though, because Gradle will generate one for us at runtime.

buildSrc/src/main/java/MD5WorkParameters.java

```java
import org.gradle.api.file.RegularFileProperty;
import org.gradle.workers.WorkParameters;

public interface MD5WorkParameters extends WorkParameters {
    RegularFileProperty getSourceFile(); ①
    RegularFileProperty getMD5File();
}
```

① Use `Property` objects to represent the source and MD5 hash files.

Second, you'll need to refactor the part of your custom task that does the work for each individual file into a separate class. This class is your "unit of work" implementation and it should be an abstract class that extends `org.gradle.workers.WorkAction`.

buildSrc/src/main/java/GenerateMD5.java

```java
import org.apache.commons.codec.digest.DigestUtils;
import org.apache.commons.io.FileUtils;
import org.gradle.workers.WorkAction;

import java.io.File;
import java.io.FileInputStream;
import java.io.InputStream;

public abstract class GenerateMD5 implements WorkAction<MD5WorkParameters> { ①
    @Override
    public void execute() {
        try {
            File sourceFile = getParameters().getSourceFile().getAsFile().get();
            File md5File = getParameters().getMD5File().getAsFile().get();
            InputStream stream = new FileInputStream(sourceFile);
            System.out.println("Generating MD5 for " + sourceFile.getName() + "
...");
            // Artificially make this task slower.
            Thread.sleep(3000);
            FileUtils.writeStringToFile(md5File, DigestUtils.md5Hex(stream),
(String) null);
        } catch (Exception e) {
            throw new RuntimeException(e);
        }
    }
}
```

① Do not implement the `getParameters()` method - Gradle will inject this at runtime.

Now, you should change your custom task class to submit work to the WorkerExecutor instead of doing the work itself.

buildSrc/src/main/java/CreateMD5.java

```java
import org.gradle.api.Action;
import org.gradle.api.file.RegularFile;
import org.gradle.api.provider.Provider;
import org.gradle.api.tasks.*;
import org.gradle.workers.*;
import org.gradle.api.file.DirectoryProperty;

import javax.inject.Inject;
import java.io.File;

abstract public class CreateMD5 extends SourceTask {

    @OutputDirectory
    abstract public DirectoryProperty getDestinationDirectory();

    @Inject
    abstract public WorkerExecutor getWorkerExecutor(); ①

    @TaskAction
    public void createHashes() {
        WorkQueue workQueue = getWorkerExecutor().noIsolation(); ②

        for (File sourceFile : getSource().getFiles()) {
            Provider<RegularFile> md5File = getDestinationDirectory().file
(sourceFile.getName() + ".md5");
            workQueue.submit(GenerateMD5.class, parameters -> { ③
                parameters.getSourceFile().set(sourceFile);
                parameters.getMD5File().set(md5File);
            });
        }
    }
}
```

① You'll need to have the WorkerExecutor service in order to submit your work. Create a abstract getter methods annotated `javax.inject.Inject` and Gradle will inject the service at runtime when the task is created.

② Before submitting work, you'll need to get a `WorkQueue` object with the desired isolation mode. We'll talk more about isolation modes later.

③ When submitting the unit of work, specify the unit of work implementation, in this case `GenerateMD5` and configure its parameters.

At this point, you should be able to try your task again.

```
$ gradle clean md5

> Task :md5
Generating MD5 for einstein.txt...
Generating MD5 for feynman.txt...
Generating MD5 for oppenheimer.txt...

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

The results should look the same as before, although the MD5 hash files may be generated in a different order due to the fact that the units of work are executed in parallel. One thing you should notice, however, is that the task runs much faster. This is because the Worker API executes the MD5 calculation for each file in parallel rather than in sequence.

== Changing the isolation mode

The isolation mode controls how strongly Gradle will isolate items of work from each other as well as from the rest of the Gradle runtime. There are three methods on `WorkerExecutor` that control this: `noIsolation()`, `classLoaderIsolation()` and `processIsolation()`. The `noIsolation()` mode is the lowest level of isolation and will prevent a unit of work from changing the project state. This is the fastest isolation mode because it requires the least overhead to set up the work item to execute, so you'll probably want to use this for simple cases. However, it will use a single shared classloader for all units of work. This means that each unit of work can potentially affect one another through static class state. It also means that every unit of work uses the same version of libraries that are on the buildscript classpath. If you wanted the user to be able to configure the task to run with a different (but compatible) version of the Apache Commons Codec library, you would need to use a different isolation mode.

First, you'll want to change the dependency in `buildSrc/build.gradle` to be `compileOnly`. This tells Gradle that it should use this dependency when building the classes, but should not put it on the build script classpath.

buildSrc/build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    implementation("commons-io:commons-io:2.5")
    compileOnly("commons-codec:commons-codec:1.9")
}
```

buildSrc/build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    implementation 'commons-io:commons-io:2.5'
    compileOnly 'commons-codec:commons-codec:1.9'
}
```

Next, you'll want to change the `CreateMD5` task to allow the user to configure the version of the codec library that they want to use. It'll resolve the appropriate version of the library at runtime and configure the workers to use this version. The `classLoaderIsolation()` method tells Gradle to run this work in a thread with an isolated classloader.

buildSrc/src/main/java/CreateMD5.java

```java
import org.gradle.api.Action;
import org.gradle.api.file.ConfigurableFileCollection;
import org.gradle.api.file.DirectoryProperty;
import org.gradle.api.file.RegularFile;
import org.gradle.api.provider.Provider;
import org.gradle.api.tasks.*;
import org.gradle.process.JavaForkOptions;
import org.gradle.workers.*;

import javax.inject.Inject;
import java.io.File;
import java.util.Set;

abstract public class CreateMD5 extends SourceTask {

    @InputFiles
    abstract public ConfigurableFileCollection getCodecClasspath(); ①

    @OutputDirectory
    abstract public DirectoryProperty getDestinationDirectory();

    @Inject
    abstract public WorkerExecutor getWorkerExecutor();

    @TaskAction
    public void createHashes() {
        WorkQueue workQueue = getWorkerExecutor().classLoaderIsolation(workerSpec
 -> {
            workerSpec.getClasspath().from(getCodecClasspath()); ②
        });

        for (File sourceFile : getSource().getFiles()) {
            Provider<RegularFile> md5File = getDestinationDirectory().file
(sourceFile.getName() + ".md5");
            workQueue.submit(GenerateMD5.class, parameters -> {
                parameters.getSourceFile().set(sourceFile);
                parameters.getMD5File().set(md5File);
            });
        }
    }
}
```

① Expose an input property for the codec library classpath.

② Configure the classpath on the ClassLoaderWorkerSpec when creating the work queue.

Next, you'll need to configure your build so that it has a repository to look up the codec version at task execution time. We'll also create a dependency to resolve our codec library from this repository.

build.gradle.kts

```kotlin
plugins { id("base") }

repositories {
    mavenCentral() ①
}

val codec = configurations.create("codec") { ②
    attributes {
        attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage.JAVA_RUNTIME))
    }
    isVisible = false
    isCanBeConsumed = false
}

dependencies {
    codec("commons-codec:commons-codec:1.10") ③
}

tasks.register<CreateMD5>("md5") {
    codecClasspath.from(codec) ④
    destinationDirectory = project.layout.buildDirectory.dir("md5")
    source(project.layout.projectDirectory.file("src"))
}
```

build.gradle

```
plugins { id 'base' }

repositories {
    mavenCentral() ①
}

configurations.create('codec') { ②
    attributes {
        attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage, Usage.JAVA_RUNTIME))
    }
    visible = false
    canBeConsumed = false
}

dependencies {
    codec 'commons-codec:commons-codec:1.10' ③
}

tasks.register('md5', CreateMD5) {
    codecClasspath.from(configurations.codec) ④
    destinationDirectory = project.layout.buildDirectory.dir('md5')
    source(project.layout.projectDirectory.file('src'))
}
```

① Add a repository to resolve the codec library - this can be a different repository than the one used to build the `CreateMD5` task class.

② Add a *configuration* to resolve our codec library version.

③ Configure an alternate, compatible version of [Apache Commons Codec](#).

④ Configure the `md5` task to use the configuration as its classpath. Note that the configuration will not be resolved until the task is actually executed.

Now, if you run your task, it should work as expected using the configured version of the codec library:

```
$ gradle clean md5

> Task :md5
Generating MD5 for einstein.txt...
Generating MD5 for feynman.txt...
Generating MD5 for oppenheimer.txt...

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

== Creating a Worker Daemon

Sometimes it is desirable to create even further isolation when executing items of work. For instance, external libraries may rely on certain system properties to be set which may conflict between work items. Or a library might not be compatible with the version of JDK that Gradle is running with and may need to be run with a different version. The Worker API can accommodate this using the `processIsolation()` method that causes the work to execute in a separate "worker daemon". These worker daemon processes will persist across builds and can be reused during subsequent builds. If system resources get low, however, Gradle will stop any unused worker daemons.

To utilize a worker daemon, simply use the `processIsolation()` method when creating the `WorkQueue`. You may also want to configure custom settings for the new process.

buildSrc/src/main/java/CreateMD5.java

```java
import org.gradle.api.Action;
import org.gradle.api.file.ConfigurableFileCollection;
import org.gradle.api.file.DirectoryProperty;
import org.gradle.api.file.RegularFile;
import org.gradle.api.provider.Provider;
import org.gradle.api.tasks.*;
import org.gradle.process.JavaForkOptions;
import org.gradle.workers.*;

import javax.inject.Inject;
import java.io.File;
import java.util.Set;

abstract public class CreateMD5 extends SourceTask {

    @InputFiles
    abstract public ConfigurableFileCollection getCodecClasspath(); ①

    @OutputDirectory
    abstract public DirectoryProperty getDestinationDirectory();

    @Inject
    abstract public WorkerExecutor getWorkerExecutor();

    @TaskAction
    public void createHashes() {
①
        WorkQueue workQueue = getWorkerExecutor().processIsolation(workerSpec -> {
            workerSpec.getClasspath().from(getCodecClasspath());
            workerSpec.forkOptions(options -> {
                options.setMaxHeapSize("64m"); ②
            });
        });

        for (File sourceFile : getSource().getFiles()) {
            Provider<RegularFile> md5File = getDestinationDirectory().file
(sourceFile.getName() + ".md5");
            workQueue.submit(GenerateMD5.class, parameters -> {
                parameters.getSourceFile().set(sourceFile);
                parameters.getMD5File().set(md5File);
            });
        }
    }
}
```

① Change the isolation mode to `PROCESS`.

② Set up the JavaForkOptions for the new process.

Now, you should be able to run your task, and it will work as expected but using worker daemons instead:

```
$ gradle clean md5

> Task :md5
Generating MD5 for einstein.txt...
Generating MD5 for feynman.txt...
Generating MD5 for oppenheimer.txt...

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

Note that the execution time may be somewhat high. This is because Gradle has to start a new process for each worker daemon, which is expensive. However, if you run your task again, you'll see that it runs much faster. This is because the worker daemon(s) started during the initial build have persisted and are available for use immediately during subsequent builds.

```
$ gradle clean md5

> Task :md5
Generating MD5 for einstein.txt...
Generating MD5 for feynman.txt...
Generating MD5 for oppenheimer.txt...

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

== DEVELOPING GRADLE PLUGINS

= Developing Custom Gradle Plugins

A Gradle plugin packages up reusable pieces of build logic, which can be used across many different projects and builds. Gradle allows you to implement your own plugins, so you can reuse your build logic, and share it with others.

You can implement a Gradle plugin in any language you like, provided the implementation ends up compiled as JVM bytecode. In our examples, we are going to use Java as the implementation language for standalone plugin project and Groovy or Kotlin in the buildscript plugin examples. In general, a plugin implemented using Java or Kotlin, which are statically typed, will perform better than the same plugin implemented using Groovy.

== Packaging a plugin

There are several places where you can put the source for the plugin.

Build script

    You can include the source for the plugin directly in the build script. This has the benefit

that the plugin is automatically compiled and included in the classpath of the build script without you having to do anything. However, the plugin is not visible outside the build script, and so you cannot reuse the plugin outside the build script it is defined in.

`buildSrc` project

You can put the source for the plugin in the `rootProjectDir/buildSrc/src/main/java` directory (or `rootProjectDir/buildSrc/src/main/groovy` or `rootProjectDir/buildSrc/src/main/kotlin` depending on which language you prefer). Gradle will take care of compiling and testing the plugin and making it available on the classpath of the build script. The plugin is visible to every build script used by the build. However, it is not visible outside the build, and so you cannot reuse the plugin outside the build it is defined in.

See Organizing Gradle Projects for more details about the `buildSrc` project.

Standalone project

You can create a separate project for your plugin. This project produces and publishes a JAR which you can then use in multiple builds and share with others. Generally, this JAR might include some plugins, or bundle several related task classes into a single library. Or some combination of the two.

In our examples, we will start with the plugin in the build script, to keep things simple. Then we will look at creating a standalone project.

== Writing a simple plugin

To create a Gradle plugin, you need to write a class that implements the Plugin interface. When the plugin is applied to a project, Gradle creates an instance of the plugin class and calls the instance's Plugin.apply() method. The project object is passed as a parameter, which the plugin can use to configure the project however it needs to. The following sample contains a greeting plugin, which adds a `hello` task to the project.

build.gradle.kts

```
class GreetingPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        project.task("hello") {
            doLast {
                println("Hello from the GreetingPlugin")
            }
        }
    }
}

// Apply the plugin
apply<GreetingPlugin>()
```

```groovy
class GreetingPlugin implements Plugin<Project> {
    void apply(Project project) {
        project.task('hello') {
            doLast {
                println 'Hello from the GreetingPlugin'
            }
        }
    }
}

// Apply the plugin
apply plugin: GreetingPlugin
```

Output of `gradle -q hello`

```
> gradle -q hello
Hello from the GreetingPlugin
```

One thing to note is that a new instance of a plugin is created for each project it is applied to. Also note that the Plugin class is a generic type. This example has it receiving the Project type as a type parameter. A plugin can instead receive a parameter of type Settings, in which case the plugin can be applied in a settings script, or a parameter of type Gradle, in which case the plugin can be applied in an initialization script.

== Making the plugin configurable

Most plugins offer some configuration options for build scripts and other plugins to use to customize how the plugin works. Plugins do this using *extension objects*. The Gradle Project has an associated ExtensionContainer object that contains all the settings and properties for the plugins that have been applied to the project. You can provide configuration for your plugin by adding an extension object to this container. An extension object is simply an object with Java Bean properties that represent the configuration.

Let's add a simple extension object to the project. Here we add a `greeting` extension object to the project, which allows you to configure the greeting.

build.gradle.kts

```kotlin
interface GreetingPluginExtension {
    val message: Property<String>
}

class GreetingPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        // Add the 'greeting' extension object
        val extension =
project.extensions.create<GreetingPluginExtension>("greeting")
        extension.message.convention("Hello from GreetingPlugin")
        // Add a task that uses configuration from the extension object
        project.task("hello") {
            doLast {
                println(extension.message.get())
            }
        }
    }
}

apply<GreetingPlugin>()

// Configure the extension
the<GreetingPluginExtension>().message = "Hi from Gradle"
```

```
interface GreetingPluginExtension {
    Property<String> getMessage()
}

class GreetingPlugin implements Plugin<Project> {
    void apply(Project project) {
        // Add the 'greeting' extension object
        def extension = project.extensions.create('greeting',
GreetingPluginExtension)
        extension.message.convention('Hello from GreetingPlugin')
        // Add a task that uses configuration from the extension object
        project.task('hello') {
            doLast {
                println extension.message.get()
            }
        }
    }
}

apply plugin: GreetingPlugin

// Configure the extension
greeting.message = 'Hi from Gradle'
```

Output of `gradle -q hello`

```
> gradle -q hello
Hi from Gradle
```

In this example, `GreetingPluginExtension` is an object with a property called `message`. The extension object is added to the project with the name `greeting`. This object then becomes available as a project property with the same name as the extension object.

Oftentimes, you have several related properties you need to specify on a single plugin. Gradle adds a configuration block for each extension object, so you can group settings together. The following example shows you how this works.

build.gradle.kts

```kotlin
interface GreetingPluginExtension {
    val message: Property<String>
    val greeter: Property<String>
}

class GreetingPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        val extension =
project.extensions.create<GreetingPluginExtension>("greeting")
        project.task("hello") {
            doLast {
                println("${extension.message.get()} from
${extension.greeter.get()}")
            }
        }
    }
}

apply<GreetingPlugin>()

// Configure the extension using a DSL block
configure<GreetingPluginExtension> {
    message = "Hi"
    greeter = "Gradle"
}
```

build.gradle

```
interface GreetingPluginExtension {
    Property<String> getMessage()
    Property<String> getGreeter()
}

class GreetingPlugin implements Plugin<Project> {
    void apply(Project project) {
        def extension = project.extensions.create('greeting',
GreetingPluginExtension)
        project.task('hello') {
            doLast {
                println "${extension.message.get()} from ${extension.greeter.get(
)}"
            }
        }
    }
}

apply plugin: GreetingPlugin

// Configure the extension using a DSL block
greeting {
    message = 'Hi'
    greeter = 'Gradle'
}
```

Output of `gradle -q hello`

```
> gradle -q hello
Hi from Gradle
```

In this example, several settings can be grouped together within the `configure<GreetingPluginExtension>` block. The type used on the `configure` function in the build script (`GreetingPluginExtension`) needs to match the extension type. Then, when the block is executed, the receiver of the block is the extension.

In this example, several settings can be grouped together within the `greeting` closure. The name of the closure block in the build script (`greeting`) needs to match the extension object name. Then, when the closure is executed, the fields on the extension object will be mapped to the variables within the closure based on the standard Groovy closure delegate feature.

In this way, using an extension object *extends* the Gradle DSL to add a project property and DSL block for the plugin. And because an extension object is simply a regular object, you can provide your own DSL nested inside the plugin block by adding properties and methods to the extension object.

=== Developing project extensions

You can find out more about implementing project extensions in Developing Custom Gradle Types.

== Working with files in custom tasks and plugins

When developing custom tasks and plugins, it's a good idea to be very flexible when accepting input configuration for file locations. You should use Gradle's managed properties and `project.layout` to select file or directory locations. By this, the actual location will only be resolved when the file is needed and can be reconfigured at any time during build configuration.

build.gradle.kts

```kotlin
abstract class GreetingToFileTask : DefaultTask() {

    @get:OutputFile
    abstract val destination: RegularFileProperty

    @TaskAction
    fun greet() {
        val file = destination.get().asFile
        file.parentFile.mkdirs()
        file.writeText("Hello!")
    }
}

val greetingFile = objects.fileProperty()

tasks.register<GreetingToFileTask>("greet") {
    destination = greetingFile
}

tasks.register("sayGreeting") {
    dependsOn("greet")
    val greetingFile = greetingFile
    doLast {
        val file = greetingFile.get().asFile
        println("${file.readText()} (file: ${file.name})")
    }
}

greetingFile = layout.buildDirectory.file("hello.txt")
```

build.gradle

```
abstract class GreetingToFileTask extends DefaultTask {

    @OutputFile
    abstract RegularFileProperty getDestination()

    @TaskAction
    def greet() {
        def file = getDestination().get().asFile
        file.parentFile.mkdirs()
        file.write 'Hello!'
    }
}

def greetingFile = objects.fileProperty()

tasks.register('greet', GreetingToFileTask) {
    destination = greetingFile
}

tasks.register('sayGreeting') {
    dependsOn greet
    doLast {
        def file = greetingFile.get().asFile
        println "${file.text} (file: ${file.name})"
    }
}

greetingFile = layout.buildDirectory.file('hello.txt')
```

```
> gradle -q sayGreeting
Hello! (file: hello.txt)
```

In this example, we configure the `greet` task `destination` property as a closure/provider, which is evaluated with the Project.file(java.lang.Object) method to turn the return value of the closure/provider into a `File` object at the last minute. You will notice that in the example above we specify the `greetingFile` property value after we have configured to use it for the task. This kind of lazy evaluation is a key benefit of accepting any value when setting a file property, then resolving that value when reading the property.

== Mapping extension properties to task properties

Capturing user input from the build script through an extension and mapping it to input/output properties of a custom task is a useful pattern. The build script author interacts only with the DSL defined by the extension. The imperative logic is hidden in the plugin implementation.

Gradle provides some types that you can use in task implementations and extensions to help you with this. Refer to Lazy Configuration for more information.

== A standalone project

Now we will move our plugin to a standalone project so that we can publish it and share it with others. This project is simply a Java project that produces a JAR containing the plugin classes. The easiest and the recommended way to package and publish a plugin is to use the Java Gradle Plugin Development Plugin. This plugin will automatically apply the Java Plugin, add the `gradleApi()` dependency to the api configuration, generate the required plugin descriptors in the resulting JAR file and configure the Plugin Marker Artifact to be used when publishing. Here is a simple build script for the project.

build.gradle.kts

```kotlin
plugins {
    `java-gradle-plugin`
}

gradlePlugin {
    plugins {
        create("simplePlugin") {
            id = "org.example.greeting"
            implementationClass = "org.example.GreetingPlugin"
        }
    }
}
```

build.gradle

```
plugins {
    id 'java-gradle-plugin'
}

gradlePlugin {
    plugins {
        simplePlugin {
            id = 'org.example.greeting'
            implementationClass = 'org.example.GreetingPlugin'
        }
    }
}
```

Creating a plugin id

Plugin ids are fully qualified in a manner similar to Java packages (i.e. a reverse domain name). This helps to avoid collisions and provides a way to group plugins with similar ownership.

Your plugin id should be a combination of components that reflect namespace (a reasonable pointer to you or your organization) and the name of the plugin it provides. For example if you had a Github account named "foo" and your plugin was named "bar", a suitable plugin id might be `com.github.foo.bar`. Similarly, if the plugin was developed at the baz organization, the plugin id might be `org.baz.bar`.

Plugin ids should conform to the following:

- May contain any alphanumeric character, '.', and '-'.
- Must contain at least one '.' character separating the namespace from the name of the plugin.
- Conventionally use a lowercase reverse domain name convention for the namespace.
- Conventionally use only lowercase characters in the name.
- `org.gradle` and `com.gradleware` namespaces may not be used.
- Cannot start or end with a '.' character.
- Cannot contain consecutive '.' characters (i.e. '..').

Although there are conventional similarities between plugin ids and package names, package names are generally more detailed than is necessary for a plugin id. For instance, it might seem reasonable to add "gradle" as a component of your plugin id, but since plugin ids are only used for Gradle plugins, this would be superfluous. Generally, a namespace that identifies ownership and a name are all that are needed for a good plugin id.

Publishing your plugin

If you are publishing your plugin internally for use within your organization, you can publish it like any other code artifact. See the Ivy and Maven chapters on publishing artifacts.

If you are interested in publishing your plugin to be used by the wider Gradle community, you can publish it to the Gradle Plugin Portal. This site provides the ability to search for and gather information about plugins contributed by the Gradle community. Please refer to the corresponding section on how to make your plugin available on this site.

Using your plugin in another project

To use a plugin in a build script, you need to configure the repository in `pluginManagement {}` block of the project's settings file. The following example shows how you might do this when the plugin has been published to a local repository:

settings.gradle.kts

```
pluginManagement {
    repositories {
        maven {
            url = uri(repoLocation)
        }
    }
}
```

build.gradle.kts

```
plugins {
    id("org.example.greeting") version "1.0-SNAPSHOT"
}
```

settings.gradle

```
pluginManagement {
    repositories {
        maven {
            url = uri(repoLocation)
        }
    }
}
```

build.gradle

```
plugins {
    id 'org.example.greeting' version '1.0-SNAPSHOT'
}
```

==== Note for plugins published without `java-gradle-plugin` If your plugin was published without using the Java Gradle Plugin Development Plugin, the publication will be lacking Plugin Marker Artifact, which is needed for plugins DSL to locate the plugin. In this case, the recommended way to resolve the plugin in another project is to add a `resolutionStrategy` section to the `pluginManagement {}` block of the project's settings file as shown below.

settings.gradle.kts

```
resolutionStrategy {
    eachPlugin {
        if (requested.id.namespace == "org.example") {
            useModule("org.example:custom-plugin:${requested.version}")
        }
    }
}
```

settings.gradle

```
resolutionStrategy {
    eachPlugin {
        if (requested.id.namespace == 'org.example') {
            useModule("org.example:custom-plugin:${requested.version}")
        }
    }
}
```

== Precompiled script plugins In addition to plugins written as standalone projects, Gradle also allows you to provide build logic written in either Groovy or Kotlin DSLs as precompiled script plugins. You write these as `*.gradle` files in `src/main/groovy` directory or `*.gradle.kts` files in `src/main/kotlin` directory.

Precompiled script plugin names have two important limitations:

- They cannot start with `org.gradle`.
- They cannot have the same name as a built-in plugin id.

This ensures that the precompiled script plugins won't be silently ignored.

Precompiled script plugins are compiled into class files and packaged into a jar. For all intents and purposes, they are binary plugins and can be applied by plugin ID, tested and published as binary plugins. In fact, the plugin metadata for them is generated using the Gradle Plugin Development Plugin.

Kotlin DSL precompiled script plugins built with Gradle 6.0 cannot be used with earlier versions of Gradle. This limitation will be lifted in a future version of Gradle.

Groovy DSL precompiled script plugins are available starting with Gradle 6.4. Groovy DSL precompiled script plugins can be applied in projects that use Gradle 5.0 and later.

To apply a precompiled script plugin, you need to know its ID which is derived from the plugin script's filename (minus the `.gradle.kts` extension) and its (optional) package declaration.

To apply a precompiled script plugin, you need to know its ID which is derived from the plugin script's filename (minus the `.gradle` extension).

For example, the script `src/main/kotlin/java-library-convention.gradle.kts` would have a plugin ID of `java-library-convention` (assuming it has no package declaration). Likewise, `src/main/kotlin/my/java-library-convention.gradle.kts` would result in a plugin ID of `my.java-library-convention` as long as it has a package declaration of `my`.

For example, the script `src/main/groovy/java-library-convention.gradle` would have a plugin ID of `java-library-convention`. Likewise, `src/main/groovy/my.java-library-convention.gradle` would result in a plugin ID of `my.java-library-convention`.

To demonstrate how you can implement and use a precompiled script plugin, let's walk through an example based on a `buildSrc` project.

First, you need a `buildSrc/build.gradle.kts` file that applies the `kotlin-dsl` plugin:

First, you need a `buildSrc/build.gradle` file that applies the `groovy-gradle-plugin` plugin:

buildSrc/build.gradle.kts

```
plugins {
    `kotlin-dsl`
}

repositories {
    mavenCentral()
}
```

buildSrc/build.gradle

```groovy
plugins {
    id 'groovy-gradle-plugin'
}
```

We recommend that you also create a `buildSrc/settings.gradle.kts` file, which you may leave empty.

We recommend that you also create a `buildSrc/settings.gradle` file, which you may leave empty.

Next, create a new `java-library-convention.gradle.kts` file in the `buildSrc/src/main/kotlin` directory and set its contents to the following:

Next, create a new `java-library-convention.gradle` file in the `buildSrc/src/main/groovy` directory and set its contents to the following:

buildSrc/src/main/kotlin/java-library-convention.gradle.kts

```kotlin
plugins {
    `java-library`
    checkstyle
}

java {
    sourceCompatibility = JavaVersion.VERSION_11
    targetCompatibility = JavaVersion.VERSION_11
}

checkstyle {
    maxWarnings = 0
    // ...
}

tasks.withType<JavaCompile> {
    options.isWarnings = true
    // ...
}

dependencies {
    testImplementation("junit:junit:4.13")
    // ...
}
```

buildSrc/src/main/groovy/java-library-convention.gradle

```groovy
plugins {
    id 'java-library'
    id 'checkstyle'
}

java {
    sourceCompatibility = JavaVersion.VERSION_11
    targetCompatibility = JavaVersion.VERSION_11
}

checkstyle {
    maxWarnings = 0
    // ...
}

tasks.withType(JavaCompile) {
    options.warnings = true
    // ...
}

dependencies {
    testImplementation("junit:junit:4.13")
    // ...
}
```

This script plugin simply applies the Java Library and Checkstyle Plugins and configures them. Note that this will actually apply the plugins to the main project, i.e. the one that applies the precompiled script plugin.

Finally, apply the script plugin to the root project as follows:

build.gradle.kts

```kotlin
plugins {
    `java-library-convention`
}
```

build.gradle

```
plugins {
    id 'java-library-convention'
}
```

=== Applying external plugins in precompiled script plugins In order to apply an external plugin in a precompiled script plugin, it has to be added to the plugin project's implementation classpath in the plugin's build file.

buildSrc/build.gradle.kts

```
plugins {
    `kotlin-dsl`
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("com.bmuschko:gradle-docker-plugin:6.4.0")
}
```

buildSrc/build.gradle

```
plugins {
    id 'groovy-gradle-plugin'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'com.bmuschko:gradle-docker-plugin:6.4.0'
}
```

It can then be applied in the precompiled script plugin.

buildSrc/src/main/kotlin/my-plugin.gradle.kts

```
plugins {
    id("com.bmuschko.docker-remote-api")
}
```

buildSrc/src/main/groovy/my-plugin.gradle

```
plugins {
    id 'com.bmuschko.docker-remote-api'
}
```

The plugin version in this case is defined in the dependency declaration.

Writing tests for your plugin

You can use the ProjectBuilder class to create Project instances to use when you test your plugin implementation.

Example: Testing a custom plugin

src/test/java/org/example/GreetingPluginTest.java

```java
public class GreetingPluginTest {
    @Test
    public void greeterPluginAddsGreetingTaskToProject() {
        Project project = ProjectBuilder.builder().build();
        project.getPluginManager().apply("org.example.greeting");

        assertTrue(project.getTasks().getByName("hello") instanceof GreetingTask);
    }
}
```

More details

Plugins often also provide custom task types. Please see Developing Custom Gradle Task Types for more details.

Gradle provides a number of features that are helpful when developing Gradle types, including plugins. Please see Developing Custom Gradle Types for more details.

| CAUTION | When developing Gradle Plugins, it is important to be cautious when logging information to the build log. Logging sensitive information (e.g. credentials, tokens, certain environment variables) is considered a security vulnerability. Build logs for public Continuous Integration services are world-viewable and can expose this sensitive information. |

Behind the scenes

So how does Gradle find the Plugin implementation? The answer is - you need to provide a properties file in the JAR's META-INF/gradle-plugins directory that matches the id of your plugin, which is handled by Java Gradle Plugin Development Plugin.

Example: Wiring for a custom plugin

Given a plugin with ID org.example.greeting and implementation class org.example.GreetingPlugin:

src/main/resources/META-INF/gradle-plugins/org.example.greeting.properties

```
implementation-class=org.example.GreetingPlugin
```

Notice that the properties filename matches the plugin id and is placed in the resources folder, and that the `implementation-class` property identifies the Plugin implementation class.

= Designing Gradle plugins

For beginners to Gradle implementing plugins can look like a daunting task that includes many considerations and deep knowledge: organizing and structuring plugin logic, testing and debugging plugin code as well as publishing the plugin artifact to a repository for consumption.

In this section, you will learn how to properly design Gradle plugins based on established practices and apply them to your own projects. This section assumes you have:

- Basic understanding of software engineering practices
- Knowledge of Gradle fundamentals like project organization, task creation and configuration as well as the Gradle build lifecycle

== Architecture

=== Reusable logic should be written as binary plugin

The Gradle User Manual differentiates two types of plugins: script plugins and binary plugins. Script plugins are basically just plain old Gradle build scripts with a different name. While script plugins have their place for organizing build logic in a Gradle project, it's hard to keep them well-maintained, they are hard to test and you can't define new reusable types in them.

Binary plugins should be used whenever logic needs to be reused or shared across independent projects. They allow for properly structuring code into classes and packages, are cachable, can follow a versioning scheme to enable smooth upgrade procedures and are easily testable.

=== Consider the impact on performance

As a developer of Gradle plugins you have full freedom in defining and organizing code. Any logic imaginable can be implemented. When designing Gradle plugins always be aware of the impact on the end user. Seemingly simple logic can have a considerable impact on the execution performance of a build. That's especially the case when code of a plugin is executed during the configuration phase of the build lifecycle e.g. resolving dependencies by iterating over them, making HTTP calls or writing to files. The section on optimizing Gradle build performance will give you additional code examples, pitfalls and recommendations.

As you write plugin code ask yourself whether the code shouldn't rather be run during the execution phase. If you suspect issues with your plugin code, try creating a build scan to identify bottlenecks. The Gradle profiler can help with automating build scan generation and gathering more low-level information.

=== Convention over configuration

Convention over configuration is a software engineering paradigm that allows a tool or framework to make an attempt at decreasing the number of decisions the user has to make

without losing its flexibility. What does that mean for Gradle plugins? Gradle plugins can provide users with sensible defaults and standards (*conventions*) in a certain context. Let's take the Java plugin as an example.

- It defines the directory *src/main/java* as the default source directory for compilation.
- The output directory for compiled source code and other artifacts (like the JAR file) is *build*.

As long as the user of the plugin does not prefer to use other conventions, no additional configuration is needed in the consuming build script. It simply works out-of-the-box. However, if the user prefers other standards, then the default conventions can be reconfigured. You get the best of both worlds.

In practice you will find that most users are comfortable with the default conventions until there's a good reason to change them e.g. if you have to work with a legacy project. When writing your own plugins, make sure that you pick sensible defaults. You can find out if you did pick sensible conventions for your plugin if you see that the majority of plugin consumers don't have to reconfigure them.

Let's have a look at an example for conventions introduced by a plugin. The plugin retrieves information from a server by making HTTP calls. The default URL used by the plugin is configured to point to a server within an organization developing the plugin: https://www.myorg.com/server. A good way to make the default URL configurable is to introduce an extension. An extension exposes a custom DSL for capturing user input that influences the runtime behavior. The following example shows such a custom DSL for the discussed example:

build.gradle.kts

```
plugins {
    id("org.myorg.server")
}

server {
    url = "http://localhost:8080/server"
}
```

build.gradle

```
plugins {
    id 'org.myorg.server'
}

server {
    url = 'http://localhost:8080/server'
}
```

As you can see, the user only declares the "what" - the server the plugin should reach out to. The actual inner workings - the "how" - is completely hidden from the end user.

=== Capabilities vs. conventions

The functionality brought in by a plugin can be extremely powerful but also very opinionated. That's especially the case if a plugin predefines tasks and conventions that a project inherits automatically when applying it. Sometimes the reality that you - as plugin developer - choose for your users might simply look different than expected. For that very reason you need to make a plugin as flexible and configurable as possible.

One way to provide these quality criteria is to separate capabilities from conventions. In practice that means separating general-purpose functionality from pre-configured, opinionated functionality. Let's have a look at an example to explain this seemingly abstract concept. There are two Gradle core plugins that demonstrate the concept perfectly: the Java Base plugin and the Java plugin.

- The Java Base plugin just provided un-opinionated functionality and general purpose concepts. For example it formalized the concept of a SourceSet and introduces dependency management configurations. However, it doesn't actually create tasks you'd use as a Java developer on a regular basis nor does it create instances of source set.

- The Java plugin applies the Java Base plugin internally and inherits all its functionality. On top, it creates source set instances like `main` and `test`, creates tasks well-known to Java developers like `classes`, `jar` or `javadoc`. It also establishes a lifecycle between those tasks that make sense for the domain.

The bottom line is that we *separated capabilities from conventions*. If a user decides that they doesn't like the tasks created or doesn't want to reconfigure a lot of the conventions because that's not how the project structure looks like, then they can just fall back to applying the Java Base plugin and take matters into their own hands.

You should consider using the same technique when designing your own plugins. You can develop both plugins within the same project and ship their compiled classes and identifiers with the same binary artifact. The following code example shows how to apply a plugin from another one, so-called plugin composition:

MyBasePlugin.java

```
import org.gradle.api.Plugin;
import org.gradle.api.Project;

public class MyBasePlugin implements Plugin<Project> {
    public void apply(Project project) {
        // define capabilities
    }
}
```

MyPlugin.java

```java
import org.gradle.api.Plugin;
import org.gradle.api.Project;

public class MyPlugin implements Plugin<Project> {
    public void apply(Project project) {
        project.getPlugins().apply(MyBasePlugin.class);

        // define conventions
    }
}
```

For inspiration, here are two open-source plugins that apply the concept:

- Docker plugin

- Cargo plugin

== Technologies

=== Prefer using a statically-typed language to implement a plugin

Gradle doesn't take a stance on the programming language you should choose for implementing a plugin. It's a developer's choice as long as the plugin binary can be executed on the JVM.

It is recommended to use a statically-typed language like Java or Kotlin for implementing plugins to decrease the likelihood of binary incompatibilities. Should you decide on using Groovy for your plugin implementation then it is a good choice to use the annotation @groovy.transform.CompileStatic.

The recommendation to use a statically-typed language is independent from the language choice for writing tests for your plugin code. The use of dynamic Groovy and (its very capable testing and mocking framework) Spock is a very viable and common option.

=== Restricting the plugin implementation to Gradle's public API

To be able to build a Gradle plugin you'll need to tell your project to use a compile-time dependency on the Gradle API. Your build script would usually contain the following declaration:

build.gradle.kts

```kotlin
dependencies {
    implementation(gradleApi())
}
```

build.gradle

```
dependencies {
    implementation gradleApi()
}
```

It's important to understand that this dependency includes the full Gradle runtime. For historical reasons, public and internal Gradle API have not been separated yet.

To ensure the best backward and forward compatibility with other Gradle versions you should only use the public API. In most cases it will support the use case you are trying to support with your plugin. Keep in mind that internal APIs are subject to change and can easily break your plugin from one Gradle version to another. Please open an issue on GitHub if you are looking for a public API that is currently internal-only.

How do you know if a class is part of the public API? If you can find the class referenced in the DSL guide or the Javadocs then you can safely assume that it is public. In the future, we are planning to clearly separate public from internal API which will allow end users to declare the relevant dependency in the build script.

=== Minimizing the use of external libraries

As application developers we have become quite accustomed to the use of external libraries to avoid having to write fundamental functionality. You likely do not want to go without your beloved Guava or HttpClient library anymore. Keep in mind that some of the libraries might pull in a huge graph of transitive dependencies when declared through Gradle's dependency management system. The dependency report does not render dependencies declared for the `classpath` configuration of the build script, effectively the classpath of the declared plugins and their transitive dependencies. However, you can call the help task `buildEnvironment` to render the full dependency graph. To demonstrate the functionality let's assume the following build script:

build.gradle.kts

```
plugins {
    id("org.asciidoctor.jvm.convert") version "3.2.0"
}
```

build.gradle

```
plugins {
    id 'org.asciidoctor.jvm.convert' version '3.2.0'
}
```

The output of the task clearly indicates the classpath of the `classpath` configuration:

```
$ gradle buildEnvironment

> Task :buildEnvironment

------------------------------------------------------------
Root project 'external-libraries'
------------------------------------------------------------

classpath
\--- org.asciidoctor.jvm.convert:org.asciidoctor.jvm.convert.gradle.plugin:3.2.0
     \--- org.asciidoctor:asciidoctor-gradle-jvm:3.2.0
          +--- org.ysb33r.gradle:grolifant:0.16.1
          |    \--- org.tukaani:xz:1.6
          \--- org.asciidoctor:asciidoctor-gradle-base:3.2.0
               \--- org.ysb33r.gradle:grolifant:0.16.1 (*)

(*) - Indicates repeated occurrences of a transitive dependency subtree. Gradle
expands transitive dependency subtrees only once per project; repeat occurrences
only display the root of the subtree, followed by this annotation.

A web-based, searchable dependency report is available by adding the --scan
option.

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

It's important to understand that a Gradle plugin does not run in its own, isolated classloader. In turn those dependencies might conflict with other versions of the same library being resolved from other plugins and might lead to unexpected runtime behavior. When writing Gradle plugins consider if you really need a specific library or if you could just implement a simple method yourself.

For logic that is executed as part of task execution, use the Worker API that allows you to isolate libraries.

= Implementing Gradle plugins

Writing plugin code is a routine activity for advanced build authors. The activity usually involves writing the plugin implementation, creating custom task type for executing desired functionality and making the runtime behavior configurable for the end user by exposing a declarative and expressive DSL. In this section you will learn established practices to make you a better plugin developer and how to make a plugin as accessible and useful for consumers as possible.

This section assumes you have:

- Basic understanding of software engineering practices

- Knowledge of Gradle fundamentals like project organization, task creation and configuration as well as the Gradle build lifecycle

- Working knowledge in writing Java code

== Using the Plugin Development plugin for writing plugins

Setting up a Gradle plugin project should require as little boilerplate code as possible. The Java Gradle Plugin Development plugin provides aid in this concern. To get started add the following code to your *build.gradle* file:

build.gradle.kts

```
plugins {
    `java-gradle-plugin`
}

gradlePlugin {
    plugins {
        create("simplePlugin") {
            id = "org.example.greeting"
            implementationClass = "org.example.GreetingPlugin"
        }
    }
}
```

build.gradle

```
plugins {
    id 'java-gradle-plugin'
}

gradlePlugin {
    plugins {
        simplePlugin {
            id = 'org.example.greeting'
            implementationClass = 'org.example.GreetingPlugin'
        }
    }
}
```

By applying the plugin, necessary plugins are applied and relevant dependencies are added. It also helps with validating the plugin metadata before publishing the binary artifact to the Gradle plugin portal. Every plugin project should apply this plugin.

== Prefer writing and using custom task types

Gradle tasks can be defined as ad-hoc tasks, simple task definitions of type `DefaultTask` with one or many actions, or as enhanced tasks, the ones that use a custom task type and expose its configurability with the help of properties. Generally speaking, custom tasks provide the means for reusability, maintainability, configurability and testability. The same principles hold true when providing tasks as part of plugins. Always prefer custom task types over ad-hoc tasks. Consumers of your plugin will also have the chance to reuse the existing task type if they want to add more tasks to the build script.

Let's say you implemented a plugin that resolves the latest version of a dependency in a binary repository by making HTTP calls by providing a custom task type. The custom task is provided by a plugin that takes care of communicating via HTTP and processing the response in machine-readable format like XML or JSON.

LatestArtifactVersion.java

```java
abstract public class LatestArtifactVersion extends DefaultTask {

    @Input
    abstract public Property<String> getCoordinates();

    @Input
    abstract public Property<String> getServerUrl();

    @TaskAction
    public void resolveLatestVersion() {
        System.out.println("Retrieving artifact " + getCoordinates().get() + "
from " + getServerUrl().get());
        // issue HTTP call and parse response
    }
}
```

The end user of the task can now easily create multiple tasks of that type with different configuration. All the imperative, potentially complex logic is completely hidden in the custom task implementation.

build.gradle.kts

```
tasks.register<LatestArtifactVersion>("latestVersionMavenCentral") {
    coordinates = "commons-lang:commons-lang"
    serverUrl = "http://repo1.maven.org/maven2"
}

tasks.register<LatestArtifactVersion>("latestVersionInhouseRepo") {
    coordinates = "commons-lang:commons-lang"
    serverUrl = "http://repo1.myorg.org/maven2"
}
```

build.gradle

```
tasks.register('latestVersionMavenCentral', LatestArtifactVersion) {
    coordinates = 'commons-lang:commons-lang'
    serverUrl = 'http://repo1.maven.org/maven2'
}

tasks.register('latestVersionInhouseRepo', LatestArtifactVersion) {
    coordinates = 'commons-lang:commons-lang'
    serverUrl = 'http://repo1.myorg.org/maven2'
}
```

Benefiting from incremental tasks

Gradle uses declared inputs and outputs to determine if a task is up-to-date and needs to perform any work. If none of the inputs or outputs have changed, Gradle can skip that task. Gradle calls this mechanism incremental build support. The advantage of incremental build support is that it can significantly improve the performance of a build.

It's very common for Gradle plugins to introduce custom task types. As a plugin author that means that you'll have to annotate all properties of a task with input or output annotations. It's highly recommended to equip every task with the information to run up-to-date checking. Remember: for up-to-date checking to work properly a task needs to define both inputs and outputs.

Let's consider the following sample task for illustration. The task generates a given number of files in an output directory. The text written to those files is provided by a String property.

Generate.java

```java
public abstract class Generate extends DefaultTask {

    @Input
    abstract public Property<Integer> getFileCount();

    @Input
    abstract public Property<String> getContent();

    @OutputDirectory
    abstract public RegularFileProperty getGeneratedFileDir();

    @TaskAction
    public void perform() throws IOException {
        for (int i = 1; i <= getFileCount().get(); i++) {
            writeFile(new File(getGeneratedFileDir().get().getAsFile(), i + ".txt"), getContent().get());
        }
    }

    private void writeFile(File destination, String content) throws IOException {
        BufferedWriter output = null;
        try {
            output = new BufferedWriter(new FileWriter(destination));
            output.write(content);
        } finally {
            if (output != null) {
                output.close();
            }
        }
    }
}
```

The first section of this guide talks about the Plugin Development plugin. As an added benefit of applying the plugin to your project, the task `validatePlugins` automatically checks for an existing input/output annotation for every public property defined in a custom task type implementation.

== Modeling DSL-like APIs

DSLs exposed by plugins should be readable and easy to understand. For illustration let's consider the following extension provided by a plugin. In its current form it offers a "flat" list of properties for configuring the creation of a web site.

build-flat.gradle.kts

```kotlin
plugins {
    id("org.myorg.site")
}

site {
    outputDir = layout.buildDirectory.file("mysite")
    websiteUrl = "https://gradle.org"
    vcsUrl = "https://github.com/gradle/gradle-site-plugin"
}
```

build-flat.gradle

```groovy
plugins {
    id 'org.myorg.site'
}

site {
    outputDir = layout.buildDirectory.file("mysite")
    websiteUrl = 'https://gradle.org'
    vcsUrl = 'https://github.com/gradle/gradle-site-plugin'
}
```

As the number of exposed properties grows, you might want to introduce a nested, more expressive structure. The following code snippet adds a new configuration block named `customData` as part of the extension. You might have noticed that it provides a stronger indication of what those properties mean.

build.gradle.kts

```kotlin
plugins {
    id("org.myorg.site")
}

site {
    outputDir = layout.buildDirectory.file("mysite")

    customData {
        websiteUrl = "https://gradle.org"
        vcsUrl = "https://github.com/gradle/gradle-site-plugin"
    }
}
```

build.gradle

```groovy
plugins {
    id 'org.myorg.site'
}

site {
    outputDir = layout.buildDirectory.file("mysite")

    customData {
        websiteUrl = 'https://gradle.org'
        vcsUrl = 'https://github.com/gradle/gradle-site-plugin'
    }
}
```

It's fairly easy to implement the backing objects of such an extension. First of all, you'll need to introduce a new data object for managing the properties `websiteUrl` and `vcsUrl`.

CustomData.java

```java
abstract public class CustomData {

    abstract public Property<String> getWebsiteUrl();

    abstract public Property<String> getVcsUrl();
}
```

In the extension, you'll need to create an instance of the `CustomData` class and a method that can delegate the captured values to the data instance. To configure underlying data objects define a parameter of type Action. The following example demonstrates the use of `Action` in an extension definition.

SiteExtension.java

```java
abstract public class SiteExtension {

    abstract public RegularFileProperty getOutputDir();

    @Nested
    abstract public CustomData getCustomData();

    public void customData(Action<? super CustomData> action) {
        action.execute(getCustomData());
    }
}
```

== Capturing user input to configure plugin runtime behavior

Plugins often times come with default conventions that make sensible assumptions about the consuming project. The Java plugin, for example, searches for Java source files in the directory `src/main/java`. Default conventions are helpful to streamline project layouts but fall short when dealing with custom project structures, legacy project requirements or a different user preference.

Plugins should expose a way to reconfigure the default runtime behavior. The section Prefer writing and using custom task types describes one way to achieve configurability: by declaring setter methods for task properties. The more sophisticated solution to the problem is to expose an extension. An extension captures user input through a custom DSL that fully blends into the DSL exposed by Gradle core.

The following example applies a plugin that exposes an extension with the name `binaryRepo` to capture a server URL:

build.gradle.kts

```kotlin
plugins {
    id("org.myorg.binary-repository-version")
}

binaryRepo {
    coordinates = "commons-lang:commons-lang"
    serverUrl = "http://repo2.myorg.org/maven2"
}
```

build.gradle

```groovy
plugins {
    id 'org.myorg.binary-repository-version'
}

binaryRepo {
    coordinates = 'commons-lang:commons-lang'
    serverUrl = 'http://repo2.myorg.org/maven2'
}
```

Let's assume that you'll also want to do something with the value of `serverUrl` once captured. In many cases the exposed extension property is directly mapped to a task property that actually uses the value when performing work. To avoid evaluation order problems you should use the public API `Property` which was introduced in Gradle 4.0.

Let's have a look at the internals of the plugin `BinaryRepositoryVersionPlugin` to give you a better idea. The plugin creates the extension of type `BinaryRepositoryExtension` and maps the extension property `serverUrl` to the task property `serverUrl`.

BinaryRepositoryVersionPlugin.java

```java
public class BinaryRepositoryVersionPlugin implements Plugin<Project> {
    public void apply(Project project) {
        BinaryRepositoryExtension extension =
            project.getExtensions().create("binaryRepo",
BinaryRepositoryExtension.class);

        project.getTasks().register("latestArtifactVersion",
LatestArtifactVersion.class, task -> {
            task.getCoordinates().set(extension.getCoordinates());
            task.getServerUrl().set(extension.getServerUrl());
        });
    }
}
```

Instead of using a plain `String` type, the extension defines the properties `coordinates` and `serverUrl` with type `Property<String>`. The abstract getters for the properties are automatically initialized by Gradle. The values of a property can then be changed on the property object obtained through the corresponding getter method.

> **NOTE**
> The Gradle classloader automatically injects setter methods alongside all getter methods with the return type `Property`. It allows developers to simplify code like `obj.prop.set 'foo'` to `obj.prop = 'foo'` in the Groovy DSL.

BinaryRepositoryExtension.java

```java
abstract public class BinaryRepositoryExtension {

    abstract public Property<String> getCoordinates();

    abstract public Property<String> getServerUrl();
}
```

The task property also defines the `serverUrl` with type `Property`. It allows for mapping the state of the property without actually accessing its value until needed for processing - that is in the task action.

LatestArtifactVersion.java

```java
abstract public class LatestArtifactVersion extends DefaultTask {

    @Input
    abstract public Property<String> getCoordinates();

    @Input
    abstract public Property<String> getServerUrl();

    @TaskAction
    public void resolveLatestVersion() {
        System.out.println("Retrieving artifact " + getCoordinates().get() + "
from " + getServerUrl().get());
        // issue HTTP call and parse response
    }
}
```

NOTE	We encourage plugin developers to migrate their plugins to the public property API as soon as possible. Plugins that are not based on Gradle 4.0 yet may continue to use the internal "convention mapping" API. Please be aware that the "convention mapping" API is undocumented and might be removed with later versions of Gradle.

Declaring a DSL configuration container

Sometimes you might want to expose a way for users to define multiple, named data objects of the same type. Let's consider the following build script for illustration purposes.

build.gradle.kts

```kotlin
plugins {
    id("org.myorg.server-env")
}

environments {
    create("dev") {
        url = "http://localhost:8080"
    }

    create("staging") {
        url = "http://staging.enterprise.com"
    }

    create("production") {
        url = "http://prod.enterprise.com"
    }
}
```

build.gradle

```groovy
plugins {
    id 'org.myorg.server-env'
}

environments {
    dev {
        url = 'http://localhost:8080'
    }

    staging {
        url = 'http://staging.enterprise.com'
    }

    production {
        url = 'http://prod.enterprise.com'
    }
}
```

The DSL exposed by the plugin exposes a *container* for defining a set of environments. Each environment configured by the user has an arbitrary but declarative name and is represented with its own DSL configuration block. The example above instantiates a development, staging and production environment including its respective URL.

Obviously, each of these environments needs to have a data representation in code to capture the values. The name of an environment is immutable and can be passed in as constructor parameter. At the moment the only other parameter stored by the data object is an URL. The POJO `ServerEnvironment` shown below fulfills those requirements.

ServerEnvironment.java

```java
abstract public class ServerEnvironment {
    private final String name;

    @javax.inject.Inject
    public ServerEnvironment(String name) {
        this.name = name;
    }

    public String getName() {
        return name;
    }

    abstract public Property<String> getUrl();
}
```

Gradle exposes the factory method ObjectFactory.domainObjectContainer(Class, NamedDomainObjectFactory) to create a container of data objects. The parameter the method takes is the class representing the data. The created instance of type NamedDomainObjectContainer can be exposed to the end user by adding it to the extension container with a specific name.

ServerEnvironmentPlugin.java

```java
public class ServerEnvironmentPlugin implements Plugin<Project> {
    @Override
    public void apply(final Project project) {
        ObjectFactory objects = project.getObjects();

        NamedDomainObjectContainer<ServerEnvironment> serverEnvironmentContainer =
            objects.domainObjectContainer(ServerEnvironment.class, name ->
objects.newInstance(ServerEnvironment.class, name));
        project.getExtensions().add("environments", serverEnvironmentContainer);

        serverEnvironmentContainer.all(serverEnvironment -> {
            String env = serverEnvironment.getName();
            String capitalizedServerEnv = env.substring(0, 1).toUpperCase() + env
.substring(1);
            String taskName = "deployTo" + capitalizedServerEnv;
            project.getTasks().register(taskName, Deploy.class, task -> task
.getUrl().set(serverEnvironment.getUrl()));
        });
    }
}
```

It's very common for a plugin to post-process the captured values within the plugin implementation e.g. to configure tasks. In the example above, a deployment task is created dynamically for every environment that was configured by the user.

== Reacting to plugins

Configuring the runtime behavior of existing plugins and tasks in a build is a common pattern in Gradle plugin implementations. For example a plugin could assume that it is applied to a Java-based project and automatically reconfigure the standard source directory.

InhouseStrongOpinionConventionJavaPlugin.java

```java
public class InhouseStrongOpinionConventionJavaPlugin implements Plugin<Project> {
    public void apply(Project project) {
        // Careful! Eagerly appyling plugins has downsides, and is not always
recommended.
        project.getPlugins().apply(JavaPlugin.class);
        SourceSetContainer sourceSets = project.getExtensions().getByType
(SourceSetContainer.class);
        SourceSet main = sourceSets.getByName(SourceSet.MAIN_SOURCE_SET_NAME);
        main.getJava().setSrcDirs(Arrays.asList("src"));
    }
}
```

The drawback to this approach is that it automatically forces the project to apply the Java plugin and therefore imposes a strong opinion on it. In practice, the project applying the plugin might not even deal with Java code. Instead of automatically applying the Java plugin

the plugin could just react to the fact that the consuming project applies the Java plugin. Only if that is the case then certain configuration is applied.

InhouseConventionJavaPlugin.java

```java
public class InhouseConventionJavaPlugin implements Plugin<Project> {
    public void apply(Project project) {
        project.getPlugins().withType(JavaPlugin.class, javaPlugin -> {
            SourceSetContainer sourceSets = project.getExtensions().getByType
(SourceSetContainer.class);
            SourceSet main = sourceSets.getByName(SourceSet.MAIN_SOURCE_SET_NAME);
            main.getJava().setSrcDirs(Arrays.asList("src"));
        });
    }
}
```

Reacting to plugins should be preferred over blindly applying other plugins if there is not a good reason for assuming that the consuming project has the expected setup. The same concept applies to task types.

InhouseConventionWarPlugin.java

```java
public class InhouseConventionWarPlugin implements Plugin<Project> {
    public void apply(Project project) {
        project.getTasks().withType(War.class).configureEach(war ->
            war.setWebXml(project.file("src/someWeb.xml")));
    }
}
```

== Reacting to build features

Plugins can access the status of build features in the build. The Build Features API allows checking whether the user requested a particular Gradle feature and if it is active in the current build. An example of a build feature is the configuration cache.

There are two main use cases:

- Using the status of build features in reports or statistics.
- Incrementally adopting experimental Gradle features by disabling incompatible plugin functionality.

Below is an example of a plugin that utilizes both of the cases.

Reacting to build features

```java
public abstract class MyPlugin implements Plugin<Project> {

    @Inject
    protected abstract BuildFeatures getBuildFeatures(); ①

    @Override
    public void apply(Project p) {
        BuildFeatures buildFeatures = getBuildFeatures();

        Boolean configCacheRequested = buildFeatures.getConfigurationCache()
.getRequested() ②
                .getOrNull(); // could be null if user did not opt in nor opt out
        String configCacheUsage = describeFeatureUsage(configCacheRequested);
        MyReport myReport = new MyReport();
        myReport.setConfigurationCacheUsage(configCacheUsage);

        boolean isolatedProjectsActive = buildFeatures.getIsolatedProjects()
.getActive() ③
                .get(); // the active state is always defined
        if (!isolatedProjectsActive) {
            myOptionalPluginLogicIncompatibleWithIsolatedProjects();
        }
    }

    private String describeFeatureUsage(Boolean requested) {
        return requested == null ? "no preference" : requested ? "opt-in" : "opt-
out";
    }

    private void myOptionalPluginLogicIncompatibleWithIsolatedProjects() {
    }
}
```

① The `BuildFeatures` service can be injected into plugins, tasks, and other managed types.

② Accessing the `requested` status of a feature for reporting.

③ Using the `active` status of a feature to disable incompatible functionality.

=== Build feature properties

The status properties of a `BuildFeature` are represented with `Provider<Boolean>` types.

The `BuildFeature.getRequested()` status of a build feature determines if the user requested to enable or disable the feature. If the user did neither, then the **value of the provider is undefined**.

When the `requested` provider value is:

- not present (undefined) — the user neither opted in nor opted out from using the feature;

- `true` — the user opted in for using the feature, e.g., using a build option;

- `false` — the user opted out from using the feature, e.g., by setting a Gradle property to `false`.

The `BuildFeature.getActive()` status of a build feature is always defined. It represents the effective state of the feature in the build.

When the `active` provider value is:

- `true` — the feature *may* affect the build behavior in a way specific to the feature;

- `false` — the feature will not affect the build behavior.

Note that the `active` status does not depend on the `requested` status. Even if the user requested a feature, it may still not be active due to other build options used in the build. Gradle can also activate a feature by default, even if the user did not specify a preference.

== Providing default dependencies for plugins

The implementation of a plugin sometimes requires the use of an external dependency. You might want to automatically download an artifact using Gradle's dependency management mechanism and later use it in the action of a task type declared in the plugin. Optimally, the plugin implementation doesn't need to ask the user for the coordinates of that dependency - it can simply predefine a sensible default version.

Let's have a look at an example. You wrote a plugin that downloads files containing data for further processing. The plugin implementation declares a custom configuration that allows for assigning those external dependencies with dependency coordinates.

DataProcessingPlugin.java

```java
public class DataProcessingPlugin implements Plugin<Project> {
    public void apply(Project project) {
        Configuration dataFiles = project.getConfigurations().create("dataFiles",
c -> {
            c.setVisible(false);
            c.setCanBeConsumed(false);
            c.setCanBeResolved(true);
            c.setDescription("The data artifacts to be processed for this plugin.
");
            c.defaultDependencies(d -> d.add(project.getDependencies().create(
"org.myorg:data:1.4.6")));
        });

        project.getTasks().withType(DataProcessing.class).configureEach(
            dataProcessing -> dataProcessing.getDataFiles().from(dataFiles));
    }
}
```

```java
abstract public class DataProcessing extends DefaultTask {

    @InputFiles
    abstract public ConfigurableFileCollection getDataFiles();

    @TaskAction
    public void process() {
        System.out.println(getDataFiles().getFiles());
    }
}
```

Now, this approach is very convenient for the end user as there's no need to actively declare a dependency. The plugin already provides all the knowledge about this implementation detail. But what if the user would like to redefine the default dependency. No problem…the plugin also exposes the custom configuration that can be used to assign a different dependency. Effectively, the default dependency is overwritten.

build.gradle.kts

```kotlin
plugins {
    id("org.myorg.data-processing")
}

dependencies {
    dataFiles("org.myorg:more-data:2.6")
}
```

build.gradle

```groovy
plugins {
    id 'org.myorg.data-processing'
}

dependencies {
    dataFiles 'org.myorg:more-data:2.6'
}
```

You will find that this pattern works well for tasks that require an external dependency when the action of the task is actually executed. You can go further and abstract the version to be used for the external dependency by exposing an extension property (e.g. `toolVersion` in the JaCoCo plugin).

== Assigning appropriate plugin identifiers

A descriptive plugin identifier makes it easy for consumers to apply the plugin to a project. The ID should reflect the purpose of the plugin with a single term. Additionally, a domain name should be added to avoid conflicts between other plugins with similar functionality. In the previous sections, dependencies shown in code examples use the group ID `org.myorg`. We could use the same identifier as domain name.

When publishing multiple plugins as part of a single JAR artifact the same naming conventions should apply. This serves as a nice way to group related plugins together. There's no limitation to the number of plugins that can be registered by identifier. For illustration, the Gradle Android plugin defines two different plugins.

The identifiers for plugins written as a class should be defined in the build script of the project containing the plugin classes. For this, the `java-gradle-plugin` needs to be applied.

buildSrc/build.gradle.kts

```
plugins {
    id("java-gradle-plugin")
}

gradlePlugin {
    plugins {
        create("androidApplicationPlugin") {
            id = "com.android.application"
            implementationClass = "com.android.AndroidApplicationPlugin"
        }
        create("androidLibraryPlugin") {
            id = "com.android.library"
            implementationClass = "com.android.AndroidLibraryPlugin"
        }
    }
}
```

buildSrc/build.gradle

```
plugins {
    id 'java-gradle-plugin'
}

gradlePlugin {
    plugins {
        androidApplicationPlugin {
            id = 'com.android.application'
            implementationClass = 'com.android.AndroidApplicationPlugin'
        }
        androidLibraryPlugin {
            id = 'com.android.library'
            implementationClass = 'com.android.AndroidLibraryPlugin'
        }
    }
}
```

Note that identifiers for precompiled script plugins are automatically registered based on the file name of the script plugin.

== Providing multiple variants of a plugin for different Gradle versions

> **NOTE** The support for multi-variant plugins currently requires you to use the raw variant aware dependency management APIs of Gradle. More conveniences around this may be provided in the future.

Currently, the most convenient way to configure additional plugin variants is to use feature variants, a concept available in all Gradle projects that apply one of the Java plugins. As described in the documentation, there are several options to design feature variants. They may be bundled inside the same Jar, or each variant may come with its own Jar. Here we show how each plugin variant is developed in isolation. That is, in a separate source set that is compiled separately and packaged in a separate Jar. Other setups are possible though.

The following sample demonstrates how to add a variant that is compatible with Gradle 7+ while the "main" variant is compatible with older versions. Note that only Gradle versions 7 or higher can be explicitly targeted by a variant, as support for this was only added in Gradle 7.

build.gradle.kts

```
val gradle7 = sourceSets.create("gradle7")
java {
    registerFeature(gradle7.name) {
        usingSourceSet(gradle7)
        capability(project.group.toString(), project.name,
project.version.toString()) ①
    }
}
configurations.configureEach {
    if (isCanBeConsumed && name.startsWith(gradle7.name))  {
        attributes {
            attribute(GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
②
                objects.named("7.0"))
        }
    }
}
tasks.named<Copy>(gradle7.processResourcesTaskName) { ③
    val copyPluginDescriptors = rootSpec.addChild()
    copyPluginDescriptors.into("META-INF/gradle-plugins")
    copyPluginDescriptors.from(tasks.pluginDescriptors)
}

dependencies {
    "gradle7CompileOnly"(gradleApi()) ④
}
```

build.gradle

```
def gradle7 = sourceSets.create('gradle7')
java {
    registerFeature(gradle7.name) {
        usingSourceSet(gradle7)
        capability(project.group.toString(), project.name, project.version
.toString()) ①
    }
}
configurations.configureEach {
    if (canBeConsumed && name.startsWith(gradle7.name))  {
        attributes {
            attribute(GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
②
                    objects.named(GradlePluginApiVersion, '7.0'))
        }
    }
}
tasks.named(gradle7.processResourcesTaskName) { ③
    def copyPluginDescriptors = rootSpec.addChild()
    copyPluginDescriptors.into('META-INF/gradle-plugins')
    copyPluginDescriptors.from(tasks.pluginDescriptors)
}

dependencies {
    gradle7CompileOnly(gradleApi()) ④
}
```

First, we declare a separate *source set,* and a *feature variant* based on that, for our Gradle7 plugin variant. We need to do some specific wiring to turn the feature into a proper Gradle plugin variant:

① Assign the implicit capability that corresponds to the components GAV to the variant.

② Assign the Gradle API version attribute to all consumable configurations of our Gradle7 variant. This information is used by Gradle to determine which variant to select during plugin resolution.

③ Configure the `processGradle7Resources` task to make sure the plugin descriptor file is added to the Gradle7 variant Jar.

④ Add a dependency to the `gradleApi()` for our new variant so that the API is visible during compilation time.

Note that there is currently no convenient way to access the API of other Gradle versions as the one you are building the plugin with. Ideally, every variant should be able to declare a dependency to the API of the minimal Gradle version it supports. This will be improved in the future.

The above snippet assumes that all variants of your plugin have the plugin class at the same location. That is, if you followed this chapter and your plugin class is `org.example.GreetingPlugin`, you need to create a second variant of that class in `src/gradle7/java/org/example`.

== Using version-specific variants of multi-variant plugins

Given a dependency on a multi-variant plugin, Gradle will automatically choose its variant that best matches the current Gradle version when it resolves any of:

- plugins specified in the `plugins {}` block;
- `buildscript` classpath dependencies;
- dependencies in the root project of the build source (`buildSrc`) that appear on the compile or runtime classpath;
- dependencies in a project that applies the Java Gradle Plugin Development plugin or the Kotlin DSL plugin, appearing on the compile or runtime classpath.

The best matching variant is the variant that targets the highest Gradle API version not exceeding the current build's Gradle version.

In all other cases, a plugin variant that does not specify the supported Gradle API version is preferred, if such a variant is present.

In projects that use plugins as dependencies, it is possible to request the variants of plugin dependencies that support a different Gradle version. This allows a multi-variant plugin that depends on other plugins to access their APIs which are exclusively provided in their version-specific variants.

This snippet makes the plugin variant `gradle7` defined above consume the matching variants of

its dependencies on other multi-variant plugins.

build.gradle.kts

```
configurations.configureEach {
    if (isCanBeResolved && name.startsWith(gradle7.name))  {
        attributes {
            attribute(GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
                objects.named("7.0"))
        }
    }
}
```

build.gradle

```
configurations.configureEach {
    if (canBeResolved && name.startsWith(gradle7.name))  {
        attributes {
            attribute(GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
                objects.named(GradlePluginApiVersion, '7.0'))
        }
    }
}
```

= Testing Gradle plugins

Testing plays a crucial role in the development process as it ensures reliable and high-quality software. The same principles apply to build code and more specifically Gradle plugins. In this section you will learn effective techniques for testing plugin code.

This section assumes you have:

- Basic understanding of software engineering practices
- Knowledge of Gradle plugin implementation techniques
- Working knowledge in writing Java code

== The sample project

All discussions in this section are centered around a sample project called *URL verifier plugin*. The plugin creates a task named `verifyUrl` that checks whether a given URL can be resolved via HTTP GET. The end user can provide the URL via an extension named `verification`.

The following build script assumes that the plugin JAR file has been published to a binary repository. In a nutshell, the script demonstrates how to apply the plugin to the project and configure its exposed extension.

build.gradle.kts

```
plugins {
    id("org.myorg.url-verifier")        ①
}

verification {
    url = "https://www.google.com/"  ②
}
```

build.gradle

```
plugins {
    id 'org.myorg.url-verifier'        ①
}

verification {
    url = 'https://www.google.com/'    ②
}
```

① Applies the plugin to the project

② Configures the URL to be verified through the exposed extension

Executing the task renders a success message if the HTTP GET call to the configured URL returns with a 200 response code.

```
$ gradle verifyUrl

> Task :verifyUrl
Successfully resolved URL 'https://www.google.com/'

BUILD SUCCESSFUL in 0s
5 actionable tasks: 5 executed
```

Before diving into the code, let's first revisit the different types of tests and the tooling that supports implementing them.

On the importance of testing

Testing is a foundational activity in the software development life cycle. Appropriate testing ensures that the software works on a functional and non-functional level before it is released to the end user. As a by product, automated testing also enables the development team to refactor and evolve the code without fearing to introduce regressions in the process.

The testing pyramid
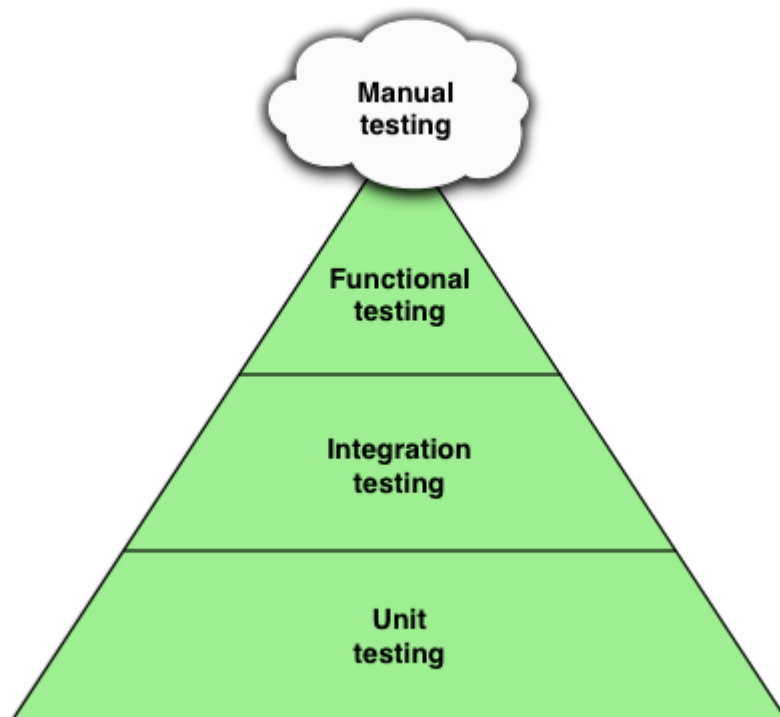
Probably the easiest way to test software is to manually exercise it. **Manual testing** can occur at any time and is not bound to writing automation code. However, manual testing is error-prone and cumbersome as it requires a human to walk through a set of predefined test cases.

Manually testing Gradle plugins requires consuming the plugin binary in a build script.

Other types of tests can be fully automated and exercised with every change to the source code. The testing pyramid introduced by Mike Cohen in his book Succeeding with Agile: Software Development Using Scrum describes three types of automated tests.

Unit testing aims to verify the smallest unit of code. In Java-based projects this unit is a method. Unit tests usually do not interact with other parts of the system e.g. a database or the file system. Interactions with other parts of the system are usually cut off with the help of Stubs or Mocks. You will find that POJOs and utility classes are good candidates for unit tests as they are self-contained and do not use the Gradle API.

Integration testing verifies that multiple classes or components work together as a whole. The code under test may reach out to external subsystems.

Functional testing is used to test the system from the end user's perspective. End-to-end tests for Gradle plugins stand up a build script, apply the plugin under test and execute the build with a specific task. The outcome of the build (e.g. standard output/error or generated artifacts) verifies the correctness of the functionality.

=== Tooling support

Implementing manual and automated testing for Gradle plugins is straight forward - it just requires the right tooling. The table below gives you a brief overview on how to approach each test type. Please be aware that you have the free choice of using the test framework you are most familiar with. For a detailed discussion and code example please refer to the dedicated section further down.

Test type	Tooling support
Manual tests	Gradle composite builds
Unit tests	Any JVM-based test framework
Integration tests	Any JVM-based test framework
Functional tests	Any JVM-based test framework and Gradle TestKit

== Setting up manual tests

The composite builds feature of Gradle makes it very easy to test a plugin manually. The standalone plugin project and the consuming project can be combined together into a single unit making it much more straight forward to try out or debug changes without the hassle of re-publishing the binary file.

```
.
├──── include-plugin-build     ①
│      ├──── build.gradle
│      └──── settings.gradle
└──── url-verifier-plugin      ②
       ├──── build.gradle
       ├──── settings.gradle
       └──── src
```
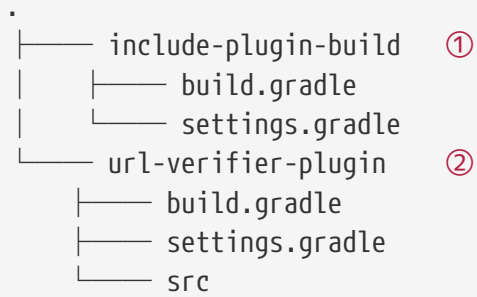
① Consuming project that includes the plugin project

② The plugin project

There are two ways to include a plugin project into a consuming project.

1. By using the command line option `--include-build`. 2. By using the method `includeBuild` in `settings.gradle`.

The following code snippet demonstrates the use of the settings file.

settings.gradle.kts

```
pluginManagement {
    includeBuild("../url-verifier-plugin")
}
```

settings.gradle

```
pluginManagement {
    includeBuild '../url-verifier-plugin'
}
```

The command line output of task `verifyUrl` from the project `include-plugin-build` looks exactly the same as shown in the introduction except that it now executed as part of a composite build.

Manual testing has its place in the development process. By no means is it a replacement for automated testing. Next up, you'll learn how to organize and implement automated tests for Gradle plugins.

== Setting up automated tests

Setting up a suite of tests earlier on is crucial to the success of your plugin. You will encounter various situations that make your tests an invaluable safety net you can rely on e.g. when upgrading the plugin to a new Gradle version and enhancing or refactoring the code.

=== Organizing test source code

We recommend to implement a good distribution of unit, integration and functional tests to cover the most important use cases. Separating the source code for each test type automatically results in a project that is more maintainable and manageable.

By default the Java project already creates a convention for organizing unit tests, the directory `src/test/java`. Additionally, if you apply the Groovy plugin source code under the directory `src/test/groovy` is taken under consideration for compilation. Consequently, source code directories for other test types should follow a similar pattern. Below you can find an exemplary project layout for a plugin project that chooses to use a Groovy-based testing approach.

```
.
└── src
    ├── functionalTest
    │   └── groovy       ①
    ├── integrationTest
    │   └── groovy       ②
    ├── main
    │   └── java         ③
    └── test
        └── groovy       ④
```
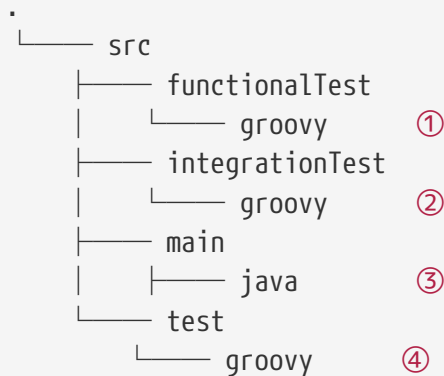
① Source directory containing functional tests

② Source directory containing integration tests

③ Source directory containing production source code

④ Source directory containing unit tests

| NOTE | The directories `src/integrationTest/groovy` and `src/functionalTest/groovy` are not based on an existing standard convention for Gradle projects. You are free to choose any project layout that works best for you. |

In the next section, you will learn how to configure those source directories for compilation and test execution. You can also rely on third-party plugins for convience e.g. the Nebula Facet plugin or the TestSets plugin.

=== Modeling test types

> **NOTE** A new configuration DSL for modeling the below `integrationTest` suite is available via the incubating JVM Test Suite plugin.

Gradle models source code directories with the help of the source set concept. By pointing an instance of a source set to one or many source code directories, *Gradle will automatically create a corresponding compilation task out-of-the-box*. A pre-configured source set can be created with one line of build script code. The source set automatically registers *configurations* to define dependencies for the sources of the source set. We use that to define an `integrationTestImplementation` dependency to the project itself, which represents the "main" variant of our project (i.e. the compiled plugin code).

build.gradle.kts

```
val integrationTest by sourceSets.creating

dependencies {
    "integrationTestImplementation"(project)
}
```

build.gradle

```
def integrationTest = sourceSets.create("integrationTest")

dependencies {
    integrationTestImplementation(project)
}
```

Source sets are only responsible for compiling source code, but do not deal with executing the byte code. For the purpose of test execution, a corresponding task of type Test needs to be established. The following listing shows the setup for executing integration tests. As you can see below, the task references the classes and runtime classpath of the integration test source set.

build.gradle.kts

```kotlin
val integrationTestTask = tasks.register<Test>("integrationTest") {
    description = "Runs the integration tests."
    group = "verification"
    testClassesDirs = integrationTest.output.classesDirs
    classpath = integrationTest.runtimeClasspath
    mustRunAfter(tasks.test)
}
tasks.check {
    dependsOn(integrationTestTask)
}
```

build.gradle

```groovy
def integrationTestTask = tasks.register("integrationTest", Test) {
    description = 'Runs the integration tests.'
    group = "verification"
    testClassesDirs = integrationTest.output.classesDirs
    classpath = integrationTest.runtimeClasspath
    mustRunAfter(tasks.named('test'))
}
tasks.named('check') {
    dependsOn(integrationTestTask)
}
```

=== Configuring a test framework

Gradle does not dictate the use of a specific test framework. Popular choices include JUnit, TestNG and Spock. Once you choose an option, you have to add its dependency to the compile classpath for your tests. The following code snippet shows how to use Spock for implementing tests. We choose to use it for all our three test types (*test, integrationTest* and *functionalTest*) and thus define a dependency for each of them.

build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    testImplementation(platform("org.spockframework:spock-bom:2.2-groovy-3.0"))
    testImplementation("org.spockframework:spock-core")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")

    "integrationTestImplementation"(platform("org.spockframework:spock-bom:2.2-
groovy-3.0"))
    "integrationTestImplementation"("org.spockframework:spock-core")
    "integrationTestRuntimeOnly"("org.junit.platform:junit-platform-launcher")

    "functionalTestImplementation"(platform("org.spockframework:spock-bom:2.2-
groovy-3.0"))
    "functionalTestImplementation"("org.spockframework:spock-core")
    "functionalTestRuntimeOnly"("org.junit.platform:junit-platform-launcher")
}

tasks.withType<Test>().configureEach {
    // Using JUnitPlatform for running tests
    useJUnitPlatform()
}
```

build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    testImplementation platform("org.spockframework:spock-bom:2.2-groovy-3.0")
    testImplementation 'org.spockframework:spock-core'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'

    integrationTestImplementation platform("org.spockframework:spock-bom:2.2-
groovy-3.0")
    integrationTestImplementation 'org.spockframework:spock-core'
    integrationTestRuntimeOnly 'org.junit.platform:junit-platform-launcher'

    functionalTestImplementation platform("org.spockframework:spock-bom:2.2-
groovy-3.0")
    functionalTestImplementation 'org.spockframework:spock-core'
    functionalTestRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}

tasks.withType(Test).configureEach {
    // Using JUnitPlatform for running tests
    useJUnitPlatform()
}
```

NOTE	Spock is a Groovy-based BDD test framework that even includes APIs for creating Stubs and Mocks. The Gradle team prefers Spock over other options for its expressiveness and conciseness.

Implementing automated tests

This section discusses representative implementation examples for unit, integration and functional tests. All test classes are based on the use of Spock though it should be relatively easy to adapt the code to a different test framework. Please revisit the section the testing pyramid for a formal discussion of the definition of each test type.

Implementing unit tests

The URL verifier plugin emits HTTP GET calls to check if a URL can be resolved successfully. The method `DefaultHttpCaller.get(String)` is responsible for calling a given URL and returns with an instance of type `HttpResponse`. `HttpResponse` is a POJO containing information about the HTTP response code and message.

HttpResponse.java

```java
package org.myorg.http;

public class HttpResponse {
    private int code;
    private String message;

    public HttpResponse(int code, String message) {
        this.code = code;
        this.message = message;
    }

    public int getCode() {
        return code;
    }

    public String getMessage() {
        return message;
    }

    @Override
    public String toString() {
        return "HTTP " + code + ", Reason: " + message;
    }
}
```

The class `HttpResponse` represents a good candidate to be tested by a unit test. It does not reach out to any other classes nor does it use the Gradle API.

HttpResponseTest.groovy

```groovy
package org.myorg.http

import spock.lang.Specification

class HttpResponseTest extends Specification {

    private static final int OK_HTTP_CODE = 200
    private static final String OK_HTTP_MESSAGE = 'OK'

    def "can access information"() {
        when:
        def httpResponse = new HttpResponse(OK_HTTP_CODE, OK_HTTP_MESSAGE)

        then:
        httpResponse.code == OK_HTTP_CODE
        httpResponse.message == OK_HTTP_MESSAGE
    }

    def "can get String representation"() {
        when:
        def httpResponse = new HttpResponse(OK_HTTP_CODE, OK_HTTP_MESSAGE)

        then:
        httpResponse.toString() == "HTTP $OK_HTTP_CODE, Reason: $OK_HTTP_MESSAGE"
    }
}
```

IMPORTANT	When writing unit tests, it's important to test boundary conditions and various forms of invalid input. Furthermore, try to extract as much logic as possible from classes that use the Gradle API to make it testable as unit tests. It will buy you the benefit of maintainable code and faster test execution.

=== Implementing integration tests

Let's have a look at a class that reaches out to another system, the piece of code that emits the HTTP calls. At the time of executing a test for the class `DefaultHttpCaller`, the runtime environment needs to be able to reach out to the internet.

DefaultHttpCaller.java

```java
package org.myorg.http;

import java.io.IOException;
import java.net.HttpURLConnection;
import java.net.URL;

public class DefaultHttpCaller implements HttpCaller {
    @Override
    public HttpResponse get(String url) {
        try {
            HttpURLConnection connection = (HttpURLConnection) new URL(url)
.openConnection();
            connection.setConnectTimeout(5000);
            connection.setRequestMethod("GET");
            connection.connect();

            int code = connection.getResponseCode();
            String message = connection.getResponseMessage();
            return new HttpResponse(code, message);
        } catch (IOException e) {
            throw new HttpCallException(String.format("Failed to call URL '%s' via
HTTP GET", url), e);
        }
    }
}
```

Implementing an integration test for `DefaultHttpCaller` doesn't look much different from the unit test shown in the previous section.

DefaultHttpCallerIntegrationTest.groovy

```groovy
package org.myorg.http

import spock.lang.Specification
import spock.lang.Subject

class DefaultHttpCallerIntegrationTest extends Specification {
    @Subject HttpCaller httpCaller = new DefaultHttpCaller()

    def "can make successful HTTP GET call"() {
        when:
        def httpResponse = httpCaller.get('https://www.google.com/')

        then:
        httpResponse.code == 200
        httpResponse.message == 'OK'
    }

    def "throws exception when calling unknown host via HTTP GET"() {
        when:
        httpCaller.get('https://www.wedonotknowyou123.com/')

        then:
        def t = thrown(HttpCallException)
        t.message == "Failed to call URL 'https://www.wedonotknowyou123.com/' via
HTTP GET"
        t.cause instanceof UnknownHostException
    }
}
```

=== Implementing functional tests

Functional tests verify the correctness of the plugin end-to-end. In practice that means applying, configuring and executing the functionality of the plugin implementation represented by the class `UrlVerifierPlugin`. As you can see, the implementation exposes an extension and a task instance that uses the URL value configured by the end user.

UrlVerifierPlugin.java

```java
package org.myorg;

import org.gradle.api.Plugin;
import org.gradle.api.Project;
import org.myorg.tasks.UrlVerify;

public class UrlVerifierPlugin implements Plugin<Project> {
    @Override
    public void apply(Project project) {
        UrlVerifierExtension extension = project.getExtensions().create(
"verification", UrlVerifierExtension.class);
        UrlVerify verifyUrlTask = project.getTasks().create("verifyUrl",
UrlVerify.class);
        verifyUrlTask.getUrl().set(extension.getUrl());
    }
}
```

Every Gradle plugin project should apply the plugin development plugin to reduce boilerplate code. By applying the plugin development plugin, the test source set is preconfigured for the use with TestKit. If we want to use a custom source set for functional tests and leave the default test source set for only unit tests, we can configure the plugin development plugin to look for TestKit tests elsewhere.

build.gradle.kts

```kotlin
gradlePlugin {
    testSourceSets(functionalTest)
}
```

build.gradle

```groovy
gradlePlugin {
    testSourceSets(sourceSets.functionalTest)
}
```

Functional tests for Gradle plugins use an instance of `GradleRunner` to execute the build under test. `GradleRunner` is an API provided by TestKit which internally uses the Tooling API to execute the build. The following example applies the plugin to the build script under test, configures the extension and executes the build with the task `verifyUrl`. Please see the TestKit documentation to get more familiar with the functionality of TestKit.

UrlVerifierPluginFunctionalTest.groovy

```groovy
package org.myorg

import org.gradle.testkit.runner.GradleRunner
import spock.lang.Specification
import spock.lang.TempDir

import static org.gradle.testkit.runner.TaskOutcome.SUCCESS

class UrlVerifierPluginFunctionalTest extends Specification {
    @TempDir File testProjectDir
    File buildFile

    def setup() {
        buildFile = new File(testProjectDir, 'build.gradle')
        buildFile << """
            plugins {
                id 'org.myorg.url-verifier'
            }
        """
    }

    def "can successfully configure URL through extension and verify it"() {
        buildFile << """
            verification {
                url = 'https://www.google.com/'
            }
        """

        when:
        def result = GradleRunner.create()
            .withProjectDir(testProjectDir)
            .withArguments('verifyUrl')
            .withPluginClasspath()
            .build()

        then:
        result.output.contains("Successfully resolved URL
'https://www.google.com/'")
        result.task(":verifyUrl").outcome == SUCCESS
    }
}
```

==== IDE integration

TestKit determines the plugin classpath by running a specific Gradle task. You will need to execute the `assemble` task to initially generate the plugin classpath or to reflect changes to it even when running TestKit-based functional tests from the IDE.

Some IDEs provide a convenience option to delegate the "test classpath generation and execution" to the build. In IntelliJ you can find this option under *Preferences... > Build, Execution, Deployment > Build Tools > Gradle > Runner > Delegate IDE build/run actions to gradle.*
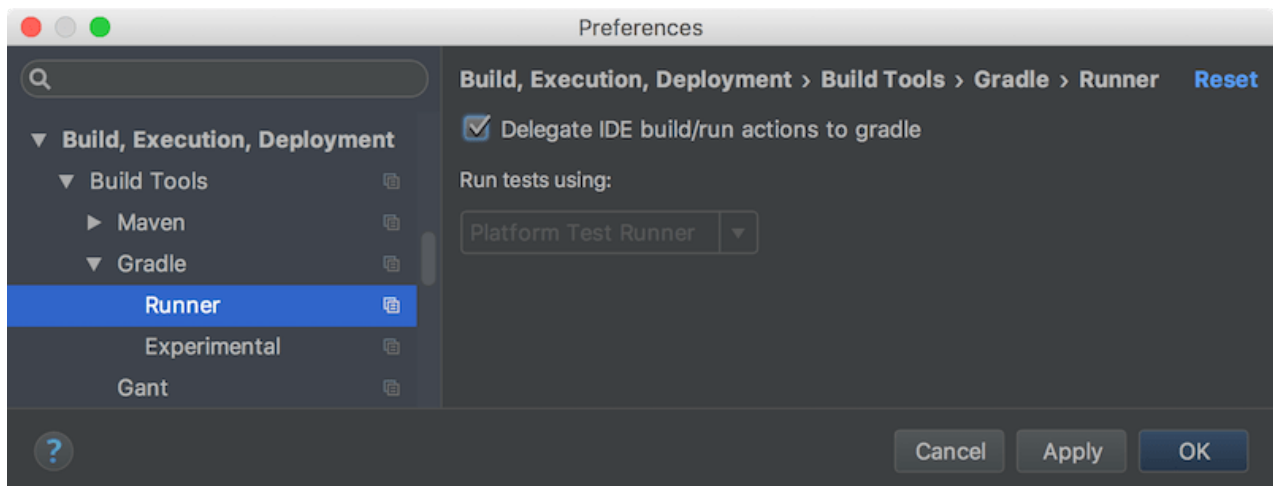
= Publishing Plugins to the Gradle Plugin Portal :portal: Gradle Plugin Portal :plugin: Greeting Plugin :publishplugin: Plugin Publishing Plugin :plugin-reference-documentation: reference documentation of the {publishplugin}

Publishing a plugin is the main way to make it available for others to use. One approach is to publish the plugin to a private repository, which is common when you want to restrict who can use it. But if you want the plugin to be available to anyone in the world, i.e. public, then you should publish it to the {portal}, a centralized, searchable repository dedicated to Gradle plugins.

This section will show you how to use the {publishplugin} to publish plugins to the {portal} using a convenient DSL. Taking this approach eliminates a large number of configuration steps and provides a number of checks to validate that your plugin meets the criteria enforced by the {portal}.

== Start with an existing Gradle plugin project

You will need an existing plugin project for this tutorial. If you don't have your own, you may use the Greeting plugin sample.

Don't worry about cluttering up the {portal} with a trivial example plugin: trying to publish this plugin will safely fail with a permission error.

== Create an account on the {portal}

If you have never published a plugin to the {portal} before, you first need to create an account there. This consists of three steps:

1. Create an account
2. Create an API key
3. Add your API key to your Gradle configuration

Start by going to the registration page — which looks like the image below – and creating an account.
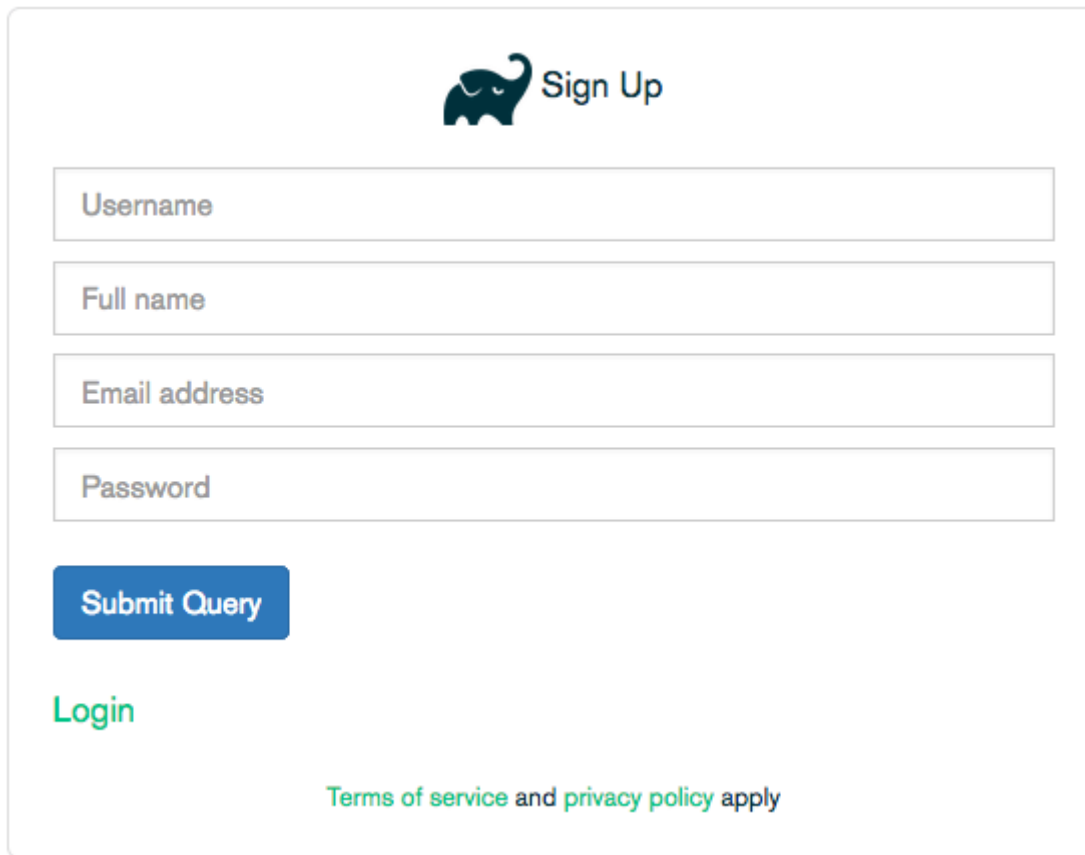
Figure 12. Registration page

Follow the instructions on that page. Once you have logged in, you can get your API key via the "API Keys" tab of your profile page.

Figure 13. API keys is the third tab

It is common practice to copy and paste the text into your $HOME/.gradle/gradle.properties file, but you can also place it in any other valid location. All that the plugin requires is that `gradle.publish.key` and `gradle.publish.secret` are available as project properties when the appropriate Plugin Portal tasks are executed.

If you are concerned about placing your credentials in `gradle.properties`, investigate use of

Seauc Credentials plugin or the Gradle Credentials plugin.

Once you have the API key you can publish as many plugins as you like.

== Add the {publishplugin} to the project

Add the {publishplugin} to the `plugins` block.

build.gradle.kts

```
plugins {
    id("com.gradle.plugin-publish") version "1.2.1"
}
```

build.gradle

```
plugins {
    id 'com.gradle.plugin-publish' version '1.2.1'
}
```

The latest version of the {publishplugin} can be found on the {portal}.

NOTE	Since version 1.0.0 the Plugin Publish Plugin automatically applies the Java Gradle Plugin Development Plugin (assists with developing Gradle plugins) and the Maven Publish Plugin (generates plugin publication metadata). If using older versions of the Plugin Publish Plugin, these helper plugins need to be applied explicitly.

== Configure the {publishplugin}

The first thing to do when configuring the publication of your plugins is to specify the common properties that apply to all of them. This includes their identity plus the sources and documentation related to them. This will help people browsing the portal find more information about your plugins and learn how to contribute to their development.

build.gradle.kts

```
group = "io.github.johndoe" ①
version = "1.0" ②

gradlePlugin { ③
    website = "<substitute your project website>" ④
    vcsUrl = "<uri to project source repository>" ⑤

    // ... ⑥
}
```

build.gradle

```
group = 'io.github.johndoe' ①
version = '1.0'      ②

gradlePlugin { ③
    website = '<substitute your project website>' ④
    vcsUrl = '<uri to project source repository>' ⑤

    // ... ⑥
}
```

① Make sure your project has a `group` set which is used to identify the artifacts (jar and metadata) you publish for your plugins in the repository of the {portal} and which is descriptive of the plugin author or the organization the plugins belong too.

② Set the version of your project, which will also be used as the version of your plugins.

③ Use the `gradlePlugin` block provided by the [Java Gradle Plugin Development Plugin](#) to configure further options of your plugin publication.

④ Set the website for your plugin's project.

⑤ Provide the source repository URI so that others can find it, if they want to contribute.

⑥ Set specific properties for each of the plugins you want to publish; see next section.

Next you need to define the specific plugins you intend to publish. Their most important property is their `id`, as that both uniquely identifies plugins on the {portal} and prevents namespace clashes between different plugin authors.

NOTE	If you would like to associate your plugin with a particular organization, you also set the ID based on that organization's domain using the reverse-domain pattern used for Java packages, for example `org.example.greeting`. If the plugin doesn't belong to any specific organization, then the plugin ID should be associated with the author, for example by using the author's GitHub ID in a reverse domain pattern, like `io.github.johndoe`. Remember that the plugin id and project group should match, i.e. have the same top level namespace.

build.gradle.kts

```
gradlePlugin { ①
    // ... ②

    plugins { ③
        create("greetingsPlugin") { ④
            id = "<your plugin identifier>" ⑤
            displayName = "<short displayable name for plugin>" ⑥
            description = "<human-readable description of what your plugin is
about>" ⑦
            tags = listOf("tags", "for", "your", "plugins") ⑧
            implementationClass = "<your plugin class>"
        }
    }
}
```

```
gradlePlugin { ①
    // ... ②

    plugins { ③
        greetingsPlugin { ④
            id = '<your plugin identifier>' ⑤
            displayName = '<short displayable name for plugin>' ⑥
            description = '<human-readable description of what your plugin is
about>' ⑦
            tags.set(['tags', 'for', 'your', 'plugins']) ⑧
            implementationClass = '<your plugin class>'
        }
    }
}
```

① Plugin specific configuration also goes into the `gradlePlugin` block.

② This is where we previously added global properties.

③ Each plugin you publish will have its own block inside `plugins`.

④ The name of a plugin block needs to be unique for each plugin you are publishing; this is a property used only locally by your build and will not be part of the publication.

⑤ Set the unique `id` of the plugin, as it will be identified in the publication.

⑥ Set the plugin name in human-readable form.

⑦ Set a description to be displayed on the portal. It provides useful information to people who might want to use your plugin.

⑧ Specifies the categories your plugin covers. Makes the plugin more likely to be discovered by people needing its functionality.

As an example consider the configuration for the GradleTest plugin, which is already published to the {portal}.

build.gradle.kts

```
gradlePlugin {
    website = "https://github.com/ysb33r/gradleTest"
    vcsUrl = "https://github.com/ysb33r/gradleTest.git"
    plugins {
        create("gradletestPlugin") {
            id = "org.ysb33r.gradletest"
            displayName = "Plugin for compatibility testing of Gradle plugins"
            description = "A plugin that helps you test your plugin against a
variety of Gradle versions"
            tags = listOf("testing", "integrationTesting", "compatibility")
            implementationClass = "org.ysb33r.gradle.gradletest.GradleTestPlugin"
        }
    }
}
```

build.gradle

```
gradlePlugin {
    website = 'https://github.com/ysb33r/gradleTest'
    vcsUrl = 'https://github.com/ysb33r/gradleTest.git'
    plugins {
        gradletestPlugin {
            id = 'org.ysb33r.gradletest'
            displayName = 'Plugin for compatibility testing of Gradle plugins'
            description = 'A plugin that helps you test your plugin against a
variety of Gradle versions'
            tags.addAll('testing', 'integrationTesting', 'compatibility')
            implementationClass = 'org.ysb33r.gradle.gradletest.GradleTestPlugin'
        }
    }
}
```

If you browse the associated page on the {portal} for the GradleTest plugin, you will see how the specified metadata is displayed.

org.ysb33r.gradletest ←——————— gradlePlugin.plugins.gradletestPlugin.id

Owner: 🔅 Schalk Cronjé

A plugin that helps you test your plugin against a variety of Gradle versions ←——— gradlePlugin.plugins.gradletestPlugin.description

https://gitlab.com/ysb33rOrg/gradleTest ←——————— gradlePlugin.website

#testing   #integrationtesting   #compatibility ←————— gradlePlugin.plugins.gradletestPlugin.tags

> ## Version 3.0.0-alpha.2 (latest)
>
> Created 11 October 2021.
>
> A plugin that helps you test your plugin against a variety of Gradle versions

Figure 14. GradleTest plugin metadata on the {portal}

=== Sources & Javadoc ===

The Plugin Publish Plugin automatically generates and publishes the Javadoc and sources JARs for your plugin publication.

=== Sign artifacts ===

Starting from version 1.0.0 of Plugin Publish Plugin, signing of published plugin artifacts has been made automatic. To enable it, all that's needed is to apply the `signing` plugin in your build.

=== Shadow dependencies ===

Starting from version 1.0.0 of Plugin Publish Plugin, shadowing the dependencies of your plugin (ie. publishing it as a fat jar) has been made automatic. To enable it, all that's needed is to apply the `com.github.johnrengelman.shadow` plugin in your build.

== Publish your plugin to a local repository

To check how the artifacts of your published plugin look, or to use it only locally or internal in your company, you can publish it to any maven repository, including a local folder. For that, you only need to configure repositories for publishing. Then you can run the `publish` task to publish your plugin to all repositories you have defined (but not the {portal}).

build.gradle.kts

```kotlin
publishing {
    repositories {
        maven {
            name = "localPluginRepository"
            url = uri("../local-plugin-repository")
        }
    }
}
```

build.gradle

```groovy
publishing {
    repositories {
        maven {
            name = 'localPluginRepository'
            url = '../local-plugin-repository'
        }
    }
}
```

To use the repository in another build, you have to add it to the repositories of the `pluginManagement {}` block in your `settings.gradle(.kts)` file.

Publish your plugin to the Plugin Portal

Publish the plugin by using the `publishPlugin` task.

```
$ ./gradlew publishPlugins
```

You can validate your plugins before actually publishing them using the `--validate-only` flag:

```
$ ./gradlew publishPlugins --validate-only
```

If you have not configured your {portal} key and secret values in your `gradle.properties` file, you can specify them on the command-line

```
$ ./gradlew publishPlugins -Pgradle.publish.key=<key>
-Pgradle.publish.secret=<secret>
```

NOTE	If you attempt to publish the example Greeting Plugin with the ID used in this section, you will encounter a permission failure. That's expected and ensures that the portal won't be overrun with multiple experimental and duplicate greeting-type plugins.

Consume the published plugin

Once you successfully publish a plugin it won't immediately appear on the Portal. It also needs to pass an approval process, which is manual and relatively slow for the initial version of your plugin, but is fully automatic for subsequent versions. For further details see here.

Once your plugin is approved, you'll be able to find instructions for its use at a URL of the form **https://plugins.gradle.org/plugin/<your-plugin-id>**. For example, the Greeting Plugin example is already on the portal at https://plugins.gradle.org/plugin/org.example.greeting.

OTHER DEVELOPING GRADLE TOPICS

Developing Custom Gradle Types

There are several different kinds of "add-ons" to Gradle that you can develop, such as plugins, tasks, project extensions or artifact transforms, that are all implemented as classes and other types that can run on the JVM. This chapter discusses some of the features and concepts that are common to these types. You can use these features to help implement custom Gradle types and provide a consistent DSL for your users.

This chapter applies to the following types:

- Plugin types.

- Task types.

- Artifact transform parameters types.

- Worker API work action parameters types.

- Extension objects created using `ExtensionContainer.create()`, for example a project extension registered by a plugin.

- Objects created using `ObjectFactory.newInstance()`.

- Objects created for a managed nested property.

- Elements of a `NamedDomainObjectContainer`.

Configuration using properties

The custom Gradle types that you implement often hold some configuration that you want to make available to build scripts and other plugins. For example, a download task may have configuration that specifies the URL to download from and the file system location to write the result to.

Managed properties

Gradle provides its own *managed properties* concept that allows you to declare each property as an abstract getter (Java, Groovy) or an abstract property (Kotlin). Gradle then provides the implementation for such a property automatically. It is called a *managed property*, as Gradle takes care of managing the state of the property. A property may be *mutable*, meaning that it has both a `get()` method and `set()` method, or *read-only*, meaning that it has only a `get()` method. *Read-only* properties are also called *providers*.

Mutable managed properties

To declare a mutable managed property, add an abstract getter method of type `Property<T>` - where `T` can be any serializable type or a fully Gradle managed type. (See the list further down for more specific property types.) The property must not have any setter methods. Here is an example of a task type with an `uri` property of type `URI`:

Download.java

```java
public abstract class Download extends DefaultTask {

    @Input
    public abstract Property<URI> getUri(); // abstract getter of type Property<T>

    @TaskAction
    void run() {
        System.out.println("Downloading " + getUri().get()); // Use the `uri` property
    }
}
```

Note that for a property to be considered a mutable managed property, the property's getter methods must be `abstract` and have `public` or `protected` visibility. The property type must be one of the following:

- `Property<T>`
- `RegularFileProperty`
- `DirectoryProperty`
- `ListProperty<T>`
- `SetProperty<T>`
- `MapProperty<K, V>`
- `ConfigurableFileCollection`
- `ConfigurableFileTree`
- `DomainObjectSet<T>`
- `NamedDomainObjectContainer<T>`
- `ExtensiblePolymorphicDomainObjectContainer<T>`

Gradle creates values for managed properties in the same way as ObjectFactory.

==== Read-only managed properties

To declare a read-only managed property, also called provider, add a getter method of type `Provider<T>`. The method implementation then needs to derive the value, for example from other properties.

Here is an example of a task type with a `uri` provider that is derived from a `location` property:

Download.java

```java
public abstract class Download extends DefaultTask {
    @Input
    public abstract Property<String> getLocation();

    @Internal
    public Provider<URI> getUri() {
        return getLocation().map(l -> URI.create("https://" + l));
    }

    @TaskAction
    void run() {
        System.out.println("Downloading " + getUri().get());  // Use the `uri`
provider (read-only property)
    }
}
```

==== Read-only managed nested properties

To declare a read-only managed nested property, add an abstract getter method for the property to the type annotated with @Nested. The property should not have any setter methods. Gradle provides an implementation for the getter method, and also creates a value for the property. The nested type is also treated as a custom type, and can use the features discussed in this chapter.

This pattern is useful when a custom type has a nested complex type which has the same lifecycle. If the lifecycle is different, consider using `Property<NestedType>` instead.

Here is an example of a task type with a `resource` property. The `Resource` type is also a custom Gradle type and defines some managed properties:

Download.java

```java
public abstract class Download extends DefaultTask {
    @Nested
    public abstract Resource getResource(); // Use an abstract getter method annotated with @Nested

    @TaskAction
    void run() {
        // Use the `resource` property
        System.out.println("Downloading https://" + getResource().getHostName().get() + "/" + getResource().getPath().get());
    }
}

public interface Resource {
    @Input
    Property<String> getHostName();
    @Input
    Property<String> getPath();
}
```

Note that for a property to be considered a read-only managed nested property, the property's getter methods must be `abstract` and have `public` or `protected` visibility. The property must not have any setter methods. In addition, the property getter must be annotated with `@Nested`.

==== Read-only managed "name" property

If the type contains an abstract property called "name" of type `String`, Gradle provides an implementation for the getter method, and extends each constructor with a "name" parameter, which comes before all other constructor parameters. If the type is an interface, Gradle will provide a constructor with a single "name" parameter and `@Inject` semantics.

You can have your type implement or extend the Named interface, which defines such a read-only "name" property.

=== Managed types

A *managed type* is an abstract class or interface with no fields and whose properties are all managed. That is, it is a type whose state is entirely managed by Gradle.

A *named managed type* is a managed type that additionally has an abstract property "name" of type `String`. Named managed types are especially useful as the element type of NamedDomainObjectContainer (see below).

Resource.java

```java
public interface Resource {
    @Input
    Property<String> getHostName();
    @Input
    Property<String> getPath();
}
```

Java bean properties.

Sometimes you may see properties implemented in the Java bean property style. That is, they do not use a `Property<T>` or `Provider<T>` types but are instead implemented with concrete setter and getter methods (or corresponding conveniences in Groovy or Kotlin). This style of property definition is legacy in Gradle and is discouraged. Properties in Gradle's core plugins that are still of this style will be migrated to managed properties in future versions.

DSL support and extensibility

When Gradle creates an instance of a custom type, it *decorates* the instance to mix-in DSL and extensibility support.

Each decorated instance implements ExtensionAware, and so can have extension objects attached to it.

Note that plugins and the elements of containers created using Project.container() are currently not decorated, due to backwards compatibility issues.

Service injection

Gradle provides a number of useful services that can be used by custom Gradle types. For example, the WorkerExecutor service can be used by a task to run work in parallel, as seen in the worker API section. The services are made available through *service injection*.

Available services

The following services are available for injection:

- ObjectFactory - Allows model objects to be created. See [nested_objects] for more details.

- ProjectLayout - Provides access to key project locations. See lazy configuration for more details. This service is unavailable in Worker API actions.

- BuildLayout - Provides access to important locations for a Gradle build. This service is only available for injection in settings plugins.

- ProviderFactory - Creates `Provider` instances. See lazy configuration for more details.

- WorkerExecutor - Allows a task to run work in parallel. See the worker API for more details.

- FileSystemOperations - Allows a task to run operations on the filesystem such as deleting files, copying files or syncing directories.

- ArchiveOperations - Allows a task to run operations on archive files such as ZIP or TAR files.

- ExecOperations - Allows a task to run external processes with dedicated support for running external `java` programs.

- ToolingModelBuilderRegistry - Allows a plugin to registers a Gradle tooling API model.

Out of the above, `ProjectLayout` and `WorkerExecutor` services are only available for injection in

project plugins.

=== Constructor injection

There are 2 ways that an object can receive the services that it needs. The first option is to add the service as a parameter of the class constructor. The constructor must be annotated with the `javax.inject.Inject` annotation. Gradle uses the declared type of each constructor parameter to determine the services that the object requires. The order of the constructor parameters and their names are not significant and can be whatever you like.

Here is an example that shows a task type that receives an `ObjectFactory` via its constructor:

Download.java

```java
public class Download extends DefaultTask {
    private final DirectoryProperty outputDirectory;

    // Inject an ObjectFactory into the constructor
    @Inject
    public Download(ObjectFactory objectFactory) {
        // Use the factory
        outputDirectory = objectFactory.directoryProperty();
    }

    @OutputDirectory
    public DirectoryProperty getOutputDirectory() {
        return outputDirectory;
    }

    @TaskAction
    void run() {
        // ...
    }
}
```

=== Property injection

Alternatively, a service can be injected by adding a property getter method annotated with the `javax.inject.Inject` annotation to the class. This can be useful, for example, when you cannot change the constructor of the class due to backwards compatibility constraints. This pattern also allows Gradle to defer creation of the service until the getter method is called, rather than when the instance is created. This can help with performance. Gradle uses the declared return type of the getter method to determine the service to make available. The name of the property is not significant and can be whatever you like.

The property getter method must be `public` or `protected`. The method can be `abstract` or, in cases where this isn't possible, can have a dummy method body. The method body is discarded.

Here is an example that shows a task type that receives a two services via property getter methods:

Download.java

```java
public abstract class Download extends DefaultTask {
    // Use an abstract getter method
    @Inject
    protected abstract ObjectFactory getObjectFactory();

    // Alternatively, use a getter method with a dummy implementation
    @Inject
    protected WorkerExecutor getWorkerExecutor() {
        // Method body is ignored
        throw new UnsupportedOperationException();
    }

    @TaskAction
    void run() {
        WorkerExecutor workerExecutor = getWorkerExecutor();
        ObjectFactory objectFactory = getObjectFactory();
        // Use the executor and factory ...
    }
}
```

Creating objects explicitly

NOTE	Prefer letting Gradle create objects automatically by using managed properties.

A custom Gradle type can use the ObjectFactory service to create instances of Gradle types to use for its property values. These instances can make use of the features discussed in this chapter, allowing you to create objects and a nested DSL.

In the following example, a project extension receives an `ObjectFactory` instance through its constructor. The constructor uses this to create a nested `Resource` object (also a custom Gradle type) and makes this object available through the `resource` property.

DownloadExtension.java

```java
public class DownloadExtension {
    // A nested instance
    private final Resource resource;

    @Inject
    public DownloadExtension(ObjectFactory objectFactory) {
        // Use an injected ObjectFactory to create a Resource object
        resource = objectFactory.newInstance(Resource.class);
    }

    public Resource getResource() {
        return resource;
    }
}

public interface Resource {
    Property<URI> getUri();
}
```

Collection types

Gradle provides types for maintaining collections of objects, intended to work well to extends Gradle's DSLs and provide useful features such as lazy configuration.

NamedDomainObjectContainer

A NamedDomainObjectContainer manages a set of objects, where each element has a name associated with it. The container takes care of creating and configuring the elements, and provides a DSL that build scripts can use to define and configure elements. It is intended to hold objects which are themselves configurable, for example a set of custom Gradle objects.

Gradle uses `NamedDomainObjectContainer` type extensively throughout the API. For example, the `project.tasks` object used to manage the tasks of a project is a `NamedDomainObjectContainer<Task>`.

You can create a container instance using the ObjectFactory service, which provides the ObjectFactory.domainObjectContainer() method. This is also available using the Project.container() method, however in a custom Gradle type it's generally better to use the injected `ObjectFactory` service instead of passing around a `Project` instance.

You can also create a container instance using a read-only managed property, described above.

In order to use a type with any of the `domainObjectContainer()` methods, it must either

- be a named managed type; or
- expose a property named "name" as the unique, and constant, name for the object. The `domainObjectContainer(Class)` variant of the method creates new instances by calling the constructor of the class that takes a string argument, which is the desired name of the object.

Objects created this way are treated as custom Gradle types, and so can make use of the features discussed in this chapter, for example service injection or managed properties.

See the above link for `domainObjectContainer()` method variants that allow custom instantiation strategies.

DownloadExtension.java

```java
public interface DownloadExtension {
    NamedDomainObjectContainer<Resource> getResources();
}

public interface Resource {
    // Type must have a read-only 'name' property
    String getName();

    Property<URI> getUri();

    Property<String> getUserName();
}
```

For each container property, Gradle automatically adds a block to the Groovy and Kotlin DSL that you can use to configure the contents of the container:

build.gradle.kts

```kotlin
plugins {
    id("org.gradle.sample.download")
}

download {
    // Can use a block to configure the container contents
    resources {
        register("gradle") {
            uri = uri("https://gradle.org")
        }
    }
}
```

build.gradle

```groovy
plugins {
    id("org.gradle.sample.download")
}

download {
    // Can use a block to configure the container contents
    resources {
        register('gradle') {
            uri = uri('https://gradle.org')
        }
    }
}
```

=== ExtensiblePolymorphicDomainObjectContainer

An ExtensiblePolymorphicDomainObjectContainer is a `NamedDomainObjectContainer` that allows you to define instantiation strategies for different types of objects.

You can create an instance using the ObjectFactory.polymorphicDomainObjectContainer() method.

=== NamedDomainObjectSet

A NamedDomainObjectSet holds a set of configurable objects, where each element has a name associated with it. This is similar to `NamedDomainObjectContainer`, however a `NamedDomainObjectSet` doesn't manage the objects in the collection. They need to be created and added manually.

You can create an instance using the ObjectFactory.namedDomainObjectSet() method.

=== NamedDomainObjectList

A NamedDomainObjectList holds a list of configurable objects, where each element has a name associated with it. This is similar to `NamedDomainObjectContainer`, however a `NamedDomainObjectList` doesn't manage the objects in the collection. They need to be created and added manually.

You can create an instance using the ObjectFactory.namedDomainObjectList() method.

=== DomainObjectSet

A DomainObjectSet simply holds a set of configurable objects. Compared to `NamedDomainObjectContainer`, a `DomainObjectSet` doesn't manage the objects in the collection. They need to be created and added manually.

You can create an instance using the ObjectFactory.domainObjectSet() method.

= Shared Build Services

Sometimes, it is useful for several tasks to share some state or resource. For example, tasks might share a cache of pre-computed values in order to do their work faster. Or tasks might do their work using a web service or database instance.

Gradle allows you to declare *build services* to represent this state. A build service is simply an object that holds the state for tasks to use. Gradle takes care of the service lifecycle, and will create the service instance only when it is required and clean it up once it is no longer required. Gradle can also optionally take care of coordinating access to the build service, so that no more than a specified number of tasks can use the service concurrently.

== Implementing a build service

To implement a build service, create an abstract class that implements BuildService. Define methods on this type that you'd like tasks to use. A build service implementation is treated as a custom Gradle type and can use any of the features available to custom Gradle types.

A build service can optionally take parameters, which Gradle injects into the service instance when creating it. To provide parameters, you define an abstract class (or interface) that holds the parameters. The parameters type must implement (or extend) BuildServiceParameters. The service implementation can access the parameters using `this.getParameters()`. The parameters type is also a custom Gradle type.

When the build service does not require any parameters, you can use BuildServiceParameters.None as the parameters type.

A build service implementation can also optionally implement `AutoCloseable`, in which case Gradle will call the build service instance's `close()` method when it discards the service instance. This happens some time between completion of the last task that uses the build service and the end of the build.

Here is an example of a service that takes parameters and is closeable:

WebServer.java

```java
import org.gradle.api.file.DirectoryProperty;
import org.gradle.api.provider.Property;
import org.gradle.api.services.BuildService;
import org.gradle.api.services.BuildServiceParameters;

import java.net.URI;
import java.net.URISyntaxException;

public abstract class WebServer implements BuildService<WebServer.Params>,
AutoCloseable {

    // Some parameters for the web server
    interface Params extends BuildServiceParameters {
        Property<Integer> getPort();

        DirectoryProperty getResources();
    }

    private final URI uri;

    public WebServer() throws URISyntaxException {
        // Use the parameters
        int port = getParameters().getPort().get();
        uri = new URI(String.format("https://localhost:%d/", port));

        // Start the server ...

        System.out.println(String.format("Server is running at %s", uri));
    }

    // A public method for tasks to use
    public URI getUri() {
        return uri;
    }

    @Override
    public void close() {
        // Stop the server ...
    }
}
```

Note that you should **not** implement the BuildService.getParameters() method, as Gradle will provide an implementation of this.

A build service implementation must be thread-safe, as it will potentially be used by multiple tasks concurrently.

Using a build service from a task

To use a build service from a task, you need to:

1. Add a property to the task of type `Property<MyServiceType>`.

2. Either annotate the property with `@Internal` or `@ServiceReference` (since 8.0).

3. Assign a shared build service provider to the property (optional, when using `@ServiceReference(<serviceName>)`).

4. Declare the association between the task and the service so Gradle can properly honor the build service lifecycle and its usage constraints (also optional, when using `@ServiceReference`).

Note that using a service with any other annotation is currently not supported. For example, it is currently not possible to mark a service as an input to a task.

Annotating a shared build service property with `@Internal`

When you annotate a shared build service property with `@Internal`, you need to do two more things:

1. Explicitly assign a build service provider obtained when registering the service with BuildServiceRegistry.registerIfAbsent() to the property.

2. Explicitly declare the association between the task and the service via the Task.usesService.

Here is an example of a task that consumes the previous service via a property annotated with `@Internal`:

Download.java

```java
import org.gradle.api.DefaultTask;
import org.gradle.api.file.RegularFileProperty;
import org.gradle.api.provider.Property;
import org.gradle.api.tasks.Internal;
import org.gradle.api.tasks.OutputFile;
import org.gradle.api.tasks.TaskAction;

import java.net.URI;

public abstract class Download extends DefaultTask {
    // This property provides access to the service instance
    @Internal
    abstract Property<WebServer> getServer();

    @OutputFile
    abstract RegularFileProperty getOutputFile();

    @TaskAction
    public void download() {
        // Use the server to download a file
        WebServer server = getServer().get();
        URI uri = server.getUri().resolve("somefile.zip");
        System.out.println(String.format("Downloading %s", uri));
    }
}
```

Annotating a shared build service property with @ServiceReference

| NOTE | The @ServiceReference annotation is an incubating API and is subject to changing in a future release. |

Otherwise, when you annotate a shared build service property with @ServiceReference, there is no need to explicitly declare the association between the task and the service; also, if you provide a service name to the annotation, and a shared build service is registered with that name, it will be automatically assigned to the property when the task is created.

Here is an example of a task that consumes the previous service via a property annotated with @ServiceReference:

Download.java

```java
import org.gradle.api.DefaultTask;
import org.gradle.api.file.RegularFileProperty;
import org.gradle.api.provider.Property;
import org.gradle.api.services.ServiceReference;
import org.gradle.api.tasks.OutputFile;
import org.gradle.api.tasks.TaskAction;

import java.net.URI;

public abstract class Download extends DefaultTask {
    // This property provides access to the service instance
    @ServiceReference("web")
    abstract Property<WebServer> getServer();

    @OutputFile
    abstract RegularFileProperty getOutputFile();

    @TaskAction
    public void download() {
        // Use the server to download a file
        WebServer server = getServer().get();
        URI uri = server.getUri().resolve("somefile.zip");
        System.out.println(String.format("Downloading %s", uri));
    }
}
```

== Registering a build service and connecting it to tasks

To create a build service, you register the service instance using the BuildServiceRegistry.registerIfAbsent() method. Registering the service does not create the service instance. This happens on demand when a task first uses the service. If no task uses the service during a build, the service instance will not be created.

Currently, build services are scoped to a build, rather than to a project, and these services are available to be shared by the tasks of all projects. You can access the registry of shared build services via `Project.getGradle().getSharedServices()`.

Here is an example of a plugin that registers the previous service when the task property consuming the service is annotated with `@Internal`:

DownloadPlugin.java

```java
import org.gradle.api.Plugin;
import org.gradle.api.Project;
import org.gradle.api.provider.Provider;

public class DownloadPlugin implements Plugin<Project> {
    public void apply(Project project) {
        // Register the service
        Provider<WebServer> serviceProvider = project.getGradle().getSharedServices()
.registerIfAbsent("web", WebServer.class, spec -> {
            // Provide some parameters
            spec.getParameters().getPort().set(5005);
        });

        project.getTasks().register("download", Download.class, task -> {
            // Connect the service provider to the task
            task.getServer().set(serviceProvider);
            // Declare the association between the task and the service
            task.usesService(serviceProvider);
            task.getOutputFile().set(project.getLayout().getBuildDirectory().file(
"result.zip"));
        });
    }
}
```

The plugin registers the service and receives a `Provider<WebService>` back. This provider can be connected to task properties to pass the service to the task. Note that for a task property annotated with `@Internal`, the task property needs to (1) be explicitly assigned with the provider obtained during registation, and (2) you must tell Gradle the task uses the service via Task.usesService.

Compare that to when the task property consuming the service is annotated with `@ServiceReference`:

```java
import org.gradle.api.Plugin;
import org.gradle.api.Project;
import org.gradle.api.provider.Provider;

public class DownloadPlugin implements Plugin<Project> {
    public void apply(Project project) {
        // Register the service
        project.getGradle().getSharedServices().registerIfAbsent("web", WebServer
.class, spec -> {
            // Provide some parameters
            spec.getParameters().getPort().set(5005);
        });

        project.getTasks().register("download", Download.class, task -> {
            task.getOutputFile().set(project.getLayout().getBuildDirectory().file(
"result.zip"));
        });
    }
}
```

As you can see, there is no need to assign the build service provider to the task, nor to declare explicitly that the task uses the service.

=== Using shared build services from configuration actions

Generally, build services are intended to be used by tasks, as they usually represent some state that is potentially expensive to create, and you should avoid using them at configuration time. However, sometimes it can make sense to use the service at configuration time. This is possible, simply call `get()` on the provider.

== Other ways of using a build service

In addition to using a build service from a task, you can use a build service from a worker API action, an artifact transform or another build service. To do this, pass the build service `Provider` as a parameter of the consuming action or service, in the same way you pass other parameters to the action or service.

For example, to pass a `MyServiceType` service to worker API action, you might add a property of type `Property<MyServiceType>` to the action's parameters object and then connect the `Provider<MyServiceType>` that you receive when registering the service to this property.

Download.java

```java
import org.gradle.api.DefaultTask;
import org.gradle.api.provider.Property;
import org.gradle.api.services.ServiceReference;
import org.gradle.api.tasks.TaskAction;
import org.gradle.workers.WorkAction;
import org.gradle.workers.WorkParameters;
import org.gradle.workers.WorkQueue;
import org.gradle.workers.WorkerExecutor;

import javax.inject.Inject;
import java.net.URI;

public abstract class Download extends DefaultTask {

    public static abstract class DownloadWorkAction implements WorkAction
<DownloadWorkAction.Parameters> {
        interface Parameters extends WorkParameters {
            // This property provides access to the service instance from the work
action

            abstract Property<WebServer> getServer();
        }

        @Override
        public void execute() {
            // Use the server to download a file
            WebServer server = getParameters().getServer().get();
            URI uri = server.getUri().resolve("somefile.zip");
            System.out.println(String.format("Downloading %s", uri));
        }
    }

    @Inject
    abstract public WorkerExecutor getWorkerExecutor();

    // This property provides access to the service instance from the task
    @ServiceReference("web")
    abstract Property<WebServer> getServer();

    @TaskAction
    public void download() {
        WorkQueue workQueue = getWorkerExecutor().noIsolation();
        workQueue.submit(DownloadWorkAction.class, parameter -> {
            parameter.getServer().set(getServer());
        });
    }
}
```

Currently, it is not possible to use a build service with a worker API action that uses ClassLoader or process isolation modes.

== Concurrent access to the service

You can constrain concurrent execution when you register the service, by using the `Property` object returned from BuildServiceSpec.getMaxParallelUsages(). When this property has no value, which is the default, Gradle does not constrain access to the service. When this property has a value > 0, Gradle will allow no more than the specified number of tasks to use the service concurrently.

| IMPORTANT | When the consuming task property is annotated with `@Internal`, for the constraint to take effect, the build service **must** be registered with the consuming task via Task.usesService(Provider<? extends BuildService<?>>). This is not necessary if, instead, the consuming property is annotated with `@ServiceReference`. |

== Receiving information about task execution

A build service can be used to receive events as tasks are executed. To do this, create and register a build service that implements OperationCompletionListener:

TaskEventsService.java

```
import org.gradle.api.services.BuildService;
import org.gradle.api.services.BuildServiceParameters;
import org.gradle.tooling.events.FinishEvent;
import org.gradle.tooling.events.OperationCompletionListener;
import org.gradle.tooling.events.task.TaskFinishEvent;

public abstract class TaskEventsService implements BuildService<
BuildServiceParameters.None>,
    OperationCompletionListener { ①

    @Override
    public void onFinish(FinishEvent finishEvent) {
        if (finishEvent instanceof TaskFinishEvent) { ②
            // Handle task finish event...
        }
    }
}
```

① Implement the `OperationCompletionListener` interface in addition to the `BuildService` interface.

② Check if the finish event is a TaskFinishEvent.

Then, in the plugin you can use the methods on the BuildEventsListenerRegistry service to start receiving events:

TaskEventsPlugin.java

```java
import org.gradle.api.Plugin;
import org.gradle.api.Project;
import org.gradle.api.provider.Provider;
import org.gradle.build.event.BuildEventsListenerRegistry;

import javax.inject.Inject;

public abstract class TaskEventsPlugin implements Plugin<Project> {
    @Inject
    public abstract BuildEventsListenerRegistry getEventsListenerRegistry(); ①

    @Override
    public void apply(Project project) {
        Provider<TaskEventsService> serviceProvider =
            project.getGradle().getSharedServices().registerIfAbsent(
                "taskEvents", TaskEventsService.class, spec -> {}); ②

        getEventsListenerRegistry().onTaskCompletion(serviceProvider); ③
    }
}
```

① Use service injection to obtain an instance of the `BuildEventsListenerRegistry`.

② Register the build service as usual.

③ Use the service `Provider` to subscribe the build service to build events.

= Dataflow Actions

NOTE	The dataflow actions support is an incubating feature, and the details described here may change.

A preferred way of executing work in a Gradle build is using a task. However, there are some kinds of work that do not fit tasks well, for example, custom handling of the build failure. What if you want to play a cheerful sound when the build succeeds and a sad one when it fails? This work piece has to process the task execution result, so it cannot be a task itself.

The dataflow actions API provides a way to schedule such kind of work. A dataflow action is a parameterized isolated piece of work that becomes eligible for execution as soon as all of its input parameters become available.

== Implementing a dataflow action

The first step is to implement the action itself. To do that you create a class implementing FlowAction interface. The `execute` method must be implemented because this is where the work happens. An action implementation is treated as a custom Gradle type and can use any of the features available to custom Gradle types. In particular, some Gradle services can be injected into the implementation.

A dataflow action may accept parameters. To provide parameters, you define an abstract class (or interface) to hold the parameters. The parameters type must implement (or extend) FlowParameters. The action implementation gets the parameters as an argument of the `execute` method. The parameters type is also a custom Gradle type.

When the action requires no parameters, you can use FlowParameters.None as the parameters type.

Here is an example of a dataflow action that takes a shared build service and a file path as parameters.

SoundPlay.java

```java
package org.gradle.sample.sound;

import org.gradle.api.flow.FlowAction;
import org.gradle.api.flow.FlowParameters;
import org.gradle.api.provider.Property;
import org.gradle.api.services.ServiceReference;
import org.gradle.api.tasks.Input;

import java.io.File;

public abstract class SoundPlay implements FlowAction<SoundPlay.Parameters> {
    interface Parameters extends FlowParameters {
        @ServiceReference ①
        Property<SoundService> getSoundService();

        @Input ②
        Property<File> getMediaFile();
    }

    @Override
    public void execute(Parameters parameters) {
        parameters.getSoundService().get().playSoundFile(parameters.getMediaFile().
get());
    }
}
```

① Parameters in the parameter type must be annotated. If a parameter is annotated with `@ServiceReference` then a suitable shared build service implementation is automatically assigned to the parameter when the action is created, according to the usual rules.

② All other parameters must be annotated with `@Input`.

== Lifecycle event providers

Besides the usual value providers, Gradle provides dedicated providers for build lifecycle events, like build completion. These providers are intended for dataflow actions and provide additional ordering guarantees when used as inputs. The ordering also applies if you derive a provider from the event provider by, for example, calling `map` or `flatMap`. You can obtain these providers from the FlowProviders class.

WARNING	If you're not using a lifecycle event provider as an input to the dataflow action, then the exact timing when the action is executed is not defined and may change in the next version of Gradle.

== Supplying the action for execution

You should not create `FlowAction` objects manually. Instead, you request to execute them in the appropriate scope of `FlowScope`. When doing that, you can configure the parameters for task to use.

SoundFeedbackPlugin.java

```java
package org.gradle.sample.sound;

import org.gradle.api.Plugin;
import org.gradle.api.flow.FlowProviders;
import org.gradle.api.flow.FlowScope;
import org.gradle.api.initialization.Settings;

import javax.inject.Inject;
import java.io.File;

public abstract class SoundFeedbackPlugin implements Plugin<Settings> {
    @Inject
    protected abstract FlowScope getFlowScope(); ①

    @Inject
    protected abstract FlowProviders getFlowProviders(); ①

    @Override
    public void apply(Settings settings) {
        final File soundsDir = new File(settings.getSettingsDir(), "sounds");
        getFlowScope().always( ②
            SoundPlay.class,  ③
            spec ->  ④
                spec.getParameters().getMediaFile().set(
                    getFlowProviders().getBuildWorkResult().map(result -> ⑤
                        new File(
                            soundsDir,
                            result.getFailure().isPresent() ? "sad-trombone.mp3" :
"tada.mp3"
                        )
                    )
                )
        );
    }
}
```

① Use service injection to obtain `FlowScope` and `FlowProviders` instances. They are available for project and settings plugins.

② Use an appropriate scope to run your actions. As the name suggests, actions in the `always` scope are executed every time the build runs.

③ Specify the class that implements the action.

④ Use the spec argument to configure the action parameters.

⑤ A lifecycle event provider can be mapped into something else while preserving the action ordering.

As a result, when you run the build, and it completes successfully, the action will play the "tada" sound. If the build fails at configuration or execution time, then you'll hear "sad-trombone" — assuming, of course, that build configuration proceeds far enough for the action to be registered.

= Testing Build Logic with TestKit

The Gradle TestKit (a.k.a. just TestKit) is a library that aids in testing Gradle plugins and build logic generally. At this time, it is focused on *functional* testing. That is, testing build logic by exercising it as part of a programmatically executed build. Over time, the TestKit will likely expand to facilitate other kinds of tests.

== Usage

To use the TestKit, include the following in your plugin's build:

build.gradle.kts

```
dependencies {
    testImplementation(gradleTestKit())
}
```

build.gradle

```
dependencies {
    testImplementation gradleTestKit()
}
```

The `gradleTestKit()` encompasses the classes of the TestKit, as well as the Gradle Tooling API client. It does not include a version of JUnit, TestNG, or any other test execution framework. Such a dependency must be explicitly declared.

build.gradle.kts

```
dependencies {
    testImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}

tasks.named<Test>("test") {
    useJUnitPlatform()
}
```

build.gradle

```
dependencies {
    testImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}

tasks.named('test', Test) {
    useJUnitPlatform()
}
```

Functional testing with the Gradle runner

The GradleRunner facilitates programmatically executing Gradle builds, and inspecting the result.

A contrived build can be created (e.g. programmatically, or from a template) that exercises the "logic under test". The build can then be executed, potentially in a variety of ways (e.g. different combinations of tasks and arguments). The correctness of the logic can then be verified by asserting the following, potentially in combination:

- The build's output;
- The build's logging (i.e. console output);
- The set of tasks executed by the build and their results (e.g. FAILED, UP-TO-DATE etc.).

After creating and configuring a runner instance, the build can be executed via the GradleRunner.build() or GradleRunner.buildAndFail() methods depending on the anticipated outcome.

The following demonstrates the usage of the Gradle runner in a Java JUnit test:

Example: Using GradleRunner with Java and JUnit

BuildLogicFunctionalTest.java

```java
import org.gradle.testkit.runner.BuildResult;
import org.gradle.testkit.runner.GradleRunner;
import org.junit.jupiter.api.BeforeEach;
import org.junit.jupiter.api.Test;
import org.junit.jupiter.api.io.TempDir;

import java.io.BufferedWriter;
import java.io.File;
import java.io.FileWriter;
import java.io.IOException;

import static org.gradle.testkit.runner.TaskOutcome.SUCCESS;
import static org.junit.jupiter.api.Assertions.assertEquals;
import static org.junit.jupiter.api.Assertions.assertTrue;

public class BuildLogicFunctionalTest {

    @TempDir File testProjectDir;
    private File settingsFile;
    private File buildFile;

    @BeforeEach
    public void setup() {
        settingsFile = new File(testProjectDir, "settings.gradle");
        buildFile = new File(testProjectDir, "build.gradle");
    }
```

```java
    @Test
    public void testHelloWorldTask() throws IOException {
        writeFile(settingsFile, "rootProject.name = 'hello-world'");
        String buildFileContent = "task helloWorld {" +
                                  "    doLast {" +
                                  "        println 'Hello world!'" +
                                  "    }" +
                                  "}";
        writeFile(buildFile, buildFileContent);

        BuildResult result = GradleRunner.create()
            .withProjectDir(testProjectDir)
            .withArguments("helloWorld")
            .build();

        assertTrue(result.getOutput().contains("Hello world!"));
        assertEquals(SUCCESS, result.task(":helloWorld").getOutcome());
    }

    private void writeFile(File destination, String content) throws IOException {
        BufferedWriter output = null;
        try {
            output = new BufferedWriter(new FileWriter(destination));
            output.write(content);
        } finally {
            if (output != null) {
                output.close();
            }
        }
    }
}
```

Any test execution framework can be used.

As Gradle build scripts can also be written in the Groovy programming language, it is often a productive choice to write Gradle functional tests in Groovy. Furthermore, it is recommended to use the (Groovy based) Spock test execution framework as it offers many compelling features over the use of JUnit.

The following demonstrates the usage of the Gradle runner in a Groovy Spock test:

=== Example: Using GradleRunner with Groovy and Spock

BuildLogicFunctionalTest.groovy

```groovy
import org.gradle.testkit.runner.GradleRunner
import static org.gradle.testkit.runner.TaskOutcome.*
import spock.lang.TempDir
import spock.lang.Specification

class BuildLogicFunctionalTest extends Specification {
    @TempDir File testProjectDir
    File settingsFile
    File buildFile

    def setup() {
        settingsFile = new File(testProjectDir, 'settings.gradle')
        buildFile = new File(testProjectDir, 'build.gradle')
    }

    def "hello world task prints hello world"() {
        given:
        settingsFile << "rootProject.name = 'hello-world'"
        buildFile << """
            task helloWorld {
                doLast {
                    println 'Hello world!'
                }
            }
        """

        when:
        def result = GradleRunner.create()
            .withProjectDir(testProjectDir)
            .withArguments('helloWorld')
            .build()

        then:
        result.output.contains('Hello world!')
        result.task(":helloWorld").outcome == SUCCESS
    }
}
```

It is a common practice to implement any custom build logic (like plugins and task types) that is more complex in nature as external classes in a standalone project. The main driver behind this approach is bundle the compiled code into a JAR file, publish it to a binary repository and reuse it across various projects.

== Getting the plugin-under-test into the test build

The GradleRunner uses the Tooling API to execute builds. An implication of this is that the builds are executed in a separate process (i.e. not the same process executing the tests). Therefore, the test build does not share the same classpath or classloaders as the test process

> and the code under test is not implicitly available to the test build.

GradleRunner supports the same range of Gradle versions as the Tooling API. The supported versions are defined in the compatibility matrix.

Builds with older Gradle versions *may* still work but there are no guarantees.

> Starting with version 2.13, Gradle provides a conventional mechanism to inject the code under test into the test build.
>
> === Automatic injection with the Java Gradle Plugin Development plugin
>
> The Java Gradle Plugin development plugin can be used to assist in the development of Gradle plugins. Starting with Gradle version 2.13, the plugin provides a direct integration with TestKit. When applied to a project, the plugin automatically adds the `gradleTestKit()` dependency to the `testApi` configuration. Furthermore, it automatically generates the classpath for the code under test and injects it via GradleRunner.withPluginClasspath() for any `GradleRunner` instance created by the user. It's important to note that the mechanism currently *only* works if the plugin under test is applied using the plugins DSL. If the target Gradle version is prior to 2.8, automatic plugin classpath injection is not performed.
>
> The plugin uses the following conventions for applying the TestKit dependency and injecting the classpath:
>
> - Source set containing code under test: `sourceSets.main`
> - Source set used for injecting the plugin classpath: `sourceSets.test`
>
> Any of these conventions can be reconfigured with the help of the class GradlePluginDevelopmentExtension.
>
> The following Groovy-based sample demonstrates how to automatically inject the plugin classpath by using the standard conventions applied by the Java Gradle Plugin Development plugin.

build.gradle.kts

```
plugins {
    groovy
    `java-gradle-plugin`
}

dependencies {
    testImplementation("org.spockframework:spock-core:2.2-groovy-3.0") {
        exclude(group = "org.codehaus.groovy")
    }
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}
```

build.gradle

```
plugins {
    id 'groovy'
    id 'java-gradle-plugin'
}

dependencies {
    testImplementation('org.spockframework:spock-core:2.2-groovy-3.0') {
        exclude group: 'org.codehaus.groovy'
    }
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}
```

=== Example: Automatically injecting the code under test classes into test builds

src/test/groovy/org/gradle/sample/BuildLogicFunctionalTest.groovy

```groovy
def "hello world task prints hello world"() {
    given:
    settingsFile << "rootProject.name = 'hello-world'"
    buildFile << """
        plugins {
            id 'org.gradle.sample.helloworld'
        }
    """

    when:
    def result = GradleRunner.create()
        .withProjectDir(testProjectDir)
        .withArguments('helloWorld')
        .withPluginClasspath()
        .build()

    then:
    result.output.contains('Hello world!')
    result.task(":helloWorld").outcome == SUCCESS
}
```

The following build script demonstrates how to reconfigure the conventions provided by the Java Gradle Plugin Development plugin for a project that uses a custom `Test` source set.

| NOTE | A new configuration DSL for modeling the below `functionalTest` suite is available via the incubating JVM Test Suite plugin. |

build.gradle.kts

```
plugins {
    groovy
    `java-gradle-plugin`
}

val functionalTest = sourceSets.create("functionalTest")
val functionalTestTask = tasks.register<Test>("functionalTest") {
    group = "verification"
    testClassesDirs = functionalTest.output.classesDirs
    classpath = functionalTest.runtimeClasspath
    useJUnitPlatform()
}

tasks.check {
    dependsOn(functionalTestTask)
}

gradlePlugin {
    testSourceSets(functionalTest)
}

dependencies {
    "functionalTestImplementation"("org.spockframework:spock-core:2.2-groovy-3.0")
    {
        exclude(group = "org.codehaus.groovy")
    }
    "functionalTestRuntimeOnly"("org.junit.platform:junit-platform-launcher")
}
```

build.gradle

```groovy
plugins {
    id 'groovy'
    id 'java-gradle-plugin'
}

def functionalTest = sourceSets.create('functionalTest')
def functionalTestTask = tasks.register('functionalTest', Test) {
    group = 'verification'
    testClassesDirs = sourceSets.functionalTest.output.classesDirs
    classpath = sourceSets.functionalTest.runtimeClasspath
    useJUnitPlatform()
}

tasks.named("check") {
    dependsOn functionalTestTask
}

gradlePlugin {
    testSourceSets sourceSets.functionalTest
}

dependencies {
    functionalTestImplementation('org.spockframework:spock-core:2.2-groovy-3.0') {
        exclude group: 'org.codehaus.groovy'
    }
    functionalTestRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}
```

Controlling the build environment

The runner executes the test builds in an isolated environment by specifying a dedicated "working directory" in a directory inside the JVM's temp directory (i.e. the location specified by the `java.io.tmpdir` system property, typically `/tmp`). Any configuration in the default Gradle User Home (e.g. `~/.gradle/gradle.properties`) is not used for test execution. The TestKit does not expose a mechanism for fine grained control of all aspects of the environment (e.g., JDK). Future versions of the TestKit will provide improved configuration options.

The TestKit uses dedicated daemon processes that are automatically shut down after test execution.

The dedicated working directory is not deleted by the runner after the build. The TestKit provides two ways to specify a location that is regularly cleaned, such as the project's build folder:

- The `org.gradle.testkit.dir` system property;
- The GradleRunner.withTestKitDir(file testKitDir) method.

The Gradle version used to test

The Gradle runner requires a Gradle distribution in order to execute the build. The TestKit does not depend on all of Gradle's implementation.

By default, the runner will attempt to find a Gradle distribution based on where the `GradleRunner` class was loaded from. That is, it is expected that the class was loaded from a Gradle distribution, as is the case when using the `gradleTestKit()` dependency declaration.

When using the runner as part of tests *being executed by Gradle* (e.g. executing the `test` task of a plugin project), the same distribution used to execute the tests will be used by the runner. When using the runner as part of tests *being executed by an IDE*, the same distribution of Gradle that was used when importing the project will be used. This means that the plugin will effectively be tested with the same version of Gradle that it is being built with.

Alternatively, a different and specific version of Gradle to use can be specified by the any of the following `GradleRunner` methods:

- GradleRunner.withGradleVersion(java.lang.String)
- GradleRunner.withGradleInstallation(java.io.File)
- GradleRunner.withGradleDistribution(java.net.URI)

This can potentially be used to test build logic across Gradle versions. The following demonstrates a cross-version compatibility test written as Groovy Spock test:

Example: Specifying a Gradle version for test execution

```groovy
import org.gradle.testkit.runner.GradleRunner
import static org.gradle.testkit.runner.TaskOutcome.*
import spock.lang.TempDir
import spock.lang.Specification

class BuildLogicFunctionalTest extends Specification {
    @TempDir File testProjectDir
    File settingsFile
    File buildFile

    def setup() {
        settingsFile = new File(testProjectDir, 'settings.gradle')
        buildFile = new File(testProjectDir, 'build.gradle')
    }

    def "can execute hello world task with Gradle version #gradleVersion"() {
        given:
        buildFile << """
            task helloWorld {
                doLast {
                    logger.quiet 'Hello world!'
                }
            }
        """
        settingsFile << ""

        when:
        def result = GradleRunner.create()
            .withGradleVersion(gradleVersion)
            .withProjectDir(testProjectDir)
            .withArguments('helloWorld')
            .build()

        then:
        result.output.contains('Hello world!')
        result.task(":helloWorld").outcome == SUCCESS

        where:
        gradleVersion << ['5.0', '6.0.1']
    }
}
```

=== Feature support when testing with different Gradle versions

It is possible to use the GradleRunner to execute builds with Gradle 1.0 and later. However, some runner features are not supported on earlier versions. In such cases, the runner will throw an exception when attempting to use the feature.

The following table lists the features that are sensitive to the Gradle version being used.

Table 7. Gradle version compatibility

Feature	Minimum Version	Description
Inspecting executed tasks	2.5	Inspecting the executed tasks, using BuildResult.getTasks() and similar methods.
Plugin classpath injection	2.8	Injecting the code under test viaGradleRunner.withPluginClasspath(java.lang.Iterable).
Inspecting build output in debug mode	2.9	Inspecting the build's text output when run in debug mode, using BuildResult.getOutput().
Automatic plugin classpath injection	2.13	Injecting the code under test automatically via GradleRunner.withPluginClasspath() by applying the Java Gradle Plugin Development plugin.
Setting environment variables to be used by the build.	3.5	The Gradle Tooling API only supports setting environment variables in later versions.

== Debugging build logic

The runner uses the Tooling API to execute builds. An implication of this is that the builds are executed in a separate process (i.e. not the same process executing the tests). Therefore, executing your *tests* in debug mode does not allow you to debug your build logic as you may expect. Any breakpoints set in your IDE will be not be tripped by the code being exercised by the test build.

The TestKit provides two different ways to enable the debug mode:

- Setting "`org.gradle.testkit.debug`" system property to `true` for the JVM *using* the `GradleRunner` (i.e. not the build being executed with the runner);
- Calling the GradleRunner.withDebug(boolean) method.

The system property approach can be used when it is desirable to enable debugging support without making an adhoc change to the runner configuration. Most IDEs offer the capability to set JVM system properties for test execution, and such a feature can be used to set this system property.

== Testing with the Build Cache

To enable the Build Cache in your tests, you can pass the `--build-cache` argument to GradleRunner or use one of the other methods described in Enable the build cache. You can then check for the task outcome TaskOutcome.FROM_CACHE when your plugin's custom task is cached. This outcome is only valid for Gradle 3.5 and newer.

=== Example: Testing cacheable tasks

BuildLogicFunctionalTest.groovy

```groovy
def "cacheableTask is loaded from cache"() {
    given:
    buildFile << """
        plugins {
            id 'org.gradle.sample.helloworld'
        }
    """

    when:
    def result = runner()
        .withArguments( '--build-cache', 'cacheableTask')
        .build()

    then:
    result.task(":cacheableTask").outcome == SUCCESS

    when:
    new File(testProjectDir, 'build').deleteDir()
    result = runner()
        .withArguments( '--build-cache', 'cacheableTask')
        .build()

    then:
    result.task(":cacheableTask").outcome == FROM_CACHE
}
```

Note that TestKit re-uses a Gradle User Home between tests (see GradleRunner.withTestKitDir(java.io.File)) which contains the default location for the local build cache. For testing with the build cache, the build cache directory should be cleaned between tests. The easiest way to accomplish this is to configure the local build cache to use a temporary directory.

=== Example: Clean build cache between tests

```
@TempDir File testProjectDir
File buildFile
File localBuildCacheDirectory

def setup() {
    localBuildCacheDirectory = new File(testProjectDir, 'local-cache')
    buildFile = new File(testProjectDir,'settings.gradle') << """
        buildCache {
            local {
                directory '${localBuildCacheDirectory.toURI()}'
            }
        }
    """
    buildFile = new File(testProjectDir,'build.gradle')
}
```

Using Ant from Gradle

Gradle provides excellent integration with Ant. You can use individual Ant tasks or entire Ant builds in your Gradle builds. In fact, you will find that it's far easier and more powerful using Ant tasks in a Gradle build script, than it is to use Ant's XML format. You could even use Gradle simply as a powerful Ant task scripting tool.

Ant can be divided into two layers. The first layer is the Ant language. It provides the syntax for the `build.xml` file, the handling of the targets, special constructs like macrodefs, and so on. In other words, everything except the Ant tasks and types. Gradle understands this language, and allows you to import your Ant `build.xml` directly into a Gradle project. You can then use the targets of your Ant build as if they were Gradle tasks.

The second layer of Ant is its wealth of Ant tasks and types, like `javac`, `copy` or `jar`. For this layer Gradle provides integration simply by relying on Groovy, and the fantastic `AntBuilder`.

Finally, since build scripts are Groovy scripts, you can always execute an Ant build as an external process. Your build script may contain statements like: `"ant clean compile".execute()`. [3]

You can use Gradle's Ant integration as a path for migrating your build from Ant to Gradle. For example, you could start by importing your existing Ant build. Then you could move your dependency declarations from the Ant script to your build file. Finally, you could move your tasks across to your build file, or replace them with some of Gradle's plugins. This process can be done in parts over time, and you can have a working Gradle build during the entire process.

WARNING	Ant integration is not fully compatible with the configuration cache. Using Task.ant to run Ant task in the task action may work, but importing the Ant build is not supported.

Using Ant tasks and types in your build

In your build script, a property called `ant` is provided by Gradle. This is a reference to an `AntBuilder` instance. This `AntBuilder` is used to access Ant tasks, types and properties from your build script. There is a very simple mapping from Ant's `build.xml` format to Groovy, which is explained below.

You execute an Ant task by calling a method on the `AntBuilder` instance. You use the task name as the method name. For example, you execute the Ant `echo` task by calling the `ant.echo()` method. The attributes of the Ant task are passed as Map parameters to the method. Below is an example of the `echo` task. Notice that we can also mix Groovy code and the Ant task markup. This can be extremely powerful.

build.gradle.kts

```
tasks.register("hello") {
    doLast {
        val greeting = "hello from Ant"
        ant.withGroovyBuilder {
            "echo"("message" to greeting)
        }
    }
}
```

build.gradle

```
tasks.register('hello') {
    doLast {
        String greeting = 'hello from Ant'
        ant.echo(message: greeting)
    }
}
```

Output of `gradle hello`

```
> gradle hello

> Task :hello
[ant:echo] hello from Ant

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

You pass nested text to an Ant task by passing it as a parameter of the task method call. In this example, we pass the message for the `echo` task as nested text:

build.gradle.kts

```
tasks.register("hello") {
    doLast {
        ant.withGroovyBuilder {
            "echo"("message" to "hello from Ant")
        }
    }
}
```

build.gradle

```
tasks.register('hello') {
    doLast {
        ant.echo('hello from Ant')
    }
}
```

Output of `gradle hello`

```
> gradle hello

> Task :hello
[ant:echo] hello from Ant

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

You pass nested elements to an Ant task inside a closure. Nested elements are defined in the same way as tasks, by calling a method with the same name as the element we want to define.

```
tasks.register("zip") {
    doLast {
        ant.withGroovyBuilder {
            "zip"("destfile" to "archive.zip") {
                "fileset"("dir" to "src") {
                    "include"("name" to "**.xml")
                    "exclude"("name" to "**.java")
                }
            }
        }
    }
}
```

```
tasks.register('zip') {
    doLast {
        ant.zip(destfile: 'archive.zip') {
            fileset(dir: 'src') {
                include(name: '**.xml')
                exclude(name: '**.java')
            }
        }
    }
}
```

You can access Ant types in the same way that you access tasks, using the name of the type as the method name. The method call returns the Ant data type, which you can then use directly in your build script. In the following example, we create an Ant `path` object, then iterate over the contents of it.

build.gradle.kts

```kotlin
import org.apache.tools.ant.types.Path

tasks.register("list") {
    doLast {
        val path = ant.withGroovyBuilder {
            "path" {
                "fileset"("dir" to "libs", "includes" to "*.jar")
            }
        } as Path
        path.list().forEach {
            println(it)
        }
    }
}
```

build.gradle

```groovy
tasks.register('list') {
    doLast {
        def path = ant.path {
            fileset(dir: 'libs', includes: '*.jar')
        }
        path.list().each {
            println it
        }
    }
}
```

More information about `AntBuilder` can be found in 'Groovy in Action' 8.4 or at the Groovy Wiki.

=== Using custom Ant tasks in your build

To make custom tasks available in your build, you can use the `taskdef` (usually easier) or `typedef` Ant task, just as you would in a `build.xml` file. You can then refer to the custom Ant task as you would a built-in Ant task.

```kotlin
tasks.register("check") {
    val checkstyleConfig = file("checkstyle.xml")
    doLast {
        ant.withGroovyBuilder {
            "taskdef"("resource" to
"com/puppycrawl/tools/checkstyle/ant/checkstyle-ant-task.properties") {
                "classpath" {
                    "fileset"("dir" to "libs", "includes" to "*.jar")
                }
            }
            "checkstyle"("config" to checkstyleConfig) {
                "fileset"("dir" to "src")
            }
        }
    }
}
```

```groovy
tasks.register('check') {
    def checkstyleConfig = file('checkstyle.xml')
    doLast {
        ant.taskdef(resource: 'com/puppycrawl/tools/checkstyle/ant/checkstyle-ant-
task.properties') {
            classpath {
                fileset(dir: 'libs', includes: '*.jar')
            }
        }
        ant.checkstyle(config: checkstyleConfig) {
            fileset(dir: 'src')
        }
    }
}
```

You can use Gradle's dependency management to assemble the classpath to use for the custom tasks. To do this, you need to define a custom configuration for the classpath, then add some dependencies to the configuration. This is described in more detail in Declaring Dependencies.

build.gradle.kts

```kotlin
val pmd = configurations.create("pmd")

dependencies {
    pmd(group = "pmd", name = "pmd", version = "4.2.5")
}
```

build.gradle

```groovy
configurations {
    pmd
}

dependencies {
    pmd group: 'pmd', name: 'pmd', version: '4.2.5'
}
```

To use the classpath configuration, use the `asPath` property of the custom configuration.

build.gradle.kts

```kotlin
tasks.register("check") {
    doLast {
        ant.withGroovyBuilder {
            "taskdef"("name" to "pmd",
                        "classname" to "net.sourceforge.pmd.ant.PMDTask",
                        "classpath" to pmd.asPath)
            "pmd"("shortFilenames" to true,
                    "failonruleviolation" to true,
                    "rulesetfiles" to file("pmd-rules.xml").toURI().toString()) {
                "formatter"("type" to "text", "toConsole" to "true")
                "fileset"("dir" to "src")
            }
        }
    }
}
```

build.gradle

```
tasks.register('check') {
    doLast {
        ant.taskdef(name: 'pmd',
                    classname: 'net.sourceforge.pmd.ant.PMDTask',
                    classpath: configurations.pmd.asPath)
        ant.pmd(shortFilenames: 'true',
                failonruleviolation: 'true',
                rulesetfiles: file('pmd-rules.xml').toURI().toString()) {
            formatter(type: 'text', toConsole: 'true')
            fileset(dir: 'src')
        }
    }
}
```

Importing an Ant build

You can use the `ant.importBuild()` method to import an Ant build into your Gradle project. When you import an Ant build, each Ant target is treated as a Gradle task. This means you can manipulate and execute the Ant targets in exactly the same way as Gradle tasks.

build.gradle.kts

```
ant.importBuild("build.xml")
```

build.gradle

```
ant.importBuild 'build.xml'
```

build.xml

```
<project>
    <target name="hello">
        <echo>Hello, from Ant</echo>
    </target>
</project>
```

```
> gradle hello

> Task :hello
[ant:echo] Hello, from Ant

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

You can add a task which depends on an Ant target:

build.gradle.kts

```
ant.importBuild("build.xml")

tasks.register("intro") {
    dependsOn("hello")
    doLast {
        println("Hello, from Gradle")
    }
}
```

build.gradle

```
ant.importBuild 'build.xml'

tasks.register('intro') {
    dependsOn("hello")
    doLast {
        println 'Hello, from Gradle'
    }
}
```

Output of `gradle intro`

```
> gradle intro

> Task :hello
[ant:echo] Hello, from Ant

> Task :intro
Hello, from Gradle

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

Or, you can add behaviour to an Ant target:

build.gradle.kts

```
ant.importBuild("build.xml")

tasks.named("hello") {
    doLast {
        println("Hello, from Gradle")
    }
}
```

build.gradle

```
ant.importBuild 'build.xml'

hello {
    doLast {
        println 'Hello, from Gradle'
    }
}
```

```
> gradle hello

> Task :hello
[ant:echo] Hello, from Ant
Hello, from Gradle

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

It is also possible for an Ant target to depend on a Gradle task:

build.gradle.kts

```kotlin
ant.importBuild("build.xml")

tasks.register("intro") {
    doLast {
        println("Hello, from Gradle")
    }
}
```

build.gradle

```groovy
ant.importBuild 'build.xml'

tasks.register('intro') {
    doLast {
        println 'Hello, from Gradle'
    }
}
```

build.xml

```xml
<project>
    <target name="hello" depends="intro">
        <echo>Hello, from Ant</echo>
    </target>
</project>
```

```
> gradle hello

> Task :intro
Hello, from Gradle

> Task :hello
[ant:echo] Hello, from Ant

BUILD SUCCESSFUL in 0s
2 actionable tasks: 2 executed
```

Sometimes it may be necessary to "rename" the task generated for an Ant target to avoid a naming collision with existing Gradle tasks. To do this, use the AntBuilder.importBuild(java.lang.Object, org.gradle.api.Transformer) method.

build.gradle.kts

```
ant.importBuild("build.xml") { antTargetName ->
    "a-" + antTargetName
}
```

build.gradle

```
ant.importBuild('build.xml') { antTargetName ->
    'a-' + antTargetName
}
```

build.xml

```xml
<project>
    <target name="hello">
        <echo>Hello, from Ant</echo>
    </target>
</project>
```

```
> gradle a-hello

> Task :a-hello
[ant:echo] Hello, from Ant

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

Note that while the second argument to this method should be a Transformer, when programming in Groovy we can simply use a closure instead of an anonymous inner class (or similar) due to Groovy's support for automatically coercing closures to single-abstract-method types.

== Ant properties and references

There are several ways to set an Ant property, so that the property can be used by Ant tasks. You can set the property directly on the `AntBuilder` instance. The Ant properties are also available as a Map which you can change. You can also use the Ant `property` task. Below are some examples of how to do this.

build.gradle.kts

```
ant.setProperty("buildDir", buildDir)
ant.properties.set("buildDir", buildDir)
ant.properties["buildDir"] = buildDir
ant.withGroovyBuilder {
    "property"("name" to "buildDir", "location" to "buildDir")
}
```

build.gradle

```
ant.buildDir = buildDir
ant.properties.buildDir = buildDir
ant.properties['buildDir'] = buildDir
ant.property(name: 'buildDir', location: buildDir)
```

Many Ant tasks set properties when they execute. There are several ways to get the value of these properties. You can get the property directly from the `AntBuilder` instance. The Ant properties are also available as a Map. Below are some examples.

build.xml

```xml
<property name="antProp" value="a property defined in an Ant build"/>
```

build.gradle.kts

```kotlin
println(ant.getProperty("antProp"))
println(ant.properties.get("antProp"))
println(ant.properties["antProp"])
```

build.gradle

```groovy
println ant.antProp
println ant.properties.antProp
println ant.properties['antProp']
```

There are several ways to set an Ant reference:

build.gradle.kts

```kotlin
ant.withGroovyBuilder { "path"("id" to "classpath", "location" to "libs") }
ant.references.set("classpath", ant.withGroovyBuilder { "path"("location" to
"libs") })
ant.references["classpath"] = ant.withGroovyBuilder { "path"("location" to "libs")
}
```

build.gradle

```groovy
ant.path(id: 'classpath', location: 'libs')
ant.references.classpath = ant.path(location: 'libs')
ant.references['classpath'] = ant.path(location: 'libs')
```

build.xml

```xml
<path refid="classpath"/>
```

There are several ways to get an Ant reference:

build.xml

```xml
<path id="antPath" location="libs"/>
```

build.gradle.kts

```kotlin
println(ant.references.get("antPath"))
println(ant.references["antPath"])
```

build.gradle

```groovy
println ant.references.antPath
println ant.references['antPath']
```

== Ant logging

Gradle maps Ant message priorities to Gradle log levels so that messages logged from Ant appear in the Gradle output. By default, these are mapped as follows:

Table 8. Ant message priority mapping

Ant Message Priority	Gradle Log Level
VERBOSE	`DEBUG`
DEBUG	`DEBUG`
INFO	`INFO`
WARN	`WARN`
ERROR	`ERROR`

=== Fine tuning Ant logging

The default mapping of Ant message priority to Gradle log level can sometimes be problematic. For example, there is no message priority that maps directly to the `LIFECYCLE` log level, which is the default for Gradle. Many Ant tasks log messages at the *INFO* priority, which means to expose those messages from Gradle, a build would have to be run with the log level set to `INFO`, potentially logging much more output than is desired.

Conversely, if an Ant task logs messages at too high of a level, to suppress those messages would require the build to be run at a higher log level, such as `QUIET`. However, this could result in other, desirable output being suppressed.

To help with this, Gradle allows the user to fine tune the Ant logging and control the mapping of message priority to Gradle log level. This is done by setting the priority that should map to the default Gradle `LIFECYCLE` log level using the AntBuilder.setLifecycleLogLevel(java.lang.String) method. When this value is set, any Ant message logged at the configured priority or above will be logged at least at `LIFECYCLE`. Any Ant message logged below this priority will be logged at most at `INFO`.

For example, the following changes the mapping such that Ant *INFO* priority messages are exposed at the `LIFECYCLE` log level.

```kotlin
ant.lifecycleLogLevel = AntBuilder.AntMessagePriority.INFO

tasks.register("hello") {
    doLast {
        ant.withGroovyBuilder {
            "echo"("level" to "info", "message" to "hello from info priority!")
        }
    }
}
```

```groovy
ant.lifecycleLogLevel = "INFO"

tasks.register('hello') {
    doLast {
        ant.echo(level: "info", message: "hello from info priority!")
    }
}
```

Output of `gradle hello`

```
> gradle hello

> Task :hello
[ant:echo] hello from info priority!

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

On the other hand, if the `lifecycleLogLevel` was set to *ERROR*, Ant messages logged at the *WARN* priority would no longer be logged at the `WARN` log level. They would now be logged at the `INFO` level and would be suppressed by default.

== API

The Ant integration is provided by AntBuilder.

== **AUTHORING JVM BUILDS**

= Building Java & JVM projects

Gradle uses a convention-over-configuration approach to building JVM-based projects that borrows several conventions from Apache Maven. In particular, it uses the same default directory structure for source files and resources, and it works with Maven-compatible repositories.

We will look at Java projects in detail in this chapter, but most of the topics apply to other supported JVM languages as well, such as Kotlin, Groovy and Scala. If you don't have much experience with building JVM-based projects with Gradle, take a look at the Java samples for step-by-step instructions on how to build various types of basic Java projects.

The example in this section use the Java Library Plugin. However the described features are shared by all JVM plugins. Specifics of the different plugins are available in their dedicated documentation.

TIP	There are a number of hands-on samples that you can explore for Java, Groovy, Scala and Kotlin.

== Introduction

The simplest build script for a Java project applies the Java Library Plugin and optionally sets the project version and selects the Java toolchain to use:

build.gradle.kts

```
plugins {
    `java-library`
}

java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}

version = "1.2.1"
```

build.gradle

```
plugins {
    id 'java-library'
}

java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}

version = '1.2.1'
```

By applying the Java Library Plugin, you get a whole host of features:

- A `compileJava` task that compiles all the Java source files under *src/main/java*

- A `compileTestJava` task for source files under *src/test/java*

- A `test` task that runs the tests from *src/test/java*

- A `jar` task that packages the `main` compiled classes and resources from *src/main/resources* into a single JAR named *<project>-<version>.jar*

- A `javadoc` task that generates Javadoc for the `main` classes

This isn't sufficient to build any non-trivial Java project — at the very least, you'll probably have some file dependencies. But it means that your build script only needs the information that is specific to *your* project.

Although the properties in the example are optional, we recommend that you specify them in your projects. Configuring the toolchain protects against problems with the project being built with

different Java versions. The version string is important for tracking the progression of the project. The project version is also used in archive names by default.

The Java Library Plugin also integrates the above tasks into the standard Base Plugin lifecycle tasks:

- `jar` is attached to `assemble`
- `test` is attached to `check`

The rest of the chapter explains the different avenues for customizing the build to your requirements. You will also see later how to adjust the build for libraries, applications, web apps and enterprise apps.

Declaring your source files via source sets

Gradle's Java support was the first to introduce a new concept for building source-based projects: *source sets*. The main idea is that source files and resources are often logically grouped by type, such as application code, unit tests and integration tests. Each logical group typically has its own sets of file dependencies, classpaths, and more. Significantly, the files that form a source set *don't have to be located in the same directory*!

Source sets are a powerful concept that tie together several aspects of compilation:

- the source files and where they're located
- the compilation classpath, including any required dependencies (via Gradle configurations)
- where the compiled class files are placed

You can see how these relate to one another in this diagram:
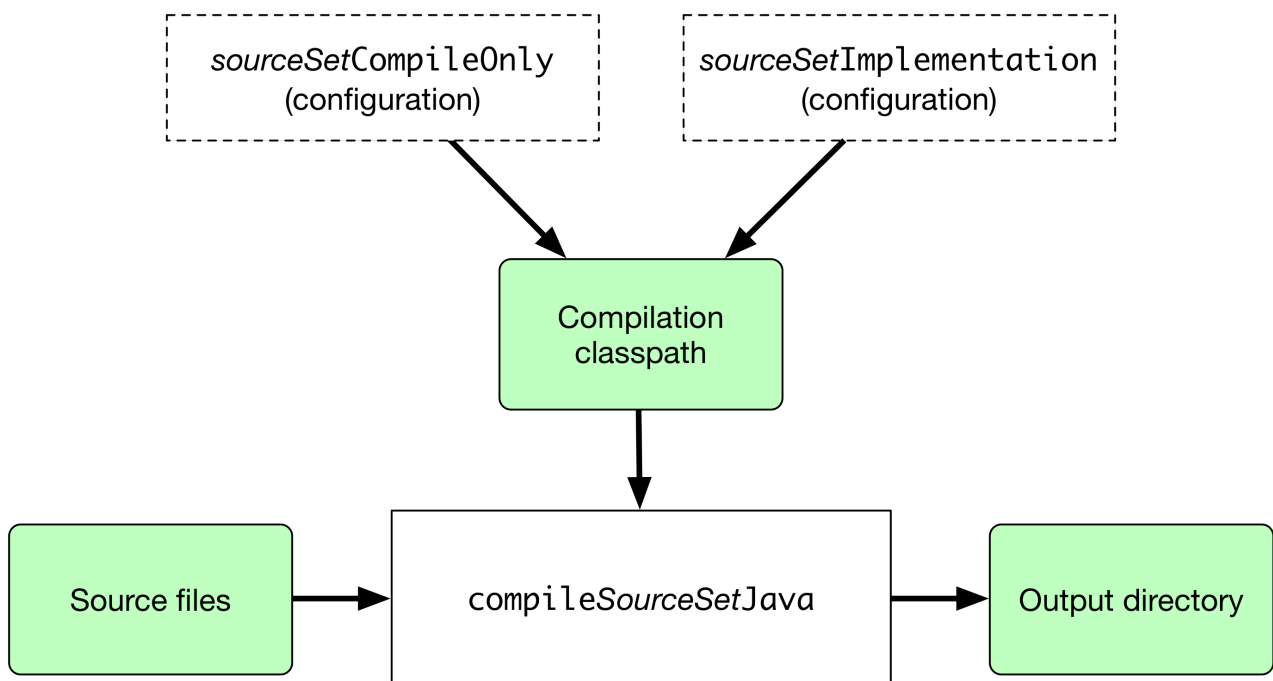
Figure 15. Source sets and Java compilation

The shaded boxes represent properties of the source set itself. On top of that, the Java Library Plugin automatically creates a compilation task for every source set you or a plugin defines — named `compileSourceSetJava` — and several dependency configurations.

The `main` *source set*

Most language plugins, Java included, automatically create a source set called `main`, which is used for the project's production code. This source set is special in that its name is not included in the names of the configurations and tasks, hence why you have just a `compileJava` task and `compileOnly` and `implementation` configurations rather than `compileMainJava`, `mainCompileOnly` and `mainImplementation` respectively.

Java projects typically include resources other than source files, such as properties files, that may need processing — for example by replacing tokens within the files — and packaging within the final JAR. The Java Library Plugin handles this by automatically creating a dedicated task for each defined source set called `process`*SourceSet*`Resources` (or `processResources` for the `main` source set). The following diagram shows how the source set fits in with this task:
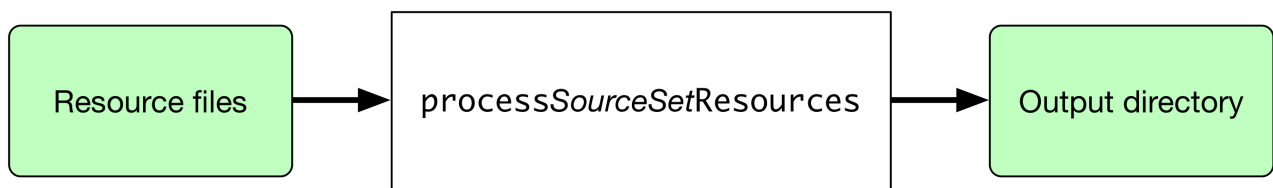
Figure 16. Processing non-source files for a source set

As before, the shaded boxes represent properties of the source set, which in this case comprises the locations of the resource files and where they are copied to.

In addition to the `main` source set, the Java Library Plugin defines a `test` source set that represents the project's tests. This source set is used by the `test` task, which runs the tests. You can learn more about this task and related topics in the Java testing chapter.

Projects typically use this source set for unit tests, but you can also use it for integration, acceptance and other types of test if you wish. The alternative approach is to define a new source set for each of your other test types, which is typically done for one or both of the following reasons:

- You want to keep the tests separate from one another for aesthetics and manageability
- The different test types require different compilation or runtime classpaths or some other difference in setup

You can see an example of this approach in the Java testing chapter, which shows you how to set up integration tests in a project.

You'll learn more about source sets and the features they provide in:

- Customizing file and directory locations
- Configuring Java integration tests

=== Source set configurations

When a source set is created, it also creates a number of configurations as described above. Build logic should **not** attempt to create or access these configurations until they are first created by the source set.

When creating a source set, if one of these automatically created configurations already exists, Gradle will emit a deprecation warning. If the existing configuration's role is different than the role that the source set would have assigned, its role will be mutated to the correct value and another deprecation warning will be emitted.

The build below demonstrates this unwanted behavior.

build.gradle.kts

```
configurations {
    val myCodeCompileClasspath: Configuration by creating
}

sourceSets {
    val myCode: SourceSet by creating
}
```

build.gradle

```
configurations {
    myCodeCompileClasspath
}

sourceSets {
    myCode
}
```

In this case, the following deprecation warning is emitted:

```
When creating configurations during sourceSet custom setup, Gradle found that
configuration customCompileClasspath already exists with permitted usage(s):
    Consumable - this configuration can be selected by another project as a
dependency
    Resolvable - this configuration can be resolved by this project to a set of
files
    Declarable - this configuration can have dependencies added to it
Yet Gradle expected to create it with the usage(s):
    Resolvable - this configuration can be resolved by this project to a set of
files
```

Following two simple best practices will avoid this problem:

1. Don't create configurations with names that will be used by source sets, such as names ending in `Api`, `Implementation`, `ApiElements`, `CompileOnly`, `CompileOnlyApi`, `RuntimeOnly`, `RuntimeClasspath` or `RuntimeElements`. (This list is not exhaustive.)

2. Create any custom source sets prior to any custom configurations.

Remember that any time you reference a configuration within the `configurations` container - with or without supplying an initialization action - Gradle will create the configuration. Sometimes when using the Groovy DSL this creation is not obvious, as in the example below, where `myCustomConfiguration` is created prior to the call to `extendsFrom`.

build.gradle

```
configurations {
    myCustomConfiguration.extendsFrom(implementation)
}
```

For more information see Don't anticipate configuration creation.

== Managing your dependencies

The vast majority of Java projects rely on libraries, so managing a project's dependencies is an important part of building a Java project. Dependency management is a big topic, so we will focus on the basics for Java projects here. If you'd like to dive into the detail, check out the introduction to dependency management.

Specifying the dependencies for your Java project requires just three pieces of information:

- Which dependency you need, such as a name and version
- What it's needed for, e.g. compilation or running
- Where to look for it

The first two are specified in a `dependencies {}` block and the third in a `repositories {}` block. For example, to tell Gradle that your project requires version 3.6.7 of Hibernate Core to compile and run your production code, and that you want to download the library from the Maven Central repository, you can use the following fragment:

build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    implementation("org.hibernate:hibernate-core:3.6.7.Final")
}
```

build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.hibernate:hibernate-core:3.6.7.Final'
}
```

The Gradle terminology for the three elements is as follows:

- *Repository* (ex: `mavenCentral()`) — where to look for the modules you declare as dependencies
- *Configuration* (ex: `implementation`) — a named collection of dependencies, grouped together for a specific goal such as compiling or running a module — a more flexible form of Maven scopes
- *Module coordinate* (ex: `org.hibernate:hibernate-core-3.6.7.Final`) — the ID of the dependency, usually in the form '*<group>*:*<module>*:*<version>*' (or '*<groupId>*:*<artifactId>*:*<version>*' in Maven terminology)

You can find a more comprehensive glossary of dependency management terms here.

As far as configurations go, the main ones of interest are:

- `compileOnly` — for dependencies that are necessary to compile your production code but shouldn't be part of the runtime classpath
- `implementation` (supersedes `compile`) — used for compilation and runtime
- `runtimeOnly` (supersedes `runtime`) — only used at runtime, not for compilation
- `testCompileOnly` — same as `compileOnly` except it's for the tests
- `testImplementation` — test equivalent of `implementation`
- `testRuntimeOnly` — test equivalent of `runtimeOnly`

You can learn more about these and how they relate to one another in the plugin reference chapter.

Be aware that the Java Library Plugin offers two additional configurations — `api` and `compileOnlyApi` — for dependencies that are required for compiling both the module and any modules that depend on it.

Why no `compile` configuration?

The Java Library Plugin has historically used the `compile` configuration for dependencies that are required to both compile and run a project's production code. It is now deprecated, and will issue warnings when used, because it doesn't distinguish between dependencies that impact the public API of a Java library project and those that don't. You can learn more about the importance of this distinction in Building Java libraries.

We have only scratched the surface here, so we recommend that you read the dedicated dependency management chapters once you're comfortable with the basics of building Java projects with Gradle. Some common scenarios that require further reading include:

- Defining a custom Maven- or Ivy-compatible repository
- Using dependencies from a local filesystem directory
- Declaring dependencies with changing (e.g. SNAPSHOT) and dynamic (range) versions
- Declaring a sibling project as a dependency

- Controlling transitive dependencies and their versions
- Testing your fixes to a 3rd-party dependency via composite builds (a better alternative to publishing to and consuming from Maven Local)

You'll discover that Gradle has a rich API for working with dependencies — one that takes time to master, but is straightforward to use for common scenarios.

Compiling your code

Compiling both your production and test code can be trivially easy if you follow the conventions:

1. Put your production source code under the *src/main/java* directory

2. Put your test source code under *src/test/java*

3. Declare your production compile dependencies in the `compileOnly` or `implementation` configurations (see previous section)

4. Declare your test compile dependencies in the `testCompileOnly` or `testImplementation` configurations

5. Run the `compileJava` task for the production code and `compileTestJava` for the tests

Other JVM language plugins, such as the one for Groovy, follow the same pattern of conventions. We recommend that you follow these conventions wherever possible, but you don't have to. There are several options for customization, as you'll see next.

Customizing file and directory locations

Imagine you have a legacy project that uses an *src* directory for the production code and *test* for the test code. The conventional directory structure won't work, so you need to tell Gradle where to find the source files. You do that via source set configuration.

Each source set defines where its source code resides, along with the resources and the output directory for the class files. You can override the convention values by using the following syntax:

build.gradle.kts

```
sourceSets {
    main {
        java {
            setSrcDirs(listOf("src"))
        }
    }

    test {
        java {
            setSrcDirs(listOf("test"))
        }
    }
}
```

build.gradle

```
sourceSets {
    main {
        java {
            srcDirs = ['src']
        }
    }

    test {
        java {
            srcDirs = ['test']
        }
    }
}
```

Now Gradle will only search directly in *src* and *test* for the respective source code. What if you don't want to override the convention, but simply want to *add* an extra source directory, perhaps one that contains some third-party source code you want to keep separate? The syntax is similar:

```
sourceSets {
    main {
        java {
            srcDir("thirdParty/src/main/java")
        }
    }
}
```

```
sourceSets {
    main {
        java {
            srcDir 'thirdParty/src/main/java'
        }
    }
}
```

Crucially, we're using the *method* `srcDir()` here to append a directory path, whereas setting the `srcDirs` property replaces any existing values. This is a common convention in Gradle: setting a property replaces values, while the corresponding method appends values.

You can see all the properties and methods available on source sets in the DSL reference for SourceSet and SourceDirectorySet. Note that `srcDirs` and `srcDir()` are both on SourceDirectorySet.

=== Changing compiler options

Most of the compiler options are accessible through the corresponding task, such as `compileJava` and `compileTestJava`. These tasks are of type JavaCompile, so read the task reference for an up-to-date and comprehensive list of the options.

For example, if you want to use a separate JVM process for the compiler and prevent compilation failures from failing the build, you can use this configuration:

build.gradle.kts

```
tasks.compileJava {
    options.isIncremental = true
    options.isFork = true
    options.isFailOnError = false
}
```

build.gradle

```
compileJava {
    options.incremental = true
    options.fork = true
    options.failOnError = false
}
```

That's also how you can change the verbosity of the compiler, disable debug output in the byte code and configure where the compiler can find annotation processors.

=== Targeting a specific Java version

By default, Gradle will compile Java code to the language level of the JVM running Gradle. If you need to target a specific version of Java when compiling, Gradle provides multiple options:

1. Using Java toolchains is a preferred way to target a language version.
   A toolchain uniformly handles compilation, execution and Javadoc generation, and it can be configured on the project level.

2. Using `release` property is possible starting from Java 10.
   Selecting a Java release makes sure that compilation is done with the configured language level and against the JDK APIs from that Java version.

3. Using `sourceCompatibility` and `targetCompatibility` properties.
   Although not generally advised, these options were historically used to configure the Java version during compilation.

==== Using toolchains

When Java code is compiled using a specific toolchain, the actual compilation is carried out by a compiler of the specified Java version. The compiler provides access to the language features and JDK APIs for the requested Java language version.

In the simplest case, the toolchain can be configured for a project using the `java` extension. This way, not only compilation benefits from it, but also other tasks such as `test` and `javadoc` will also consistently use the same toolchain.

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

You can learn more about this in the Java toolchains guide.

==== Using Java release version

Setting the release flag ensures the specified language level is used regardless of which compiler actually performs the compilation. To use this feature, the compiler must support the requested release version. It is possible to specify an earlier release version while compiling with a more recent toolchain.

Gradle supports using the release flag from Java 10. It can be configured on the compilation task as follows.

build.gradle.kts

```
tasks.compileJava {
    options.release = 7
}
```

build.gradle

```
compileJava {
    options.release = 7
}
```

The release flag provides guarantees similar to toolchains. It validates that the Java sources are not using language features introduced in later Java versions, and also that the code does not access APIs from more recent JDKs. The bytecode produced by the compiler also corresponds to the requested Java version, meaning that the compiled code cannot be executed on older JVMs.

The `release` option of the Java compiler was introduced in Java 9. However, using this option with Gradle is only possible starting with Java 10, due to a bug in Java 9.

==== Using Java compatibility options

| **WARNING** | Using compatibility properties can lead to runtime failures when executing compiled code due to weaker guarantees they provide. Instead, consider using toolchains or the release flag. |

The `sourceCompatibility` and `targetCompatibility` options correspond to the Java compiler options `-source` and `-target`. They are considered a legacy mechanism for targeting a specific Java version. However, these options do not protect against the use of APIs introduced in later Java versions.

`sourceCompatibility`

Defines the language version of Java used in your source files.

`targetCompatibility`

Defines the minimum JVM version your code should run on, i.e. it determines the version of the bytecode generated by the compiler.

These options can be set per JavaCompile task, or on the `java { }` extension for all compile tasks, using properties with the same names.

==== Targeting Java 6 and Java 7

Gradle itself can only run on a JVM with Java version 8 or higher. However, Gradle still supports compiling, testing, generating Javadocs and executing applications for Java 6 and Java 7. Java 5 and below are not supported.

| **NOTE** | If using Java 10+, leveraging the `release` flag might be an easier solution, see above. |

To use Java 6 or Java 7, the following tasks need to be configured:

- `JavaCompile` task to fork and use the correct Java home
- `Javadoc` task to use the correct `javadoc` executable
- `Test` and the `JavaExec` task to use the correct `java` executable.

With the usage of Java toolchains, this can be done as follows:

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(7)
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(7)
    }
}
```

The only requirement is that Java 7 is installed and has to be either in a location Gradle can detect automatically or explicitly configured.

=== Compiling independent sources separately

Most projects have at least two independent sets of sources: the production code and the test code. Gradle already makes this scenario part of its Java convention, but what if you have other sets of sources? One of the most common scenarios is when you have separate integration tests of some form or other. In that case, a custom source set may be just what you need.

You can see a complete example for setting up integration tests in the Java testing chapter. You can set up other source sets that fulfil different roles in the same way. The question then becomes: when should you define a custom source set?

To answer that question, consider whether the sources:

1. Need to be compiled with a unique classpath

2. Generate classes that are handled differently from the `main` and `test` ones

3. Form a natural part of the project

If your answer to both 3 and either one of the others is yes, then a custom source set is probably the right approach. For example, integration tests are typically part of the project because they test the code in `main`. In addition, they often have either their own dependencies independent of the `test` source set or they need to be run with a custom `Test` task.

Other common scenarios are less clear cut and may have better solutions. For example:

• Separate API and implementation JARs — it may make sense to have these as separate projects, particularly if you already have a multi-project build

• Generated sources — if the resulting sources should be compiled with the production code, add their path(s) to the `main` source set and make sure that the `compileJava` task depends on the task that generates the sources

If you're unsure whether to create a custom source set or not, then go ahead and do so. It should be straightforward and if it's not, then it's probably not the right tool for the job.

== Managing resources

Many Java projects make use of resources beyond source files, such as images, configuration files and localization data. Sometimes these files simply need to be packaged unchanged and sometimes they need to be processed as template files or in some other way. Either way, the Java Library Plugin adds a specific Copy task for each source set that handles the processing of its associated resources.

The task's name follows the convention of `processSourceSetResources` — or `processResources` for the `main` source set — and it will automatically copy any files in *src/[sourceSet]/resources* to a directory that will be included in the production JAR. This target directory will also be included in the runtime classpath of the tests.

Since `processResources` is an instance of the `ProcessResources` task, you can perform any of the processing described in the Working With Files chapter.

=== Java properties files and reproducible builds

You can easily create Java properties files via the WriteProperties task, which fixes a well-known problem with `Properties.store()` that can reduce the usefulness of incremental builds.

The standard Java API for writing properties files produces a unique file every time, even when the same properties and values are used, because it includes a timestamp in the comments. Gradle's `WriteProperties` task generates exactly the same output byte-for-byte if none of the properties have changed. This is achieved by a few tweaks to how a properties file is generated:

- no timestamp comment is added to the output

- the line separator is system independent, but can be configured explicitly (it defaults to `'\n'`)

- the properties are sorted alphabetically

Sometimes it can be desirable to recreate archives in a byte for byte way on different machines. You want to be sure that building an artifact from source code produces the same result, byte for byte, no matter when and where it is built. This is necessary for projects like reproducible-builds.org.

These tweaks not only lead to better incremental build integration, but they also help with reproducible builds. In essence, reproducible builds guarantee that you will see the same results from a build execution — including test results and production binaries — no matter when or on what system you run it.

== Running tests

Alongside providing automatic compilation of unit tests in *src/test/java*, the Java Library Plugin has native support for running tests that use JUnit 3, 4 & 5 (JUnit 5 support came in Gradle 4.6) and TestNG. You get:

- An automatic `test` task of type Test, using the `test` source set

- An HTML test report that includes the results from *all* `Test` tasks that run

- Easy filtering of which tests to run

- Fine-grained control over how the tests are run

- The opportunity to create your own test execution and test reporting tasks

You do *not* get a `Test` task for every source set you declare, since not every source set represents tests! That's why you typically need to create your own `Test` tasks for things like integration and acceptance tests if they can't be included with the `test` source set.

As there is a lot to cover when it comes to testing, the topic has its own chapter in which we look at:

- How tests are run

- How to run a subset of tests via filtering

- How Gradle discovers tests

- How to configure test reporting and add your own reporting tasks

- How to make use of specific JUnit and TestNG features

You can also learn more about configuring tests in the DSL reference for Test.

== Packaging and publishing

How you package and potentially publish your Java project depends on what type of project it is. Libraries, applications, web applications and enterprise applications all have differing requirements. In this section, we will focus on the bare bones provided by the Java Library Plugin.

By default, the Java Library Plugin provides the `jar` task that packages all the compiled production classes and resources into a single JAR. This JAR is also automatically built by the `assemble` task. Furthermore, the plugin can be configured to provide the `javadocJar` and `sourcesJar` tasks to package Javadoc and source code if so desired. If a publishing plugin is used, these tasks will automatically run during publishing or can be called directly.

build.gradle.kts

```
java {
    withJavadocJar()
    withSourcesJar()
}
```

build.gradle

```
java {
    withJavadocJar()
    withSourcesJar()
}
```

If you want to create an 'uber' (AKA 'fat') JAR, then you can use a task definition like this:

build.gradle.kts

```kotlin
plugins {
    java
}

version = "1.0.0"

repositories {
    mavenCentral()
}

dependencies {
    implementation("commons-io:commons-io:2.6")
}

tasks.register<Jar>("uberJar") {
    archiveClassifier = "uber"

    from(sourceSets.main.get().output)

    dependsOn(configurations.runtimeClasspath)
    from({
        configurations.runtimeClasspath.get().filter { it.name.endsWith("jar")
}.map { zipTree(it) }
    })
}
```

```gradle
plugins {
    id 'java'
}

version = '1.0.0'

repositories {
    mavenCentral()
}

dependencies {
    implementation 'commons-io:commons-io:2.6'
}

tasks.register('uberJar', Jar) {
    archiveClassifier = 'uber'

    from sourceSets.main.output

    dependsOn configurations.runtimeClasspath
    from {
        configurations.runtimeClasspath.findAll { it.name.endsWith('jar') }
.collect { zipTree(it) }
    }
}
```

See Jar for more details on the configuration options available to you. And note that you need to use `archiveClassifier` rather than `archiveAppendix` here for correct publication of the JAR.

You can use one of the publishing plugins to publish the JARs created by a Java project:

- Maven Publish Plugin
- Ivy Publish Plugin

=== Modifying the JAR manifest

Each instance of the `Jar`, `War` and `Ear` tasks has a `manifest` property that allows you to customize the *MANIFEST.MF* file that goes into the corresponding archive. The following example demonstrates how to set attributes in the JAR's manifest:

build.gradle.kts

```
tasks.jar {
    manifest {
        attributes(
            "Implementation-Title" to "Gradle",
            "Implementation-Version" to archiveVersion
        )
    }
}
```

build.gradle

```
jar {
    manifest {
        attributes("Implementation-Title": "Gradle",
                   "Implementation-Version": archiveVersion)
    }
}
```

See Manifest for the configuration options it provides.

You can also create standalone instances of `Manifest`. One reason for doing so is to share manifest information between JARs. The following example demonstrates how to share common attributes between JARs:

build.gradle.kts

```
val sharedManifest = java.manifest {
    attributes (
        "Implementation-Title" to "Gradle",
        "Implementation-Version" to version
    )
}

tasks.register<Jar>("fooJar") {
    manifest = java.manifest {
        from(sharedManifest)
    }
}
```

build.gradle

```
def sharedManifest = java.manifest {
    attributes("Implementation-Title": "Gradle",
                "Implementation-Version": version)
}
tasks.register('fooJar', Jar) {
    manifest = java.manifest {
        from sharedManifest
    }
}
```

Another option available to you is to merge manifests into a single `Manifest` object. Those source manifests can take the form of a text for or another `Manifest` object. In the following example, the source manifests are all text files except for `sharedManifest`, which is the `Manifest` object from the previous example:

build.gradle.kts

```
tasks.register<Jar>("barJar") {
    manifest {
        attributes("key1" to "value1")
        from(sharedManifest, "src/config/basemanifest.txt")
        from(listOf("src/config/javabasemanifest.txt",
 "src/config/libbasemanifest.txt")) {
            eachEntry(Action<ManifestMergeDetails> {
                if (baseValue != mergeValue) {
                    value = baseValue
                }
                if (key == "foo") {
                    exclude()
                }
            })
        }
    }
}
```

```
tasks.register('barJar', Jar) {
    manifest {
        attributes key1: 'value1'
        from sharedManifest, 'src/config/basemanifest.txt'
        from(['src/config/javabasemanifest.txt', 'src/config/libbasemanifest.txt'
]) {
            eachEntry { details ->
                if (details.baseValue != details.mergeValue) {
                    details.value = baseValue
                }
                if (details.key == 'foo') {
                    details.exclude()
                }
            }
        }
    }
}
```

Manifests are merged in the order they are declared in the `from` statement. If the base manifest and the merged manifest both define values for the same key, the merged manifest wins by default. You can fully customize the merge behavior by adding `eachEntry` actions in which you have access to a ManifestMergeDetails instance for each entry of the resulting manifest. Note that the merge is done lazily, either when generating the JAR or when `Manifest.writeTo()` or `Manifest.getEffectiveManifest()` are called.

Speaking of `writeTo()`, you can use that to easily write a manifest to disk at any time, like so:

```
tasks.jar { manifest.writeTo(layout.buildDirectory.file("mymanifest.mf")) }
```

```
tasks.named('jar') { manifest.writeTo(layout.buildDirectory.file('mymanifest.mf'))
}
```

Generating API documentation

The Java Library Plugin provides a `javadoc` task of type Javadoc, that will generate standard Javadocs for all your production code, i.e. whatever source is in the `main` source set. The task supports the core Javadoc and standard doclet options described in the Javadoc reference documentation. See CoreJavadocOptions and StandardJavadocDocletOptions for a complete list of those options.

As an example of what you can do, imagine you want to use Asciidoc syntax in your Javadoc comments. To do this, you need to add Asciidoclet to Javadoc's doclet path. Here's an example that does just that:

build.gradle.kts

```
val asciidoclet by configurations.creating

dependencies {
    asciidoclet("org.asciidoctor:asciidoclet:1.+")
}

tasks.register("configureJavadoc") {
    doLast {
        tasks.javadoc {
            options.doclet = "org.asciidoctor.Asciidoclet"
            options.docletpath = asciidoclet.files.toList()
        }
    }
}

tasks.javadoc {
    dependsOn("configureJavadoc")
}
```

build.gradle

```
configurations {
    asciidoclet
}

dependencies {
    asciidoclet 'org.asciidoctor:asciidoclet:1.+'
}

tasks.register('configureJavadoc') {
    doLast {
        javadoc {
            options.doclet = 'org.asciidoctor.Asciidoclet'
            options.docletpath = configurations.asciidoclet.files.toList()
        }
    }
}

javadoc {
    dependsOn configureJavadoc
}
```

You don't have to create a configuration for this, but it's an elegant way to handle dependencies that are required for a unique purpose.

You might also want to create your own Javadoc tasks, for example to generate API docs for the tests:

build.gradle.kts

```
tasks.register<Javadoc>("testJavadoc") {
    source = sourceSets.test.get().allJava
}
```

build.gradle

```
tasks.register('testJavadoc', Javadoc) {
    source = sourceSets.test.allJava
}
```

These are just two non-trivial but common customizations that you might come across.

== Cleaning the build

The Java Library Plugin adds a `clean` task to your project by virtue of applying the Base Plugin. This task simply deletes everything in the `layout.buildDirectory` directory, hence why you should always put files generated by the build in there. The task is an instance of Delete and you can change what directory it deletes by setting its `dir` property.

== Building JVM components

All of the specific JVM plugins are built on top of the Java Plugin. The examples above only illustrated concepts provided by this base plugin and shared with all JVM plugins.

Read on to understand which plugins fits which project type, as it is recommended to pick a specific plugin instead of applying the Java Plugin directly.

== Building Java libraries

The unique aspect of library projects is that they are used (or "consumed") by other Java projects. That means the dependency metadata published with the JAR file — usually in the form of a Maven POM — is crucial. In particular, consumers of your library should be able to distinguish between two different types of dependencies: those that are only required to compile your library and those that are also required to compile the consumer.

Gradle manages this distinction via the Java Library Plugin, which introduces an *api* configuration in addition to the *implementation* one covered in this chapter. If the types from a dependency appear in public fields or methods of your library's public classes, then that dependency is exposed via your library's public API and should therefore be added to the *api* configuration. Otherwise, the dependency is an internal implementation detail and should be added to *implementation*.

If you're unsure of the difference between an API and implementation dependency, the Java Library Plugin chapter has a detailed explanation. In addition, you can explore a basic, practical sample of building a Java library.

== Building Java applications

Java applications packaged as a JAR aren't set up for easy launching from the command line or a desktop environment. The Application Plugin solves the command line aspect by creating a distribution that includes the production JAR, its dependencies and launch scripts Unix-like and Windows systems.

See the plugin's chapter for more details, but here's a quick summary of what you get:

- `assemble` creates ZIP and TAR distributions of the application containing everything needed to run it
- A `run` task that starts the application from the build (for easy testing)
- Shell and Windows Batch scripts to start the application

You can see a basic example of building a Java application in the corresponding sample.

Building Java web applications

Java web applications can be packaged and deployed in a number of ways depending on the technology you use. For example, you might use Spring Boot with a fat JAR or a Reactive-based system running on Netty. Whatever technology you use, Gradle and its large community of plugins will satisfy your needs. Core Gradle, though, only directly supports traditional Servlet-based web applications deployed as WAR files.

That support comes via the War Plugin, which automatically applies the Java Plugin and adds an extra packaging step that does the following:

- Copies static resources from *src/main/webapp* into the root of the WAR
- Copies the compiled production classes into a *WEB-INF/classes* subdirectory of the WAR
- Copies the library dependencies into a *WEB-INF/lib* subdirectory of the WAR

This is done by the `war` task, which effectively replaces the `jar` task — although that task remains — and is attached to the `assemble` lifecycle task. See the plugin's chapter for more details and configuration options.

There is no core support for running your web application directly from the build, but we do recommend that you try the Gretty community plugin, which provides an embedded Servlet container.

Building Java EE applications

Java enterprise systems have changed a lot over the years, but if you're still deploying to JEE application servers, you can make use of the Ear Plugin. This adds conventions and a task for building EAR files. The plugin's chapter has more details.

Building Java Platforms

A Java platform represents a set of dependency declarations and constraints that form a cohesive unit to be applied on consuming projects. The platform has no source and no artifact of its own. It maps in the Maven world to a BOM.

The support comes via the Java Platform plugin, which sets up the different configurations and publication components.

| NOTE | This plugin is the exception as it does not apply the Java Plugin. |

Enabling Java preview features

| WARNING | Using a Java preview feature is very likely to make your code incompatible with that compiled without a feature preview. As a consequence, we strongly recommend you not to publish libraries compiled with preview features and restrict the use of feature previews to toy projects. |

To enable Java preview features for compilation, test execution and runtime, you can use the following DSL snippet:

build.gradle.kts

```kotlin
tasks.withType<JavaCompile>().configureEach {
    options.compilerArgs.add("--enable-preview")
}

tasks.withType<Test>().configureEach {
    jvmArgs("--enable-preview")
}

tasks.withType<JavaExec>().configureEach {
    jvmArgs("--enable-preview")
}
```

build.gradle

```groovy
tasks.withType(JavaCompile).configureEach {
    options.compilerArgs += "--enable-preview"
}

tasks.withType(Test).configureEach {
    jvmArgs += "--enable-preview"
}

tasks.withType(JavaExec).configureEach {
    jvmArgs += "--enable-preview"
}
```

Building other JVM language projects

If you want to leverage the multi language aspect of the JVM, most of what was described here will still apply.

Gradle itself provides Groovy and Scala plugins. The plugins automatically apply support for compiling Java code and can be further enhanced by combining them with the `java-library` plugin.

Compilation dependency between languages

These plugins create a dependency between Groovy/Scala compilation and Java compilation (of source code in the `java` folder of a source set). You can change this default behavior by adjusting the classpath of the involved compile tasks as shown in the following example:

build.gradle.kts

```
tasks.named<AbstractCompile>("compileGroovy") {
    // Groovy only needs the declared dependencies
    // (and not longer the output of compileJava)
    classpath = sourceSets.main.get().compileClasspath
}
tasks.named<AbstractCompile>("compileJava") {
    // Java also depends on the result of Groovy compilation
    // (which automatically makes it depend of compileGroovy)
    classpath += files(sourceSets.main.get().groovy.classesDirectory)
}
```

build.gradle

```
tasks.named('compileGroovy') {
    // Groovy only needs the declared dependencies
    // (and not longer the output of compileJava)
    classpath = sourceSets.main.compileClasspath
}
tasks.named('compileJava') {
    // Java also depends on the result of Groovy compilation
    // (which automatically makes it depend of compileGroovy)
    classpath += files(sourceSets.main.groovy.classesDirectory)
}
```

1. By setting the `compileGroovy` classpath to be only `sourceSets.main.compileClasspath`, we effectively remove the previous dependency on `compileJava` that was declared by having the classpath also take into consideration `sourceSets.main.java.classesDirectory`

2. By adding `sourceSets.main.groovy.classesDirectory` to the `compileJava` classpath, we effectively declare a dependency on the `compileGroovy` task

All of this is possible through the use of directory properties.

=== Extra language support

Beyond core Gradle, there are other great plugins for more JVM languages!

= Testing in Java & JVM projects

Testing on the JVM is a rich subject matter. There are many different testing libraries and frameworks, as well as many different types of test. All need to be part of the build, whether they are executed frequently or infrequently. This chapter is dedicated to explaining how Gradle handles differing requirements between and within builds, with significant coverage of how it integrates with the two most common testing frameworks: JUnit and TestNG.

It explains:

- Ways to control how the tests are run (Test execution)
- How to select specific tests to run (Test filtering)
- What test reports are generated and how to influence the process (Test reporting)
- How Gradle finds tests to run (Test detection)
- How to make use of the major frameworks' mechanisms for grouping tests together (Test grouping)

But first, let's look at the basics of JVM testing in Gradle.

| NOTE | A new configuration DSL for modeling test execution phases is available via the incubating JVM Test Suite plugin. |

== The basics

All JVM testing revolves around a single task type: Test. This runs a collection of test cases using any supported test library — JUnit, JUnit Platform or TestNG — and collates the results. You can then turn those results into a report via an instance of the TestReport task type.

In order to operate, the `Test` task type requires just two pieces of information:

- Where to find the compiled test classes (property: Test.getTestClassesDirs())
- The execution classpath, which should include the classes under test as well as the test library that you're using (property: Test.getClasspath())

When you're using a JVM language plugin — such as the Java Plugin — you will automatically

get the following:

- A dedicated `test` source set for unit tests

- A `test` task of type `Test` that runs those unit tests

The JVM language plugins use the source set to configure the task with the appropriate execution classpath and the directory containing the compiled test classes. In addition, they attach the `test` task to the `check` lifecycle task.

It's also worth bearing in mind that the `test` source set automatically creates corresponding dependency configurations — of which the most useful are `testImplementation` and `testRuntimeOnly` — that the plugins tie into the `test` task's classpath.

All you need to do in most cases is configure the appropriate compilation and runtime dependencies and add any necessary configuration to the `test` task. The following example shows a simple setup that uses JUnit Platform and changes the maximum heap size for the tests' JVM to 1 gigabyte:

build.gradle.kts

```
dependencies {
    testImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}

tasks.named<Test>("test") {
    useJUnitPlatform()

    maxHeapSize = "1G"

    testLogging {
        events("passed")
    }
}
```

build.gradle

```
dependencies {
    testImplementation 'org.junit.jupiter:junit-jupiter:5.7.1'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}

tasks.named('test', Test) {
    useJUnitPlatform()

    maxHeapSize = '1G'

    testLogging {
        events "passed"
    }
}
```

The Test task has many generic configuration options as well as several framework-specific ones that you can find described in JUnitOptions, JUnitPlatformOptions and TestNGOptions. We cover a significant number of them in the rest of the chapter.

If you want to set up your own Test task with its own set of test classes, then the easiest approach is to create your own source set and Test task instance, as shown in Configuring integration tests.

== Test execution

Gradle executes tests in a separate ('forked') JVM, isolated from the main build process. This prevents classpath pollution and excessive memory consumption for the build process. It also allows you to run the tests with different JVM arguments than the build is using.

You can control how the test process is launched via several properties on the Test task, including the following:

maxParallelForks — **default: 1**

You can run your tests in parallel by setting this property to a value greater than 1. This may make your test suites complete faster, particularly if you run them on a multi-core CPU. When using parallel test execution, make sure your tests are properly isolated from one another. Tests that interact with the filesystem are particularly prone to conflict, causing intermittent test failures.

Your tests can distinguish between parallel test processes by using the value of the org.gradle.test.worker property, which is unique for each process. You can use this for anything you want, but it's particularly useful for filenames and other resource identifiers to prevent the kind of conflict we just mentioned.

forkEvery — **default: 0 (no maximum)**

This property specifies the maximum number of test classes that Gradle should run on a test process before its disposed of and a fresh one created. This is mainly used as a way to manage leaky tests or frameworks that have static state that can't be cleared or reset between tests.

Warning: a low value (other than 0) can severely hurt the performance of the tests

ignoreFailures — **default: false**

If this property is true, Gradle will continue with the project's build once the tests have completed, even if some of them have failed. Note that, by default, the Test task always executes every test that it detects, irrespective of this setting.

failFast — **(since Gradle 4.6) default: false**

Set this to true if you want the build to fail and finish as soon as one of your tests fails. This can save a lot of time when you have a long-running test suite and is particularly useful when running the build on continuous integration servers. When a build fails before all tests have run, the test reports only include the results of the tests that have completed, successfully or not.

You can also enable this behavior by using the `--fail-fast` command line option, or disable it respectively with `--no-fail-fast`.

`testLogging` — default: *not set*

This property represents a set of options that control which test events are logged and at what level. You can also configure other logging behavior via this property. See TestLoggingContainer for more detail.

`dryRun` — default: false

If this property is `true`, Gradle will simulate the execution of the tests without actually running them. This will still generate reports, allowing for inspection of what tests were selected. This can be used to verify that your test filtering configuration is correct without actually running the tests.

You can also enable this behavior by using the `--test-dry-run` command-line option, or disable it respectively with `--no-test-dry-run`.

See Test for details on all the available configuration options.

The test process can exit unexpectedly if configured incorrectly. For instance, if the Java executable does not exist or an invalid JVM argument is provided, the test process will fail to start. Similarly, if a test makes programmatic changes to the test process, this can also cause unexpected failures.

For example, issues may occur if a `SecurityManager` is modified in a test because Gradle's internal messaging depends on reflection and socket communication, which may be disrupted if the permissions on the security manager change. In this particular case, you should restore the original `SecurityManager` after the test so that the gradle test worker process can continue to function.

== Test filtering

It's a common requirement to run subsets of a test suite, such as when you're fixing a bug or developing a new test case. Gradle provides two mechanisms to do this:

- Filtering (the preferred option)

- Test inclusion/exclusion

Filtering supersedes the inclusion/exclusion mechanism, but you may still come across the latter in the wild.

With Gradle's test filtering you can select tests to run based on:

- A fully-qualified class name or fully qualified method name, e.g. `org.gradle.SomeTest`, `org.gradle.SomeTest.someMethod`

- A simple class name or method name if the pattern starts with an upper-case letter, e.g. `SomeTest`, `SomeTest.someMethod` (since Gradle 4.7)

- '*' wildcard matching

You can enable filtering either in the build script or via the `--tests` command-line option. Here's an example of some filters that are applied every time the build runs:

build.gradle.kts

```
tasks.test {
    filter {
        //include specific method in any of the tests
        includeTestsMatching("*UiCheck")

        //include all tests from package
        includeTestsMatching("org.gradle.internal.*")

        //include all integration tests
        includeTestsMatching("*IntegTest")
    }
}
```

build.gradle

```
test {
    filter {
        //include specific method in any of the tests
        includeTestsMatching "*UiCheck"

        //include all tests from package
        includeTestsMatching "org.gradle.internal.*"

        //include all integration tests
        includeTestsMatching "*IntegTest"
    }
}
```

For more details and examples of declaring filters in the build script, please see the TestFilter reference.

The command-line option is especially useful to execute a single test method. When you use `--tests`, be aware that the inclusions declared in the build script are still honored. It is also possible to supply multiple `--tests` options, all of whose patterns will take effect. The following sections have several examples of using the command-line option.

NOTE	Not all test frameworks play well with filtering. Some advanced, synthetic tests may not be fully compatible. However, the vast majority of tests and use cases work perfectly well with Gradle's filtering mechanism.

The following two sections look at the specific cases of simple class/method names and fully-qualified names.

=== Simple name pattern

Since 4.7, Gradle has treated a pattern starting with an uppercase letter as a simple class name, or a class name + method name. For example, the following command lines run either all or exactly one of the tests in the `SomeTestClass` test case, regardless of what package it's in:

```
# Executes all tests in SomeTestClass
gradle test --tests SomeTestClass

# Executes a single specified test in SomeTestClass
gradle test --tests SomeTestClass.someSpecificMethod

gradle test --tests SomeTestClass.*someMethod*
```

=== Fully-qualified name pattern

Prior to 4.7 or if the pattern doesn't start with an uppercase letter, Gradle treats the pattern as fully-qualified. So if you want to use the test class name irrespective of its package, you would use `--tests *.SomeTestClass`. Here are some more examples:

```
# specific class
gradle test --tests org.gradle.SomeTestClass

# specific class and method
gradle test --tests org.gradle.SomeTestClass.someSpecificMethod

# method name containing spaces
gradle test --tests "org.gradle.SomeTestClass.some method containing spaces"

# all classes at specific package (recursively)
gradle test --tests 'all.in.specific.package*'

# specific method at specific package (recursively)
gradle test --tests 'all.in.specific.package*.someSpecificMethod'

gradle test --tests '*IntegTest'

gradle test --tests '*IntegTest*ui*'

gradle test --tests '*ParameterizedTest.foo*'

# the second iteration of a parameterized test
gradle test --tests '*ParameterizedTest.*[2]'
```

Note that the wildcard '*' has no special understanding of the '.' package separator. It's purely text based. So `--tests *.SomeTestClass` will match any package, regardless of its 'depth'.

You can also combine filters defined at the command line with continuous build to re-execute a subset of tests immediately after every change to a production or test source file. The following executes all tests in the 'com.mypackage.foo' package or subpackages whenever a change triggers the tests to run:

```
gradle test --continuous --tests "com.mypackage.foo.*"
```

== Test reporting

The `Test` task generates the following results by default:

- An HTML test report

- XML test results in a format compatible with the Ant JUnit report task — one that is supported by many other tools, such as CI servers

- An efficient binary format of the results used by the `Test` task to generate the other formats

In most cases, you'll work with the standard HTML report, which automatically includes the results from *all* your `Test` tasks, even the ones you explicitly add to the build yourself. For example, if you add a `Test` task for integration tests, the report will include the results of both the unit tests and the integration tests if both tasks are run.

NOTE	To aggregate test results across multiple subprojects, see the Test Report Aggregation Plugin.

Unlike with many of the testing configuration options, there are several project-level convention properties that affect the test reports. For example, you can change the destination of the test results and reports like so:

build.gradle.kts

```kotlin
reporting.baseDir = file("my-reports")
java.testResultsDir = layout.buildDirectory.dir("my-test-results")

tasks.register("showDirs") {
    val rootDir = project.rootDir
    val reportsDir = project.reporting.baseDirectory
    val testResultsDir = project.java.testResultsDir

    doLast {

logger.quiet(rootDir.toPath().relativize(reportsDir.get().asFile.toPath()).toStrin
g())

logger.quiet(rootDir.toPath().relativize(testResultsDir.get().asFile.toPath()).toS
tring())
    }
}
```

```
reporting.baseDir = "my-reports"
java.testResultsDir = layout.buildDirectory.dir("my-test-results")

tasks.register('showDirs') {
    def rootDir = project.rootDir
    def reportsDir = project.reporting.baseDirectory
    def testResultsDir = project.java.testResultsDir

    doLast {
        logger.quiet(rootDir.toPath().relativize(reportsDir.get().asFile.toPath()
).toString())
        logger.quiet(rootDir.toPath().relativize(testResultsDir.get().asFile
.toPath()).toString())
    }
}
```

Output of `gradle -q showDirs`

```
> gradle -q showDirs
my-reports
build/my-test-results
```

Follow the link to the convention properties for more details.

There is also a standalone TestReport task type that you can use to generate a custom HTML test report. All it requires are a value for `destinationDir` and the test results you want included in the report. Here is a sample which generates a combined report for the unit tests from all subprojects:

buildSrc/src/main/kotlin/myproject.java-conventions.gradle.kts

```kotlin
plugins {
    id("java")
}

// Disable the test report for the individual test task
tasks.named<Test>("test") {
    reports.html.required = false
}

// Share the test report data to be aggregated for the whole project
configurations.create("binaryTestResultsElements") {
    isCanBeResolved = false
    isCanBeConsumed = true
    attributes {
        attribute(Category.CATEGORY_ATTRIBUTE,
objects.named(Category.DOCUMENTATION))
        attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named("test-report-data"))
    }
    outgoing.artifact(tasks.test.map { task ->
task.getBinaryResultsDirectory().get() })
}
```

build.gradle.kts

```kotlin
val testReportData by configurations.creating {
    isCanBeConsumed = false
    attributes {
        attribute(Category.CATEGORY_ATTRIBUTE,
objects.named(Category.DOCUMENTATION))
        attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named("test-report-data"))
    }
}

dependencies {
    testReportData(project(":core"))
    testReportData(project(":util"))
}

tasks.register<TestReport>("testReport") {
    destinationDirectory = reporting.baseDirectory.dir("allTests")
    // Use test results from testReportData configuration
    testResults.from(testReportData)
}
```

buildSrc/src/main/groovy/myproject.java-conventions.gradle

```
plugins {
    id 'java'
}

// Disable the test report for the individual test task
test {
    reports.html.required = false
}

// Share the test report data to be aggregated for the whole project
configurations {
    binaryTestResultsElements {
        canBeResolved = false
        canBeConsumed = true
        attributes {
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.DOCUMENTATION))
            attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named(DocsType, 'test-
report-data'))
        }
        outgoing.artifact(test.binaryResultsDirectory)
    }
}
```

build.gradle

```
// A resolvable configuration to collect test reports data
configurations {
    testReportData {
        canBeConsumed = false
        attributes {
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.DOCUMENTATION))
            attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named(DocsType, 'test-
report-data'))
        }
    }
}

dependencies {
    testReportData project(':core')
    testReportData project(':util')
}

tasks.register('testReport', TestReport) {
    destinationDirectory = reporting.baseDirectory.dir('allTests')
    // Use test results from testReportData configuration
    testResults.from(configurations.testReportData)
}
```

In this example, we use a convention plugin `myproject.java-conventions` to expose the test results from a project to Gradle's variant aware dependency management engine.

The plugin declares a consumable `binaryTestResultsElements` configuration that represents the binary test results of the `test` task. In the aggregation project's build file, we declare the `testReportData` configuration and depend on all of the projects that we want to aggregate the results from. Gradle will automatically select the binary test result variant from each of the subprojects instead of the project's jar file. Lastly, we add a `testReport` task that aggregates the test results from the `testResultsDirs` property, which contains all of the binary test results resolved from the `testReportData` configuration.

You should note that the `TestReport` type combines the results from multiple test tasks and needs to aggregate the results of individual test classes. This means that if a given test class is executed by multiple test tasks, then the test report will include executions of that class, but it can be hard to distinguish individual executions of that class and their output.

=== Communicating test results to CI servers and other tools via XML files

The Test tasks creates XML files describing the test results, in the "JUnit XML" pseudo standard. It is common for CI servers and other tooling to observe test results via these XML files.

By default, the files are written to `layout.buildDirectory.dir("test-results/$testTaskName")` with a file per test class. The location can be changed for all test tasks of a project, or individually per test task.

build.gradle.kts

```
java.testResultsDir = layout.buildDirectory.dir("junit-xml")
```

build.gradle

```
java.testResultsDir = layout.buildDirectory.dir("junit-xml")
```

With the above configuration, the XML files will be written to `layout.buildDirectory.dir("junit-xml/$testTaskName")`.

build.gradle.kts

```kotlin
tasks.test {
    reports {
        junitXml.outputLocation = layout.buildDirectory.dir("test-junit-xml")
    }
}
```

build.gradle

```groovy
test {
    reports {
        junitXml.outputLocation = layout.buildDirectory.dir("test-junit-xml")
    }
}
```

With the above configuration, the XML files for the `test` task will be written to `layout.buildDirectory.dir("test-results/test-junit-xml")`. The location of the XML files for other test tasks will be unchanged.

==== Configuration options

The content of the XML files can also be configured to convey the results differently, by configuring the JUnitXmlReport options.

build.gradle.kts

```kotlin
tasks.test {
    reports {
        junitXml.apply {
            isOutputPerTestCase = true // defaults to false
            mergeReruns = true // defaults to false
        }
    }
}
```

build.gradle

```
test {
    reports {
        junitXml {
            outputPerTestCase = true // defaults to false
            mergeReruns = true // defaults to false
        }
    }
}
```

===== outputPerTestCase

The `outputPerTestCase` option, when enabled, associates any output logging generated during a test case to that test case in the results. When disabled (the default) output is associated with the test class as whole and not the individual test cases (e.g. test methods) that produced the logging output. Most modern tools that observe JUnit XML files support the "output per test case" format.

If you are using the XML files to communicate test results, it is recommended to enable this option as it provides more useful reporting.

===== mergeReruns

When `mergeReruns` is enabled, if a test fails but is then retried and succeeds, its failures will be recorded as `<flakyFailure>` instead of `<failure>`, within one `<testcase>`. This is effectively the reporting produced by the surefire plugin of Apache Maven™ when enabling reruns. If your CI server understands this format, it will indicate that the test was flaky. If it does not, it will indicate that the test succeeded as it will ignore the `<flakyFailure>` information. If the test does not succeed (i.e. it fails for every retry), it will be indicated as having failed whether your tool understands this format or not.

When `mergeReruns` is disabled (the default), each execution of a test will be listed as a separate test case.

If you are using build scans or Develocity, flaky tests will be detected regardless of this setting.

Enabling this option is especially useful when using a CI tool that uses the XML test results to determine build failure instead of relying on Gradle's determination of whether the build failed or not, and you wish to not consider the build failed if all failed tests passed when retried. This is the case for the Jenkins CI server and its JUnit plugin. With `mergeReruns` enabled, tests that pass-on-retry will no longer cause this Jenkins plugin to consider the build to have failed. However, failed test executions will be omitted from the Jenkins test result visualizations as it does not consider `<flakyFailure>` information. The separate Flaky Test Handler Jenkins plugin can be used in addition to the JUnit Jenkins plugin to have such "flaky failures" also be visualized.

Tests are grouped and merged based on their reported name. When using any kind of test parameterization that affects the reported test name, or any other kind of mechanism that produces a potentially dynamic test name, care should be taken to ensure that the test name is stable and does not unnecessarily change.

Enabling the `mergeReruns` option does not add any retry/rerun functionality to test execution. Rerunning can be enabled by the test execution framework (e.g. JUnit's @RepeatedTest), or via the separate Test Retry Gradle plugin.

== Test detection

By default, Gradle will run all tests that it detects, which it does by inspecting the compiled test classes. This detection uses different criteria depending on the test framework used.

For *JUnit*, Gradle scans for both JUnit 3 and 4 test classes. A class is considered to be a JUnit test if it:

- Ultimately inherits from `TestCase` or `GroovyTestCase`

- Is annotated with `@RunWith`

- Contains a method annotated with `@Test` or a super class does

For *TestNG*, Gradle scans for methods annotated with `@Test`.

Note that abstract classes are not executed. In addition, be aware that Gradle scans up the inheritance tree into jar files on the test classpath. So if those JARs contain test classes, they will also be run.

If you don't want to use test class detection, you can disable it by setting the `scanForTestClasses` property on Test to `false`. When you do that, the test task uses only the `includes` and `excludes` properties to find test classes.

If `scanForTestClasses` is false and no include or exclude patterns are specified, Gradle defaults to running any class that matches the patterns `**/*Tests.class` and `**/*Test.class`, excluding those that match `**/Abstract*.class`.

NOTE	With JUnit Platform, only `includes` and `excludes` are used to filter test classes — `scanForTestClasses` has no effect.

Test logging

Gradle allows fine-tuned control over events that are logged to the console. Logging is configurable on a per-log-level basis and by default, the following events are logged:

When the log level is	Events that are logged	Additional configuration
`ERROR`, `QUIET` or `WARNING`	None	None
`LIFECYCLE`	Test failures	Exception format is SHORT
`INFO`	Test failures, skipped tests, test standard output and test standard error	Stacktraces are truncated.
`DEBUG`	All events	Full stacktraces are logged.

Test logging can be modified on a per-log-level basis by adjusting the appropriate TestLogging instances in the testLogging property of the test task. For example, to adjust the `INFO` level test logging configuration, modify the TestLoggingContainer.getInfo() property.

Test grouping

JUnit, JUnit Platform and TestNG allow sophisticated groupings of test methods.

JUnit 4.8 introduced the concept of categories for grouping JUnit 4 tests classes and methods.[4] Test.useJUnit(org.gradle.api.Action) allows you to specify the JUnit categories you want to include and exclude. For example, the following configuration includes tests in `CategoryA` and excludes those in `CategoryB` for the `test` task:

build.gradle.kts

```
tasks.test {
    useJUnit {
        includeCategories("org.gradle.junit.CategoryA")
        excludeCategories("org.gradle.junit.CategoryB")
    }
}
```

build.gradle

```
test {
    useJUnit {
        includeCategories 'org.gradle.junit.CategoryA'
        excludeCategories 'org.gradle.junit.CategoryB'
    }
}
```

JUnit Platform introduced tagging to replace categories. You can specify the included/excluded tags via Test.useJUnitPlatform(org.gradle.api.Action), as follows:

build.gradle.kts

```
tasks.withType<Test>().configureEach {
    useJUnitPlatform {
        includeTags("fast")
        excludeTags("slow")
    }
}
```

```
tasks.withType(Test).configureEach {
    useJUnitPlatform {
        includeTags 'fast'
        excludeTags 'slow'
    }
}
```

The TestNG framework uses the concept of test groups for a similar effect.[5] You can configure which test groups to include or exclude during the test execution via the Test.useTestNG(org.gradle.api.Action) setting, as seen here:

build.gradle.kts

```
tasks.named<Test>("test") {
    useTestNG {
        val options = this as TestNGOptions
        options.excludeGroups("integrationTests")
        options.includeGroups("unitTests")
    }
}
```

build.gradle

```
test {
    useTestNG {
        excludeGroups 'integrationTests'
        includeGroups 'unitTests'
    }
}
```

== Using JUnit 5

JUnit 5 is the latest version of the well-known JUnit test framework. Unlike its predecessor, JUnit 5 is modularized and composed of several modules:

```
JUnit 5 = JUnit Platform + JUnit Jupiter + JUnit Vintage
```

The JUnit Platform serves as a foundation for launching testing frameworks on the JVM. JUnit Jupiter is the combination of the new programming model and extension model for writing tests and extensions in JUnit 5. JUnit Vintage provides a `TestEngine` for running JUnit 3 and JUnit 4 based tests on the platform.

The following code enables JUnit Platform support in `build.gradle`:

build.gradle.kts

```
tasks.named<Test>("test") {
    useJUnitPlatform()
}
```

build.gradle

```
tasks.named('test', Test) {
    useJUnitPlatform()
}
```

See Test.useJUnitPlatform() for more details.

=== Compiling and executing JUnit Jupiter tests

To enable JUnit Jupiter support in Gradle, all you need to do is add the following dependency:

build.gradle.kts

```
dependencies {
    testImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}
```

build.gradle

```
dependencies {
    testImplementation 'org.junit.jupiter:junit-jupiter:5.7.1'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}
```

You can then put your test cases into *src/test/java* as normal and execute them with `gradle test`.

=== Executing legacy tests with JUnit Vintage

If you want to run JUnit 3/4 tests on JUnit Platform, or even mix them with Jupiter tests, you should add extra JUnit Vintage Engine dependencies:

build.gradle.kts

```
dependencies {
    testImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    testCompileOnly("junit:junit:4.13")
    testRuntimeOnly("org.junit.vintage:junit-vintage-engine")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}
```

build.gradle

```
dependencies {
    testImplementation 'org.junit.jupiter:junit-jupiter:5.7.1'
    testCompileOnly 'junit:junit:4.13'
    testRuntimeOnly 'org.junit.vintage:junit-vintage-engine'
    testRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}
```

In this way, you can use `gradle test` to test JUnit 3/4 tests on JUnit Platform, without the need to rewrite them.

=== Filtering test engine

JUnit Platform allows you to use different test engines. JUnit currently provides two `TestEngine` implementations out of the box: junit-jupiter-engine and junit-vintage-engine. You can also write and plug in your own `TestEngine` implementation as documented here.

By default, all test engines on the test runtime classpath will be used. To control specific test engine implementations explicitly, you can add the following setting to your build script:

build.gradle.kts

```
tasks.withType<Test>().configureEach {
    useJUnitPlatform {
        includeEngines("junit-vintage")
        // excludeEngines("junit-jupiter")
    }
}
```

build.gradle

```
tasks.withType(Test).configureEach {
    useJUnitPlatform {
        includeEngines 'junit-vintage'
        // excludeEngines 'junit-jupiter'
    }
}
```

== Test execution order in TestNG

TestNG allows explicit control of the execution order of tests when you use a *testng.xml* file. Without such a file — or an equivalent one configured by TestNGOptions.getSuiteXmlBuilder() — you can't specify the test execution order. However, what you *can* do is control whether all aspects of a test — including its associated `@BeforeXXX` and `@AfterXXX` methods, such as those annotated with `@Before/AfterClass` and `@Before/AfterMethod` — are executed before the next test starts. You do this by setting the TestNGOptions.getPreserveOrder() property to `true`. If you set it to `false`, you may encounter scenarios in which the execution order is something like: `TestA.doBeforeClass()` → `TestB.doBeforeClass()` → `TestA` tests.

While preserving the order of tests is the default behavior when directly working with *testng.xml* files, the TestNG API that is used by Gradle's TestNG integration executes tests in unpredictable order by default.[6] The ability to preserve test execution order was introduced with TestNG version 5.14.5. Setting the `preserveOrder` property to `true` for an older TestNG version will cause the build to fail.

build.gradle.kts

```
tasks.test {
    useTestNG {
        preserveOrder = true
    }
}
```

build.gradle

```
test {
    useTestNG {
        preserveOrder true
    }
}
```

The `groupByInstance` property controls whether tests should be grouped by instance rather than by class. The [TestNG documentation](#) explains the difference in more detail, but essentially, if you have a test method `A()` that depends on `B()`, grouping by instance ensures that each A-B pairing, e.g. `B(1)-A(1)`, is executed before the next pairing. With group by class, all `B()` methods are run and then all `A()` ones.

Note that you typically only have more than one instance of a test if you're using a data provider to parameterize it. Also, grouping tests by instances was introduced with TestNG version 6.1. Setting the `groupByInstances` property to `true` for an older TestNG version will cause the build to fail.

build.gradle.kts

```
tasks.test {
    useTestNG {
        groupByInstances = true
    }
}
```

build.gradle

```
test {
    useTestNG {
        groupByInstances = true
    }
}
```

=== TestNG parameterized methods and reporting

TestNG supports parameterizing test methods, allowing a particular test method to be executed multiple times with different inputs. Gradle includes the parameter values in its reporting of the test method execution.

Given a parameterized test method named `aTestMethod` that takes two parameters, it will be reported with the name `aTestMethod(toStringValueOfParam1, toStringValueOfParam2)`. This makes it easy to identify the parameter values for a particular iteration.

== Configuring integration tests

A common requirement for projects is to incorporate integration tests in one form or another. Their aim is to verify that the various parts of the project are working together properly. This often means that they require special execution setup and dependencies compared to unit tests.

The simplest way to add integration tests to your build is by leveraging the incubating JVM Test Suite plugin. If an incubating solution is not something for you, here are the steps you need to take in your build:

1. Create a new source set for them

2. Add the dependencies you need to the appropriate configurations for that source set

3. Configure the compilation and runtime classpaths for that source set

4. Create a task to run the integration tests

You may also need to perform some additional configuration depending on what form the integration tests take. We will discuss those as we go.

Let's start with a practical example that implements the first three steps in a build script, centered around a new source set `intTest`:

build.gradle.kts

```kotlin
sourceSets {
    create("intTest") {
        compileClasspath += sourceSets.main.get().output
        runtimeClasspath += sourceSets.main.get().output
    }
}

val intTestImplementation by configurations.getting {
    extendsFrom(configurations.implementation.get())
}
val intTestRuntimeOnly by configurations.getting

configurations["intTestRuntimeOnly"].extendsFrom(configurations.runtimeOnly.get())

dependencies {
    intTestImplementation("org.junit.jupiter:junit-jupiter:5.7.1")
    intTestRuntimeOnly("org.junit.platform:junit-platform-launcher")
}
```

build.gradle

```groovy
sourceSets {
    intTest {
        compileClasspath += sourceSets.main.output
        runtimeClasspath += sourceSets.main.output
    }
}

configurations {
    intTestImplementation.extendsFrom implementation
    intTestRuntimeOnly.extendsFrom runtimeOnly
}

dependencies {
    intTestImplementation 'org.junit.jupiter:junit-jupiter:5.7.1'
    intTestRuntimeOnly 'org.junit.platform:junit-platform-launcher'
}
```

This will set up a new source set called `intTest` that automatically creates:

- `intTestImplementation`, `intTestCompileOnly`, `intTestRuntimeOnly` configurations (and a few others that are less commonly needed)

- A `compileIntTestJava` task that will compile all the source files under *src/intTest/java*

NOTE	If you are working with the IntelliJ IDE, you may wish to flag the directories in these additional source sets as containing test source rather than production source as explained in the Idea Plugin documentation.

The example also does the following, not all of which you may need for your specific integration tests:

- Adds the production classes from the `main` source set to the compilation and runtime classpaths of the integration tests — `sourceSets.main.output` is a file collection of all the directories containing compiled production classes and resources

- Makes the `intTestImplementation` configuration extend from `implementation`, which means that all the declared dependencies of the production code also become dependencies of the integration tests

- Does the same for the `intTestRuntimeOnly` configuration

In most cases, you want your integration tests to have access to the classes under test, which is why we ensure that those are included on the compilation and runtime classpaths in this example. But some types of test interact with the production code in a different way. For example, you may have tests that run your application as an executable and verify the output. In the case of web applications, the tests may interact with your application via HTTP. Since the tests don't need direct access to the classes under test in such cases, you don't need to add the production classes to the test classpath.

Another common step is to attach all the unit test dependencies to the integration tests as well — via `intTestImplementation.extendsFrom testImplementation` — but that only makes sense if the integration tests require *all* or nearly all the same dependencies that the unit tests have.

There are a couple of other facets of the example you should take note of:

- `+=` allows you to append paths and collections of paths to `compileClasspath` and `runtimeClasspath` instead of overwriting them

- If you want to use the convention-based configurations, such as `intTestImplementation`, you *must* declare the dependencies *after* the new source set

Creating and configuring a source set automatically sets up the compilation stage, but it does nothing with respect to running the integration tests. So the last piece of the puzzle is a custom test task that uses the information from the new source set to configure its runtime classpath and the test classes:

build.gradle.kts

```kotlin
val integrationTest = task<Test>("integrationTest") {
    description = "Runs integration tests."
    group = "verification"

    testClassesDirs = sourceSets["intTest"].output.classesDirs
    classpath = sourceSets["intTest"].runtimeClasspath
    shouldRunAfter("test")

    useJUnitPlatform()

    testLogging {
        events("passed")
    }
}

tasks.check { dependsOn(integrationTest) }
```

build.gradle

```groovy
tasks.register('integrationTest', Test) {
    description = 'Runs integration tests.'
    group = 'verification'

    testClassesDirs = sourceSets.intTest.output.classesDirs
    classpath = sourceSets.intTest.runtimeClasspath
    shouldRunAfter test

    useJUnitPlatform()

    testLogging {
        events "passed"
    }
}

check.dependsOn integrationTest
```

Again, we're accessing a source set to get the relevant information, i.e. where the compiled test classes are — the `testClassesDirs` property — and what needs to be on the classpath when running them — `classpath`.

Users commonly want to run integration tests after the unit tests, because they are often slower to run and you want the build to fail early on the unit tests rather than later on the integration tests. That's why the above example adds a `shouldRunAfter()` declaration. This is preferred over `mustRunAfter()` so that Gradle has more flexibility in executing the build in parallel.

For information on how to determine code coverage for tests in additional source sets, see the JaCoCo Plugin and the JaCoCo Report Aggregation Plugin chapters.

== Testing Java Modules

If you are developing Java Modules, everything described in this chapter still applies and any of the supported test frameworks can be used. However, there are some things to consider depending on whether you need module information to be available, and module boundaries to be enforced, during test execution. In this context, the terms *whitebox testing* (module boundaries are deactivated or relaxed) and *blackbox testing* (module boundaries are in place) are often used. Whitebox testing is used/needed for unit testing and blackbox testing fits functional or integration test requirements.

Sample: Java Modules multi-project with integration tests

=== Whitebox unit test execution on the classpath

The simplest setup to write unit tests for functions or classes in modules is to *not* use module specifics during test execution. For this, you just need to write tests the same way you would write them for normal libraries. If you don't have a `module-info.java` file in your test source set (`src/test/java`) this source set will be considered as traditional Java library during compilation and test runtime. This means, all dependencies, including Jars with module information, are put on the classpath. The advantage is that all internal classes of your (or other) modules are then accessible directly in tests. This may be a totally valid setup for unit testing, where we do not care about the larger module structure, but only about testing single functions.

If you are using Eclipse: By default, Eclipse also runs unit tests as modules using module patching (see below). In an imported Gradle project, unit testing a module with the Eclipse test runner might fail. You then need to manually adjust the classpath/module path in the test run configuration or delegate test execution to Gradle.

This only concerns the test execution. Unit test compilation and development works fine in Eclipse.

=== Blackbox integration testing

For integration tests, you have the option to define the test set itself as additional module. You do this similar to how you turn your main sources into a module: by adding a `module-info.java` file to the corresponding source set (e.g. `integrationTests/java/module-info.java`).

You can find a full example that includes blackbox integration tests [here](#).

> **NOTE** In Eclipse, compiling multiple modules in one project is [currently not support](#). Therefore the integration test (blackbox) setup described here only works in Eclipse if the tests are moved to a separate subproject.

=== Whitebox test execution with module patching

Another approach for whitebox testing is to stay in the module world by *patching* the tests into the module under test. This way, module boundaries stay in place, but the tests themselves become part of the module under test and can then access the module's internals.

For which uses cases this is relevant and how this is best done is a topic of discussion. There is no general best approach at the moment. Thus, there is no special support for this in Gradle right now.

You can however, setup module patching for tests like this:

- Add a `module-info.java` to your test source set that is a copy of the main `module-info.java` with additional dependencies needed for testing (e.g. `requires org.junit.jupiter.api`).

- Configure both the `testCompileJava` and `test` tasks with arguments to patch the main classes with the test classes as shown below.

build.gradle.kts

```
val moduleName = "org.gradle.sample"
val patchArgs = listOf("--patch-module",
"$moduleName=${tasks.compileJava.get().destinationDirectory.asFile.get().path}")
tasks.compileTestJava {
    options.compilerArgs.addAll(patchArgs)
}
tasks.test {
    jvmArgs(patchArgs)
}
```

build.gradle

```
def moduleName = "org.gradle.sample"
def patchArgs = ["--patch-module", "$moduleName=${tasks.compileJava
.destinationDirectory.asFile.get().path}"]
tasks.named('compileTestJava') {
    options.compilerArgs += patchArgs
}
tasks.named('test') {
    jvmArgs += patchArgs
}
```

> **NOTE** If custom arguments are used for patching, these are not picked up by Eclipse and IDEA. You will most likely see invalid compilation errors in the IDE.

== Skipping the tests

If you want to skip the tests when running a build, you have a few options. You can either do it via command line arguments or in the build script. To do it on the command line, you can use the `-x` or `--exclude-task` option like so:

```
gradle build -x test
```

This excludes the `test` task and any other task that it *exclusively* depends on, i.e. no other task depends on the same task. Those tasks will not be marked "SKIPPED" by Gradle, but will simply not appear in the list of tasks executed.

Skipping a test via the build script can be done a few ways. One common approach is to make test execution conditional via the Task.onlyIf(String, org.gradle.api.specs.Spec) method. The following sample skips the `test` task if the project has a property called `mySkipTests`:

build.gradle.kts

```
tasks.test {
    val skipTestsProvider = providers.gradleProperty("mySkipTests")
    onlyIf("mySkipTests property is not set") {
        !skipTestsProvider.isPresent()
    }
}
```

build.gradle

```
def skipTestsProvider = providers.gradleProperty('mySkipTests')
test.onlyIf("mySkipTests property is not set") {
    !skipTestsProvider.present
}
```

In this case, Gradle will mark the skipped tests as "SKIPPED" rather than exclude them from the build.

== Forcing tests to run

In well-defined builds, you can rely on Gradle to only run tests if the tests themselves or the production code change. However, you may encounter situations where the tests rely on a third-party service or something else that might change but can't be modeled in the build.

You can always use the `--rerun` built-in task option to force a task to rerun.

```
gradle test --rerun
```

Alternatively, if build caching is not enabled, you can also force tests to run by cleaning the output of the relevant `Test` task — say `test` — and running the tests again, like so:

```
gradle cleanTest test
```

`cleanTest` is based on a task rule provided by the Base Plugin. You can use it for *any* task.

== Debugging when running tests

On the few occasions that you want to debug your code while the tests are running, it can be helpful if you can attach a debugger at that point. You can either set the Test.getDebug() property to `true` or use the `--debug-jvm` command line option, or use `--no-debug-jvm` to set it to false.

When debugging for tests is enabled, Gradle will start the test process suspended and listening on port 5005.

You can also enable debugging in the DSL, where you can also configure other properties:

```
test {
    debugOptions {
        enabled = true
        host = 'localhost'
        port = 4455
        server = true
        suspend = true
    }
}
```

With this configuration the test JVM will behave just like when passing the `--debug-jvm` argument but it will listen on port 4455.

To debug the test process remotely via network, the `host` needs to be set to the machine's IP address or `"*"` (listen on all interfaces).

Using test fixtures

Producing and using test fixtures within a single project

Test fixtures are commonly used to setup the code under test, or provide utilities aimed at facilitating the tests of a component. Java projects can enable test fixtures support by applying the `java-test-fixtures` plugin, in addition to the `java` or `java-library` plugins:

lib/build.gradle.kts

```
plugins {
    // A Java Library
    `java-library`
    // which produces test fixtures
    `java-test-fixtures`
    // and is published
    `maven-publish`
}
```

lib/build.gradle

```
plugins {
    // A Java Library
    id 'java-library'
    // which produces test fixtures
    id 'java-test-fixtures'
    // and is published
    id 'maven-publish'
}
```

This will automatically create a `testFixtures` source set, in which you can write your test fixtures. Test fixtures are configured so that:

- they can see the *main* source set classes
- *test* sources can see the *test fixtures* classes

For example for this main class:

src/main/java/com/acme/Person.java

```java
public class Person {
    private final String firstName;
    private final String lastName;

    public Person(String firstName, String lastName) {
        this.firstName = firstName;
        this.lastName = lastName;
    }

    public String getFirstName() {
        return firstName;
    }

    public String getLastName() {
        return lastName;
    }

    // ...
```

A test fixture can be written in `src/testFixtures/java`:

```java
public class Simpsons {
    private static final Person HOMER = new Person("Homer", "Simpson");
    private static final Person MARGE = new Person("Marjorie", "Simpson");
    private static final Person BART = new Person("Bartholomew", "Simpson");
    private static final Person LISA = new Person("Elisabeth Marie", "Simpson");
    private static final Person MAGGIE = new Person("Margaret Eve", "Simpson");
    private static final List<Person> FAMILY = new ArrayList<Person>() {{
        add(HOMER);
        add(MARGE);
        add(BART);
        add(LISA);
        add(MAGGIE);
    }};

    public static Person homer() { return HOMER; }

    public static Person marge() { return MARGE; }

    public static Person bart() { return BART; }

    public static Person lisa() { return LISA; }

    public static Person maggie() { return MAGGIE; }

    // ...
```

Declaring dependencies of test fixtures

Similarly to the Java Library Plugin, test fixtures expose an API and an implementation configuration:

lib/build.gradle.kts

```kotlin
dependencies {
    testImplementation("junit:junit:4.13")

    // API dependencies are visible to consumers when building
    testFixturesApi("org.apache.commons:commons-lang3:3.9")

    // Implementation dependencies are not leaked to consumers when building
    testFixturesImplementation("org.apache.commons:commons-text:1.6")
}
```

lib/build.gradle

```
dependencies {
    testImplementation 'junit:junit:4.13'

    // API dependencies are visible to consumers when building
    testFixturesApi 'org.apache.commons:commons-lang3:3.9'

    // Implementation dependencies are not leaked to consumers when building
    testFixturesImplementation 'org.apache.commons:commons-text:1.6'
}
```

It's worth noticing that if a dependency is an *implementation* dependency of test fixtures, then *when compiling tests that depend on those test fixtures,* the implementation dependencies will *not leak* into the compile classpath. This results in improved separation of concerns and better compile avoidance.

=== Consuming test fixtures of another project

Test fixtures are not limited to a single project. It is often the case that a dependent project tests also needs the test fixtures of the dependency. This can be achieved very easily using the testFixtures keyword:

build.gradle.kts

```
dependencies {
    implementation(project(":lib"))

    testImplementation("junit:junit:4.13")
    testImplementation(testFixtures(project(":lib")))
}
```

build.gradle

```
dependencies {
    implementation(project(":lib"))

    testImplementation 'junit:junit:4.13'
    testImplementation(testFixtures(project(":lib")))
}
```

=== Publishing test fixtures

One of the advantages of using the `java-test-fixtures` plugin is that test fixtures are published. By convention, test fixtures will be published with an artifact having the `test-fixtures` classifier. For both Maven and Ivy, an artifact with that classifier is simply published alongside the regular artifacts. However, if you use the `maven-publish` or `ivy-publish` plugin, test fixtures are published as additional variants in Gradle Module Metadata and you can directly depend on test fixtures of external libraries in another Gradle project:

build.gradle.kts

```
dependencies {
    // Adds a dependency on the test fixtures of Gson, however this
    // project doesn't publish such a thing
    functionalTest(testFixtures("com.google.code.gson:gson:2.8.5"))
}
```

build.gradle

```
dependencies {
    // Adds a dependency on the test fixtures of Gson, however this
    // project doesn't publish such a thing
    functionalTest testFixtures("com.google.code.gson:gson:2.8.5")
}
```

It's worth noting that if the external project is *not* publishing Gradle Module Metadata, then resolution will fail with an error indicating that such a variant cannot be found:

Output of `gradle dependencyInsight --configuration functionalTestClasspath --dependency gson`

```
> gradle dependencyInsight --configuration functionalTestClasspath --dependency
gson

> Task :dependencyInsight
com.google.code.gson:gson:2.8.5 FAILED
   Failures:
      - Could not resolve com.google.code.gson:gson:2.8.5.
          - Unable to find a variant of com.google.code.gson:gson:2.8.5 providing
the requested capability com.google.code.gson:gson-test-fixtures:
                - Variant compile provides com.google.code.gson:gson:2.8.5
                - Variant runtime provides com.google.code.gson:gson:2.8.5
                - Variant sources provides com.google.code.gson:gson:2.8.5
                - Variant javadoc provides com.google.code.gson:gson:2.8.5
                - Variant platform-compile provides com.google.code.gson:gson-
derived-platform:2.8.5
                - Variant platform-runtime provides com.google.code.gson:gson-
derived-platform:2.8.5
                - Variant enforced-platform-compile provides
com.google.code.gson:gson-derived-enforced-platform:2.8.5
                - Variant enforced-platform-runtime provides
com.google.code.gson:gson-derived-enforced-platform:2.8.5

com.google.code.gson:gson:2.8.5 FAILED
\--- functionalTestClasspath

A web-based, searchable dependency report is available by adding the --scan
option.

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

The error message mentions the missing `com.google.code.gson:gson-test-fixtures` capability, which is indeed not defined for this library. That's because by convention, for projects that use the `java-test-fixtures` plugin, Gradle automatically creates test fixtures variants with a capability whose name is the name of the main component, with the appendix `-test-fixtures`.

| NOTE | If you publish your library and use test fixtures, but do not want to publish the fixtures, you can deactivate publishing of the *test fixtures variants* as shown below. |

Managing Dependencies of JVM Projects

This chapter explains how to apply basic dependency management concepts to JVM-based projects. For a detailed introduction to dependency management, see dependency management in Gradle.

Dissecting a typical build script

Let's have a look at a very simple build script for a JVM-based project. It applies the Java Library plugin which automatically introduces a standard project layout, provides tasks for performing typical work and adequate support for dependency management.

build.gradle.kts

```
plugins {
    `java-library`
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("org.hibernate:hibernate-core:3.6.7.Final")
    api("com.google.guava:guava:23.0")
    testImplementation("junit:junit:4.+")
}
```

build.gradle

```
plugins {
    id 'java-library'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.hibernate:hibernate-core:3.6.7.Final'
    api 'com.google.guava:guava:23.0'
    testImplementation 'junit:junit:4.+'
}
```

The Project.dependencies{} code block declares that Hibernate core 3.6.7.Final is required to compile the project's production source code. It also states that junit >= 4.0 is required to compile the project's tests. All dependencies are supposed to be looked up in the Maven Central repository as defined by Project.repositories{}. The following sections explain each aspect in more detail.

== Declaring module dependencies

There are various types of dependencies that you can declare. One such type is a *module dependency*. A module dependency represents a dependency on a module with a specific version built outside the current build. Modules are usually stored in a repository, such as Maven Central, a corporate Maven or Ivy repository, or a directory in the local file system.

To define an module dependency, you add it to a dependency configuration:

build.gradle.kts

```
dependencies {
    implementation("org.hibernate:hibernate-core:3.6.7.Final")
}
```

build.gradle

```
dependencies {
    implementation 'org.hibernate:hibernate-core:3.6.7.Final'
}
```

To find out more about defining dependencies, have a look at Declaring Dependencies.

== Using dependency configurations

A Configuration is a named set of dependencies and artifacts. There are three main purposes for a *configuration*:

Declaring dependencies

> A plugin uses configurations to make it easy for build authors to declare what other subprojects or external artifacts are needed for various purposes during the execution of tasks defined by the plugin. For example a plugin may need the Spring web framework dependency to compile the source code.

Resolving dependencies

> A plugin uses configurations to find (and possibly download) inputs to the tasks it defines. For example Gradle needs to download Spring web framework JAR files from Maven Central.

Exposing artifacts for consumption

> A plugin uses configurations to define what *artifacts* it generates for other projects to consume. For example the project would like to publish its compiled source code packaged in the JAR file to an in-house Artifactory repository.

With those three purposes in mind, let's take a look at a few of the standard configurations defined by the Java Library Plugin.

implementation

> The dependencies required to compile the production source of the project which *are not* part of the API exposed by the project. For example the project uses Hibernate for its internal persistence layer implementation.

api

> The dependencies required to compile the production source of the project which *are* part of the API exposed by the project. For example the project uses Guava and exposes public interfaces with Guava classes in their method signatures.

testImplementation

> The dependencies required to compile and run the test source of the project. For example the project decided to write test code with the test framework JUnit.

Various plugins add further standard configurations. You can also define your own custom configurations in your build via Project.configurations{}. See What are dependency configurations for the details of defining and customizing dependency configurations.

== Declaring common Java repositories

How does Gradle know where to find the files for external dependencies? Gradle looks for them in a *repository*. A repository is a collection of modules, organized by `group`, `name` and `version`. Gradle understands different repository types, such as Maven and Ivy, and supports

various ways of accessing the repository via HTTP or other protocols.

By default, Gradle does not define any repositories. You need to define at least one with the help of Project.repositories{} before you can use module dependencies. One option is use the Maven Central repository:

build.gradle.kts

```
repositories {
    mavenCentral()
}
```

build.gradle

```
repositories {
    mavenCentral()
}
```

You can also have repositories on the local file system. This works for both Maven and Ivy repositories.

build.gradle.kts

```
repositories {
    ivy {
        // URL can refer to a local directory
        url = uri("../local-repo")
    }
}
```

build.gradle

```
repositories {
    ivy {
        // URL can refer to a local directory
        url "../local-repo"
    }
}
```

A project can have multiple repositories. Gradle will look for a dependency in each repository in the order they are specified, stopping at the first repository that contains the requested module.

To find out more about defining repositories, have a look at Declaring Repositories.

== Publishing artifacts

To learn more about publishing artifacts, have a look at publishing plugins.

== JAVA TOOLCHAINS

= Toolchains for JVM projects

Working on multiple projects can require interacting with multiple versions of the Java language. Even within a single project different parts of the codebase may be fixed to a particular language level due to backward compatibility requirements. This means different versions of the same tools (a toolchain) must be installed and managed on each machine that builds the project.

A **Java toolchain** is a set of tools to build and run Java projects, which is usually provided by the environment via local JRE or JDK installations. Compile tasks may use `javac` as their compiler, test and exec tasks may use the `java` command while `javadoc` will be used to generate documentation.

By default, Gradle uses the same Java toolchain for running Gradle itself and building JVM projects. However, this may only sometimes be desirable. Building projects with different Java versions on different developer machines and CI servers may lead to unexpected issues. Additionally, you may want to build a project using a Java version that is not supported for running Gradle.

In order to improve reproducibility of the builds and make build requirements clearer, Gradle allows configuring toolchains on both project and task levels.

== Toolchains for projects

You can define what toolchain to use for a project by stating the Java language version in the `java` extension block:

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

Executing the build (e.g. using `gradle check`) will now handle several things for you and others running your build:

1. Gradle configures all compile, test and javadoc tasks to use the defined toolchain.

2. Gradle detects locally installed toolchains.

3. Gradle chooses a toolchain matching the requirements (any Java 17 toolchain for the example above).

4. If no matching toolchain is found, Gradle can automatically download a matching one based on the configured toolchain download repositories.

Toolchain support is available in the Java plugins and for the tasks they define.

For the Groovy plugin, compilation is supported but not yet Groovydoc generation. For the Scala plugin, compilation and Scaladoc generation are supported.

=== Selecting toolchains by vendor

In case your build has specific requirements from the used JRE/JDK, you may want to define the vendor for the toolchain as well. `JvmVendorSpec` has a list of well-known JVM vendors recognized by Gradle. The advantage is that Gradle can handle any inconsistencies across JDK versions in how exactly the JVM encodes the vendor information.

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.ADOPTIUM
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.ADOPTIUM
    }
}
```

If the vendor you want to target is not a known vendor, you can still restrict the toolchain to those matching the `java.vendor` system property of the available toolchains.

The following snippet uses filtering to include a subset of available toolchains. This example only includes toolchains whose `java.vendor` property contains the given match string. The matching is done in a case-insensitive manner.

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.matching("customString")
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.matching("customString")
    }
}
```

=== Selecting toolchains by virtual machine implementation

If your project requires a specific implementation, you can filter based on the implementation as well. Currently available implementations to choose from are:

VENDOR_SPECIFIC

Acts as a placeholder and matches any implementation from any vendor (e.g. hotspot, zulu, …)

J9

Matches only virtual machine implementations using the OpenJ9/IBM J9 runtime engine.

For example, to use an IBM JVM, distributed via AdoptOpenJDK, you can specify the filter as shown in the example below.

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.IBM
        implementation = JvmImplementation.J9
    }
}
```

build.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
        vendor = JvmVendorSpec.IBM
        implementation = JvmImplementation.J9
    }
}
```

> **NOTE** The Java major version, the vendor (if specified) and implementation (if specified) will be tracked as an input for compilation and test execution.

=== Configuring toolchain specifications

Gradle allows configuring multiple properties that affect the selection of a toolchain, such as language version or vendor. Even though these properties can be configured independently, the configuration must follow certain rules in order to form a *valid* specification.

A `JavaToolchainSpec` is considered *valid* in two cases:

1. when no properties have been set, i.e. the specification is *empty*;

2. when `languageVersion` has been set, optionally followed by setting any other property.

In other words, if a vendor or an implementation are specified, they must be accompanied by the language version. Gradle distinguishes between toolchain specifications that configure the language version and the ones that do not. A specification without a language version, in most cases, would be treated as a one that selects the toolchain of the current build.

Usage of *invalid* instances of `JavaToolchainSpec` results in a build error since Gradle 8.0.

== Toolchains for tasks

In case you want to tweak which toolchain is used for a specific task, you can specify the exact tool a task is using. For example, the `Test` task exposes a `JavaLauncher` property that defines which java executable to use for launching the tests.

In the example below, we configure all java compilation tasks to use Java 8. Additionally, we introduce a new `Test` task that will run our unit tests using a JDK 17.

list/build.gradle.kts

```
tasks.withType<JavaCompile>().configureEach {
    javaCompiler = javaToolchains.compilerFor {
        languageVersion = JavaLanguageVersion.of(8)
    }
}

tasks.register<Test>("testsOn17") {
    javaLauncher = javaToolchains.launcherFor {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

list/build.gradle

```
tasks.withType(JavaCompile).configureEach {
    javaCompiler = javaToolchains.compilerFor {
        languageVersion = JavaLanguageVersion.of(8)
    }
}

task('testsOn17', type: Test) {
    javaLauncher = javaToolchains.launcherFor {
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

In addition, in the `application` subproject, we add another Java execution task to run our application with JDK 17.

application/build.gradle.kts

```
tasks.register<JavaExec>("runOn17") {
    javaLauncher = javaToolchains.launcherFor {
        languageVersion = JavaLanguageVersion.of(17)
    }

    classpath = sourceSets["main"].runtimeClasspath
    mainClass = application.mainClass
}
```

application/build.gradle

```
task('runOn17', type: JavaExec) {
    javaLauncher = javaToolchains.launcherFor {
        languageVersion = JavaLanguageVersion.of(17)
    }

    classpath = sourceSets.main.runtimeClasspath
    mainClass = application.mainClass
}
```

Depending on the task, a JRE might be enough while for other tasks (e.g. compilation), a JDK is required. By default, Gradle prefers installed JDKs over JREs if they can satisfy the requirements.

Toolchains tool providers can be obtained from the `javaToolchains` extension.

Three tools are available:

- A `JavaCompiler` which is the tool used by the JavaCompile task
- A `JavaLauncher` which is the tool used by the JavaExec or Test tasks
- A `JavadocTool` which is the tool used by the Javadoc task

=== Integration with tasks relying on a Java executable or Java home

Any task that can be configured with a path to a Java executable, or a Java home location, can benefit from toolchains.

While you will not be able to wire a toolchain tool directly, they all have the metadata that gives access to their full path or to the path of the Java installation they belong to.

For example, you can configure the `java` executable for a task as follows:

build.gradle.kts

```
val launcher = javaToolchains.launcherFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.sampleTask {
    javaExecutable = launcher.map { it.executablePath }
}
```

build.gradle

```
def launcher = javaToolchains.launcherFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.named('sampleTask') {
    javaExecutable = launcher.map { it.executablePath }
}
```

As another example, you can configure the *Java Home* for a task as follows:

build.gradle.kts

```
val launcher = javaToolchains.launcherFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.anotherSampleTask {
    javaHome = launcher.map { it.metadata.installationPath }
}
```

build.gradle

```
def launcher = javaToolchains.launcherFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.named('anotherSampleTask') {
    javaHome = launcher.map { it.metadata.installationPath }
}
```

If you require a path to a specific tool such as Java compiler, you can obtain it as follows:

build.gradle.kts

```
val compiler = javaToolchains.compilerFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.yetAnotherSampleTask {
    javaCompilerExecutable = compiler.map { it.executablePath }
}
```

```
def compiler = javaToolchains.compilerFor {
    languageVersion = JavaLanguageVersion.of(11)
}

tasks.named('yetAnotherSampleTask') {
    javaCompilerExecutable = compiler.map { it.executablePath }
}
```

WARNING	The examples above use tasks with `RegularFileProperty` and `DirectoryProperty` properties which allow lazy configuration. Doing respectively `launcher.get().executablePath`, `launcher.get().metadata.installationPath` or `compiler.get().executablePath` instead will give you the full path for the given toolchain but note that this may realize (and provision) a toolchain eagerly.

Auto detection of installed toolchains

By default, Gradle automatically detects local JRE/JDK installations so no further configuration is required by the user. The following is a list of common package managers, tools, and locations that are supported by the JVM auto-detection.

JVM auto-detection knows how to work with:

- Operation-system specific locations: Linux, macOS, Windows

- Package Managers: Asdf-vm, Jabba, SDKMAN!

- Maven Toolchain specifications

- IntelliJ IDEA installations

Among the set of all detected JRE/JDK installations, one will be picked according to the Toolchain Precedence Rules.

NOTE	Whether you are using toolchain auto-detection or you are configuring [sec:custom_loc], installations that are non-existing or without a `bin/java` executable will be ignored with a warning, but they won't generate an error.

How to disable auto-detection

In order to disable auto-detection, you can use the `org.gradle.java.installations.auto-detect` Gradle property:

- Either start gradle using `-Porg.gradle.java.installations.auto-detect=false`
- Or put `org.gradle.java.installations.auto-detect=false` into your `gradle.properties` file.

Auto-provisioning

If Gradle can't find a locally available toolchain that matches the requirements of the build, it can automatically download one (as long as a toolchain download repository has been configured; for detail, see relevant section). Gradle installs the downloaded JDKs in the Gradle User Home.

NOTE	Gradle only downloads JDK versions for GA releases. There is no support for downloading early access versions.

Once installed in the Gradle User Home, a provisioned JDK becomes one of the JDKs visible to

auto-detection and can be used by any subsequent builds, just like any other JDK installed on the system.

Since auto-provisioning only kicks in when auto-detection fails to find a matching JDK, auto-provisioning can only download new JDKs and is in no way involved in updating any of the already installed ones. None of the auto-provisioned JDKs will ever be revisited and automatically updated by auto-provisioning, even if there is a newer minor version available for them.

=== Toolchain Download Repositories

Toolchain download repository definitions are added to a build by applying specific settings plugins. For details on writing such plugins, consult the Toolchain Resolver Plugins page.

One example of a toolchain resolver plugin is the Disco Toolchains Plugin, based on the foojay Disco API. It even has a convention variant, which automatically takes care of all the needed configuration, just by being applied:

settings.gradle.kts

```
plugins {
    id("org.gradle.toolchains.foojay-resolver-convention") version("0.7.0")
}
```

settings.gradle

```
plugins {
    id 'org.gradle.toolchains.foojay-resolver-convention' version '0.7.0'
}
```

In general, when applying toolchain resolver plugins, the toolchain download resolvers provided by them also need to be configured. Let's illustrate with an example. Consider two toolchain resolver plugins applied by the build:

- One is the Foojay plugin mentioned above, which downloads toolchains via the `FoojayToolchainResolver` it provides.
- The other contains a **FICTITIOUS** resolver named `MadeUpResolver`.

The following example uses these toolchain resolvers in a build via the `toolchainManagement` block in the settings file:

settings.gradle.kts

```
toolchainManagement {
    jvm { ①
        javaRepositories {
            repository("foojay") { ②
                resolverClass =
org.gradle.toolchains.foojay.FoojayToolchainResolver::class.java
            }
            repository("made_up") { ③
                resolverClass = MadeUpResolver::class.java
                credentials {
                    username = "user"
                    password = "password"
                }
                authentication {
                    create<DigestAuthentication>("digest")
                } ④
            }
        }
    }
}
```

settings.gradle

```
toolchainManagement {
    jvm { ①
        javaRepositories {
            repository('foojay') { ②
                resolverClass = org.gradle.toolchains.foojay
.FoojayToolchainResolver
            }
            repository('made_up') { ③
                resolverClass = MadeUpResolver
                credentials {
                    username "user"
                    password "password"
                }
                authentication {
                    digest(BasicAuthentication)
                } ④
            }
        }
    }
}
```

① In the `toolchainManagement` block, the `jvm` block contains configuration for Java toolchains.

② The `javaRepositories` block defines named Java toolchain repository configurations. Use the `resolverClass` property to link these configurations to plugins.

③ Toolchain declaration order matters. Gradle downloads from the first repository that provides a match, starting with the first repository in the list.

④ You can configure toolchain repositories with the same set of authentication and authorization options used for dependency management.

WARNING	The `jvm` block in `toolchainManagement` only resolves after applying a toolchain resolver plugin.

=== Viewing and debugging toolchains

Gradle can display the list of all detected toolchains including their metadata.

For example, to show all toolchains of a project, run:

```
gradle -q javaToolchains
```

Output of `gradle -q javaToolchains`

```
> gradle -q javaToolchains

 + Options
     | Auto-detection:      Enabled
     | Auto-download:       Enabled

 + AdoptOpenJDK 1.8.0_242
     | Location:            /Users/username/myJavaInstalls/8.0.242.hs-adpt/jre
     | Language Version:    8
     | Vendor:              AdoptOpenJDK
     | Architecture:        x86_64
     | Is JDK:              false
     | Detected by:         Gradle property 'org.gradle.java.installations.paths'

 + Microsoft JDK 16.0.2+7
     | Location:            /Users/username/.sdkman/candidates/java/16.0.2.7.1-ms
     | Language Version:    16
     | Vendor:              Microsoft
     | Architecture:        aarch64
     | Is JDK:              true
     | Detected by:         SDKMAN!

 + OpenJDK 15-ea
     | Location:            /Users/user/customJdks/15.ea.21-open
     | Language Version:    15
     | Vendor:              AdoptOpenJDK
     | Architecture:        x86_64
     | Is JDK:              true
     | Detected by:         environment variable 'JDK16'

 + Oracle JDK 1.7.0_80
     | Location:
/Library/Java/JavaVirtualMachines/jdk1.7.0_80.jdk/Contents/Home/jre
     | Language Version:    7
     | Vendor:              Oracle
     | Architecture:        x86_64
     | Is JDK:              false
     | Detected by:         MacOS java_home
```

This can help to debug which toolchains are available to the build, how they are detected and what kind of metadata Gradle knows about those toolchains.

=== How to disable auto provisioning

In order to disable auto-provisioning, you can use the `org.gradle.java.installations.auto-download` Gradle property:

- Either start gradle using `-Porg.gradle.java.installations.auto-download=false`

- Or put `org.gradle.java.installations.auto-download=false` into a `gradle.properties` file.

== Custom toolchain locations

If auto-detecting local toolchains is not sufficient or disabled, there are additional ways you can let Gradle know about installed toolchains.

If your setup already provides environment variables pointing to installed JVMs, you can also let Gradle know about which environment variables to take into account. Assuming the environment variables `JDK8` and `JRE17` point to valid java installations, the following instructs Gradle to resolve those environment variables and consider those installations when looking for a matching toolchain.

```
org.gradle.java.installations.fromEnv=JDK8,JRE17
```

Additionally, you can provide a comma-separated list of paths to specific installations using the `org.gradle.java.installations.paths` property. For example, using the following in your `gradle.properties` will let Gradle know which directories to look at when detecting toolchains. Gradle will treat these directories as possible installations but will not descend into any nested directories.

```
org.gradle.java.installations.paths=/custom/path/jdk1.8,/shared/jre11
```

Gradle does not prioritize custom toolchains over auto-detected toolchains. If you enable auto-detection in your build, custom toolchains extend the set of toolchain locations. Gradle picks a toolchain according to the precedence rules.

== Toolchain installations precedence

Gradle will sort all the JDK/JRE installations matching the toolchain specification of the build and will pick the first one. Sorting is done based on the following rules:

1. the installation currently running Gradle is preferred over any other

2. JDK installations are preferred over JRE ones

3. certain vendors take precedence over others; their ordering (from the highest priority to lowest):

   a. ADOPTIUM

   b. ADOPTOPENJDK

   c. AMAZON

   d. APPLE

   e. AZUL

   f. BELLSOFT

   g. GRAAL_VM

   h. HEWLETT_PACKARD

   i. IBM

   j. JETBRAINS

   k. MICROSOFT

   l. ORACLE

   m. SAP

   n. TENCENT

   o. everything else

4. higher major versions take precedence over lower ones

5. higher minor versions take precedence over lower ones

6. installation paths take precedence according to their lexicographic ordering (last resort criteria for deterministically deciding between installations of the same type, from the same vendor and with the same version)

All these rules are applied as multilevel sorting criteria, **in the order shown**. Let's illustrate with an example. A toolchain specification requests Java version 17. Gradle detects the following matching installations:

- Oracle JRE v17.0.1

- Oracle JDK v17.0.0

- Microsoft JDK 17.0.0

- Microsoft JRE 17.0.1

- Microsoft JDK 17.0.1

Assume that Gradle runs on a major Java version other than 17. Otherwise, that installation would have priority.

When we apply the above rules to sort this set we will end up with following ordering:

1. Microsoft JDK 17.0.1

2. Microsoft JDK 17.0.0

3. Oracle JDK v17.0.0

4. Microsoft JRE v17.0.1

5. Oracle JRE v17.0.1

Gradle prefers JDKs over JREs, so the JREs come last. Gradle prefers the Microsoft vendor over Oracle, so the Microsoft installations come first. Gradle prefers higher version numbers, so JDK 17.0.1 comes before JDK 17.0.0.

So Gradle picks the first match in this order: Microsoft JDK 17.0.1.

== Toolchains for plugin authors

When creating a plugin or a task that uses toolchains, it is essential to provide sensible defaults and allow users to override them.

For JVM projects, it is usually safe to assume that the `java` plugin has been applied to the project. The `java` plugin is automatically applied for the core Groovy and Scala plugins, as well as for the Kotlin plugin. In such a case, using the toolchain defined via the `java` extension as a default value for the tool property is appropriate. This way, the users will need to configure the toolchain only once on the project level.

The example below showcases how to use the default toolchain as convention while allowing users to individually configure the toolchain per task.

build.gradle.kts

```
abstract class CustomTaskUsingToolchains : DefaultTask() {

    @get:Nested
    abstract val launcher: Property<JavaLauncher> ①

    init {
        val toolchain =
project.extensions.getByType<JavaPluginExtension>().toolchain ②
        val defaultLauncher = javaToolchainService.launcherFor(toolchain) ③
        launcher.convention(defaultLauncher) ④
    }

    @TaskAction
    fun showConfiguredToolchain() {
        println(launcher.get().executablePath)
        println(launcher.get().metadata.installationPath)
    }

    @get:Inject
    protected abstract val javaToolchainService: JavaToolchainService
}
```

```
abstract class CustomTaskUsingToolchains extends DefaultTask {

    @Nested
    abstract Property<JavaLauncher> getLauncher() ①

    CustomTaskUsingToolchains() {
        def toolchain = project.extensions.getByType(JavaPluginExtension.class)
.toolchain ②
        Provider<JavaLauncher> defaultLauncher = getJavaToolchainService()
.launcherFor(toolchain) ③
        launcher.convention(defaultLauncher) ④
    }

    @TaskAction
    def showConfiguredToolchain() {
        println launcher.get().executablePath
        println launcher.get().metadata.installationPath
    }

    @Inject
    protected abstract JavaToolchainService getJavaToolchainService()
}
```

① We declare a `JavaLauncher` property on the task. The property must be marked as a `@Nested` input to make sure the task is responsive to toolchain changes.

② We obtain the toolchain spec from the `java` extension to use it as a default.

③ Using the `JavaToolchainService` we get a provider of the `JavaLauncher` that matches the toolchain.

④ Finally, we wire the launcher provider as a convention for our property.

In a project where the `java` plugin was applied, we can use the task as follows:

build.gradle.kts

```
plugins {
    java
}

java {
    toolchain { ①
        languageVersion = JavaLanguageVersion.of(8)
    }
}

tasks.register<CustomTaskUsingToolchains>("showDefaultToolchain") ②

tasks.register<CustomTaskUsingToolchains>("showCustomToolchain") {
    launcher = javaToolchains.launcherFor { ③
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

build.gradle

```
plugins {
    id 'java'
}

java {
    toolchain { ①
        languageVersion = JavaLanguageVersion.of(8)
    }
}

tasks.register('showDefaultToolchain', CustomTaskUsingToolchains) ②

tasks.register('showCustomToolchain', CustomTaskUsingToolchains) {
    launcher = javaToolchains.launcherFor { ③
        languageVersion = JavaLanguageVersion.of(17)
    }
}
```

① The toolchain defined on the `java` extension is used by default to resolve the launcher.

② The custom task without additional configuration will use the default Java 8 toolchain.

③ The other task overrides the value of the launcher by selecting a different toolchain using `javaToolchains` service.

When a task needs access to toolchains without the `java` plugin being applied the toolchain service can be used directly. If an unconfigured toolchain spec is provided to the service, it will always return a tool provider for the toolchain that is running Gradle. This can be achieved by passing an empty lambda when requesting a tool: `javaToolchainService.launcherFor({})`.

You can find more details on defining custom tasks in the Authoring tasks documentation.

== Toolchains limitations

Gradle may detect toolchains incorrectly when it's running in a JVM compiled against `musl`, an alternative implementation of the C standard library. JVMs compiled against `musl` can sometimes override the `LD_LIBRARY_PATH` environment variable to control dynamic library resolution. This can influence forked java processes launched by Gradle, resulting in unexpected behavior.

As a consequence, using multiple java toolchains is discouraged in environments with the `musl` library. This is the case in most Alpine distributions — consider using another distribution, like Ubuntu, instead. If you are using a single toolchain, the JVM running Gradle, to build and run your application, you can safely ignore this limitation.

= Toolchain Resolver Plugins

In Gradle version 7.6 and above, Gradle provides a way to define Java toolchain auto-provisioning logic in plugins. This page explains how to author a toolchain resolver plugin. For details on how toolchain auto-provisioning interacts with these plugins, see Toolchains.

== Provide a download URI

Toolchain resolver plugins provide logic to map a toolchain request to a download response. At the moment the download response only contains a download URL, but may be extended in the future.

| WARNING | For the download URL only secure protocols like `https` are accepted. This is required to make sure no one can tamper with the download in flight. |

The plugins provide the mapping logic via an implementation of JavaToolchainResolver:

JavaToolchainResolverImplementation.java

```java
public abstract class JavaToolchainResolverImplementation
        implements JavaToolchainResolver { ①

    public Optional<JavaToolchainDownload> resolve(JavaToolchainRequest request) {
②
        return Optional.empty(); // custom mapping logic goes here instead
    }
}
```

① This class is `abstract` because `JavaToolchainResolver` is a build service. Gradle provides dynamic implementations for certain abstract methods at runtime.

② The mapping method returns a download response wrapped in an `Optional`. If the resolver implementation can't provide a matching toolchain, the enclosing `Optional` contains an empty value.

Register the resolver in a plugin

Use a settings plugin (`Plugin<Settings>`) to register the `JavaToolchainResolver` implementation:

JavaToolchainResolverPlugin.java

```java
public abstract class JavaToolchainResolverPlugin implements Plugin<Settings> { ①
    @Inject
    protected abstract JavaToolchainResolverRegistry getToolchainResolverRegistry
(); ②

    public void apply(Settings settings) {
        settings.getPlugins().apply("jvm-toolchain-management"); ③

        JavaToolchainResolverRegistry registry = getToolchainResolverRegistry();
        registry.register(JavaToolchainResolverImplementation.class);
    }
}
```

① The plugin uses property injection, so it must be `abstract` and a settings plugin.

② To register the resolver implementation, use property injection to access the JavaToolchainResolverRegistry Gradle service.

③ Resolver plugins must apply the `jvm-toolchain-management` base plugin. This dynamically adds the `jvm` block to `toolchainManagement`, which makes registered toolchain repositories usable from the build.

JVM PLUGINS

The Java Library Plugin

The Java Library plugin expands the capabilities of the Java Plugin (`java`) by providing specific knowledge about Java libraries. In particular, a Java library exposes an API to consumers (i.e.,

other projects using the Java or the Java Library plugin). All the source sets, tasks and configurations exposed by the Java plugin are implicitly available when using this plugin.

== Usage

To use the Java Library plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    `java-library`
}
```

build.gradle

```
plugins {
    id 'java-library'
}
```

== API and implementation separation

The key difference between the standard Java plugin and the Java Library plugin is that the latter introduces the concept of an *API* exposed to consumers. A library is a Java component meant to be consumed by other components. It's a very common use case in multi-project builds, but also as soon as you have external dependencies.

The plugin exposes two configurations that can be used to declare dependencies: `api` and `implementation`. The `api` configuration should be used to declare dependencies which are exported by the library API, whereas the `implementation` configuration should be used to declare dependencies which are internal to the component.

build.gradle.kts

```
dependencies {
    api("org.apache.httpcomponents:httpclient:4.5.7")
    implementation("org.apache.commons:commons-lang3:3.5")
}
```

build.gradle

```
dependencies {
    api 'org.apache.httpcomponents:httpclient:4.5.7'
    implementation 'org.apache.commons:commons-lang3:3.5'
}
```

Dependencies appearing in the `api` configurations will be transitively exposed to consumers of the library, and as such will appear on the compile classpath of consumers. Dependencies found in the `implementation` configuration will, on the other hand, not be exposed to consumers, and therefore not leak into the consumers' compile classpath. This comes with several benefits:

- dependencies do not leak into the compile classpath of consumers anymore, so you will never accidentally depend on a transitive dependency

- faster compilation thanks to reduced classpath size

- less recompilations when implementation dependencies change: consumers would not need to be recompiled

- cleaner publishing: when used in conjunction with the new `maven-publish` plugin, Java libraries produce POM files that distinguish exactly between what is required to compile against the library and what is required to use the library at runtime (in other words, don't mix what is needed to compile the library itself and what is needed to compile against the library).

> **NOTE** The `compile` and `runtime` configurations have been removed with Gradle 7.0. Please refer to the upgrade guide how to migrate to `implementation` and `api` configurations`.

If your build consumes a published module with POM metadata, the Java and Java Library plugins both honor api and implementation separation through the scopes used in the POM. Meaning that the compile classpath only includes Maven `compile` scoped dependencies, while the runtime classpath adds the Maven `runtime` scoped dependencies as well.

This often does not have an effect on modules published with Maven, where the POM that defines the project is directly published as metadata. There, the compile scope includes both dependencies that were required to compile the project (i.e. implementation dependencies) and dependencies required to compile against the published library (i.e. API dependencies). For most published libraries, this means that all dependencies belong to the compile scope. If you encounter such an issue with an existing library, you can consider a component metadata rule to fix the incorrect metadata in your build. However, as mentioned above, if the library is published with Gradle, the produced POM file only puts `api` dependencies into the compile scope and the remaining `implementation` dependencies into the runtime scope.

If your build consumes modules with Ivy metadata, you might be able to activate api and implementation separation as described here if all modules follow a certain structure.

> **NOTE** Separating compile and runtime scope of modules is active by default in Gradle 5.0+. In Gradle 4.6+, you need to activate it by adding `enableFeaturePreview('IMPROVED_POM_SUPPORT')` in *settings.gradle*.

== Recognizing API and implementation dependencies

This section will help you identify API and Implementation dependencies in your code using simple rules of thumb. The first of these is:

- Prefer the `implementation` configuration over `api` when possible

This keeps the dependencies off of the consumer's compilation classpath. In addition, the consumers will immediately fail to compile if any implementation types accidentally leak into the public API.

So when should you use the `api` configuration? An API dependency is one that contains at least one type that is exposed in the library binary interface, often referred to as its ABI (Application Binary Interface). This includes, but is not limited to:

- types used in super classes or interfaces
- types used in public method parameters, including generic parameter types (where *public* is something that is visible to compilers. I.e. , *public*, *protected* and *package private* members in the Java world)
- types used in public fields
- public annotation types

By contrast, any type that is used in the following list is irrelevant to the ABI, and therefore should be declared as an `implementation` dependency:

- types exclusively used in method bodies
- types exclusively used in private members
- types exclusively found in internal classes (future versions of Gradle will let you declare which packages belong to the public API)

The following class makes use of a couple of third-party libraries, one of which is exposed in the class's public API and the other is only used internally. The import statements don't help us determine which is which, so we have to look at the fields, constructors and methods instead:

=== Example: Making the difference between API and implementation

src/main/java/org/gradle/HttpClientWrapper.java

```java
// The following types can appear anywhere in the code
// but say nothing about API or implementation usage
import org.apache.commons.lang3.exception.ExceptionUtils;
import org.apache.http.HttpEntity;
import org.apache.http.HttpResponse;
import org.apache.http.HttpStatus;
import org.apache.http.client.HttpClient;
import org.apache.http.client.methods.HttpGet;

import java.io.ByteArrayOutputStream;
import java.io.IOException;
import java.io.UnsupportedEncodingException;

public class HttpClientWrapper {

    private final HttpClient client; // private member: implementation details

    // HttpClient is used as a parameter of a public method
    // so "leaks" into the public API of this component
    public HttpClientWrapper(HttpClient client) {
        this.client = client;
    }

    // public methods belongs to your API
    public byte[] doRawGet(String url) {
        HttpGet request = new HttpGet(url);
        try {
            HttpEntity entity = doGet(request);
            ByteArrayOutputStream baos = new ByteArrayOutputStream();
            entity.writeTo(baos);
            return baos.toByteArray();
        } catch (Exception e) {
            ExceptionUtils.rethrow(e); // this dependency is internal only
        } finally {
            request.releaseConnection();
        }
        return null;
    }

    // HttpGet and HttpEntity are used in a private method, so they don't belong
to the API
    private HttpEntity doGet(HttpGet get) throws Exception {
        HttpResponse response = client.execute(get);
        if (response.getStatusLine().getStatusCode() != HttpStatus.SC_OK) {
            System.err.println("Method failed: " + response.getStatusLine());
        }
        return response.getEntity();
    }
}
```

The *public* constructor of `HttpClientWrapper` uses `HttpClient` as a parameter, so it is exposed to consumers and therefore belongs to the API. Note that `HttpGet` and `HttpEntity` are used in the signature of a *private* method, and so they don't count towards making HttpClient an API dependency.

On the other hand, the `ExceptionUtils` type, coming from the `commons-lang` library, is only used in a method body (not in its signature), so it's an implementation dependency.

Therefore, we can deduce that `httpclient` is an API dependency, whereas `commons-lang` is an implementation dependency. This conclusion translates into the following declaration in the build script:

build.gradle.kts

```
dependencies {
    api("org.apache.httpcomponents:httpclient:4.5.7")
    implementation("org.apache.commons:commons-lang3:3.5")
}
```

build.gradle

```
dependencies {
    api 'org.apache.httpcomponents:httpclient:4.5.7'
    implementation 'org.apache.commons:commons-lang3:3.5'
}
```

== The Java Library plugin configurations

The following graph describes how configurations are setup when the Java Library plugin is in use.
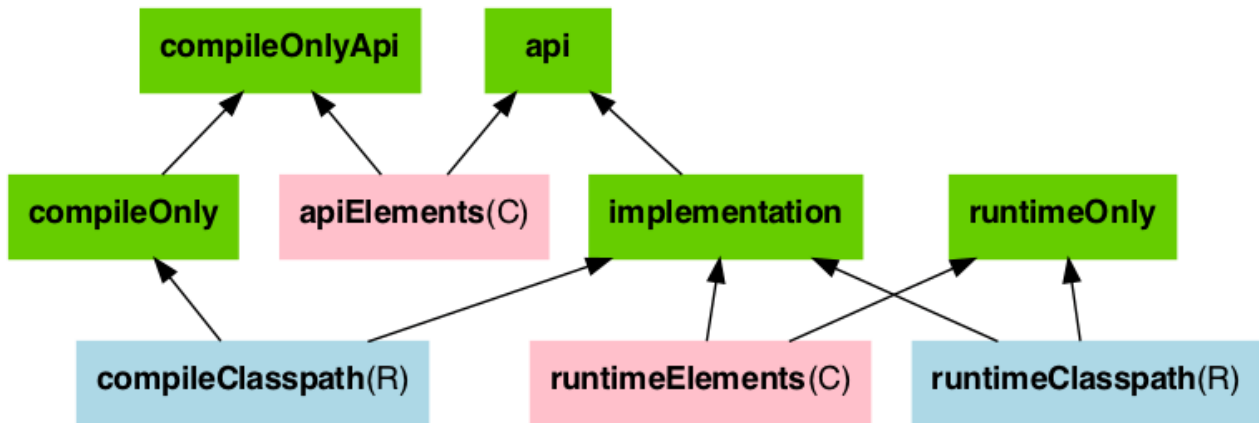
- The configurations in *green* are the ones a user should use to declare dependencies
- The configurations in *pink* are the ones used when a component compiles, or runs against the library
- The configurations in *blue* are internal to the component, for its own use

And the next graph describes the test configurations setup:
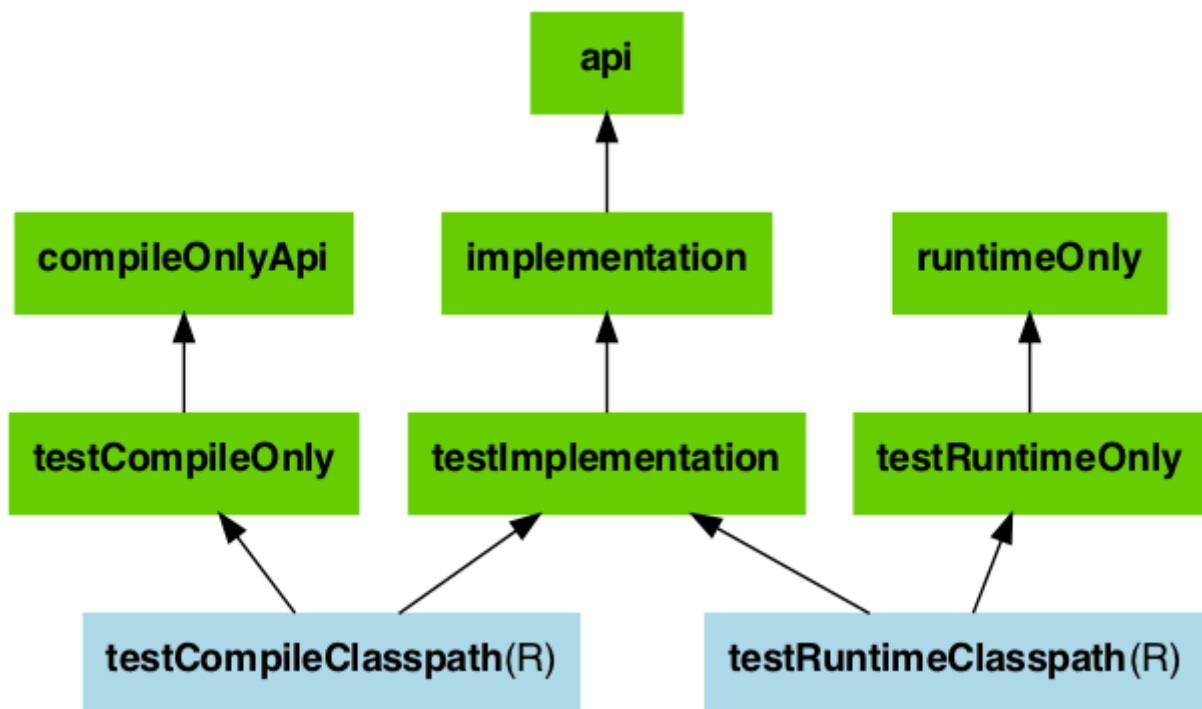
The role of each configuration is described in the following tables:

Table 9. Java Library plugin - configurations used to declare dependencies

Configuration name	Role	Consumable?	Resolvable?	Description
`api`	Declaring API dependencies	no	no	This is where you declare dependencies which are transitively exported to consumers, for compile time and runtime.
`implementation`	Declaring implementation dependencies	no	no	This is where you declare dependencies which are purely internal and not meant to be exposed to consumers (they are still exposed to consumers at runtime).
`compileOnly`	Declaring compile only dependencies	no	no	This is where you declare dependencies which are required at compile time, but not at runtime. This typically includes dependencies which are shaded when found at runtime.
`compileOnlyApi`	Declaring compile only API dependencies	no	no	This is where you declare dependencies which are required at compile time by your module and consumers, but not at runtime. This typically includes dependencies which are shaded when found at runtime.
`runtimeOnly`	Declaring runtime dependencies	no	no	This is where you declare dependencies which are only required at runtime, and not at compile time.
`testImplementation`	Test dependencies	no	no	This is where you declare dependencies which are used to compile tests.
`testCompileOnly`	Declaring test compile only dependencies	no	no	This is where you declare dependencies which are only required at test compile time, but should not leak into the runtime. This typically includes dependencies which are shaded when found at runtime.
`testRuntimeOnly`	Declaring test runtime dependencies	no	no	This is where you declare dependencies which are only required at test runtime, and not at test compile time.

Table 10. Java Library plugin — configurations used by consumers

Configuration name	Role	Consumable?	Resolvable?	Description
`apiElements`	For compiling against this library	yes	no	This configuration is meant to be used by consumers, to retrieve all the elements necessary to compile against this library.

Configuration name	Role	Consumable?	Resolvable?	Description
`runtimeElements`	For executing this library	yes	no	This configuration is meant to be used by consumers, to retrieve all the elements necessary to run against this library.

Table 11. Java Library plugin - configurations used by the library itself

Configuration name	Role	Consumable?	Resolvable?	Description
compileClasspath	For compiling this library	no	yes	This configuration contains the compile classpath of this library, and is therefore used when invoking the java compiler to compile it.
runtimeClasspath	For executing this library	no	yes	This configuration contains the runtime classpath of this library
testCompileClasspath	For compiling the tests of this library	no	yes	This configuration contains the test compile classpath of this library.
testRuntimeClasspath	For executing tests of this library	no	yes	This configuration contains the test runtime classpath of this library

Building Modules for the Java Module System

Since Java 9, Java itself offers a module system that allows for strict encapsulation during compile and runtime. You can turn a Java library into a *Java Module* by creating a `module-info.java` file in the `main/java` source folder.

```
src
└── main
    └── java
        └── module-info.java
```

In the module info file, you declare a *module name*, which packages of your module you want to *export* and which other modules you *require*.

module-info.java file

```
module org.gradle.sample {
    requires com.google.gson;         // real module
    requires org.apache.commons.lang3; // automatic module
    // commons-cli-1.4.jar is not a module and cannot be required
}
```

To tell the Java compiler that a Jar is a module, as opposed to a traditional Java library, Gradle needs to place it on the so called *module path*. It is an alternative to the *classpath*, which is the traditional way to tell the compiler about compiled dependencies. Gradle will automatically put a Jar of your dependencies on the module path, instead of the classpath, if these three things are true:

- `java.modularity.inferModulePath` is **not** turned off

- We are actually building a module (as opposed to a traditional library) which we expressed by adding the `module-info.java` file. (Another option is to add the `Automatic-Module-Name` Jar manifest attribute as [described further down](#).)

- The Jar our module depends on is itself a module, which Gradles decides based on the presence of a `module-info.class` — the compiled version of the module descriptor — in the Jar. (Or, alternatively, the presence of an `Automatic-Module-Name` attribute the Jar manifest)

In the following, some more details about defining Java modules and how that interacts with Gradle's dependency management are described. You can also look at a [ready made example](#) to try out the Java Module support directly.

=== Declaring module dependencies

There is a direct relationship to the dependencies you declare in the build file and the module dependencies you declare in the `module-info.java` file. Ideally the declarations should be in sync as seen in the following table.

Table 12. Mapping between Java module directives and Gradle configurations to declare dependencies

Java Module Directive	Gradle Configuration	Purpose
`requires`	`implementation`	Declaring implementation dependencies
`requires transitive`	`api`	Declaring API dependencies
`requires static`	`compileOnly`	Declaring compile only dependencies
`requires static transitive`	`compileOnlyApi`	Declaring compile only API dependencies

Gradle currently does not automatically check if the dependency declarations are in sync. This may be added in future versions.

For more details on declaring module dependencies, please refer to [documentation on the Java Module System](#).

=== Declaring package visibility and services

The Java module system supports additional more fine granular encapsulation concepts than Gradle itself currently does. For example, you explicitly need to declare which packages are part of your API and which are only visible inside your module. Some of these capabilities might be added to Gradle itself in future versions. For now, please refer to [documentation on the Java Module System](#) to learn how to use these features in Java Modules.

Declaring module versions

Java Modules also have a version that is encoded as part of the module identity in the `module-info.class` file. This version can be inspected when a module is running.

build.gradle.kts

```
version = "1.2"

tasks.compileJava {
    // use the project's version or define one directly
    options.javaModuleVersion = provider { version as String }
}
```

build.gradle

```
version = '1.2'

tasks.named('compileJava') {
    // use the project's version or define one directly
    options.javaModuleVersion = provider { version }
}
```

Using libraries that are not modules

You probably want to use external libraries, like OSS libraries from Maven Central, in your modular Java project. Some libraries, in their newer versions, are already full modules with a module descriptor. For example, `com.google.code.gson:gson:2.8.9` that has the module name `com.google.gson`.

Others, like `org.apache.commons:commons-lang3:3.10`, may not offer a full module descriptor but will at least contain an `Automatic-Module-Name` entry in their manifest file to define the module's name (`org.apache.commons.lang3` in the example). Such modules, that only have a name as module description, are called *automatic module* that export **all** their packages and can read **all** modules on the module path.

A third case are traditional libraries that provide no module information at all — for example `commons-cli:commons-cli:1.4`. Gradle puts such libraries on the classpath instead of the module path. The classpath is then treated as one module (the so called *unnamed* module) by Java.

build.gradle.kts

```
dependencies {
    implementation("com.google.code.gson:gson:2.8.9")        // real module
    implementation("org.apache.commons:commons-lang3:3.10") // automatic module
    implementation("commons-cli:commons-cli:1.4")           // plain library
}
```

build.gradle

```
dependencies {
    implementation 'com.google.code.gson:gson:2.8.9'        // real module
    implementation 'org.apache.commons:commons-lang3:3.10' // automatic module
    implementation 'commons-cli:commons-cli:1.4'           // plain library
}
```

Module dependencies declared in module-info.java file

```
module org.gradle.sample.lib {
    requires com.google.gson;          // real module
    requires org.apache.commons.lang3; // automatic module
    // commons-cli-1.4.jar is not a module and cannot be required
}
```

While a real module cannot directly depend on the unnamed module (only by adding command line flags), automatic modules can also see the unnamed module. Thus, if you cannot avoid to rely on a library without module information, you can wrap that library in an automatic module as part of your project. How you do that is described in the next section.

Another way to deal with non-modules is to enrich existing Jars with module descriptors yourself using artifact transforms. This sample contains a small *buildSrc* plugin registering such a transform which you may use and adjust to your needs. This can be interesting if you want to build a fully modular application and want the java runtime to treat everything as a real module.

=== Disabling Java Module support

In rare cases, you might want to disable the built-in Java Module support and define the module path by other means. To achieve this, you can disable the functionality to automatically put any Jar on the module path. Then Gradle puts Jars with module information on the classpath, even if you have a `module-info.java` in your source set. This corresponds to the behaviour of Gradle versions <7.0.

To make this work, you need to set `modularity.inferModulePath = false` on the Java extension (for all tasks) or on individual tasks.

build.gradle.kts

```
java {
    modularity.inferModulePath = false
}

tasks.compileJava {
    modularity.inferModulePath = false
}
```

```
java {
    modularity.inferModulePath = false
}

tasks.named('compileJava') {
    modularity.inferModulePath = false
}
```

=== Building an automatic module

If you can, you should always write complete `module-info.java` descriptors for your modules. Still, there are a few cases where you might consider to (initally) only provide a *module name* for an automatic module:

- You are working on a library that is **not** a module but you want to make it usable as such in the next release. Adding an `Automatic-Module-Name` is a good first step (most popular OSS libraries on Maven central have done it by now).

- As discussed in the previous section, an automatic module can be used as an adapter between your real modules and a traditional library on the classpath.

To turn a normal Java project into an *automatic module,* just add the manifest entry with the module name:

build.gradle.kts

```
tasks.jar {
    manifest {
        attributes("Automatic-Module-Name" to "org.gradle.sample")
    }
}
```

build.gradle

```
tasks.named('jar') {
    manifest {
        attributes('Automatic-Module-Name': 'org.gradle.sample')
    }
}
```

NOTE	=== You can define an automatic module as part of a multi-project that otherwise defines real modules (e.g. as an adapter to another library). While this works fine in the Gradle build, such automatic module projects are not correctly recognized by IDEA/Eclipse at the moment. You can work around it by manually adding the Jar built for the automatic module to the dependencies of the project that does not find it in the IDE's UI. ===

Using classes instead of jar for compilation

A feature of the `java-library` plugin is that projects which consume the library only require the classes folder for compilation, instead of the full JAR. This enables lighter inter-project dependencies as resources processing (`processResources` task) and archive construction (`jar` task) are no longer executed when only Java code compilation is performed during development.

NOTE	The usage or not of the classes output instead of the JAR is a *consumer* decision. For example, Groovy consumers will request classes *and* processed resources as these may be needed for executing AST transformation as part of the compilation process.

Increased memory usage for consumers

An indirect consequence is that up-to-date checking will require more memory, because Gradle will snapshot individual class files instead of a single jar. This may lead to increased memory consumption for large projects, with the benefit of having the `compileJava` task up-to-date in more cases (e.g. changing resources no longer changes the input for `compileJava` tasks of upstream projects)

Significant build performance drop on Windows for huge multi-projects

Another side effect of the snapshotting of individual class files, only affecting Windows systems, is that the performance can significantly drop when processing a very large amount of class files on the compile classpath. This only concerns very large multi-projects where a lot of classes are present on the classpath by using many `api` or (deprecated) `compile` dependencies. To mitigate this, you can set the `org.gradle.java.compile-classpath-packaging` system property to `true` to change the behavior of the Java Library plugin to use jars instead of class folders for everything on the compile classpath. Note, since this has other performance impacts and potentially side effects, by triggering all jar tasks at compile time, it is only recommended to activate this if you suffer from the described performance issue on Windows.

Distributing a library

Aside from publishing a library to a component repository, you may sometimes need to package a library and its dependencies in a distribution deliverable. The Java Library Distribution Plugin is there to help you do just that.

The Application Plugin

The Application plugin facilitates creating an executable JVM application. It makes it easy to start the application locally during development, and to package the application as a TAR and/or ZIP including operating system specific start scripts.

Applying the Application plugin also implicitly applies the Java plugin. The `main` source set is effectively the "application".

Applying the Application plugin also implicitly applies the Distribution plugin. A `main` distribution is created that packages up the application, including code dependencies and generated start scripts.

== Building JVM applications

To use the application plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    application
}
```

build.gradle

```
plugins {
    id 'application'
}
```

The only mandatory configuration for the plugin is the specification of the main class (i.e. entry point) of the application.

build.gradle.kts

```
application {
    mainClass = "org.gradle.sample.Main"
}
```

build.gradle

```
application {
    mainClass = 'org.gradle.sample.Main'
}
```

You can run the application by executing the `run` task (type: JavaExec). This will compile the main source set, and launch a new JVM with its classes (along with all runtime dependencies) as the classpath and using the specified main class. You can launch the application in debug mode with `gradle run --debug-jvm` (see JavaExec.setDebug(boolean)).

Since Gradle 4.9, the command line arguments can be passed with `--args`. For example, if you want to launch the application with command line arguments `foo --bar`, you can use `gradle run --args="foo --bar"` (see JavaExec.setArgsString(java.lang.String).

If your application requires a specific set of JVM settings or system properties, you can configure the `applicationDefaultJvmArgs` property. These JVM arguments are applied to the `run` task and also considered in the generated start scripts of your distribution.

build.gradle.kts

```
application {
    applicationDefaultJvmArgs = listOf("-Dgreeting.language=en")
}
```

build.gradle

```
application {
    applicationDefaultJvmArgs = ['-Dgreeting.language=en']
}
```

If your application's start scripts should be in a different directory than `bin`, you can configure the `executableDir` property.

build.gradle.kts

```
application {
    executableDir = "custom_bin_dir"
}
```

build.gradle

```
application {
    executableDir = 'custom_bin_dir'
}
```

== Building applications using the Java Module System

Gradle supports the building of Java Modules as described in the corresponding section of the Java Library plugin documentation. Java modules can also be runnable and you can use the application plugin to run and package such a modular application. For this, you need to do two things in addition to what you do for a non-modular application.

First, you need to add a `module-info.java` file to describe your application module. Please refer to the Java Library plugin documentation for more details on this topic.

Second, you need to tell Gradle the name of the module you want to run in addition to the main class name like this:

build.gradle.kts

```
application {
    mainModule = "org.gradle.sample.app" // name defined in module-info.java
    mainClass = "org.gradle.sample.Main"
}
```

build.gradle

```
application {
    mainModule = 'org.gradle.sample.app' // name defined in module-info.java
    mainClass = 'org.gradle.sample.Main'
}
```

That's all. If you run your application, by executing the `run` task or through a generated start script, it will run as module and respect module boundaries at runtime. For example, reflective access to an internal package from another module can fail.

The configured *main class* is also baked into the `module-info.class` file of your application Jar. If you run the modular application directly using the `java` command, it is then sufficient to provide the module name.

You can also look at a ready made example that includes a modular application as part of a multi-project.

== Building a distribution

A distribution of the application can be created, by way of the Distribution plugin (which is automatically applied). A `main` distribution is created with the following content:

Table 13. Distribution content

Location	Content
(root dir)	`src/dist`
`lib`	All runtime dependencies and main source set class files.
`bin`	Start scripts (generated by `startScripts` task).

Static files to be added to the distribution can be simply added to `src/dist`. More advanced customization can be done by configuring the CopySpec exposed by the main distribution.

build.gradle.kts

```
val createDocs by tasks.registering {
    val docs = layout.buildDirectory.dir("docs")
    outputs.dir(docs)
    doLast {
        docs.get().asFile.mkdirs()
        docs.get().file("readme.txt").asFile.writeText("Read me!")
    }
}

distributions {
    main {
        contents {
            from(createDocs) {
                into("docs")
            }
        }
    }
}
```

build.gradle

```groovy
tasks.register('createDocs') {
    def docs = layout.buildDirectory.dir('docs')
    outputs.dir docs
    doLast {
        docs.get().asFile.mkdirs()
        docs.get().file('readme.txt').asFile.write('Read me!')
    }
}

distributions {
    main {
        contents {
            from(createDocs) {
                into 'docs'
            }
        }
    }
}
```

By specifying that the distribution should include the task's output files (see incremental builds), Gradle knows that the task that produces the files must be invoked before the distribution can be assembled and will take care of this for you.

You can run `gradle installDist` to create an image of the application in `build/install/`projectName. You can run `gradle distZip` to create a ZIP containing the distribution, `gradle distTar` to create an application TAR or `gradle assemble` to build both.

=== Customizing start script generation

The application plugin can generate Unix (suitable for Linux, macOS etc.) and Windows start scripts out of the box. The start scripts launch a JVM with the specified settings defined as part of the original build and runtime environment (e.g. `JAVA_OPTS` env var). The default script templates are based on the same scripts used to launch Gradle itself, that ship as part of a Gradle distribution.

The start scripts are completely customizable. Please refer to the documentation of CreateStartScripts for more details and customization examples.

== Tasks

The Application plugin adds the following tasks to the project.

`run` — **JavaExec**

 Depends on: `classes`

 Starts the application.

`startScripts` — **CreateStartScripts**

 Depends on: `jar`

 Creates OS specific scripts to run the project as a JVM application.

`installDist` — **Sync**

 Depends on: `jar`, `startScripts`

 Installs the application into a specified directory.

`distZip` — **Zip**

 Depends on: `jar`, `startScripts`

 Creates a full distribution ZIP archive including runtime libraries and OS specific scripts.

`distTar` — **Tar**

 Depends on: `jar`, `startScripts`

 Creates a full distribution TAR archive including runtime libraries and OS specific scripts.

== Application extension

The Application Plugin adds an extension to the project, which you can use to configure its behavior. See the JavaApplication DSL documentation for more information on the properties available on the extension.

You can configure the extension via the `application {}` block shown earlier, for example using the following in your build script:

build.gradle.kts

```
application {
    executableDir = "custom_bin_dir"
}
```

build.gradle

```
application {
    executableDir = 'custom_bin_dir'
}
```

== License of start scripts

The start scripts generated for the application are licensed under the Apache 2.0 Software License.

== Convention properties (deprecated)

This plugin also adds some convention properties to the project, which you can use to configure its behavior. These are **deprecated** and superseded by the extension described above. See the Project DSL documentation for information on them.

Unlike the extension properties, these properties appear as top-level project properties in the build script. For example, to change the application name you can just add the following to your build script:

build.gradle.kts

```
application.applicationName = "my-app"
```

build.gradle

```
application.applicationName = 'my-app'
```

= The Java Platform Plugin

The Java Platform plugin brings the ability to declare platforms for the Java ecosystem. A platform can be used for different purposes:

- a description of modules which are published together (and for example, share the same version)
- a set of recommended versions for heterogeneous libraries. A typical example includes the Spring Boot BOM
- sharing a set of dependency versions between subprojects

A platform is a special kind of software component which doesn't contain any sources: it is only used to reference other libraries, so that they play well together during dependency resolution.

Platforms can be published as Gradle Module Metadata and Maven BOMs.

NOTE	The `java-platform` plugin cannot be used in combination with the `java` or `java-library` plugins in a given project. Conceptually a project is either a platform, with no binaries, *or* produces binaries.

== Usage

To use the Java Platform plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    `java-platform`
}
```

build.gradle

```
plugins {
    id 'java-platform'
}
```

== API and runtime separation

A major difference between a Maven BOM and a Java platform is that in Gradle dependencies and constraints are declared and scoped to a configuration and the ones extending it. While many users will only care about declaring constraints for *compile time* dependencies, thus inherited by runtime and tests ones, it allows declaring dependencies or constraints that only apply to runtime or test.

For this purpose, the plugin exposes two configurations that can be used to declare dependencies: `api` and `runtime`. The `api` configuration should be used to declare constraints and dependencies which should be used when compiling against the platform, whereas the `runtime` configuration should be used to declare constraints or dependencies which are visible at runtime.

build.gradle.kts

```
dependencies {
    constraints {
        api("commons-httpclient:commons-httpclient:3.1")
        runtime("org.postgresql:postgresql:42.2.5")
    }
}
```

build.gradle

```
dependencies {
    constraints {
        api 'commons-httpclient:commons-httpclient:3.1'
        runtime 'org.postgresql:postgresql:42.2.5'
    }
}
```

Note that this example makes use of *constraints* and not dependencies. In general, this is what you would like to do: constraints will only apply if such a component is added to the dependency graph, either directly or transitively. This means that all constraints listed in a platform would not add a dependency unless another component brings it in: they can be seen as *recommendations*.

For example, if a platform declares a constraint on `org:foo:1.1`, and that nothing else brings in a dependency on `foo`, `foo` will *not* appear in the graph. However, if `foo` appears, then usual conflict resolution would kick in. If a dependency brings in `org:foo:1.0`, then we would select `org:foo:1.1` to satisfy the platform constraint.

By default, in order to avoid the common mistake of adding a dependency in a platform instead of a constraint, Gradle will fail if you try to do so. If, for some reason, you also want to add *dependencies* in addition to constraints, you need to enable it explicitly:

build.gradle.kts

```
javaPlatform {
    allowDependencies()
}
```

build.gradle

```
javaPlatform {
    allowDependencies()
}
```

== Local project constraints

If you have a multi-project build and want to publish a platform that links to subprojects, you can do it by declaring constraints on the subprojects which belong to the platform, as in the example below:

build.gradle.kts

```
dependencies {
    constraints {
        api(project(":core"))
        api(project(":lib"))
    }
}
```

build.gradle

```
dependencies {
    constraints {
        api project(":core")
        api project(":lib")
    }
}
```

The project notation will become a classical `group:name:version` notation in the published metadata.

== Sourcing constraints from another platform

Sometimes the platform you define is an extension of another existing platform.

In order to have your platform include the constraints from that third party platform, it needs to be imported as a `platform` *dependency*:

build.gradle.kts

```
javaPlatform {
    allowDependencies()
}

dependencies {
    api(platform("com.fasterxml.jackson:jackson-bom:2.9.8"))
}
```

build.gradle

```
javaPlatform {
    allowDependencies()
}

dependencies {
    api platform('com.fasterxml.jackson:jackson-bom:2.9.8')
}
```

== Publishing platforms

Publishing Java platforms is done by applying the `maven-publish` plugin and configuring a Maven publication that uses the `javaPlatform` component:

```
publishing {
    publications {
        create<MavenPublication>("myPlatform") {
            from(components["javaPlatform"])
        }
    }
}
```

```
publishing {
    publications {
        myPlatform(MavenPublication) {
            from components.javaPlatform
        }
    }
}
```

This will generate a BOM file for the platform, with a `<dependencyManagement>` block where its `<dependencies>` correspond to the constraints defined in the platform module.

== Consuming platforms

Because a Java Platform is a special kind of component, a dependency on a Java platform has to be declared using the `platform` or `enforcedPlatform` keyword, as explained in the managing transitive dependencies section. For example, if you want to share dependency versions between subprojects, you can define a platform module which would declare all versions:

```
dependencies {
    constraints {
        // Platform declares some versions of libraries used in subprojects
        api("commons-httpclient:commons-httpclient:3.1")
        api("org.apache.commons:commons-lang3:3.8.1")
    }
}
```

```
dependencies {
    constraints {
        // Platform declares some versions of libraries used in subprojects
        api 'commons-httpclient:commons-httpclient:3.1'
        api 'org.apache.commons:commons-lang3:3.8.1'
    }
}
```

And then have subprojects depend on the platform to get recommendations:

```
dependencies {
    // get recommended versions from the platform project
    api(platform(project(":platform")))
    // no version required
    api("commons-httpclient:commons-httpclient")
}
```

```
dependencies {
    // get recommended versions from the platform project
    api platform(project(':platform'))
    // no version required
    api 'commons-httpclient:commons-httpclient'
}
```

The Groovy Plugin

The Groovy plugin extends the Java plugin to add support for Groovy projects. It can deal with Groovy code, mixed Groovy and Java code, and even pure Java code (although we don't necessarily recommend to use it for the latter). The plugin supports *joint compilation*, which allows you to freely mix and match Groovy and Java code, with dependencies in both directions. For example, a Groovy class can extend a Java class that in turn extends a Groovy class. This makes it possible to use the best language for the job, and to rewrite any class in the other language if needed.

Note that if you want to benefit from the API / implementation separation, you can also apply the `java-library` plugin to your Groovy project.

Usage

To use the Groovy plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    groovy
}
```

build.gradle

```
plugins {
    id 'groovy'
}
```

== Tasks

The Groovy plugin adds the following tasks to the project. Information about altering the dependencies to Java compile tasks are found here.

compileGroovy — **GroovyCompile**
  Depends on: `compileJava`

  Compiles production Groovy source files.

compileTestGroovy — **GroovyCompile**
  Depends on: `compileTestJava`

  Compiles test Groovy source files.

compileSourceSetGroovy — **GroovyCompile**
  Depends on: `compileSourceSetJava`

  Compiles the given source set's Groovy source files.

groovydoc — **Groovydoc**
  Generates API documentation for the production Groovy source files.

The Groovy plugin adds the following dependencies to tasks added by the Java plugin.

Table 14. Groovy plugin - additional task dependencies

Task name	Depends on
`classes`	`compileGroovy`
`testClasses`	`compileTestGroovy`
`sourceSetClasses`	`compileSourceSetGroovy`
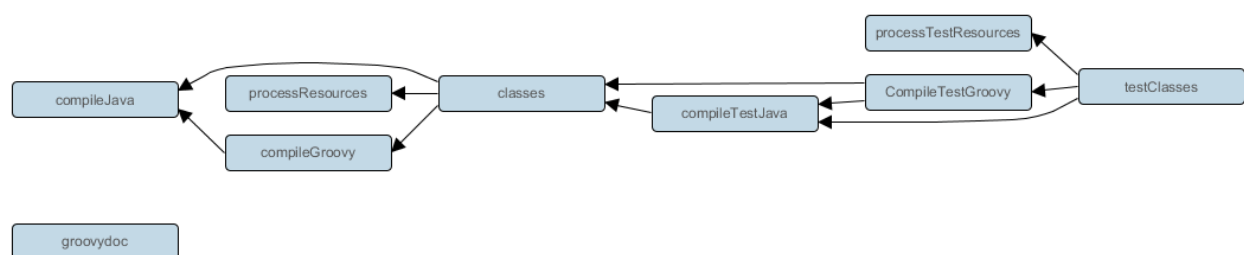
Figure 17. Groovy plugin - tasks

== Project layout

The Groovy plugin assumes the project layout shown in Groovy Layout. All the Groovy source directories can contain Groovy *and* Java code. The Java source directories may only contain Java source code.[7] None of these directories need to exist or have anything in them; the Groovy plugin will simply compile whatever it finds.

`src/main/java`

    Production Java source.

`src/main/resources`

    Production resources, such as XML and properties files.

`src/main/groovy`

    Production Groovy source. May also contain Java source files for joint compilation.

`src/test/java`

    Test Java source.

`src/test/resources`

    Test resources.

`src/test/groovy`

    Test Groovy source. May also contain Java source files for joint compilation.

`src/`**`sourceSet`**`/java`

    Java source for the source set named *sourceSet*.

`src/`**`sourceSet`**`/resources`

    Resources for the source set named *sourceSet*.

`src/`**`sourceSet`**`/groovy`

    Groovy source files for the given source set. May also contain Java source files for joint compilation.

=== Changing the project layout

Just like the Java plugin, the Groovy plugin allows you to configure custom locations for Groovy production and test source files.

build.gradle.kts

```
sourceSets {
    main {
        groovy {
            setSrcDirs(listOf("src/groovy"))
        }
    }

    test {
        groovy {
            setSrcDirs(listOf("test/groovy"))
        }
    }
}
```

build.gradle

```
sourceSets {
    main {
        groovy {
            srcDirs = ['src/groovy']
        }
    }

    test {
        groovy {
            srcDirs = ['test/groovy']
        }
    }
}
```

== Dependency management

Because Gradle's build language is based on Groovy, and parts of Gradle are implemented in Groovy, Gradle already ships with a Groovy library. Nevertheless, Groovy projects need to explicitly declare a Groovy dependency. This dependency will then be used on compile and runtime class paths. It will also be used to get hold of the Groovy compiler and Groovydoc tool, respectively.

If Groovy is used for production code, the Groovy dependency should be added to the `implementation` configuration:

```
repositories {
    mavenCentral()
}

dependencies {
    implementation("org.codehaus.groovy:groovy-all:2.4.15")
}
```

```
repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.codehaus.groovy:groovy-all:2.4.15'
}
```

If Groovy is only used for test code, the Groovy dependency should be added to the `testImplementation` configuration:

```
dependencies {
    testImplementation("org.codehaus.groovy:groovy-all:2.4.15")
}
```

```
dependencies {
    testImplementation 'org.codehaus.groovy:groovy-all:2.4.15'
}
```

To use the Groovy library that ships with Gradle, declare a `localGroovy()` dependency. Note that different Gradle versions ship with different Groovy versions; as such, using `localGroovy()` is less safe then declaring a regular Groovy dependency.

build.gradle.kts

```
dependencies {
    implementation(localGroovy())
}
```

build.gradle

```
dependencies {
    implementation localGroovy()
}
```

== Automatic configuration of groovyClasspath

The `GroovyCompile` and `Groovydoc` tasks consume Groovy code in two ways: on their `classpath`, and on their `groovyClasspath`. The former is used to locate classes referenced by the source code, and will typically contain the Groovy library along with other libraries. The latter is used to load and execute the Groovy compiler and Groovydoc tool, respectively, and should only contain the Groovy library and its dependencies.

Unless a task's `groovyClasspath` is configured explicitly, the Groovy (base) plugin will try to infer it from the task's `classpath`. This is done as follows:

- If a `groovy-all(-indy)` Jar is found on `classpath`, that jar will be added to `groovyClasspath`.
- If a `groovy(-indy)` jar is found on `classpath`, and the project has at least one repository declared, a corresponding `groovy(-indy)` repository dependency will be added to `groovyClasspath`.
- Otherwise, execution of the task will fail with a message saying that `groovyClasspath` could not be inferred.

Note that the "`-indy`" variation of each jar refers to the version with `invokedynamic` support.

== Convention properties

The Groovy plugin does not add any convention properties to the project.

== Source set properties

The Groovy plugin adds the following extensions to each source set in the project. You can use these properties in your build script as though they were properties of the source set object.

=== Groovy Plugin — source set properties

`groovy` — **GroovySourceDirectorySet** **(read-only)**
> *Default value*: Not null
>
> The Groovy source files of this source set. Contains all `.groovy` and `.java` files found in the Groovy source directories, and excludes all other types of files.

`groovy.srcDirs` — **Set<File>**
> *Default value*: [`projectDir`/`src`/`name`/`groovy`]
>
> The source directories containing the Groovy source files of this source set. May also contain Java source files for joint compilation. Can set using anything described in Specifying Multiple Files.

`allGroovy` — **FileTree** **(read-only)**
> *Default value*: Not null
>
> All Groovy source files of this source set. Contains only the `.groovy` files found in the Groovy source directories.

These properties are provided by a convention object of type GroovySourceSet.

The Groovy plugin also modifies some source set properties:

=== Groovy Plugin - modified source set properties

Property name	Change
allJava	Adds all `.java` files found in the Groovy source directories.
allSource	Adds all source files found in the Groovy source directories.

== GroovyCompile

The Groovy plugin adds a GroovyCompile task for each source set in the project. The task type shares much with the `JavaCompile` task by extending `AbstractCompile` (see the relevant Java Plugin section). The `GroovyCompile` task supports most configuration options of the official Groovy compiler. The task can also leverage the Java toolchain support.

Table 15. Groovy plugin - GroovyCompile properties

Task Property	Type	Default Value
classpath	FileCollection	`sourceSet.compileClasspath`
source	FileTree. Can set using anything described in Specifying Multiple Files.	`sourceSet.groovy`
destinationDirectory	File.	`sourceSet.groovy.destinationDirectory`
groovyClasspath	FileCollection	`groovy` configuration if non-empty; Groovy library found on `classpath` otherwise
javaLauncher	`Property<JavaLauncher>`, see the toolchain documentation.	None but will be configured if a toolchain is defined on the `java` extension.

=== Compilation avoidance

Caveat: Groovy compilation avoidance is an incubating feature since Gradle 5.6. There are known inaccuracies so please enable it at your own risk.

To enable the incubating support for Groovy compilation avoidance, add a `enableFeaturePreview` to your settings file:

settings.gradle

```
enableFeaturePreview('GROOVY_COMPILATION_AVOIDANCE')
```

```
enableFeaturePreview("GROOVY_COMPILATION_AVOIDANCE")
```

If a dependent project has changed in an ABI-compatible way (only its private API has changed), then Groovy compilation tasks will be up-to-date. This means that if project A depends on project B and a class in B is changed in an ABI-compatible way (typically, changing only the body of a method), then Gradle won't recompile A.

See Java compile avoidance for a detailed list of the types of changes that do not affect the ABI and are ignored.

However, similar to Java's annotation processing, there are various ways to customize the Groovy compilation process, for which implementation details matter. Some well-known examples are Groovy AST transformations. In these cases, these dependencies must be declared separately in a classpath called `astTransformationClasspath`:

build.gradle.kts

```
val astTransformation by configurations.creating
dependencies {
    astTransformation(project(":ast-transformation"))
}
tasks.withType<GroovyCompile>().configureEach {
    astTransformationClasspath.from(astTransformation)
}
```

build.gradle

```
configurations { astTransformation }
dependencies {
    astTransformation(project(":ast-transformation"))
}
tasks.withType(GroovyCompile).configureEach {
    astTransformationClasspath.from(configurations.astTransformation)
}
```

== Incremental Groovy compilation

Since 5.6, Gradle introduces an experimental incremental Groovy compiler. To enable incremental compilation for Groovy, you need:

- Enable Groovy compilation avoidance.

- Explicitly enable incremental Groovy compilation in the build script:

buildSrc/src/main/kotlin/myproject.groovy-conventions.gradle.kts

```
tasks.withType<GroovyCompile>().configureEach {
    options.isIncremental = true
    options.incrementalAfterFailure = true
}
```

buildSrc/src/main/groovy/myproject.groovy-conventions.gradle

```
tasks.withType(GroovyCompile).configureEach {
    options.incremental = true
    options.incrementalAfterFailure = true
}
```

This gives you the following benefits:

- Incremental builds are much faster.

- If only a small set of Groovy source files are changed, only the affected source files will be recompiled. Classes that don't need to be recompiled remain unchanged in the output directory. For example, if you only change a few Groovy test classes, you don't need to recompile all Groovy test source files — only the changed ones need to be recompiled.

To understand how incremental compilation works, see Incremental Java compilation for a detailed overview. Note that there's several differences from Java incremental compilation:

The Groovy compiler doesn't keep `@Retention` in generated annotation class bytecode (GROOVY-9185), thus all annotations are `RUNTIME`. This means that changes to source-retention annotations won't trigger a full recompilation.

=== Known issues

Also see Known issues for incremental Java compilation.

- Changes to resources won't trigger a recompilation, this might result in some incorrectness — for example Extension Modules.

== Compiling and testing for Java 6 or Java 7

With toolchain support added to `GroovyCompile`, it is possible to compile Groovy code using a different Java version than the one running Gradle. If you also have Java source files, this will also configure `JavaCompile` to use the right Java compiler is used, as can be seen in the Java plugin documentation.

=== Example: Configure Java 7 build for Groovy

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(7)
    }
}
```

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(7)
    }
}
```

= The Scala Plugin

The Scala plugin extends the Java plugin to add support for Scala projects. The plugin also supports *joint compilation*, which allows you to freely mix and match Scala and Java code with dependencies in both directions. For example, a Scala class can extend a Java class that in turn extends a Scala class. This makes it possible to use the best language for the job, and to rewrite any class in the other language if needed.

Note that if you want to benefit from the API / implementation separation, you can also apply the `java-library` plugin to your Scala project.

== Usage

To use the Scala plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    scala
}
```

build.gradle

```
plugins {
    id 'scala'
}
```

== Tasks

The Scala plugin adds the following tasks to the project. Information about altering the dependencies to Java compile tasks are found here.

compileScala — **ScalaCompile**
> *Depends on*: compileJava
>
> Compiles production Scala source files.

compileTestScala — **ScalaCompile**
> *Depends on*: compileTestJava
>
> Compiles test Scala source files.

compileSourceSetScala — **ScalaCompile**
> *Depends on*: compileSourceSetJava
>
> Compiles the given source set's Scala source files.

scaladoc — **ScalaDoc**
> Generates API documentation for the production Scala source files.

The ScalaCompile and ScalaDoc tasks support Java toolchains out of the box.

The Scala plugin adds the following dependencies to tasks added by the Java plugin.

Table 16. Scala plugin - additional task dependencies

Task name	Depends on
classes	compileScala
testClasses	compileTestScala
sourceSetClasses	compileSourceSetScala
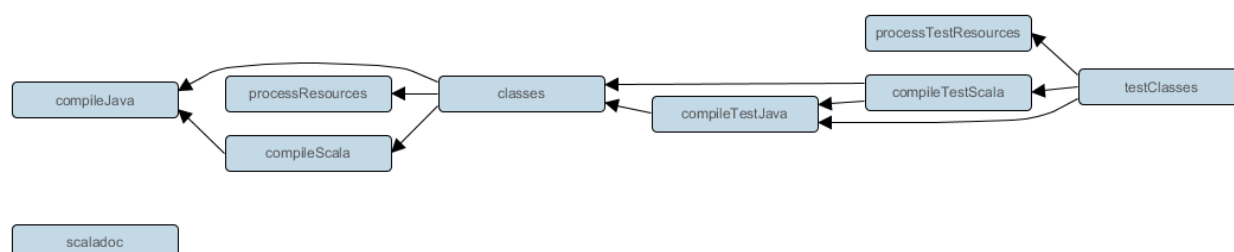
Figure 18. Scala plugin - tasks

== Project layout

The Scala plugin assumes the project layout shown below. All the Scala source directories can contain Scala *and* Java code. The Java source directories may only contain Java source code.

None of these directories need to exist or have anything in them; the Scala plugin will simply compile whatever it finds.

`src/main/java`

Production Java source.

`src/main/resources`

Production resources, such as XML and properties files.

`src/main/scala`

Production Scala source. May also contain Java source files for joint compilation.

`src/test/java`

Test Java source.

`src/test/resources`

Test resources.

`src/test/scala`

Test Scala source. May also contain Java source files for joint compilation.

`src/`**`sourceSet`**`/java`

Java source for the source set named *sourceSet*.

`src/`**`sourceSet`**`/resources`

Resources for the source set named *sourceSet*.

`src/`**`sourceSet`**`/scala`

Scala source files for the given source set. May also contain Java source files for joint compilation.

=== Changing the project layout

Just like the Java plugin, the Scala plugin allows you to configure custom locations for Scala production and test source files.

build.gradle.kts

```
sourceSets {
    main {
        scala {
            setSrcDirs(listOf("src/scala"))
        }
    }
    test {
        scala {
            setSrcDirs(listOf("test/scala"))
        }
    }
}
```

build.gradle

```
sourceSets {
    main {
        scala {
            srcDirs = ['src/scala']
        }
    }
    test {
        scala {
            srcDirs = ['test/scala']
        }
    }
}
```

== Dependency management

Scala projects need to declare a `scala-library` dependency. This dependency will then be used on compile and runtime class paths. It will also be used to get hold of the Scala compiler and Scaladoc tool, respectively.[8]

If Scala is used for production code, the `scala-library` dependency should be added to the `implementation` configuration:

build.gradle.kts

```
repositories {
    mavenCentral()
}

dependencies {
    implementation("org.scala-lang:scala-library:2.13.12")
    testImplementation("junit:junit:4.13")
}
```

build.gradle

```
repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.scala-lang:scala-library:2.13.12'
    testImplementation 'junit:junit:4.13'
}
```

If you want to use Scala 3 instead of the `scala-library` dependency you should add the `scala3-library_3` dependency:

```
plugins {
    scala
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("org.scala-lang:scala3-library_3:3.0.1")
    testImplementation("org.scalatest:scalatest_3:3.2.9")
    testImplementation("junit:junit:4.13")
}

dependencies {
    implementation("commons-collections:commons-collections:3.2.2")
}
```

```
plugins {
    id 'scala'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.scala-lang:scala3-library_3:3.0.1'
    implementation 'commons-collections:commons-collections:3.2.2'
    testImplementation 'org.scalatest:scalatest_3:3.2.9'
    testImplementation 'junit:junit:4.13'
}
```

If Scala is only used for test code, the `scala-library` dependency should be added to the `testImplementation` configuration:

build.gradle.kts

```
dependencies {
    testImplementation("org.scala-lang:scala-library:2.13.12")
}
```

build.gradle

```
dependencies {
    testImplementation 'org.scala-lang:scala-library:2.13.12'
}
```

== Automatic configuration of scalaClasspath

The `ScalaCompile` and `ScalaDoc` tasks consume Scala code in two ways: on their `classpath`, and on their `scalaClasspath`. The former is used to locate classes referenced by the source code, and will typically contain `scala-library` along with other libraries. The latter is used to load and execute the Scala compiler and Scaladoc tool, respectively, and should only contain the `scala-compiler` library and its dependencies.

Unless a task's `scalaClasspath` is configured explicitly, the Scala (base) plugin will try to infer it from the task's `classpath`. This is done as follows:

- If a `scala-library` jar is found on `classpath`, and the project has at least one repository declared, a corresponding `scala-compiler` repository dependency will be added to `scalaClasspath`.

- Otherwise, execution of the task will fail with a message saying that `scalaClasspath` could not be inferred.

== Configuring the Zinc compiler

The Scala plugin uses a configuration named `zinc` to resolve the Zinc compiler and its dependencies. Gradle will provide a default version of Zinc, but if you need to use a particular Zinc version, you can change it. Gradle supports version 1.6.0 of Zinc and above.

build.gradle.kts

```
scala {
    zincVersion = "1.9.3"
}
```

build.gradle

```
scala {
    zincVersion = "1.9.3"
}
```

The Zinc compiler itself needs a compatible version of `scala-library` that may be different from the version required by your application. Gradle takes care of specifying a compatible version of `scala-library` for you.

You can diagnose problems with the version of the Zinc compiler selected by running dependencyInsight for the `zinc` configuration.

Table 17. Zinc compatibility table

Gradle version	Supported Zinc versions	Zinc coordinates	Required Scala version	Supported Scala compilation version
7.5 and newer	SBT Zinc. Versions 1.6.0 and above.	`org.scala-sbt:zinc_2.13`	Scala `2.13.x` is required for *running* Zinc.	Scala `2.10.x` through `3.x` can be compiled.
6.0 to 7.5	SBT Zinc. Versions 1.2.0 and above.	`org.scala-sbt:zinc_2.12`	Scala `2.12.x` is required for *running* Zinc.	Scala `2.10.x` through `2.13.x` can be compiled.
1.x through 5.x	**Deprecated** Typesafe Zinc compiler. Versions 0.3.0 and above, except for 0.3.2 through 0.3.5.2.	`com.typesafe.zinc:zinc`	Scala `2.10.x` is required for *running* Zinc.	Scala `2.9.x` through `2.12.x` can be compiled.

== Adding plugins to the Scala compiler

The Scala plugin adds a configuration named `scalaCompilerPlugins` which is used to declare and resolve optional compiler plugins.

build.gradle.kts

```
dependencies {
    implementation("org.scala-lang:scala-library:2.13.12")
    scalaCompilerPlugins("org.typelevel:kind-projector_2.13.12:0.13.2")
}
```

build.gradle

```
dependencies {
    implementation "org.scala-lang:scala-library:2.13.12"
    scalaCompilerPlugins "org.typelevel:kind-projector_2.13.12:0.13.2"
}
```

== Convention properties

The Scala plugin does not add any convention properties to the project.

== Source set properties

The Scala plugin adds the following extensions to each source set in the project. You can use these in your build script as though they were properties of the source set object.

`scala` — **SourceDirectorySet** **(read-only)**

> The Scala source files of this source set. Contains all `.scala` and `.java` files found in the Scala source directories, and excludes all other types of files. *Default value:* non-null.

`scala.srcDirs` — `Set<File>`

> The source directories containing the Scala source files of this source set. May also contain Java source files for joint compilation. Can set using anything described in Understanding implicit conversion to file collections. *Default value:* `[projectDir/src/name/scala]`.

`allScala` — **FileTree** **(read-only)**

> All Scala source files of this source set. Contains only the `.scala` files found in the Scala source directories. *Default value:* non-null.

These extensions are backed by an object of type ScalaSourceSet.

The Scala plugin also modifies some source set properties:

Table 18. Scala plugin - source set properties

Property name	Change
`allJava`	Adds all `.java` files found in the Scala source directories.
`allSource`	Adds all source files found in the Scala source directories.

== Target bytecode level and Java APIs version

When running the Scala compile task, Gradle will always add a parameter to configure the Java target for the Scala compiler that is derived from the Gradle configuration:

- When using toolchains, the `-release` option, or `target` for older Scala versions, is selected, with a version matching the Java language level of the toolchain configured.

- When not using toolchains, Gradle will always pass a `target` flag — with exact value dependent on the Scala version — to compile to Java 8 bytecode.

| NOTE | This means that using toolchains with a recent Java version and an old Scala version can result in failures because Scala only supported Java 8 bytecode for some time. The solution is then to either use the right Java version in the toolchain or explicitly downgrade the target when needed. |

The following table explains the values computed by Gradle:

Table 19. Scala target parameter based on project configuration

Scala version	Toolchain in use	Parameter value
version < 2.13.1	yes	`-target:jvm-1.<java_version>`
	no	`-target:jvm-1.8`
2.13.1 <= version < 2.13.9	yes	`-target:<java_version>`
	no	`-target:8`
2.13.9 <= version < 3.0	yes	`-release:<java_version>`
	no	`-target:8`
3.0 <= version	yes	`-release:<java_version>`
	no	`-Xtarget:8`

Setting any of these flags explicitly, or using flags containing `java-output-version`, on `ScalaCompile.scalaCompileOptions.additionalParameters` disables that logic in favor of the explicit flag.

== Compiling in external process

Scala compilation takes place in an external process.

Memory settings for the external process default to the defaults of the JVM. To adjust memory settings, configure the `scalaCompileOptions.forkOptions` property as needed:

build.gradle.kts

```
tasks.withType<ScalaCompile>().configureEach {
    scalaCompileOptions.forkOptions.apply {
        memoryMaximumSize = "1g"
        jvmArgs = listOf("-XX:MaxMetaspaceSize=512m")
    }
}
```

```
tasks.withType(ScalaCompile) {
    scalaCompileOptions.forkOptions.with {
        memoryMaximumSize = '1g'
        jvmArgs = ['-XX:MaxMetaspaceSize=512m']
    }
}
```

== Incremental compilation

By compiling only classes whose source code has changed since the previous compilation, and classes affected by these changes, incremental compilation can significantly reduce Scala compilation time. It is particularly effective when frequently compiling small code increments, as is often done at development time.

The Scala plugin defaults to incremental compilation by integrating with Zinc, a standalone version of sbt's incremental Scala compiler. If you want to disable the incremental compilation, set `force = true` in your build file:

build.gradle.kts

```
tasks.withType<ScalaCompile>().configureEach {
    scalaCompileOptions.apply {
        isForce = true
    }
}
```

build.gradle

```
tasks.withType(ScalaCompile) {
    scalaCompileOptions.with {
        force = true
    }
}
```

Note: This will only cause all classes to be recompiled if at least one input source file has changed. If there are no changes to the source files, the `compileScala` task will still be considered `UP-TO-DATE` as usual.

The Zinc-based Scala Compiler supports joint compilation of Java and Scala code. By default, all Java and Scala code under `src/main/scala` will participate in joint compilation. Even Java code will be compiled incrementally.

Incremental compilation requires dependency analysis of the source code. The results of this analysis are stored in the file designated by `scalaCompileOptions.incrementalOptions.analysisFile` (which has a sensible default). In a multi-project build, analysis files are passed on to downstream `ScalaCompile` tasks to enable incremental compilation across project boundaries. For `ScalaCompile` tasks added by the Scala plugin, no configuration is necessary to make this work. For other `ScalaCompile` tasks that you might add, the property `scalaCompileOptions.incrementalOptions.publishedCode` needs to be configured to point to the classes folder or Jar archive by which the code is passed on to compile class paths of downstream `ScalaCompile` tasks. Note that if `publishedCode` is not set correctly, downstream tasks may not recompile code affected by upstream changes, leading to incorrect compilation results.

Note that Zinc's Nailgun based daemon mode is not supported. Instead, we plan to enhance Gradle's own compiler daemon to stay alive across Gradle invocations, reusing the same Scala compiler. This is expected to yield another significant speedup for Scala compilation.

== Eclipse Integration

When the Eclipse plugin encounters a Scala project, it adds additional configuration to make the project work with Scala IDE out of the box. Specifically, the plugin adds a Scala nature and dependency container.

== IntelliJ IDEA Integration

When the IDEA plugin encounters a Scala project, it adds additional configuration to make the project work with IDEA out of the box. Specifically, the plugin adds a Scala SDK (IntelliJ IDEA 14+) and a Scala compiler library that matches the Scala version on the project's class path. The Scala plugin is backwards compatible with earlier versions of IntelliJ IDEA and it is possible to add a Scala facet instead of the default Scala SDK by configuring `targetVersion` on IdeaModel.

build.gradle.kts

```
idea {
    targetVersion = "13"
}
```

build.gradle

```
idea {
    targetVersion = '13'
}
```

== WORKING WITH DEPENDENCIES

= Dependency Management Terminology

Dependency management comes with a wealth of terminology. Here you can find the most commonly-used terms including references to the user guide to learn about their practical application.

== Artifact

A file or directory produced by a build, such as a JAR, a ZIP distribution, or a native executable.

Artifacts are typically designed to be used or consumed by users or other projects, or deployed to hosting systems. In such cases, the artifact is a single file. Directories are common in the case of inter-project dependencies to avoid the cost of producing the publishable artifact.

== Capability

A capability identifies a feature offered by one or multiple components. A capability is identified by coordinates similar to the coordinates used for module versions. By default, each module version offers a capability that matches its coordinates, for example `com.google:guava:18.0`. Capabilities can be used to express that a component provides multiple feature variants or that two different components implement the same feature (and thus cannot be used together). For more details, see the section on capabilities.

== Component

Any single version of a module.

For external libraries, the term component refers to one published version of the library.

In a build, components are defined by plugins (e.g. the Java Library plugin) and provide a simple way to define a publication for publishing. They comprise artifacts as well as the appropriate metadata that describes a component's variants in detail. For example, the `java` component in its default setup consists of a JAR — produced by the `jar` task — and the dependency information of the Java *api* and *runtime* variants. It may also define additional variants, for example *sources* and *Javadoc*, with the corresponding artifacts.

== Configuration

A configuration is a named set of dependencies grouped together for a specific goal. Configurations provide access to the underlying, resolved modules and their artifacts. For more information, see the sections on dependency configurations as well as resolvable and consumable configurations.

> **NOTE** The word "configuration" is an overloaded term and has a different meaning outside of the context of dependency management.

== Dependency

A dependency is a pointer to another piece of software required to build, test or run a module. For more information, see the section on declaring dependencies.

Dependency constraint

A dependency constraint defines requirements that need to be met by a module to make it a valid resolution result for the dependency. For example, a dependency constraint can narrow down the set of supported module versions. Dependency constraints can be used to express such requirements for transitive dependencies. For more information, see the sections on upgrading and downgrading transitive dependencies.

Feature Variant

A feature variant is a variant representing a feature of a component that can be individually selected or not. A feature variant is identified by one or more capabilities. For more information, see the sections on modeling feature variants and optional dependencies.

Module

A piece of software that evolves over time e.g. Google Guava. Every module has a name. Each release of a module is optimally represented by a module version. For convenient consumption, modules can be hosted in a repository.

Module metadata

Releases of a module provide metadata. Metadata is the data that describes the module in more detail e.g. information about the location of artifacts or required transitive dependencies. Gradle offers its own metadata format called Gradle Module Metadata (`.module` file) but also supports Maven (`.pom`) and Ivy (`ivy.xml`) metadata. See the section on understanding Gradle Module Metadata for more information on the supported metadata formats.

Component metadata rule

A component metadata rule is a rule that modifies a component's metadata after it was fetched from a repository, e.g. to add missing information or to correct wrong information. In contrast to resolution rules, component metadata rules are applied **before** resolution starts. Component metadata rules are defined as part of the build logic and can be shared through plugins. For more information, see the section on fixing metadata with component metadata rules.

Module version

A module version represents a distinct set of changes of a released module. For example `18.0` represents the version of the module with the coordinates `com.google:guava:18.0`. In practice there's no limitation to the scheme of the module version. Timestamps, numbers, special suffixes like `-GA` are all allowed identifiers. The most widely-used versioning strategy is semantic versioning.

Platform

A platform is a set of modules aimed to be used together. There are different categories of platforms, corresponding to different use cases:

- module set: often a set of modules published together as a whole. Using one module of the set often means we want to use the same version for all modules of the set. For example, if using `groovy` 1.2, also use `groovy-json` 1.2.

- runtime environment: a set of libraries known to work well together. e.g., the Spring Platform, recommending versions for both Spring and components that work well with Spring.

- deployment environment: Java runtime, application server, …

In addition Gradle defines virtual platforms.

NOTE	Maven's BOM (bill-of-material) is a popular kind of platform that Gradle supports.

== Publication

A description of the files and metadata that should be published to a repository as a single entity for use by consumers.

A publication has a name and consists of one or more artifacts plus information about those artifacts (the metadata).

== Repository

A repository hosts a set of modules, each of which may provide one or many releases (components) indicated by a module version. The repository can be based on a binary repository product (e.g. Artifactory or Nexus) or a directory structure in the filesystem. For more information, see Declaring Repositories.

== Resolution rule

A resolution rule influences the behavior of how a dependency is resolved directly. Resolution rules are defined as part of the build logic. For more information, see the section on customizing resolution of a dependency directly.

== Transitive dependency

A variant of a component can have dependencies on other modules to work properly, so-called transitive dependencies. Releases of a module hosted on a repository can provide metadata to declare those transitive dependencies. By default, Gradle resolves transitive dependencies automatically. The version selection for transitive dependencies can be influenced by declaring dependency constraints.

== Variant (of a component)

Each component consists of one or more variants. A variant consists of a set of artifacts and defines a set of dependencies. It is identified by a set of attributes and capabilities.

Gradle's dependency resolution is variant-aware and selects one or more variants of each component after a component (i.e. one version of a module) has been selected. It may also fail if the variant selection result is ambiguous, meaning that Gradle does not have enough information to select one of multiple mutual exclusive variants. In that case, more information can be provided through variant attributes. Examples of variants each Java components typically offers are *api* and *runtime* variants. Others examples are JDK8 and JDK11 variants. For more information, see the section on variant selection.

Variant Attribute

Attributes are used to identify and select variants. A variant has one or more attributes defined, for example `org.gradle.usage=java-api`, `org.gradle.jvm.version=11`. When dependencies are resolved, a set of attributes are requested and Gradle finds the best fitting variant(s) for each component in the dependency graph. Compatibility and disambiguation rules can be implemented for an attribute to express compatibility between values (e.g. Java 8 is compatible with Java 11, but Java 11 should be preferred if the requested version is 11 or higher). Such rules are typically provided by plugins. For more information, see the sections on variant selection and declaring attributes.

LEARNINGS THE BASICS

Dependency Management

Software projects rarely work in isolation. Projects often rely on reusable functionality from libraries. Some projects organize unrelated functionality into separate parts of a modular system.

Dependency management is an automated technique for declaring, resolving, and using functionality required by a project.

> **TIP** For an overview of dependency management terms, see Dependency Management Terminology.

Dependency Management in Gradle
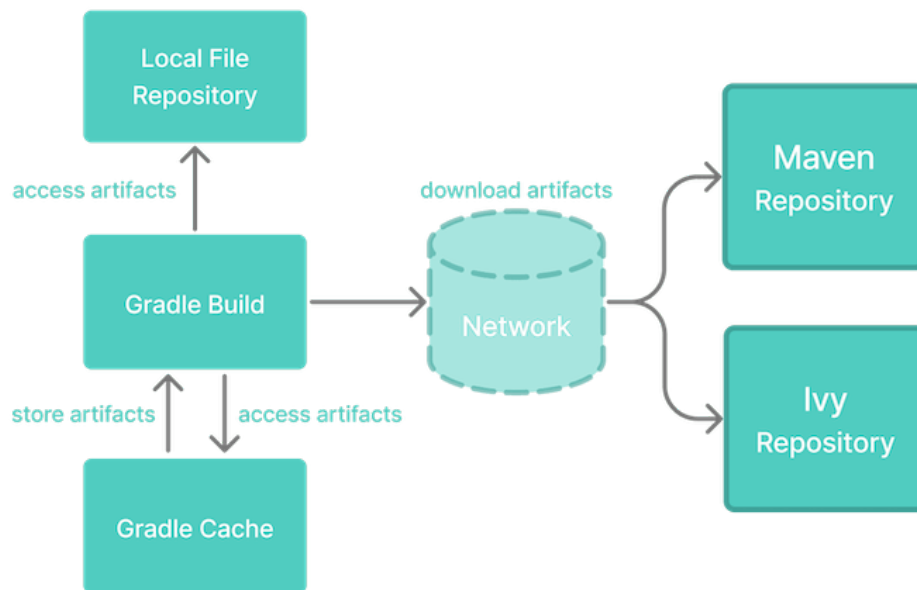
Figure 19. Dependencies management at a glance

Gradle has built-in support for dependency management.

Let's explore the main concepts with the help of a theoretical but common project:

- This project builds Java source code.
- Some Java source files import classes from the Google Guava library.
- This project uses JUnit for testing.

The Gradle build file might look as follows:

build.gradle.kts

```
plugins {
    `java-library`
}

repositories { ①
    google() ②
    mavenCentral()
}

dependencies { ③
    implementation("com.google.guava:guava:32.1.2-jre") ④
    testImplementation("junit:junit:4.13.2")
}
```

build.gradle

```
plugins {
    id 'java-library'
}

repositories { ①
    google() ②
    mavenCentral()
}

dependencies { ③
    implementation 'com.google.guava:guava:32.1.2-jre' ④
    testImplementation 'junit:junit:4.13.2'
}
```

① **Here we define repositories for the project.**

② **Here we declare remote and local repositories for dependency locations.**

You can declare *repositories* to tell Gradle where to fetch local or remote *dependencies*.

In this example, Gradle fetches *dependencies* from the Maven Central and Google *repositories*.

During a build, Gradle locates and downloads the dependencies, a process called *dependency resolution*. Gradle then stores resolved dependencies in a local cache called the *dependency cache*. Subsequent builds use this cache to avoid unnecessary network calls and speed up the build process.

③ **Here we define dependencies used by the project.**

④ **Here we declare the specific dependency name and version within a scope.**

You can add code to your Java project from an external library such as `com.google.common.base` (a Guava package) which becomes a *dependency*.

In this example, the theoretical project uses Guava version 32.1.2-jre and JUnit 4.13.2 as *dependencies*.

A build engineer can declare dependencies for different scopes. For example, you can declare dependencies that are only used at compile time. Gradle calls the scope of a dependency a *configuration*.

Repositories offer dependencies in multiple formats. For information about the formats supported by Gradle, see dependency types.

Metadata describes dependencies. Some examples of metadata include:

- coordinates for finding the dependency in a repository
- information about the project that created the dependency
- the authors of the dependency
- other dependencies required for a dependency to work properly, known as *transitive dependencies*

You can customize Gradle's handling of transitive dependencies based on the requirements of a project.

Projects with hundreds of declared dependencies can be difficult to debug. Gradle provides tools to visualize and analyze a project's dependency graph (i.e. dependency tree). You can use a Build Scan™ or built-in tasks.
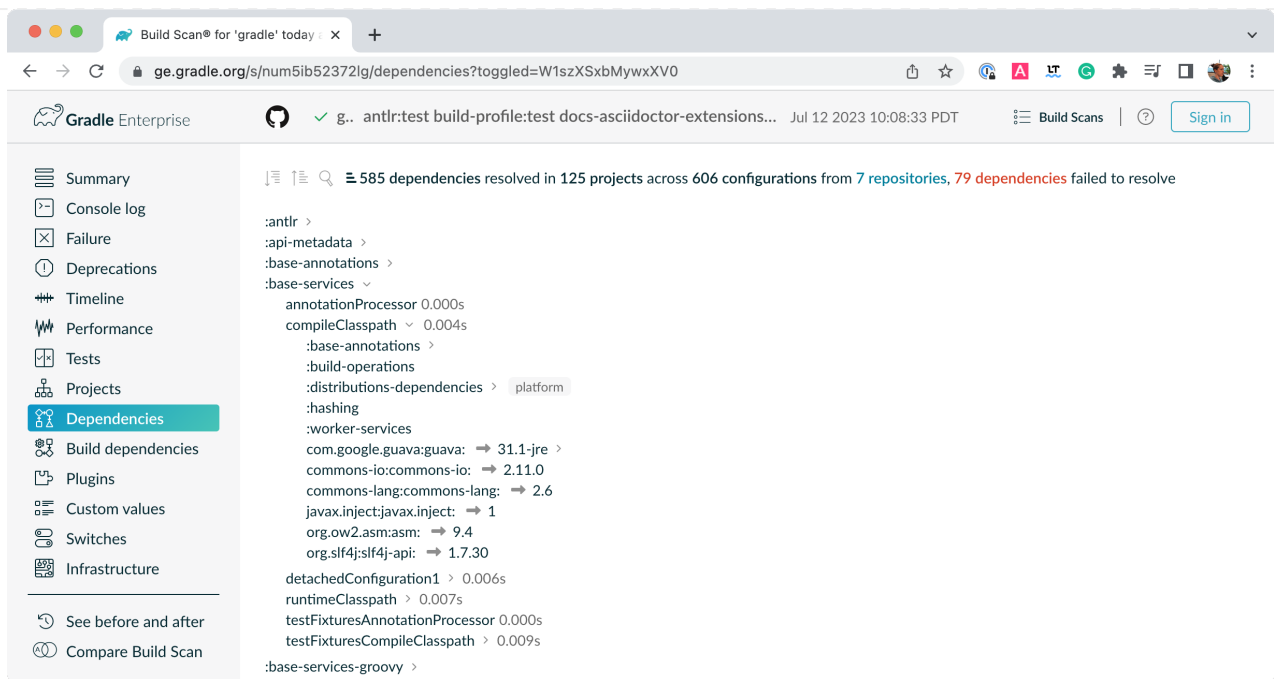
Figure 20. Build scan dependencies report

= Declaring repositories

Gradle can resolve dependencies from one or many repositories based on Maven, Ivy or flat directory formats. Check out the full reference on all types of repositories for more information.

== Declaring a publicly-available repository

Organizations building software may want to leverage public binary repositories to download and consume open source dependencies. Popular public repositories include Maven Central and the Google Android repository. Gradle provides built-in shorthand notations for these widely-used repositories.
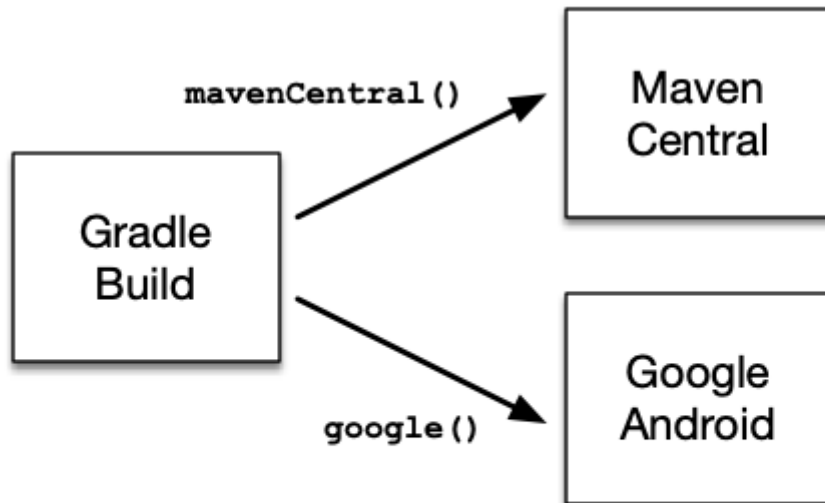
Figure 21. Declaring a repository with the help of shorthand notations

Under the covers Gradle resolves dependencies from the respective URL of the public repository defined by the shorthand notation. All shorthand notations are available via the RepositoryHandler API. Alternatively, you can spell out the URL of the repository for more fine-grained control.

=== Maven Central repository

Maven Central is a popular repository hosting open source libraries for consumption by Java projects.

To declare the Maven Central repository for your build add this to your script:

build.gradle.kts

```
repositories {
    mavenCentral()
}
```

build.gradle

```
repositories {
    mavenCentral()
}
```

=== Google Maven repository

The Google repository hosts Android-specific artifacts including the Android SDK. For usage examples, see the relevant Android documentation.

To declare the Google Maven repository add this to your build script:

build.gradle.kts

```
repositories {
    google()
}
```

build.gradle

```
repositories {
    google()
}
```

== Declaring a custom repository by URL

Most enterprise projects set up a binary repository available only within an intranet. In-house repositories enable teams to publish internal binaries, setup user management and security measure and ensure uptime and availability. Specifying a custom URL is also helpful if you want to declare a less popular, but publicly-available repository.

Repositories with custom URLs can be specified as Maven or Ivy repositories by calling the corresponding methods available on the RepositoryHandler API. Gradle supports other protocols than `http` or `https` as part of the custom URL e.g. `file`, `sftp` or `s3`. For a full coverage see the section on supported repository types.

You can also define your own repository layout by using `ivy { }` repositories as they are very flexible in terms of how modules are organised in a repository.

== Declaring multiple repositories

You can define more than one repository for resolving dependencies. Declaring multiple repositories is helpful if some dependencies are only available in one repository but not the other. You can mix any type of repository described in the reference section.

This example demonstrates how to declare various named and custom URL repositories for a project:

```kotlin
repositories {
    mavenCentral()
    maven {
        url = uri("https://repo.spring.io/release")
    }
    maven {
        url = uri("https://repository.jboss.org/maven2")
    }
}
```

```groovy
repositories {
    mavenCentral()
    maven {
        url "https://repo.spring.io/release"
    }
    maven {
        url "https://repository.jboss.org/maven2"
    }
}
```

The order of declaration determines how Gradle will check for dependencies at runtime. If Gradle finds a module descriptor in a particular repository, it will attempt to download all of the artifacts for that module from *the same repository*. You can learn more about the inner workings of dependency downloads.

=== Strict limitation to declared repositories

Maven POM metadata can reference additional repositories. These will be *ignored* by Gradle, which will only use the repositories declared in the build itself.

| NOTE | This is a reproducibility safe-guard but also a security protection. Without it, an updated version of a dependency could pull artifacts from anywhere into your build. |

== Supported repository types

Gradle supports a wide range of sources for dependencies, both in terms of format and in terms of connectivity. You may resolve dependencies from:

- Different formats
    - a Maven compatible artifact repository (e.g: Maven Central)
    - an Ivy compatible artifact repository (including custom layouts)
    - local (flat) directories
- with different connectivity
    - authenticated repositories
    - a wide variety of remote protocols such as HTTPS, SFTP, AWS S3 and Google Cloud Storage

=== Flat directory repository

Some projects might prefer to store dependencies on a shared drive or as part of the project source code instead of a binary repository product. If you want to use a (flat) filesystem directory as a repository, simply type:

build.gradle.kts

```
repositories {
    flatDir {
        dirs("lib")
    }
    flatDir {
        dirs("lib1", "lib2")
    }
}
```

build.gradle

```
repositories {
    flatDir {
        dirs 'lib'
    }
    flatDir {
        dirs 'lib1', 'lib2'
    }
}
```

This adds repositories which look into one or more directories for finding dependencies.

This type of repository does not support any meta-data formats like Ivy XML or Maven POM files. Instead, Gradle will dynamically generate a module descriptor (without any dependency information) based on the presence of artifacts.

As Gradle prefers to use modules whose descriptor has been created from real meta-data rather than being generated, flat directory repositories cannot be used to override artifacts with real meta-data from other repositories declared in the build.

For example, if Gradle finds only `jmxri-1.2.1.jar` in a flat directory repository, but `jmxri-1.2.1.pom` in another repository that supports meta-data, it will use the second repository to provide the module.

For the use case of overriding remote artifacts with local ones consider using an Ivy or Maven repository instead whose URL points to a local directory.

If you only work with flat directory repositories you don't need to set all attributes of a dependency.

=== Local repositories

The following sections describe repositories format, Maven or Ivy. These can be declared as local repositories, using a local filesystem path to access them.

The difference with the flat directory repository is that they do respect a format and contain metadata.

When such a repository is configured, Gradle totally bypasses its dependency cache for it as there can be no guarantee that content may not change between executions. Because of that limitation, they can have a performance impact.

They also make build reproducibility much harder to achieve and their use should be limited to tinkering or prototyping.

== Maven repositories

Many organizations host dependencies in an in-house Maven repository only accessible within the company's network. Gradle can declare Maven repositories by URL.

For adding a custom Maven repository you can do:

build.gradle.kts

```kotlin
repositories {
    maven {
        url = uri("http://repo.mycompany.com/maven2")
    }
}
```

build.gradle

```groovy
repositories {
    maven {
        url "http://repo.mycompany.com/maven2"
    }
}
```

=== Setting up composite Maven repositories

Sometimes a repository will have the POMs published to one location, and the JARs and other artifacts published at another location. To define such a repository, you can do:

build.gradle.kts

```
repositories {
    maven {
        // Look for POMs and artifacts, such as JARs, here
        url = uri("http://repo2.mycompany.com/maven2")
        // Look for artifacts here if not found at the above location
        artifactUrls("http://repo.mycompany.com/jars")
        artifactUrls("http://repo.mycompany.com/jars2")
    }
}
```

build.gradle

```
repositories {
    maven {
        // Look for POMs and artifacts, such as JARs, here
        url "http://repo2.mycompany.com/maven2"
        // Look for artifacts here if not found at the above location
        artifactUrls "http://repo.mycompany.com/jars"
        artifactUrls "http://repo.mycompany.com/jars2"
    }
}
```

Gradle will look at the base `url` location for the POM and the JAR. If the JAR can't be found there, the extra `artifactUrls` are used to look for JARs.

=== Accessing authenticated Maven repositories

You can specify credentials for Maven repositories secured by different type of authentication.

See [sec:supported_transport_protocols] for authentication options.

=== Local Maven repository

Gradle can consume dependencies available in the local Maven repository. Declaring this repository is beneficial for teams that publish to the local Maven repository with one project and consume the artifacts by Gradle in another project.

| NOTE | Gradle stores resolved dependencies in its own cache. A build does not need to declare the local Maven repository even if you resolve dependencies from a Maven-based, remote repository. |

| WARNING | Before adding Maven local as a repository, you should make sure this is really required. |

To declare the local Maven cache as a repository add this to your build script:

build.gradle.kts

```
repositories {
    mavenLocal()
}
```

build.gradle

```
repositories {
    mavenLocal()
}
```

Gradle uses the same logic as Maven to identify the location of your local Maven cache. If a local repository location is defined in a `settings.xml`, this location will be used. The `settings.xml` in `<home directory of the current user>/.m2` takes precedence over the `settings.xml` in `M2_HOME/conf`. If no `settings.xml` is available, Gradle uses the default location `<home directory of the current user>/.m2/repository`.

== The case for mavenLocal()

As a general advice, you should avoid adding `mavenLocal()` as a repository. There are different issues with using `mavenLocal()` that you should be aware of:

- Maven uses it as a cache, not a repository, meaning it can contain partial modules.
  ◦ For example, if Maven never downloaded the source or javadoc files for a given module, Gradle will not find them either since it searches for files in a single repository once a module has been found.
- As a local repository, Gradle does not trust its content, because:
  ◦ Origin of artifacts cannot be tracked, which is a correctness and security problem
  ◦ Artifacts can be easily overwritten, which is a security, correctness and reproducibility problem
- To mitigate the fact that metadata and/or artifacts can be changed, Gradle does not perform any caching for local repositories
  ◦ As a consequence, your builds are slower
  ◦ Given that order of repositories is important, adding `mavenLocal()` *first* means that all your builds are going to be slower

There are a few cases where you might have to use `mavenLocal()`:

- For interoperability with Maven
  ◦ For example, project A is built with Maven, project B is built with Gradle, and you need to share the artifacts during development
  ◦ It is *always* preferable to use an internal full featured repository instead
  ◦ In case this is not possible, you should limit this to *local builds only*
- For interoperability with Gradle itself
  ◦ In a multi-repository world, you want to check that changes to project A work with project B
  ◦ It is preferable to use composite builds for this use case
  ◦ If for some reason neither composite builds nor full featured repository are possible, then `mavenLocal()` is a last resort option

After all these warnings, if you end up using `mavenLocal()`, consider combining it with a repository filter. This will make sure it only provides what is expected and nothing else.

== Ivy repositories

Organizations might decide to host dependencies in an in-house Ivy repository. Gradle can declare Ivy repositories by URL.

Defining an Ivy repository with a standard layout

To declare an Ivy repository using the standard layout no additional customization is needed. You just declare the URL.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
    }
}
```

build.gradle

```
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
    }
}
```

Defining a named layout for an Ivy repository

You can specify that your repository conforms to the Ivy or Maven default layout by using a named layout.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
        layout("maven")
    }
}
```

```
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
        layout "maven"
    }
}
```

Valid named layout values are `'gradle'` (the default), `'maven'` and `'ivy'`. See IvyArtifactRepository.layout(java.lang.String) in the API documentation for details of these named layouts.

=== Defining custom pattern layout for an Ivy repository

To define an Ivy repository with a non-standard layout, you can define a *pattern* layout for the repository:

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
        patternLayout {
            artifact("[module]/[revision]/[type]/[artifact].[ext]")
        }
    }
}
```

```
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
        patternLayout {
            artifact "[module]/[revision]/[type]/[artifact].[ext]"
        }
    }
}
```

To define an Ivy repository which fetches Ivy files and artifacts from different locations, you can define separate patterns to use to locate the Ivy files and artifacts:

Each `artifact` or `ivy` specified for a repository adds an *additional* pattern to use. The patterns are used in the order that they are defined.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
        patternLayout {
            artifact("3rd-party-
artifacts/[organisation]/[module]/[revision]/[artifact]-[revision].[ext]")
            artifact("company-
artifacts/[organisation]/[module]/[revision]/[artifact]-[revision].[ext]")
            ivy("ivy-files/[organisation]/[module]/[revision]/ivy.xml")
        }
    }
}
```

build.gradle

```
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
        patternLayout {
            artifact "3rd-party-
artifacts/[organisation]/[module]/[revision]/[artifact]-[revision].[ext]"
            artifact "company-
artifacts/[organisation]/[module]/[revision]/[artifact]-[revision].[ext]"
            ivy "ivy-files/[organisation]/[module]/[revision]/ivy.xml"
        }
    }
}
```

Optionally, a repository with pattern layout can have its `'organisation'` part laid out in Maven style, with forward slashes replacing dots as separators. For example, the organisation `my.company` would then be represented as `my/company`.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
        patternLayout {
            artifact("[organisation]/[module]/[revision]/[artifact]-
[revision].[ext]")
            setM2compatible(true)
        }
    }
}
```

build.gradle

```
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
        patternLayout {
            artifact "[organisation]/[module]/[revision]/[artifact]-
[revision].[ext]"
            m2compatible = true
        }
    }
}
```

=== Accessing authenticated Ivy repositories

You can specify credentials for Ivy repositories secured by basic authentication.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("http://repo.mycompany.com")
        credentials {
            username = "user"
            password = "password"
        }
    }
}
```

build.gradle

```
repositories {
    ivy {
        url "http://repo.mycompany.com"
        credentials {
            username "user"
            password "password"
        }
    }
}
```

See [sec:supported_transport_protocols] for authentication options.

Repository content filtering

Gradle exposes an API to declare what a repository may or may not contain. There are different use cases for it:

- performance, when you know a dependency will never be found in a specific repository
- security, by avoiding leaking what dependencies are used in a private project
- reliability, when some repositories contain corrupted metadata or artifacts

It's even more important when considering that the declared order of repositories matter.

Declaring a repository filter

build.gradle.kts

```kotlin
repositories {
    maven {
        url = uri("https://repo.mycompany.com/maven2")
        content {
            // this repository *only* contains artifacts with group "my.company"
            includeGroup("my.company")
        }
    }
    mavenCentral {
        content {
            // this repository contains everything BUT artifacts with group
starting with "my.company"
            excludeGroupByRegex("my\\.company.*")
        }
    }
}
```

build.gradle

```groovy
repositories {
    maven {
        url "https://repo.mycompany.com/maven2"
        content {
            // this repository *only* contains artifacts with group "my.company"
            includeGroup "my.company"
        }
    }
    mavenCentral {
        content {
            // this repository contains everything BUT artifacts with group
starting with "my.company"
            excludeGroupByRegex "my\\.company.*"
        }
    }
}
```

By default, repositories include everything and exclude nothing:

- If you declare an include, then it excludes everything *but* what is included.

- If you declare an exclude, then it includes everything *but* what is excluded.

- If you declare both includes and excludes, then it includes only what is explicitly included and not excluded.

It is possible to filter either by explicit *group*, *module* or *version*, either strictly or using regular expressions. When using a strict version, it is possible to use a version range, using the format supported by Gradle. In addition, there are filtering options by resolution context: configuration name or even configuration attributes. See RepositoryContentDescriptor for details.

=== Declaring content exclusively found in one repository

Filters declared using the repository-level content filter are not exclusive. This means that declaring that a repository *includes* an artifact doesn't mean that the other repositories can't have it either: you must declare what every repository contains in extension.

Alternatively, Gradle provides an API which lets you declare that a repository *exclusively includes* an artifact. If you do so:

- an artifact declared in a repository *can't* be found in any other

- exclusive repository content must be declared in extension (just like for repository-level content)

---

build.gradle.kts

```
repositories {
    // This repository will _not_ be searched for artifacts in my.company
    // despite being declared first
    mavenCentral()
    exclusiveContent {
        forRepository {
            maven {
                url = uri("https://repo.mycompany.com/maven2")
            }
        }
        filter {
            // this repository *only* contains artifacts with group "my.company"
            includeGroup("my.company")
        }
    }
}
```

build.gradle

```
repositories {
    // This repository will _not_ be searched for artifacts in my.company
    // despite being declared first
    mavenCentral()
    exclusiveContent {
        forRepository {
            maven {
                url "https://repo.mycompany.com/maven2"
            }
        }
        filter {
            // this repository *only* contains artifacts with group "my.company"
            includeGroup "my.company"
        }
    }
}
```

It is possible to filter either by explicit *group*, *module* or *version*, either strictly or using regular expressions. See InclusiveRepositoryContentDescriptor for details.

If you leverage exclusive content filtering in the `pluginManagement` section of the `settings.gradle(.kts)`, it becomes illegal to add more repositories through the project `buildscript.repositories`. In that case, the build configuration will fail.

Your options are either to declare all repositories in settings or to use non-exclusive content filtering.

=== Maven repository filtering

For Maven repositories, it's often the case that a repository would either contain releases or snapshots. Gradle lets you declare what kind of artifacts are found in a repository using this DSL:

```kotlin
repositories {
    maven {
        url = uri("https://repo.mycompany.com/releases")
        mavenContent {
            releasesOnly()
        }
    }
    maven {
        url = uri("https://repo.mycompany.com/snapshots")
        mavenContent {
            snapshotsOnly()
        }
    }
}
```

build.gradle

```groovy
repositories {
    maven {
        url "https://repo.mycompany.com/releases"
        mavenContent {
            releasesOnly()
        }
    }
    maven {
        url "https://repo.mycompany.com/snapshots"
        mavenContent {
            snapshotsOnly()
        }
    }
}
```

Supported metadata sources

When searching for a module in a repository, Gradle, by default, checks for supported metadata file formats in that repository. In a Maven repository, Gradle looks for a `.pom` file, in an ivy repository it looks for an `ivy.xml` file and in a flat directory repository it looks directly for `.jar` files as it does not expect any metadata. Starting with 5.0, Gradle also looks for `.module` (Gradle module metadata) files.

However, if you define a customized repository you might want to configure this behavior. For example, you can define a Maven repository without `.pom` files but only jars. To do so, you can configure *metadata sources* for any repository.

build.gradle.kts

```
repositories {
    maven {
        url = uri("http://repo.mycompany.com/repo")
        metadataSources {
            mavenPom()
            artifact()
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url "http://repo.mycompany.com/repo"
        metadataSources {
            mavenPom()
            artifact()
        }
    }
}
```

You can specify multiple sources to tell Gradle to keep looking if a file was not found. In that case, the order of checking for sources is predefined.

The following metadata sources are supported:

Table 20. Supported metadata sources

Metadata source	Description	Order	Maven	Ivy / flat dir
`gradleMetadata()`	Look for Gradle `.module` files	1st	yes	yes
`mavenPom()`	Look for Maven `.pom` files	2nd	yes	yes
`ivyDescriptor()`	Look for `ivy.xml` files	2nd	no	yes
`artifact()`	Look directly for artifact	3rd	yes	yes

The defaults for Ivy and Maven repositories change with Gradle 6.0. Before 6.0, `artifact()` was included in the defaults. Leading to some inefficiency when modules are missing completely.

To restore this behavior, for example, for Maven central you can use:

```
mavenCentral { metadataSources { mavenPom(); artifact() } }
```

In a similar way, you can opt into the new behavior in older Gradle versions using:

```
mavenCentral { metadataSources { mavenPom() } }
```

Since Gradle 5.3, when parsing a metadata file, be it Ivy or Maven, Gradle will look for a marker indicating that a matching Gradle Module Metadata files exists. If it is found, it will be used instead of the Ivy or Maven file.

Starting with Gradle 5.6, you can disable this behavior by adding `ignoreGradleMetadataRedirection()` to the metadataSources declaration.

build.gradle.kts

```kotlin
repositories {
    maven {
        url = uri("http://repo.mycompany.com/repo")
        metadataSources {
            mavenPom()
            artifact()
            ignoreGradleMetadataRedirection()
        }
    }
}
```

build.gradle

```groovy
repositories {
    maven {
        url "http://repo.mycompany.com/repo"
        metadataSources {
            mavenPom()
            artifact()
            ignoreGradleMetadataRedirection()
        }
    }
}
```

Plugin repositories vs. build repositories

Gradle will use repositories at two different phases during your build.

The first phase is when configuring your build and loading the plugins it applied. To do that Gradle will use a special set of repositories.

The second phase is during dependency resolution. At this point Gradle will use the repositories declared in your project, as shown in the previous sections.

Plugin repositories

By default Gradle will use the Gradle plugin portal to look for plugins.

However, for different reasons, there are plugins available in other, public or not, repositories. When a build requires one of these plugins, additional repositories need to be specified so that Gradle knows where to search.

As the way to declare the repositories and what they are expected to contain depends on the way the plugin is applied, it is best to refer to Custom Plugin Repositories.

Centralizing repositories declaration

Instead of declaring repositories in every subproject of your build or via an `allprojects` block, Gradle offers a way to declare them in a central place for all projects.

> **NOTE** Central declaration of repositories is an incubating feature.

Repositories used by convention in every subproject can be declared in the `settings.gradle(.kts)` file:

settings.gradle.kts

```
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
```

The `dependencyResolutionManagement` repositories block accepts the same notations as in a project. This includes Maven or Ivy repositories, with or without credentials, etc.

By default, repositories declared by a project in `build.gradle(.kts)` will **override** whatever is declared in `settings.gradle(.kts)`:

settings.gradle.kts

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.PREFER_PROJECT
}
```

settings.gradle

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.PREFER_PROJECT
}
```

There are three modes for dependency resolution management:

Mode	Description	Default?	Use-Case
PREFER_PROJECT	Any repository declared on a project will cause the project to use the repositories declared by the project, ignoring those declared in settings.	Yes	Useful when teams need to use different repositories not common among subprojects.
PREFER_SETTINGS	Any repository declared directly in a project, either directly or via a plugin, will be ignored.	No	Useful for enforcing large teams to use approved repositories only, but will not fail the build when a project or plugin declares a repository.
FAIL_ON_PROJECT_REPOS	Any repository declared directly in a project, either directly or via a plugin, will trigger a build error.	No	Useful for enforcing large teams to use approved repositories only.

You can change the behavior to prefer the repositories in the `settings.gradle(.kts)` file by using `repositoriesMode`:

settings.gradle.kts

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.PREFER_SETTINGS
}
```

settings.gradle

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.PREFER_SETTINGS
}
```

Gradle will warn you if a project or a plugin declares a repository in a project.

You can force Gradle to *fail the build* if you want to enforce that **only** settings repositories are used:

settings.gradle.kts

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.FAIL_ON_PROJECT_REPOS
}
```

settings.gradle

```
dependencyResolutionManagement {
    repositoriesMode = RepositoriesMode.FAIL_ON_PROJECT_REPOS
}
```

== Supported repository transport protocols

Maven and Ivy repositories support the use of various transport protocols. At the moment the following protocols are supported:

Table 21. Repository transport protocols

Type	Credential types	Link
`file`	none	
`http`	username/password	Documentation
`https`	username/password	Documentation
`sftp`	username/password	Documentation
`s3`	access key/secret key/session token or Environment variables	Documentation
`gcs`	default application credentials sourced from well known files, Environment variables etc.	Documentation

NOTE	Username and password should never be checked in plain text into version control as part of your build file. You can store the credentials in a local `gradle.properties` file and use one of the open source Gradle plugins for encrypting and consuming credentials e.g. the credentials plugin.

The transport protocol is part of the URL definition for a repository. The following build script demonstrates how to create HTTP-based Maven and Ivy repositories:

build.gradle.kts

```
repositories {
    maven {
        url = uri("http://repo.mycompany.com/maven2")
    }

    ivy {
        url = uri("http://repo.mycompany.com/repo")
    }
}
```

```
repositories {
    maven {
        url "http://repo.mycompany.com/maven2"
    }

    ivy {
        url "http://repo.mycompany.com/repo"
    }
}
```

The following example shows how to declare SFTP repositories:

```
repositories {
    maven {
        url = uri("sftp://repo.mycompany.com:22/maven2")
        credentials {
            username = "user"
            password = "password"
        }
    }

    ivy {
        url = uri("sftp://repo.mycompany.com:22/repo")
        credentials {
            username = "user"
            password = "password"
        }
    }
}
```

```
repositories {
    maven {
        url "sftp://repo.mycompany.com:22/maven2"
        credentials {
            username "user"
            password "password"
        }
    }

    ivy {
        url "sftp://repo.mycompany.com:22/repo"
        credentials {
            username "user"
            password "password"
        }
    }
}
```

For details on HTTP related authentication, see the section [sec:authentication_schemes].

When using an AWS S3 backed repository you need to authenticate using AwsCredentials, providing access-key and a private-key. The following example shows how to declare a S3 backed repository and providing AWS credentials:

build.gradle.kts

```kotlin
repositories {
    maven {
        url = uri("s3://myCompanyBucket/maven2")
        credentials(AwsCredentials::class) {
            accessKey = "someKey"
            secretKey = "someSecret"
            // optional
            sessionToken = "someSTSToken"
        }
    }

    ivy {
        url = uri("s3://myCompanyBucket/ivyrepo")
        credentials(AwsCredentials::class) {
            accessKey = "someKey"
            secretKey = "someSecret"
            // optional
            sessionToken = "someSTSToken"
        }
    }
}
```

```
repositories {
    maven {
        url "s3://myCompanyBucket/maven2"
        credentials(AwsCredentials) {
            accessKey "someKey"
            secretKey "someSecret"
            // optional
            sessionToken "someSTSToken"
        }
    }

    ivy {
        url "s3://myCompanyBucket/ivyrepo"
        credentials(AwsCredentials) {
            accessKey "someKey"
            secretKey "someSecret"
            // optional
            sessionToken "someSTSToken"
        }
    }
}
```

You can also delegate all credentials to the AWS sdk by using the AwsImAuthentication. The following example shows how:

```
repositories {
    maven {
        url = uri("s3://myCompanyBucket/maven2")
        authentication {
            create<AwsImAuthentication>("awsIm") // load from EC2 role or env var
        }
    }

    ivy {
        url = uri("s3://myCompanyBucket/ivyrepo")
        authentication {
            create<AwsImAuthentication>("awsIm")
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url "s3://myCompanyBucket/maven2"
        authentication {
            awsIm(AwsImAuthentication) // load from EC2 role or env var
        }
    }

    ivy {
        url "s3://myCompanyBucket/ivyrepo"
        authentication {
            awsIm(AwsImAuthentication)
        }
    }
}
```

For details on AWS S3 related authentication, see the section [sec:s3-repositories].

When using a Google Cloud Storage backed repository default application credentials will be used with no further configuration required:

build.gradle.kts

```
repositories {
    maven {
        url = uri("gcs://myCompanyBucket/maven2")
    }

    ivy {
        url = uri("gcs://myCompanyBucket/ivyrepo")
    }
}
```

build.gradle

```
repositories {
    maven {
        url "gcs://myCompanyBucket/maven2"
    }

    ivy {
        url "gcs://myCompanyBucket/ivyrepo"
    }
}
```

For details on Google GCS related authentication, see the section [sec:gcs-repositories].

== HTTP(S) authentication schemes configuration

When configuring a repository using HTTP or HTTPS transport protocols, multiple authentication schemes are available. By default, Gradle will attempt to use all schemes that are supported by the Apache HttpClient library, documented here. In some cases, it may be preferable to explicitly specify which authentication schemes should be used when exchanging credentials with a remote server. When explicitly declared, only those schemes are used when authenticating to a remote repository.

You can specify credentials for Maven repositories secured by basic authentication using PasswordCredentials.

build.gradle.kts

```
repositories {
    maven {
        url = uri("http://repo.mycompany.com/maven2")
        credentials {
            username = "user"
            password = "password"
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url "http://repo.mycompany.com/maven2"
        credentials {
            username "user"
            password "password"
        }
    }
}
```

The following example show how to configure a repository to use only DigestAuthentication:

build.gradle.kts

```
repositories {
    maven {
        url = uri("https://repo.mycompany.com/maven2")
        credentials {
            username = "user"
            password = "password"
        }
        authentication {
            create<DigestAuthentication>("digest")
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url 'https://repo.mycompany.com/maven2'
        credentials {
            username "user"
            password "password"
        }
        authentication {
            digest(DigestAuthentication)
        }
    }
}
```

Currently supported authentication schemes are:

BasicAuthentication

Basic access authentication over HTTP. When using this scheme, credentials are sent preemptively.

DigestAuthentication

Digest access authentication over HTTP.

HttpHeaderAuthentication

Authentication based on any custom HTTP header, e.g. private tokens, OAuth tokens, etc.

=== Using preemptive authentication

Gradle's default behavior is to only submit credentials when a server responds with an authentication challenge in the form of an HTTP 401 response. In some cases, the server will respond with a different code (ex. for repositories hosted on GitHub a 404 is returned) causing dependency resolution to fail. To get around this behavior, credentials may be sent to the server preemptively. To enable preemptive authentication simply configure your repository to explicitly use the BasicAuthentication scheme:

build.gradle.kts

```
repositories {
    maven {
        url = uri("https://repo.mycompany.com/maven2")
        credentials {
            username = "user"
            password = "password"
        }
        authentication {
            create<BasicAuthentication>("basic")
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url 'https://repo.mycompany.com/maven2'
        credentials {
            username "user"
            password "password"
        }
        authentication {
            basic(BasicAuthentication)
        }
    }
}
```

=== Using HTTP header authentication

You can specify any HTTP header for secured Maven repositories requiring token, OAuth2 or other HTTP header based authentication using HttpHeaderCredentials with HttpHeaderAuthentication.

build.gradle.kts

```
repositories {
    maven {
        url = uri("http://repo.mycompany.com/maven2")
        credentials(HttpHeaderCredentials::class) {
            name = "Private-Token"
            value = "TOKEN"
        }
        authentication {
            create<HttpHeaderAuthentication>("header")
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url "http://repo.mycompany.com/maven2"
        credentials(HttpHeaderCredentials) {
            name = "Private-Token"
            value = "TOKEN"
        }
        authentication {
            header(HttpHeaderAuthentication)
        }
    }
}
```

AWS S3 repositories configuration

S3 configuration properties

The following system properties can be used to configure the interactions with s3 repositories:

`org.gradle.s3.endpoint`

Used to override the AWS S3 endpoint when using a non AWS, S3 API compatible, storage service.

`org.gradle.s3.maxErrorRetry`

Specifies the maximum number of times to retry a request in the event that the S3 server responds with a HTTP 5xx status code. When not specified a default value of 3 is used.

S3 URL formats

S3 URL's are 'virtual-hosted-style' and must be in the following format

```
s3://<bucketName>[.<regionSpecificEndpoint>]/<s3Key>
```

e.g. `s3://myBucket.s3.eu-central-1.amazonaws.com/maven/release`

- `myBucket` is the AWS S3 bucket name.
- `s3.eu-central-1.amazonaws.com` is the *optional* region specific endpoint.
- `/maven/release` is the AWS S3 key (unique identifier for an object within a bucket)

S3 proxy settings

A proxy for S3 can be configured using the following system properties:

- `https.proxyHost`
- `https.proxyPort`
- `https.proxyUser`
- `https.proxyPassword`
- `http.nonProxyHosts` (NOTE: this is not a typo.)

If the `org.gradle.s3.endpoint` property has been specified with a HTTP (not HTTPS) URI the following system proxy settings can be used:

- `http.proxyHost`
- `http.proxyPort`
- `http.proxyUser`
- `http.proxyPassword`
- `http.nonProxyHosts`

=== AWS S3 V4 Signatures (AWS4-HMAC-SHA256)

Some of the AWS S3 regions (eu-central-1 - Frankfurt) require that all HTTP requests are signed in accordance with AWS's [signature version 4](). It is recommended to specify S3 URL's containing the region specific endpoint when using buckets that require V4 signatures. e.g.

```
s3://somebucket.s3.eu-central-1.amazonaws.com/maven/release
```

When a region-specific endpoint is not specified for buckets requiring V4 Signatures, Gradle will use the default AWS region (us-east-1) and the following warning will appear on the console:

```
Attempting to re-send the request to .... with AWS V4 authentication. To avoid
this warning in the future, use region-specific endpoint to access buckets located
in regions that require V4 signing.
```

Failing to specify the region-specific endpoint for buckets requiring V4 signatures means:

- 3 round-trips to AWS, as opposed to one, for every file upload and download.
- Depending on location - increased network latencies and slower builds.
- Increased likelihood of transmission failures.

==== AWS S3 Cross Account Access

Some organizations may have multiple AWS accounts, e.g. one for each team. The AWS account of the bucket owner is often different from the artifact publisher and consumers. The bucket owner needs to be able to grant the consumers access otherwise the artifacts will only be usable by the publisher's account. This is done by adding the `bucket-owner-full-control` [Canned ACL]() to the uploaded objects. Gradle will do this in every upload. Make sure the publisher has the required IAM permission, `PutObjectAcl` (and `PutObjectVersionAcl` if bucket versioning is enabled), either directly or via an assumed IAM Role (depending on your case). You can read more at [AWS S3 Access Permissions]().

== Google Cloud Storage repositories configuration

=== GCS configuration properties

The following system properties can be used to configure the interactions with [Google Cloud Storage]() repositories:

`org.gradle.gcs.endpoint`

Used to override the Google Cloud Storage endpoint when using a non-Google Cloud Platform, Google Cloud Storage API compatible, storage service.

`org.gradle.gcs.servicePath`

Used to override the Google Cloud Storage root service path which the Google Cloud Storage client builds requests from, defaults to `/`.

=== GCS URL formats

Google Cloud Storage URL's are 'virtual-hosted-style' and must be in the following format `gcs://<bucketName>/<objectKey>`

e.g. `gcs://myBucket/maven/release`

- `myBucket` is the Google Cloud Storage bucket name.
- `/maven/release` is the Google Cloud Storage key (unique identifier for an object within a bucket)

== Handling credentials

Repository credentials should never be part of your build script but rather be kept external. Gradle provides an API in artifact repositories that allows you to declare only the type of required credentials. Credential values are looked up from the Gradle Properties during the build that requires them.

For example, given repository configuration:

build.gradle.kts

```
repositories {
    maven {
        name = "mySecureRepository"
        credentials(PasswordCredentials::class)
        // url = uri(<<some repository url>>)
    }
}
```

build.gradle

```
repositories {
    maven {
        name = 'mySecureRepository'
        credentials(PasswordCredentials)
        // url = uri(<<some repository url>>)
    }
}
```

The username and password will be looked up from `mySecureRepositoryUsername` and `mySecureRepositoryPassword` properties.

Note that the configuration property prefix - the identity - is determined from the repository name. Credentials can then be provided in any of supported ways for Gradle Properties - `gradle.properties` file, command line arguments, environment variables or a combination of those options.

Also, note that credentials will only be required if the invoked build requires them. If for example a project is configured to publish artifacts to a secured repository, but the build does not invoke publishing task, Gradle will not require publishing credentials to be present. On the other hand, if the build needs to execute a task that requires credentials at some point, Gradle will check for credential presence first thing and will not start running any of the tasks if it knows that the build will fail at a later point because of missing credentials.

Here is a downloadable sample that demonstrates the concept in more detail.

Lookup is only supported for credentials listed in the Table 22.

Table 22. Credentials that support value lookup and their corresponding properties

Type	Argument	Base property name	Required?
`PasswordCredentials`	`username`	`Username`	required
	`password`	`Password`	required
`AwsCredentials`	`accessKey`	`AccessKey`	required
	`secretKey`	`SecretKey`	required
	`sessionToken`	`SessionToken`	optional
`HttpHeaderCredentials`	`name`	`AuthHeaderName`	required
	`value`	`AuthHeaderValue`	required

= Declaring dependencies

Before looking at dependency declarations themselves, the concept of *dependency configuration* needs to be defined.

== What are dependency configurations

Every dependency declared for a Gradle project applies to a specific scope. For example some dependencies should be used for compiling source code whereas others only need to be available at runtime. Gradle represents the scope of a dependency with the help of a Configuration. Every configuration can be identified by a unique name.

Many Gradle plugins add pre-defined configurations to your project. The Java plugin, for example, adds configurations to represent the various classpaths it needs for source code compilation, executing tests and the like. See the Java plugin chapter for an example.
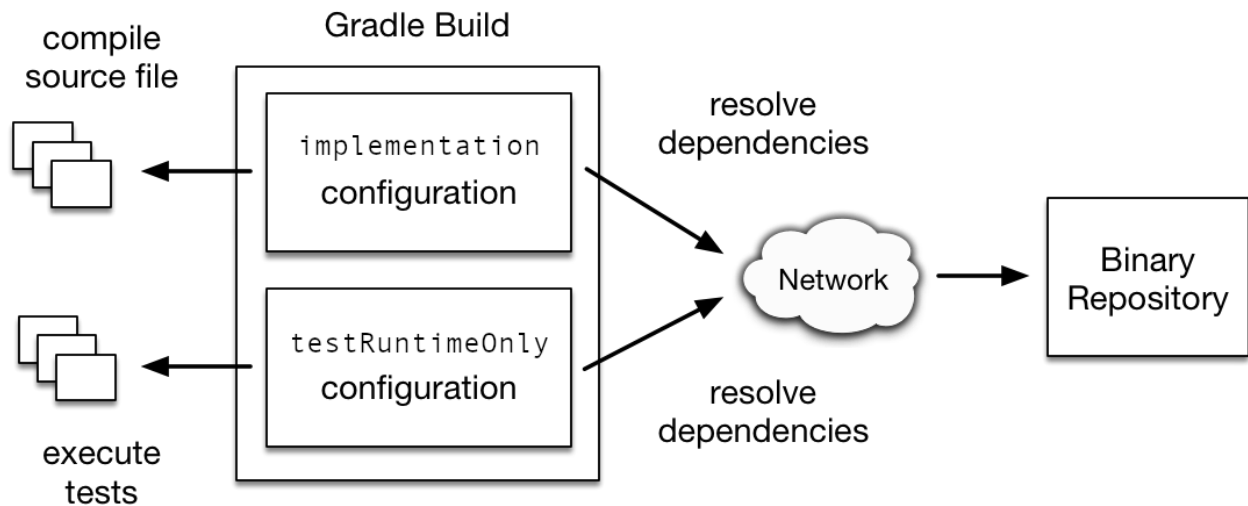
Figure 22. Configurations use declared dependencies for specific purposes

For more examples on the usage of configurations to navigate, inspect and post-process metadata and artifacts of assigned dependencies, have a look at the resolution result APIs.

=== Configuration inheritance and composition

A configuration can extend other configurations to form an inheritance hierarchy. Child configurations inherit the whole set of dependencies declared for any of its superconfigurations.

Configuration inheritance is heavily used by Gradle core plugins like the Java plugin. For example the `testImplementation` configuration extends the `implementation` configuration. The configuration hierarchy has a practical purpose: compiling tests requires the dependencies of the source code under test on top of the dependencies needed write the test class. A Java project that uses JUnit to write and execute test code also needs Guava if its classes are imported in the production source code.
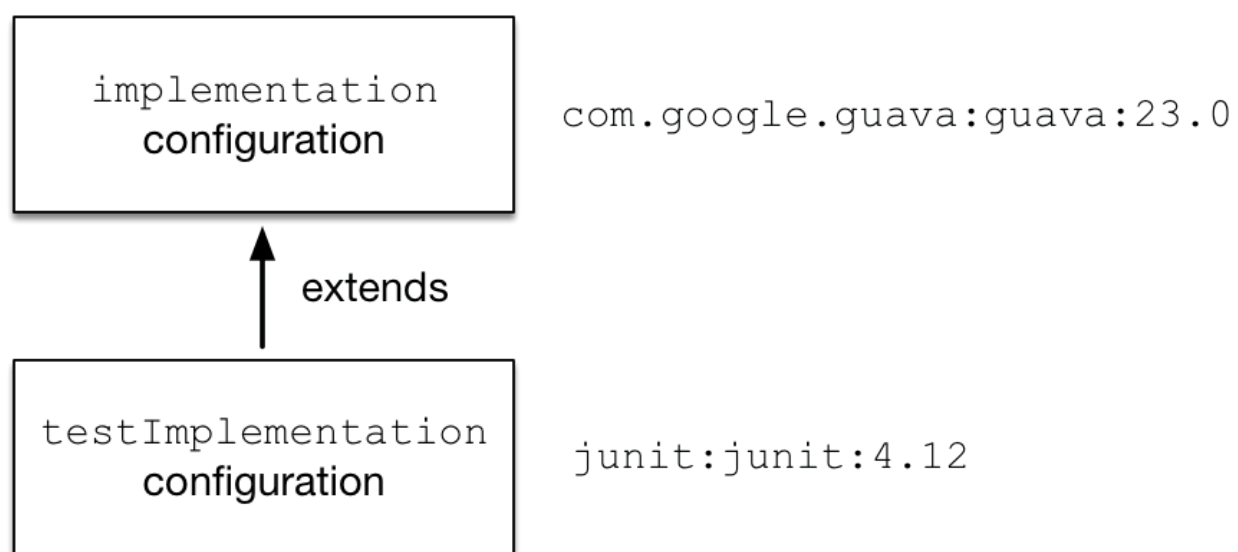
Figure 23. Configuration inheritance provided by the Java plugin

Under the covers the `testImplementation` and `implementation` configurations form an inheritance hierarchy by calling the method

Configuration.extendsFrom(org.gradle.api.artifacts.Configuration[]). A configuration can extend any other configuration irrespective of its definition in the build script or a plugin.

Let's say you wanted to write a suite of smoke tests. Each smoke test makes a HTTP call to verify a web service endpoint. As the underlying test framework the project already uses JUnit. You can define a new configuration named `smokeTest` that extends from the `testImplementation` configuration to reuse the existing test framework dependency.

build.gradle.kts

```kotlin
val smokeTest by configurations.creating {
    extendsFrom(configurations.testImplementation.get())
}

dependencies {
    testImplementation("junit:junit:4.13")
    smokeTest("org.apache.httpcomponents:httpclient:4.5.5")
}
```

build.gradle

```groovy
configurations {
    smokeTest.extendsFrom testImplementation
}

dependencies {
    testImplementation 'junit:junit:4.13'
    smokeTest 'org.apache.httpcomponents:httpclient:4.5.5'
}
```

== Resolvable and consumable configurations

Configurations are a fundamental part of dependency resolution in Gradle. In the context of dependency resolution, it is useful to distinguish between a *consumer* and a *producer*. Along these lines, configurations have at least 3 different roles:

1. to declare dependencies

2. as a *consumer*, to resolve a set of dependencies to files

3. as a *producer*, to expose artifacts and their dependencies for consumption by other projects (such *consumable* configurations usually represent the variants the producer offers to its consumers)

For example, to express that an application `app` *depends on* library `lib`, *at least* one configuration is required:

build.gradle.kts

```kotlin
// declare a "configuration" named "someConfiguration"
val someConfiguration by configurations.creating

dependencies {
    // add a project dependency to the "someConfiguration" configuration
    someConfiguration(project(":lib"))
}
```

build.gradle

```groovy
configurations {
    // declare a "configuration" named "someConfiguration"
    someConfiguration
}
dependencies {
    // add a project dependency to the "someConfiguration" configuration
    someConfiguration project(":lib")
}
```

Configurations can inherit dependencies from other configurations by extending from them. Now, notice that the code above doesn't tell us anything about the intended *consumer* of this configuration. In particular, it doesn't tell us how the configuration is meant to be *used*. Let's say that `lib` is a Java library: it might expose different things, such as its API, implementation, or test fixtures. It might be necessary to change how we resolve the dependencies of `app` depending upon the task we're performing (compiling against the API of `lib`, executing the application, compiling tests, etc.). To address this problem, you'll often find companion configurations, which are meant to unambiguously declare the usage:

build.gradle.kts

```
configurations {
    // declare a configuration that is going to resolve the compile classpath of
the application
    compileClasspath {
        extendsFrom(someConfiguration)
    }

    // declare a configuration that is going to resolve the runtime classpath of
the application
    runtimeClasspath {
        extendsFrom(someConfiguration)
    }
}
```

build.gradle

```
configurations {
    // declare a configuration that is going to resolve the compile classpath of
the application
    compileClasspath.extendsFrom(someConfiguration)

    // declare a configuration that is going to resolve the runtime classpath of
the application
    runtimeClasspath.extendsFrom(someConfiguration)
}
```

At this point, we have 3 different configurations with different roles:

- `someConfiguration` declares the dependencies of my application. It is simply a collection of dependencies.

- `compileClasspath` and `runtimeClasspath` are configurations *meant to be resolved*: when resolved they should contain the compile classpath, and the runtime classpath of the application respectively.

This distinction is represented by the `canBeResolved` flag in the `Configuration` type. A configuration that *can be resolved* is a configuration for which we can compute a dependency graph, because it contains all the necessary information for resolution to happen. That is to say we're going to compute a dependency graph, resolve the components in the graph, and eventually get artifacts. A configuration which has `canBeResolved` set to `false` is not meant to be resolved. Such a configuration is there *only to declare dependencies*. The reason is that depending on the usage (compile classpath, runtime classpath), it *can* resolve to different graphs. It is an error to try to resolve a configuration which has `canBeResolved` set to `false`. To some extent, this is similar to an *abstract class* (`canBeResolved`=false) which is not supposed to be instantiated, and a concrete class extending the abstract class (`canBeResolved`=true). A resolvable configuration will extend at least one non-resolvable configuration (and may extend more than one).

On the other end, at the library project side (the *producer*), we also use configurations to represent what can be consumed. For example, the library may expose an API or a runtime, and we would attach artifacts to either one, the other, or both. Typically, to compile against `lib`, we need the API of `lib`, but we don't need its runtime dependencies. So the `lib` project will expose an `apiElements` configuration, which is aimed at consumers looking for its API. Such a configuration is consumable, but is not meant to be resolved. This is expressed via the *canBeConsumed* flag of a `Configuration`:

build.gradle.kts

```kotlin
configurations {
    // A configuration meant for consumers that need the API of this component
    create("exposedApi") {
        // This configuration is an "outgoing" configuration, it's not meant to be
resolved
        isCanBeResolved = false
        // As an outgoing configuration, explain that consumers may want to
consume it
        assert(isCanBeConsumed)
    }
    // A configuration meant for consumers that need the implementation of this
component
    create("exposedRuntime") {
        isCanBeResolved = false
        assert(isCanBeConsumed)
    }
}
```

build.gradle

```groovy
configurations {
    // A configuration meant for consumers that need the API of this component
    exposedApi {
        // This configuration is an "outgoing" configuration, it's not meant to be
resolved
        canBeResolved = false
        // As an outgoing configuration, explain that consumers may want to
consume it
        assert canBeConsumed
    }
    // A configuration meant for consumers that need the implementation of this
component
    exposedRuntime {
        canBeResolved = false
        assert canBeConsumed
    }
}
```

In short, a configuration's role is determined by the `canBeResolved` and `canBeConsumed` flag combinations:

Table 23. Configuration roles

Configuration role	can be resolved	can be consumed
Dependency Scope	false	false
Resolve for certain usage	true	false
Exposed to consumers	false	true
Legacy, don't use	true	true

For backwards compatibility, both flags have a default value of `true`, but as a plugin author, you should always determine the right values for those flags, or you might accidentally introduce resolution errors.

== Choosing the right configuration for dependencies

The choice of the configuration where you declare a dependency is important. However there is no fixed rule into which configuration a dependency must go. It mostly depends on the way the configurations are organised, which is most often a property of the applied plugin(s).

For example, in the `java` plugin, the created configuration are documented and should serve as the basis for determining where to declare a dependency, based on its role for your code.

As a recommendation, plugins should clearly document the way their configurations are linked together and should strive as much as possible to isolate their roles.

== Deprecated configurations

Configurations are intended to be used for a single role: declaring dependencies, performing resolution, or defining consumable variants. In the past, some configurations did not define which role they were intended to be used for. A deprecation warning is emitted when a configuration is used in a way that was not intended. To fix the deprecation, you will need to stop using the configuration in the deprecated role. The exact changes required depend on how the configuration is used and if there are alternative configurations that should be used instead.

== Defining custom configurations

You can define configurations yourself, so-called *custom configurations*. A custom configuration is useful for separating the scope of dependencies needed for a dedicated purpose.

Let's say you wanted to declare a dependency on the Jasper Ant task for the purpose of pre-compiling JSP files that should *not* end up in the classpath for compiling your source code. It's fairly simple to achieve that goal by introducing a custom configuration and using it in a task.

build.gradle.kts

```kotlin
val jasper by configurations.creating

repositories {
    mavenCentral()
}

dependencies {
    jasper("org.apache.tomcat.embed:tomcat-embed-jasper:9.0.2")
}

tasks.register("preCompileJsps") {
    val jasperClasspath = jasper.asPath
    val projectLayout = layout
    doLast {
        ant.withGroovyBuilder {
            "taskdef"("classname" to "org.apache.jasper.JspC",
                      "name" to "jasper",
                      "classpath" to jasperClasspath)
            "jasper"("validateXml" to false,
                     "uriroot" to
projectLayout.projectDirectory.file("src/main/webapp").asFile,
                     "outputDir" to projectLayout.buildDirectory.file("compiled-
jsps").get().asFile)
        }
    }
}
```

```
configurations {
    jasper
}

repositories {
    mavenCentral()
}

dependencies {
    jasper 'org.apache.tomcat.embed:tomcat-embed-jasper:9.0.2'
}

tasks.register('preCompileJsps') {
    def jasperClasspath = configurations.jasper.asPath
    def projectLayout = layout
    doLast {
        ant.taskdef(classname: 'org.apache.jasper.JspC',
                    name: 'jasper',
                    classpath: jasperClasspath)
        ant.jasper(validateXml: false,
                   uriroot: projectLayout.projectDirectory.file('src/main/webapp'
).asFile,
                   outputDir: projectLayout.buildDirectory.file("compiled-jsps")
.get().asFile)
    }
}
```

You can manage project configurations with a `configurations` object. Configurations have a name and can extend each other. To learn more about this API have a look at ConfigurationContainer.

== Different kinds of dependencies

=== Module dependencies

Module dependencies are the most common dependencies. They refer to a module in a repository.

```kotlin
dependencies {
    runtimeOnly(group = "org.springframework", name = "spring-core", version =
"2.5")
    runtimeOnly("org.springframework:spring-aop:2.5")
    runtimeOnly("org.hibernate:hibernate:3.0.5") {
        isTransitive = true
    }
    runtimeOnly(group = "org.hibernate", name = "hibernate", version = "3.0.5") {
        isTransitive = true
    }
}
```

```groovy
dependencies {
    runtimeOnly group: 'org.springframework', name: 'spring-core', version: '2.5'
    runtimeOnly 'org.springframework:spring-core:2.5',
            'org.springframework:spring-aop:2.5'
    runtimeOnly(
        [group: 'org.springframework', name: 'spring-core', version: '2.5'],
        [group: 'org.springframework', name: 'spring-aop', version: '2.5']
    )
    runtimeOnly('org.hibernate:hibernate:3.0.5') {
        transitive = true
    }
    runtimeOnly group: 'org.hibernate', name: 'hibernate', version: '3.0.5',
transitive: true
    runtimeOnly(group: 'org.hibernate', name: 'hibernate', version: '3.0.5') {
        transitive = true
    }
}
```

See the DependencyHandler class in the API documentation for more examples and a complete reference.

Gradle provides different notations for module dependencies. There is a string notation and a map notation. A module dependency has an API which allows further configuration. Have a look at ExternalModuleDependency to learn all about the API. This API provides properties and configuration methods. Via the string notation you can define a subset of the properties. With the map notation you can define all properties. To have access to the complete API, either with the map or with the string notation, you can assign a single dependency to a configuration together with a closure.

If you declare a module dependency, Gradle looks for a module metadata file (`.module`, `.pom` or `ivy.xml`) in the repositories. If such a module metadata file exists, it is parsed and the artifacts of this module (e.g. `hibernate-3.0.5.jar`) as well as its dependencies (e.g. `cglib`) are downloaded. If no such module metadata file exists, as of Gradle 6.0, you need to configure metadata sources definitions to look for an artifact file called `hibernate-3.0.5.jar` directly.

In Maven, a module can have one and only one artifact.

In Gradle and Ivy, a module can have multiple artifacts. Each artifact can have a different set of dependencies.

File dependencies

Projects sometimes do not rely on a binary repository product e.g. JFrog Artifactory or Sonatype Nexus for hosting and resolving external dependencies. It's common practice to host those dependencies on a shared drive or check them into version control alongside the project source code. Those dependencies are referred to as *file dependencies*, the reason being that they represent a file without any metadata (like information about transitive dependencies, the origin or its author) attached to them.
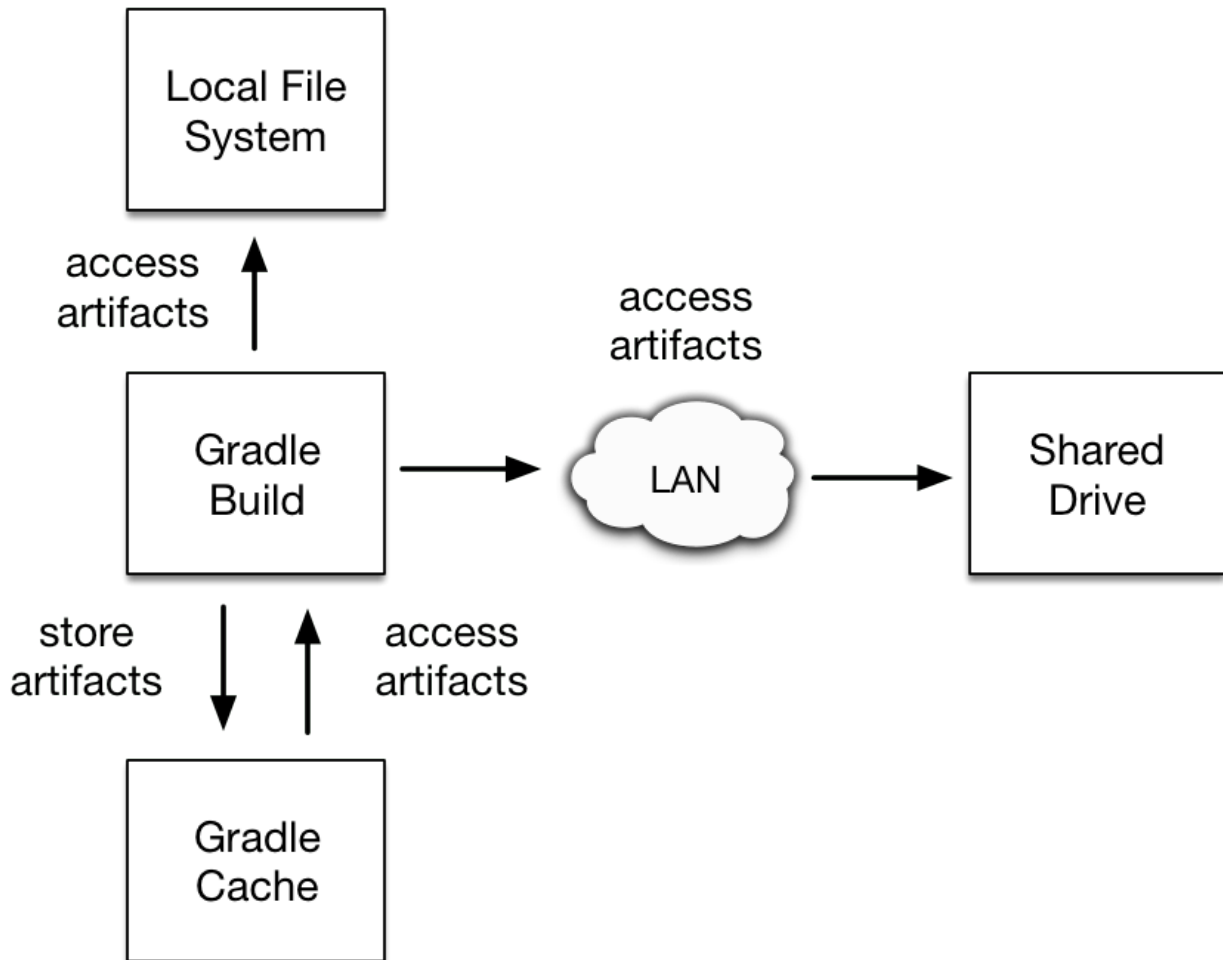
Figure 24. Resolving file dependencies from the local file system and a shared drive

The following example resolves file dependencies from the directories `ant`, `libs` and `tools`.

build.gradle.kts

```kotlin
configurations {
    create("antContrib")
    create("externalLibs")
    create("deploymentTools")
}

dependencies {
    "antContrib"(files("ant/antcontrib.jar"))
    "externalLibs"(files("libs/commons-lang.jar", "libs/log4j.jar"))
    "deploymentTools"(fileTree("tools") { include("*.exe") })
}
```

build.gradle

```groovy
configurations {
    antContrib
    externalLibs
    deploymentTools
}

dependencies {
    antContrib files('ant/antcontrib.jar')
    externalLibs files('libs/commons-lang.jar', 'libs/log4j.jar')
    deploymentTools(fileTree('tools') { include '*.exe' })
}
```

As you can see in the code example, every dependency has to define its exact location in the file system. The most prominent methods for creating a file reference are Project.files(java.lang.Object...), ProjectLayout.files(java.lang.Object...) and Project.fileTree(java.lang.Object) Alternatively, you can also define the source directory of one or many file dependencies in the form of a flat directory repository.

The order of the files in a `FileTree` is not stable, even on a single computer. It means that dependency configuration seeded with such a construct may produce a resolution result which has a different ordering, possibly impacting the cacheability of tasks using the result as an input. Using the simpler `files` instead is recommended where possible.

File dependencies allow you to directly add a set of files to a configuration, without first adding them to a repository. This can be useful if you cannot, or do not want to, place certain files in a repository. Or if you do not want to use any repositories at all for storing your dependencies.

To add some files as a dependency for a configuration, you simply pass a file collection as a dependency:

build.gradle.kts

```
dependencies {
    runtimeOnly(files("libs/a.jar", "libs/b.jar"))
    runtimeOnly(fileTree("libs") { include("*.jar") })
}
```

build.gradle

```
dependencies {
    runtimeOnly files('libs/a.jar', 'libs/b.jar')
    runtimeOnly fileTree('libs') { include '*.jar' }
}
```

File dependencies are not included in the published dependency descriptor for your project. However, file dependencies are included in transitive project dependencies within the same build. This means they cannot be used outside the current build, but they can be used within the same build.

You can declare which tasks produce the files for a file dependency. You might do this when, for example, the files are generated by the build.

build.gradle.kts

```kotlin
dependencies {
    implementation(files(layout.buildDirectory.dir("classes")) {
        builtBy("compile")
    })
}

tasks.register("compile") {
    doLast {
        println("compiling classes")
    }
}

tasks.register("list") {
    val compileClasspath: FileCollection = configurations["compileClasspath"]
    dependsOn(compileClasspath)
    doLast {
        println("classpath = ${compileClasspath.map { file: File -> file.name }}")
    }
}
```

build.gradle

```groovy
dependencies {
    implementation files(layout.buildDirectory.dir('classes')) {
        builtBy 'compile'
    }
}

tasks.register('compile') {
    doLast {
        println 'compiling classes'
    }
}

tasks.register('list') {
    FileCollection compileClasspath = configurations.compileClasspath
    dependsOn compileClasspath
    doLast {
        println "classpath = ${compileClasspath.collect { File file -> file.name
}}"
    }
}
```

```
$ gradle -q list
compiling classes
classpath = [classes]
```

==== Versioning of file dependencies

It is recommended to clearly express the intention and a concrete version for file dependencies. File dependencies are not considered by Gradle's version conflict resolution. Therefore, it is extremely important to assign a version to the file name to indicate the distinct set of changes shipped with it. For example `commons-beanutils-1.3.jar` lets you track the changes of the library by the release notes.

As a result, the dependencies of the project are easier to maintain and organize. It is much easier to uncover potential API incompatibilities by the assigned version.

=== Project dependencies

Software projects often break up software components into modules to improve maintainability and prevent strong coupling. Modules can define dependencies between each other to reuse code within the same project.
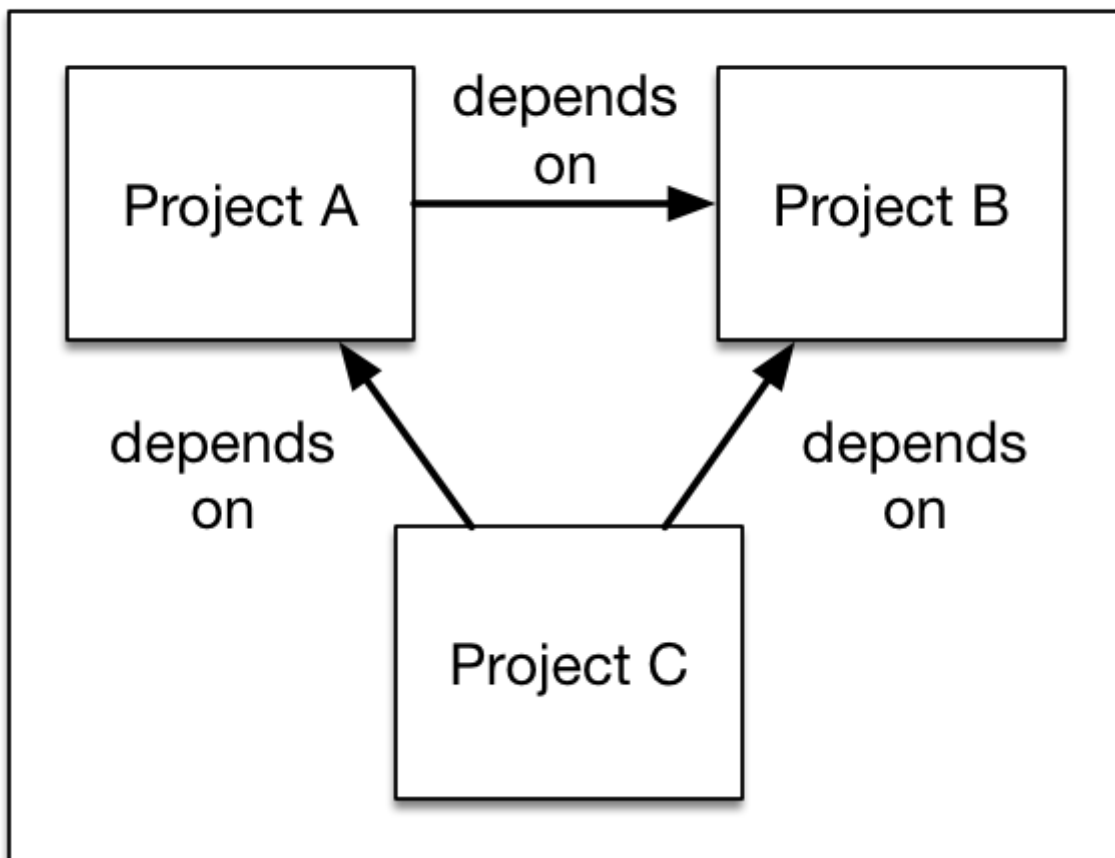
Figure 25. Dependencies between projects

Gradle can model dependencies between modules. Those dependencies are called *project dependencies* because each module is represented by a Gradle project.

build.gradle.kts

```
dependencies {
    implementation(project(":shared"))
}
```

build.gradle

```
dependencies {
    implementation project(':shared')
}
```

At runtime, the build automatically ensures that project dependencies are built in the correct order and added to the classpath for compilation. The chapter Authoring Multi-Project Builds discusses how to set up and configure multi-project builds in more detail.

For more information see the API documentation for ProjectDependency.

The following example declares the dependencies on the `utils` and `api` project from the `web-service` project. The method Project.project(java.lang.String) creates a reference to a specific subproject by path.

web-service/build.gradle.kts

```
dependencies {
    implementation(project(":utils"))
    implementation(project(":api"))
}
```

web-service/build.gradle

```
dependencies {
    implementation project(':utils')
    implementation project(':api')
}
```

==== Type-safe project dependencies

Type-safe project accessors are an incubating feature which must be enabled explicitly. Implementation may change at any time.

To add support for type-safe project accessors, add this to your `settings.gradle(.kts)` file:

```
enableFeaturePreview("TYPESAFE_PROJECT_ACCESSORS")
```

One issue with the `project(":some:path")` notation is that you have to remember the path to every project you want to depend on. In addition, changing a project path requires you to change all places where the project dependency is used, but it is easy to miss one or more occurrences (because you have to rely on search and replace).

Since Gradle 7, Gradle offers an experimental type-safe API for project dependencies. The same example as above can now be rewritten as:

web-service/build.gradle.kts

```
dependencies {
    implementation(projects.utils)
    implementation(projects.api)
}
```

web-service/build.gradle

```
dependencies {
    implementation projects.utils
    implementation projects.api
}
```

The type-safe API has the advantage of providing IDE completion so you don't need to figure out the actual names of the projects.

If you add or remove a project that uses the Kotlin DSL, build script compilation fails if you forget to update a dependency.

The project accessors are mapped from the *project path*. For example, if a project path is `:commons:utils:some:lib` then the project accessor will be `projects.commons.utils.some.lib` (which is the short-hand notation for `projects.getCommons().getUtils().getSome().getLib()`).

A project name with kebab case (`some-lib`) or snake case (`some_lib`) will be converted to camel case in accessors: `projects.someLib`.

=== Local forks of module dependencies

A module dependency can be substituted by a dependency to a local fork of the sources of that module, if the module itself is built with Gradle. This can be done by utilising composite builds. This allows you, for example, to fix an issue in a library you use in an application by using, and building, a locally patched version instead of the published binary version. The details of this are described in the section on composite builds.

=== Gradle distribution-specific dependencies

==== Gradle API dependency

You can declare a dependency on the API of the current version of Gradle by using the DependencyHandler.gradleApi() method. This is useful when you are developing custom Gradle tasks or plugins.

build.gradle.kts

```
dependencies {
    implementation(gradleApi())
}
```

build.gradle

```
dependencies {
    implementation gradleApi()
}
```

==== Gradle TestKit dependency

You can declare a dependency on the TestKit API of the current version of Gradle by using the DependencyHandler.gradleTestKit() method. This is useful for writing and executing functional tests for Gradle plugins and build scripts.

build.gradle.kts

```
dependencies {
    testImplementation(gradleTestKit())
}
```

build.gradle

```
dependencies {
    testImplementation gradleTestKit()
}
```

The TestKit chapter explains the use of TestKit by example.

==== Local Groovy dependency

You can declare a dependency on the Groovy that is distributed with Gradle by using the DependencyHandler.localGroovy() method. This is useful when you are developing custom Gradle tasks or plugins in Groovy.

build.gradle.kts

```
dependencies {
    implementation(localGroovy())
}
```

build.gradle

```
dependencies {
    implementation localGroovy()
}
```

== Documenting dependencies

When you declare a dependency or a dependency constraint, you can provide a custom reason for the declaration. This makes the dependency declarations in your build script and the dependency insight report easier to interpret.

build.gradle.kts

```
plugins {
    `java-library`
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("org.ow2.asm:asm:7.1") {
        because("we require a JDK 9 compatible bytecode generator")
    }
}
```

build.gradle

```
plugins {
    id 'java-library'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation('org.ow2.asm:asm:7.1') {
        because 'we require a JDK 9 compatible bytecode generator'
    }
}
```

=== Example: Using the dependency insight report with custom reasons

Output of `gradle -q dependencyInsight --dependency asm`

```
> gradle -q dependencyInsight --dependency asm
org.ow2.asm:asm:7.1
  Variant compile:
    | Attribute Name                | Provided | Requested    |
    |-------------------------------|----------|--------------|
    | org.gradle.status             | release  |              |
    | org.gradle.category           | library  | library      |
    | org.gradle.libraryelements    | jar      | classes      |
    | org.gradle.usage              | java-api | java-api     |
    | org.gradle.dependency.bundling |         | external     |
    | org.gradle.jvm.environment    |          | standard-jvm |
    | org.gradle.jvm.version        |          | 11           |
  Selection reasons:
     - Was requested: we require a JDK 9 compatible bytecode generator

org.ow2.asm:asm:7.1
\--- compileClasspath

A web-based, searchable dependency report is available by adding the --scan
option.
```

== Resolving specific artifacts from a module dependency

Whenever Gradle tries to resolve a module from a Maven or Ivy repository, it looks for a metadata file and the default artifact file, a JAR. The build fails if none of these artifact files can be resolved. Under certain conditions, you might want to tweak the way Gradle resolves artifacts for a dependency.

- The dependency only provides a non-standard artifact without any metadata e.g. a ZIP file.

- The module metadata declares more than one artifact e.g. as part of an Ivy dependency descriptor.

- You only want to download a specific artifact without any of the transitive dependencies declared in the metadata.

Gradle is a polyglot build tool and not limited to just resolving Java libraries. Let's assume you wanted to build a web application using JavaScript as the client technology. Most projects check in external JavaScript libraries into version control. An external JavaScript library is no different than a reusable Java library so why not download it from a repository instead?

Google Hosted Libraries is a distribution platform for popular, open-source JavaScript libraries. With the help of the artifact-only notation you can download a JavaScript library file e.g. JQuery. The `@` character separates the dependency's coordinates from the artifact's file extension.

build.gradle.kts

```kotlin
repositories {
    ivy {
        url = uri("https://ajax.googleapis.com/ajax/libs")
        patternLayout {
            artifact("[organization]/[revision]/[module].[ext]")
        }
        metadataSources {
            artifact()
        }
    }
}

configurations {
    create("js")
}

dependencies {
    "js"("jquery:jquery:3.2.1@js")
}
```

build.gradle

```groovy
repositories {
    ivy {
        url 'https://ajax.googleapis.com/ajax/libs'
        patternLayout {
            artifact '[organization]/[revision]/[module].[ext]'
        }
        metadataSources {
            artifact()
        }
    }
}

configurations {
    js
}

dependencies {
    js 'jquery:jquery:3.2.1@js'
}
```

Some modules ship different "flavors" of the same artifact or they publish multiple artifacts that belong to a specific module version but have a different purpose. It's common for a Java library to publish the artifact with the compiled class files, another one with just the source code in it and a third one containing the Javadocs.

In JavaScript, a library may exist as uncompressed or minified artifact. In Gradle, a specific artifact identifier is called *classifier*, a term generally used in Maven and Ivy dependency management.

Let's say we wanted to download the minified artifact of the JQuery library instead of the uncompressed file. You can provide the classifier `min` as part of the dependency declaration.

build.gradle.kts

```
repositories {
    ivy {
        url = uri("https://ajax.googleapis.com/ajax/libs")
        patternLayout {
            artifact("[organization]/[revision]/[module](.[classifier]).[ext]")
        }
        metadataSources {
            artifact()
        }
    }
}

configurations {
    create("js")
}

dependencies {
    "js"("jquery:jquery:3.2.1:min@js")
}
```

build.gradle

```
repositories {
    ivy {
        url 'https://ajax.googleapis.com/ajax/libs'
        patternLayout {
            artifact '[organization]/[revision]/[module](.[classifier]).[ext]'
        }
        metadataSources {
            artifact()
        }
    }
}

configurations {
    js
}

dependencies {
    js 'jquery:jquery:3.2.1:min@js'
}
```

Supported Metadata formats

External module dependencies require module metadata (so that, typically, Gradle can figure out the transitive dependencies of a module). To do so, Gradle supports different metadata formats.

You can also tweak which format will be looked up in the repository definition.

Gradle Module Metadata files

Gradle Module Metadata has been specifically designed to support all features of Gradle's dependency management model and is hence the preferred format. You can find its specification here.

POM files

Gradle natively supports Maven POM files. It's worth noting that by default Gradle will first look for a POM file, but if this file contains a special marker, Gradle will use Gradle Module Metadata instead.

Ivy files

Similarly, Gradle supports Apache Ivy metadata files. Again, Gradle will first look for an `ivy.xml` file, but if this file contains a special marker, Gradle will use Gradle Module Metadata instead.

Understanding the difference between libraries and applications

Producers vs consumers

A key concept in dependency management with Gradle is the difference between consumers and producers.

When you *build* a library, you are effectively on the *producer* side: you are producing *artifacts* which are going to be *consumed* by someone else, the *consumer*.

A lot of problems with traditional build systems is that they don't make the difference between a producer and a consumer.

A *consumer* needs to be understood in the large sense:

- a project that depends on another project is a *consumer*
- a *task* that depends on an artifact is a finer grained consumer

In dependency management, a lot of the decisions we make depend on the type of project we are building, that is to say, what kind of *consumer* we are.

Producer variants

A producer may want to generate different artifacts for different kinds of consumers: for the same source code, different *binaries* are produced. Or, a project may produce artifacts which

are for consumption by other projects (same repository) but not for external use.

A typical example in the Java world is the Guava library which is published in different versions: one for Java projects, and one for Android projects.

However, it's the consumer responsibility to tell what version to use, and it's the dependency management engine responsibility to ensure *consistency of the graph* (for example making sure that you don't end up with both Java and Android versions of Guava on your classpath). This is where the [variant model](#) of Gradle comes into play.

In Gradle, *producer variants* are exposed via [consumable configurations](#).

== Strong encapsulation

In order for a producer to compile a library, it needs all its *implementation dependencies* on the compile classpath. There are dependencies which are only required *as an implementation detail* of the library and there are libraries which are effectively part of the API.

However, a library *depending* on this produced library only needs to "see" the public API of your library and therefore the dependencies of this API. It's a subset of the compile classpath of the producer: this is strong encapsulation of dependencies.

The consequence is that a dependency which is assigned to the `implementation` configuration of a library *does not end up on the compile classpath of the consumer*. On the other hand, a dependency which is assigned to the `api` configuration of a library *would end up on the compile classpath of the consumer*. At *runtime*, however, all dependencies are required. Gradle makes the difference between different kinds of consumer even within a single project: the Java compile task, for example, is a different consumer than the Java exec task.

More details on the segregation of API and runtime dependencies in the Java world [can be found here](#).

== Being respectful of consumers

Whenever, as a developer, you decide to include a dependency, you must understand that there are *consequences for your consumers*. For example, if you add a dependency to your project, it becomes a *transitive dependency* of your consumers, and therefore may participate in conflict resolution if the consumer needs a different version.

A lot of the problems Gradle handles are about fixing the mismatch between the expectations of a consumer and a producer.

However, some projects are easier than others:

- if you are at the end of the consumption chain, that is to say you build an *application*, then there are effectively *no consumer* of your project (apart from final customers): adding [exclusions](#) will have no other consequence than fixing your problem.
- however if you are a library, adding [exclusions](#) may prevent consumers from working properly, because they would exercise a path of the code that you don't

Always keep in mind that the solution you choose to fix a problem can "leak" to your

consumers. This documentation aims at guiding you to find the right solution to the right problem, and more importantly, make decisions which help the resolution engine to take the right decisions in case of conflicts.

View and Debug Dependencies

Gradle provides tooling to navigate dependency graphs and mitigate dependency hell. Users can render the full graph of dependencies as well as identify the selection reason and origin for a dependency. Dependencies can originate through build script declared dependencies or transitive dependencies. You can visualize dependencies with:

- the built-in Gradle CLI `dependencies` task
- the built-in Gradle CLI `dependencyInsight` task
- build scans

List Project Dependencies

Gradle provides the built-in `dependencies` task to render a dependency tree from the command line. By default, the dependency tree renders dependencies for all configurations within a single project. The dependency tree indicates the selected version of each dependency. It also displays information about dependency conflict resolution.

The `dependencies` task can be especially helpful for issues related to transitive dependencies. Your build file lists direct dependencies, but the `dependencies` task can help you understand which transitive dependencies resolve during your build.

NOTE	Graph of dependencies declared in the `buildscript classpath` configuration can be rendered using task `buildEnvironment`.

Output Annotations

The `dependencies` task marks dependency trees with the following annotations:

- `(*)`: Indicates repeated occurrences of a transitive dependency subtree. Gradle expands transitive dependency subtrees only once per project; repeat occurrences only display the root of the subtree, followed by this annotation.
- `(c)`: This element is a dependency constraint, not a dependency. Look for the matching dependency elsewhere in the tree.
- `(n)`: A dependency or dependency configuration that cannot be resolved.

Specify a Dependency Configuration

To focus on the information about one dependency configuration, provide the optional parameter `--configuration`. Just like project and task names, Gradle accepts abbreviated names to select a dependency configuration. For example, you can specify `tRC` instead of `testRuntimeClasspath` if the pattern matches to a single dependency configuration. Both of the following examples show dependencies in the `testRuntimeClasspath` dependency configuration of a Java project:

```
> gradle -q dependencies --configuration testRuntimeClasspath
```

```
> gradle -q dependencies --configuration tRC
```

To see a list of all the configurations available in a project, including those added by any plugins, you can run a `resolvableConfigurations` report.

For more info, see that plugin's documentation (for instance, the Java Plugin is documented [here](#)).

=== Example

Consider a project that uses the [JGit library](#) to execute Source Control Management (SCM) operations for a release process. You can declare dependencies for external tooling with the help of a [custom dependency configuration](#). This avoids polluting other contexts, such as the compilation classpath for your production source code.

The following example declares a custom dependency configuration named "scm" that contains the JGit dependency:

build.gradle.kts

```
repositories {
    mavenCentral()
}

configurations {
    create("scm")
}

dependencies {
    "scm"("org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r")
}
```

build.gradle

```
repositories {
    mavenCentral()
}

configurations {
    scm
}

dependencies {
    scm 'org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r'
}
```

Use the following command to view a dependency tree for the `scm` dependency configuration:

```
> gradle -q dependencies --configuration scm


------------------------------------------------------------
Root project 'dependencies-report'
------------------------------------------------------------

scm
\--- org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r
     +--- com.jcraft:jsch:0.1.54
     +--- com.googlecode.javaewah:JavaEWAH:1.1.6
     +--- org.apache.httpcomponents:httpclient:4.3.6
     |    +--- org.apache.httpcomponents:httpcore:4.3.3
     |    +--- commons-logging:commons-logging:1.1.3
     |    \--- commons-codec:commons-codec:1.6
     \--- org.slf4j:slf4j-api:1.7.2

A web-based, searchable dependency report is available by adding the --scan
option.
```

== Identify the Dependency Version Selected

A project may request two different versions of the same dependency either directly or transitively. Gradle applies version conflict resolution to ensure that only one version of the dependency exists in the dependency graph. The following example introduces a conflict with `commons-codec:commons-codec`, added both as a direct dependency and a transitive dependency of JGit:

build.gradle.kts

```kotlin
repositories {
    mavenCentral()
}

configurations {
    create("scm")
}

dependencies {
    "scm"("org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r")
    "scm"("commons-codec:commons-codec:1.7")
}
```

build.gradle

```groovy
repositories {
    mavenCentral()
}

configurations {
    scm
}

dependencies {
    scm 'org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r'
    scm 'commons-codec:commons-codec:1.7'
}
```

The dependency tree in a build scan shows information about conflicts. Click on a dependency and select the "Required By" tab to see the selection reason and origin of the dependency.
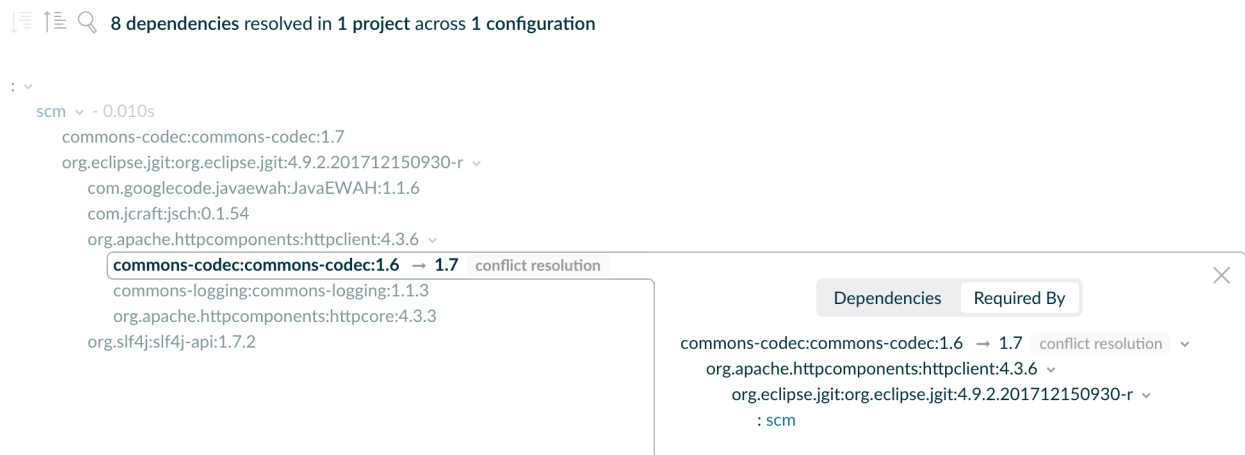
=== Dependency Insights

Gradle provides the built-in `dependencyInsight` task to render a *dependency insight report* from the command line. Dependency insights provide information about a single dependency within a single configuration. Given a dependency, you can identify the selection reason and origin.

`dependencyInsight` accepts the following parameters:

`--dependency <dependency>` **(mandatory)**

   The dependency to investigate. You can supply a complete `group:name`, or part of it. If multiple dependencies match, Gradle generates a report covering all matching dependencies.

`--configuration <name>` **(mandatory)**

   The dependency configuration which resolves the given dependency. This parameter is optional for projects that use the Java plugin, since the plugin provides a default value of `compileClasspath`.

`--single-path` **(optional)**

   Render only a single path to the dependency.

The following code snippet demonstrates how to run a dependency insight report for all paths to a dependency named "commons-codec" within the "scm" configuration:

```
> gradle -q dependencyInsight --dependency commons-codec --configuration scm
commons-codec:commons-codec:1.7
  Variant default:
    | Attribute Name    | Provided | Requested |
    |-------------------|----------|-----------|
    | org.gradle.status | release  |           |
  Selection reasons:
    - By conflict resolution: between versions 1.7 and 1.6

commons-codec:commons-codec:1.7
\--- scm

commons-codec:commons-codec:1.6 -> 1.7
\--- org.apache.httpcomponents:httpclient:4.3.6
     \--- org.eclipse.jgit:org.eclipse.jgit:4.9.2.201712150930-r
          \--- scm

A web-based, searchable dependency report is available by adding the --scan
option.
```

For more information about configurations, see the dependency configuration documentation.

==== Selection Reasons

The "Selection reasons" section of the dependency insight report lists the reasons why a dependency was selected. Have a look at the table below to understand the meaning of the different terms used:

Table 24. Terminology

Reason	Meaning
(Absent)	No reason other than a reference, direct or transitive, was present.
Was requested : <text>	The dependency appears in the graph, and the inclusion came with a because text.
Was requested : didn't match versions <versions>	The dependency appears with a dynamic version which did not include the listed versions. May be followed by a because text.
Was requested : reject version <versions>	The dependency appears with a rich version containing one or more reject. May be followed by a because text.
By conflict resolution : between versions <version>	The dependency appeared multiple times, with different version requests. This resulted in conflict resolution to select the most appropriate version.
By constraint	A dependency constraint participated in the version selection. May be followed by a because text.

Reason	Meaning
By ancestor	There is a rich version with a `strictly` which enforces the version of this dependency.
Selected by rule	A dependency resolution rule overruled the default selection process. May be followed by a `because` text.
Rejection : <version> by rule because <text>	A `ComponentSelection.reject` rejected the given version of the dependency.
Rejection: version <version>: <attributes information>	The dependency has a dynamic version and some versions did not match the requested attributes.
Forced	The build enforces the version of the dependency through an enforced platform or resolution strategy.

If multiple selection reasons exist, the insight report lists all of them.

== Troubleshooting

=== Version Conflicts

If the selected version does not match your expectation, Gradle offers a series of tools to help you control transitive dependencies.

=== Variant Selection Errors

Sometimes a selection error happens at the variant selection level. Have a look at the dedicated section to understand these errors and how to resolve them.

=== Unsafe Configuration Resolution Errors

Resolving a configuration can have side effects on Gradle's project model. As a result, Gradle must manage access to each project's configurations. There are a number of ways a configuration might be resolved unsafely. For example:

- A task from one project directly resolves a configuration in another project in the task's action.
- A task specifies a configuration from another project as an input file collection.
- A build script for one project resolves a configuration in another project during evaluation.
- Project configurations are resolved in the settings file.

Gradle produces a deprecation warning for each unsafe access. Unsafe access can cause indeterminate errors. You should fix unsafe access warnings in your build.

In most cases, you can resolve unsafe accesses by creating a cross-project dependency on the other project. See the documentation for sharing outputs between projects for more information.

If you find a use case that can't be resolved using these techniques, please let us know by filing a GitHub Issue.

Understanding dependency resolution

This chapter covers the way dependency resolution works *inside* Gradle. After covering how you can declare repositories and dependencies, it makes sense to explain how these declarations come together during dependency resolution.

Dependency resolution is a process that consists of two phases, which are repeated until the dependency graph is complete:

- When a new dependency is added to the graph, perform conflict resolution to determine which version should be added to the graph.

- When a specific dependency, that is a module with a version, is identified as part of the graph, retrieve its metadata so that its dependencies can be added in turn.

The following section will describe what Gradle identifies as conflicts and how it can resolve them automatically. After that, the retrieval of metadata will be covered, explaining how Gradle can follow dependency links.

How Gradle handles conflicts?

When doing dependency resolution, Gradle handles two types of conflicts:

Version conflicts

That is when two or more dependencies require a given dependency but with different versions.

Implementation conflicts

That is when the dependency graph contains multiple modules that provide the same implementation, or capability in Gradle terminology.

The following sections will explain in detail how Gradle attempts to resolve these conflicts.

The dependency resolution process is highly customizable to meet enterprise requirements. For more information, see the chapter on Controlling transitive dependencies.

Version conflict resolution

A version conflict occurs when two components:

- Depend on the same module, let's say `com.google.guava:guava`

- But on different versions, let's say `20.0` and `25.1-android`
  - Our project itself depends on `com.google.guava:guava:20.0`
  - Our project also depends on `com.google.inject:guice:4.2.2` which itself depends on `com.google.guava:guava:25.1-android`

Resolution strategy

Given the conflict above, there exist multiple ways to handle it, either by selecting a version or failing the resolution. Different tools that handle dependency management have different ways of handling these type of conflicts.

Apache Maven uses a nearest first strategy.

Maven will take the *shortest* path to a dependency and use that version. In case there are multiple paths of the same length, the first one wins.

This means that in the example above, the version of `guava` will be `20.0` because the direct dependency is *closer* than the `guice` dependency.

The main drawback of this method is that it is ordering dependent. Keeping order in a very large graph can be a challenge. For example, what if the new version of a dependency ends up having its own dependency declarations in a different order than the previous version?

With Maven, this could have unwanted impact on resolved versions.

Apache Ivy is a very flexible dependency management tool. It offers the possibility to customize dependency resolution, including conflict resolution.

This flexibility comes with the price of making it hard to reason about.

Gradle will consider *all* requested versions, wherever they appear in the dependency graph. Out of these versions, it will select the *highest* one. More information on version ordering here.

As you have seen, Gradle supports a concept of rich version declaration, so what is the highest version depends on the way versions were declared:

- If no ranges are involved, then the highest version that is not rejected will be selected.
  - If a version declared as `strictly` is lower than that version, selection will fail.
- If ranges are involved:
  - If there is a non range version that falls within the specified ranges or is higher than their upper bound, it will be selected.
  - If there are only ranges, the selection will depend on the intersection of ranges:
    - If all the ranges intersect, then the highest *existing* version of the intersection will be selected.
    - If there is no clear intersection between all the ranges, the highest *existing* version will be selected from the highest range. If there is no version available for the highest range, the resolution will fail.
  - If a version declared as `strictly` is lower than that version, selection will fail.

Note that in the case where ranges come into play, Gradle requires metadata to determine which versions do exist for the considered range. This causes an intermediate lookup for metadata, as described in [sec:how-gradle-downloads-deps].

=== Qualifiers There is a caveat to comparing versions when it comes to selecting the *highest* one. All the rules of version ordering still apply, but the conflict resolver has a bias towards versions without qualifiers.

The "qualifier" of a version, if it exists, is the tail end of the version string, starting at the first non-dot separator found in it. The other (first) part of the version string is called the "base form" of the version. Here are some examples to illustrate:

Original version	Base version	Qualifier
1.2.3	1.2.3	<none>
1.2-3	1.2	3
1_alpha	1	alpha
abc	abc	<none>
1.2b3	1.2	b3
abc.1+3	abc.1	3
b1-2-3.3	b	1-2-3.3

As you can see separators are any of the `.`, `-`, `_`, `+` characters, plus the empty string when a numeric and a non-numeric part of the version are next to each-other.

When resolving the conflict between competing versions, the following logic applies:

- first the versions with the highest base version are selected, the rest are discarded
- if there are still multiple competing versions left, then one is picked with a preference for not having a qualifier or having release status.

Implementation conflict resolution

Gradle uses variants and capabilities to identify what a module *provides*.

This is a unique feature that deserves its own chapter to understand what it means and enables.

A conflict occurs the moment two modules either:

- Attempt to select incompatible variants,
- Declare the same capability

Learn more about handling these type of conflicts in Selecting between candidates.

How Gradle retrieves dependency metadata?

Gradle requires metadata about the modules included in your dependency graph. That information is required for two main points:

- Determine the existing versions of a module when the declared version is dynamic.
- Determine the dependencies of the module for a given version.

Discovering versions

Faced with a dynamic version, Gradle needs to identify the concrete matching versions:

- Each repository is inspected, Gradle does not stop on the first one returning some metadata. When multiple are defined, they are inspected *in the order they were added.*
- For Maven repositories, Gradle will use the `maven-metadata.xml` which provides information about the available versions.
- For Ivy repositories, Gradle will resort to directory listing.

This process results in a list of candidate versions that are then matched to the dynamic version expressed. At this point, version conflict resolution is resumed.

Note that Gradle caches the version information, more information can be found in the section Controlling dynamic version caching.

Obtaining module metadata

Given a required dependency, with a version, Gradle attempts to resolve the dependency by searching for the module the dependency points at.

- Each repository is inspected in order.

- Depending on the type of repository, Gradle looks for metadata files describing the module (`.module`, `.pom` or `ivy.xml` file) or directly for artifact files.
- Modules that have a module metadata file (`.module`, `.pom` or `ivy.xml` file) are preferred over modules that have an artifact file only.
- Once a repository returns a *metadata* result, following repositories are ignored.

- Metadata for the dependency is retrieved and parsed, if found

  - If the module metadata is a POM file that has a parent POM declared, Gradle will recursively attempt to resolve each of the parent modules for the POM.

- All of the artifacts for the module are then requested from the *same repository* that was chosen in the process above.

- All of that data, including the repository source and potential misses are then stored in the [sec:dependency_cache].

The penultimate point above is what can make the integration with Maven Local problematic. As it is a cache for Maven, it will sometimes miss some artifacts of a given module. If Gradle is sourcing such a module from Maven Local, it will consider the missing artifacts to be missing altogether.

=== Repository disabling

When Gradle fails to retrieve information from a repository, it will disable it for the duration of the build and fail all dependency resolution.

That last point is important for reproducibility. If the build was allowed to continue, ignoring the faulty repository, subsequent builds could have a different result once the repository is back online.

==== HTTP Retries

Gradle will make several attempts to connect to a given repository before disabling it. If connection fails, Gradle will retry on certain errors which have a chance of being transient, increasing the amount of time waiting between each retry.

Blacklisting happens when the repository cannot be contacted, either because of a permanent error or because the maximum retries was reached.

== The Dependency Cache

Gradle contains a highly sophisticated dependency caching mechanism, which seeks to minimise the number of remote requests made in dependency resolution, while striving to guarantee that the results of dependency resolution are correct and reproducible.

The Gradle dependency cache consists of two storage types located under `$GRADLE_USER_HOME/caches`:

- A file-based store of downloaded artifacts, including binaries like jars as well as raw downloaded meta-data like POM files and Ivy files. The storage path for a downloaded artifact includes the SHA1 checksum, meaning that 2 artifacts with the same name but different content can easily be cached.
- A binary store of resolved module metadata, including the results of resolving dynamic versions, module descriptors, and artifacts.

The Gradle cache does not allow the local cache to hide problems and create other mysterious and difficult to debug behavior. Gradle enables reliable and reproducible enterprise builds with a focus on bandwidth and storage efficiency.

=== Separate metadata cache

Gradle keeps a record of various aspects of dependency resolution in binary format in the metadata cache. The information stored in the metadata cache includes:

- The result of resolving a dynamic version (e.g. `1.+`) to a concrete version (e.g. `1.2`).
- The resolved module metadata for a particular module, including module artifacts and module dependencies.
- The resolved artifact metadata for a particular artifact, including a pointer to the downloaded artifact file.

- The *absence* of a particular module or artifact in a particular repository, eliminating repeated attempts to access a resource that does not exist.

Every entry in the metadata cache includes a record of the repository that provided the information as well as a timestamp that can be used for cache expiry.

Repository caches are independent

As described above, for each repository there is a separate metadata cache. A repository is identified by its URL, type and layout. If a module or artifact has not been previously resolved from *this repository,* Gradle will attempt to resolve the module against the repository. This will always involve a remote lookup on the repository, however in many cases no download will be required.

Dependency resolution will fail if the required artifacts are not available in any repository specified by the build, even if the local cache has a copy of this artifact which was retrieved from a different repository. Repository independence allows builds to be isolated from each other in an advanced way that no build tool has done before. This is a key feature to create builds that are reliable and reproducible in any environment.

Artifact reuse

Before downloading an artifact, Gradle tries to determine the checksum of the required artifact by downloading the sha file associated with that artifact. If the checksum can be retrieved, an artifact is not downloaded if an artifact already exists with the same id and checksum. If the checksum cannot be retrieved from the remote server, the artifact will be downloaded (and ignored if it matches an existing artifact).

As well as considering artifacts downloaded from a different repository, Gradle will also attempt to reuse artifacts found in the local Maven Repository. If a candidate artifact has been downloaded by Maven, Gradle will use this artifact if it can be verified to match the checksum declared by the remote server.

Checksum based storage

It is possible for different repositories to provide a different binary artifact in response to the same artifact identifier. This is often the case with Maven SNAPSHOT artifacts, but can also be true for any artifact which is republished without changing its identifier. By caching artifacts based on their SHA1 checksum, Gradle is able to maintain multiple versions of the same artifact. This means that when resolving against one repository Gradle will never overwrite the cached artifact file from a different repository. This is done without requiring a separate artifact file store per repository.

Cache Locking

The Gradle dependency cache uses file-based locking to ensure that it can safely be used by multiple Gradle processes concurrently. The lock is held whenever the binary metadata store is being read or written, but is released for slow operations such as downloading remote artifacts.

This concurrent access is only supported if the different Gradle processes can communicate together. This is usually *not the case* for containerized builds.

==== Cache Cleanup

Gradle keeps track of which artifacts in the dependency cache are accessed. Using this information, the cache is periodically (at most every 24 hours) scanned for artifacts that have not been used for more than 30 days. Obsolete artifacts are then deleted to ensure the cache does not grow indefinitely.

== Dealing with ephemeral builds

It's a common practice to run builds in ephemeral containers. A container is typically spawned to only execute a single build before it is destroyed. This can become a practical problem when a build depends on a lot of dependencies which each container has to re-download. To help with this scenario, Gradle provides a couple of options:

- copying the dependency cache into each container

- sharing a read-only dependency cache between multiple containers

=== Copying and reusing the cache

The dependency cache, both the file and metadata parts, are fully encoded using relative paths. This means that it is perfectly possible to copy a cache around and see Gradle benefit from it.

The path that can be copied is `$GRADLE_USER_HOME/caches/modules-<version>`. The only constraint is placing it using the same structure at the destination, where the value of `GRADLE_USER_HOME` can be different.

Do not copy the `*.lock` or `gc.properties` files if they exist.

Note that creating the cache and consuming it should be done using compatible Gradle version, as shown in the table below. Otherwise, the build might still require some interactions with remote repositories to complete missing information, which might be available in a different version. If multiple incompatible Gradle versions are in play, all should be used when seeding the cache.

Table 25. Dependency cache compatibility

Module cache version	File cache version	Metadata cache version	Gradle version(s)
`modules-2`	`files-2.1`	`metadata-2.95`	Gradle 6.1 to Gradle 6.3
`modules-2`	`files-2.1`	`metadata-2.96`	Gradle 6.4 to Gradle 6.7
`modules-2`	`files-2.1`	`metadata-2.97`	Gradle 6.8 to Gradle 7.4
`modules-2`	`files-2.1`	`metadata-2.99`	Gradle 7.5 to Gradle 7.6.1
`modules-2`	`files-2.1`	`metadata-2.101`	Gradle 7.6.2
`modules-2`	`files-2.1`	`metadata-2.100`	Gradle 8.0

Module cache version	File cache version	Metadata cache version	Gradle version(s)
modules-2	files-2.1	metadata-2.105	Gradle 8.1
modules-2	files-2.1	metadata-2.106	Gradle 8.2 and above

=== Sharing the dependency cache with other Gradle instances

Instead of copying the dependency cache into each container, it's possible to mount a shared, read-only directory that will act as a dependency cache for all containers. This cache, unlike the classical dependency cache, is accessed without locking, making it possible for multiple builds to read from the cache concurrently. It's important that the read-only cache is not written to when other builds may be reading from it.

When using the shared read-only cache, Gradle looks for dependencies (artifacts or metadata) in both the writable cache in the local Gradle User Home directory and the shared read-only cache. If a dependency is present in the read-only cache, it will not be downloaded. If a dependency is missing from the read-only cache, it will be downloaded and added to the writable cache. In practice, this means that the writable cache will only contain dependencies that are unavailable in the read-only cache.

The read-only cache should be sourced from a Gradle dependency cache that already contains some of the required dependencies. The cache can be incomplete; however, an empty shared cache will only add overhead.

NOTE   The shared read-only dependency cache is an incubating feature.

The first step in using a shared dependency cache is to create one by copying of an existing *local* cache. For this you need to follow the instructions above.

Then set the GRADLE_RO_DEP_CACHE environment variable to point to the directory containing the cache:

```
$GRADLE_RO_DEP_CACHE
    |-- modules-2 : the read-only dependency cache, should be mounted with read-
only privileges

$GRADLE_HOME
    |-- caches
          |-- modules-2 : the container specific dependency cache, should be
writable
          |-- ...
    |-- ...
```

In a CI environment, it's a good idea to have one build which "seeds" a Gradle dependency cache, which is then *copied* to a different directory. This directory can then be used as the read-only cache for other builds. You shouldn't use an existing Gradle installation cache as the read-only cache, because this directory may contain locks and may be modified by the seeding

build.

Accessing the resolution result programmatically

While most users only need access to a "flat list" of files, there are cases where it can be interesting to reason on a *graph* and get more information about the resolution result:

- for tooling integration, where a model of the dependency graph is required
- for tasks generating a visual representation (image, `.dot` file, …) of a dependency graph
- for tasks providing diagnostics (similar to the `dependencyInsight` task)
- for tasks which need to perform dependency resolution at execution time (e.g, download files on demand)

For those use cases, Gradle provides lazy, thread-safe APIs, accessible by calling the Configuration.getIncoming() method:

- the ResolutionResult API gives access to a resolved dependency graph, whether the resolution was successful or not.
- the artifacts API provides a simple access to the resolved artifacts, untransformed, but with lazy download of artifacts (they would only be downloaded on demand).
- the artifact view API provides an advanced, filtered view of artifacts, possibly transformed.

NOTE	See the documentation on using dependency resolution results for more details on how to consume the results in a task.

Verifying dependencies

Working with external dependencies and plugins published on third-party repositories puts your build at risk. In particular, you need to be aware of what binaries are brought in transitively and if they are legit. To mitigate the security risks and avoid integrating compromised dependencies in your project, Gradle supports *dependency verification*.

Dependency verification is, by nature, an inconvenient feature to use. It means that whenever you're going to update a dependency, builds are likely to fail. It means that merging branches are going to be harder because each branch can have different dependencies. It means that you will be tempted to switch it off.

So why should you bother?

Dependency verification is about **trust** in what you get and what you ship.

Without dependency verification it's easy for an attacker to compromise your supply chain. There are many real world examples of tools compromised by adding a malicious dependency. Dependency verification is meant to protect yourself from those attacks, by forcing you to ensure that the artifacts you include in your build are the ones that you expect. It is not meant, however, to prevent you from including *vulnerable* dependencies.

Finding the right balance between security and convenience is hard but Gradle will try to let

you choose the "right level" for you.

Dependency verification consists of two different and complementary operations:

- *checksum verification,* which allows asserting the integrity of a dependency
- *signature verification*, which allows asserting the provenance of a dependency

Gradle supports both checksum and signature verification out of the box but performs no dependency verification by default. This section will guide you into configuring dependency verification properly for your needs.

This feature can be used for:

- detecting compromised dependencies
- detecting compromised plugins
- detecting tampered dependencies in the local dependency caches

== Enabling dependency verification

=== The verification metadata file

| NOTE | Currently the only source of dependency verification metadata is this XML configuration file. Future versions of Gradle may include other sources (for example via external services). |

Dependency verification is automatically enabled once the configuration file for dependency verification is discovered. This configuration file is located at `$PROJECT_ROOT/gradle/verification-metadata.xml`. This file minimally consists of the following:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>true</verify-metadata>
      <verify-signatures>false</verify-signatures>
    </configuration>
</verification-metadata>
```

Doing so, Gradle will verify all artifacts using checksums, but will not verify signatures. Gradle will verify any artifact downloaded using its dependency management engine, which includes, but is not limited to:

- artifact files (e.g jar files, zips, …) used during a build
- metadata artifacts (POM files, Ivy descriptors, Gradle Module Metadata)

- plugins (both project and settings plugins)
- artifacts resolved using the advanced dependency resolution APIs

Gradle will *not* verify changing dependencies (in particular `SNAPSHOT` dependencies) nor locally produced artifacts (typically jars produced during the build itself) as by nature their checksums and signatures would always change.

With such a minimal configuration file, a project using *any* external dependency or plugin would immediately start failing because it doesn't contain any checksum to verify.

Scope of the dependency verification

A dependency verification configuration is *global*: a single file is used to configure verification of the whole build. In particular, the same file is used for both the (sub)projects and `buildSrc`.

If an included build is used:

- the configuration file of the *current* build is used for verification
- so if the included build itself uses verification, its configuration is ignored in favor of the current one
- which means that including a build works similarly to upgrading a dependency: it may require you to update your current verification metadata

An easy way to get started is therefore to generate the minimal configuration for an existing build.

Configuring the console output

By default, if dependency verification fails, Gradle will generate a small summary about the verification failure as well as an HTML report containing the full information about the failures. If your environment prevents you from reading this HTML report file (for example if you run a build on CI and that it's not easy to fetch the remote artifacts), Gradle provides a way to opt-in a verbose console report. For this, you need to add this Gradle property to your `gradle.properties` file:

```
org.gradle.dependency.verification.console=verbose
```

Bootstrapping dependency verification

It's worth mentioning that while Gradle can generate a dependency verification file for you, you should always check whatever Gradle generated for you because your build may *already* contain compromised dependencies without you knowing about it. Please refer to the appropriate checksum verification or signature verification section for more information.

If you plan on using signature verification, please also read the corresponding section of the docs.

Bootstrapping can either be used to create a file from the beginning, or also to *update* an

existing file with new information. Therefore, it's recommended to always use the same parameters once you started bootstrapping.

The dependency verification file can be generated with the following CLI instructions:

```
gradle --write-verification-metadata sha256 help
```

The `write-verification-metadata` flag requires the list of [checksums](#) that you want to generate or `pgp` for [signatures](#).

Executing this command line will cause Gradle to:

- resolve all [resolvable configurations](#), which includes:
  - configurations from the root project
  - configurations from all subprojects
  - configurations from `buildSrc`
  - included builds configurations
  - configurations used by plugins
- download all artifacts discovered during resolution
- compute the requested checksums and possibly verify signatures depending on what you asked
- At the end of the build, generate the configuration file which will contain the inferred *verification metadata*

As a consequence, the `verification-metadata.xml` file will be used in subsequent builds to verify dependencies.

There are dependencies that Gradle *cannot* discover this way. In particular, you will notice that the CLI above uses the `help` task. If you don't specify any task, Gradle will automatically run the default task and generate a configuration file at the end of the build too.

The difference is that Gradle *may* discover more dependencies and artifacts depending on the tasks you execute. As a matter of fact, Gradle cannot automatically discover *detached configurations*, which are basically dependency graphs resolved as an internal implementation detail of the execution of a task: they are not, in particular, declared as an input of the task because they effectively depend on the configuration of the task at execution time.

A good way to start is just to use the simplest task, `help`, which will discover as much as possible, and if subsequent builds fail with a verification error, you can re-execute generation with the appropriate tasks to "discover" more dependencies.

Gradle won't verify either checksums or signatures of plugins which use their own HTTP clients. Only plugins which use the infrastructure provided by Gradle for performing requests will see their requests verified.

=== Using generation for incremental updates

The verification file generated by Gradle has a strict ordering for all its content. It also uses the information from the existing state to limit changes to the strict minimum.

This means that generation is actually a convenient tool for *updating* a verification file:

- Checksum entries generated by Gradle will have a clear `origin` that starts with "Generated by Gradle", which is a good indicator that an entry needs to be reviewed,
- Entries added by hand will immediately be accounted for, and appear at the right location after writing the file,
- The header comments of the file will be preserved, i.e. comments before the root XML node. This allows you to have a license header or instructions on which tasks and which parameters to use for generating that file.

With the above benefits, it is really easy to account for new dependencies or dependency versions by simply generating the file again and reviewing the changes.

=== Using dry mode

By default, bootstrapping is incremental, which means that if you run it multiple times, information is *added* to the file and in particular you can rely on your VCS to check the diffs. There are situations where you would just want to *see* what the generated verification metadata file would look like without actually changing the existing one or overwriting it.

For this purpose, you can just add `--dry-run`:

```
gradle --write-verification-metadata sha256 help --dry-run
```

Then instead of generating the `verification-metadata.xml` file, a *new file* will be generated, called `verification-metadata.dryrun.xml`.

> **NOTE** Because `--dry-run` doesn't execute tasks, this would be much faster, but it will miss any resolution happening at task execution time.

=== Disabling metadata verification

By default, Gradle will not only verify artifacts (jars, ...) but also the metadata associated with those artifacts (typically POM files). Verifying this ensures the maximum level of security: metadata files typically tell what transitive dependencies will be included, so a compromised metadata file may cause the introduction of undesired dependencies in the graph. However, because all artifacts are verified, such artifacts would in general easily be discovered by you, because they would cause a checksum verification failure (checksums would be *missing* from verification metadata). Because metadata verification can significantly increase the size of your configuration file, you may therefore want to disable verification of metadata. If you understand the risks of doing so, set the `<verify-metadata>` flag to `false` in the configuration file:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>false</verify-metadata>
      <verify-signatures>false</verify-signatures>
   </configuration>
   <!-- the rest of this file doesn't need to declare anything about metadata
files -->
</verification-metadata>
```

Verifying dependency checksums

Checksum verification allows you to ensure the integrity of an artifact. This is the simplest thing that Gradle can do for you to make sure that the artifacts you use are un-tampered.

Gradle supports MD5, SHA1, SHA-256 and SHA-512 checksums. However, only SHA-256 and SHA-512 checksums are considered secure nowadays.

Adding the checksum for an artifact

External components are identified by GAV coordinates, then each of the artifacts by their file names. To declare the checksums of an artifact, you need to add the corresponding section in the verification metadata file. For example, to declare the checksum for Apache PDFBox. The GAV coordinates are:

- group `org.apache.pdfbox`
- name `pdfbox`
- version `2.0.17`

Using this dependency will trigger the download of 2 different files:

- `pdfbox-2.0.17.jar` which is the main artifact
- `pdfbox-2.0.17.pom` which is the metadata file associated with this artifact

As a consequence, you need to declare the checksums for both of them (unless you disabled metadata verification):

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
    <configuration>
        <verify-metadata>true</verify-metadata>
        <verify-signatures>false</verify-signatures>
    </configuration>
    <components>
        <component group="org.apache.pdfbox" name="pdfbox" version="2.0.17">
            <artifact name="pdfbox-2.0.17.jar">
                <sha512 value=
"7e11e54a21c395d461e59552e88b0de0ebaf1bf9d9bcacadf17b240d9bbc29bf6beb8e36896c186fe
405d287f5d517b02c89381aa0fcc5e0aa5814e44f0ab331" origin="PDFBox Official site
(https://pdfbox.apache.org/download.cgi)"/>
            </artifact>
            <artifact name="pdfbox-2.0.17.pom">
                <sha512 value=
"82de436b38faf6121d8d2e71dda06e79296fc0f7bc7aba0766728c8d306fd1b0684b5379c18808ca7
24bf91707277eba81eb4fe19518e99e8f2a56459b79742f" origin="Generated by Gradle"/>
            </artifact>
        </component>
    </components>
</verification-metadata>
```

=== Where to get checksums from?

In general, checksums are published alongside artifacts on public repositories. However, if a dependency is compromised in a repository, it's likely its checksum will be too, so it's a good practice to get the checksum from a different place, usually the website of the library itself.

In fact, it's a good security practice to publish the checksums of artifacts on a *different server* than the server where the artifacts themselves are hosted: it's harder to compromise a library both on the repository *and* the official website.

In the example above, the checksum was published on the website for the JAR, but not the POM file. This is why it's usually easier to let Gradle generate the checksums and verify by reviewing the generated file carefully.

In this example, not only could we check that the checksum was correct, but we could also find it on the official website, which is why we changed the value of the of `origin` attribute on the `sha512` element from `Generated by Gradle` to `PDFBox Official site`. Changing the `origin` gives users a sense of how trustworthy your build it.

Interestingly, using `pdfbox` will require *much more* than those 2 artifacts, because it will also bring in transitive dependencies. If the dependency verification file only included the checksums for the main artifacts you used, the build would fail with an error like this one:

```
Execution failed for task ':compileJava'.
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact commons-logging-1.2.jar (commons-logging:commons-logging:1.2) in
repository 'MavenRepo': checksum is missing from verification metadata.
    - On artifact commons-logging-1.2.pom (commons-logging:commons-logging:1.2) in
repository 'MavenRepo': checksum is missing from verification metadata.
```

What this indicates is that your build requires `commons-logging` when executing `compileJava`, however the verification file doesn't contain enough information for Gradle to verify the integrity of the dependencies, meaning you need to add the required information to the verification metadata file.

See troubleshooting dependency verification for more insights on what to do in this situation.

=== What checksums are verified?

If a dependency verification metadata file declares more than one checksum for a dependency, Gradle will verify *all of them* and fail if *any of them fails*. For example, the following configuration would check both the `md5` and `sha1` checksums:

```
<component group="org.apache.pdfbox" name="pdfbox" version="2.0.17">
    <artifact name="pdfbox-2.0.17.jar">
        <md5 value="c713a8e252d0add65e9282b151adf6b4" origin="official site"/>
        <sha1 value="b5c8dff799bd967c70ccae75e6972327ae640d35" origin="official
site" reason="Additional check for this artifact"/>
    </artifact>
</component>
```

There are multiple reasons why you'd like to do so:

1. an official site doesn't publish *secure* checksums (SHA-256, SHA-512) but publishes multiple insecure ones (MD5, SHA1). While it's easy to fake a MD5 checksum and hard but possible to fake a SHA1 checksum, it's harder to fake both of them for the same artifact.

2. you might want to add generated checksums to the list above

3. when *updating* dependency verification file with more secure checksums, you don't want to accidentally erase checksums

== Verifying dependency signatures

In addition to checksums, Gradle supports verification of signatures. Signatures are used to assess the *provenance* of a dependency (it tells who signed the artifacts, which usually corresponds to who produced it).

As enabling signature verification usually means a higher level of security, you might want to replace checksum verification with signature verification.

Signatures *can* also be used to assess the integrity of a dependency similarly to checksums.

Signatures are signatures of the *hash* of artifacts, not artifacts themselves. This means that if the signature is done on an *unsafe hash* (even SHA1), then you're not correctly assessing the *integrity* of a file. For this reason, if you care about both, you need to add both signatures *and* checksums to your verification metadata.

However:

- Gradle only supports verification of signatures published on remote repositories as ASCII-armored PGP files

- Not all artifacts are published with signatures

- A good signature doesn't mean that the signatory was legit

As a consequence, signature verification will often be used alongside checksum verification.

About expired keys

It's very common to find artifacts which are signed with an expired key. This is not a problem for *verification*: key expiry is mostly used to avoid signing with a stolen key. If an artifact was signed before expiry, it's still valid.

=== Enabling signature verification

Because verifying signatures is more expensive (both I/O and CPU wise) and harder to check manually, it's not enabled by default.

Enabling it requires you to change the configuration option in the `verification-metadata.xml` file:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-signatures>true</verify-signatures>
   </configuration>
</verification-metadata>
```

== Understanding signature verification

Once signature verification is enabled, for each artifact, Gradle will:

- try to download the corresponding `.asc` file
- if it's present
  - automatically download the keys required to perform verification of the signature
  - verify the artifact using the downloaded public keys
  - if signature verification passes, perform additional requested checksum verification
- if it's absent, fallback to checksum verification

That is to say that Gradle's verification mechanism is much stronger if signature verification is enabled than just with checksum verification. In particular:

- if an artifact is signed with multiple keys, all of them must pass validation or the build will fail

- if an artifact passes verification, any additional checksum configured for the artifact *will also be checked*

However, it's not because an artifact passes signature verification that you can trust it: you need to *trust the keys*.

In practice, it means you need to list the keys that you trust for each artifact, which is done by adding a pgp entry instead of a sha1 for example:

```
<component group="com.github.javaparser" name="javaparser-core" version="3.6.11">
    <artifact name="javaparser-core-3.6.11.jar">
        <pgp value="8756c4f765c9ac3cb6b85d62379ce192d401ab61"/>
    </artifact>
</component>
```

For the pgp and trusted-key elements, Gradle *requires* full fingerprint IDs (e.g. b801e2f8ef035068ec1139cc29579f18fa8fd93b instead of a long ID 29579f18fa8fd93b). This minimizes the chance of a collision attack.

At the time, V4 key fingerprints are of 160-bit (40 characters) length. We accept longer keys to be future-proof in case a longer key fingerprint is introduced.

In ignore-key elements, either fingerprints or long (64-bit) IDs can be used. A shorter ID can only result in a bigger range of exclusion, therefore, it's safe to use.

> This effectively means that you trust com.github.javaparser:javaparser-core:3.6.11 if it's signed with the key 8756c4f765c9ac3cb6b85d62379ce192d401ab61.
>
> Without this, the build would fail with this error:
>
> ```
> > Dependency verification failed for configuration ':compileClasspath':
>     - On artifact javaparser-core-3.6.11.jar (com.github.javaparser:javaparser-
>   core:3.6.11) in repository 'MavenRepo': Artifact was signed with key
>   '8756c4f765c9ac3cb6b85d62379ce192d401ab61' (Bintray (by JFrog) <****>) and passed
>   verification but the key isn't in your trusted keys list.
> ```

The key IDs that Gradle shows in error messages are the key IDs found in the signature file it tries to verify. It doesn't mean that it's necessarily the keys that you should trust. In particular, if the signature is correct but done by a malicious entity, Gradle wouldn't tell you.

=== Trusting keys globally

Signature verification has the advantage that it can make the configuration of dependency verification easier by not having to explicitly list all artifacts like for checksum verification only. In fact, it's common that the same key can be used to sign several artifacts. If this is the case, you can move the trusted key from the artifact level to the global configuration block:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>true</verify-metadata>
      <verify-signatures>true</verify-signatures>
      <trusted-keys>
         <trusted-key id="8756c4f765c9ac3cb6b85d62379ce192d401ab61" group=
"com.github.javaparser"/>
      </trusted-keys>
   </configuration>
   <components/>
</verification-metadata>
```

The configuration above means that for any artifact belonging to the group `com.github.javaparser`, we trust it if it's signed with the `8756c4f765c9ac3cb6b85d62379ce192d401ab61` fingerprint.

The `trusted-key` element works similarly to the trusted-artifact element:

- `group`, the group of the artifact to trust
- `name`, the name of the artifact to trust
- `version`, the version of the artifact to trust
- `file`, the name of the artifact *file* to trust
- `regex`, a boolean saying if the `group`, `name`, `version` and `file` attributes need to be interpreted as regular expressions (defaults to `false`)

You should be careful when trusting a key globally.

Try to limit it to the appropriate groups or artifacts:

- a valid key may have been used to sign artifact A which you trust
- later on, the key is stolen and used to sign artifact B

It means you can trust the key A for the first artifact, probably only up to the released version before the key was stolen, but not for B.

Remember that anybody can put an arbitrary name when generating a PGP key, so never trust the key solely based on the key name. Verify if the key is listed at the official site. For example, Apache projects typically provide a KEYS.txt file that you can trust.

=== Specifying key servers and ignoring keys

Gradle will automatically download the public keys required to verify a signature. For this it uses a list of well known and trusted key servers (the list may change between Gradle versions, please refer to the implementation to figure out what servers are used by default).

You can explicitly set the list of key servers that you want to use by adding them to the configuration:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>true</verify-metadata>
      <verify-signatures>true</verify-signatures>
      <key-servers>
         <key-server uri="hkp://my-key-server.org"/>
         <key-server uri="https://my-other-key-server.org"/>
      </key-servers>
   </configuration>
</verification-metadata>
```

Despite this, it's possible that a key is not available:

- because it wasn't published to a public key server
- because it was lost

In this case, you can ignore a key in the configuration block:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>true</verify-metadata>
      <verify-signatures>true</verify-signatures>
      <ignored-keys>
         <ignored-key id="abcdef1234567890" reason="Key is not available in any
key server"/>
      </ignored-keys>
   </configuration>
</verification-metadata>
```

As soon as a key is ignored, it will not be used for verification, even if the signature file mentions it. However, if the signature cannot be verified with at least one other key, Gradle will mandate that you provide a checksum.

=== Exporting keys for faster verification

Gradle automatically downloads the required keys but this operation can be quite slow and requires everyone to download the keys. To avoid this, Gradle offers the ability to use a local keyring file containing the required public keys. Note that only public key packets and a single userId per key are stored and used. All other information (user attributes, signatures, etc.) is stripped from downloaded or exported keys.

Gradle supports 2 different file formats for keyrings: a binary format (`.gpg` file) and a plain text format (`.keys`), also known as ASCII-armored format.

There are pros and cons for each of the formats: the binary format is more compact and can be updated directly via GPG commands, but is completely opaque (binary). On the opposite, the ASCII-armored format is human-readable, can be easily updated by hand and makes it easier to do code reviews thanks to readable diffs.

You can configure which file type would be used by adding the `keyring-format` configuration option:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <verify-metadata>true</verify-metadata>
      <verify-signatures>true</verify-signatures>
      <keyring-format>armored</keyring-format>
   </configuration>
</verification-metadata>
```

Available options for keyring format are `armored` and `binary`.

Without `keyring-format`, if the `gradle/verification-keyring.gpg` or `gradle/verification-keyring.keys` file is present, Gradle will search for keys there in priority. The plain text file will be ignored if there's already a `.gpg` file (the binary version takes precedence).

You can generate the binary version using GPG, for example issuing the following commands (syntax may depend on the tool you use):

```
$ gpg --no-default-keyring --keyring gradle/verification-keyring.gpg --recv-keys
8756c4f765c9ac3cb6b85d62379ce192d401ab61

gpg: keybox 'gradle/verification-keyring.gpg' created
gpg: key 379CE192D401AB61: public key "Bintray (by JFrog) <****>" imported
gpg: Total number processed: 1
gpg:               imported: 1

$ gpg --no-default-keyring --keyring gradle/verification-keyring.gpg --recv-keys
6f538074ccebf35f28af9b066a0975f8b1127b83

gpg: key 0729A0AFF8999A87: public key "Kotlin Release <****>" imported
gpg: Total number processed: 1
gpg:               imported: 1
```

The plain text version, on the other hand, can be updated manually. The file must be formatted with the `US-ASCII` encoding and consists of a list of keys in ASCII-armored format.

In the example above, you could amend an existing KEYS file by issuing the following commands:

```
$ gpg --no-default-keyring --keyring /tmp/keyring.gpg --recv-keys
8756c4f765c9ac3cb6b85d62379ce192d401ab61

gpg: keybox '/tmp/keyring.gpg' created
gpg: key 379CE192D401AB61: public key "Bintray (by JFrog) <****>" imported
gpg: Total number processed: 1
gpg:               imported: 1

# First let's add a header so that we can recognize the added key
$ gpg --keyring /tmp/keyring.gpg --list-sigs
8756c4f765c9ac3cb6b85d62379ce192d401ab61 > gradle/verification-keyring.keys

# Then write its ASCII-armored version
$ gpg --keyring /tmp/keyring.gpg --export --armor
8756c4f765c9ac3cb6b85d62379ce192d401ab61 > gradle/verification-keyring.keys
```

Or, alternatively, you can *ask Gradle to export all keys it used for verification of this build to the keyring* during bootstrapping:

```
./gradlew --write-verification-metadata pgp,sha256 --export-keys
```

Unless `keyring-format` is specified, this command will generate **both** the binary version and the ASCII-armored file. Use this option to choose the preferred format. You should only pick one for your project.

It's a good idea to commit this file to VCS (as long as you trust your VCS). If you use git and use the binary version, make sure to make it treat this file as binary, by adding this to your `.gitattributes` file:

```
*.gpg           binary
```

You can also ask Gradle to export all trusted keys without updating the verification metadata file:

```
./gradlew --export-keys
```

| NOTE | This command will not report verification errors, only export keys. |

=== Bootstrapping and signature verification

| WARNING | Signature verification bootstrapping takes an *optimistic point of view* that signature verification is *enough*. Therefore, if you also care about *integrity*, you **must** first bootstrap using checksum verification, *then* with signature verification. |

Similarly to bootstrapping for checksums, Gradle provides a convenience for bootstrapping a configuration file with signature verification enabled. For this, just add the `pgp` option to the list of verifications to generate. However, because there might be verification failures, missing keys or missing signature files, you **must** provide a fallback checksum verification algorithm:

```
./gradlew --write-verification-metadata pgp,sha256
```

this means that Gradle will verify the signatures and fallback to SHA-256 checksums when there's a problem.

When bootstrapping, Gradle performs *optimistic verification* and therefore assumes a sane build environment. It will therefore:

- automatically add the trusted keys as soon as verification passes
- automatically add ignored keys for keys which couldn't be downloaded from public key servers
- automatically generate checksums for artifacts without signatures or ignored keys

If, for some reason, verification fails during the generation, Gradle will automatically generate an ignored key entry but warn you that you must absolutely check what happens.

This situation is common as explained for this section: a typical case is when the POM file for a dependency differs from one repository to the other (often in a non-meaningful way).

In addition, Gradle will try to group keys automatically and generate the `trusted-keys` block which reduced the configuration file size as much as possible.

== Forcing use of local keyrings only

The local keyring files (`.gpg` or `.keys`) can be used to avoid reaching out to key servers whenever a key is required to verify an artifact. However, it may be that the local keyring doesn't contain a key, in which case Gradle would use the key servers to fetch the missing key. If the local keyring file isn't regularly updated, using key export, then it may be that your CI builds, for example, would reach out to key servers too often (especially if you use disposable containers for builds).

To avoid this, Gradle offers the ability to disallow use of key servers altogether: only the local keyring file would be used, and if a key is missing from this file, the build will fail.

To enable this mode, you need to disable key servers in the configuration file:

```
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <key-servers enabled="false"/>
      ...
   </configuration>
   ...
</verification-metadata>
```

NOTE	If you are asking Gradle to generate a verification metadata file and that an existing verification metadata file sets `enabled` to `false`, then this flag will be ignored, so that potentially missing keys are downloaded.

== Troubleshooting dependency verification

=== Dealing with a verification failure

Dependency verification can fail in different ways, this section explains how you should deal with the various cases.

==== Missing verification metadata

The simplest failure you can have is when verification metadata is missing from the dependency verification file. This is the case for example if you use checksum verification, then you update a dependency and new versions of the dependency (and potentially its transitive dependencies) are brought in.

Gradle will tell you what metadata is missing:

```
Execution failed for task ':compileJava'.
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact commons-logging-1.2.jar (commons-logging:commons-logging:1.2) in
repository 'MavenRepo': checksum is missing from verification metadata.
```

- the missing module group is `commons-logging`, it's artifact name is `commons-logging` and its version is `1.2`. The corresponding artifact is `commons-logging-1.2.jar` so you need to add the following entry to the verification file:

```
<component group="commons-logging" name="commons-logging" version="1.2">
    <artifact name="commons-logging-1.2.jar">
        <sha256 value=
"daddea1ea0be0f56978ab3006b8ac92834afeefbd9b7e4e6316fca57df0fa636" origin=
"official distribution"/>
    </artifact>
</component>
```

Alternatively, you can ask Gradle to generate the missing information by using the bootstrapping mechanism: existing information in the metadata file will be preserved, Gradle will only add the missing verification metadata.

==== Incorrect checksums

A more problematic issue is when the actual checksum verification fails:

```
Execution failed for task ':compileJava'.
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact commons-logging-1.2.jar (commons-logging:commons-logging:1.2) in
repository 'MavenRepo': expected a 'sha256' checksum of
'91f7a33096ea69bac2cbaf6d01feb934cac002c48d8c8cfa9c240b40f1ec21df' but was
'daddea1ea0be0f56978ab3006b8ac92834afeefbd9b7e4e6316fca57df0fa636'
```

This time, Gradle tells you what dependency is at fault, what was the expected checksum (the one you declared in the verification metadata file) and the one which was actually computed during verification.

Such a failure indicates that a **dependency may have been compromised**. At this stage, you **must** perform manual verification and check what happens. Several things can happen:

- a dependency was tampered in the local dependency cache of Gradle. This is usually harmless: erase the file from the cache and Gradle would redownload the dependency.
- a dependency is available in multiple sources with slightly different binaries (additional whitespace, …)
    - please inform the maintainers of the library that they have such an issue
    - you can use `also-trust` to accept the additional checksums
- the dependency was compromised
    - immediately inform the maintainers of the library
    - notify the repository maintainers of the compromised library

Note that a variation of a compromised library is often *name squatting*, when a hacker would use GAV coordinates which *look legit* but are actually different by one character, or *repository shadowing*, when a dependency with the official GAV coordinates is published in a malicious repository which comes first in your build.

==== Untrusted signatures

If you have signature verification enabled, Gradle will perform verification of the signatures but will not trust them automatically:

```
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact javaparser-core-3.6.11.jar (com.github.javaparser:javaparser-
  core:3.6.11) in repository 'MavenRepo': Artifact was signed with key
  '379ce192d401ab61' (Bintray (by JFrog) <****>) and passed verification but the key
  isn't in your trusted keys list.
```

In this case it means you need to check yourself if the key that was used for verification (and therefore the signature) can be trusted, in which case refer to this section of the documentation to figure out how to declare trusted keys.

==== Failed signature verification

If Gradle fails to verify a signature, you will need to take action and verify artifacts manually because this **may indicate a compromised dependency**.

If such a thing happens, Gradle will fail with:

```
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact javaparser-core-3.6.11.jar (com.github.javaparser:javaparser-
  core:3.6.11) in repository 'MavenRepo': Artifact was signed with key
  '379ce192d401ab61' (Bintray (by JFrog) <****>) but signature didn't match
```

There are several options:

1. signature was wrong in the first place, which happens frequently with dependencies published on different repositories.

2. the signature is correct but the artifact has been compromised (either in the local dependency cache or remotely)

The right approach here is to go to the official site of the dependency and see if they publish signatures for their artifacts. If they do, verify that the signature that Gradle downloaded matches the one published.

If you have checked that the dependency is *not* compromised and that it's "only" the signature which is wrong, you should declare an *artifact level key exclusion*:

```xml
    <components>
        <component group="com.github.javaparser" name="javaparser-core" version=
"3.6.11">
            <artifact name="javaparser-core-3.6.11.pom">
                <ignored-keys>
                    <ignored-key id="379ce192d401ab61" reason="internal repo has
corrupted POM"/>
                </ignored-keys>
            </artifact>
        </component>
    </components>
```

However, if you only do so, Gradle will still fail because all keys for this artifact will be ignored and you didn't provide a checksum:

```xml
    <components>
        <component group="com.github.javaparser" name="javaparser-core" version=
"3.6.11">
            <artifact name="javaparser-core-3.6.11.pom">
                <ignored-keys>
                    <ignored-key id="379ce192d401ab61" reason="internal repo has
corrupted POM"/>
                </ignored-keys>
                <sha256 value=
"a2023504cfd611332177f96358b6f6db26e43d96e8ef4cff59b0f5a2bee3c1e1"/>
            </artifact>
        </component>
    </components>
```

==== Manual verification of a dependency

You will likely face a dependency verification failure (either checksum verification or signature verification) and will need to figure out if the dependency has been compromised or not.

In this section we give *an example* how you can manually check if a dependency was compromised.

For this we will take this example failure:

```
> Dependency verification failed for configuration ':compileClasspath':
- On artifact j2objc-annotations-1.1.jar (com.google.j2objc:j2objc-
annotations:1.1) in repository 'MyCompany Mirror': Artifact was signed with key
'29579f18fa8fd93b' but signature didn't match
```

This error message gives us the GAV coordinates of the problematic dependency, as well as an indication of where the dependency was fetched from. Here, the dependency comes from

`MyCompany Mirror`, which is a repository declared in our build.

The first thing to do is therefore to download the artifact and its signature manually from the mirror:

```
$ curl https://my-company-mirror.com/repo/com/google/j2objc/j2objc-
annotations/1.1/j2objc-annotations-1.1.jar --output j2objc-annotations-1.1.jar
$ curl https://my-company-mirror.com/repo/com/google/j2objc/j2objc-
annotations/1.1/j2objc-annotations-1.1.jar.asc --output j2objc-annotations-
1.1.jar.asc
```

Then we can use the key information provided in the error message to import the key locally:

```
$ gpg --recv-keys B801E2F8EF035068EC1139CC29579F18FA8FD93B
```

And perform verification:

```
$ gpg --verify j2objc-annotations-1.1.jar.asc
gpg: assuming signed data in 'j2objc-annotations-1.1.jar'
gpg: Signature made Thu 19 Jan 2017 12:06:51 AM CET
gpg:                using RSA key 29579F18FA8FD93B
gpg: BAD signature from "Tom Ball <****>" [unknown]
```

What this tells us is that the problem is *not* on the local machine: the repository *already contains a bad signature*.

The next step is to do the same by downloading what is actually on Maven Central:

```
$ curl https://my-company-mirror.com/repo/com/google/j2objc/j2objc-
annotations/1.1/j2objc-annotations-1.1.jar  --output central-j2objc-annotations-
1.1.jar
$ curl https://my-company-mirror.com/repo/com/google/j2objc/j2objc-
annotations/1/1/j2objc-annotations-1.1.jar.asc  --output central-j2objc-
annotations-1.1.jar.asc
```

And we can now check the signature again:

```
$ gpg --verify central-j2objc-annotations-1.1.jar.asc

gpg: assuming signed data in 'central-j2objc-annotations-1.1.jar'
gpg: Signature made Thu 19 Jan 2017 12:06:51 AM CET
gpg:                using RSA key 29579F18FA8FD93B
gpg: Good signature from "Tom Ball <****>" [unknown]
gpg: WARNING: This key is not certified with a trusted signature!
gpg:          There is no indication that the signature belongs to the owner.
Primary key fingerprint: B801 E2F8 EF03 5068 EC11  39CC 2957 9F18 FA8F D93B
```

This indicates that the dependency is *valid* on Maven Central. At this stage, we already know that the problem lives in the mirror, it *may* have been compromised, but we need to verify.

A good idea is to compare the 2 artifacts, which you can do with a tool like [diffoscope](#).

We then figure out that the intent wasn't malicious but that somehow a build has been overwritten with a newer version (the version in Central is newer than the one in our repository).

In this case, you can decide to:

- ignore the signature for this artifact and trust the different possible checksums (both for the old artifact and the new version)

- or cleanup your mirror so that it contains the same version as in Maven Central

It's worth noting that if you choose to delete the version from your repository, you will *also* need to remove it from the local Gradle cache.

This is facilitated by the fact the error message tells you were the file is located:

```
> Dependency verification failed for configuration ':compileClasspath':
    - On artifact j2objc-annotations-1.1.jar (com.google.j2objc:j2objc-
annotations:1.1) in repository 'MyCompany Mirror': Artifact was signed with key
'29579f18fa8fd93b' but signature didn't match

   This can indicate that a dependency has been compromised. Please carefully
verify the signatures and checksums.

   For your information here are the path to the files which failed verification:
      -
$<<directory_layout.adoc#dir:gradle_user_home,GRADLE_USER_HOME>>/caches/modules-
2/files-2.1/com.google.j2objc/j2objc-
annotations/1.1/976d8d30bebc251db406f2bdb3eb01962b5685b3/j2objc-annotations-
1.1.jar (signature: GRADLE_USER_HOME/caches/modules-2/files-
2.1/com.google.j2objc/j2objc-
annotations/1.1/82e922e14f57d522de465fd144ec26eb7da44501/j2objc-annotations-
1.1.jar.asc)

   GRADLE_USER_HOME = /home/jiraya/.gradle
```

You can safely delete the artifact file as Gradle would automatically re-download it:

```
rm -rf ~/.gradle/caches/modules-2/files-2.1/com.google.j2objc/j2objc-
annotations/1.1
```

=== Disabling verification or making it lenient

Dependency verification can be expensive, or sometimes verification could get in the way of day to day development (because of frequent dependency upgrades, for example).

Alternatively, you might want to enable verification on CI servers but not on local machines.

Gradle actually provides 3 different verification modes:

- `strict`, which is the default. Verification fails *as early as possible*, in order to avoid the use of compromised dependencies during the build.
- `lenient`, which will run the build even if there are verification failures. The verification errors will be displayed during the build without causing a build failure.
- `off` when verification is totally ignored.

All those modes can be activated on the CLI using the `--dependency-verification` flag, for example:

```
./gradlew --dependency-verification lenient build
```

Alternatively, you can set the `org.gradle.dependency.verification` system property, either on

the CLI:

```
./gradlew -Dorg.gradle.dependency.verification=lenient build
```

or in a `gradle.properties` file:

```
org.gradle.dependency.verification=lenient
```

=== Trusting some particular artifacts

You might want to trust some artifacts more than others. For example, it's legitimate to think that artifacts produced in your company and found in your internal repository only are safe, but you want to check every external component.

| NOTE | This is a typical *company policy*. In practice, **nothing** prevents your internal repository from being compromised, so it's a good idea to check your internal artifacts too! |

For this purpose, Gradle offers a way to automatically trust some artifacts. You can trust all artifacts in a group by adding this to your configuration:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <trusted-artifacts>
         <trust group="com.mycompany" reason="We trust mycompany artifacts"/>
      </trusted-artifacts>
   </configuration>
</verification-metadata>
```

This means that all components which group is `com.mycompany` will automatically be trusted. Trusted means that Gradle will not perform any verification whatsoever.

The `trust` element accepts those attributes:

- `group`, the group of the artifact to trust
- `name`, the name of the artifact to trust
- `version`, the version of the artifact to trust
- `file`, the name of the artifact *file* to trust
- `regex`, a boolean saying if the `group`, `name`, `version` and `file` attributes need to be interpreted as regular expressions (defaults to `false`)

- `reason`, an optional reason, why matched artifacts are trusted

In the example above it means that the trusted artifacts would be artifacts in `com.mycompany` but not `com.mycompany.other`. To trust all artifacts in `com.mycompany` and all subgroups, you can use:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<verification-metadata xmlns="https://schema.gradle.org/dependency-verification"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="https://schema.gradle.org/dependency-verification
https://schema.gradle.org/dependency-verification/dependency-verification-1.3.xsd
">
   <configuration>
      <trusted-artifacts>
         <trust group="^com[.]mycompany($|([.].*))" regex="true" reason="We trust
all mycompany artifacts"/>
      </trusted-artifacts>
   </configuration>
</verification-metadata>
```

=== Trusting multiple checksums for an artifact

It's quite common to have *different checksums for the same artifact* in the wild. How is that possible? Despite progress, it's often the case that developers publish, for example, to Maven Central and another repository separately, using different builds. In general, this is not a problem but sometimes it means that the metadata files would be different (different timestamps, additional whitespaces, …). Add to this that your build may use several repositories or repository mirrors and it makes it quite likely that a single build can "see" different metadata files for the same component! In general, it's not malicious (but you **must** verify that the artifact is actually correct), so Gradle lets you declare the additional artifact checksums. For example:

```xml
      <component group="org.apache" name="apache" version="13">
         <artifact name="apache-13.pom">
            <sha256 value=
"2fafa38abefe1b40283016f506ba9e844bfcf18713497284264166a5dbf4b95e">
               <also-trust value=
"ff513db0361fd41237bef4784968bc15aae478d4ec0a9496f811072ccaf3841d"/>
            </sha256>
         </artifact>
      </component>
```

You can have as many `also-trust` entries as needed, but in general you shouldn't have more than 2.

=== Skipping Javadocs and sources

By default Gradle will verify *all* downloaded artifacts, which includes Javadocs and sources. In general this is not a problem but you might face an issue with IDEs which automatically try to

download them during import: if you didn't set the checksums for those too, importing would fail.

To avoid this, you can configure Gradle to trust automatically all javadocs/sources:

```
<trusted-artifacts>
    <trust file=".*-javadoc[.]jar" regex="true"/>
    <trust file=".*-sources[.]jar" regex="true"/>
</trusted-artifacts>
```

Cleaning up the verification file

If you do nothing, the dependency verification metadata will grow over time as you add new dependencies or change versions: Gradle will not automatically remove *unused* entries from this file. The reason is that there's no way for Gradle to know upfront if a dependency will effectively be used during the build or not.

As a consequence, adding dependencies or changing dependency version can easily lead to more entries in the file, while leaving unnecessary entries out there.

One option to cleanup the file is to move the existing `verification-metadata.xml` file to a different location and call Gradle with the `--dry-run` mode: while not perfect (it will not notice dependencies only resolved at configuration time), it generates *a new file* that you can compare with the existing one.

We need to move the existing file because both the bootstrapping mode and the dry-run mode are incremental: they copy information from the existing metadata verification file (in particular, trusted keys).

Refreshing missing keys

Gradle caches missing keys for 24 hours, meaning it will not attempt to re-download the missing keys for 24 hours after failing.

If you want to retry immediately, you can run with the `--refresh-keys` CLI flag:

```
./gradlew build --refresh-keys
```

Disabling dependency verification for some configurations only

In order to provide the strongest security level possible, dependency verification is enabled globally. This will ensure, for example, that you trust all the plugins you use. However, the plugins themselves may need to resolve additional dependencies that it doesn't make sense to ask the user to accept. For this purpose, Gradle provides an API which allows *disabling dependency verification on some specific configurations.*

Disabling dependency verification, if you care about security, is not a good idea. This API mostly exist for cases where it doesn't make sense to check dependencies. However, in order to be on the

safe side, Gradle will systematically print a warning whenever verification has been disabled for a specific configuration.

As an example, a plugin may want to check if there are *newer* versions of a library available and list those versions. It doesn't make sense, in this context, to ask the user to put the checksums of the POM files of the newer releases because by definition, they don't know about them. So the plugin might need to run its code *independently of the dependency verification configuration.*

To do this, you need to call the `ResolutionStrategy#disableDependencyVerification` method:

build.gradle.kts

```
configurations {
    "myPluginClasspath" {
        resolutionStrategy {
            disableDependencyVerification()
        }
    }
}
```

build.gradle

```
configurations {
    myPluginClasspath {
        resolutionStrategy {
            disableDependencyVerification()
        }
    }
}
```

It's also possible to disable verification on detached configurations like in the following example:

build.gradle.kts

```
tasks.register("checkDetachedDependencies") {
    val detachedConf: FileCollection =
configurations.detachedConfiguration(dependencies.create("org.apache.commons:commo
ns-lang3:3.3.1")).apply {
        resolutionStrategy.disableDependencyVerification()
    }
    doLast {
        println(detachedConf.files)
    }
}
```

build.gradle

```
tasks.register("checkDetachedDependencies") {
    def detachedConf = configurations.detachedConfiguration(dependencies.create(
"org.apache.commons:commons-lang3:3.3.1"))
    detachedConf.resolutionStrategy.disableDependencyVerification()
    doLast {
        println(detachedConf.files)
    }
}
```

== DECLARING VERSIONS

= Declaring Versions and Ranges

The simplest version declaration is a *simple string* representing the version to use. Gradle supports different ways of declaring a version string:

- An exact version: e.g. `1.3`, `1.3.0-beta3`, `1.0-20150201.131010-1`
- A Maven-style version range: e.g. `[1.0,)`, `[1.1, 2.0)`, `(1.2, 1.5]`
    - The `[` and `]` symbols indicate an inclusive bound; `(` and `)` indicate an exclusive bound.
    - When the upper or lower bound is missing, the range has no upper or lower bound.
    - The symbol `]` can be used instead of `(` for an exclusive lower bound, and `[` instead of `)` for exclusive upper bound. e.g `]1.0, 2.0[`
    - An upper bound exclude acts as a prefix exclude. This means that `[1.0, 2.0[` will also exclude all versions starting with `2.0` that are smaller than `2.0`. For example versions like `2.0-dev1` or `2.0-SNAPSHOT` are no longer included in the range.
- A *prefix* version range: e.g. `1.+`, `1.3.+`
    - Only versions exactly matching the portion before the `+` are included.
    - The range `+` on it's own will include any version.
- A `latest-status` version: e.g. `latest.integration`, `latest.release`
    - Will match the highest versioned module with the specified status. See ComponentMetadata.getStatus().
- A Maven `SNAPSHOT` version identifier: e.g. `1.0-SNAPSHOT`, `1.4.9-beta1-SNAPSHOT`

== Version ordering

Versions have an implicit ordering. Version ordering is used to:

- Determine if a particular version is included in a range.
- Determine which version is 'newest' when performing conflict resolution (watch out though, conflict resolution uses "base versions").

Versions are ordered based on the following rules:

- Each version is split into it's constituent "parts":
    - The characters `[. - _ +]` are used to separate the different "parts" of a version.
    - Any part that contains both digits and letters is split into separate parts for each: `1a1 == 1.a.1`
    - Only the parts of a version are compared. The actual separator characters are not significant: `1.a.1 == 1-a+1 == 1.a-1 == 1a1` (watch out though, in the context of conflict resolution there are exceptions to this rule).
- The equivalent parts of 2 versions are compared using the following rules:
    - If both parts are numeric, the highest numeric value is **higher**: `1.1 < 1.2`

- If one part is numeric, it is considered **higher** than the non-numeric part: `1.a` < `1.1`
- If both are non-numeric, the parts are compared **alphabetically**, in a **case-sensitive** manner: `1.A` < `1.B` < `1.a` < `1.b`
- A version with an extra numeric part is considered **higher** than a version without (even when it's zero): `1.1` < `1.1.0`
- A version with an extra non-numeric part is considered **lower** than a version without: `1.1.a` < `1.1`

- Certain non-numeric parts have special meaning for the purposes of ordering:
  - `dev` is consider **lower** than any other non-numeric part: `1.0-dev` < `1.0-ALPHA` < `1.0-alpha` < `1.0-rc`.
  - The strings `rc`, `snapshot`, `final`, `ga`, `release` and `sp` are considered **higher** than any other string part (sorted in this order): `1.0-zeta` < `1.0-rc` < `1.0-snapshot` < `1.0-final` < `1.0-ga` < `1.0-release` < `1.0-sp` < `1.0`.
  - These special values are **NOT case sensitive**, as opposed to regular string parts and they do not depend on the separator used around them: `1.0-RC-1` == `1.0.rc.1`

== Simple version declaration semantics

When you declare a version using the short-hand notation, for example:

build.gradle.kts

```
dependencies {
    implementation("org.slf4j:slf4j-api:1.7.15")
}
```

build.gradle

```
dependencies {
    implementation('org.slf4j:slf4j-api:1.7.15')
}
```

Then the version is considered a required version which means that it should *minimally* be `1.7.15` but can be upgraded by the engine (optimistic upgrade).

There is, however, a shorthand notation for strict versions, using the `!!` notation:

build.gradle.kts

```
dependencies {
    // short-hand notation with !!
    implementation("org.slf4j:slf4j-api:1.7.15!!")
    // is equivalent to
    implementation("org.slf4j:slf4j-api") {
        version {
            strictly("1.7.15")
        }
    }

    // or...
    implementation("org.slf4j:slf4j-api:[1.7, 1.8[!!1.7.25")
    // is equivalent to
    implementation("org.slf4j:slf4j-api") {
        version {
            strictly("[1.7, 1.8[")
            prefer("1.7.25")
        }
    }
}
```

build.gradle

```
dependencies {
    // short-hand notation with !!
    implementation('org.slf4j:slf4j-api:1.7.15!!')
    // is equivalent to
    implementation("org.slf4j:slf4j-api") {
        version {
            strictly '1.7.15'
        }
    }

    // or...
    implementation('org.slf4j:slf4j-api:[1.7, 1.8[!!1.7.25')
    // is equivalent to
    implementation('org.slf4j:slf4j-api') {
        version {
            strictly '[1.7, 1.8['
            prefer '1.7.25'
        }
    }
}
```

A strict version *cannot be upgraded* and overrides whatever transitive dependencies originating from this dependency provide. It is recommended to use ranges for strict versions.

The notation [1.7, 1.8[!!1.7.25 above is equivalent to:

- strictly [1.7, 1.8[
- prefer 1.7.25

which means that the engine **must** select a version between 1.7 (included) and 1.8 (excluded), and that if no other component in the graph needs a different version, it should *prefer* 1.7.25.

== Declaring a dependency without version

A recommended practice for larger projects is to declare dependencies without versions and use dependency constraints for version declaration. The advantage is that dependency constraints allow you to manage versions of all dependencies, including transitive ones, in one place.

build.gradle.kts

```
dependencies {
    implementation("org.springframework:spring-web")
}

dependencies {
    constraints {
        implementation("org.springframework:spring-web:5.0.2.RELEASE")
    }
}
```

build.gradle

```
dependencies {
    implementation 'org.springframework:spring-web'
}

dependencies {
    constraints {
        implementation 'org.springframework:spring-web:5.0.2.RELEASE'
    }
}
```

Declaring Rich Versions

Gradle supports a rich model for declaring versions, which allows to combine different level of version information. The terms and their meaning are explained below, from the strongest to the weakest:

`strictly`

> Any version not matched by this version notation will be excluded. This is the strongest version declaration. On a declared dependency, a `strictly` can downgrade a version. When on a transitive dependency, it will cause dependency resolution to fail if no version acceptable by this clause can be selected. See overriding dependency version for details. This term supports dynamic versions.
>
> When defined, this overrides any previous `require` declaration and clears previous `reject`.

`require`

> Implies that the selected version cannot be lower than what `require` accepts but could be higher through conflict resolution, even if higher has an exclusive higher bound. This is what a direct dependency translates to. This term supports dynamic versions.
>
> When defined, this overrides any previous `strictly` declaration and clears previous `reject`.

`prefer`

> This is a very soft version declaration. It applies only if there is no stronger non dynamic opinion on a version for the module. This term does not support dynamic versions.
>
> Definition can complement `strictly` or `require`.
>
> When defined, this overrides any previous `prefer` declaration and clears previous `reject`.

There is also an additional term outside of the level hierarchy:

`reject`

> Declares that specific version(s) are not accepted for the module. This will cause dependency resolution to fail if the only versions selectable are also rejected. This term supports dynamic versions.

The following table illustrates a number of use cases and how to combine the different terms for rich version declaration:

Table 26. Rich version use cases

Which version(s) of this dependency are acceptable?	strictly	require	prefer	rejects	Selection result
Tested with version `1.5`, believe all future versions should work.		1.5			Any version starting from `1.5`, equivalent of `org:foo:1.5`. An upgrade to `2.4` is accepted.

Which version(s) of this dependency are acceptable?	strictly	require	prefer	rejects	Selection result
Tested with 1.5, soft constraint upgrades according to semantic versioning.		[1.0, 2.0[	1.5		Any version between 1.0 and 2.0, 1.5 if nobody else cares. An upgrade to 2.4 is accepted. 🔒
Tested with 1.5, but follows semantic versioning.	[1.0, 2.0[		1.5		Any version between 1.0 and 2.0 (exclusive), 1.5 if nobody else cares. Overwrites versions from transitive dependencies. 🔒
Same as above, with 1.4 known broken.	[1.0, 2.0[		1.5	1.4	Any version between 1.0 and 2.0 (exclusive) except for 1.4, 1.5 if nobody else cares. Overwrites versions from transitive dependencies. 🔒
No opinion, works with 1.5.			1.5		1.5 if no other opinion, any otherwise.
No opinion, prefer latest release.			latest.release		The latest release at build time. 🔒
On the edge, latest release, no downgrade.		latest.release			The latest release at build time. 🔒
No other version than 1.5.	1.5				1.5, or failure if another strict or higher require constraint disagrees. Overwrites versions from transitive dependencies.
1.5 or a patch version of it exclusively.	[1.5, 1.6[				Latest 1.5.x patch release, or failure if another strict or higher require constraint disagrees. Overwrites versions from transitive dependencies. 🔒

Lines annotated with a lock (🔒) indicate that leveraging dependency locking makes sense in this context. Another concept that relates with rich version declaration is the ability to publish resolved versions instead of declared ones.

Using strictly, especially for a library, must be a well thought process as it has an impact on downstream consumers. At the same time, used correctly, it will help consumers understand what combination of libraries do not work together in their context. See overriding dependency version for more information.

Rich version information will be preserved in the Gradle Module Metadata format. However conversion to Ivy or Maven metadata formats will be lossy. The highest level will be published, that is `strictly` or `require` over `prefer`. In addition, any `reject` will be ignored.

Rich version declaration is accessed through the `version` DSL method on a dependency or constraint declaration which gives access to [MutableVersionConstraint](#).

build.gradle.kts

```
dependencies {
    implementation("org.slf4j:slf4j-api") {
        version {
            strictly("[1.7, 1.8[")
            prefer("1.7.25")
        }
    }
}

    constraints {
        add("implementation", "org.springframework:spring-core") {
            version {
                require("4.2.9.RELEASE")
                reject("4.3.16.RELEASE")
            }
        }
    }
}
```

build.gradle

```
dependencies {
    implementation('org.slf4j:slf4j-api') {
        version {
            strictly '[1.7, 1.8['
            prefer '1.7.25'
        }
    }

    constraints {
        implementation('org.springframework:spring-core') {
            version {
                require '4.2.9.RELEASE'
                reject '4.3.16.RELEASE'
            }
        }
    }
}
```

= Handling versions which change over time

There are many situations when you want to use the latest version of a particular module dependency, or the latest in a range of versions. This can be a requirement during development, or you may be developing a library that is designed to work with a range of dependency versions. You can easily depend on these constantly changing dependencies by using a *dynamic version*. A dynamic version can be either a version range (e.g. `2.+`) or it can be a placeholder for the latest version available e.g. `latest.integration`.

Alternatively, the module you request can change over time even for the same version, a so-called changing version. An example of this type of *changing module* is a Maven `SNAPSHOT` module, which always points at the latest artifact published. In other words, a standard Maven snapshot is a module that is continually evolving, it is a "changing module".

CAUTION	Using dynamic versions and changing modules can lead to unreproducible builds. As new versions of a particular module are published, its API may become incompatible with your source code. Use this feature with caution!

== Declaring a dynamic version

Projects might adopt a more aggressive approach for consuming dependencies to modules. For example you might want to always integrate the latest version of a dependency to consume cutting edge features at any given time. A *dynamic version* allows for resolving the latest version or the latest version of a version range for a given module.

CAUTION	Using dynamic versions in a build bears the risk of potentially breaking it. As soon as a new version of the dependency is released that contains an incompatible API change your source code might stop compiling.

build.gradle.kts

```
plugins {
    `java-library`
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("org.springframework:spring-web:5.+")
}
```

build.gradle

```
plugins {
    id 'java-library'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.springframework:spring-web:5.+'
}
```

A build scan can effectively visualize dynamic dependency versions and their respective, selected versions.


```
compileClasspath ∨ - 0.819s
    org.springframework:spring-web:5.+  →  5.0.2.RELEASE ∨
        org.springframework:spring-beans:5.0.2.RELEASE ∨
            org.springframework:spring-core:5.0.2.RELEASE ∨
                org.springframework:spring-jcl:5.0.2.RELEASE
        org.springframework:spring-core:5.0.2.RELEASE ∨
            org.springframework:spring-jcl:5.0.2.RELEASE
```

Figure 26. Dynamic dependencies in build scan

By default, Gradle caches dynamic versions of dependencies for 24 hours. Within this time frame, Gradle does not try to resolve newer versions from the declared repositories. The threshold can be configured as needed for example if you want to resolve new versions earlier.

== Declaring a changing version

A team might decide to implement a series of features before releasing a new version of the application or library. A common strategy to allow consumers to integrate an unfinished version of their artifacts early and often is to release a module with a so-called *changing version*. A changing version indicates that the feature set is still under active development and hasn't released a stable version for general availability yet.

In Maven repositories, changing versions are commonly referred to as snapshot versions. Snapshot versions contain the suffix `-SNAPSHOT`. The following example demonstrates how to declare a snapshot version on the Spring dependency.

build.gradle.kts

```
plugins {
    `java-library`
}

repositories {
    mavenCentral()
    maven {
        url = uri("https://repo.spring.io/snapshot/")
    }
}

dependencies {
    implementation("org.springframework:spring-web:5.0.3.BUILD-SNAPSHOT")
}
```

build.gradle

```
plugins {
    id 'java-library'
}

repositories {
    mavenCentral()
    maven {
        url 'https://repo.spring.io/snapshot/'
    }
}

dependencies {
    implementation 'org.springframework:spring-web:5.0.3.BUILD-SNAPSHOT'
}
```

By default, Gradle caches changing versions of dependencies for 24 hours. Within this time frame, Gradle does not try to resolve newer versions from the declared repositories. The threshold can be configured as needed for example if you want to resolve new snapshot versions earlier.

Gradle is flexible enough to treat any version as changing version e.g. if you wanted to model snapshot behavior for an Ivy module. All you need to do is to set the property ExternalModuleDependency.setChanging(boolean) to `true`.

== Controlling dynamic version caching

By default, Gradle caches dynamic versions and changing modules for 24 hours. During that time frame Gradle does not contact any of the declared, remote repositories for new versions. If you want Gradle to check the remote repository more frequently or with every execution of your build, then you will need to change the time to live (TTL) threshold.

| NOTE | Using a short TTL threshold for dynamic or changing versions may result in longer build times due to the increased number of HTTP(s) calls. |

You can override the default cache modes using command line options. You can also change the cache expiry times in your build programmatically using the resolution strategy.

== Controlling dependency caching programmatically

You can fine-tune certain aspects of caching programmatically using the ResolutionStrategy for a configuration. The programmatic approach is useful if you would like to change the settings permanently.

By default, Gradle caches dynamic versions for 24 hours. To change how long Gradle will cache the resolved version for a dynamic version, use:

build.gradle.kts

```
configurations.all {
    resolutionStrategy.cacheDynamicVersionsFor(10, "minutes")
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.cacheDynamicVersionsFor 10, 'minutes'
}
```

By default, Gradle caches changing modules for 24 hours. To change how long Gradle will cache the meta-data and artifacts for a changing module, use:

build.gradle.kts

```
configurations.all {
    resolutionStrategy.cacheChangingModulesFor(4, "hours")
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.cacheChangingModulesFor 4, 'hours'
}
```

Controlling dependency caching from the command line

Avoiding network access with offline mode

The `--offline` command line switch tells Gradle to always use dependency modules from the cache, regardless if they are due to be checked again. When running with offline, Gradle will never attempt to access the network to perform dependency resolution. If required modules are not present in the dependency cache, build execution will fail.

Refreshing dependencies

You can control the behavior of dependency caching for a distinct build invocation from the command line. Command line options are helpful for making a selective, ad-hoc choice for a single execution of the build.

At times, the Gradle Dependency Cache can become out of sync with the actual state of the configured repositories. Perhaps a repository was initially misconfigured, or perhaps a "non-changing" module was published incorrectly. To refresh all dependencies in the dependency cache, use the `--refresh-dependencies` option on the command line.

The `--refresh-dependencies` option tells Gradle to ignore all cached entries for resolved modules and artifacts. A fresh resolve will be performed against all configured repositories, with dynamic versions recalculated, modules refreshed, and artifacts downloaded. However, where possible Gradle will check if the previously downloaded artifacts are valid before downloading again. This is done by comparing published SHA1 values in the repository with the SHA1 values for existing downloaded artifacts.

- new versions of dynamic dependencies
- new versions of changing modules (modules which use the same version string but can have different contents)

Refreshing dependencies will cause Gradle to invalidate its listing caches. However:

- it will perform HTTP HEAD requests on metadata files but *will not re-download them* if they are identical
- it will perform HTTP HEAD requests on artifact files but *will not re-download them* if they are identical

In other words, refreshing dependencies *only* has an impact if you actually use dynamic dependencies *or* that you have changing dependencies that you were not aware of (in which case it is your responsibility to declare them correctly to Gradle as changing dependencies).

It's a common misconception to think that using `--refresh-dependencies` will force download of dependencies. This is **not** the case: Gradle will only perform what is strictly required to refresh the dynamic dependencies. This *may* involve downloading new listing or metadata files, or even artifacts, but if nothing changed, the impact is minimal.

Using component selection rules

Component selection rules may influence which component instance should be selected when multiple versions are available that match a version selector. Rules are applied against every available version and allow the version to be explicitly rejected by rule. This allows Gradle to ignore any component instance that does not satisfy conditions set by the rule. Examples include:

- For a dynamic version like `1.+` certain versions may be explicitly rejected from selection.

- For a static version like `1.4` an instance may be rejected based on extra component metadata such as the Ivy branch attribute, allowing an instance from a subsequent repository to be used.

Rules are configured via the ComponentSelectionRules object. Each rule configured will be called with a ComponentSelection object as an argument which contains information about the candidate version being considered. Calling ComponentSelection.reject(java.lang.String) causes the given candidate version to be explicitly rejected, in which case the candidate will not be considered for the selector.

The following example shows a rule that disallows a particular version of a module but allows the dynamic version to choose the next best candidate.

build.gradle.kts

```
configurations {
    create("rejectConfig") {
        resolutionStrategy {
            componentSelection {
                // Accept the highest version matching the requested version that
isn't '1.5'
                all {
                    if (candidate.group == "org.sample" && candidate.module ==
"api" && candidate.version == "1.5") {
                        reject("version 1.5 is broken for 'org.sample:api'")
                    }
                }
            }
        }
    }
}

dependencies {
    "rejectConfig"("org.sample:api:1.+")
}
```

build.gradle

```gradle
configurations {
    rejectConfig {
        resolutionStrategy {
            componentSelection {
                // Accept the highest version matching the requested version that
isn't '1.5'
                all { ComponentSelection selection ->
                    if (selection.candidate.group == 'org.sample' && selection
.candidate.module == 'api' && selection.candidate.version == '1.5') {
                        selection.reject("version 1.5 is broken for
'org.sample:api'")
                    }
                }
            }
        }
    }
}

dependencies {
    rejectConfig "org.sample:api:1.+"
}
```

Note that version selection is applied starting with the highest version first. The version selected will be the first version found that all component selection rules accept. A version is considered accepted if no rule explicitly rejects it.

Similarly, rules can be targeted at specific modules. Modules must be specified in the form of `group:module`.

```kotlin
configurations {
    create("targetConfig") {
        resolutionStrategy {
            componentSelection {
                withModule("org.sample:api") {
                    if (candidate.version == "1.5") {
                        reject("version 1.5 is broken for 'org.sample:api'")
                    }
                }
            }
        }
    }
}
```

```groovy
configurations {
    targetConfig {
        resolutionStrategy {
            componentSelection {
                withModule("org.sample:api") { ComponentSelection selection ->
                    if (selection.candidate.version == "1.5") {
                        selection.reject("version 1.5 is broken for
'org.sample:api'")
                    }
                }
            }
        }
    }
}
```

Component selection rules can also consider component metadata when selecting a version. Possible additional metadata that can be considered are ComponentMetadata and IvyModuleDescriptor. Note that this extra information may not always be available and thus should be checked for null values.

build.gradle.kts

```
configurations {
    create("metadataRulesConfig") {
        resolutionStrategy {
            componentSelection {
                // Reject any versions with a status of 'experimental'
                all {
                    if (candidate.group == "org.sample" && metadata?.status ==
"experimental") {
                        reject("don't use experimental candidates from
'org.sample'")
                    }
                }
                // Accept the highest version with either a "release" branch or a
status of 'milestone'
                withModule("org.sample:api") {
                    if (getDescriptor(IvyModuleDescriptor::class)?.branch !=
"release" && metadata?.status != "milestone") {
                        reject("'org.sample:api' must have testing branch or
milestone status")
                    }
                }
            }
        }
    }
}
```

build.gradle

```
configurations {
    metadataRulesConfig {
        resolutionStrategy {
            componentSelection {
                // Reject any versions with a status of 'experimental'
                all { ComponentSelection selection ->
                    if (selection.candidate.group == 'org.sample' && selection
.metadata?.status == 'experimental') {
                        selection.reject("don't use experimental candidates from
'org.sample'")
                    }
                }
                // Accept the highest version with either a "release" branch or a
status of 'milestone'
                withModule('org.sample:api') { ComponentSelection selection ->
                    if (selection.getDescriptor(IvyModuleDescriptor)?.branch !=
"release" && selection.metadata?.status != 'milestone') {
                        selection.reject("'org.sample:api' must be a release
branch or have milestone status")
                    }
                }
            }
        }
    }
}
```

Note that a ComponentSelection argument is *always* required as parameter when declaring a component selection rule.

= Locking dependency versions

Use of dynamic dependency versions (e.g. `1.+` or `[1.0,2.0)`) makes builds non-deterministic. This causes builds to break without any obvious change, and worse, can be caused by a transitive dependency that the build author has no control over.

To achieve reproducible builds, it is necessary to *lock* versions of dependencies and transitive dependencies such that a build with the same inputs will always resolve the same module versions. This is called *dependency locking*.

It enables, amongst others, the following scenarios:

- Companies dealing with multi repositories no longer need to rely on `-SNAPSHOT` or changing dependencies, which sometimes result in cascading failures when a dependency introduces a bug or incompatibility. Now dependencies can be declared against major or minor version range, enabling to test with the latest versions on CI while leveraging locking for stable developer builds.

- Teams that want to always use the latest of their dependencies can use dynamic versions, locking their dependencies only for releases. The release tag will contain the lock states, allowing that build to be fully reproducible when bug fixes need to be developed.

Combined with publishing resolved versions, you can also replace the declared dynamic version part at publication time. Consumers will instead see the versions that your release resolved.

Locking is enabled per dependency configuration. Once enabled, you must create an initial lock state. It will cause Gradle to verify that resolution results do not change, resulting in the same selected dependencies even if newer versions are produced. Modifications to your build that would impact the resolved set of dependencies will cause it to fail. This makes sure that changes, either in published dependencies or build definitions, do not alter resolution without adapting the lock state.

Dependency locking makes sense only with dynamic versions. It will have no impact on changing versions (like `-SNAPSHOT`) whose coordinates remain the same, though the content may change. Gradle will even emit a warning when persisting lock state and changing dependencies are present in the resolution result.

== Enabling locking on configurations

Locking of a configuration happens through the ResolutionStrategy:

build.gradle.kts

```
configurations {
    compileClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
}
```

build.gradle

```
configurations {
    compileClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
}
```

NOTE Only configurations that can be resolved will have lock state attached to them. Applying locking on non resolvable-configurations is simply a no-op.

Or the following, as a way to lock all configurations:

build.gradle.kts

```
dependencyLocking {
    lockAllConfigurations()
}
```

build.gradle

```
dependencyLocking {
    lockAllConfigurations()
}
```

NOTE The above will lock all *project* configurations, but not the *buildscript* ones.

You can also disable locking on a specific configuration. This can be useful if a plugin configured locking on all configurations but you happen to add one that should not be locked.

build.gradle.kts

```
configurations.compileClasspath {
    resolutionStrategy.deactivateDependencyLocking()
}
```

build.gradle

```
configurations {
    compileClasspath {
        resolutionStrategy.deactivateDependencyLocking()
    }
}
```

=== Locking buildscript classpath configuration

If you apply plugins to your build, you may want to leverage dependency locking there as well. In order to lock the `classpath` configuration used for script plugins, do the following:

build.gradle.kts

```
buildscript {
    configurations.classpath {
        resolutionStrategy.activateDependencyLocking()
    }
}
```

build.gradle

```
buildscript {
    configurations.classpath {
        resolutionStrategy.activateDependencyLocking()
    }
}
```

Generating and updating dependency locks

In order to generate or update lock state, you specify the `--write-locks` command line argument in addition to the normal tasks that would trigger configurations to be resolved. This will cause the creation of lock state for each resolved configuration in that build execution. Note that if lock state existed previously, it is overwritten.

NOTE	Gradle will not write lock state to disk if the build fails. This prevents persisting possibly invalid state.

Lock all configurations in one build execution

When locking multiple configurations, you may want to lock them all at once, during a single build execution.

For this, you have two options:

- Run `gradle dependencies --write-locks`. This will effectively lock all resolvable configurations that have locking enabled. Note that in a multi project setup, `dependencies` only is executed on *one* project, the root one in this case.

- Declare a custom task that resolves all configurations. This does not work for Android projects.

build.gradle.kts

```
tasks.register("resolveAndLockAll") {
    notCompatibleWithConfigurationCache("Filters configurations at execution
time")
    doFirst {
        require(gradle.startParameter.isWriteDependencyLocks) { "$path must be run
from the command line with the `--write-locks` flag" }
    }
    doLast {
        configurations.filter {
            // Add any custom filtering on the configurations to be resolved
            it.isCanBeResolved
        }.forEach { it.resolve() }
    }
}
```

```
tasks.register('resolveAndLockAll') {
    notCompatibleWithConfigurationCache("Filters configurations at execution time
")
    doFirst {
        assert gradle.startParameter.writeDependencyLocks : "$path must be run
from the command line with the `--write-locks` flag"
    }
    doLast {
        configurations.findAll {
            // Add any custom filtering on the configurations to be resolved
            it.canBeResolved
        }.each { it.resolve() }
    }
}
```

That second option, with proper selection of configurations, can be the only option in the native world, where not all configurations can be resolved on a single platform.

== Lock state location and format

Lock state will be preserved in a file located at the root of the project or subproject directory. Each file is named `gradle.lockfile`. The one exception to this rule is for the lock file for the buildscript itself. In that case the file will be named `buildscript-gradle.lockfile`.

The lockfile will have the following content:

gradle.lockfile

```
# This is a Gradle generated file for dependency locking.
# Manual edits can break the build and are not advised.
# This file is expected to be part of source control.
org.springframework:spring-beans:5.0.5.RELEASE=compileClasspath, runtimeClasspath
org.springframework:spring-core:5.0.5.RELEASE=compileClasspath, runtimeClasspath
org.springframework:spring-jcl:5.0.5.RELEASE=compileClasspath, runtimeClasspath
empty=annotationProcessor
```

- Each line still represents a single dependency in the `group:artifact:version` notation
- It then lists all configurations that contain the given dependency
- Module and configurations are ordered alphabetically, to ease diffs
- The last line of the file lists all empty configurations, that is configurations known to have no dependencies

which matches the following dependency declaration:

build.gradle.kts

```kotlin
configurations {
    compileClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
    runtimeClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
    annotationProcessor {
        resolutionStrategy.activateDependencyLocking()
    }
}

dependencies {
    implementation("org.springframework:spring-beans:[5.0,6.0)")
}
```

build.gradle

```groovy
configurations {
    compileClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
    runtimeClasspath {
        resolutionStrategy.activateDependencyLocking()
    }
    annotationProcessor {
        resolutionStrategy.activateDependencyLocking()
    }
}

dependencies {
    implementation 'org.springframework:spring-beans:[5.0,6.0)'
}
```

=== Migrating from the lockfile per configuration format

If your project uses the legacy lock file format of a file per locked configuration, follow these instructions to migrate to the new format:

- Follow the documentation for writing or updating dependency lock state.
- Upon writing the single lock file per project, Gradle will also delete all lock files per configuration for which the state was transferred.

| NOTE | Migration can be done one configuration at a time. Gradle will keep sourcing the lock state from the per configuration files as long as there is no information for that configuration in the single lock file. |

=== Configuring the per project lock file name and location

When using the single lock file per project, you can configure its name and location. The main reason for providing this is to enable having a file name that is determined by some project properties, effectively allowing a single project to store different lock state for different execution contexts. One trivial example in the JVM ecosystem is the Scala version that is often found in artifact coordinates.

build.gradle.kts

```
val scalaVersion = "2.12"
dependencyLocking {
    lockFile = file("$projectDir/locking/gradle-${scalaVersion}.lockfile")
}
```

build.gradle

```
def scalaVersion = "2.12"
dependencyLocking {
    lockFile = file("$projectDir/locking/gradle-${scalaVersion}.lockfile")
}
```

== Running a build with lock state present

The moment a build needs to resolve a configuration that has locking enabled and it finds a matching lock state, it will use it to verify that the given configuration still resolves the same versions.

A successful build indicates that the same dependencies are used as stored in the lock state, regardless if new versions matching the dynamic selector have been produced.

The complete validation is as follows:

- Existing entries in the lock state must be matched in the build
  - A version mismatch or missing resolved module causes a build failure
- Resolution result must not contain extra dependencies compared to the lock state

=== Fine tuning dependency locking behaviour with lock mode

While the default lock mode behaves as described above, two other modes are available:

Strict mode

In this mode, in addition to the validations above, dependency locking will fail if a configuration marked as *locked* does not have lock state associated with it.

Lenient mode

In this mode, dependency locking will still pin dynamic versions but otherwise changes to the dependency resolution are no longer errors.

The lock mode can be controlled from the `dependencyLocking` block as shown below:

build.gradle.kts

```
dependencyLocking {
    lockMode = LockMode.STRICT
}
```

build.gradle

```
dependencyLocking {
    lockMode = LockMode.STRICT
}
```

Selectively updating lock state entries

In order to update only specific modules of a configuration, you can use the `--update-locks` command line flag. It takes a comma (`,`) separated list of module notations. In this mode, the existing lock state is still used as input to resolution, filtering out the modules targeted by the update.

```
⬡ gradle classes --update-locks org.apache.commons:commons-lang3,org.slf4j:slf4j-api
```

Wildcards, indicated with `*`, can be used in the group or module name. They can be the only character or appear at the end of the group or module respectively. The following wildcard notation examples are valid:

- `org.apache.commons:*`: will let all modules belonging to group `org.apache.commons` update
- `*:guava`: will let all modules named `guava`, whatever their group, update
- `org.springframework.spring*:spring*`: will let all modules having their group starting with `org.springframework.spring` and name starting with `spring` update

NOTE	The resolution may cause other module versions to update, as dictated by the Gradle resolution rules.

Disabling dependency locking

1. Make sure that the configuration for which you no longer want locking is not configured with locking.
2. Next time you update the save lock state, Gradle will automatically clean up all stale lock state from it.

Gradle needs to resolve a configuration, no longer marked as locked, to detect that associated lock state can be dropped.

Ignoring specific dependencies from the lock state

Dependency locking can be used in cases where reproducibility is not the main goal. As a build author, you may want to have different frequency of dependency version updates, based on their origin for example. In that case, it might be convenient to ignore some dependencies because you always want to use the latest version for those. An example is the internal dependencies in an organization which should always use the latest version as opposed to third party dependencies which have a different upgrade cycle.

WARNING	This feature can break reproducibility and should be used with caution. There are scenarios that are better served with leveraging different lock modes or using different names for lock files.

You can configure ignored dependencies in the `dependencyLocking` project extension:

build.gradle.kts

```kotlin
dependencyLocking {
    ignoredDependencies.add("com.example:*")
}
```

build.gradle

```groovy
dependencyLocking {
    ignoredDependencies.add('com.example:*')
}
```

The notation is a `<group>:<name>` dependency notation, where `*` can be used as a trailing wildcard. See the description on updating lock files for more details. Note that the value `*:*` is not accepted as it is equivalent to disabling locking.

Ignoring dependencies will have the following effects:

- An ignored dependency applies to all locked configurations. The setting is project scoped.

- Ignoring a dependency does not mean lock state ignores its transitive dependencies.

- There is no validation that an ignored dependency is present in any configuration resolution.

- If the dependency is present in lock state, loading it will filter out the dependency.

- If the dependency is present in the resolution result, it will be ignored when validating that resolution matches the lock state.

- Finally, if the dependency is present in the resolution result and the lock state is persisted, it will be absent from the written lock state.

== Locking limitations

- Locking cannot yet be applied to source dependencies.

== Nebula locking plugin

This feature is inspired by the Nebula Gradle dependency lock plugin.

== CONTROLLING TRANSITIVES

= Upgrading versions of transitive dependencies

== Direct dependencies vs dependency constraints

A component may have two different kinds of dependencies:

- direct dependencies are *directly required by the component*. A direct dependency is also referred to as a *first level dependency*. For example, if your project source code requires Guava, Guava should be declared as *direct dependency*.

- transitive dependencies are dependencies that your component needs, but only because another dependency needs them.

It's quite common that issues with dependency management are about *transitive dependencies*. Often developers incorrectly fix transitive dependency issues by adding *direct dependencies*. To avoid this, Gradle provides the concept of *dependency constraints*.

== Adding constraints on transitive dependencies

Dependency constraints allow you to define the version or the version range of both dependencies declared in the build script and transitive dependencies. It is the preferred method to express constraints that should be applied to all dependencies of a configuration. When Gradle attempts to resolve a dependency to a module version, all dependency

declarations with version, all transitive dependencies and all dependency constraints for that module are taken into consideration. The highest version that matches all conditions is selected. If no such version is found, Gradle fails with an error showing the conflicting declarations. If this happens you can adjust your dependencies or dependency constraints declarations, or make other adjustments to the transitive dependencies if needed. Similar to dependency declarations, dependency constraint declarations are scoped by configurations and can therefore be selectively defined for parts of a build. If a dependency constraint influenced the resolution result, any type of dependency resolve rules may still be applied afterwards.

build.gradle.kts

```kotlin
dependencies {
    implementation("org.apache.httpcomponents:httpclient")
    constraints {
        implementation("org.apache.httpcomponents:httpclient:4.5.3") {
            because("previous versions have a bug impacting this application")
        }
        implementation("commons-codec:commons-codec:1.11") {
            because("version 1.9 pulled from httpclient has bugs affecting this
application")
        }
    }
}
```

build.gradle

```groovy
dependencies {
    implementation 'org.apache.httpcomponents:httpclient'
    constraints {
        implementation('org.apache.httpcomponents:httpclient:4.5.3') {
            because 'previous versions have a bug impacting this application'
        }
        implementation('commons-codec:commons-codec:1.11') {
            because 'version 1.9 pulled from httpclient has bugs affecting this
application'
        }
    }
}
```

In the example, all versions are omitted from the dependency declaration. Instead, the versions are defined in the constraints block. The version definition for `commons-codec:1.11` is only taken into account if `commons-codec` is brought in as transitive dependency, since `commons-codec` is not defined as dependency in the project. Otherwise, the constraint has no effect. Dependency constraints can also define a rich version constraint and support strict versions to enforce a version even if it contradicts with the version defined by a transitive dependency (e.g. if the version needs to be downgraded).

> **NOTE** Dependency constraints are only published when using Gradle Module Metadata. This means that currently they are only fully supported if Gradle is used for publishing and consuming (i.e. they are 'lost' when consuming modules with Maven or Ivy).

Dependency constraints themselves can also be added transitively.

= Downgrading versions and excluding dependencies

== Overriding transitive dependency versions

Gradle resolves any dependency version conflicts by selecting the latest version found in the dependency graph. Some projects might need to divert from the default behavior and enforce an earlier version of a dependency e.g. if the source code of the project depends on an older API of a dependency than some of the external libraries.

Forcing a version of a dependency requires a conscious decision. Changing the version of a transitive dependency might lead to runtime errors if external libraries do not properly function without them. Consider upgrading your source code to use a newer version of the library as an alternative approach.

In general, forcing dependencies is done to downgrade a dependency. There might be different use cases for downgrading:

- a bug was discovered in the latest release
- your code depends on a lower version which is not binary compatible
- your code doesn't depend on the code paths which need a higher version of a dependency

In all situations, this is best expressed saying that your code *strictly depends on* a version of a transitive. Using strict versions, you will effectively depend on the version you declare, even if a transitive dependency says otherwise.

Strict dependencies are to some extent similar to Maven's *nearest first* strategy, but there are subtle differences:

- *strict dependencies* don't suffer an ordering problem: they are applied transitively to the subgraph, and it doesn't matter in which order dependencies are declared.
- conflicting strict dependencies will trigger a build failure that you have to resolve

- strict dependencies can be used with rich versions, meaning that it's better to express the requirement in terms of a *strict range* combined with a single *preferred version*.

Let's say a project uses the HttpClient library for performing HTTP calls. HttpClient pulls in Commons Codec as transitive dependency with version 1.10. However, the production source code of the project requires an API from Commons Codec 1.9 which is not available in 1.10 anymore. A dependency version can be enforced by declaring it as strict it in the build script:

build.gradle.kts

```
dependencies {
    implementation("org.apache.httpcomponents:httpclient:4.5.4")
    implementation("commons-codec:commons-codec") {
        version {
            strictly("1.9")
        }
    }
}
```

build.gradle

```
dependencies {
    implementation 'org.apache.httpcomponents:httpclient:4.5.4'
    implementation('commons-codec:commons-codec') {
        version {
            strictly '1.9'
        }
    }
}
```

=== Consequences of using strict versions

Using a strict version must be carefully considered, in particular by library authors. As the *producer*, a strict version will effectively behave like a *force*: the version declaration takes precedence over whatever is found in the transitive dependency graph. In particular, a *strict version* will override any other *strict version* on the same module found transitively.

However, for consumers, strict versions are still considered globally during graph resolution and *may trigger an error* if the consumer disagrees.

For example, imagine that your project `B` *strictly* depends on `C:1.0`. Now, a consumer, `A`, depends on both `B` and `C:1.1`.

Then this would trigger a resolution error because `A` says it needs `C:1.1` but `B`, *within its subgraph*, strictly needs `1.0`. This means that if you choose a *single version* in a strict constraint, then the version can *no longer be upgraded,* unless the consumer also sets a strict version constraint on the same module.

In the example above, `A` would have to say it *strictly depends on 1.1*.

For this reason, a good practice is that if you use *strict versions*, you should express them in terms of ranges and a preferred version within this range. For example, `B` might say, instead of `strictly 1.0`, that it *strictly depends* on the `[1.0, 2.0[` range, but *prefers* `1.0`. Then if a consumer chooses 1.1 (or any other version in the range), the build will *no longer fail* (constraints are resolved).

=== Forced dependencies vs strict dependencies

If the project requires a specific version of a dependency at the configuration-level this can be achieved by calling the method [ResolutionStrategy.force(java.lang.Object[])](#).

build.gradle.kts

```kotlin
configurations {
    "compileClasspath" {
        resolutionStrategy.force("commons-codec:commons-codec:1.9")
    }
}

dependencies {
    implementation("org.apache.httpcomponents:httpclient:4.5.4")
}
```

build.gradle

```
configurations {
    compileClasspath {
        resolutionStrategy.force 'commons-codec:commons-codec:1.9'
    }
}

dependencies {
    implementation 'org.apache.httpcomponents:httpclient:4.5.4'
}
```

== Excluding transitive dependencies

While the previous section showed how you can enforce a certain version of a transitive dependency, this section covers *excludes* as a way to remove a transitive dependency completely.

Similar to forcing a version of a dependency, excluding a dependency completely requires a conscious decision. Excluding a transitive dependency might lead to runtime errors if external libraries do not properly function without them. If you use excludes, make sure that you do not utilise any code path requiring the excluded dependency by sufficient test coverage.

Transitive dependencies can be excluded on the level of a declared dependency. Exclusions are spelled out as a key/value pair via the attributes `group` and/or `module` as shown in the example below. For more information, refer to ModuleDependency.exclude(java.util.Map).

build.gradle.kts

```
dependencies {
    implementation("commons-beanutils:commons-beanutils:1.9.4") {
        exclude(group = "commons-collections", module = "commons-collections")
    }
}
```

build.gradle

```
dependencies {
    implementation('commons-beanutils:commons-beanutils:1.9.4') {
        exclude group: 'commons-collections', module: 'commons-collections'
    }
}
```

In this example, we add a dependency to `commons-beanutils` but exclude the transitive dependency `commons-collections`. In our code, shown below, we only use one method from the beanutils library, `PropertyUtils.setSimpleProperty()`. Using this method for existing setters does not require any functionality from `commons-collections` as we verified through test coverage.

src/main/java/Main.java

```java
import org.apache.commons.beanutils.PropertyUtils;

public class Main {
    public static void main(String[] args) throws Exception {
        Object person = new Person();
        PropertyUtils.setSimpleProperty(person, "name", "Bart Simpson");
        PropertyUtils.setSimpleProperty(person, "age", 38);
    }
}
```

Effectively, we are expressing that we only use a *subset* of the library, which does not require the `commons-collection` library. This can be seen as implicitly defining a [feature variant](#) that has not been explicitly declared by `commons-beanutils` itself. However, the risk of breaking an untested code path increased by doing this.

For example, here we use the `setSimpleProperty()` method to modify properties defined by setters in the `Person` class, which works fine. If we would attempt to set a property not existing on the class, we *should* get an error like `Unknown property on class Person`. However, because the error handling path uses a class from `commons-collections`, the error we now get is `NoClassDefFoundError: org/apache/commons/collections/FastHashMap`. So if our code would be more dynamic, and we would forget to cover the error case sufficiently, consumers of our library might be confronted with unexpected errors.

This is only an example to illustrate potential pitfalls. In practice, larger libraries or frameworks can bring in a huge set of dependencies. If those libraries fail to declare features separately and can only be consumed in a "all or nothing" fashion, excludes can be a valid method to reduce the library to the feature set actually required.

On the upside, Gradle's exclude handling is, in contrast to Maven, taking the whole dependency graph into account. So if there are multiple dependencies on a library, excludes are only exercised if all dependencies agree on them. For example, if we add `opencsv` as another dependency to our project above, which also depends on `commons-beanutils`, `commons-collection` is no longer excluded as `opencsv` itself does **not** exclude it.

build.gradle.kts

```
dependencies {
    implementation("commons-beanutils:commons-beanutils:1.9.4") {
        exclude(group = "commons-collections", module = "commons-collections")
    }
    implementation("com.opencsv:opencsv:4.6") // depends on 'commons-beanutils'
without exclude and brings back 'commons-collections'
}
```

build.gradle

```
dependencies {
    implementation('commons-beanutils:commons-beanutils:1.9.4') {
        exclude group: 'commons-collections', module: 'commons-collections'
    }
    implementation 'com.opencsv:opencsv:4.6' // depends on 'commons-beanutils'
without exclude and brings back 'commons-collections'
}
```

If we still want to have commons-collections excluded, because our combined usage of commons-beanutils and opencsv does not need it, we need to exclude it from the transitive dependencies of opencsv as well.

build.gradle.kts

```kotlin
dependencies {
    implementation("commons-beanutils:commons-beanutils:1.9.4") {
        exclude(group = "commons-collections", module = "commons-collections")
    }
    implementation("com.opencsv:opencsv:4.6") {
        exclude(group = "commons-collections", module = "commons-collections")
    }
}
```

build.gradle

```groovy
dependencies {
    implementation('commons-beanutils:commons-beanutils:1.9.4') {
        exclude group: 'commons-collections', module: 'commons-collections'
    }
    implementation('com.opencsv:opencsv:4.6') {
        exclude group: 'commons-collections', module: 'commons-collections'
    }
}
```

Historically, excludes were also used as a band aid to fix other issues not supported by some dependency management systems. Gradle however, offers a variety of features that might be better suited to solve a certain use case. You may consider to look into the following features:

- Update or downgrade dependency versions: If versions of dependencies clash, it is usually better to adjust the version through a dependency constraint, instead of attempting to exclude the dependency with the undesired version.

- Component Metadata Rules: If a library's metadata is clearly wrong, for example if it includes a compile time dependency which is never needed at compile time, a possible solution is to remove the dependency in a component metadata rule. By this, you tell Gradle that a dependency between two modules is never needed — i.e. the metadata was wrong — and therefore should **never** be considered. If you are developing a library, you have to be aware that this information is not published, and so sometimes an *exclude* can be the better alternative.

- Resolving mutually exclusive dependency conflicts: Another situation that you often see solved by excludes is that two dependencies cannot be used together because they represent two implementations of the same thing (the same capability). Some popular examples are clashing logging API implementations (like `log4j` and `log4j-over-slf4j`) or modules that have different coordinates in different versions (like `com.google.collections` and `guava`). In these cases, if this information is not known to Gradle, it is recommended to add the missing capability information via component metadata rules as described in the declaring component capabilities section. Even if you are developing a library, and your consumers will have to deal with resolving the conflict again, it is often the right solution to leave the decision to the final consumers of libraries. I.e. you as a library author should not have to decide which logging implementation your consumers use in the end.

= Sharing dependency versions between projects

== Central declaration of dependencies

=== Using a version catalog

A *version catalog* is a list of dependencies, represented as dependency coordinates, that a user can pick from when declaring dependencies in a build script.

For example, instead of declaring a dependency using a string notation, the dependency coordinates can be picked from a *version catalog*:

build.gradle.kts

```
dependencies {
    implementation(libs.groovy.core)
}
```

build.gradle

```
dependencies {
    implementation(libs.groovy.core)
}
```

In this context, `libs` is a catalog and `groovy` represents a dependency available in this catalog. A version catalog provides a number of advantages over declaring the dependencies directly in build scripts:

- For each catalog, Gradle generates *type-safe accessors* so that you can easily add dependencies with autocompletion in the IDE.
- Each catalog is visible to all projects of a build. It is a central place to declare a version of a dependency and to make sure that a change to that version applies to every subproject.
- Catalogs can declare dependency bundles, which are "groups of dependencies" that are commonly used together.
- Catalogs can separate the group and name of a dependency from its actual version and use version references instead, making it possible to share a version declaration between multiple dependencies.

Adding a dependency using the `libs.someLib` notation works exactly like if you had hardcoded the group, artifact and version directly in the build script.

WARNING	A dependency catalog doesn't enforce the version of a dependency: like a regular dependency notation, it declares the requested version or a rich version. That version is not necessarily the version that is selected during conflict resolution.

=== Declaring a version catalog

Version catalogs can be declared in the `settings.gradle(.kts)` file. In the example above, in order to make `groovy` available via the `libs` catalog, we need to associate an alias with GAV (group, artifact, version) coordinates:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            library("groovy-core", "org.codehaus.groovy:groovy:3.0.5")
            library("groovy-json", "org.codehaus.groovy:groovy-json:3.0.5")
            library("groovy-nio", "org.codehaus.groovy:groovy-nio:3.0.5")
            library("commons-lang3", "org.apache.commons", "commons-
lang3").version {
                strictly("[3.8, 4.0[")
                prefer("3.9")
            }
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            library('groovy-core', 'org.codehaus.groovy:groovy:3.0.5')
            library('groovy-json', 'org.codehaus.groovy:groovy-json:3.0.5')
            library('groovy-nio', 'org.codehaus.groovy:groovy-nio:3.0.5')
            library('commons-lang3', 'org.apache.commons', 'commons-lang3')
.version {
                strictly '[3.8, 4.0['
                prefer '3.9'
            }
        }
    }
}
```

==== Aliases and their mapping to type safe accessors

Aliases must consist of a series of identifiers separated by a dash (`-`, recommended), an underscore (`_`) or a dot (`.`). Identifiers themselves must consist of ascii characters, preferably lowercase, eventually followed by numbers.

For example:

- `guava` is a valid alias
- `groovy-core` is a valid alias
- `commons-lang3` is a valid alias
- `androidx.awesome.lib` is also a valid alias
- but `this.#is.not!`

Then type safe accessors are generated for *each subgroup.* For example, given the following aliases in a version catalog named `libs`:

`guava`, `groovy-core`, `groovy-xml`, `groovy-json`, `androidx.awesome.lib`

We would generate the following type-safe accessors:

- `libs.guava`
- `libs.groovy.core`
- `libs.groovy.xml`
- `libs.groovy.json`
- `libs.androidx.awesome.lib`

Where the `libs` prefix comes from the version catalog name.

In case you want to avoid the generation of a subgroup accessor, we recommend relying on case to differentiate. For example the aliases `groovyCore`, `groovyJson` and `groovyXml` would be mapped to the `libs.groovyCore`, `libs.groovyJson` and `libs.groovyXml` accessors respectively.

When declaring aliases, it's worth noting that any of the `-`, `_` and `.` characters can be used as separators, but the generated catalog will have all normalized to `.`: for example `foo-bar` as an alias is converted to `foo.bar` automatically.

Some keywords are reserved, so they cannot be used as an alias. Next words cannot be used as an alias:

- extensions
- class
- convention

Additional to that next words cannot be used as a first subgroup of an alias for dependencies (for bundles, versions and plugins this restriction doesn't apply):

- bundles

- versions

- plugins

So for example for dependencies an alias `versions-dependency` is not valid, but `versionsDependency` or `dependency-versions` are valid.

==== Dependencies with same version numbers

In the first example in declaring a version catalog, we can see that we declare 3 aliases for various components of the `groovy` library and that all of them share the same version number.

Instead of repeating the same version number, we can declare a version and reference it:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            version("groovy", "3.0.5")
            version("checkstyle", "8.37")
            library("groovy-core", "org.codehaus.groovy",
"groovy").versionRef("groovy")
            library("groovy-json", "org.codehaus.groovy", "groovy-
json").versionRef("groovy")
            library("groovy-nio", "org.codehaus.groovy", "groovy-
nio").versionRef("groovy")
            library("commons-lang3", "org.apache.commons", "commons-
lang3").version {
                strictly("[3.8, 4.0[")
                prefer("3.9")
            }
        }
    }
}
```

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            version('groovy', '3.0.5')
            version('checkstyle', '8.37')
            library('groovy-core', 'org.codehaus.groovy', 'groovy').versionRef(
'groovy')
            library('groovy-json', 'org.codehaus.groovy', 'groovy-json')
.versionRef('groovy')
            library('groovy-nio', 'org.codehaus.groovy', 'groovy-nio').versionRef
('groovy')
            library('commons-lang3', 'org.apache.commons', 'commons-lang3')
.version {
                strictly '[3.8, 4.0['
                prefer '3.9'
            }
        }
    }
}
```

Versions declared separately are *also* available via type-safe accessors, making them usable for more use cases than dependency versions, in particular for tooling:

build.gradle.kts

```
checkstyle {
    // will use the version declared in the catalog
    toolVersion = libs.versions.checkstyle.get()
}
```

build.gradle

```
checkstyle {
    // will use the version declared in the catalog
    toolVersion = libs.versions.checkstyle.get()
}
```

If the alias of a declared version is also a prefix of some more specific alias, as in `libs.versions.zinc` and `libs.versions.zinc.apiinfo`, then the value of the more generic version is available via `asProvider()` on the type-safe accessor:

build.gradle.kts

```
scala {
    zincVersion = libs.versions.zinc.asProvider().get()
}
```

build.gradle

```
scala {
    zincVersion = libs.versions.zinc.asProvider().get()
}
```

Dependencies declared in a catalog are exposed to build scripts via an extension corresponding to their name. In the example above, because the catalog declared in settings is named `libs`, the extension is available via the name `libs` in all build scripts of the current build. Declaring dependencies using the following notation…

build.gradle.kts

```
dependencies {
    implementation(libs.groovy.core)
    implementation(libs.groovy.json)
    implementation(libs.groovy.nio)
}
```

build.gradle

```
dependencies {
    implementation libs.groovy.core
    implementation libs.groovy.json
    implementation libs.groovy.nio
}
```

…has **exactly the same** effect as writing:

build.gradle.kts

```
dependencies {
    implementation("org.codehaus.groovy:groovy:3.0.5")
    implementation("org.codehaus.groovy:groovy-json:3.0.5")
    implementation("org.codehaus.groovy:groovy-nio:3.0.5")
}
```

build.gradle

```
dependencies {
    implementation 'org.codehaus.groovy:groovy:3.0.5'
    implementation 'org.codehaus.groovy:groovy-json:3.0.5'
    implementation 'org.codehaus.groovy:groovy-nio:3.0.5'
}
```

Versions declared in the catalog are rich versions. Please refer to the version catalog builder API for the full version declaration support documentation.

==== Dependency bundles

Because it's frequent that some dependencies are systematically used together in different projects, a version catalog offers the concept of a "dependency bundle". A bundle is basically an alias for several dependencies. For example, instead of declaring 3 individual dependencies like above, you could write:

build.gradle.kts

```
dependencies {
    implementation(libs.bundles.groovy)
}
```

build.gradle

```
dependencies {
    implementation libs.bundles.groovy
}
```

The bundle named `groovy` needs to be declared in the catalog:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            version("groovy", "3.0.5")
            version("checkstyle", "8.37")
            library("groovy-core", "org.codehaus.groovy",
"groovy").versionRef("groovy")
            library("groovy-json", "org.codehaus.groovy", "groovy-
json").versionRef("groovy")
            library("groovy-nio", "org.codehaus.groovy", "groovy-
nio").versionRef("groovy")
            library("commons-lang3", "org.apache.commons", "commons-
lang3").version {
                strictly("[3.8, 4.0[")
                prefer("3.9")
            }
            bundle("groovy", listOf("groovy-core", "groovy-json", "groovy-nio"))
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            version('groovy', '3.0.5')
            version('checkstyle', '8.37')
            library('groovy-core', 'org.codehaus.groovy', 'groovy').versionRef(
'groovy')
            library('groovy-json', 'org.codehaus.groovy', 'groovy-json')
.versionRef('groovy')
            library('groovy-nio', 'org.codehaus.groovy', 'groovy-nio').versionRef
('groovy')
            library('commons-lang3', 'org.apache.commons', 'commons-lang3')
.version {
                strictly '[3.8, 4.0['
                prefer '3.9'
            }
            bundle('groovy', ['groovy-core', 'groovy-json', 'groovy-nio'])
        }
    }
}
```

The semantics are again equivalent: adding a single bundle is equivalent to adding all dependencies which are part of the bundle individually.

==== Plugins

In addition to libraries, version catalog supports declaring plugin versions. While libraries are represented by their group, artifact and version coordinates, Gradle plugins are identified by their id and version only. Therefore, they need to be declared separately:

| WARNING | You cannot use a plugin declared in a version catalog in your settings file or settings plugin (because catalogs are defined in settings themselves, it would be a chicken and egg problem). |

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            plugin("versions", "com.github.ben-manes.versions").version("0.45.0")
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            plugin('versions', 'com.github.ben-manes.versions').version('0.45.0')
        }
    }
}
```

Then the plugin is accessible in the `plugins` block and can be consumed in any project of the build using:

build.gradle.kts

```
plugins {
    `java-library`
    checkstyle
    alias(libs.plugins.versions)
}
```

build.gradle

```
plugins {
    id 'java-library'
    id 'checkstyle'
    // Use the plugin `versions` as declared in the `libs` version catalog
    alias(libs.plugins.versions)
}
```

==== Using multiple catalogs

Aside from the conventional `libs` catalog, you can declare any number of catalogs through the `Settings` API. This allows you to separate dependency declarations in multiple sources in a way that makes sense for your projects.

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("testLibs") {
            val junit5 = version("junit5", "5.7.1")
            library("junit-api", "org.junit.jupiter", "junit-jupiter-
api").versionRef(junit5)
            library("junit-engine", "org.junit.jupiter", "junit-jupiter-
engine").versionRef(junit5)
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        testLibs {
            def junit5 = version('junit5', '5.7.1')
            library('junit-api', 'org.junit.jupiter', 'junit-jupiter-api')
.versionRef(junit5)
            library('junit-engine', 'org.junit.jupiter', 'junit-jupiter-engine')
.versionRef(junit5)
        }
    }
}
```

Each catalog will generate an extension applied to all projects for accessing its content. As such it makes sense to reduce the chance of collisions by picking a name that reduces the potential conflicts. As an example, one option is to pick a name that ends with `Libs`.

=== The libs.versions.toml file

In addition to the settings API above, Gradle offers a conventional file to declare a catalog. If a `libs.versions.toml` file is found in the `gradle` subdirectory of the root build, then a catalog will be automatically declared with the contents of this file.

Declaring a `libs.versions.toml` file doesn't make it the single source of truth for dependencies: it's a conventional location where dependencies can be declared. As soon as you start using catalogs, it's strongly recommended to declare all your dependencies in a catalog and not hardcode group/artifact/version strings in build scripts. Be aware that it may happen that plugins add dependencies, which are dependencies defined outside of this file.

Just like `src/main/java` is a convention to find the Java sources, which doesn't prevent additional source directories to be declared (either in a build script or a plugin), the presence of the `libs.versions.toml` file doesn't prevent the declaration of dependencies elsewhere.

The presence of this file does, however, suggest that most dependencies, if not all, will be declared in this file. Therefore, updating a dependency version, for most users, should only consists of changing a line in this file.

By default, the `libs.versions.toml` file will be an input to the `libs` catalog. It is possible to change the name of the default catalog, for example if you already have an extension with the same name:

settings.gradle.kts

```
dependencyResolutionManagement {
    defaultLibrariesExtensionName = "projectLibs"
}
```

settings.gradle

```
dependencyResolutionManagement {
    defaultLibrariesExtensionName = 'projectLibs'
}
```

==== The version catalog TOML file format

The TOML file consists of 4 major sections:

- the `[versions]` section is used to declare versions which can be referenced by dependencies
- the `[libraries]` section is used to declare the aliases to coordinates
- the `[bundles]` section is used to declare dependency bundles
- the `[plugins]` section is used to declare plugins

For example:

The libs.versions.toml file

```
[versions]
groovy = "3.0.5"
checkstyle = "8.37"

[libraries]
groovy-core = { module = "org.codehaus.groovy:groovy", version.ref = "groovy" }
groovy-json = { module = "org.codehaus.groovy:groovy-json", version.ref = "groovy"
}
groovy-nio = { module = "org.codehaus.groovy:groovy-nio", version.ref = "groovy" }
commons-lang3 = { group = "org.apache.commons", name = "commons-lang3", version =
{ strictly = "[3.8, 4.0[", prefer="3.9" } }

[bundles]
groovy = ["groovy-core", "groovy-json", "groovy-nio"]

[plugins]
versions = { id = "com.github.ben-manes.versions", version = "0.45.0" }
```

Versions can be declared either as a single string, in which case they are interpreted as a *required* version, or as a rich versions:

```
[versions]
my-lib = { strictly = "[1.0, 2.0[", prefer = "1.2" }
```

Supported members of a version declaration are:

- `require`: the required version
- `strictly`: the strict version
- `prefer`: the preferred version
- `reject`: the list of rejected versions
- `rejectAll`: a boolean to reject all versions

Dependency declaration can either be declared as a simple string, in which case they are

interpreted as `group:artifact:version` coordinates, or separating the version declaration from the group and name:

NOTE	For aliases, the rules described in the section aliases and their mapping to type safe accessors apply as well.

Different dependency notations

```
[versions]
common = "1.4"

[libraries]
my-lib = "com.mycompany:mylib:1.4"
my-other-lib = { module = "com.mycompany:other", version = "1.4" }
my-other-lib2 = { group = "com.mycompany", name = "alternate", version = "1.4" }
mylib-full-format = { group = "com.mycompany", name = "alternate", version = {
require = "1.4" } }

[plugins]
short-notation = "some.plugin.id:1.4"
long-notation = { id = "some.plugin.id", version = "1.4" }
reference-notation = { id = "some.plugin.id", version.ref = "common" }
```

In case you want to reference a version declared in the `[versions]` section, you should use the `version.ref` property:

```
[versions]
some = "1.4"

[libraries]
my-lib = { group = "com.mycompany", name="mylib", version.ref="some" }
```

The TOML file format is very lenient and lets you write "dotted" properties as shortcuts to full object declarations. For example, this:

```
a.b.c="d"
```

is equivalent to:

```
a.b = { c = "d" }
```

or

```
a = { b = { c = "d" } }
```

See the TOML specification for details.

=== Type unsafe API

Version catalogs can be accessed through a type unsafe API. This API is available in situations where generated accessors are not. It is accessed through the version catalog extension:

build.gradle.kts

```kotlin
val versionCatalog =
    extensions.getByType<VersionCatalogsExtension>().named("libs")
println("Library aliases: ${versionCatalog.libraryAliases}")
dependencies {
    versionCatalog.findLibrary("groovy-json").ifPresent {
        implementation(it)
    }
}
```

build.gradle

```groovy
def versionCatalog = extensions.getByType(VersionCatalogsExtension).named("libs")
println "Library aliases: ${versionCatalog.libraryAliases}"
dependencies {
    versionCatalog.findLibrary("groovy-json").ifPresent {
        implementation(it)
    }
}
```

Check the version catalog API for all supported methods.

== Sharing catalogs

Version catalogs are used in a single build (possibly multi-project build) but may also be shared between builds. For example, an organization may want to create a catalog of dependencies that different projects, from different teams, may use.

=== Importing a catalog from a TOML file

The version catalog builder API supports including a model from an external file. This makes it possible to reuse the catalog of the main build for `buildSrc`, if needed. For example, the `buildSrc/settings.gradle(.kts)` file can include this file using:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            from(files("../gradle/libs.versions.toml"))
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            from(files("../gradle/libs.versions.toml"))
        }
    }
}
```

Only a single file will be accepted when using the VersionCatalogBuilder.from(Object dependencyNotation) method. This means that notations like Project.files(java.lang.Object...) must refer to a single file, otherwise the build will fail.

If a more complicated structure is required (version catalogs imported from multiple files), it's advisable to use a code-based approach, instead of TOML file.

> This technique can therefore be used to declare multiple catalogs from different files:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        // declares an additional catalog, named 'testLibs', from the 'test-
libs.versions.toml' file
        create("testLibs") {
            from(files("gradle/test-libs.versions.toml"))
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        // declares an additional catalog, named 'testLibs', from the 'test-
libs.versions.toml' file
        testLibs {
            from(files('gradle/test-libs.versions.toml'))
        }
    }
}
```

=== The version catalog plugin

While importing catalogs from local files is convenient, it doesn't solve the problem of sharing a catalog in an organization or for external consumers. One option to share a catalog is to write a settings plugin, publish it on the Gradle plugin portal or an internal repository, and let the consumers apply the plugin on their settings file.

Alternatively, Gradle offers a *version catalog* plugin, which offers the ability to declare, then publish a catalog.

To do this, you need to apply the `version-catalog` plugin:

build.gradle.kts

```
plugins {
    `version-catalog`
    `maven-publish`
}
```

build.gradle

```
plugins {
    id 'version-catalog'
    id 'maven-publish'
}
```

This plugin will then expose the catalog extension that you can use to declare a catalog:

build.gradle.kts

```
catalog {
    // declare the aliases, bundles and versions in this block
    versionCatalog {
        library("my-lib", "com.mycompany:mylib:1.2")
    }
}
```

build.gradle

```
catalog {
    // declare the aliases, bundles and versions in this block
    versionCatalog {
        library('my-lib', 'com.mycompany:mylib:1.2')
    }
}
```

Such a catalog can then be published by applying either the `maven-publish` or `ivy-publish` plugin and configuring the publication to use the `versionCatalog` component:

build.gradle.kts

```
publishing {
    publications {
        create<MavenPublication>("maven") {
            from(components["versionCatalog"])
        }
    }
}
```

build.gradle

```
publishing {
    publications {
        maven(MavenPublication) {
            from components.versionCatalog
        }
    }
}
```

When publishing such a project, a `libs.versions.toml` file will automatically be generated (and uploaded), which can then be consumed from other Gradle builds.

=== Importing a published catalog

A catalog produced by the version catalog plugin can be imported via the settings API:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("libs") {
            from("com.mycompany:catalog:1.0")
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        libs {
            from("com.mycompany:catalog:1.0")
        }
    }
}
```

==== Overwriting catalog versions

In case a catalog declares a version, you can overwrite the version when importing the catalog:

settings.gradle.kts

```
dependencyResolutionManagement {
    versionCatalogs {
        create("amendedLibs") {
            from("com.mycompany:catalog:1.0")
            // overwrite the "groovy" version declared in the imported catalog
            version("groovy", "3.0.6")
        }
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    versionCatalogs {
        amendedLibs {
            from("com.mycompany:catalog:1.0")
            // overwrite the "groovy" version declared in the imported catalog
            version("groovy", "3.0.6")
        }
    }
}
```

In the example above, any dependency which was using the `groovy` version as reference will be automatically updated to use `3.0.6`.

NOTE	Again, overwriting a version doesn't mean that the actual *resolved* dependency version will be the same: this only changes what is *imported*, that is to say what is used when declaring a dependency. The actual version will be subject to traditional conflict resolution, if any.

== Using a platform to control transitive versions

A platform is a special software component which can be used to control transitive dependency versions. In most cases it's exclusively composed of dependency constraints which will either *suggest* dependency versions or *enforce* some versions. As such, this is a perfect tool whenever you need to *share dependency versions between projects*. In this case, a project will typically be organized this way:

- a `platform` project which defines constraints for the various dependencies found in the different sub-projects
- a number of sub-projects which *depend on* the platform and declare dependencies *without version*

In the Java ecosystem, Gradle provides a plugin for this purpose.

It's also common to find platforms published as Maven BOMs which Gradle supports natively.

A dependency on a platform is created using the `platform` keyword:

build.gradle.kts

```kotlin
dependencies {
    // get recommended versions from the platform project
    api(platform(project(":platform")))
    // no version required
    api("commons-httpclient:commons-httpclient")
}
```

build.gradle

```groovy
dependencies {
    // get recommended versions from the platform project
    api platform(project(':platform'))
    // no version required
    api 'commons-httpclient:commons-httpclient'
}
```

This `platform` notation is a short-hand notation which actually performs several operations under the hood:

- it sets the org.gradle.category attribute to `platform`, which means that Gradle will select the *platform* component of the dependency.
- it sets the endorseStrictVersions behavior by default, meaning that if the platform declares strict dependencies, they will be enforced.

This means that by default, a dependency to a platform triggers the inheritance of all strict versions defined in that platform, which can be useful for platform authors to make sure that all consumers respect their decisions in terms of versions of dependencies. This can be turned off by explicitly calling the `doNotEndorseStrictVersions` method.

== Importing Maven BOMs

Gradle provides support for importing bill of materials (BOM) files, which are effectively `.pom` files that use `<dependencyManagement>` to control the dependency versions of direct and transitive dependencies. The BOM support in Gradle works similar to using `<scope>import</scope>` when depending on a BOM in Maven. In Gradle however, it is done via a regular dependency declaration on the BOM:

build.gradle.kts

```kotlin
dependencies {
    // import a BOM
    implementation(platform("org.springframework.boot:spring-boot-
dependencies:1.5.8.RELEASE"))

    // define dependencies without versions
    implementation("com.google.code.gson:gson")
    implementation("dom4j:dom4j")
}
```

build.gradle

```groovy
dependencies {
    // import a BOM
    implementation platform('org.springframework.boot:spring-boot-
dependencies:1.5.8.RELEASE')

    // define dependencies without versions
    implementation 'com.google.code.gson:gson'
    implementation 'dom4j:dom4j'
}
```

In the example, the versions of `gson` and `dom4j` are provided by the Spring Boot BOM. This way, if you are developing for a platform like Spring Boot, you do not have to declare any versions yourself but can rely on the versions the platform provides.

Gradle treats all entries in the `<dependencyManagement>` block of a BOM similar to Gradle's dependency constraints. This means that any version defined in the `<dependencyManagement>` block can impact the dependency resolution result. In order to qualify as a BOM, a `.pom` file needs to have `<packaging>pom</packaging>` set.

However often BOMs are not only providing versions as recommendations, but also a way to override any other version found in the graph. You can enable this behavior by using the `enforcedPlatform` keyword, instead of `platform`, when importing the BOM:

build.gradle.kts

```
dependencies {
    // import a BOM. The versions used in this file will override any other
version found in the graph
    implementation(enforcedPlatform("org.springframework.boot:spring-boot-
dependencies:1.5.8.RELEASE"))

    // define dependencies without versions
    implementation("com.google.code.gson:gson")
    implementation("dom4j:dom4j")

    // this version will be overridden by the one found in the BOM
    implementation("org.codehaus.groovy:groovy:1.8.6")
}
```

build.gradle

```
dependencies {
    // import a BOM. The versions used in this file will override any other
version found in the graph
    implementation enforcedPlatform('org.springframework.boot:spring-boot-
dependencies:1.5.8.RELEASE')

    // define dependencies without versions
    implementation 'com.google.code.gson:gson'
    implementation 'dom4j:dom4j'

    // this version will be overridden by the one found in the BOM
    implementation 'org.codehaus.groovy:groovy:1.8.6'
}
```

Using `enforcedPlatform` needs to be considered with care if your software component can be consumed by others. This declaration is effectively transitive and so will apply to the dependency graph of your consumers. Unfortunately they will have to use `exclude` if they happen to disagree with one of the forced versions. Instead, if your reusable software component has a strong opinion on some third party dependency versions, consider using a rich version declaration with a `strictly`.

Should I use a platform or a catalog?

Because platforms and catalogs both talk about dependency versions and can both be used to share dependency versions in a project, there might be a confusion regarding what to use and if one is preferable to the other.

In short, you should:

- use catalogs to only define dependencies and their versions for projects and to generate type-safe accessors
- use platform to apply versions to dependency graph and to affect dependency resolution

A catalog helps with centralizing the dependency versions and is only, as it name implies, a catalog of dependencies you can pick from. We recommend using it to declare the coordinates of your dependencies, in all cases. It will be used by Gradle to generate type-safe accessors, present short-hand notations for external dependencies and it allows sharing those coordinates between different projects easily. Using a catalog will not have any kind of consequence on downstream consumers: it's transparent to them.

A platform is a more heavyweight construct: it's a component of a dependency graph, like any other library. If you depend on a platform, that platform is itself a component in the graph. It means, in particular, that:

- Constraints defined in a platform can influence *transitive* dependencies, not only the direct dependencies of your project.
- A platform is versioned, and a transitive dependency in the graph can depend on a different version of the platform, causing various dependency upgrades.
- A platform can tie components together, and in particular can be used as a construct for aligning versions.
- A dependency on a platform is "inherited" by the consumers of your dependency: it means that a dependency on a platform can influence what versions of libraries would be used by your consumers even if you don't directly, or transitively, depend on components the platform references.

In summary, using a catalog is always a good engineering practice as it centralizes common definitions, allows sharing of dependency versions or plugin versions, but it is an "implementation detail" of the build: it will not be visible to consumers and unused elements of a catalog are just ignored.

A platform is meant to influence the dependency resolution graph, for example by adding constraints on transitive dependencies: it's a solution for structuring a dependency graph and influencing the resolution result.

In practice, your project can both use a catalog *and* declare a platform which itself uses the catalog:

```
plugins {
    `java-platform`
}

dependencies {
    constraints {
        api(libs.mylib)
    }
}
```

```
plugins {
    id 'java-platform'
}

dependencies {
    constraints {
        api(libs.mylib)
    }
}
```

= Aligning dependency versions

Dependency version alignment allows different modules belonging to the same logical group (a *platform*) to have identical versions in a dependency graph.

== Handling inconsistent module versions

Gradle supports aligning versions of modules which belong to the same "platform". It is often preferable, for example, that the API and implementation modules of a component are using the same version. However, because of the game of transitive dependency resolution, it is possible that different modules belonging to the same platform end up using different versions. For example, your project may depend on the `jackson-databind` and `vert.x` libraries, as illustrated below:

build.gradle.kts

```
dependencies {
    // a dependency on Jackson Databind
    implementation("com.fasterxml.jackson.core:jackson-databind:2.8.9")

    // and a dependency on vert.x
    implementation("io.vertx:vertx-core:3.5.3")
}
```

build.gradle

```
dependencies {
    // a dependency on Jackson Databind
    implementation 'com.fasterxml.jackson.core:jackson-databind:2.8.9'

    // and a dependency on vert.x
    implementation 'io.vertx:vertx-core:3.5.3'
}
```

Because `vert.x` depends on `jackson-core`, we would actually resolve the following dependency versions:

- `jackson-core` version `2.9.5` (brought by `vertx-core`)
- `jackson-databind` version `2.9.5` (by conflict resolution)
- `jackson-annotation` version `2.9.0` (dependency of `jackson-databind:2.9.5`)

It's easy to end up with a set of versions which do not work well together. To fix this, Gradle supports dependency version alignment, which is supported by the concept of platforms. A platform represents a set of modules which "work well together". Either because they are actually published as a whole (when one of the members of the platform is published, all other modules are also published with the same version), or because someone tested the modules and indicates that they work well together (typically, the Spring Platform).

== Aligning versions natively with Gradle

Gradle natively supports alignment of modules produced by Gradle. This is a direct consequence of the transitivity of dependency constraints. So if you have a multi-project build, and you wish that consumers get the same version of all your modules, Gradle provides a simple way to do this using the Java Platform Plugin.

For example, if you have a project that consists of 3 modules:

- `lib`
- `utils`
- `core`, depending on `lib` and `utils`

And a consumer that declares the following dependencies:

- `core` version 1.0
- `lib` version 1.1

Then by default resolution would select `core:1.0` and `lib:1.1`, because `lib` has no dependency on `core`. We can fix this by adding a new module in our project, a *platform*, that will add constraints on all the modules of your project:

```
plugins {
    `java-platform`
}

dependencies {
    // The platform declares constraints on all components that
    // require alignment
    constraints {
        api(project(":core"))
        api(project(":lib"))
        api(project(":utils"))
    }
}
```

```
plugins {
    id 'java-platform'
}

dependencies {
    // The platform declares constraints on all components that
    // require alignment
    constraints {
        api(project(":core"))
        api(project(":lib"))
        api(project(":utils"))
    }
}
```

Once this is done, we need to make sure that all modules now *depend on the platform*, like this:

build.gradle.kts

```kotlin
dependencies {
    // Each project has a dependency on the platform
    api(platform(project(":platform")))

    // And any additional dependency required
    implementation(project(":lib"))
    implementation(project(":utils"))
}
```

build.gradle

```groovy
dependencies {
    // Each project has a dependency on the platform
    api(platform(project(":platform")))

    // And any additional dependency required
    implementation(project(":lib"))
    implementation(project(":utils"))
}
```

It is important that the platform contains a constraint on all the components, but also that each component has a dependency on the platform. By doing this, whenever Gradle will add a dependency to a module of the platform on the graph, it will *also* include constraints on the other modules of the platform. This means that if we see another module belonging to the same platform, we will automatically upgrade to the same version.

In our example, it means that we first see `core:1.0`, which brings a platform `1.0` with constraints on `lib:1.0` and `lib:1.0`. Then we add `lib:1.1` which has a dependency on `platform:1.1`. By conflict resolution, we select the `1.1` platform, which has a constraint on `core:1.1`. Then we conflict resolve between `core:1.0` and `core:1.1`, which means that `core` and `lib` are now aligned properly.

NOTE	This behavior is enforced for published components only if you use Gradle Module Metadata.

== Aligning versions of modules not published with Gradle

Whenever the publisher doesn't use Gradle, like in our Jackson example, we can explain to Gradle that all Jackson modules "belong to" the same platform and benefit from the same behavior as with native alignment. There are two options to express that a set of modules belong to a platform:

1. A platform is **published** as a BOM and can be used: For example, `com.fasterxml.jackson:jackson-bom` can be used as platform. The information missing to Gradle in that case is that the platform should be added to the dependencies if one of its members is used.

2. No existing platform can be used. Instead, a **virtual platform** should be created by Gradle: In this case, Gradle builds up the platform itself based on all the members that are used.

To provide the missing information to Gradle, you can define component metadata rules as explained in the following.

=== Align versions of modules using a published BOM

```kotlin
abstract class JacksonBomAlignmentRule: ComponentMetadataRule {
    override fun execute(ctx: ComponentMetadataContext) {
        ctx.details.run {
            if (id.group.startsWith("com.fasterxml.jackson")) {
                // declare that Jackson modules belong to the platform defined by
the Jackson BOM
                belongsTo("com.fasterxml.jackson:jackson-bom:${id.version}",
false)
            }
        }
    }
}
```

```groovy
abstract class JacksonBomAlignmentRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext ctx) {
        ctx.details.with {
            if (id.group.startsWith("com.fasterxml.jackson")) {
                // declare that Jackson modules belong to the platform defined by
the Jackson BOM
                belongsTo("com.fasterxml.jackson:jackson-bom:${id.version}",
false)
            }
        }
    }
}
```

By using the `belongsTo` with `false` (**not** virtual), we declare that all modules belong to the same *published platform*. In this case, the platform is `com.fasterxml.jackson:jackson-bom` and Gradle will look for it, as for any other module, in the declared repositories.

```kotlin
dependencies {
    components.all<JacksonBomAlignmentRule>()
}
```

```
dependencies {
    components.all(JacksonBomAlignmentRule)
}
```

Using the rule, the versions in the example above align to whatever the selected version of `com.fasterxml.jackson:jackson-bom` defines. In this case, `com.fasterxml.jackson:jackson-bom:2.9.5` will be selected as `2.9.5` is the highest version of a module selected. In that BOM, the following versions are defined and will be used: `jackson-core:2.9.5`, `jackson-databind:2.9.5` and `jackson-annotation:2.9.0`. The lower versions of `jackson-annotation` here might be the desired result as it is what the BOM recommends.

| NOTE | This behavior is working reliable since Gradle 6.1. Effectively, it is similar to a component metadata rule that adds a platform dependency to all members of the platform using `withDependencies`. |

=== Align versions of modules without a published platform

build.gradle.kts

```
abstract class JacksonAlignmentRule: ComponentMetadataRule {
    override fun execute(ctx: ComponentMetadataContext) {
        ctx.details.run {
            if (id.group.startsWith("com.fasterxml.jackson")) {
                // declare that Jackson modules all belong to the Jackson virtual
platform
                belongsTo("com.fasterxml.jackson:jackson-virtual-
platform:${id.version}")
            }
        }
    }
}
```

build.gradle

```groovy
abstract class JacksonAlignmentRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext ctx) {
        ctx.details.with {
            if (id.group.startsWith("com.fasterxml.jackson")) {
                // declare that Jackson modules all belong to the Jackson virtual
platform
                belongsTo("com.fasterxml.jackson:jackson-virtual-platform:${id
.version}")
            }
        }
    }
}
```

By using the `belongsTo` keyword without further parameter (platform **is** virtual), we declare that all modules belong to the same *virtual platform*, which is treated specially by the engine. A virtual platform will not be retrieved from a repository. The identifier, in this case `com.fasterxml.jackson:jackson-virtual-platform`, is something you as the build author define yourself. The "content" of the platform is then created by Gradle on the fly by collecting all `belongsTo` statements pointing at the same virtual platform.

build.gradle.kts

```kotlin
dependencies {
    components.all<JacksonAlignmentRule>()
}
```

build.gradle

```groovy
dependencies {
    components.all(JacksonAlignmentRule)
}
```

Using the rule, all versions in the example above would align to `2.9.5`. In this case, also `jackson-annotation:2.9.5` will be taken, as that is how we defined our local virtual platform.

For both published and virtual platforms, Gradle lets you override the version choice of the platform itself by specifying an *enforced* dependency on the platform:

build.gradle.kts

```kotlin
dependencies {
    // Forcefully downgrade the virtual Jackson platform to 2.8.9
    implementation(enforcedPlatform("com.fasterxml.jackson:jackson-virtual-
platform:2.8.9"))
}
```

build.gradle

```groovy
dependencies {
    // Forcefully downgrade the virtual Jackson platform to 2.8.9
    implementation enforcedPlatform('com.fasterxml.jackson:jackson-virtual-
platform:2.8.9')
}
```

Handling mutually exclusive dependencies

Introduction to component capabilities

Often a dependency graph would accidentally contain multiple implementations of the same API. This is particularly common with logging frameworks, where multiple bindings are available, and that one library chooses a binding when another transitive dependency chooses another. Because those implementations live at different GAV coordinates, the build tool has usually no way to find out that there's a conflict between those libraries. To solve this, Gradle provides the concept of *capability*.

It's illegal to find two components providing the same *capability* in a single dependency graph. Intuitively, it means that if Gradle finds two components that provide the same thing on classpath, it's going to fail with an error indicating what modules are in conflict. In our example, it means that different bindings of a logging framework provide the same capability.

Capability coordinates

A *capability* is defined by a `(group, module, version)` triplet. Each component defines an implicit capability corresponding to its GAV coordinates (group, artifact, version). For example, the `org.apache.commons:commons-lang3:3.8` module has an implicit capability with group `org.apache.commons`, name `commons-lang3` and version `3.8`. It is important to realize that capabilities are *versioned*.

Declaring component capabilities

By default, Gradle will fail if two components in the dependency graph provide the same capability. Because most modules are currently published without Gradle Module Metadata, capabilities are not always automatically discovered by Gradle. It is however interesting to use *rules* to declare component capabilities in order to discover conflicts as soon as possible, during the build instead of runtime.

A typical example is whenever a component is relocated at different coordinates in a new release. For example, the ASM library lived at `asm:asm` coordinates until version `3.3.1`, then changed to `org.ow2.asm:asm` since `4.0`. It is illegal to have both ASM <= 3.3.1 and 4.0+ on the classpath, because they provide the same feature, it's just that the component has been relocated. Because each component has an implicit capability corresponding to its GAV coordinates, we can "fix" this by having a rule that will declare that the `asm:asm` module provides the `org.ow2.asm:asm` capability:

```kotlin
class AsmCapability : ComponentMetadataRule {
    override
    fun execute(context: ComponentMetadataContext) = context.details.run {
        if (id.group == "asm" && id.name == "asm") {
            allVariants {
                withCapabilities {
                    // Declare that ASM provides the org.ow2.asm:asm capability,
but with an older version
                    addCapability("org.ow2.asm", "asm", id.version)
                }
            }
        }
    }
}
```

```groovy
@CompileStatic
class AsmCapability implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        context.details.with {
            if (id.group == "asm" && id.name == "asm") {
                allVariants {
                    it.withCapabilities {
                        // Declare that ASM provides the org.ow2.asm:asm
capability, but with an older version
                        it.addCapability("org.ow2.asm", "asm", id.version)
                    }
                }
            }
        }
    }
}
```

Now the build is going to *fail* whenever the two components are found in the same dependency graph.

At this stage, Gradle will *only* make more builds fail. It will **not** automatically fix the problem for you, but it helps you realize that you have a problem. It is recommended to write such rules in *plugins* which are then applied to your builds. Then, users *have to* express their preferences, if possible, or fix the problem of having incompatible things on the classpath, as explained in the following section.

Selecting between candidates

At some point, a dependency graph is going to include either *incompatible modules*, or modules which are *mutually exclusive*. For example, you may have different logger implementations and you need to choose one binding. Capabilities help *realizing* that you have a conflict, but Gradle also provides tools to express how to solve the conflicts.

Selecting between different capability candidates

In the relocation example above, Gradle was able to tell you that you have two versions of the same API on classpath: an "old" module and a "relocated" one. Now we can solve the conflict by automatically choosing the component which has the highest capability version:

build.gradle.kts

```
configurations.all {
    resolutionStrategy.capabilitiesResolution.withCapability("org.ow2.asm:asm") {
        selectHighestVersion()
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.capabilitiesResolution.withCapability('org.ow2.asm:asm') {
        selectHighestVersion()
    }
}
```

However, fixing by choosing the highest capability version conflict resolution is not always suitable. For a logging framework, for example, it doesn't matter what version of the logging frameworks we use, we should always select Slf4j.

In this case, we can fix it by explicitly selecting slf4j as the winner:

build.gradle.kts

```
configurations.all {
    resolutionStrategy.capabilitiesResolution.withCapability("log4j:log4j") {
        val toBeSelected = candidates.firstOrNull { it.id.let { id -> id is
ModuleComponentIdentifier && id.module == "log4j-over-slf4j" } }
        if (toBeSelected != null) {
            select(toBeSelected)
        }
        because("use slf4j in place of log4j")
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.capabilitiesResolution.withCapability("log4j:log4j") {
        def toBeSelected = candidates.find { it.id instanceof
ModuleComponentIdentifier && it.id.module == 'log4j-over-slf4j' }
        if (toBeSelected != null) {
            select(toBeSelected)
        }
        because 'use slf4j in place of log4j'
    }
}
```

Note that this approach works also well if you have multiple *Slf4j bindings* on the classpath: bindings are basically different logger implementations and you need only one. However, the selected implementation may depend on the configuration being resolved. For example, for tests, `slf4j-simple` may be enough but for production, `slf4-over-log4j` may be better.

Resolution can only be made in favor of a module *found* in the graph.

The `select` method only accepts a module found in the *current* candidates. If the module you want to select is not part of the conflict, you can abstain from performing a selection, effectively not resolving *this* conflict. It might be that another conflict exists in the graph for the same capability and will have the module you want to select.

If no resolution is given for all conflicts on a given capability, the build will fail given the module chosen for resolution was not part of the graph at all.

In addition `select(null)` will result in an error and so should be avoided.

For more information, check out the the capabilities resolution API.

= Fixing metadata with component metadata rules

Each module that is pulled from a repository has metadata associated with it, such as its group, name, version as well as the different variants it provides with their artifacts and dependencies. Sometimes, this metadata is incomplete or incorrect. To manipulate such incomplete metadata from within the build script, Gradle offers an API to write *component metadata rules*. These rules take effect after a module's metadata has been downloaded, but before it is used in dependency resolution.

== Basics of writing a component metadata rule

Component metadata rules are applied in the components (ComponentMetadataHandler) section of the dependencies block (DependencyHandler) of a build script or in the settings script. The rules can be defined in two different ways:

1. As an action directly when they are applied in the *components* section

2. As an isolated class implementing the ComponentMetadataRule interface

While defining rules inline as action can be convenient for experimentation, it is generally recommended to define rules as separate classes. Rules that are written as isolated classes can be annotated with `@CacheableRule` to cache the results of their application such that they do not need to be re-executed each time dependencies are resolved.

```kotlin
@CacheableRule
abstract class TargetJvmVersionRule @Inject constructor(val jvmVersion: Int) :
ComponentMetadataRule {
    @get:Inject abstract val objects: ObjectFactory

    override fun execute(context: ComponentMetadataContext) {
        context.details.withVariant("compile") {
            attributes {
                attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE,
jvmVersion)
                attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage.JAVA_API))
            }
        }
    }
}
dependencies {
    components {
        withModule<TargetJvmVersionRule>("commons-io:commons-io") {
            params(7)
        }
        withModule<TargetJvmVersionRule>("commons-collections:commons-
collections") {
            params(8)
        }
    }
    implementation("commons-io:commons-io:2.6")
    implementation("commons-collections:commons-collections:3.2.2")
}
```

build.gradle

```
@CacheableRule
abstract class TargetJvmVersionRule implements ComponentMetadataRule {
    final Integer jvmVersion
    @Inject TargetJvmVersionRule(Integer jvmVersion) {
        this.jvmVersion = jvmVersion
    }

    @Inject abstract ObjectFactory getObjects()

    void execute(ComponentMetadataContext context) {
        context.details.withVariant("compile") {
            attributes {
                attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE,
jvmVersion)
                attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage, Usage
.JAVA_API))
            }
        }
    }
}
dependencies {
    components {
        withModule("commons-io:commons-io", TargetJvmVersionRule) {
            params(7)
        }
        withModule("commons-collections:commons-collections",
TargetJvmVersionRule) {
            params(8)
        }
    }
    implementation("commons-io:commons-io:2.6")
    implementation("commons-collections:commons-collections:3.2.2")
}
```

As can be seen in the examples above, component metadata rules are defined by implementing ComponentMetadataRule which has a single `execute` method receiving an instance of ComponentMetadataContext as parameter. In this example, the rule is also further configured through an ActionConfiguration. This is supported by having a constructor in your implementation of `ComponentMetadataRule` accepting the parameters that were configured and the services that need injecting.

Gradle enforces isolation of instances of `ComponentMetadataRule`. This means that all parameters must be `Serializable` or known Gradle types that can be isolated.

In addition, Gradle services can be injected into your `ComponentMetadataRule`. Because of this, the moment you have a constructor, it must be annotated with `@javax.inject.Inject`. A commonly required service is ObjectFactory to create instances of strongly typed value objects like a value for setting an Attribute. A service which is helpful for advanced usage of component metadata rules with custom metadata is the RepositoryResourceAccessor.

A component metadata rule can be applied to all modules — `all(rule)` — or to a selected module — `withModule(groupAndName, rule)`. Usually, a rule is specifically written to enrich metadata of one specific module and hence the `withModule` API should be preferred.

=== Declaring rules in a central place

> **NOTE**   Declaring component metadata rules in settings is an incubating feature

Instead of declaring rules for each subproject individually, it is possible to declare rules in the `settings.gradle(.kts)` file for the whole build. Rules declared in settings are the *conventional* rules applied to each project: if the project doesn't declare any rules, the rules from the settings script will be used.

settings.gradle.kts

```
dependencyResolutionManagement {
    components {
        withModule<GuavaRule>("com.google.guava:guava")
    }
}
```

settings.gradle

```
dependencyResolutionManagement {
    components {
        withModule("com.google.guava:guava", GuavaRule)
    }
}
```

By default, rules declared in a project will **override** whatever is declared in settings. It is possible to change this default, for example to always prefer the settings rules:

settings.gradle.kts

```
dependencyResolutionManagement {
    rulesMode = RulesMode.PREFER_SETTINGS
}
```

settings.gradle

```
dependencyResolutionManagement {
    rulesMode = RulesMode.PREFER_SETTINGS
}
```

If this method is called and that a project or plugin declares rules, a warning will be issued. You can make this a failure instead by using this alternative:

settings.gradle.kts

```
dependencyResolutionManagement {
    rulesMode = RulesMode.FAIL_ON_PROJECT_RULES
}
```

settings.gradle

```
dependencyResolutionManagement {
    rulesMode = RulesMode.FAIL_ON_PROJECT_RULES
}
```

The default behavior is equivalent to calling this method:

settings.gradle.kts

```
dependencyResolutionManagement {
    rulesMode = RulesMode.PREFER_PROJECT
}
```

settings.gradle

```
dependencyResolutionManagement {
    rulesMode = RulesMode.PREFER_PROJECT
}
```

== Which parts of metadata can be modified?

The component metadata rules API is oriented at the features supported by Gradle Module Metadata and the *dependencies* API in build scripts. The main difference between writing rules and defining dependencies and artifacts in the build script is that component metadata rules, following the structure of Gradle Module Metadata, operate on variants directly. On the contrary, in build scripts you often influence the shape of multiple variants at once (e.g. an *api* dependency is added to the *api* and *runtime* variant of a Java library, the artifact produced by the *jar* task is also added to these two variants).

Variants can be addressed for modification through the following methods:

- `allVariants`: modify all variants of a component

- `withVariant(name)`: modify a single variant identified by its name

- `addVariant(name)` or `addVariant(name, base)`: add a new variant to the component either *from scratch* or by *copying* the details of an existing variant (base)

The following details of each variant can be adjusted:

- The attributes that identify the variant — `attributes {}` block

- The capabilities the variant provides — `withCapabilities { }` block

- The dependencies of the variant, including rich versions — `withDependencies {}` block

- The dependency constraints of the variant, including rich versions — `withDependencyConstraints {}` block

- The location of the published files that make up the actual content of the variant — `withFiles { }` block

There are also a few properties of the whole component that can be changed:

- The *component level attributes*, currently the only meaningful attribute there is `org.gradle.status`

- The *status scheme* to influence interpretation of the `org.gradle.status` attribute during version selection

- The *belongsTo* property for version alignment through virtual platforms

Depending on the format of the metadata of a module, it is mapped differently to the variant-centric representation of the metadata:

- If the module has Gradle Module Metadata, the data structure the rule operates on is very similar to what you find in the module's `.module` file.

- If the module was published only with `.pom` metadata, a number of fixed variants is derived as explained in the mapping of POM files to variants section.

- If the module was published only with an `ivy.xml` file, the *Ivy configurations* defined in the file can be accessed instead of variants. Their dependencies, dependency constraints and files can be modified. Additionally, the `addVariant(name, baseVariantOrConfiguration) { }`

API can be used to derive variants from *Ivy configurations* if desired (for example, *compile* and *runtime* variants for the Java library plugin can be defined with this).

== When to use Component Metadata Rules? ==

In general, if you consider using component metadata rules to adjust the metadata of a certain module, you should check first if that module was published with Gradle Module Metadata (`.module` file) or traditional metadata only (`.pom` or `ivy.xml`).

If a module was published with Gradle Module Metadata, the metadata is likely complete although there can still be cases where something is just plainly wrong. For these modules you should only use component metadata rules if you have clearly identified a problem with the metadata itself. If you have an issue with the dependency resolution result, you should first check if you can solve the issue by declaring dependency constraints with rich versions. In particular, if you are developing a library that you publish, you should remember that dependency constraints, in contrast to component metadata rules, are published as part of the metadata of your own library. So with dependency constraints, you automatically share the solution of dependency resolution issues with your consumers, while component metadata rules are only applied to your own build.

If a module was published with traditional metadata (`.pom` or `ivy.xml` only, no `.module` file) it is more likely that the metadata is incomplete as features such as variants or dependency constraints are not supported in these formats. Still, conceptually such modules can contain different variants or might have dependency constraints they just omitted (or wrongly defined as dependencies). In the next sections, we explore a number existing oss modules with such incomplete metadata and the rules for adding the missing metadata information.

As a rule of thumb, you should contemplate if the rule you are writing also works out of context of your build. That is, does the rule still produce a correct and useful result if applied in any other build that uses the module(s) it affects?

== Fixing wrong dependency details ==

Let's consider as an example the publication of the Jaxen XPath Engine on Maven central. The pom of version 1.1.3 declares a number of dependencies in the compile scope which are not actually needed for compilation. These have been removed in the 1.1.4 pom. Assuming that we need to work with 1.1.3 for some reason, we can fix the metadata with the following rule:

```kotlin
@CacheableRule
abstract class JaxenDependenciesRule: ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        context.details.allVariants {
            withDependencies {
                removeAll { it.group in listOf("dom4j", "jdom", "xerces",  "maven-
plugins", "xml-apis", "xom") }
            }
        }
    }
}
```

```groovy
@CacheableRule
abstract class JaxenDependenciesRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        context.details.allVariants {
            withDependencies {
                removeAll { it.group in ["dom4j", "jdom", "xerces",  "maven-
plugins", "xml-apis", "xom"] }
            }
        }
    }
}
```

Within the `withDependencies` block you have access to the full list of dependencies and can use all methods available on the Java collection interface to inspect and modify that list. In addition, there are `add(notation, configureAction)` methods accepting the usual notations similar to declaring dependencies in the build script. Dependency constraints can be inspected and modified the same way in the `withDependencyConstraints` block.

If we take a closer look at the Jaxen 1.1.4 pom, we observe that the *dom4j*, *jdom* and *xerces* dependencies are still there but marked as *optional*. Optional dependencies in poms are not automatically processed by Gradle nor Maven. The reason is that they indicate that there are optional feature variants provided by the Jaxen library which require one or more of these dependencies, but the information what these features are and which dependency belongs to which is missing. Such information cannot be represented in pom files, but in Gradle Module Metadata through variants and capabilities. Hence, we can add this information in a rule as well.

```kotlin
@CacheableRule
abstract class JaxenCapabilitiesRule: ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        context.details.addVariant("runtime-dom4j", "runtime") {
            withCapabilities {
                removeCapability("jaxen", "jaxen")
                addCapability("jaxen", "jaxen-dom4j", context.details.id.version)
            }
            withDependencies {
                add("dom4j:dom4j:1.6.1")
            }
        }
    }
}
```

```groovy
@CacheableRule
abstract class JaxenCapabilitiesRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        context.details.addVariant("runtime-dom4j", "runtime") {
            withCapabilities {
                removeCapability("jaxen", "jaxen")
                addCapability("jaxen", "jaxen-dom4j", context.details.id.version)
            }
            withDependencies {
                add("dom4j:dom4j:1.6.1")
            }
        }
    }
}
```

Here, we first use the `addVariant(name, baseVariant)` method to create an additional variant, which we identify as *feature variant* by defining a new capability *jaxen-dom4j* to represent the optional dom4j integration feature of Jaxen. This works similar to defining optional feature variants in build scripts. We then use one of the `add` methods for adding dependencies to define which dependencies this optional feature needs.

In the build script, we can then add a dependency to the optional feature and Gradle will use the enriched metadata to discover the correct transitive dependencies.

```
dependencies {
    components {
        withModule<JaxenDependenciesRule>("jaxen:jaxen")
        withModule<JaxenCapabilitiesRule>("jaxen:jaxen")
    }
    implementation("jaxen:jaxen:1.1.3")
    runtimeOnly("jaxen:jaxen:1.1.3") {
        capabilities { requireCapability("jaxen:jaxen-dom4j") }
    }
}
```

```
dependencies {
    components {
        withModule("jaxen:jaxen", JaxenDependenciesRule)
        withModule("jaxen:jaxen", JaxenCapabilitiesRule)
    }
    implementation("jaxen:jaxen:1.1.3")
    runtimeOnly("jaxen:jaxen:1.1.3") {
        capabilities { requireCapability("jaxen:jaxen-dom4j") }
    }
}
```

== Making variants published as classified jars explicit ==

While in the previous example, all variants, "main variants" and optional features, were packaged in one jar file, it is common to publish certain variants as separate files. In particular, when the variants are mutual exclusive — i.e. they are **not** feature variants, but different variants offering alternative choices. One example **all** pom-based libraries already have are the *runtime* and *compile* variants, where Gradle can choose only one depending on the task at hand. Another of such alternatives discovered often in the Java ecosystems are jars targeting different Java versions.

As example, we look at version 0.7.9 of the asynchronous programming library Quasar published on Maven central. If we inspect the directory listing, we discover that a `quasar-core-0.7.9-jdk8.jar` was published, in addition to `quasar-core-0.7.9.jar`. Publishing additional jars with a *classifier* (here *jdk8*) is common practice in maven repositories. And while both Maven and Gradle allow you to reference such jars by classifier, they are not mentioned at all in the metadata. Thus, there is no information that these jars exist and if there are any other differences, like different dependencies, between the variants represented by such jars.

In Gradle Module Metadata, this variant information would be present and for the already published Quasar library, we can add it using the following rule:

build.gradle.kts

```
@CacheableRule
abstract class QuasarRule: ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        listOf("compile", "runtime").forEach { base ->
            context.details.addVariant("jdk8${base.capitalize()}", base) {
                attributes {
                    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 8)
                }
                withFiles {
                    removeAllFiles()
                    addFile("${context.details.id.name}-
${context.details.id.version}-jdk8.jar")
                }
            }
            context.details.withVariant(base) {
                attributes {
                    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 7)
                }
            }
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class QuasarRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        ["compile", "runtime"].each { base ->
            context.details.addVariant("jdk8${base.capitalize()}", base) {
                attributes {
                    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 8)
                }
                withFiles {
                    removeAllFiles()
                    addFile("${context.details.id.name}-${context.details.id
.version}-jdk8.jar")
                }
            }
            context.details.withVariant(base) {
                attributes {
                    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 7)
                }
            }
        }
    }
}
```

In this case, it is pretty clear that the classifier stands for a target Java version, which is a known Java ecosystem attribute. Because we also need both a *compile* and *runtime* for Java 8, we create two new variants but use the existing *compile* and *runtime* variants as *base*. This way, all other Java ecosystem attributes are already set correctly and all dependencies are carried over. Then we set the `TARGET_JVM_VERSION_ATTRIBUTE` to 8 for both variants, remove any existing file from the new variants with `removeAllFiles()`, and add the jdk8 jar file with `addFile()`. The `removeAllFiles()` is needed, because the reference to the main jar `quasar-core-0.7.5.jar` is copied from the corresponding base variant.

We also enrich the existing *compile* and *runtime* variants with the information that they target Java 7 — `attribute(TARGET_JVM_VERSION_ATTRIBUTE, 7)`.

Now, we can request a Java 8 versions for all of our dependencies on the compile classpath in the build script and Gradle will automatically select the best fitting variant for each library. In the case of Quasar this will now be the *jdk8Compile* variant exposing the `quasar-core-0.7.9-jdk8.jar`.

build.gradle.kts

```
configurations["compileClasspath"].attributes {
    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 8)
}
dependencies {
    components {
        withModule<QuasarRule>("co.paralleluniverse:quasar-core")
    }
    implementation("co.paralleluniverse:quasar-core:0.7.9")
}
```

build.gradle

```
configurations.compileClasspath.attributes {
    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 8)
}
dependencies {
    components {
        withModule("co.paralleluniverse:quasar-core", QuasarRule)
    }
    implementation("co.paralleluniverse:quasar-core:0.7.9")
}
```

== Making variants encoded in versions explicit ==

Another solution to publish multiple alternatives for the same library is the usage of a versioning pattern as done by the popular Guava library. Here, each new version is published twice by appending the classifier to the version instead of the jar artifact. In the case of Guava 28 for example, we can find a *28.0-jre* (Java 8) and *28.0-android* (Java 6) version on Maven central. The advantage of using this pattern when working only with pom metadata is that both variants are discoverable through the version. The disadvantage is that there is no information what the different version suffixes mean semantically. So in the case of conflict, Gradle would just pick the highest version when comparing the version strings.

Turning this into proper variants is a bit more tricky, as Gradle first selects a version of a module and then selects the best fitting variant. So the concept that variants are encoded as versions is not supported directly. However, since both variants are always published together we can assume that the files are physically located in the same repository. And since they are published with Maven repository conventions, we know the location of each file if we know module name and version. We can write the following rule:

build.gradle.kts

```
@CacheableRule
abstract class GuavaRule: ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        val variantVersion = context.details.id.version
        val version = variantVersion.substring(0, variantVersion.indexOf("-"))
        listOf("compile", "runtime").forEach { base ->
            mapOf(6 to "android", 8 to "jre").forEach { (targetJvmVersion,
jarName) ->

context.details.addVariant("jdk$targetJvmVersion${base.capitalize()}", base) {
                    attributes {

attributes.attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE,
targetJvmVersion)
                    }
                    withFiles {
                        removeAllFiles()
                        addFile("guava-$version-$jarName.jar", "../$version-
$jarName/guava-$version-$jarName.jar")
                    }
                }
            }
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class GuavaRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        def variantVersion = context.details.id.version
        def version = variantVersion.substring(0, variantVersion.indexOf("-"))
        ["compile", "runtime"].each { base ->
            [6: "android", 8: "jre"].each { targetJvmVersion, jarName ->
                context.details.addVariant("jdk$targetJvmVersion${base.capitalize
()}", base) {
                    attributes {
                        attributes.attribute(TargetJvmVersion
.TARGET_JVM_VERSION_ATTRIBUTE, targetJvmVersion)
                    }
                    withFiles {
                        removeAllFiles()
                        addFile("guava-$version-${jarName}.jar", "../$version-
$jarName/guava-$version-${jarName}.jar")
                    }
                }
            }
        }
    }
}
```

Similar to the previous example, we add runtime and compile variants for both Java versions. In the `withFiles` block however, we now also specify a relative path for the corresponding jar file which allows Gradle to find the file no matter if it has selected a *-jre* or *-android* version. The path is always relative to the location of the metadata (in this case `pom`) file of the selection module version. So with this rules, both Guava 28 "versions" carry both the *jdk6* and *jdk8* variants. So it does not matter to which one Gradle resolves. The variant, and with it the correct jar file, is determined based on the requested `TARGET_JVM_VERSION_ATTRIBUTE` value.

```
configurations["compileClasspath"].attributes {
    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 6)
}
dependencies {
    components {
        withModule<GuavaRule>("com.google.guava:guava")
    }
    // '23.3-android' and '23.3-jre' are now the same as both offer both variants
    implementation("com.google.guava:guava:23.3+")
}
```

build.gradle

```
configurations.compileClasspath.attributes {
    attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, 6)
}
dependencies {
    components {
        withModule("com.google.guava:guava", GuavaRule)
    }
    // '23.3-android' and '23.3-jre' are now the same as both offer both variants
    implementation("com.google.guava:guava:23.3+")
}
```

== Adding variants for native jars

Jars with classifiers are also used to separate parts of a library for which multiple alternatives exists, for example native code, from the main artifact. This is for example done by the Lightweight Java Game Library (LWGJ), which publishes several platform specific jars to Maven central from which always one is needed, in addition to the main jar, at runtime. It is not possible to convey this information in pom metadata as there is no concept of putting multiple artifacts in relation through the metadata. In Gradle Module Metadata, each variant can have arbitrary many files and we can leverage that by writing the following rule:

build.gradle.kts

```kotlin
@CacheableRule
abstract class LwjglRule: ComponentMetadataRule {
    data class NativeVariant(val os: String, val arch: String, val classifier:
String)

    private val nativeVariants = listOf(
        NativeVariant(OperatingSystemFamily.LINUX,   "arm32",  "natives-linux-
arm32"),
        NativeVariant(OperatingSystemFamily.LINUX,   "arm64",  "natives-linux-
arm64"),
        NativeVariant(OperatingSystemFamily.WINDOWS, "x86",    "natives-windows-
x86"),
        NativeVariant(OperatingSystemFamily.WINDOWS, "x86-64", "natives-windows"),
        NativeVariant(OperatingSystemFamily.MACOS,   "x86-64", "natives-macos")
    )

    @get:Inject abstract val objects: ObjectFactory

    override fun execute(context: ComponentMetadataContext) {
        context.details.withVariant("runtime") {
            attributes {

attributes.attribute(OperatingSystemFamily.OPERATING_SYSTEM_ATTRIBUTE,
objects.named("none"))
                attributes.attribute(MachineArchitecture.ARCHITECTURE_ATTRIBUTE,
objects.named("none"))
            }
        }
        nativeVariants.forEach { variantDefinition ->
            context.details.addVariant("${variantDefinition.classifier}-runtime",
"runtime") {
                attributes {

attributes.attribute(OperatingSystemFamily.OPERATING_SYSTEM_ATTRIBUTE,
objects.named(variantDefinition.os))

attributes.attribute(MachineArchitecture.ARCHITECTURE_ATTRIBUTE,
objects.named(variantDefinition.arch))
                }
                withFiles {
                    addFile("${context.details.id.name}-
${context.details.id.version}-${variantDefinition.classifier}.jar")
                }
            }
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class LwjglRule implements ComponentMetadataRule { //val os: String, val
arch: String, val classifier: String)
    private def nativeVariants = [
        [os: OperatingSystemFamily.LINUX,   arch: "arm32",  classifier: "natives-
linux-arm32"],
        [os: OperatingSystemFamily.LINUX,   arch: "arm64",  classifier: "natives-
linux-arm64"],
        [os: OperatingSystemFamily.WINDOWS, arch: "x86",    classifier: "natives-
windows-x86"],
        [os: OperatingSystemFamily.WINDOWS, arch: "x86-64", classifier: "natives-
windows"],
        [os: OperatingSystemFamily.MACOS,   arch: "x86-64", classifier: "natives-
macos"]
    ]

    @Inject abstract ObjectFactory getObjects()

    void execute(ComponentMetadataContext context) {
        context.details.withVariant("runtime") {
            attributes {
                attributes.attribute(OperatingSystemFamily
.OPERATING_SYSTEM_ATTRIBUTE, objects.named(OperatingSystemFamily, "none"))
                attributes.attribute(MachineArchitecture.ARCHITECTURE_ATTRIBUTE,
objects.named(MachineArchitecture, "none"))
            }
        }
        nativeVariants.each { variantDefinition ->
            context.details.addVariant("${variantDefinition.classifier}-runtime",
"runtime") {
                attributes {
                    attributes.attribute(OperatingSystemFamily
.OPERATING_SYSTEM_ATTRIBUTE, objects.named(OperatingSystemFamily,
variantDefinition.os))
                    attributes.attribute(MachineArchitecture
.ARCHITECTURE_ATTRIBUTE, objects.named(MachineArchitecture, variantDefinition.
arch))
                }
                withFiles {
                    addFile("${context.details.id.name}-${context.details.id
.version}-${variantDefinition.classifier}.jar")
                }
            }
        }
    }
}
```

This rule is quite similar to the Quasar library example above. Only this time we have five different runtime variants we add and nothing we need to change for the compile variant. The runtime variants are all based on the existing *runtime* variant and we do not change any existing information. All Java ecosystem attributes, the dependencies and the main jar file stay part of each of the runtime variants. We only set the additional attributes `OPERATING_SYSTEM_ATTRIBUTE` and `ARCHITECTURE_ATTRIBUTE` which are defined as part of Gradle's native support. And we add the corresponding native jar file so that each runtime variant now carries two files: the main jar and the native jar.

In the build script, we can now request a specific variant and Gradle will fail with a selection error if more information is needed to make a decision.

build.gradle.kts

```
configurations["runtimeClasspath"].attributes {
    attribute(OperatingSystemFamily.OPERATING_SYSTEM_ATTRIBUTE,
objects.named("windows"))
}
dependencies {
    components {
        withModule<LwjglRule>("org.lwjgl:lwjgl")
    }
    implementation("org.lwjgl:lwjgl:3.2.3")
}
```

build.gradle

```
configurations["runtimeClasspath"].attributes {
    attribute(OperatingSystemFamily.OPERATING_SYSTEM_ATTRIBUTE, objects.named
(OperatingSystemFamily, "windows"))
}
dependencies {
    components {
        withModule("org.lwjgl:lwjgl", LwjglRule)
    }
    implementation("org.lwjgl:lwjgl:3.2.3")
}
```

> *Gradle fails to select a variant because a machine architecture needs to be chosen*

```
> Could not resolve all files for configuration ':runtimeClasspath'.
   > Could not resolve org.lwjgl:lwjgl:3.2.3.
     Required by:
         project :
     > Cannot choose between the following variants of org.lwjgl:lwjgl:3.2.3:
         - natives-windows-runtime
         - natives-windows-x86-runtime
```

== Making different flavors of a library available through capabilities

Because it is difficult to model optional feature variants as separate jars with pom metadata, libraries sometimes compose different jars with a different feature set. That is, instead of composing your flavor of the library from different feature variants, you select one of the pre-composed variants (offering everything in one jar). One such library is the well-known dependency injection framework Guice, published on Maven central, which offers a complete flavor (the main jar) and a reduced variant without aspect-oriented programming support (`guice-4.2.2-no_aop.jar`). That second variant with a classifier is not mentioned in the pom metadata. With the following rule, we create compile and runtime variants based on that file and make it selectable through a capability named `com.google.inject:guice-no_aop`.

build.gradle.kts

```kotlin
@CacheableRule
abstract class GuiceRule: ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        listOf("compile", "runtime").forEach { base ->
            context.details.addVariant("noAop${base.capitalize()}", base) {
                withCapabilities {
                    addCapability("com.google.inject", "guice-no_aop",
context.details.id.version)
                }
                withFiles {
                    removeAllFiles()
                    addFile("guice-${context.details.id.version}-no_aop.jar")
                }
                withDependencies {
                    removeAll { it.group == "aopalliance" }
                }
            }
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class GuiceRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        ["compile", "runtime"].each { base ->
            context.details.addVariant("noAop${base.capitalize()}", base) {
                withCapabilities {
                    addCapability("com.google.inject", "guice-no_aop", context
.details.id.version)
                }
                withFiles {
                    removeAllFiles()
                    addFile("guice-${context.details.id.version}-no_aop.jar")
                }
                withDependencies {
                    removeAll { it.group == "aopalliance" }
                }
            }
        }
    }
}
```

The new variants also have the dependency on the standardized aop interfaces library `aopalliance:aopalliance` removed, as this is clearly not needed by these variants. Again, this is information that cannot be expressed in pom metadata. We can now select a `guice-no_aop` variant and will get the correct jar file **and** the correct dependencies.

build.gradle.kts

```
dependencies {
    components {
        withModule<GuiceRule>("com.google.inject:guice")
    }
    implementation("com.google.inject:guice:4.2.2") {
        capabilities { requireCapability("com.google.inject:guice-no_aop") }
    }
}
```

```
dependencies {
    components {
        withModule("com.google.inject:guice", GuiceRule)
    }
    implementation("com.google.inject:guice:4.2.2") {
        capabilities { requireCapability("com.google.inject:guice-no_aop") }
    }
}
```

Adding missing capabilities to detect conflicts

Another usage of capabilities is to express that two different modules, for example `log4j` and `log4j-over-slf4j`, provide alternative implementations of the same thing. By declaring that both provide the same capability, Gradle only accepts one of them in a dependency graph. This example, and how it can be tackled with a component metadata rule, is described in detail in the feature modelling section.

Making Ivy modules variant-aware ==

Modules with Ivy metadata, do not have variants by default. However, *Ivy configurations* can be mapped to variants as the `addVariant(name, baseVariantOrConfiguration)` accepts any Ivy configuration that was published as base. This can be used, for example, to define runtime and compile variants. An example of a corresponding rule can be found here. Ivy details of Ivy configurations (e.g. dependencies and files) can also be modified using the `withVariant(configurationName)` API. However, modifying attributes or capabilities on Ivy configurations has no effect.

For very Ivy specific use cases, the component metadata rules API also offers access to other details only found in Ivy metadata. These are available through the IvyModuleDescriptor interface and can be accessed using `getDescriptor(IvyModuleDescriptor)` on the ComponentMetadataContext.

build.gradle.kts

```
@CacheableRule
abstract class IvyComponentRule : ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        val descriptor = context.getDescriptor(IvyModuleDescriptor::class)
        if (descriptor != null && descriptor.branch == "testing") {
            context.details.status = "rc"
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class IvyComponentRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        def descriptor = context.getDescriptor(IvyModuleDescriptor)
        if (descriptor != null && descriptor.branch == "testing") {
            context.details.status = "rc"
        }
    }
}
```

== Filter using Maven metadata ==

For Maven specific use cases, the component metadata rules API also offers access to other details only found in POM metadata. These are available through the PomModuleDescriptor interface and can be accessed using getDescriptor(PomModuleDescriptor) on the ComponentMetadataContext.

build.gradle.kts

```
@CacheableRule
abstract class MavenComponentRule : ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        val descriptor = context.getDescriptor(PomModuleDescriptor::class)
        if (descriptor != null && descriptor.packaging == "war") {
            // ...
        }
    }
}
```

build.gradle

```
@CacheableRule
abstract class MavenComponentRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        def descriptor = context.getDescriptor(PomModuleDescriptor)
        if (descriptor != null && descriptor.packaging == "war") {
            // ...
        }
    }
}
```

Modifying metadata on the component level for alignment

While all the examples above made modifications to variants of a component, there is also a limited set of modifications that can be done to the metadata of the component itself. This information can influence the version selection process for a module during dependency resolution, which is performed *before* one or multiple variants of a component are selected.

The first API available on the component is `belongsTo()` to create virtual platforms for aligning versions of multiple modules without Gradle Module Metadata. It is explained in detail in the section on aligning versions of modules not published with Gradle.

Modifying metadata on the component level for version selection based on status

Gradle and Gradle Module Metadata also allow attributes to be set on the whole component instead of a single variant. Each of these attributes carries special semantics as they influence version selection which is done *before* variant selection. While variant selection can handle any custom attribute, version selection only considers attributes for which specific semantics are implemented. At the moment, the only attribute with meaning here is `org.gradle.status`. It is therefore recommended to only modify this attribute, if any, on the component level. A dedicated API `setStatus(value)` is available for this. To modify another attribute for all variants of a component `withAllVariants { attributes {} }` should be utilised instead.

A module's status is taken into consideration when a *latest* version selector is resolved. Specifically, `latest.someStatus` will resolve to the highest module version that has status `someStatus` or a more mature status. For example, `latest.integration` will select the highest module version regardless of its status (because `integration` is the least mature status as explained below), whereas `latest.release` will select the highest module version with status `release`.

The interpretation of the status can be influenced by changing a module's *status scheme* through the `setStatusScheme(valueList)` API. This concept models the different levels of maturity that a module transitions through over time with different publications. The default status scheme, ordered from least to most mature status, is `integration`, `milestone`, `release`. The `org.gradle.status` attribute must be set, to one of the values in the components status scheme. Thus each component always has a status which is determined from the metadata as follows:

- Gradle Module Metadata: the value that was published for the `org.gradle.status` attribute on the component

- Ivy metadata: `status` defined in the ivy.xml, defaults to `integration` if missing

- Pom metadata: `integration` for modules with a SNAPSHOT version, `release` for all others

The following example demonstrates `latest` selectors based on a custom status scheme declared in a component metadata rule that applies to all modules:

build.gradle.kts

```kotlin
@CacheableRule
abstract class CustomStatusRule : ComponentMetadataRule {
    override fun execute(context: ComponentMetadataContext) {
        context.details.statusScheme = listOf("nightly", "milestone", "rc",
"release")
        if (context.details.status == "integration") {
            context.details.status = "nightly"
        }
    }
}

dependencies {
    components {
        all<CustomStatusRule>()
    }
    implementation("org.apache.commons:commons-lang3:latest.rc")
}
```

build.gradle

```groovy
@CacheableRule
abstract class CustomStatusRule implements ComponentMetadataRule {
    void execute(ComponentMetadataContext context) {
        context.details.statusScheme = ["nightly", "milestone", "rc", "release"]
        if (context.details.status == "integration") {
            context.details.status = "nightly"
        }
    }
}

dependencies {
    components {
        all(CustomStatusRule)
    }
    implementation("org.apache.commons:commons-lang3:latest.rc")
}
```

Compared to the default scheme, the rule inserts a new status `rc` and replaces `integration` with `nightly`. Existing modules with the state `integration` are mapped to `nightly`.

Customizing resolution of a dependency directly

This section covers mechanisms Gradle offers to directly influence the behavior of the dependency resolution engine. In contrast to the other concepts covered in this chapter, like dependency constraints or component metadata rules, which are all **inputs** to resolution, the following mechanisms allow you to write rules which are directly injected into the resolution engine. Because of this, they can be seen as *brute force* solutions, that may hide future problems (e.g. if new dependencies are added). Therefore, the general advice is to only use the following mechanisms if other means are not sufficient. If you are authoring a library, you should always prefer dependency constraints as they are published for your consumers.

Using dependency resolve rules

A dependency resolve rule is executed for each resolved dependency, and offers a powerful api for manipulating a requested dependency prior to that dependency being resolved. The feature currently offers the ability to change the group, name and/or version of a requested dependency, allowing a dependency to be substituted with a completely different module during resolution.

Dependency resolve rules provide a very powerful way to control the dependency resolution process, and can be used to implement all sorts of advanced patterns in dependency management. Some of these patterns are outlined below. For more information and code samples see the ResolutionStrategy class in the API documentation.

Implementing a custom versioning scheme

In some corporate environments, the list of module versions that can be declared in Gradle builds is maintained and audited externally. Dependency resolve rules provide a neat implementation of this pattern:

- In the build script, the developer declares dependencies with the module group and name, but uses a placeholder version, for example: `default`.
- The `default` version is resolved to a specific version via a dependency resolve rule, which looks up the version in a corporate catalog of approved modules.

This rule implementation can be neatly encapsulated in a corporate plugin, and shared across all builds within the organisation.

build.gradle.kts

```kotlin
configurations.all {
    resolutionStrategy.eachDependency {
        if (requested.version == "default") {
            val version = findDefaultVersionInCatalog(requested.group,
requested.name)
            useVersion(version.version)
            because(version.because)
        }
    }
}

data class DefaultVersion(val version: String, val because: String)

fun findDefaultVersionInCatalog(group: String, name: String): DefaultVersion {
    //some custom logic that resolves the default version into a specific version
    return DefaultVersion(version = "1.0", because = "tested by QA")
}
```

build.gradle

```groovy
configurations.all {
    resolutionStrategy.eachDependency { DependencyResolveDetails details ->
        if (details.requested.version == 'default') {
            def version = findDefaultVersionInCatalog(details.requested.group,
details.requested.name)
            details.useVersion version.version
            details.because version.because
        }
    }
}

def findDefaultVersionInCatalog(String group, String name) {
    //some custom logic that resolves the default version into a specific version
    [version: "1.0", because: 'tested by QA']
}
```

Denying a particular version with a replacement

Dependency resolve rules provide a mechanism for denying a particular version of a dependency and providing a replacement version. This can be useful if a certain dependency version is broken and should not be used, where a dependency resolve rule causes this version to be replaced with a known good version. One example of a broken module is one that declares a dependency on a library that cannot be found in any of the public repositories, but there are many other reasons why a particular module version is unwanted and a different version is preferred.

In example below, imagine that version 1.2.1 contains important fixes and should always be used in preference to 1.2. The rule provided will enforce just this: any time version 1.2 is encountered it will be replaced with 1.2.1. Note that this is different from a forced version as described above, in that any other versions of this module would not be affected. This means that the 'newest' conflict resolution strategy would still select version 1.3 if this version was also pulled transitively.

build.gradle.kts

```
configurations.all {
    resolutionStrategy.eachDependency {
        if (requested.group == "org.software" && requested.name == "some-library"
&& requested.version == "1.2") {
            useVersion("1.2.1")
            because("fixes critical bug in 1.2")
        }
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.eachDependency { DependencyResolveDetails details ->
        if (details.requested.group == 'org.software' && details.requested.name ==
'some-library' && details.requested.version == '1.2') {
            details.useVersion '1.2.1'
            details.because 'fixes critical bug in 1.2'
        }
    }
}
```

There's a difference with using the *reject* directive of rich version constraints: rich versions will cause the build to fail if a rejected version is found in the graph, or select a non rejected version

when using dynamic dependencies. Here, we *manipulate the requested versions* in order to select a different version when we find a rejected one. In other words, this is a *solution* to rejected versions, while rich version constraints allow declaring the *intent* (you should not use this version).

Using module replacement rules

It is preferable to express module conflicts in terms of capabilities conflicts. However, if there's no such rule declared or that you are working on versions of Gradle which do not support capabilities, Gradle provides tooling to work around those issues.

Module replacement rules allow a build to declare that a legacy library has been replaced by a new one. A good example when a new library replaced a legacy one is the `google-collections` -> `guava` migration. The team that created google-collections decided to change the module name from `com.google.collections:google-collections` into `com.google.guava:guava`. This is a legal scenario in the industry: teams need to be able to change the names of products they maintain, including the module coordinates. Renaming of the module coordinates has impact on conflict resolution.

To explain the impact on conflict resolution, let's consider the `google-collections` -> `guava` scenario. It may happen that both libraries are pulled into the same dependency graph. For example, *our project* depends on `guava` but some of *our dependencies* pull in a legacy version of `google-collections`. This can cause runtime errors, for example during test or application execution. Gradle does not automatically resolve the `google-collections` -> `guava` conflict because it is not considered as a *version conflict*. It's because the module coordinates for both libraries are completely different and conflict resolution is activated when `group` and `module` coordinates are the same but there are different versions available in the dependency graph (for more info, refer to the section on conflict resolution). Traditional remedies to this problem are:

- Declare exclusion rule to avoid pulling in `google-collections` to graph. It is probably the most popular approach.

- Avoid dependencies that pull in legacy libraries.

- Upgrade the dependency version if the new version no longer pulls in a legacy library.

- Downgrade to `google-collections`. It's not recommended, just mentioned for completeness.

Traditional approaches work but they are not general enough. For example, an organisation wants to resolve the `google-collections` -> `guava` conflict resolution problem in all projects. It is possible to declare that certain module was replaced by other. This enables organisations to include the information about module replacement in the corporate plugin suite and resolve the problem holistically for all Gradle-powered projects in the enterprise.

build.gradle.kts

```
dependencies {
    modules {
        module("com.google.collections:google-collections") {
            replacedBy("com.google.guava:guava", "google-collections is now part
of Guava")
        }
    }
}
```

build.gradle

```
dependencies {
    modules {
        module("com.google.collections:google-collections") {
            replacedBy("com.google.guava:guava", "google-collections is now part
of Guava")
        }
    }
}
```

For more examples and detailed API, refer to the DSL reference for ComponentMetadataHandler.

What happens when we declare that `google-collections` is replaced by `guava`? Gradle can use this information for conflict resolution. Gradle will consider every version of `guava` newer/better than any version of `google-collections`. Also, Gradle will ensure that only guava jar is present in the classpath / resolved file list. Note that if only `google-collections` appears in the dependency graph (e.g. no `guava`) Gradle will not eagerly replace it with `guava`. Module replacement is an information that Gradle uses for resolving conflicts. If there is no conflict (e.g. only `google-collections` or only `guava` in the graph) the replacement information is not used.

Currently it is not possible to declare that a given module is replaced by a set of modules. However, it is possible to declare that multiple modules are replaced by a single module.

== Using dependency substitution rules

Dependency substitution rules work similarly to dependency resolve rules. In fact, many capabilities of dependency resolve rules can be implemented with dependency substitution rules. They allow project and module dependencies to be transparently substituted with specified replacements. Unlike dependency resolve rules, dependency substitution rules allow project and module dependencies to be substituted interchangeably.

Adding a dependency substitution rule to a configuration changes the timing of when that configuration is resolved. Instead of being resolved on first use, the configuration is instead resolved when the task graph is being constructed. This can have unexpected consequences if the configuration is being further modified during task execution, or if the configuration relies on modules that are published during execution of another task.

To explain:

- A `Configuration` can be declared as an input to any Task, and that configuration can include project dependencies when it is resolved.

- If a project dependency is an input to a Task (via a configuration), then tasks to build the project artifacts must be added to the task dependencies.

- In order to determine the project dependencies that are inputs to a task, Gradle needs to resolve the `Configuration` inputs.

- Because the Gradle task graph is fixed once task execution has commenced, Gradle needs to perform this resolution prior to executing any tasks.

In the absence of dependency substitution rules, Gradle knows that an external module dependency will never transitively reference a project dependency. This makes it easy to determine the full set of project dependencies for a configuration through simple graph traversal. With this functionality, Gradle can no longer make this assumption, and must perform a full resolve in order to determine the project dependencies.

=== Substituting an external module dependency with a project dependency

One use case for dependency substitution is to use a locally developed version of a module in place of one that is downloaded from an external repository. This could be useful for testing a local, patched version of a dependency.

The module to be replaced can be declared with or without a version specified.

build.gradle.kts

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(module("org.utils:api"))
            .using(project(":api")).because("we work with the unreleased
development version")
        substitute(module("org.utils:util:2.5")).using(project(":util"))
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute module("org.utils:api") using project(":api") because "we work
with the unreleased development version"
        substitute module("org.utils:util:2.5") using project(":util")
    }
}
```

Note that a project that is substituted must be included in the multi-project build (via `settings.gradle`). Dependency substitution rules take care of replacing the module dependency with the project dependency and wiring up any task dependencies, but do not implicitly include the project in the build.

=== Substituting a project dependency with a module replacement

Another way to use substitution rules is to replace a project dependency with a module in a multi-project build. This can be useful to speed up development with a large multi-project build, by allowing a subset of the project dependencies to be downloaded from a repository rather than being built.

The module to be used as a replacement must be declared with a version specified.

build.gradle.kts

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(project(":api"))
            .using(module("org.utils:api:1.3")).because("we use a stable version
of org.utils:api")
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute project(":api") using module("org.utils:api:1.3") because "we
use a stable version of org.utils:api"
    }
}
```

When a project dependency has been replaced with a module dependency, that project is still included in the overall multi-project build. However, tasks to build the replaced dependency will not be executed in order to resolve the depending `Configuration`.

=== Conditionally substituting a dependency

A common use case for dependency substitution is to allow more flexible assembly of sub-projects within a multi-project build. This can be useful for developing a local, patched version of an external dependency or for building a subset of the modules within a large multi-project build.

The following example uses a dependency substitution rule to replace any module dependency with the group `org.example`, but only if a local project matching the dependency name can be located.

build.gradle.kts

```kotlin
configurations.all {
    resolutionStrategy.dependencySubstitution.all {
        requested.let {
            if (it is ModuleComponentSelector && it.group == "org.example") {
                val targetProject = findProject(":${it.module}")
                if (targetProject != null) {
                    useTarget(targetProject)
                }
            }
        }
    }
}
```

build.gradle

```groovy
configurations.all {
    resolutionStrategy.dependencySubstitution.all { DependencySubstitution
dependency ->
        if (dependency.requested instanceof ModuleComponentSelector && dependency
.requested.group == "org.example") {
            def targetProject = findProject(":${dependency.requested.module}")
            if (targetProject != null) {
                dependency.useTarget targetProject
            }
        }
    }
}
```

Note that a project that is substituted must be included in the multi-project build (via `settings.gradle`). Dependency substitution rules take care of replacing the module dependency with the project dependency, but do not implicitly include the project in the build.

=== Substituting a dependency with another variant

Gradle's dependency management engine is variant-aware meaning that for a single component, the engine may select different artifacts and transitive dependencies.

What to select is determined by the attributes of the consumer configuration and the attributes of the variants found on the producer side. It is, however, possible that some specific dependencies override attributes from the configuration itself. This is typically the case when using the Java Platform plugin: this plugin builds a special kind of component which is called a "platform" and can be addressed by setting the component category attribute to `platform`, in opposition to typical dependencies which are targetting libraries.

Therefore, you may face situations where you want to substitute a platform dependency with a regular dependency, or the other way around.

==== Substituting a dependency with attributes

Let's imagine that you want to substitute a platform dependency with a regular dependency. This means that the library you are consuming declared something like this:

lib/build.gradle.kts

```
dependencies {
    // This is a platform dependency but you want the library
    implementation(platform("com.google.guava:guava:28.2-jre"))
}
```

lib/build.gradle

```
dependencies {
    // This is a platform dependency but you want the library
    implementation platform('com.google.guava:guava:28.2-jre')
}
```

The `platform` keyword is actually a short-hand notation for a *dependency with attributes*. If we want to substitute this dependency with a regular dependency, then we need to select precisely the dependencies which have the `platform` attribute.

This can be done by using a substitution rule:

consumer/build.gradle.kts

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(platform(module("com.google.guava:guava:28.2-jre")))
            .using(module("com.google.guava:guava:28.2-jre"))
    }
}
```

consumer/build.gradle

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(platform(module('com.google.guava:guava:28.2-jre'))).
            using module('com.google.guava:guava:28.2-jre')
    }
}
```

The same rule *without* the `platform` keyword would try to substitute *regular dependencies* with a regular dependency, which is not what you want, so it's important to understand that the substitution rules apply on a *dependency specification*: it matches the requested dependency (`substitute XXX`) with a substitute (`using YYY`).

You can have attributes on both the requested dependency *or* the substitute and the substitution is not limited to `platform`: you can actually specify the whole set of dependency attributes using the `variant` notation. The following rule is *strictly equivalent* to the rule above:

consumer/build.gradle.kts

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(variant(module("com.google.guava:guava:28.2-jre")) {
            attributes {
                attribute(Category.CATEGORY_ATTRIBUTE,
objects.named(Category.REGULAR_PLATFORM))
            }
        }).using(module("com.google.guava:guava:28.2-jre"))
    }
}
```

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute variant(module('com.google.guava:guava:28.2-jre')) {
            attributes {
                attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.REGULAR_PLATFORM))
            }
        } using module('com.google.guava:guava:28.2-jre')
    }
}
```

Please refer to the Substitution DSL API docs for a complete reference of the variant substitution API.

WARNING	In composite builds, the rule that you have to match the exact requested dependency attributes is not applied: when using composites, Gradle will automatically match the requested attributes. In other words, it is implicit that if you include another build, you are substituting *all variants* of the substituted module with an equivalent variant in the included build.

==== Substituting a dependency with a dependency with capabilities

Similarly to attributes substitution, Gradle lets you substitute a dependency with or without capabilities with another dependency with or without capabilities.

For example, let's imagine that you need to substitute a regular dependency with its test fixtures instead. You can achieve this by using the following dependency substitution rule:

build.gradle.kts

```
configurations.testCompileClasspath {
    resolutionStrategy.dependencySubstitution {

substitute(module("com.acme:lib:1.0")).using(variant(module("com.acme:lib:1.0")) {
            capabilities {
                requireCapability("com.acme:lib-test-fixtures")
            }
        })
    }
}
```

build.gradle

```
configurations.testCompileClasspath {
    resolutionStrategy.dependencySubstitution {
        substitute(module('com.acme:lib:1.0'))
            .using variant(module('com.acme:lib:1.0')) {
            capabilities {
                requireCapability('com.acme:lib-test-fixtures')
            }
        }
    }
}
```

Capabilities which are declared in a substitution rule on the requested dependency constitute part of the dependency match specification, and therefore dependencies which do *not* require the capabilities will not be matched.

Please refer to the Substitution DSL API docs for a complete reference of the variant substitution API.

=== Substituting a dependency with a classifier or artifact

While external modules are in general addressed via their group/artifact/version coordinates, it is common that such modules are published with additional artifacts that you may want to use in place of the main artifact. This is typically the case for *classified* artifacts, but you may also need to select an artifact with a different file type or extension. Gradle discourages use of classifiers in dependencies and prefers to model such artifacts as additional variants of a module. There are lots of advantages of using variants instead of classified artifacts, including, but not only, a different set of dependencies for those artifacts.

However, in order to help bridging the two models, Gradle provides means to change or remove a classifier in a substitution rule.

consumer/build.gradle.kts

```
dependencies {
    implementation("com.google.guava:guava:28.2-jre")
    implementation("co.paralleluniverse:quasar-core:0.8.0")
    implementation(project(":lib"))
}
```

consumer/build.gradle

```
dependencies {
    implementation 'com.google.guava:guava:28.2-jre'
    implementation 'co.paralleluniverse:quasar-core:0.8.0'
    implementation project(':lib')
}
```

In the example above, the first level dependency on `quasar` makes us think that Gradle would resolve `quasar-core-0.8.0.jar` but it's not the case: the build would fail with this message:

```
Execution failed for task ':resolve'.
> Could not resolve all files for configuration ':runtimeClasspath'.
   > Could not find quasar-core-0.8.0-jdk8.jar (co.paralleluniverse:quasar-
core:0.8.0).
     Searched in the following locations:
         https://repo1.maven.org/maven2/co/paralleluniverse/quasar-
core/0.8.0/quasar-core-0.8.0-jdk8.jar
```

That's because there's a dependency on another project, `lib`, which itself depends on a different version of `quasar-core`:

lib/build.gradle.kts

```
dependencies {
    implementation("co.paralleluniverse:quasar-core:0.7.10:jdk8")
}
```

lib/build.gradle

```
dependencies {
    implementation "co.paralleluniverse:quasar-core:0.7.10:jdk8"
}
```

What happens is that Gradle would perform conflict resolution between `quasar-core` 0.8.0 and `quasar-core` 0.7.10. Because 0.8.0 is higher, we select this version, but the dependency in `lib` has a classifier, `jdk8` and this classifier *doesn't exist anymore* in release 0.8.0.

To fix this problem, you can ask Gradle to resolve both dependencies *without classifier*:

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute(module("co.paralleluniverse:quasar-core"))
            .using(module("co.paralleluniverse:quasar-core:0.8.0"))
            .withoutClassifier()
    }
}
```

```
configurations.all {
    resolutionStrategy.dependencySubstitution {
        substitute module('co.paralleluniverse:quasar-core') using module(
'co.paralleluniverse:quasar-core:0.8.0') withoutClassifier()
    }
}
```

This rule effectively replaces any dependency on `quasar-core` found in the graph with a dependency without classifier.

Alternatively, it's possible to select a dependency *with* a specific classifier or, for more specific use cases, substitute with a very specific artifact (type, extension and classifier).

For more information, please refer to the following API documentation:

- artifact selection via the Substitution DSL
- artifact selection via the DependencySubstitution API
- artifact selection via the ResolutionStrategy API

== Disabling transitive resolution

By default Gradle resolves all transitive dependencies specified by the dependency metadata. Sometimes this behavior may not be desirable e.g. if the metadata is incorrect or defines a large graph of transitive dependencies. You can tell Gradle to disable transitive dependency management for a dependency by setting ModuleDependency.setTransitive(boolean) to `false`. As a result only the main artifact will be resolved for the declared dependency.

build.gradle.kts

```
dependencies {
    implementation("com.google.guava:guava:23.0") {
        isTransitive = false
    }
}
```

build.gradle

```
dependencies {
    implementation('com.google.guava:guava:23.0') {
        transitive = false
    }
}
```

NOTE	Disabling transitive dependency resolution will likely require you to declare the necessary runtime dependencies in your build script which otherwise would have been resolved automatically. Not doing so might lead to runtime classpath issues.

A project can decide to disable transitive dependency resolution completely. You either don't want to rely on the metadata published to the consumed repositories or you want to gain full control over the dependencies in your graph. For more information, see Configuration.setTransitive(boolean).

build.gradle.kts

```
configurations.all {
    isTransitive = false
}

dependencies {
    implementation("com.google.guava:guava:23.0")
}
```

build.gradle

```
configurations.all {
    transitive = false
}

dependencies {
    implementation 'com.google.guava:guava:23.0'
}
```

== Changing configuration dependencies prior to resolution

At times, a plugin may want to modify the dependencies of a configuration before it is resolved. The `withDependencies` method permits dependencies to be added, removed or modified programmatically.

build.gradle.kts

```
configurations {
    create("implementation") {
        withDependencies {
            val dep = this.find { it.name == "to-modify" } as
ExternalModuleDependency
            dep.version {
                strictly("1.2")
            }
        }
    }
}
```

build.gradle

```
configurations {
    implementation {
        withDependencies { DependencySet dependencies ->
            ExternalModuleDependency dep = dependencies.find { it.name == 'to-
modify' } as ExternalModuleDependency
            dep.version {
                strictly "1.2"
            }
        }
    }
}
```

== Setting default configuration dependencies

A configuration can be configured with default dependencies to be used if no dependencies are explicitly set for the configuration. A primary use case of this functionality is for developing plugins that make use of versioned tools that the user might override. By specifying default dependencies, the plugin can use a default version of the tool only if the user has not specified a particular version to use.

build.gradle.kts

```kotlin
configurations {
    create("pluginTool") {
        defaultDependencies {
            add(project.dependencies.create("org.gradle:my-util:1.0"))
        }
    }
}
```

build.gradle

```groovy
configurations {
    pluginTool {
        defaultDependencies { dependencies ->
            dependencies.add(project.dependencies.create("org.gradle:my-util:1.0"
))
        }
    }
}
```

== Excluding a dependency from a configuration completely

Similar to excluding a dependency in a dependency declaration, you can exclude a transitive dependency for a particular configuration completely by using Configuration.exclude(java.util.Map). This will automatically exclude the transitive dependency for all dependencies declared on the configuration.

build.gradle.kts

```kotlin
configurations {
    "implementation" {
        exclude(group = "commons-collections", module = "commons-collections")
    }
}

dependencies {
    implementation("commons-beanutils:commons-beanutils:1.9.4")
    implementation("com.opencsv:opencsv:4.6")
}
```

build.gradle

```groovy
configurations {
    implementation {
        exclude group: 'commons-collections', module: 'commons-collections'
    }
}

dependencies {
    implementation 'commons-beanutils:commons-beanutils:1.9.4'
    implementation 'com.opencsv:opencsv:4.6'
}
```

== Matching dependencies to repositories

Gradle exposes an API to declare what a repository may or may not contain. This feature offers a fine grained control on which repository serve which artifacts, which can be one way of controlling the source of dependencies.

Head over to the section on repository content filtering to know more about this feature.

== Enabling Ivy dynamic resolve mode

Gradle's Ivy repository implementations support the equivalent to Ivy's dynamic resolve mode. Normally, Gradle will use the `rev` attribute for each dependency definition included in an `ivy.xml` file. In dynamic resolve mode, Gradle will instead prefer the `revConstraint` attribute over the `rev` attribute for a given dependency definition. If the `revConstraint` attribute is not present, the `rev` attribute is used instead.

To enable dynamic resolve mode, you need to set the appropriate option on the repository definition. A couple of examples are shown below. Note that dynamic resolve mode is only available for Gradle's Ivy repositories. It is not available for Maven repositories, or custom Ivy `DependencyResolver` implementations.

build.gradle.kts

```
// Can enable dynamic resolve mode when you define the repository
repositories {
    ivy {
        url = uri("http://repo.mycompany.com/repo")
        resolve.isDynamicMode = true
    }
}

// Can use a rule instead to enable (or disable) dynamic resolve mode for all
repositories
repositories.withType<IvyArtifactRepository> {
    resolve.isDynamicMode = true
}
```

```
// Can enable dynamic resolve mode when you define the repository
repositories {
    ivy {
        url "http://repo.mycompany.com/repo"
        resolve.dynamicMode = true
    }
}

// Can use a rule instead to enable (or disable) dynamic resolve mode for all
repositories
repositories.withType(IvyArtifactRepository) {
    resolve.dynamicMode = true
}
```

= Preventing accidental dependency upgrades

In some situations, you might want to be in total control of the dependency graph. In particular, you may want to make sure that:

- the versions declared in a build script actually correspond to the ones being resolved

- or make sure that dependency resolution is reproducible over time

Gradle provides ways to perform this by configuring the resolution strategy.

== Failing on version conflict

There's a version conflict whenever Gradle finds the same module in two different versions in a dependency graph. By default, Gradle performs *optimistic upgrades*, meaning that if version 1.1 and 1.3 are found in the graph, we resolve to the highest version, 1.3. However, it is easy to miss that some dependencies are upgraded because of a transitive dependency. In the example above, if 1.1 was a version used in your build script and 1.3 a version brought transitively, you could use 1.3 without actually noticing.

To make sure that you are aware of such upgrades, Gradle provides a mode that can be activated in the resolution strategy of a configuration. Imagine the following dependencies declaration:

build.gradle.kts

```
dependencies {
    implementation("org.apache.commons:commons-lang3:3.0")
    // the following dependency brings lang3 3.8.1 transitively
    implementation("com.opencsv:opencsv:4.6")
}
```

build.gradle

```
dependencies {
    implementation 'org.apache.commons:commons-lang3:3.0'
    // the following dependency brings lang3 3.8.1 transitively
    implementation 'com.opencsv:opencsv:4.6'
}
```

Then by default Gradle would upgrade `commons-lang3`, but it is possible to *fail* the build:

build.gradle.kts

```
configurations.all {
    resolutionStrategy {
        failOnVersionConflict()
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy {
        failOnVersionConflict()
    }
}
```

== Making sure resolution is reproducible

There are cases where dependency resolution can be *unstable* over time. That is to say that if you build at date D, building at date D+x may give a different resolution result.

This is possible in the following cases:

- dynamic dependency versions are used (version ranges, `latest.release`, `1.+`, …)
- or *changing* versions are used (SNAPSHOTs, fixed version with changing contents, …)

The recommended way to deal with dynamic versions is to use dependency locking. However, it is possible to prevent the use of dynamic versions altogether, which is an alternate strategy:

build.gradle.kts

```
configurations.all {
    resolutionStrategy {
        failOnDynamicVersions()
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy {
        failOnDynamicVersions()
    }
}
```

Likewise, it's possible to prevent the use of changing versions by activating this flag:

build.gradle.kts

```
configurations.all {
    resolutionStrategy {
        failOnChangingVersions()
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy {
        failOnChangingVersions()
    }
}
```

It's a good practice to fail on changing versions at release time.

Eventually, it's possible to combine both failing on dynamic versions and changing versions using a single call:

build.gradle.kts

```
configurations.all {
    resolutionStrategy {
        failOnNonReproducibleResolution()
    }
}
```

build.gradle

```
configurations.all {
    resolutionStrategy {
        failOnNonReproducibleResolution()
    }
}
```

Getting consistent dependency resolution results

> **NOTE**   Dependency resolution consistency is an incubating feature

It's a common misconception that there's a single dependency graph for an application. In fact Gradle will, during a build, resolve a number of distinct dependency graphs, even within a single project. For example, the graph of dependencies to use at compile time is different from the graph of dependencies to use at runtime. In general, the graph of dependencies at runtime is a superset of the compile dependencies (there are exceptions to the rule, for example in case some dependencies are repackaged within the runtime binary).

Gradle resolves those dependency graphs independently. This means, in the Java ecosystem for example, that the resolution of the "compile classpath" doesn't influence the resolution of the "runtime classpath". Similarly, test dependencies could end up bumping the version of production dependencies, causing some surprising results when executing tests.

These surprising behaviors can be mitigated by enabling dependency resolution consistency.

Enabling project-local dependency resolution consistency

For example, imagine that your Java library depends on the following libraries:

build.gradle.kts

```kotlin
dependencies {
    implementation("org.codehaus.groovy:groovy:3.0.1")
    runtimeOnly("io.vertx:vertx-lang-groovy:3.9.4")
}
```

build.gradle

```groovy
dependencies {
    implementation 'org.codehaus.groovy:groovy:3.0.1'
    runtimeOnly 'io.vertx:vertx-lang-groovy:3.9.4'
}
```

Then resolving the `compileClasspath` configuration would resolve the `groovy` library to version `3.0.1` as expected. However, resolving the `runtimeClasspath` configuration would instead return `groovy 3.0.2`.

The reason for this is that a transitive dependency of `vertx`, which is a `runtimeOnly` dependency, brings a higher version of `groovy`. In general, this isn't a problem, but it also means that the version of the Groovy library that you are going to use at runtime is going to be different from the one that you used for compilation.

In order to avoid this situation, Gradle offers an API to explain that configurations should be resolved consistently.

=== Declaring resolution consistency between configurations

In the example above, we can declare that we want, at runtime, the same versions of the common dependencies as compile time, by declaring that the "runtime classpath" *should be consistent with* the "compile classpath":

build.gradle.kts

```
configurations {
    runtimeClasspath.get().shouldResolveConsistentlyWith(compileClasspath.get())
}
```

build.gradle

```
configurations {
    runtimeClasspath.shouldResolveConsistentlyWith(compileClasspath)
}
```

As a result, both the `runtimeClasspath` and `compileClasspath` will resolve Groovy 3.0.1.

The relationship is *directed*, which means that if the `runtimeClasspath` configuration has to be resolved, Gradle will *first* resolve the `compileClasspath` and then "inject" the result of resolution as strict constraints into the `runtimeClasspath`.

If, for some reason, the versions of the two graphs cannot be "aligned", then resolution will fail with a call to action.

=== Declaring consistent resolution in the Java ecosystem

The `runtimeClasspath` and `compileClasspath` example above are common in the Java ecosystem. However, it's often not enough to declare consistency between those two configurations only. For example, you most likely want the *test runtime classpath* to be consistent with the *runtime classpath*.

To make this easier, Gradle provides a way to configure consistent resolution for the Java ecosystem using the `java` extension:

build.gradle.kts

```
java {
    consistentResolution {
        useCompileClasspathVersions()
    }
}
```

build.gradle

```
java {
    consistentResolution {
        useCompileClasspathVersions()
    }
}
```

Please refer to the Java Plugin Extension docs for more configuration options.

== PRODUCING AND CONSUMING VARIANTS OF LIBRARIES

= Declaring Capabilities of a Library

== Capabilities as first-level concept

Components provide a number of features which are often orthogonal to the software architecture used to provide those features. For example, a library may include several features in a single artifact. However, such a library would be published at single GAV (group, artifact and version) coordinates. This means that, at single coordinates, potentially co-exist different "features" of a component.

With Gradle it becomes interesting to explicitly declare what features a component provides. For this, Gradle provides the concept of capability.

A feature is often built by combining different *capabilities*.

In an ideal world, components shouldn't declare dependencies on explicit GAVs, but rather express their requirements in terms of capabilities:

- "give me a component which provides logging"
- "give me a scripting engine"
- "give me a scripting engine that supports Groovy"

By modeling *capabilities*, the dependency management engine can be smarter and tell you whenever you have *incompatible capabilities* in a dependency graph, or ask you to choose whenever different modules in a graph provide the same *capability*.

== Declaring capabilities for external modules

It's worth noting that Gradle supports declaring capabilities for components you build, but also for external components in case they didn't.

For example, if your build file contains the following dependencies:

build.gradle.kts

```
dependencies {
    // This dependency will bring log4:log4j transitively
    implementation("org.apache.zookeeper:zookeeper:3.4.9")

    // We use log4j over slf4j
    implementation("org.slf4j:log4j-over-slf4j:1.7.10")
}
```

```
dependencies {
    // This dependency will bring log4:log4j transitively
    implementation 'org.apache.zookeeper:zookeeper:3.4.9'

    // We use log4j over slf4j
    implementation 'org.slf4j:log4j-over-slf4j:1.7.10'
}
```

As is, it's pretty hard to figure out that you will end up with two logging frameworks on the classpath. In fact, `zookeeper` will bring in `log4j`, where what we want to use is `log4j-over-slf4j`. We can preemptively detect the conflict by adding a rule which will declare that both logging frameworks provide the same capability:

```
dependencies {
    // Activate the "LoggingCapability" rule
    components.all(LoggingCapability::class.java)
}

class LoggingCapability : ComponentMetadataRule {
    val loggingModules = setOf("log4j", "log4j-over-slf4j")

    override
    fun execute(context: ComponentMetadataContext) = context.details.run {
        if (loggingModules.contains(id.name)) {
            allVariants {
                withCapabilities {
                    // Declare that both log4j and log4j-over-slf4j provide the
same capability
                    addCapability("log4j", "log4j", id.version)
                }
            }
        }
    }
}
```

build.gradle

```
dependencies {
    // Activate the "LoggingCapability" rule
    components.all(LoggingCapability)
}

@CompileStatic
class LoggingCapability implements ComponentMetadataRule {
    final static Set<String> LOGGING_MODULES = ["log4j", "log4j-over-slf4j"] as
Set<String>

    void execute(ComponentMetadataContext context) {
        context.details.with {
            if (LOGGING_MODULES.contains(id.name)) {
                allVariants {
                    it.withCapabilities {
                        // Declare that both log4j and log4j-over-slf4j provide
the same capability
                        it.addCapability("log4j", "log4j", id.version)
                    }
                }
            }
        }
    }
}
```

By adding this rule, we will make sure that Gradle *will* detect conflicts and properly fail:

```
> Could not resolve all files for configuration ':compileClasspath'.
   > Could not resolve org.slf4j:log4j-over-slf4j:1.7.10.
     Required by:
         project :
      > Module 'org.slf4j:log4j-over-slf4j' has been rejected:
           Cannot select module with conflict on capability 'log4j:log4j:1.7.10'
also provided by [log4j:log4j:1.2.16(compile)]
   > Could not resolve log4j:log4j:1.2.16.
     Required by:
         project : > org.apache.zookeeper:zookeeper:3.4.9
      > Module 'log4j:log4j' has been rejected:
           Cannot select module with conflict on capability 'log4j:log4j:1.2.16'
also provided by [org.slf4j:log4j-over-slf4j:1.7.10(compile)]
```

See the capabilities section of the documentation to figure out how to fix capability conflicts.

== Declaring additional capabilities for a local component

All components have an *implicit capability* corresponding to the same GAV coordinates as the component. However, it is also possible to declare additional *explicit capabilities* for a component. This is convenient whenever a library published at different GAV coordinates is an *alternate implementation* of the same API:

build.gradle.kts

```
configurations {
    apiElements {
        outgoing {
            capability("com.acme:my-library:1.0")
            capability("com.other:module:1.1")
        }
    }
    runtimeElements {
        outgoing {
            capability("com.acme:my-library:1.0")
            capability("com.other:module:1.1")
        }
    }
}
```

build.gradle

```
configurations {
    apiElements {
        outgoing {
            capability("com.acme:my-library:1.0")
            capability("com.other:module:1.1")
        }
    }
    runtimeElements {
        outgoing {
            capability("com.acme:my-library:1.0")
            capability("com.other:module:1.1")
        }
    }
}
```

Capabilities must be attached to *outgoing configurations*, which are consumable configurations of a component.

This example shows that we declare two capabilities:

1. `com.acme:my-library:1.0`, which corresponds to the *implicit capability* of the library

2. `com.other:module:1.1`, which corresponds to another capability of this library

It's worth noting we need to do 1. because as soon as you start declaring *explicit* capabilities, then *all* capabilities need to be declared, including the *implicit* one.

The second capability can be specific to this library, or it can correspond to a capability provided by an external component. In that case, if `com.other:module` appears in the same dependency graph, the build will fail and consumers will have to choose what module to use.

Capabilities are published to Gradle Module Metadata. However, they have *no equivalent* in POM or Ivy metadata files. As a consequence, when publishing such a component, Gradle will warn you that this feature is only for Gradle consumers:

```
Maven publication 'maven' contains dependencies that cannot be represented in a
published pom file.
  - Declares capability com.acme:my-library:1.0
  - Declares capability com.other:module:1.1
```

= Modeling library features

Gradle supports the concept of *features*: it's often the case that a single library can be split up into multiple related yet distinct libraries, where each *feature* can be used alongside the *main* library.

Features allow a component to expose multiple related libraries, each of which can declare its own dependencies. These libraries are exposed as variants, similar to how the *main* library exposes variants for its API and runtime.

This allows for a number of different scenarios (list is non-exhaustive):

- a (better) substitute for Maven optional dependencies

- a *main* library is built with support for different mutually-exclusive implementations of runtime features; the user must choose one, and only one, implementation of each such feature

- a *main* library is built with support for optional runtime features, each of which requires a different set of dependencies

- a *main* library comes with supplementary features like *test fixtures*

- a *main* library comes with a main artifact, and enabling an additional feature requires additional artifacts

== Selection of features via capabilities

Declaring a dependency on a component is usually done by providing a set of coordinates (group, artifact, version also known as GAV coordinates). This allows the engine to determine the *component* we're looking for, but such a component may provide different *variants*. A *variant* is typically chosen based on the usage. For example, we might choose a different variant for compiling against a component (in which case we need the API of the component) or when executing code (in which case we need the runtime of the component). All variants of a component provide a number of capabilities, which are denoted similarly using GAV coordinates.

A capability is denoted by GAV coordinates, but you must think of it as feature description:

- "I provide an SLF4J binding"

- "I provide runtime support for MySQL"

- "I provide a Groovy runtime"

And in general, having two components that provide the *same thing* in the graph is a problem (they conflict).

This is an important concept because:

- By default, a variant provides a capability corresponding to the GAV coordinates of its component

- No two variants in a dependency graph can provide the same capability

- Multiple variants of a single component may be selected as long as they provide *different capabilities*

A typical component will **only** provide variants with the default capability. A Java library, for example, exposes two variants (API and runtime) which provide the *same capability*. As a consequence, it is an error to have both the *API* and *runtime* of a single component in a dependency graph.

However, imagine that you need the *runtime* and the *test fixtures runtime* of a component. Then it is allowed as long as the *runtime* and *test fixtures runtime* variant of the library declare different capabilities.

If we do so, a consumer would then have to declare two dependencies:

- one on the "main" feature, the library

- one on the "test fixtures" feature, by *requiring its capability*

| NOTE | While the resolution engine supports multi-variant components independently of the ecosystem, *features* are currently only available using the Java plugins. |

== Registering features

Features can be declared by applying the `java-library` plugin. The following code illustrates how to declare a feature named `mongodbSupport`:

build.gradle.kts

```
sourceSets {
    create("mongodbSupport") {
        java {
            srcDir("src/mongodb/java")
        }
    }
}

java {
    registerFeature("mongodbSupport") {
        usingSourceSet(sourceSets["mongodbSupport"])
    }
}
```

build.gradle

```
sourceSets {
    mongodbSupport {
        java {
            srcDir 'src/mongodb/java'
        }
    }
}

java {
    registerFeature('mongodbSupport') {
        usingSourceSet(sourceSets.mongodbSupport)
    }
}
```

Gradle will automatically set up a number of things for you, in a very similar way to how the Java Library Plugin sets up configurations.

Dependency scope configurations are created in the same manner as for the main feature:

- the configuration `mongodbSupportApi`, used to *declare API dependencies* for this feature
- the configuration `mongodbSupportImplementation`, used to *declare implementation dependencies* for this feature
- the configuration `mongodbSupportRuntimeOnly`, used to *declare runtime-only dependencies* for this feature
- the configuration `mongodbSupportCompileOnly`, used to *declare compile-only dependencies* for this feature
- the configuration `mongodbSupportCompileOnlyApi`, used to *declare compile-only API dependencies* for this feature

Furthermore, consumable configurations are created in the same manner as for the main feature:

- the configuration `mongodbSupportApiElements`, used by consumers to fetch the artifacts and API dependencies of this feature
- the configuration `mongodbSupportRuntimeElements`, used by consumers to fetch the artifacts and runtime dependencies of this feature

A feature should have a *source set* with the same name. Gradle will create a `Jar` task to bundle the classes built from the feature source set, using a classifier corresponding to the kebab-case name of the feature.

WARNING	Do not use the *main* source set when registering a feature. This behavior will be deprecated in a future version of Gradle.

Most users will only need to care about the dependency scope configurations, to declare the specific dependencies of this feature:

build.gradle.kts

```
dependencies {
    "mongodbSupportImplementation"("org.mongodb:mongodb-driver-sync:3.9.1")
}
```

```
dependencies {
    mongodbSupportImplementation 'org.mongodb:mongodb-driver-sync:3.9.1'
}
```

By convention, Gradle maps the feature name to a capability whose group and version are the same as the group and version of the main component, respectively, but whose name is the main component name followed by a `-` followed by the kebab-cased feature name.

For example, if the component's group is `org.gradle.demo`, its name is `provider`, its version is `1.0`, and the feature is named `mongodbSupport`, the feature's variants will have the `org.gradle.demo:provider-mongodb-support:1.0` capability.

If you choose the capability name yourself or add more capabilities to a variant, it is recommended to follow the same convention.

== Publishing features

Depending on the metadata file format, publishing features may be lossy:

- using Gradle Module Metadata, everything is published and consumers will get the full benefit of features
- using POM metadata (Maven), features are published as **optional dependencies** and artifacts of features are published with different *classifiers*
- using Ivy metadata, features are published as extra configurations, which are *not* extended by the `default` configuration

Publishing features is supported using the `maven-publish` and `ivy-publish` plugins only. The Java Library Plugin will take care of registering the additional variants for you, so there's no additional configuration required, only the regular publications:

build.gradle.kts

```
plugins {
    `java-library`
    `maven-publish`
}
// ...
publishing {
    publications {
        create("myLibrary", MavenPublication::class.java) {
            from(components["java"])
        }
    }
}
```

build.gradle

```
plugins {
    id 'java-library'
    id 'maven-publish'
}
// ...
publishing {
    publications {
        myLibrary(MavenPublication) {
            from components.java
        }
    }
}
```

=== Adding javadoc and sources JARs

Similar to the main Javadoc and sources JARs, you can configure the added feature so that it produces JARs for the Javadoc and sources.

```
java {
    registerFeature("mongodbSupport") {
        usingSourceSet(sourceSets["mongodbSupport"])
        withJavadocJar()
        withSourcesJar()
    }
}
```

```
java {
    registerFeature('mongodbSupport') {
        usingSourceSet(sourceSets.mongodbSupport)
        withJavadocJar()
        withSourcesJar()
    }
}
```

== Dependencies on features

As mentioned earlier, features can be lossy when published. As a consequence, a consumer can depend on a feature only in these cases:

- with a project dependency (in a multi-project build)
- with Gradle Module Metadata available, that is the publisher MUST have published it
- within the Ivy world, by declaring a dependency on the configuration matching the feature

A consumer can specify that it needs a specific feature of a producer by declaring required capabilities. For example, if a producer declares a "MySQL support" feature like this:

build.gradle.kts

```kotlin
group = "org.gradle.demo"

sourceSets {
    create("mysqlSupport") {
        java {
            srcDir("src/mysql/java")
        }
    }
}

java {
    registerFeature("mysqlSupport") {
        usingSourceSet(sourceSets["mysqlSupport"])
    }
}

dependencies {
    "mysqlSupportImplementation"("mysql:mysql-connector-java:8.0.14")
}
```

build.gradle

```groovy
group = 'org.gradle.demo'

sourceSets {
    mysqlSupport {
        java {
            srcDir 'src/mysql/java'
        }
    }
}

java {
    registerFeature('mysqlSupport') {
        usingSourceSet(sourceSets.mysqlSupport)
    }
}

dependencies {
    mysqlSupportImplementation 'mysql:mysql-connector-java:8.0.14'
}
```

Then the consumer can declare a dependency on the MySQL support feature by doing this:

build.gradle.kts

```
dependencies {
    // This project requires the main producer component
    implementation(project(":producer"))

    // But we also want to use its MySQL support
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-mysql-support")
        }
    }
}
```

build.gradle

```
dependencies {
    // This project requires the main producer component
    implementation(project(":producer"))

    // But we also want to use its MySQL support
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-mysql-support")
        }
    }
}
```

This will automatically bring the `mysql-connector-java` dependency on the runtime classpath. If there were more than one dependency, all of them would be brought, meaning that a feature can be used to group dependencies which contribute to a feature together.

Similarly, if an external library with features was published with Gradle Module Metadata, it is possible to depend on a feature provided by that library:

build.gradle.kts

```
dependencies {
    // This project requires the main producer component
    implementation("org.gradle.demo:producer:1.0")

    // But we also want to use its MongoDB support
    runtimeOnly("org.gradle.demo:producer:1.0") {
        capabilities {
            requireCapability("org.gradle.demo:producer-mongodb-support")
        }
    }
}
```

build.gradle

```
dependencies {
    // This project requires the main producer component
    implementation('org.gradle.demo:producer:1.0')

    // But we also want to use its MongoDB support
    runtimeOnly('org.gradle.demo:producer:1.0') {
        capabilities {
            requireCapability("org.gradle.demo:producer-mongodb-support")
        }
    }
}
```

Handling mutually exclusive variants

The main advantage of using *capabilities* as a way to handle features is that you can precisely handle compatibility of variants. The rule is simple:

> No two variants in a dependency graph can provide the same capability

We can leverage this to ensure that Gradle fails whenever the user mis-configures dependencies. Consider a situation where your library supports MySQL, Postgres and MongoDB, but that it's only allowed to choose *one* of those at the same time. We can model this restriction by ensuring each feature also provides the same capability, thus making it impossible for these features to be used together in the same graph.

build.gradle.kts

```
java {
    registerFeature("mysqlSupport") {
        usingSourceSet(sourceSets["mysqlSupport"])
        capability("org.gradle.demo", "producer-db-support", "1.0")
        capability("org.gradle.demo", "producer-mysql-support", "1.0")
    }
    registerFeature("postgresSupport") {
        usingSourceSet(sourceSets["postgresSupport"])
        capability("org.gradle.demo", "producer-db-support", "1.0")
        capability("org.gradle.demo", "producer-postgres-support", "1.0")
    }
    registerFeature("mongoSupport") {
        usingSourceSet(sourceSets["mongoSupport"])
        capability("org.gradle.demo", "producer-db-support", "1.0")
        capability("org.gradle.demo", "producer-mongo-support", "1.0")
    }
}

dependencies {
    "mysqlSupportImplementation"("mysql:mysql-connector-java:8.0.14")
    "postgresSupportImplementation"("org.postgresql:postgresql:42.2.5")
    "mongoSupportImplementation"("org.mongodb:mongodb-driver-sync:3.9.1")
}
```

```
java {
    registerFeature('mysqlSupport') {
        usingSourceSet(sourceSets.mysqlSupport)
        capability('org.gradle.demo', 'producer-db-support', '1.0')
        capability('org.gradle.demo', 'producer-mysql-support', '1.0')
    }
    registerFeature('postgresSupport') {
        usingSourceSet(sourceSets.postgresSupport)
        capability('org.gradle.demo', 'producer-db-support', '1.0')
        capability('org.gradle.demo', 'producer-postgres-support', '1.0')
    }
    registerFeature('mongoSupport') {
        usingSourceSet(sourceSets.mongoSupport)
        capability('org.gradle.demo', 'producer-db-support', '1.0')
        capability('org.gradle.demo', 'producer-mongo-support', '1.0')
    }
}

dependencies {
    mysqlSupportImplementation 'mysql:mysql-connector-java:8.0.14'
    postgresSupportImplementation 'org.postgresql:postgresql:42.2.5'
    mongoSupportImplementation 'org.mongodb:mongodb-driver-sync:3.9.1'
}
```

Here, the producer declares 3 features, one for each database runtime support:

- `mysql-support` provides both the `db-support` and `mysql-support` capabilities

- `postgres-support` provides both the `db-support` and `postgres-support` capabilities

- `mongo-support` provides both the `db-support` and `mongo-support` capabilities

Then if the consumer tries to get both the `postgres-support` and `mysql-support` features (this also works transitively):

build.gradle.kts

```
dependencies {
    // This project requires the main producer component
    implementation(project(":producer"))

    // Let's try to ask for both MySQL and Postgres support
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-mysql-support")
        }
    }
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-postgres-support")
        }
    }
}
```

build.gradle

```
dependencies {
    implementation(project(":producer"))

    // Let's try to ask for both MySQL and Postgres support
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-mysql-support")
        }
    }
    runtimeOnly(project(":producer")) {
        capabilities {
            requireCapability("org.gradle.demo:producer-postgres-support")
        }
    }
}
```

Dependency resolution would fail with the following error:

```
Cannot choose between
    org.gradle.demo:producer:1.0 variant mysqlSupportRuntimeElements and
    org.gradle.demo:producer:1.0 variant postgresSupportRuntimeElements
    because they provide the same capability: org.gradle.demo:producer-db-
support:1.0
```

= Understanding variant selection

In other dependency management engines, like Apache Maven™, dependencies and artifacts are bound to a component that is published at a particular GAV (group-artifact-version) coordinates. The set of dependencies for this component are always the same, regardless of which artifact may be used from the component.

If the component does have multiple artifacts, each one is identified by a cumbersome *classifier*. There are no common semantics associated with classifiers and that makes it difficult to guarantee a globally consistent dependency graph. This means that nothing prevents multiple artifacts for a single component (e.g., jdk7 and jdk8 classifiers) from appearing in a classpath and causing hard to diagnose problems.

== Maven component model
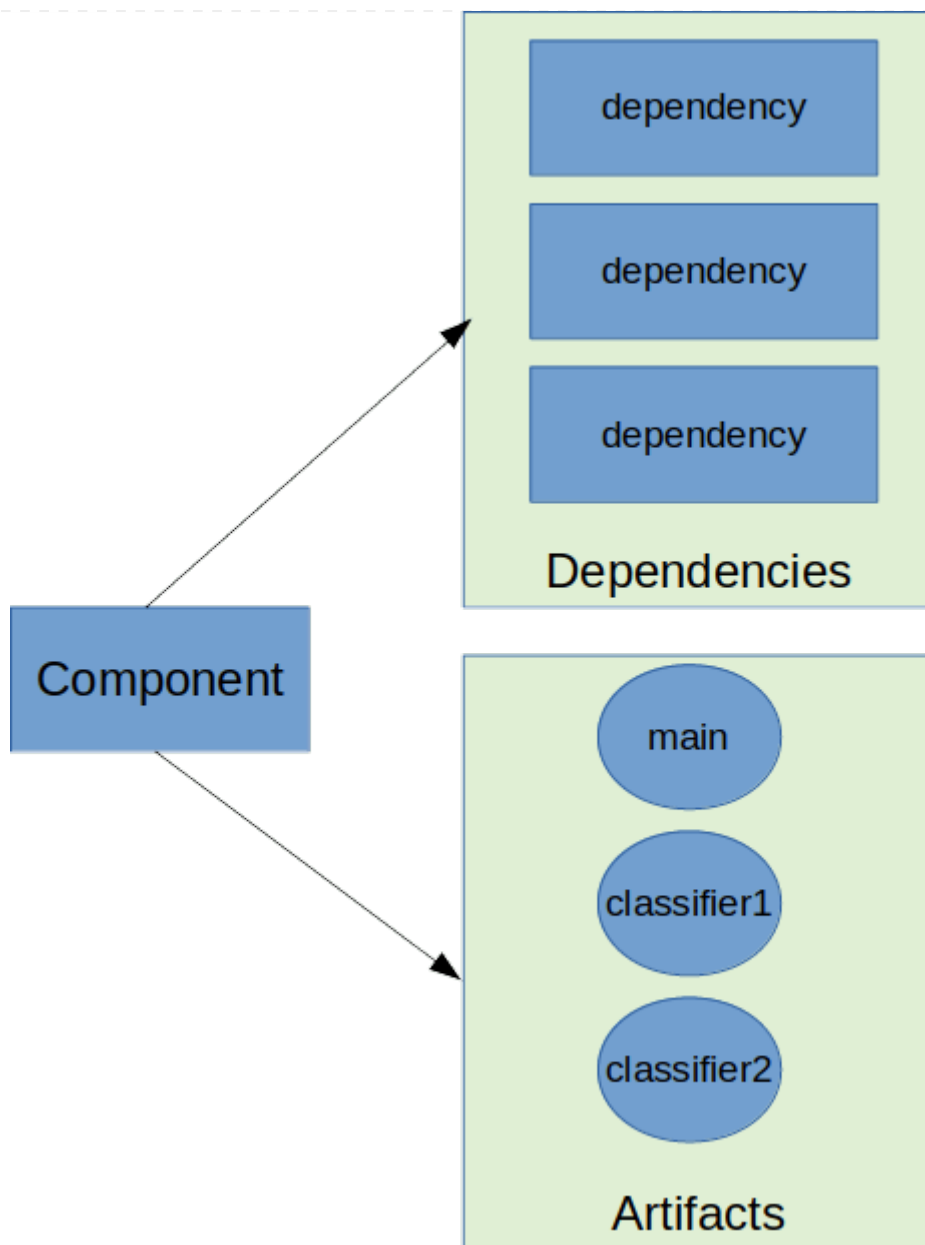
Figure 27. The Maven component model

== Gradle component model
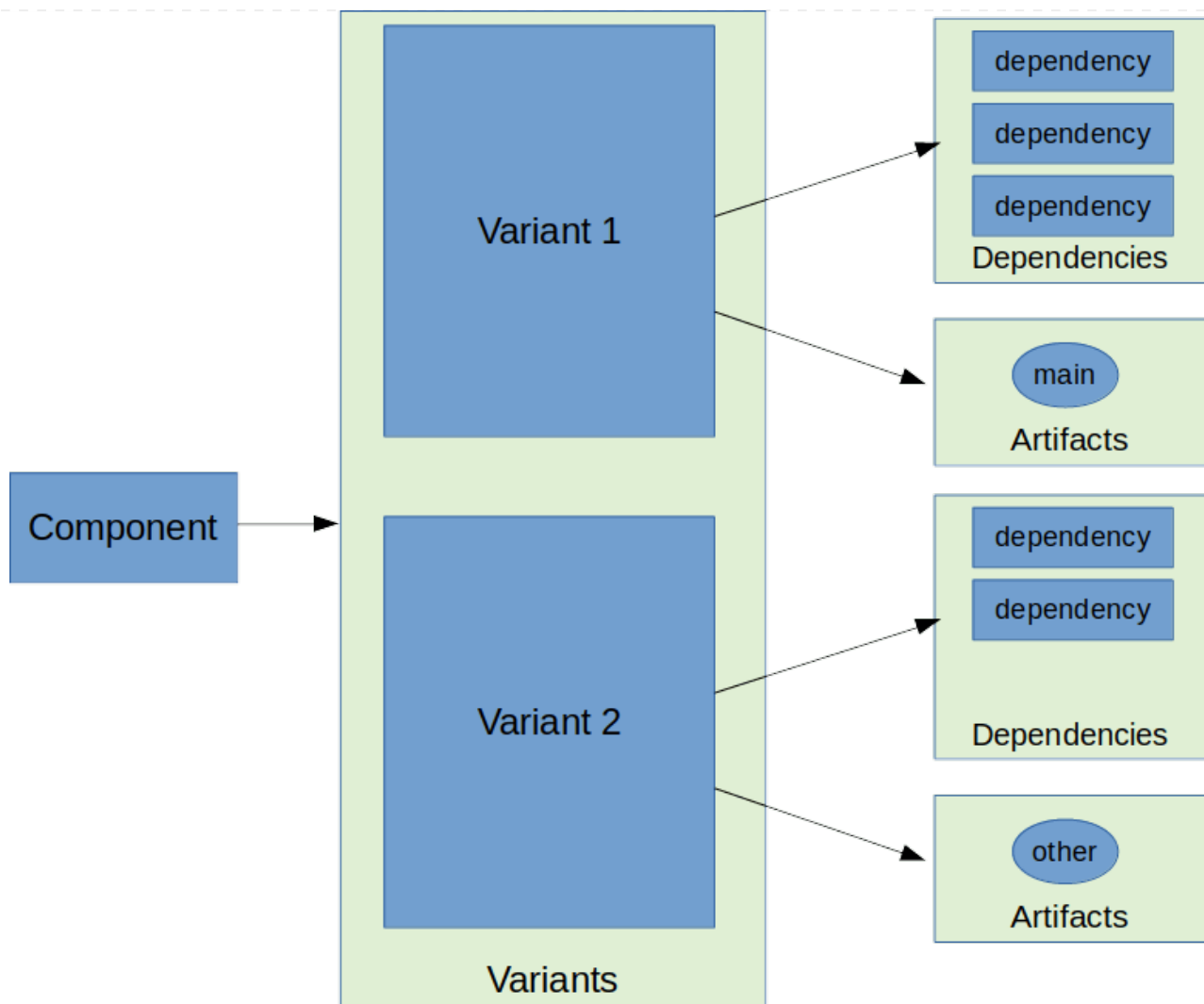
Figure 28. The Gradle component model

Gradle's dependency management engine is *variant aware*.

In addition to a component, Gradle has the concept of *variants* of a component. Variants correspond to the different ways a component can be used, such as for Java compilation or native linking or documentation. Artifacts are attached to a *variant* and each variant can have a different set of dependencies.

How does Gradle know which variant to choose when there's more than one? Variants are matched by use of attributes, which provide semantics to the variants and help the engine to produce a *consistent* resolution result.

Gradle differentiates between two kind of components:

- local components (like projects), built from sources
- external components, published to repositories

For local components, variants are mapped to consumable configurations. For external components, variants are defined by published Gradle Module Metadata or are derived from Ivy/Maven metadata.

Variants vs configurations

Variants and configurations are sometimes used interchangeably in the documentation, DSL or API for historical reasons.

All components provide *variants* and those variants may be backed by a consumable configuration. Not all configurations are variants because they may be used for declaring or resolving dependencies.

Variant attributes

Attributes are type-safe key-value pairs that are defined by the consumer (for a resolvable configuration) and the producer (for each variant).

The consumer can define any number of attributes. Each attribute helps narrow the possible variants that can be selected. Attribute values do not need to be exact matches.

The variant can also define any number of attributes. The attributes should describe how the variant is intended to be used. For example, Gradle uses an attribute named `org.gradle.usage` to describe with how a component is used by the consumer (for compilation, for runtime execution, etc). It is not unusual for a variant to have more attributes than the consumer needs to provide to select it.

Variant attribute matching

About producer variants

The variant *name* is mostly for debugging purposes and error messages. The name does not participate variant matching—only its attributes do.

There are no restrictions on the number of variants a component can define. Usually, a component has at least an implementation variant, but it could also expose test fixtures, documentation or source code. A component may also expose *different variants* for different consumers for the same usage. For example, when compiling, a component could have different headers for Linux vs Windows vs macOS.

Gradle performs *variant aware selection* by matching the attributes requested by the consumer against attributes defined by the producer. The selection algorithm is detailed in another section.

There are two exceptions to this rule that bypass variant aware resolution:

- when a producer has no variants, a default artifact is chosen.
- when a consumer *explicitly selects a configuration by name,* the artifacts of the configuration are chosen.

A simple example

Let's consider an example where a consumer is trying to use a library for compilation.

First, the consumer needs to explain how it's going to use the result of dependency resolution. This is done by setting *attributes* on the resolvable configuration of the consumer.

The consumer wants to resolve a variant that matches: `org.gradle.usage=JAVA_API`

Second, the producer needs to expose the different variants of the component.

The producer component exposes 2 variants:

- its API (named `apiElements`) with attribute `org.gradle.usage=JAVA_API`
- its runtime (named `runtimeElements`) with attribute `org.gradle.usage=JAVA_RUNTIME`

Finally, Gradle selects the appropriate variant by looking at the variant attributes:

- the consumer wants a variant with attributes `org.gradle.usage=JAVA_API`
- the producer has a matching variant (`apiElements`)
- the producer has a non-matching variant (`runtimeElements`)

Gradle provides the artifacts and dependencies from the `apiElements` variant to the consumer.

A more complicated example

In the real world, consumers and producers have more than one attribute.

A Java Library project in Gradle will involve several different attributes:

- `org.gradle.usage` that describes how the variant is used
- `org.gradle.dependency.bundling` that describes how the variant handles dependencies (shadow jar vs fat jar vs regular jar)
- `org.gradle.libraryelements`, that describes the packaging of the variant (classes or jar)
- `org.gradle.jvm.version` that describes the *minimal version* of Java this variant targets
- `org.gradle.jvm.environment` that describes the type of JVM this variant targets

Let's consider an example where the consumer wants to run tests with a library on Java 8 and the producer supports two different Java versions (Java 8 and Java 11).

First, the consumer needs to explain which version of the Java it needs.

The consumer wants to resolve a variant that:

- can be used at runtime (has `org.gradle.usage=JAVA_RUNTIME`)
- can be run on *at least* Java 8 (`org.gradle.jvm.version=8`)

Second, the producer needs to expose the different variants of the component.

Like in the simple example, there is both a API (compilation) and runtime variant. These exist for both the Java 8 and Java 11 version of the component.

- its API for Java 8 consumers (named `apiJava8Elements`) with attribute `org.gradle.usage=JAVA_API` and `org.gradle.jvm.version=8`
- its runtime for Java 8 consumers (named `runtime8Elements`) with attribute `org.gradle.usage=JAVA_RUNTIME` and `org.gradle.jvm.version=8`
- its API for Java 11 consumers (named `apiJava11Elements`) with attribute `org.gradle.usage=JAVA_API` and `org.gradle.jvm.version=11`
- its runtime for Java 11 consumers (named `runtime11Elements`) with attribute `org.gradle.usage=JAVA_RUNTIME` and `org.gradle.jvm.version=11`

Finally, Gradle selects the best matching variant by looking at all of the attributes:

- the consumer wants a variant with compatible attributes to `org.gradle.usage=JAVA_RUNTIME` and `org.gradle.jvm.version=8`
- the variants `runtime8Elements` and `runtime11Elements` have `org.gradle.usage=JAVA_RUNTIME`
- the variants `apiJava8Elements` and `apiJava11Elements` are incompatible
- the variant `runtime8Elements` is compatible because it can run on Java 8
- the variant `runtime11Elements` is incompatible because it cannot run on Java 8

Gradle provides the artifacts and dependencies from the `runtime8Elements` variant to the consumer.

Compatibility of variants

What if the consumer sets `org.gradle.jvm.version` to 7?

Dependency resolution would *fail* with an error message explaining that there's no suitable variant. Gradle recognizes that the consumer wants a Java 7 compatible library and the *minimal* version of Java available on the producer is 8.

If the consumer requested `org.gradle.jvm.version=15`, then Gradle knows either the Java 8 or Java 11 variants could work. Gradle select the highest compatible Java version (11).

== Variant selection errors

When selecting the most compatible variant of a component, resolution may fail:

- when more than one variant from the producer matches the consumer attributes (ambiguity error)
- when no variants from the producer match the consumer attributes (incompatibility error)

=== Dealing with ambiguity errors

An ambiguous variant selection looks like the following:

```
> Could not resolve all files for configuration ':compileClasspath'.
   > Could not resolve project :lib.
     Required by:
         project :ui
      > Cannot choose between the following variants of project :lib:
           - feature1ApiElements
           - feature2ApiElements
         All of them match the consumer attributes:
           - Variant 'feature1ApiElements' capability org.test:test-capability:1.0:
               - Unmatched attribute:
                   - Found org.gradle.category 'library' but wasn't required.
               - Compatible attributes:
                   - Provides org.gradle.dependency.bundling 'external'
                   - Provides org.gradle.jvm.version '11'
                   - Required org.gradle.libraryelements 'classes' and found value
  'jar'.
                   - Provides org.gradle.usage 'java-api'
           - Variant 'feature2ApiElements' capability org.test:test-capability:1.0:
               - Unmatched attribute:
                   - Found org.gradle.category 'library' but wasn't required.
               - Compatible attributes:
                   - Provides org.gradle.dependency.bundling 'external'
                   - Provides org.gradle.jvm.version '11'
                   - Required org.gradle.libraryelements 'classes' and found value
  'jar'.
                   - Provides org.gradle.usage 'java-api'
```

All *compatible* candidate variants are displayed with their attributes.

- Unmatched attributes are presented first, as they might be the missing piece in selecting the proper variant.

- Compatible attributes are presented second as they indicate what the consumer wanted and how these variants do match that request.

- There will not be any incompatible attributes as the variant would not be considered a candidate.

In the example above, the fix does not lie in attribute matching but in capability matching, which are shown next to the variant name. Because these two variants effectively provide the same attributes and capabilities, they cannot be disambiguated. So in this case, the fix is most likely to provide different capabilities on the producer side (project :lib) and express a capability choice on the consumer side (project :ui).

=== Dealing with no matching variant errors

A no matching variant error looks like the following:

```
> No variants of project :lib match the consumer attributes:
  - Configuration ':lib:compile':
      - Incompatible attribute:
          - Required artifactType 'dll' and found incompatible value 'jar'.
      - Other compatible attribute:
          - Provides usage 'api'
  - Configuration ':lib:compile' variant debug:
      - Incompatible attribute:
          - Required artifactType 'dll' and found incompatible value 'jar'.
      - Other compatible attributes:
          - Found buildType 'debug' but wasn't required.
          - Provides usage 'api'
  - Configuration ':lib:compile' variant release:
      - Incompatible attribute:
          - Required artifactType 'dll' and found incompatible value 'jar'.
      - Other compatible attributes:
          - Found buildType 'release' but wasn't required.
          - Provides usage 'api'
```

or like:

```
> No variants of project : match the consumer attributes:
  - Configuration ':myElements' declares attribute 'color' with value 'blue':
      - Incompatible because this component declares attribute 'artifactType'
with value 'jar' and the consumer needed attribute 'artifactType' with value 'dll'
  - Configuration ':myElements' variant secondary declares attribute 'color' with
value 'blue':
      - Incompatible because this component declares attribute 'artifactType'
with value 'jar' and the consumer needed attribute 'artifactType' with value 'dll'
```

depending upon the stage in the variant selection algorithm where the error occurs.

All *potentially compatible* candidate variants are displayed with their attributes.

- Incompatible attributes are presented first, as they usually are the key in understanding why a variant could not be selected.

- Other attributes are presented second, this includes *requested* and *compatible* ones as well as all extra *producer* attributes that are not requested by the consumer.

Similar to the ambiguous variant error, the goal is to understand which variant should be selected. In some cases, there may not be any compatible variants from the producer (e.g., trying to run on Java 8 with a library built for Java 11).

=== Dealing with incompatible variant errors

An incompatible variant error looks like the following example, where a consumer wants to select a variant with `color=green`, but the only variant available has `color=blue`:

```
> Could not resolve all task dependencies for configuration ':resolveMe'.
   > Could not resolve project :.
     Required by:
         project :
      > Configuration 'mismatch' in project : does not match the consumer
attributes
        Configuration 'mismatch':
          - Incompatible because this component declares attribute 'color' with
value 'blue' and the consumer needed attribute 'color' with value 'green'
```

It occurs when Gradle cannot select a single variant of a dependency because an explicitly requested attribute value does not match (and is not compatible with) the value of that attribute on any of the variants of the dependency.

A sub-type of this failure occurs when Gradle **successfully** selects multiple variants of the same component, but the selected variants are incompatible with **each other**.

This looks like the following, where a consumer wants to select two different variants of a component, each supplying different capabilities, which is acceptable. Unfortunately one variant has color=blue and the other has color=green:

```
> Could not resolve all task dependencies for configuration ':resolveMe'.
   > Could not resolve project :.
     Required by:
         project :
      > Multiple incompatible variants of org.example:nyvu:1.0 were selected:
          - Variant org.example:nyvu:1.0 variant blueElementsCapability1 has
attributes {color=blue}
          - Variant org.example:nyvu:1.0 variant greenElementsCapability2 has
attributes {color=green}

   > Could not resolve project :.
     Required by:
         project :
      > Multiple incompatible variants of org.example:pi2e5:1.0 were selected:
          - Variant org.example:pi2e5:1.0 variant blueElementsCapability1 has
attributes {color=blue}
          - Variant org.example:pi2e5:1.0 variant greenElementsCapability2 has
attributes {color=green}
```

=== Dealing with ambiguous transformation errors

ArtifactTransforms can be used to transform artifacts from one type to another, changing their attributes. Variant selection can use the attributes available as the result of an artifact transform as a candidate variant.

If a project registers multiple artifact transforms, needs to use an artifact transform to produce a matching variant for a consumer's request, and multiple artifact transforms could each be

used to accomplish this, then Gradle will fail with an ambiguous transformation error like the following:

```
> Could not resolve all task dependencies for configuration ':resolveMe'.
   > Found multiple transforms that can produce a variant of project : with
requested attributes:
       - color 'red'
       - shape 'round'
     Found the following transforms:
       - From 'configuration ':roundBlueLiquidElements'':
           - With source attributes:
               - color 'blue'
               - shape 'round'
               - state 'liquid'
           - Candidate transform(s):
               - Transform 'BrokenTransform' producing attributes:
                   - color 'red'
                   - shape 'round'
                   - state 'gas'
               - Transform 'BrokenTransform' producing attributes:
                   - color 'red'
                   - shape 'round'
                   - state 'solid'
```

== Visualizing variant information

=== Outgoing variants report

The report task `outgoingVariants` shows the list of variants available for selection by consumers of the project. It displays the capabilities, attributes and artifacts for each variant.

This task is similar to the `dependencyInsight` reporting task.

By default, `outgoingVariants` prints information about all variants. It offers the optional parameter `--variant <variantName>` to select a single variant to display. It also accepts the `--all` flag to include information about legacy and deprecated configurations, or `--no-all` to exclude this information.

Here is the output of the `outgoingVariants` task on a freshly generated `java-library` project:

```
> Task :outgoingVariants
--------------------------------------------------
Variant apiElements
--------------------------------------------------
API elements for the 'main' feature.

Capabilities
    - new-java-library:lib:unspecified (default capability)
Attributes
```

```
        - org.gradle.category         = library
        - org.gradle.dependency.bundling = external
        - org.gradle.jvm.version      = 11
        - org.gradle.libraryelements  = jar
        - org.gradle.usage            = java-api
Artifacts
    - build/libs/lib.jar (artifactType = jar)


Secondary Variants (*)


    --------------------------------------------------
    Secondary Variant classes
    --------------------------------------------------
        Description = Directories containing compiled class files for main.

        Attributes
            - org.gradle.category         = library
            - org.gradle.dependency.bundling = external
            - org.gradle.jvm.version      = 11
            - org.gradle.libraryelements  = classes
            - org.gradle.usage            = java-api
        Artifacts
            - build/classes/java/main (artifactType = java-classes-directory)


--------------------------------------------------
Variant mainSourceElements (i)
--------------------------------------------------
Description = List of source directories contained in the Main SourceSet.

Capabilities
    - new-java-library:lib:unspecified (default capability)
Attributes
    - org.gradle.category         = verification
    - org.gradle.dependency.bundling = external
    - org.gradle.verificationtype = main-sources
Artifacts
    - src/main/java (artifactType = directory)
    - src/main/resources (artifactType = directory)


--------------------------------------------------
Variant runtimeElements
--------------------------------------------------
Runtime elements for the 'main' feature.

Capabilities
    - new-java-library:lib:unspecified (default capability)
Attributes
    - org.gradle.category         = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.version      = 11
    - org.gradle.libraryelements  = jar
```

```
        - org.gradle.usage              = java-runtime
Artifacts
    - build/libs/lib.jar (artifactType = jar)

Secondary Variants (*)

    --------------------------------------------------
    Secondary Variant classes
    --------------------------------------------------
        Description = Directories containing compiled class files for main.

        Attributes
            - org.gradle.category          = library
            - org.gradle.dependency.bundling = external
            - org.gradle.jvm.version       = 11
            - org.gradle.libraryelements   = classes
            - org.gradle.usage             = java-runtime
        Artifacts
            - build/classes/java/main (artifactType = java-classes-directory)

    --------------------------------------------------
    Secondary Variant resources
    --------------------------------------------------
        Description = Directories containing the project's assembled resource
files for use at runtime.

        Attributes
            - org.gradle.category          = library
            - org.gradle.dependency.bundling = external
            - org.gradle.jvm.version       = 11
            - org.gradle.libraryelements   = resources
            - org.gradle.usage             = java-runtime
        Artifacts
            - build/resources/main (artifactType = java-resources-directory)

--------------------------------------------------
Variant testResultsElementsForTest (i)
--------------------------------------------------
Description = Directory containing binary results of running tests for the test
Test Suite's test target.

Capabilities
    - new-java-library:lib:unspecified (default capability)
Attributes
    - org.gradle.category            = verification
    - org.gradle.testsuite.name      = test
    - org.gradle.testsuite.target.name = test
    - org.gradle.testsuite.type      = unit-test
    - org.gradle.verificationtype    = test-results
Artifacts
    - build/test-results/test/binary (artifactType = directory)
```

```
(i) Configuration uses incubating attributes such as Category.VERIFICATION.
(*) Secondary variants are variants created via the Configuration#getOutgoing():
ConfigurationPublications API which also participate in selection, in addition to
the configuration itself.
```

From this you can see the two main variants that are exposed by a java library, `apiElements` and `runtimeElements`. Notice that the main difference is on the `org.gradle.usage` attribute, with values `java-api` and `java-runtime`. As they indicate, this is where the difference is made between what needs to be on the *compile* classpath of consumers, versus what's needed on the *runtime* classpath.

It also shows *secondary* variants, which are exclusive to Gradle projects and not published. For example, the secondary variant `classes` from `apiElements` is what allows Gradle to skip the JAR creation when compiling against a `java-library` project.

==== Information about invalid consumable configurations

A project cannot have multiple configurations with the same attributes and capabilities. In that case, the project will fail to build.

In order to be able to visualize such issues, the outgoing variant reports handle those errors in a lenient fashion. This allows the report to display information about the issue.

=== Resolvable configurations report

Gradle also offers a complimentary report task called `resolvableConfigurations` that displays the *resolvable* configurations of a project, which are those which can have dependencies added and be resolved. The report will list their attributes and any configurations that they extend. It will also list a summary of any attributes which will be affected by Compatibility Rules or Disambiguation Rules during resolution.

By default, `resolvableConfigurations` prints information about all purely resolvable configurations. These are configurations that are marked resolvable but **not** marked consumable. Though some resolvable configurations are also marked consumable, these are legacy configurations that should **not** have dependencies added in build scripts. This report offers the optional parameter `--configuration <configurationName>` to select a single configuration to display. It also accepts the `--all` flag to include information about legacy and deprecated configurations, or `--no-all` to exclude this information. Finally, it accepts the `--recursive` flag to list in the extended configurations section those configurations which are extended *transitively* rather than directly. Alternatively, `--no-recursive` can be used to exclude this information.

Here is the output of the `resolvableConfigurations` task on a freshly generated `java-library` project:

```
> Task :resolvableConfigurations
--------------------------------------------------
Configuration annotationProcessor
```

```
--------------------------------------------------
Description = Annotation processors and their dependencies for source set 'main'.

Attributes
    - org.gradle.category            = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
    - org.gradle.libraryelements     = jar
    - org.gradle.usage               = java-runtime


--------------------------------------------------
Configuration compileClasspath
--------------------------------------------------
Description = Compile classpath for source set 'main'.

Attributes
    - org.gradle.category            = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
    - org.gradle.jvm.version         = 11
    - org.gradle.libraryelements     = classes
    - org.gradle.usage               = java-api
Extended Configurations
    - compileOnly
    - implementation


--------------------------------------------------
Configuration runtimeClasspath
--------------------------------------------------
Description = Runtime classpath of source set 'main'.

Attributes
    - org.gradle.category            = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
    - org.gradle.jvm.version         = 11
    - org.gradle.libraryelements     = jar
    - org.gradle.usage               = java-runtime
Extended Configurations
    - implementation
    - runtimeOnly


--------------------------------------------------
Configuration testAnnotationProcessor
--------------------------------------------------
Description = Annotation processors and their dependencies for source set 'test'.

Attributes
    - org.gradle.category            = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
```

```
    - org.gradle.libraryelements    = jar
    - org.gradle.usage              = java-runtime


-----------------------------------------------
Configuration testCompileClasspath
-----------------------------------------------
Description = Compile classpath for source set 'test'.

Attributes
    - org.gradle.category           = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
    - org.gradle.jvm.version         = 11
    - org.gradle.libraryelements     = classes
    - org.gradle.usage               = java-api
Extended Configurations
    - testCompileOnly
    - testImplementation


-----------------------------------------------
Configuration testRuntimeClasspath
-----------------------------------------------
Description = Runtime classpath of source set 'test'.

Attributes
    - org.gradle.category           = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.environment     = standard-jvm
    - org.gradle.jvm.version         = 11
    - org.gradle.libraryelements     = jar
    - org.gradle.usage               = java-runtime
Extended Configurations
    - testImplementation
    - testRuntimeOnly


-----------------------------------------------
Compatibility Rules
-----------------------------------------------
Description = The following Attributes have compatibility rules defined.

    - org.gradle.dependency.bundling
    - org.gradle.jvm.environment
    - org.gradle.jvm.version
    - org.gradle.libraryelements
    - org.gradle.plugin.api-version
    - org.gradle.usage


-----------------------------------------------
Disambiguation Rules
-----------------------------------------------
Description = The following Attributes have disambiguation rules defined.
```

```
        - org.gradle.category
        - org.gradle.dependency.bundling
        - org.gradle.jvm.environment
        - org.gradle.jvm.version
        - org.gradle.libraryelements
        - org.gradle.plugin.api-version
        - org.gradle.usage
```

From this you can see the two main configurations used to resolve dependencies, `compileClasspath` and `runtimeClasspath`, as well as their corresponding test configurations.

== Mapping from Maven/Ivy to Gradle variants

Neither Maven nor Ivy have the concept of *variants*, which are only natively supported by Gradle Module Metadata. Gradle can still work with Maven and Ivy by using different variant derivation strategies.

Relationship with Gradle Module Metadata

Gradle Module Metadata is a metadata format for modules published on Maven, Ivy and other kinds of repositories. It is similar to the `pom.xml` or `ivy.xml` metadata file, but this format contains details about variants.

See the Gradle Module Metadata specification for more information.

=== Mapping of Maven POM metadata to variants

Modules published on a Maven repository are automatically converted into variant-aware modules.

There is no way for Gradle to know which kind of component was published:

- a BOM that represents a Gradle platform

- a BOM used as a super-POM

- a POM that is both a platform *and* a library

The default strategy used by Java projects in Gradle is to derive 8 different variants:

- two "library" variants (attribute `org.gradle.category` = `library`)

  ◦ the `compile` variant maps the `<scope>compile</scope>` dependencies. This variant is equivalent to the `apiElements` variant of the Java Library plugin. All dependencies of this scope are considered *API dependencies*.

  ◦ the `runtime` variant maps both the `<scope>compile</scope>` and `<scope>runtime</scope>` dependencies. This variant is equivalent to the `runtimeElements` variant of the Java Library plugin. All dependencies of those scopes are considered *runtime dependencies*.

    ▪ in both cases, the `<dependencyManagement>` dependencies are *not converted to constraints*

- a "sources" variant that represents the sources jar for the component

- a "javadoc" variant that represents the javadoc jar for the component
- four "platform" variants derived from the `<dependencyManagement>` block (attribute `org.gradle.category = platform`):
  - the `platform-compile` variant maps the `<scope>compile</scope>` dependency management dependencies as *dependency constraints*.
  - the `platform-runtime` variant maps both the `<scope>compile</scope>` and `<scope>runtime</scope>` dependency management dependencies as *dependency constraints*.
  - the `enforced-platform-compile` is similar to `platform-compile` but all the constraints are *forced*
  - the `enforced-platform-runtime` is similar to `platform-runtime` but all the constraints are *forced*

You can understand more about the use of platform and enforced platforms variants by looking at the importing BOMs section of the manual. By default, whenever you declare a dependency on a Maven module, Gradle is going to look for the `library` variants. However, using the `platform` or `enforcedPlatform` keyword, Gradle is now looking for one of the "platform" variants, which allows you to import the constraints from the POM files, instead of the dependencies.

=== Mapping of Ivy files to variants

Gradle has no built-in derivation strategy implemented for Ivy files. Ivy is a flexible format that allows you to publish arbitrary files and can be heavily customized.

If you want to implement a derivation strategy for *compile* and *runtime* variants for Ivy, you can do so with component metadata rule. The component metadata rules API allows you to access Ivy configurations and create variants based on them. If you know that all the Ivy modules your are consuming have been published with Gradle without further customizations of the `ivy.xml` file, you can add the following rule to your build:

build.gradle.kts

```kotlin
abstract class IvyVariantDerivationRule @Inject internal
constructor(objectFactory: ObjectFactory) : ComponentMetadataRule {
    private val jarLibraryElements: LibraryElements
    private val libraryCategory: Category
    private val javaRuntimeUsage: Usage
    private val javaApiUsage: Usage

    init {
        jarLibraryElements = objectFactory.named(LibraryElements.JAR)
        libraryCategory = objectFactory.named(Category.LIBRARY)
        javaRuntimeUsage = objectFactory.named(Usage.JAVA_RUNTIME)
        javaApiUsage = objectFactory.named(Usage.JAVA_API)
    }

    override fun execute(context: ComponentMetadataContext) {
        // This filters out any non Ivy module
        if(context.getDescriptor(IvyModuleDescriptor::class) == null) {
            return
        }

        context.details.addVariant("runtimeElements", "default") {
            attributes {
                attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
jarLibraryElements)
                attribute(Category.CATEGORY_ATTRIBUTE, libraryCategory)
                attribute(Usage.USAGE_ATTRIBUTE, javaRuntimeUsage)
            }
        }
        context.details.addVariant("apiElements", "compile") {
            attributes {
                attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
jarLibraryElements)
                attribute(Category.CATEGORY_ATTRIBUTE, libraryCategory)
                attribute(Usage.USAGE_ATTRIBUTE, javaApiUsage)
            }
        }
    }
}

dependencies {
    components { all<IvyVariantDerivationRule>() }
}
```

build.gradle

```
abstract class IvyVariantDerivationRule implements ComponentMetadataRule {
    final LibraryElements jarLibraryElements
    final Category libraryCategory
    final Usage javaRuntimeUsage
    final Usage javaApiUsage

    @Inject
    IvyVariantDerivationRule(ObjectFactory objectFactory) {
        jarLibraryElements = objectFactory.named(LibraryElements, LibraryElements
.JAR)
        libraryCategory = objectFactory.named(Category, Category.LIBRARY)
        javaRuntimeUsage = objectFactory.named(Usage, Usage.JAVA_RUNTIME)
        javaApiUsage = objectFactory.named(Usage, Usage.JAVA_API)
    }

    void execute(ComponentMetadataContext context) {
        // This filters out any non Ivy module
        if(context.getDescriptor(IvyModuleDescriptor) == null) {
            return
        }

        context.details.addVariant("runtimeElements", "default") {
            attributes {
                attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
jarLibraryElements)
                attribute(Category.CATEGORY_ATTRIBUTE, libraryCategory)
                attribute(Usage.USAGE_ATTRIBUTE, javaRuntimeUsage)
            }
        }
        context.details.addVariant("apiElements", "compile") {
            attributes {
                attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
jarLibraryElements)
                attribute(Category.CATEGORY_ATTRIBUTE, libraryCategory)
                attribute(Usage.USAGE_ATTRIBUTE, javaApiUsage)
            }
        }
    }
}

dependencies {
    components { all(IvyVariantDerivationRule) }
}
```

The rule creates an `apiElements` variant based on the `compile` configuration and a `runtimeElements` variant based on the `default` configuration of each ivy module. For each variant, it sets the corresponding Java ecosystem attributes. Dependencies and artifacts of the variants are taken from the underlying configurations. If not all consumed Ivy modules follow this pattern, the rule can be adjusted or only applied to a selected set of modules.

For all Ivy modules without variants, Gradle has a fallback selection method. Gradle does *not* perform variant aware resolution and instead selects either the `default` configuration or an explicitly named configuration.

= Working with Variant Attributes

As explained in the section on variant aware matching, attributes give semantics to variants and are used by Gradle's dependency management engine to select the best matching variant.

As a user of Gradle, attributes are often hidden as implementation details. But it might be useful to understand the *standard attributes* defined by Gradle and its core plugins.

As a plugin author, these attributes, and the way they are defined, can serve as a basis for building your own set of attributes in your eco system plugin.

== Standard attributes defined by Gradle

Gradle defines a list of standard attributes used by Gradle's core plugins.

=== Ecosystem-independent standard attributes

Table 27. Ecosystem-independent standard variant attributes

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle .usage`	Indicates main purpose of variant	`Usage` values built from constants defined in Usage	Following ecosystem semantics (e.g. `java-runtime` can be used in place of `java-api` but not the opposite)
`org.gradle .category`	Indicates the category of this software component	`Category` values built from constants defined in Category	Following ecosystem semantics (e.g. `library` is default on the JVM, no compatibility otherwise)
`org.gradle .libraryel ements`	Indicates the contents of a `org.gradle.category=li brary` variant	`LibraryElements` values built from constants defined in LibraryElements	Following ecosystem semantics(e.g. in the JVM world, `jar` is the default and is compatible with `classes`)
`org.gradle .docstype`	Indicates the contents of a `org.gradle.category=do cumentation` variant	`DocsType` values built from constants defined in DocsType	No default, no compatibility

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle .dependenc y.bundling`	Indicates how dependencies of a variant are accessed.	`Bundling` values built from constants defined in Bundling	Following ecosystem semantics (e.g. in the JVM world, `embedded` is compatible with `external`)
`org.gradle .verificat iontype`	Indicates what kind of verification task produced this output.	`VerificationType` values built from constants defined in VerificationType	No default, no compatibility

When the `Category` attribute is present with the incubating value `org.gradle.category=verification` on a variant, that variant is considered to be a verification-time only variant.

These variants are meant to contain only the results of running verification tasks, such as test results or code coverage reports. They are **not publishable**, and will produce an error if added to a component which is published.

Table 28. Ecosystem-independent standard component attributes

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle.status`	Component level attribute, derived	Based on a status scheme, with a default one existing based on the source repository.	Based on the scheme in use

=== JVM ecosystem specific attributes

In addition to the ecosystem independent attributes defined above, the JVM ecosystem adds the following attribute:

Table 29. JVM ecosystem standard component attributes

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle.jvm.version`	Indicates the JVM version compatibility.	Integer using the version after the `1.` for Java 1.4 and before, the major version for Java 5 and beyond.	Defaults to the JVM version used by Gradle, lower is compatible with higher, prefers highest compatible.
`org.gradle.jvm.environment`	Indicates that a variant is optimized for a certain JVM environment.	Common values are `standard-jvm` and `android`. Other values are allowed.	The attribute is used to prefer one variant over another if multiple are available, but in general all values are compatible. The default is `standard-jvm`.
`org.gradle.testsuite.name`	Indicates the name of the TestSuite that produced this output.	Value is the name of the Suite.	No default, no compatibility
`org.gradle.testsuite.target.name`	Indicates the name of the TestSuiteTarget that produced this output.	Value is the name of the Target.	No default, no compatibility
`org.gradle.testsuite.type`	Indicates the type of test suite (unit test, integration test, performance test, etc.)	TestSuiteType values built from constants defined in TestSuiteType or other custom values for user-defined test suite types.	No default, no compatibility

The JVM ecosystem also contains a number of compatibility and disambiguation rules over the different attributes. The reader willing to know more can take a look at the code for `org.gradle.api.internal.artifacts.JavaEcosystemSupport`.

=== Native ecosystem specific attributes

In addition to the ecosystem independent attributes defined above, the native ecosystem adds the following attributes:

Table 30. Native ecosystem standard component attributes

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle.native.debuggable`	Indicates if the binary was built with debugging symbols	Boolean	N/A
`org.gradle.native.optimized`	Indicates if the binary was built with optimization flags	Boolean	N/A
`org.gradle.native.architecture`	Indicates the target architecture of the binary	`MachineArchitecture` values built from constants defined in MachineArchitecture	None
`org.gradle.native.operatingSystem`	Indicates the target operating system of the binary	`OperatingSystemFamily` values built from constants defined in OperatingSystemFamily	None

=== Gradle plugin ecosystem specific attributes

For Gradle plugin development, the following attribute is supported since Gradle 7.0. A Gradle plugin variant can specify compatibility with a Gradle API version through this attribute.

Table 31. Gradle plugin ecosystem standard component attributes

Attribute name	Description	Values	compatibility and disambiguation rules
`org.gradle.plugin.api‑version`	Indicates the Gradle API version compatibility.	Valid Gradle version strings.	Defaults to the currently running Gradle, lower is compatible with higher, prefers highest compatible.

== Declaring custom attributes

If you are extending Gradle, e.g. by writing a plugin for another ecosystem, declaring custom attributes could be an option if you want to support variant-aware dependency management features in your plugin. However, you should be cautious if you also attempt to publish libraries. Semantics of new attributes are usually defined through a plugin, which can carry compatibility and disambiguation rules. Consequently, builds that consume libraries published for a certain ecosystem, also need to apply the corresponding plugin to interpret attributes correctly. If your plugin is intended for a larger audience, i.e. if it is openly available and libraries are published to public repositories, defining new attributes effectively extends the semantics of Gradle Module Metadata and comes with responsibilities. E.g., support for attributes that are already published should not be removed again, or should be handled in some kind of compatibility layer in future versions of the plugin.

== Creating attributes in a build script or plugin

Attributes are *typed*. An attribute can be created via the `Attribute<T>.of` method:

build.gradle.kts

```
// An attribute of type `String`
val myAttribute = Attribute.of("my.attribute.name", String::class.java)
// An attribute of type `Usage`
val myUsage = Attribute.of("my.usage.attribute", Usage::class.java)
```

build.gradle

```
// An attribute of type `String`
def myAttribute = Attribute.of("my.attribute.name", String)
// An attribute of type `Usage`
def myUsage = Attribute.of("my.usage.attribute", Usage)
```

Attribute types support most Java primitive classes; such as `String` and `Integer`; Or anything extending `org.gradle.api.Named`. Attributes must be declared in the *attribute schema* found on the `dependencies` handler:

build.gradle.kts

```
dependencies.attributesSchema {
    // registers this attribute to the attributes schema
    attribute(myAttribute)
    attribute(myUsage)
}
```

build.gradle

```
dependencies.attributesSchema {
    // registers this attribute to the attributes schema
    attribute(myAttribute)
    attribute(myUsage)
}
```

Then configurations can be configured to set values for attributes:

build.gradle.kts

```
configurations {
    create("myConfiguration") {
        attributes {
            attribute(myAttribute, "my-value")
        }
    }
}
```

build.gradle

```
configurations {
    myConfiguration {
        attributes {
            attribute(myAttribute, 'my-value')
        }
    }
}
```

For attributes which type extends `Named`, the value of the attribute **must** be created via the *object factory*:

build.gradle.kts

```
configurations {
    "myConfiguration" {
        attributes {
            attribute(myUsage, project.objects.named(Usage::class.java, "my-value"))
        }
    }
}
```

build.gradle

```
configurations {
    myConfiguration {
        attributes {
            attribute(myUsage, project.objects.named(Usage, 'my-value'))
        }
    }
}
```

== Attribute matching

=== Attribute compatibility rules

Attributes let the engine select *compatible variants*. There are cases where a producer may not have *exactly* what the consumer requests but has a variant that can be used.

For example, if the consumer is asking for the API of a library and the producer doesn't have an exactly matching variant, the *runtime* variant could be considered compatible. This is typical of libraries published to external repositories. In this case, we know that even if we don't have an exact match (API), we can still compile against the runtime variant (it contains *more* than what we need to compile but it's still ok to use).

Gradle provides attribute compatibility rules that can be defined for each attribute. The role of a compatibility rule is to explain which attribute values are *compatible* based on what the consumer asked for.

Attribute compatibility rules have to be registered via the attribute matching strategy that you can obtain from the attributes schema.

=== Attribute disambiguation rules

Since multiple values for an attribute can be *compatible*, Gradle needs to choose the "best" candidate between all compatible candidates. This is called "disambiguation".

This is done by implementing an attribute disambiguation rule.

Attribute disambiguation rules have to be registered via the attribute matching strategy that you can obtain from the attributes schema, which is a member of DependencyHandler.

=== Variant attribute matching algorithm

Finding the best variant can get complicated when there are many different variants available for a component and many different attributes. Gradle's dependency resolution engine performs the following algorithm when finding the best result (or failing):

1. Each candidate's attribute value is compared to the consumer's requested attribute value. A candidate is considered compatible if its value matches the consumer's value exactly, passes the attribute's compatibility rule or is not provided.

2. If only one candidate is considered compatible, that candidate wins.

3. If several candidates are compatible, but one of the candidates matches all of the same attributes as the other candidates, Gradle chooses that candidate. This is the candidate with the "longest" match.

4. If several candidates are compatible and are compatible with an equal number of attributes, Gradle needs to disambiguate the candidates.

   1. For each requested attribute, if a candidate does not have a value matching the disambiguation rule, it's eliminated from consideration.

   2. If the attribute has a known precedence, Gradle will stop as soon as there is a single

candidate remaining.

    3. If the attribute does not have a known precedence, Gradle must consider all attributes.

5. If several candidates still remain, Gradle will start to consider "extra" attributes to disambiguate between multiple candidates. Extra attributes are attributes that were not requested by the consumer but are present on at least one candidate. These extra attributes are considered in precedence order.

    1. If the attribute has a known precedence, Gradle will stop as soon as there is a single candidate remaining.

    2. After all extra attributes with precedence are considered, the remaining candidates can be chosen if they are compatible with all of the non-ordered disambiguation rules.

6. If several candidates still remain, Gradle will consider extra attributes again. A candidate can be chosen if it has the fewest number of extra attributes.

If at any step no candidates remain compatible, resolution fails. Additionally, Gradle outputs a list of all compatible candidates from step 1 to help with debugging variant matching failures.

Plugins and ecosystems can influence the selection algorithm by implementing compatibility rules, disambiguation rules and telling Gradle the precedence of attributes. Attributes with a higher precedence are used to eliminate compatible matches in order.

For example, in the Java ecosystem, the `org.gradle.usage` attribute has a higher precedence than `org.gradle.libraryelements`. This means that if two candidates were available with compatible values for both `org.gradle.usage` and `org.gradle.libraryelements`, Gradle will choose the candidate that passes the disambiguation rule for `org.gradle.usage`.

= Sharing outputs between projects

A common pattern, in multi-project builds, is that one project consumes the artifacts of another project. In general, the simplest consumption form in the Java ecosystem is that when `A` depends on `B`, then `A` would depend on the `jar` produced by project `B`. As previously described in this chapter, this is modeled by `A` depending on a *variant of* `B`, where the variant is selected based on the needs of `A`. For compilation, we need the API dependencies of `B`, provided by the `apiElements` variant. For runtime, we need the runtime dependencies of `B`, provided by the `runtimeElements` variant.

However, what if you need a *different* artifact than the main one? Gradle provides, for example, built-in support for depending on the test fixtures of another project, but sometimes the artifact you need to depend on simply isn't exposed as a variant.

In order to be *safe to share* between projects and allow maximum performance (parallelism), such artifacts must be exposed via *outgoing configurations*.

Don't reference other project tasks directly

A frequent anti-pattern to declare cross-project dependencies is:

```
dependencies {
    // this is unsafe!
    implementation project(":other").tasks.someOtherJar
}
```

This publication model is *unsafe* and can lead to non-reproducible and hard to parallelize builds. This section explains how to *properly create cross-project boundaries* by defining "exchanges" between projects by using *variants*.

There are two, complementary, options to share artifacts between projects. The simplified version is only suitable if what you need to share is a simple artifact that doesn't depend on the consumer. The simple solution is also limited to cases where this artifact is not published to a repository. This also implies that the consumer does not publish a dependency to this artifact. In cases where the consumer resolves to different artifacts in different contexts (e.g., different target platforms) or that publication is required, you need to use the advanced version.

== Simple sharing of artifacts between projects

First, a producer needs to declare a configuration which is going to be *exposed* to consumers. As explained in the configurations chapter, this corresponds to a *consumable configuration*.

Let's imagine that the consumer requires *instrumented classes* from the producer, but that this artifact is *not* the main one. The producer can expose its instrumented classes by creating a configuration that will "carry" this artifact:

producer/build.gradle.kts

```
val instrumentedJars by configurations.creating {
    isCanBeConsumed = true
    isCanBeResolved = false
    // If you want this configuration to share the same dependencies, otherwise
omit this line
    extendsFrom(configurations["implementation"], configurations["runtimeOnly"])
}
```

producer/build.gradle

```
configurations {
    instrumentedJars {
        canBeConsumed = true
        canBeResolved = false
        // If you want this configuration to share the same dependencies,
otherwise omit this line
        extendsFrom implementation, runtimeOnly
    }
}
```

This configuration is *consumable*, which means it's an "exchange" meant for consumers. We're now going to add artifacts to this configuration, that consumers would get when they consume it:

producer/build.gradle.kts

```
artifacts {
    add("instrumentedJars", instrumentedJar)
}
```

producer/build.gradle

```
artifacts {
    instrumentedJars(instrumentedJar)
}
```

Here the "artifact" we're attaching is a *task* that actually generates a Jar. Doing so, Gradle can automatically track dependencies of this task and build them as needed. This is possible because the `Jar` task extends `AbstractArchiveTask`. If it's not the case, you will need to explicitly declare how the artifact is generated.

producer/build.gradle.kts

```
artifacts {
    add("instrumentedJars", someTask.outputFile) {
        builtBy(someTask)
    }
}
```

producer/build.gradle

```
artifacts {
    instrumentedJars(someTask.outputFile) {
        builtBy(someTask)
    }
}
```

Now the *consumer* needs to depend on this configuration in order to get the right artifact:

consumer/build.gradle.kts

```
dependencies {
    instrumentedClasspath(project(mapOf(
        "path" to ":producer",
        "configuration" to "instrumentedJars")))
}
```

consumer/build.gradle

```
dependencies {
    instrumentedClasspath(project(path: ":producer", configuration:
'instrumentedJars'))
}
```

WARNING	Declaring a dependency on an explicit target configuration is *not recommended*. If you plan to publish the component which has this dependency, this will likely lead to broken metadata. If you need to publish the component on a remote repository, follow the instructions of the variant-aware cross publication documentation.

In this case, we're adding the dependency to the *instrumentedClasspath* configuration, which is a *consumer specific configuration*. In Gradle terminology, this is called a resolvable configuration, which is defined this way:

consumer/build.gradle.kts

```
val instrumentedClasspath by configurations.creating {
    isCanBeConsumed = false
}
```

consumer/build.gradle

```
configurations {
    instrumentedClasspath {
        canBeConsumed = false
    }
}
```

Variant-aware sharing of artifacts between projects

In the simple sharing solution, we defined a configuration on the producer side which serves as an exchange of artifacts between the producer and the consumer. However, the consumer has to explicitly tell which configuration it depends on, which is something we want to avoid in *variant aware resolution*. In fact, we also have explained that it is possible for a consumer to express requirements using *attributes* and that the producer should provide the appropriate outgoing variants using attributes too. This allows for smarter selection, because using a single dependency declaration, without any explicit target configuration, the consumer may resolve different things. The typical example is that using a single dependency declaration `project(":myLib")`, we would either choose the `arm64` or `i386` version of `myLib` depending on the architecture.

To do this, we will add attributes to both the consumer and the producer.

It is important to understand that once configurations have attributes, they participate in *variant aware resolution*, which means that they are candidates considered whenever *any* notation like `project(":myLib")` is used. In other words, the attributes set on the producer *must be consistent with the other variants produced on the same project*. They must not, in particular, introduce ambiguity for the existing selection.

In practice, it means that the attribute set used on the configuration you create are likely to be dependent on the *ecosystem* in use (Java, C++, …) because the relevant plugins for those ecosystems often use different attributes.

Let's enhance our previous example which happens to be a Java Library project. Java libraries expose a couple of variants to their consumers, `apiElements` and `runtimeElements`. Now, we're adding a 3rd one, `instrumentedJars`.

Therefore, we need to understand what our new variant is used for in order to set the proper attributes on it. Let's look at the attributes we find on the `runtimeElements` configuration on the producer:

gradle outgoingVariants --variant runtimeElements

```
Attributes
    - org.gradle.category            = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.version         = 11
    - org.gradle.libraryelements     = jar
    - org.gradle.usage               = java-runtime
```

What it tells us is that the Java Library plugin produces variants with 5 attributes:

- `org.gradle.category` tells us that this variant represents a *library*

- `org.gradle.dependency.bundling` tells us that the dependencies of this variant are found as jars (they are not, for example, repackaged inside the jar)

- `org.gradle.jvm.version` tells us that the minimum Java version this library supports is Java

- `org.gradle.libraryelements` tells us this variant contains all elements found in a jar (classes and resources)

- `org.gradle.usage` says that this variant is a Java runtime, therefore suitable for a Java compiler but also at runtime

As a consequence, if we want our instrumented classes to be used in place of this variant when executing tests, we need to attach similar attributes to our variant. In fact, the attribute we care about is `org.gradle.libraryelements` which explains *what the variant contains*, so we can setup the variant this way:

producer/build.gradle.kts

```
val instrumentedJars by configurations.creating {
    isCanBeConsumed = true
    isCanBeResolved = false
    attributes {
        attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category.LIBRARY))
        attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage.JAVA_RUNTIME))
        attribute(Bundling.BUNDLING_ATTRIBUTE, objects.named(Bundling.EXTERNAL))
        attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE,
JavaVersion.current().majorVersion.toInt())
        attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
objects.named("instrumented-jar"))
    }
}
```

```
configurations {
    instrumentedJars {
        canBeConsumed = true
        canBeResolved = false
        attributes {
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.LIBRARY))
            attribute(Usage.USAGE_ATTRIBUTE, objects.named(Usage, Usage
.JAVA_RUNTIME))
            attribute(Bundling.BUNDLING_ATTRIBUTE, objects.named(Bundling,
Bundling.EXTERNAL))
            attribute(TargetJvmVersion.TARGET_JVM_VERSION_ATTRIBUTE, JavaVersion
.current().majorVersion.toInteger())
            attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE, objects.named
(LibraryElements, 'instrumented-jar'))
        }
    }
}
```

Choosing the right attributes to set is the hardest thing in this process, because they carry the semantics of the variant. Therefore, before adding *new attributes*, you should always ask yourself if there isn't an attribute which carries the semantics you need. If there isn't, then you may add a new attribute. When adding new attributes, you must also be careful because it's possible that it creates ambiguity during selection. Often adding an attribute means adding it to *all* existing variants.

What we have done here is that we have added a *new* variant, which can be used *at runtime*, but contains instrumented classes instead of the normal classes. However, it now means that for runtime, the consumer has to choose between two variants:

- `runtimeElements`, the regular variant offered by the `java-library` plugin
- `instrumentedJars`, the variant we have created

In particular, say we want the instrumented classes on the test runtime classpath. We can now, on the consumer, declare our dependency as a regular project dependency:

```
dependencies {
    testImplementation("junit:junit:4.13")
    testImplementation(project(":producer"))
}
```

consumer/build.gradle

```
dependencies {
    testImplementation 'junit:junit:4.13'
    testImplementation project(':producer')
}
```

If we stop here, Gradle will still select the `runtimeElements` variant in place of our `instrumentedJars` variant. This is because the `testRuntimeClasspath` configuration asks for a configuration which `libraryelements` attribute is `jar`, and our new `instrumented-jars` value is *not compatible.*

So we need to change the requested attributes so that we now look for instrumented jars:

consumer/build.gradle.kts

```
configurations {
    testRuntimeClasspath {
        attributes {
            attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE,
objects.named(LibraryElements::class.java, "instrumented-jar"))
        }
    }
}
```

consumer/build.gradle

```
configurations {
    testRuntimeClasspath {
        attributes {
            attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE, objects.named
(LibraryElements, 'instrumented-jar'))
        }
    }
}
```

We can look at another report *on the consumer side* to view exactly what attributes of each dependency will be requested:

gradle resolvableConfigurations --configuration testRuntimeClasspath

```
Attributes
    - org.gradle.category          = library
    - org.gradle.dependency.bundling = external
    - org.gradle.jvm.version       = 11
    - org.gradle.libraryelements   = instrumented-jar
    - org.gradle.usage             = java-runtime
```

The `resolvableConfigurations` report is the complement of the `outgoingVariants` report. By running both of these reports on the consumer and producer sides of a relationship, respectively, you can see exactly what attributes are involved in matching during dependency resolution and better predict the outcome when configurations are resolved.

Now, we're saying that whenever we're going to resolve the test runtime classpath, what we are looking for is *instrumented classes*. There is a problem though: in our dependencies list, we have JUnit, which, obviously, is *not* instrumented. So if we stop here, Gradle is going to fail, explaining that there's no variant of JUnit which provide instrumented classes. This is because we didn't explain that it's fine to use the regular jar, if no instrumented version is available. To do this, we need to write a *compatibility rule*:

consumer/build.gradle.kts

```
abstract class InstrumentedJarsRule: AttributeCompatibilityRule<LibraryElements> {

    override fun execute(details: CompatibilityCheckDetails<LibraryElements>) =
details.run {
        if (consumerValue?.name == "instrumented-jar" && producerValue?.name ==
"jar") {
            compatible()
        }
    }
}
```

consumer/build.gradle

```
abstract class InstrumentedJarsRule implements AttributeCompatibilityRule
<LibraryElements> {

    @Override
    void execute(CompatibilityCheckDetails<LibraryElements> details) {
        if (details.consumerValue.name == 'instrumented-jar' && details
.producerValue.name == 'jar') {
            details.compatible()
        }
    }
}
```

which we need to declare on the attributes schema:

consumer/build.gradle.kts

```
dependencies {
    attributesSchema {
        attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE) {
            compatibilityRules.add(InstrumentedJarsRule::class.java)
        }
    }
}
```

consumer/build.gradle

```
dependencies {
    attributesSchema {
        attribute(LibraryElements.LIBRARY_ELEMENTS_ATTRIBUTE) {
            compatibilityRules.add(InstrumentedJarsRule)
        }
    }
}
```

And that's it! Now we have:

- added a variant which provides instrumented jars
- explained that this variant is a substitute for the runtime
- explained that the consumer needs this variant *only for test runtime*

Gradle therefore offers a powerful mechanism to select the right variants based on preferences and compatibility. More details can be found in the [variant aware plugins section of the documentation](#).

By adding a value to an existing attribute like we have done, or by defining new attributes, we are extending the model. This means that *all consumers* have to know about this extended model.

For local consumers, this is usually not a problem because all projects understand and share the same schema, but if you had to publish this new variant to an external repository, it means that external consumers would have to add the same rules to their builds for them to pass. This is in general not a problem for *ecosystem plugins* (e.g: the Kotlin plugin) where consumption is in any case not possible without applying the plugin, but it is a problem if you add custom values or attributes.

So, **avoid publishing custom variants** if they are for internal use only.

== Targeting different platforms

It is common for a library to target different platforms. In the Java ecosystem, we often see different artifacts for the same library, distinguished by a different *classifier*. A typical example is Guava, which is published as this:

- `guava-jre` for JDK 8 and above
- `guava-android` for JDK 7

The problem with this approach is that there's no semantics associated with the classifier. The dependency resolution engine, in particular, cannot determine automatically which version to use based on the consumer requirements. For example, it would be better to express that you have a dependency on Guava, and let the engine choose between `jre` and `android` based on what is compatible.

Gradle provides an improved model for this, which doesn't have the weakness of classifiers: attributes.

In particular, in the Java ecosystem, Gradle provides a built-in attribute that library authors can use to express compatibility with the Java ecosystem: `org.gradle.jvm.version`. This attribute expresses the *minimal version that a consumer must have in order to work properly*.

When you apply the `java` or `java-library` plugins, Gradle will automatically associate this attribute to the outgoing variants. This means that all libraries published with Gradle automatically tell which target platform they use.

By default, the `org.gradle.jvm.version` is set to the value of the `release` property (or as fallback to the `targetCompatibility` value) of the main compilation task of the source set.

While this attribute is automatically set, Gradle *will not*, by default, let you build a project for different JVMs. If you need to do this, then you will need to create additional variants following the instructions on variant-aware matching.

| NOTE | Future versions of Gradle will provide ways to automatically build for different Java platforms. |

= Transforming dependency artifacts on resolution

As described in different kinds of configurations, there may be different variants for the same dependency. For example, an external Maven dependency has a variant which should be used when compiling against the dependency (`java-api`), and a variant for running an application which uses the dependency (`java-runtime`). A project dependency has even more variants, for example the classes of the project which are used for compilation are available as classes directories (`org.gradle.usage=java-api, org.gradle.libraryelements=classes`) or as JARs (`org.gradle.usage=java-api, org.gradle.libraryelements=jar`).

The variants of a dependency may differ in its transitive dependencies or in the artifact itself. For example, the `java-api` and `java-runtime` variants of a Maven dependency only differ in the transitive dependencies and both use the same artifact — the JAR file. For a project

dependency, the `java-api,classes` and the `java-api,jars` variants have the same transitive dependencies and different artifacts — the classes directories and the JAR files respectively.

Gradle identifies a variant of a dependency uniquely by its set of attributes. The `java-api` variant of a dependency is the variant identified by the `org.gradle.usage` attribute with value `java-api`.

When Gradle resolves a configuration, the attributes on the resolved configuration determine the *requested attributes*. For all dependencies in the configuration, the variant with the requested attributes is selected when resolving the configuration. For example, when the configuration requests `org.gradle.usage=java-api`, `org.gradle.libraryelements=classes` on a project dependency, then the classes directory is selected as the artifact.

When the dependency does not have a variant with the requested attributes, resolving the configuration fails. Sometimes it is possible to transform the artifact of the dependency into the requested variant without changing the transitive dependencies. For example, unzipping a JAR transforms the artifact of the `java-api,jars` variant into the `java-api,classes` variant. Such a transformation is called *Artifact Transform*. Gradle allows registering artifact transforms, and when the dependency does not have the requested variant, then Gradle will try to find a chain of artifact transforms for creating the variant.

== Artifact transform selection and execution

As described above, when Gradle resolves a configuration and a dependency in the configuration does not have a variant with the requested attributes, Gradle tries to find a chain of artifact transforms to create the variant. The process of finding a matching chain of artifact transforms is called *artifact transform selection*. Each registered transform converts from a set of attributes to a set of attributes. For example, the unzip transform can convert from `org.gradle.usage=java-api`, `org.gradle.libraryelements=jars` to `org.gradle.usage=java-api`, `org.gradle.libraryelements=classes`.

In order to find a chain, Gradle starts with the requested attributes and then considers all transforms which modify some of the requested attributes as possible paths leading there. Going backwards, Gradle tries to obtain a path to some existing variant using transforms.

For example, consider a `minified` attribute with two values: `true` and `false`. The minified attribute represents a variant of a dependency with unnecessary class files removed. There is an artifact transform registered, which can transform `minified` from `false` to `true`. When `minified=true` is requested for a dependency, and there are only variants with `minified=false`, then Gradle selects the registered minify transform. The minify transform is able to transform the artifact of the dependency with `minified=false` to the artifact with `minified=true`.

Of all the found transform chains, Gradle tries to select the best one:

- If there is only one transform chain, it is selected.

- If there are two transform chains, and one is a suffix of the other one, it is selected.

- If there is a shortest transform chain, then it is selected.

- In all other cases, the selection fails and an error is reported.

IMPORTANT	Gradle does not try to select artifact transforms when there is already a variant of the dependency matching the requested attributes.

The `artifactType` attribute is special, since it is only present on resolved artifacts and not on dependencies. As a consequence, any transform which is only mutating `artifactType` will never be selected when resolving a configuration with only the `artifactType` as requested attribute. It will only be considered when using an ArtifactView.

After selecting the required artifact transforms, Gradle resolves the variants of the dependencies which are necessary for the initial transform in the chain. As soon as Gradle finishes resolving the artifacts for the variant, either by downloading an external dependency or executing a task producing the artifact, Gradle starts transforming the artifacts of the variant with the selected chain of artifact transforms. Gradle executes the transform chains in parallel when possible.

Picking up the minify example above, consider a configuration with two dependencies, the external `guava` dependency and a project dependency on the `producer` project. The configuration has the attributes `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=true`. The external `guava` dependency has two variants:

- `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=false` and
- `org.gradle.usage=java-api,org.gradle.libraryelements=jar,minified=false`.

Using the minify transform, Gradle can convert the variant `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=false` of `guava` to `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=true`, which are the requested attributes. The project dependency also has variants:

- `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=false`,
- `org.gradle.usage=java-runtime,org.gradle.libraryelements=classes,minified=false`,
- `org.gradle.usage=java-api,org.gradle.libraryelements=jar,minified=false`,
- `org.gradle.usage=java-api,org.gradle.libraryelements=classes,minified=false`
- and a few more.

Again, using the minify transform, Gradle can convert the variant `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=false` of the project `producer` to `org.gradle.usage=java-runtime,org.gradle.libraryelements=jar,minified=true`, which are the requested attributes.

When the configuration is resolved, Gradle needs to download the `guava` JAR and minify it. Gradle also needs to execute the `producer:jar` task to generate the JAR artifact of the project and then minify it. The downloading and the minification of the `guava.jar` happens in parallel to the execution of the `producer:jar` task and the minification of the resulting JAR.

Here is how to setup the `minified` attribute so that the above works. You need to register the new attribute in the schema, add it to all JAR artifacts and request it on all resolvable configurations.

build.gradle.kts

```kotlin
val artifactType = Attribute.of("artifactType", String::class.java)
val minified = Attribute.of("minified", Boolean::class.javaObjectType)
dependencies {
    attributesSchema {
        attribute(minified)                                 ①
    }
    artifactTypes.getByName("jar") {
        attributes.attribute(minified, false)    ②
    }
}

configurations.all {
    afterEvaluate {
        if (isCanBeResolved) {
            attributes.attribute(minified, true) ③
        }
    }
}

dependencies {
    registerTransform(Minify::class) {
        from.attribute(minified, false).attribute(artifactType, "jar")
        to.attribute(minified, true).attribute(artifactType, "jar")
    }
}

dependencies {                                              ④
    implementation("com.google.guava:guava:27.1-jre")
    implementation(project(":producer"))
}

tasks.register<Copy>("resolveRuntimeClasspath") { ⑤
    from(configurations.runtimeClasspath)
    into(layout.buildDirectory.dir("runtimeClasspath"))
}
```

build.gradle

```
def artifactType = Attribute.of('artifactType', String)
def minified = Attribute.of('minified', Boolean)
dependencies {
    attributesSchema {
        attribute(minified)                         ①
    }
    artifactTypes.getByName("jar") {
        attributes.attribute(minified, false)    ②
    }
}

configurations.all {
    afterEvaluate {
        if (canBeResolved) {
            attributes.attribute(minified, true) ③
        }
    }
}

dependencies {
    registerTransform(Minify) {
        from.attribute(minified, false).attribute(artifactType, "jar")
        to.attribute(minified, true).attribute(artifactType, "jar")
    }
}
dependencies {                                        ④
    implementation('com.google.guava:guava:27.1-jre')
    implementation(project(':producer'))
}

tasks.register("resolveRuntimeClasspath", Copy) {⑤
    from(configurations.runtimeClasspath)
    into(layout.buildDirectory.dir("runtimeClasspath"))
}
```

① Add the attribute to the schema

② All JAR files are not minified

③ Request `minified=true` on all resolvable configurations

④ Add the dependencies which will be transformed

⑤ Add task that requires the transformed artifacts

You can now see what happens when we run the `resolveRuntimeClasspath` task which resolves the `runtimeClasspath` configuration. Observe that Gradle transforms the project dependency before the `resolveRuntimeClasspath` task starts. Gradle transforms the binary dependencies when it executes the `resolveRuntimeClasspath` task.

Output when resolving the runtimeClasspath configuration

```
> gradle resolveRuntimeClasspath

> Task :producer:compileJava
> Task :producer:processResources NO-SOURCE
> Task :producer:classes
> Task :producer:jar

> Transform producer.jar (project :producer) with Minify
Nothing to minify - using producer.jar unchanged

> Task :resolveRuntimeClasspath
Minifying guava-27.1-jre.jar
Nothing to minify - using listenablefuture-9999.0-empty-to-avoid-conflict-with-
guava.jar unchanged
Nothing to minify - using jsr305-3.0.2.jar unchanged
Nothing to minify - using checker-qual-2.5.2.jar unchanged
Nothing to minify - using error_prone_annotations-2.2.0.jar unchanged
Nothing to minify - using j2objc-annotations-1.1.jar unchanged
Nothing to minify - using animal-sniffer-annotations-1.17.jar unchanged
Nothing to minify - using failureaccess-1.0.1.jar unchanged

BUILD SUCCESSFUL in 0s
3 actionable tasks: 3 executed
```

Implementing artifact transforms

Similar to task types, an artifact transform consists of an action and some parameters. The major difference to custom task types is that the action and the parameters are implemented as two separate classes.

The implementation of the artifact transform action is a class implementing TransformAction. You need to implement the `transform()` method on the action, which converts an input artifact into zero, one or multiple of output artifacts. Most artifact transforms will be one-to-one, so the transform method will transform the input artifact to exactly one output artifact.

The implementation of the artifact transform action needs to register each output artifact by calling TransformOutputs.dir() or TransformOutputs.file().

You can only supply two types of paths to the `dir` or `file` methods:

- An absolute path to the input artifact or in the input artifact (for an input directory).

- A relative path.

Gradle uses the absolute path as the location of the output artifact. For example, if the input artifact is an exploded WAR, then the transform action can call `TransformOutputs.file()` for all jar files in the `WEB-INF/lib` directory. The output of the transform would then be the library JARs of the web application.

For a relative path, the `dir()` or `file()` method returns a workspace to the transform action. The implementation of the transform action needs to create the transformed artifact at the location of the provided workspace.

The output artifacts replace the input artifact in the transformed variant in the order they were registered. For example, if the configuration consists of the artifacts `lib1.jar`, `lib2.jar`, `lib3.jar`, and the transform action registers a minified output artifact `<artifact-name>-min.jar` for the input artifact, then the transformed configuration consists of the artifacts `lib1-min.jar`, `lib2-min.jar` and `lib3-min.jar`.

Here is the implementation of an `Unzip` transform which transforms a JAR file into a classes directory by unzipping it. The `Unzip` transform does not require any parameters. Note how the implementation uses `@InputArtifact` to inject the artifact to transform into the action. It requests a directory for the unzipped classes by using `TransformOutputs.dir()` and then unzips the JAR file into this directory.

build.gradle.kts

```
abstract class Unzip : TransformAction<TransformParameters.None> {    ①
    @get:InputArtifact                                                  ②
    abstract val inputArtifact: Provider<FileSystemLocation>

    override
    fun transform(outputs: TransformOutputs) {
        val input = inputArtifact.get().asFile
        val unzipDir = outputs.dir(input.name)                          ③
        unzipTo(input, unzipDir)                                        ④
    }

    private fun unzipTo(zipFile: File, unzipDir: File) {
        // implementation...
    }
}
```

build.gradle

```
abstract class Unzip implements TransformAction<TransformParameters.None> {   ①
    @InputArtifact                                                            ②
    abstract Provider<FileSystemLocation> getInputArtifact()

    @Override
    void transform(TransformOutputs outputs) {
        def input = inputArtifact.get().asFile
        def unzipDir = outputs.dir(input.name)                                ③
        unzipTo(input, unzipDir)                                              ④
    }

    private static void unzipTo(File zipFile, File unzipDir) {
        // implementation...
    }
}
```

① Use `TransformParameters.None` if the transform does not use parameters

② Inject the input artifact

③ Request an output location for the unzipped files

④ Do the actual work of the transform

An artifact transform may require parameters, like a `String` determining some filter, or some file collection which is used for supporting the transformation of the input artifact. In order to pass those parameters to the transform action, you need to define a new type with the desired parameters. The type needs to implement the marker interface TransformParameters. The parameters must be represented using managed properties and the parameters type must be a managed type. You can use an interface or abstract class declaring the getters and Gradle will generate the implementation. All getters need to have proper input annotations, see incremental build annotations table.

You can find out more about implementing artifact transform parameters in Developing Custom Gradle Types.

Here is the implementation of a `Minify` transform that makes JARs smaller by only keeping certain classes in them. The `Minify` transform requires the classes to keep as parameters. Observe how you can obtain the parameters by `TransformAction.getParameters()` in the `transform()` method. The implementation of the `transform()` method requests a location for the minified JAR by using `TransformOutputs.file()` and then creates the minified JAR at this location.

build.gradle.kts

```kotlin
abstract class Minify : TransformAction<Minify.Parameters> {    ①
    interface Parameters : TransformParameters {                ②
        @get:Input
        var keepClassesByArtifact: Map<String, Set<String>>

    }

    @get:PathSensitive(PathSensitivity.NAME_ONLY)
    @get:InputArtifact
    abstract val inputArtifact: Provider<FileSystemLocation>

    override
    fun transform(outputs: TransformOutputs) {
        val fileName = inputArtifact.get().asFile.name
        for (entry in parameters.keepClassesByArtifact) {       ③
            if (fileName.startsWith(entry.key)) {
                val nameWithoutExtension = fileName.substring(0, fileName.length -
4)
                minify(inputArtifact.get().asFile, entry.value,
outputs.file("${nameWithoutExtension}-min.jar"))
                return
            }
        }
        println("Nothing to minify - using ${fileName} unchanged")
        outputs.file(inputArtifact)                             ④
    }

    private fun minify(artifact: File, keepClasses: Set<String>, jarFile: File) {
        println("Minifying ${artifact.name}")
        // Implementation ...
    }
}
```

build.gradle

```
abstract class Minify implements TransformAction<Parameters> { ①
    interface Parameters extends TransformParameters {          ②
        @Input
        Map<String, Set<String>> getKeepClassesByArtifact()
        void setKeepClassesByArtifact(Map<String, Set<String>> keepClasses)
    }

    @PathSensitive(PathSensitivity.NAME_ONLY)
    @InputArtifact
    abstract Provider<FileSystemLocation> getInputArtifact()

    @Override
    void transform(TransformOutputs outputs) {
        def fileName = inputArtifact.get().asFile.name
        for (entry in parameters.keepClassesByArtifact) {       ③
            if (fileName.startsWith(entry.key)) {
                def nameWithoutExtension = fileName.substring(0, fileName.length()
- 4)
                minify(inputArtifact.get().asFile, entry.value, outputs.file("
${nameWithoutExtension}-min.jar"))
                return
            }
        }
        println "Nothing to minify - using ${fileName} unchanged"
        outputs.file(inputArtifact)                             ④
    }

    private void minify(File artifact, Set<String> keepClasses, File jarFile) {
        println "Minifying ${artifact.name}"
        // Implementation ...
    }
}
```

① Declare the parameter type

② Interface for the transform parameters

③ Use the parameters

④ Use the unchanged input artifact when no minification is required

Remember that the input artifact is a dependency, which may have its own dependencies. If your artifact transform needs access to those transitive dependencies, it can declare an abstract getter returning a `FileCollection` and annotate it with @InputArtifactDependencies. When your transform runs, Gradle will inject the transitive dependencies into that `FileCollection` property by implementing the getter. Note that using input artifact dependencies in a transform has performance implications, only inject them when you really need them.

Moreover, artifact transforms can make use of the build cache for their outputs. To enable the build cache for an artifact transform, add the `@CacheableTransform` annotation on the action class. For cacheable transforms, you must annotate its @InputArtifact property — and any property marked with @InputArtifactDependencies — with normalization annotations such as @PathSensitive.

The following example shows a more complicated transform. It moves some selected classes of a JAR to a different package, rewriting the byte code of the moved classes and all classes using the moved classes (class relocation). In order to determine the classes to relocate, it looks at the packages of the input artifact and the dependencies of the input artifact. It also does not relocate packages contained in JAR files in an external classpath.

build.gradle.kts

```
@CacheableTransform                                                        ①
abstract class ClassRelocator : TransformAction<ClassRelocator.Parameters> {
    interface Parameters : TransformParameters {                           ②
        @get:CompileClasspath                                              ③
        val externalClasspath: ConfigurableFileCollection
        @get:Input
        val excludedPackage: Property<String>
    }

    @get:Classpath                                                         ④
    @get:InputArtifact
    abstract val primaryInput: Provider<FileSystemLocation>

    @get:CompileClasspath
    @get:InputArtifactDependencies                                         ⑤
    abstract val dependencies: FileCollection

    override
    fun transform(outputs: TransformOutputs) {
        val primaryInputFile = primaryInput.get().asFile
        if (parameters.externalClasspath.contains(primaryInputFile)) {     ⑥
            outputs.file(primaryInput)
        } else {
            val baseName = primaryInputFile.name.substring(0,
primaryInputFile.name.length - 4)
            relocateJar(outputs.file("$baseName-relocated.jar"))
        }
    }

    private fun relocateJar(output: File) {
        // implementation...
        val relocatedPackages = (dependencies.flatMap { it.readPackages() } +
primaryInput.get().asFile.readPackages()).toSet()
        val nonRelocatedPackages = parameters.externalClasspath.flatMap {
it.readPackages() }
        val relocations = (relocatedPackages - nonRelocatedPackages).map {
packageName ->
            val toPackage = "relocated.$packageName"
            println("$packageName -> $toPackage")
            Relocation(packageName, toPackage)
        }
        JarRelocator(primaryInput.get().asFile, output, relocations).run()
    }
}
```

```
build.gradle

@CacheableTransform                                                        ①
abstract class ClassRelocator implements TransformAction<Parameters> {
    interface Parameters extends TransformParameters {                     ②
        @CompileClasspath                                                  ③
        ConfigurableFileCollection getExternalClasspath()
        @Input
        Property<String> getExcludedPackage()
    }

    @Classpath                                                             ④
    @InputArtifact
    abstract Provider<FileSystemLocation> getPrimaryInput()

    @CompileClasspath
    @InputArtifactDependencies                                             ⑤
    abstract FileCollection getDependencies()

    @Override
    void transform(TransformOutputs outputs) {
        def primaryInputFile = primaryInput.get().asFile
        if (parameters.externalClasspath.contains(primaryInput)) {         ⑥
            outputs.file(primaryInput)
        } else {
            def baseName = primaryInputFile.name.substring(0, primaryInputFile
.name.length - 4)
            relocateJar(outputs.file("$baseName-relocated.jar"))
        }
    }

    private relocateJar(File output) {
        // implementation...
        def relocatedPackages = (dependencies.collectMany { readPackages(it) } +
readPackages(primaryInput.get().asFile)) as Set
        def nonRelocatedPackages = parameters.externalClasspath.collectMany {
readPackages(it) }
        def relocations = (relocatedPackages - nonRelocatedPackages).collect {
packageName ->
            def toPackage = "relocated.$packageName"
            println("$packageName -> $toPackage")
            new Relocation(packageName, toPackage)
        }
        new JarRelocator(primaryInput.get().asFile, output, relocations).run()
    }
}
```

① Declare the transform cacheable

② Interface for the transform parameters

③ Declare input type for each parameter

④ Declare a normalization for the input artifact

⑤ Inject the input artifact dependencies

⑥ Use the parameters

== Registering artifact transforms

You need to register the artifact transform actions, providing parameters if necessary, so that they can be selected when resolving dependencies.

In order to register an artifact transform, you must use registerTransform() within the dependencies {} block.

There are a few points to consider when using registerTransform():

- The from and to attributes are required.

- The transform action itself can have configuration options. You can configure them with the parameters {} block.

- You must register the transform on the project that has the configuration that will be resolved.

- You can supply any type implementing TransformAction to the registerTransform() method.

For example, imagine you want to unpack some dependencies and put the unpacked directories and files on the classpath. You can do so by registering an artifact transform action of type Unzip, as shown here:

build.gradle.kts

```
val artifactType = Attribute.of("artifactType", String::class.java)

dependencies {
    registerTransform(Unzip::class) {
        from.attribute(artifactType, "jar")
        to.attribute(artifactType, "java-classes-directory")
    }
}
```

```
def artifactType = Attribute.of('artifactType', String)

dependencies {
    registerTransform(Unzip) {
        from.attribute(artifactType, 'jar')
        to.attribute(artifactType, 'java-classes-directory')
    }
}
```

Another example is that you want to minify JARs by only keeping some `class` files from them. Note the use of the `parameters {}` block to provide the classes to keep in the minified JARs to the `Minify` transform.

```
val artifactType = Attribute.of("artifactType", String::class.java)
val minified = Attribute.of("minified", Boolean::class.javaObjectType)
val keepPatterns = mapOf(
    "guava" to setOf(
        "com.google.common.base.Optional",
        "com.google.common.base.AbstractIterator"
    )
)


dependencies {
    registerTransform(Minify::class) {
        from.attribute(minified, false).attribute(artifactType, "jar")
        to.attribute(minified, true).attribute(artifactType, "jar")

        parameters {
            keepClassesByArtifact = keepPatterns
        }
    }
}
```

```groovy
def artifactType = Attribute.of('artifactType', String)
def minified = Attribute.of('minified', Boolean)
def keepPatterns = [
    "guava": [
        "com.google.common.base.Optional",
        "com.google.common.base.AbstractIterator"
    ] as Set
]


dependencies {
    registerTransform(Minify) {
        from.attribute(minified, false).attribute(artifactType, "jar")
        to.attribute(minified, true).attribute(artifactType, "jar")

        parameters {
            keepClassesByArtifact = keepPatterns
        }
    }
}
```

== Implementing incremental artifact transforms

Similar to incremental tasks, artifact transforms can avoid work by only processing changed files from the last execution. This is done by using the InputChanges interface. For artifact transforms, only the input artifact is an incremental input, and therefore the transform can only query for changes there. In order to use InputChanges in the transform action, inject it into the action. For more information on how to use InputChanges, see the corresponding documentation for incremental tasks.

Here is an example of an incremental transform that counts the lines of code in Java source files:

build.gradle.kts

```
abstract class CountLoc : TransformAction<TransformParameters.None> {

    @get:Inject                                                        ①
    abstract val inputChanges: InputChanges

    @get:PathSensitive(PathSensitivity.RELATIVE)
    @get:InputArtifact
    abstract val input: Provider<FileSystemLocation>

    override
    fun transform(outputs: TransformOutputs) {
        val outputDir = outputs.dir("${input.get().asFile.name}.loc")
        println("Running transform on ${input.get().asFile.name}, incremental:
${inputChanges.isIncremental}")
        inputChanges.getFileChanges(input).forEach { change ->          ②
            val changedFile = change.file
            if (change.fileType != FileType.FILE) {
                return@forEach
            }
            val outputLocation = outputDir.resolve("${change.normalizedPath}.loc")
            when (change.changeType) {
                ChangeType.ADDED, ChangeType.MODIFIED -> {

                    println("Processing file ${changedFile.name}")
                    outputLocation.parentFile.mkdirs()


outputLocation.writeText(changedFile.readLines().size.toString())
                }
                ChangeType.REMOVED -> {
                    println("Removing leftover output file
${outputLocation.name}")
                    outputLocation.delete()
                }
            }
        }
    }
}
```

build.gradle

```
abstract class CountLoc implements TransformAction<TransformParameters.None> {

    @Inject                                                          ①
    abstract InputChanges getInputChanges()

    @PathSensitive(PathSensitivity.RELATIVE)
    @InputArtifact
    abstract Provider<FileSystemLocation> getInput()

    @Override
    void transform(TransformOutputs outputs) {
        def outputDir = outputs.dir("${input.get().asFile.name}.loc")
        println("Running transform on ${input.get().asFile.name}, incremental:
${inputChanges.incremental}")
        inputChanges.getFileChanges(input).forEach { change ->           ②
            def changedFile = change.file
            if (change.fileType != FileType.FILE) {
                return
            }
            def outputLocation = new File(outputDir, "${change.normalizedPath}
.loc")
            switch (change.changeType) {
                case ADDED:
                case MODIFIED:
                    println("Processing file ${changedFile.name}")
                    outputLocation.parentFile.mkdirs()

                    outputLocation.text = changedFile.readLines().size()

                case REMOVED:
                    println("Removing leftover output file ${outputLocation.name}
")
                    outputLocation.delete()

            }
        }
    }
}
```

① Inject `InputChanges`

② Query for changes in the input artifact

== PUBLISHING LIBRARIES

= Publishing a project as module

The vast majority of software projects build something that aims to be consumed in some way. It could be a library that other software projects use or it could be an application for end users. *Publishing* is the process by which the thing being built is made available to consumers.

In Gradle, that process looks like this:

1. Define what to publish

2. Define where to publish it to

3. Do the publishing

Each of the these steps is dependent on the type of repository to which you want to publish artifacts. The two most common types are Maven-compatible and Ivy-compatible repositories, or Maven and Ivy repositories for short.

As of Gradle 6.0, the Gradle Module Metadata will always be published alongside the Ivy XML or Maven POM metadata file.

Gradle makes it easy to publish to these types of repository by providing some prepackaged infrastructure in the form of the Maven Publish Plugin and the Ivy Publish Plugin. These plugins allow you to configure what to publish and perform the publishing with a minimum of effort.
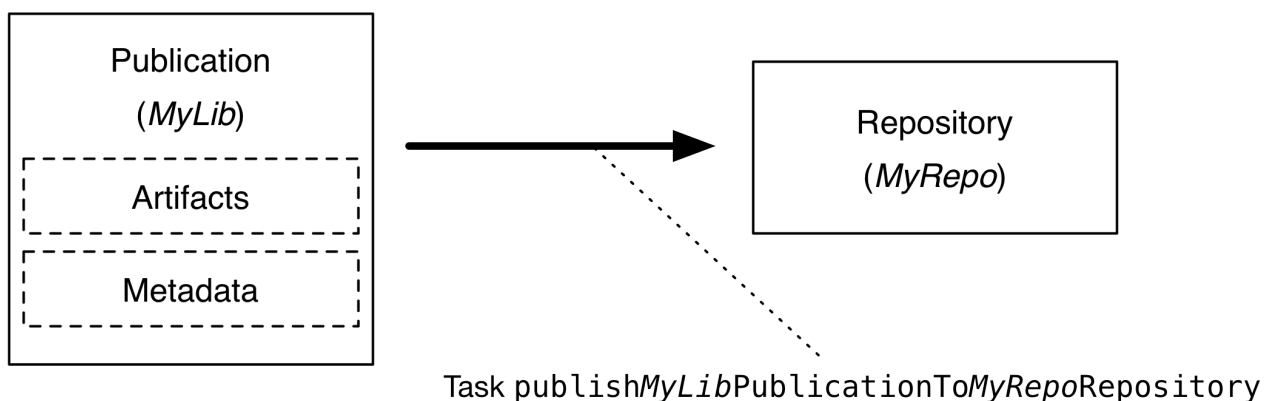
Figure 29. The publishing process

Let's take a look at those steps in more detail:

What to publish

Gradle needs to know what files and information to publish so that consumers can use your project. This is typically a combination of artifacts and metadata that Gradle calls a publication. Exactly what a publication contains depends on the type of repository it's being published to.

For example, a publication destined for a Maven repository includes:

- One or more artifacts — typically built by the project,
- The Gradle Module Metadata file which will describe the variants of the published component,
- The Maven POM file will identify the primary artifact and its dependencies. The primary artifact is typically the project's production JAR and secondary artifacts might consist of "-sources" and "-javadoc" JARs.

In addition, Gradle will publish checksums for all of the above, and signatures when configured to do so. From Gradle 6.0 onwards, this includes SHA256 and SHA512 checksums.

Where to publish

Gradle needs to know where to publish artifacts so that consumers can get hold of them. This is done via repositories, which store and make available all sorts of artifact. Gradle also needs to interact with the repository, which is why you must provide the type of the repository and its location.

How to publish

Gradle automatically generates publishing tasks for all possible combinations of publication and repository, allowing you to publish any artifact to any repository. If you're publishing to a Maven repository, the tasks are of type PublishToMavenRepository, while for Ivy repositories the tasks are of type PublishToIvyRepository.

What follows is a practical example that demonstrates the entire publishing process.

== Setting up basic publishing

The first step in publishing, irrespective of your project type, is to apply the appropriate publishing plugin. As mentioned in the introduction, Gradle supports both Maven and Ivy repositories via the following plugins:

- Maven Publish Plugin
- Ivy Publish Plugin

These provide the specific publication and repository classes needed to configure publishing for the corresponding repository type. Since Maven repositories are the most commonly used ones, they will be the basis for this example and for the other samples in the chapter. Don't worry, we will explain how to adjust individual samples for Ivy repositories.

Let's assume we're working with a simple Java library project, so only the following plugins are applied:

build.gradle.kts

```
plugins {
    `java-library`
    `maven-publish`
}
```

build.gradle

```
plugins {
    id 'java-library'
    id 'maven-publish'
}
```

Once the appropriate plugin has been applied, you can configure the publications and repositories. For this example, we want to publish the project's production JAR file — the one produced by the `jar` task — to a custom Maven repository. We do that with the following `publishing {}` block, which is backed by PublishingExtension:

build.gradle.kts

```
group = "org.example"
version = "1.0"

publishing {
    publications {
        create<MavenPublication>("myLibrary") {
            from(components["java"])
        }
    }

    repositories {
        maven {
            name = "myRepo"
            url = uri(layout.buildDirectory.dir("repo"))
        }
    }
}
```

build.gradle

```
group = 'org.example'
version = '1.0'

publishing {
    publications {
        myLibrary(MavenPublication) {
            from components.java
        }
    }

    repositories {
        maven {
            name = 'myRepo'
            url = layout.buildDirectory.dir("repo")
        }
    }
}
```

This defines a publication called "myLibrary" that can be published to a Maven repository by virtue of its type: MavenPublication. This publication consists of just the production JAR artifact and its metadata, which combined are represented by the `java` component of the project.

> **NOTE**
> Components are the standard way of defining a publication. They are provided by plugins, usually of the language or platform variety. For example, the Java Plugin defines the `components.java` SoftwareComponent, while the War Plugin defines `components.web`.

The example also defines a file-based Maven repository with the name "myRepo". Such a file-based repository is convenient for a sample, but real-world builds typically work with HTTPS-based repository servers, such as Maven Central or an internal company server.

> **NOTE**
> You may define one, and only one, repository without a name. This translates to an implicit name of "Maven" for Maven repositories and "Ivy" for Ivy repositories. All other repository definitions must be given an explicit name.

In combination with the project's `group` and `version`, the publication and repository definitions provide everything that Gradle needs to publish the project's production JAR. Gradle will then create a dedicated `publishMyLibraryPublicationToMyRepoRepository` task that does just that. Its name is based on the template `publishPubNamePublicationToRepoNameRepository`. See the appropriate publishing plugin's documentation for more details on the nature of this task and any other tasks that may be available to you.

You can either execute the individual publishing tasks directly, or you can execute `publish`, which will run all the available publishing tasks. In this example, `publish` will just run `publishMyLibraryPublicationToMavenRepository`.

Basic publishing to an Ivy repository is very similar: you simply use the Ivy Publish Plugin, replace `MavenPublication` with IvyPublication, and use `ivy` instead of `maven` in the repository definition.

There are differences between the two types of repository, particularly around the extra metadata that each support — for example, Maven repositories require a POM file while Ivy ones have their own metadata format — so see the plugin chapters for comprehensive information on how to configure both publications and repositories for whichever repository type you're working with.

> That's everything for the basic use case. However, many projects need more control over what gets published, so we look at several common scenarios in the following sections.
>
> == Suppressing validation errors
>
> Gradle performs validation of generated module metadata. In some cases, validation can fail, indicating that you most likely have an error to fix, but you may have done something intentionally. If this is the case, Gradle will indicate the name of the validation error you can disable on the `GenerateModuleMetadata` tasks:

build.gradle.kts

```kotlin
tasks.withType<GenerateModuleMetadata> {
    // The value 'enforced-platform' is provided in the validation
    // error message you got
    suppressedValidationErrors.add("enforced-platform")
}
```

build.gradle

```groovy
tasks.withType(GenerateModuleMetadata).configureEach {
    // The value 'enforced-platform' is provided in the validation
    // error message you got
    suppressedValidationErrors.add('enforced-platform')
}
```

Understanding Gradle Module Metadata

Gradle Module Metadata is a format used to serialize the Gradle component model. It is similar to Apache Maven™'s POM file or Apache Ivy™ ivy.xml files. The goal of metadata files is to provide *to consumers* a reasonable model of what is published on a repository.

Gradle Module Metadata is a unique format aimed at improving dependency resolution by making it multi-platform and variant-aware.

In particular, Gradle Module Metadata supports:

- rich version constraints
- dependency constraints
- component capabilities
- variant-aware resolution

Publication of Gradle Module Metadata will enable better dependency management for your consumers:

- early discovery of problems by detecting incompatible modules
- consistent selection of platform-specific dependencies
- native dependency version alignment
- automatically getting dependencies for specific features of your library

Gradle Module Metadata is automatically published when using the Maven Publish plugin or the Ivy Publish plugin.

The specification for Gradle Module Metadata can be found here.

Mapping with other formats

Gradle Module Metadata is automatically published on Maven or Ivy repositories. However, it doesn't replace the *pom.xml* or *ivy.xml* files: it is published alongside those files. This is done to maximize compatibility with third-party build tools.

Gradle does its best to map Gradle-specific concepts to Maven or Ivy. When a build file uses features that can only be represented in Gradle Module Metadata, Gradle will warn you at publication time. The table below summarizes how some Gradle specific features are mapped to Maven and Ivy:

Table 32. Mapping of Gradle specific concepts to Maven and Ivy

Gradle	Maven	Ivy	Description
dependency constraints	`<dependencyManagement>` dependencies	Not published	Gradle dependency constraints are *transitive*, while Maven's dependency management block *isn't*
rich version constraints	Publishes the *requires* version	Published the *requires* version	
component capabilities	Not published	Not published	Component capabilities are unique to Gradle
Feature variants	Variant artifacts are uploaded, dependencies are published as *optional* dependencies	Variant artifacts are uploaded, dependencies are not published	Feature variants are a good replacement for optional dependencies
Custom component types	Artifacts are uploaded, dependencies are those described by the mapping	Artifacts are uploaded, dependencies are ignored	Custom component types are probably not consumable from Maven or Ivy in any case. They usually exist in the context of a custom ecosystem.

=== Disabling metadata compatibility publication warnings

If you want to suppress warnings, you can use the following APIs to do so:

- For Maven, see the `suppress*` methods in MavenPublication

- For Ivy, see the `suppress*` methods in IvyPublication

build.gradle.kts

```
publications {
    register<MavenPublication>("maven") {
        from(components["java"])
        suppressPomMetadataWarningsFor("runtimeElements")
    }
}
```

```
publications {
    maven(MavenPublication) {
        from components.java
        suppressPomMetadataWarningsFor('runtimeElements')
    }
}
```

== Interactions with other build tools

Because Gradle Module Metadata is not widely spread and because it aims at maximizing compatibility with other tools, Gradle does a couple of things:

- Gradle Module Metadata is systematically published alongside the normal descriptor for a given repository (Maven or Ivy)

- the `pom.xml` or `ivy.xml` file will contain a *marker comment* which tells Gradle that Gradle Module Metadata exists for this module

The goal of the marker is *not* for other tools to parse module metadata: it's for Gradle users only. It explains to Gradle that a *better* module metadata file exists and that it should use it instead. It doesn't mean that consumption from Maven or Ivy would be broken either, only that it works in degraded mode.

NOTE	This must be seen as a *performance optimization*: instead of having to do 2 network requests, one to get Gradle Module Metadata, then one to get the POM/Ivy file in case of a miss, Gradle will first look at the file which is most likely to be present, then only perform a 2nd request if the module was actually published with Gradle Module Metadata.

If you know that the modules you depend on are always published with Gradle Module Metadata, you can optimize the network calls by configuring the metadata sources for a repository:

build.gradle.kts

```
repositories {
    maven {
        setUrl("http://repo.mycompany.com/repo")
        metadataSources {
            gradleMetadata()
        }
    }
}
```

build.gradle

```
repositories {
    maven {
        url "http://repo.mycompany.com/repo"
        metadataSources {
            gradleMetadata()
        }
    }
}
```

Gradle Module Metadata validation

Gradle Module Metadata is validated before being published.

The following rules are enforced:

- Variant names must be unique,
- Each variant must have at least one attribute,
- Two variants cannot have the exact same attributes and capabilities,
- If there are dependencies, at least one, across all variants, must carry version information.

These rules ensure the quality of the metadata produced, and help confirm that consumption will not be problematic.

Gradle Module Metadata reproducibility

The task generating the module metadata files is currently never marked `UP-TO-DATE` by Gradle due to the way it is implemented. However, if neither build inputs nor build scripts changed, the task result is effectively up-to-date: it always produces the same output.

If users desire to have a unique `module` file per build invocation, it is possible to link an identifier in the produced metadata to the build that created it. Users can choose to enable this unique identifier in their `publication`:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("myLibrary") {
            from(components["java"])
            withBuildIdentifier()
        }
    }
}
```

build.gradle

```
publishing {
    publications {
        myLibrary(MavenPublication) {
            from components.java
            withBuildIdentifier()
        }
    }
}
```

With the changes above, the generated Gradle Module Metadata file will always be different, forcing downstream tasks to consider it out-of-date.

== Disabling Gradle Module Metadata publication

There are situations where you might want to disable publication of Gradle Module Metadata:

- the repository you are uploading to rejects the metadata file (unknown format)
- you are using Maven or Ivy specific concepts which are not properly mapped to Gradle Module Metadata

In this case, disabling the publication of Gradle Module Metadata is done simply by disabling the task which generates the metadata file:

build.gradle.kts

```
tasks.withType<GenerateModuleMetadata> {
    enabled = false
}
```

build.gradle

```
tasks.withType(GenerateModuleMetadata) {
    enabled = false
}
```

= Signing artifacts

The Signing Plugin can be used to sign all artifacts and metadata files that make up a publication, including Maven POM files and Ivy module descriptors. In order to use it:

1. Apply the Signing Plugin

2. Configure the signatory credentials — follow the link to see how

3. Specify the publications you want signed

Here's an example that configures the plugin to sign the `mavenJava` publication:

build.gradle.kts

```
signing {
    sign(publishing.publications["mavenJava"])
}
```

build.gradle

```
signing {
    sign publishing.publications.mavenJava
}
```

This will create a `Sign` task for each publication you specify and wire all `publish PubNamePublicationToRepoNameRepository` tasks to depend on it. Thus, publishing any publication will automatically create and publish the signatures for its artifacts and metadata, as you can see from this output:

== Example: Sign and publish a project

Output of `gradle publish`

```
> gradle publish
> Task :compileJava
> Task :processResources
> Task :classes
> Task :jar
> Task :javadoc
> Task :javadocJar
> Task :sourcesJar
> Task :generateMetadataFileForMavenJavaPublication
> Task :generatePomFileForMavenJavaPublication
> Task :signMavenJavaPublication
> Task :publishMavenJavaPublicationToMavenRepository
> Task :publish

BUILD SUCCESSFUL in 0s
10 actionable tasks: 10 executed
```

= Customizing publishing

== Modifying and adding variants to existing components for publishing

Gradle's publication model is based on the notion of *components*, which are defined by plugins. For example, the Java Library plugin defines a `java` component which corresponds to a library, but the Java Platform plugin defines another kind of component, named `javaPlatform`, which is effectively a different kind of software component (a *platform*).

Sometimes we want to add *more variants* to or modify *existing variants* of an existing component. For example, if you added a variant of a Java library for a different platform, you may just want to declare this additional variant on the `java` component itself. In general, declaring additional variants is often the best solution to publish *additional artifacts*.

To perform such additions or modifications, the `AdhocComponentWithVariants` interface declares two methods called `addVariantsFromConfiguration` and `withVariantsFromConfiguration` which accept two parameters:

- the outgoing configuration that is used as a variant source

- a customization action which allows you to *filter* which variants are going to be published

To utilise these methods, you must make sure that the `SoftwareComponent` you work with is itself an `AdhocComponentWithVariants`, which is the case for the components created by the Java

plugins (Java, Java Library, Java Platform). Adding a variant is then very simple:

InstrumentedJarsPlugin.kt

```
val javaComponent = components.findByName("java") as AdhocComponentWithVariants
javaComponent.addVariantsFromConfiguration(outgoing) {
    // dependencies for this variant are considered runtime dependencies
    mapToMavenScope("runtime")
    // and also optional dependencies, because we don't want them to leak
    mapToOptional()
}
```

InstrumentedJarsPlugin.groovy

```
AdhocComponentWithVariants javaComponent = (AdhocComponentWithVariants) project
.components.findByName("java")
javaComponent.addVariantsFromConfiguration(outgoing) {
    // dependencies for this variant are considered runtime dependencies
    it.mapToMavenScope("runtime")
    // and also optional dependencies, because we don't want them to leak
    it.mapToOptional()
}
```

In other cases, you might want to modify a variant that was added by one of the Java plugins already. For example, if you activate publishing of Javadoc and sources, these become additional variants of the java component. If you only want to publish one of them, e.g. only Javadoc but no sources, you can modify the sources variant to not being published:

build.gradle.kts

```
java {
    withJavadocJar()
    withSourcesJar()
}

val javaComponent = components["java"] as AdhocComponentWithVariants
javaComponent.withVariantsFromConfiguration(configurations["sourcesElements"]) {
    skip()
}

publishing {
    publications {
        create<MavenPublication>("mavenJava") {
            from(components["java"])
        }
    }
}
```

build.gradle

```
java {
    withJavadocJar()
    withSourcesJar()
}

components.java.withVariantsFromConfiguration(configurations.sourcesElements) {
    skip()
}

publishing {
    publications {
        mavenJava(MavenPublication) {
            from components.java
        }
    }
}
```

== Creating and publishing custom components

In the previous example, we have demonstrated how to extend or modify an existing component, like the components provided by the Java plugins. But Gradle also allows you to build a custom component (not a Java Library, not a Java Platform, not something supported natively by Gradle).

To create a custom component, you first need to create an empty *adhoc* component. At the moment, this is only possible via a plugin because you need to get a handle on the SoftwareComponentFactory :

InstrumentedJarsPlugin.kt

```kotlin
class InstrumentedJarsPlugin @Inject constructor(
    private val softwareComponentFactory: SoftwareComponentFactory) :
Plugin<Project> {
```

InstrumentedJarsPlugin.groovy

```groovy
private final SoftwareComponentFactory softwareComponentFactory

@Inject
InstrumentedJarsPlugin(SoftwareComponentFactory softwareComponentFactory) {
    this.softwareComponentFactory = softwareComponentFactory
}
```

Declaring *what* a custom component publishes is still done via the AdhocComponentWithVariants API. For a custom component, the first step is to create custom outgoing variants, following the instructions in this chapter. At this stage, what you should have is variants which can be used in cross-project dependencies, but that we are now going to publish to external repositories.

InstrumentedJarsPlugin.kt

```kotlin
// create an adhoc component
val adhocComponent = softwareComponentFactory.adhoc("myAdhocComponent")
// add it to the list of components that this project declares
components.add(adhocComponent)
// and register a variant for publication
adhocComponent.addVariantsFromConfiguration(outgoing) {
    mapToMavenScope("runtime")
}
```

InstrumentedJarsPlugin.groovy

```groovy
// create an adhoc component
def adhocComponent = softwareComponentFactory.adhoc("myAdhocComponent")
// add it to the list of components that this project declares
project.components.add(adhocComponent)
// and register a variant for publication
adhocComponent.addVariantsFromConfiguration(outgoing) {
    it.mapToMavenScope("runtime")
}
```

First we use the factory to create a new adhoc component. Then we add a variant through the `addVariantsFromConfiguration` method, which is described in more detail in the previous section.

In simple cases, there's a one-to-one mapping between a `Configuration` and a variant, in which case you can publish all variants issued from a single `Configuration` because they are effectively the same thing. However, there are cases where a `Configuration` is associated with additional configuration publications that we also call *secondary variants*. Such configurations make sense in the cross-project publications use case, but not when publishing externally. This is for example the case when between projects you share a *directory of files*, but there's no way you can publish a *directory* directly on a Maven repository (only packaged things like jars or zips). Look at the ConfigurationVariantDetails class for details about how to skip publication of a particular variant. If `addVariantsFromConfiguration` has already been called for a configuration, further modification of the resulting variants can be performed using `withVariantsFromConfiguration`.

When publishing an adhoc component like this:

- Gradle Module Metadata will *exactly* represent the published variants. In particular, all outgoing variants will inherit dependencies, artifacts and attributes of the published configuration.
- Maven and Ivy metadata files will be generated, but you need to declare how the dependencies are mapped to Maven scopes via the ConfigurationVariantDetails class.

In practice, it means that components created this way can be consumed by Gradle the same way as if they were "local components".

== Adding custom artifacts to a publication

Instead of thinking in terms of artifacts, you should embrace the variant aware model of Gradle. It is expected that a single module may need multiple artifacts. However this rarely stops there, if the additional artifacts represent an optional feature, they might also have different dependencies and more.

Gradle, via *Gradle Module Metadata*, supports the publication of *additional variants* which make those artifacts known to the dependency resolution engine. Please refer to the variant-aware sharing section of the documentation to see how to declare such variants and check out how to publish custom components.

If you attach extra artifacts to a publication directly, they are published "out of context". That means, they are not referenced in the metadata at all and can then only be addressed directly through a classifier on a dependency. In contrast to Gradle Module Metadata, Maven pom metadata will not contain information on additional artifacts regardless of whether they are added through a variant or directly, as variants cannot be represented in the pom format.

The following section describes how you publish artifacts directly if you are sure that metadata, for example Gradle or POM metadata, is irrelevant for your use case. For example, if your project doesn't need to be consumed by other projects and the only thing required as result of the publishing are the artifacts themselves.

In general, there are two options:

- Create a publication only with artifacts

- Add artifacts to a publication based on a component with metadata (not recommended, instead adjust a component or use a adhoc component publication which will both also produce metadata fitting your artifacts)

To create a publication based on artifacts, start by defining a custom artifact and attaching it to a Gradle configuration of your choice. The following sample defines an RPM artifact that is produced by an `rpm` task (not shown) and attaches that artifact to the `conf` configuration:

build.gradle.kts

```
configurations {
    create("conf")
}
val rpmFile = layout.buildDirectory.file("rpms/my-package.rpm")
val rpmArtifact = artifacts.add("conf", rpmFile.get().asFile) {
    type = "rpm"
    builtBy("rpm")
}
```

build.gradle

```
configurations {
    conf
}
def rpmFile = layout.buildDirectory.file('rpms/my-package.rpm')
def rpmArtifact = artifacts.add('conf', rpmFile.get().asFile) {
    type 'rpm'
    builtBy 'rpm'
}
```

The `artifacts.add()` method — from ArtifactHandler — returns an artifact object of type PublishArtifact that can then be used in defining a publication, as shown in the following sample:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("maven") {
            artifact(rpmArtifact)
        }
    }
}
```

build.gradle

```groovy
publishing {
    publications {
        maven(MavenPublication) {
            artifact rpmArtifact
        }
    }
}
```

- The `artifact()` method accepts *publish artifacts* as argument — like `rpmArtifact` in the sample — as well as any type of argument accepted by Project.file(java.lang.Object), such as a `File` instance, a string file path or a archive task.

- Publishing plugins support different artifact configuration properties, so always check the plugin documentation for more details. The `classifier` and `extension` properties are supported by both the Maven Publish Plugin and the Ivy Publish Plugin.

- Custom artifacts need to be distinct within a publication, typically via a unique combination of `classifier` and `extension`. See the documentation for the plugin you're using for the precise requirements.

- If you use `artifact()` with an archive task, Gradle automatically populates the artifact's metadata with the `classifier` and `extension` properties from that task.

Now you can publish the RPM.

If you really want to add an artifact to a publication based on a component, instead of adjusting the component itself, you can combine the `from components.someComponent` and `artifact someArtifact` notations.

== Restricting publications to specific repositories

When you have defined multiple publications or repositories, you often want to control which publications are published to which repositories. For instance, consider the following sample that defines two publications — one that consists of just a binary and another that contains the binary and associated sources — and two repositories — one for internal use and one for external consumers:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("binary") {
            from(components["java"])
        }
        create<MavenPublication>("binaryAndSources") {
            from(components["java"])
            artifact(tasks["sourcesJar"])
        }
    }
    repositories {
        // change URLs to point to your repos, e.g. http://my.org/repo
        maven {
            name = "external"
            url = uri(layout.buildDirectory.dir("repos/external"))
        }
        maven {
            name = "internal"
            url = uri(layout.buildDirectory.dir("repos/internal"))
        }
    }
}
```

```
publishing {
    publications {
        binary(MavenPublication) {
            from components.java
        }
        binaryAndSources(MavenPublication) {
            from components.java
            artifact sourcesJar
        }
    }
    repositories {
        // change URLs to point to your repos, e.g. http://my.org/repo
        maven {
            name = 'external'
            url = layout.buildDirectory.dir('repos/external')
        }
        maven {
            name = 'internal'
            url = layout.buildDirectory.dir('repos/internal')
        }
    }
}
```

The publishing plugins will create tasks that allow you to publish either of the publications to either repository. They also attach those tasks to the `publish` aggregate task. But let's say you want to restrict the binary-only publication to the external repository and the binary-with-sources publication to the internal one. To do that, you need to make the publishing *conditional*.

Gradle allows you to skip any task you want based on a condition via the Task.onlyIf(String, org.gradle.api.specs.Spec) method. The following sample demonstrates how to implement the constraints we just mentioned:

build.gradle.kts

```kotlin
tasks.withType<PublishToMavenRepository>().configureEach {
    val predicate = provider {
        (repository == publishing.repositories["external"] &&
            publication == publishing.publications["binary"]) ||
        (repository == publishing.repositories["internal"] &&
            publication == publishing.publications["binaryAndSources"])
    }
    onlyIf("publishing binary to the external repository, or binary and sources to
the internal one") {
        predicate.get()
    }
}
tasks.withType<PublishToMavenLocal>().configureEach {
    val predicate = provider {
        publication == publishing.publications["binaryAndSources"]
    }
    onlyIf("publishing binary and sources") {
        predicate.get()
    }
}
```

build.gradle

```groovy
tasks.withType(PublishToMavenRepository) {
    def predicate = provider {
        (repository == publishing.repositories.external &&
            publication == publishing.publications.binary) ||
        (repository == publishing.repositories.internal &&
            publication == publishing.publications.binaryAndSources)
    }
    onlyIf("publishing binary to the external repository, or binary and sources to
the internal one") {
        predicate.get()
    }
}
tasks.withType(PublishToMavenLocal) {
    def predicate = provider {
        publication == publishing.publications.binaryAndSources
    }
    onlyIf("publishing binary and sources") {
        predicate.get()
    }
}
```

```
> gradle publish
> Task :compileJava
> Task :processResources
> Task :classes
> Task :jar
> Task :generateMetadataFileForBinaryAndSourcesPublication
> Task :generatePomFileForBinaryAndSourcesPublication
> Task :sourcesJar
> Task :publishBinaryAndSourcesPublicationToExternalRepository SKIPPED
> Task :publishBinaryAndSourcesPublicationToInternalRepository
> Task :generateMetadataFileForBinaryPublication
> Task :generatePomFileForBinaryPublication
> Task :publishBinaryPublicationToExternalRepository
> Task :publishBinaryPublicationToInternalRepository SKIPPED
> Task :publish

BUILD SUCCESSFUL in 0s
10 actionable tasks: 10 executed
```

You may also want to define your own aggregate tasks to help with your workflow. For example, imagine that you have several publications that should be published to the external repository. It could be very useful to publish all of them in one go without publishing the internal ones.

The following sample demonstrates how you can do this by defining an aggregate task — `publishToExternalRepository` — that depends on all the relevant publish tasks:

build.gradle.kts

```
tasks.register("publishToExternalRepository") {
    group = "publishing"
    description = "Publishes all Maven publications to the external Maven
repository."
    dependsOn(tasks.withType<PublishToMavenRepository>().matching {
        it.repository == publishing.repositories["external"]
    })
}
```

```
tasks.register('publishToExternalRepository') {
    group = 'publishing'
    description = 'Publishes all Maven publications to the external Maven
repository.'
    dependsOn tasks.withType(PublishToMavenRepository).matching {
        it.repository == publishing.repositories.external
    }
}
```

This particular sample automatically handles the introduction or removal of the relevant publishing tasks by using TaskCollection.withType(java.lang.Class) with the PublishToMavenRepository task type. You can do the same with PublishToIvyRepository if you're publishing to Ivy-compatible repositories.

== Configuring publishing tasks

The publishing plugins create their non-aggregate tasks after the project has been evaluated, which means you cannot directly reference them from your build script. If you would like to configure any of these tasks, you should use deferred task configuration. This can be done in a number of ways via the project's `tasks` collection.

For example, imagine you want to change where the `generatePomFileForPubNamePublication` tasks write their POM files. You can do this by using the TaskCollection.withType(java.lang.Class) method, as demonstrated by this sample:

```
tasks.withType<GenerateMavenPom>().configureEach {
    val matcher =
Regex("""generatePomFileFor(\w+)Publication""").matchEntire(name)
    val publicationName = matcher?.let { it.groupValues[1] }
    destination = layout.buildDirectory.file("poms/${publicationName}-
pom.xml").get().asFile
}
```

build.gradle

```
tasks.withType(GenerateMavenPom).all {
    def matcher = name =~ /generatePomFileFor(\w+)Publication/
    def publicationName = matcher[0][1]
    destination = layout.buildDirectory.file("poms/${publicationName}-pom.xml")
.get().asFile
}
```

The above sample uses a regular expression to extract the name of the publication from the name of the task. This is so that there is no conflict between the file paths of all the POM files that might be generated. If you only have one publication, then you don't have to worry about such conflicts since there will only be one POM file.

= Maven Publish Plugin

The Maven Publish Plugin provides the ability to publish build artifacts to an Apache Maven repository. A module published to a Maven repository can be consumed by Maven, Gradle (see Declaring Dependencies) and other tools that understand the Maven repository format. You can learn about the fundamentals of publishing in Publishing Overview.

== Usage

To use the Maven Publish Plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    `maven-publish`
}
```

build.gradle

```
plugins {
    id 'maven-publish'
}
```

The Maven Publish Plugin uses an extension on the project named `publishing` of type [PublishingExtension](#). This extension provides a container of named publications and a container of named repositories. The Maven Publish Plugin works with [MavenPublication](#) publications and [MavenArtifactRepository](#) repositories.

== Tasks

`generatePomFileForPubNamePublication` — **GenerateMavenPom**

Creates a POM file for the publication named *PubName,* populating the known metadata such as project name, project version, and the dependencies. The default location for the POM file is *build/publications/$pubName/pom-default.xml.*

`publishPubNamePublicationToRepoNameRepository` — **PublishToMavenRepository**

Publishes the *PubName* publication to the repository named *RepoName.* If you have a repository definition without an explicit name, *RepoName* will be "Maven".

`publishPubNamePublicationToMavenLocal` — **PublishToMavenLocal**

Copies the *PubName* publication to the local Maven cache — typically *<home directory of the current user>/.m2/repository* — along with the publication's POM file and other metadata.

`publish`

Depends on: All `publishPubNamePublicationToRepoNameRepository` tasks

An aggregate task that publishes all defined publications to all defined repositories. It does *not* include copying publications to the local Maven cache.

`publishToMavenLocal`

Depends on: All `publishPubNamePublicationToMavenLocal` tasks

Copies all defined publications to the local Maven cache, including their metadata (POM files, etc.).

== Publications

This plugin provides [publications](#) of type [MavenPublication](#). To learn how to define and use publications, see the section on [basic publishing](#).

There are four main things you can configure in a Maven publication:

- A component — via [MavenPublication.from(org.gradle.api.component.SoftwareComponent)](#).
- [Custom artifacts](#) — via the [MavenPublication.artifact(java.lang.Object)](#) method. See [MavenArtifact](#) for the available configuration options for custom Maven artifacts.
- Standard metadata like `artifactId`, `groupId` and `version`.
- Other contents of the POM file — via [MavenPublication.pom(org.gradle.api.Action)](#).

You can see all of these in action in the [complete publishing example](#). The API documentation for `MavenPublication` has additional code samples.

=== Identity values in the generated POM

The attributes of the generated POM file will contain identity values derived from the following project properties:

- groupId - Project.getGroup()
- artifactId - Project.getName()
- version - Project.getVersion()

Overriding the default identity values is easy: simply specify the groupId, artifactId or version attributes when configuring the MavenPublication.

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("maven") {
            groupId = "org.gradle.sample"
            artifactId = "library"
            version = "1.1"

            from(components["java"])
        }
    }
}
```

build.gradle

```groovy
publishing {
    publications {
        maven(MavenPublication) {
            groupId = 'org.gradle.sample'
            artifactId = 'library'
            version = '1.1'

            from components.java
        }
    }
}
```

TIP	Certain repositories will not be able to handle all supported characters. For example, the `:` character cannot be used as an identifier when publishing to a filesystem-backed repository on Windows.

Maven restricts `groupId` and `artifactId` to a limited character set (`[A-Za-z0-9_\\-.]+`) and Gradle enforces this restriction. For `version` (as well as the artifact `extension` and `classifier` properties), Gradle will handle any valid Unicode character.

The only Unicode values that are explicitly prohibited are `\`, `/` and any ISO control character. Supplied values are validated early in publication.

=== Customizing the generated POM

The generated POM file can be customized before publishing. For example, when publishing a library to Maven Central you will need to set certain metadata. The Maven Publish Plugin provides a DSL for that purpose. Please see MavenPom in the DSL Reference for the complete documentation of available properties and methods. The following sample shows how to use the most common ones:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<MavenPublication>("mavenJava") {
            pom {
                name = "My Library"
                description = "A concise description of my library"
                url = "http://www.example.com/library"
                properties = mapOf(
                    "myProp" to "value",
                    "prop.with.dots" to "anotherValue"
                )
                licenses {
                    license {
                        name = "The Apache License, Version 2.0"
                        url = "http://www.apache.org/licenses/LICENSE-2.0.txt"
                    }
                }
                developers {
                    developer {
                        id = "johnd"
                        name = "John Doe"
                        email = "john.doe@example.com"
                    }
                }
                scm {
                    connection = "scm:git:git://example.com/my-library.git"
                    developerConnection = "scm:git:ssh://example.com/my-
library.git"
                    url = "http://example.com/my-library/"
                }
            }
        }
    }
}
```

build.gradle

```
publishing {
    publications {
        mavenJava(MavenPublication) {
            pom {
                name = 'My Library'
                description = 'A concise description of my library'
                url = 'http://www.example.com/library'
                properties = [
                    myProp: "value",
                    "prop.with.dots": "anotherValue"
                ]
                licenses {
                    license {
                        name = 'The Apache License, Version 2.0'
                        url = 'http://www.apache.org/licenses/LICENSE-2.0.txt'
                    }
                }
                developers {
                    developer {
                        id = 'johnd'
                        name = 'John Doe'
                        email = 'john.doe@example.com'
                    }
                }
                scm {
                    connection = 'scm:git:git://example.com/my-library.git'
                    developerConnection = 'scm:git:ssh://example.com/my-
library.git'
                    url = 'http://example.com/my-library/'
                }
            }
        }
    }
}
```

=== Customizing dependencies versions

Two strategies are supported for publishing dependencies:

Declared versions (default)

> This strategy publishes the versions that are defined by the build script author with the dependency declarations in the `dependencies` block. Any other kind of processing, for example through a rule changing the resolved version, will not be taken into account for the publication.

Resolved versions

> This strategy publishes the versions that were resolved during the build, possibly by applying resolution rules and automatic conflict resolution. This has the advantage that the published versions correspond to the ones the published artifact was tested against.

Example use cases for resolved versions:

- A project uses dynamic versions for dependencies but prefers exposing the resolved version for a given release to its consumers.
- In combination with dependency locking, you want to publish the locked versions.
- A project leverages the rich versions constraints of Gradle, which have a lossy conversion to Maven. Instead of relying on the conversion, it publishes the resolved versions.

This is done by using the `versionMapping` DSL method which allows to configure the VersionMappingStrategy:

build.gradle.kts

```
publishing {
    publications {
        create<MavenPublication>("mavenJava") {
            versionMapping {
                usage("java-api") {
                    fromResolutionOf("runtimeClasspath")
                }
                usage("java-runtime") {
                    fromResolutionResult()
                }
            }
        }
    }
}
```

build.gradle

```
publishing {
    publications {
        mavenJava(MavenPublication) {
            versionMapping {
                usage('java-api') {
                    fromResolutionOf('runtimeClasspath')
                }
                usage('java-runtime') {
                    fromResolutionResult()
                }
            }
        }
    }
}
```

In the example above, Gradle will use the versions resolved on the `runtimeClasspath` for dependencies declared in `api`, which are mapped to the `compile` scope of Maven. Gradle will also use the versions resolved on the `runtimeClasspath` for dependencies declared in `implementation`, which are mapped to the `runtime` scope of Maven. `fromResolutionResult()` indicates that Gradle should use the default classpath of a variant and `runtimeClasspath` is the default classpath of `java-runtime`.

== Repositories

This plugin provides repositories of type MavenArtifactRepository. To learn how to define and use repositories for publishing, see the section on basic publishing.

Here's a simple example of defining a publishing repository:

build.gradle.kts

```
publishing {
    repositories {
        maven {
            // change to point to your repo, e.g. http://my.org/repo
            url = uri(layout.buildDirectory.dir("repo"))
        }
    }
}
```

build.gradle

```
publishing {
    repositories {
        maven {
            // change to point to your repo, e.g. http://my.org/repo
            url = layout.buildDirectory.dir('repo')
        }
    }
}
```

The two main things you will want to configure are the repository's:

- URL (required)
- Name (optional)

You can define multiple repositories as long as they have unique names within the build script. You may also declare one (and only one) repository without a name. That repository will take on an implicit name of "Maven".

You can also configure any authentication details that are required to connect to the repository. See MavenArtifactRepository for more details.

=== Snapshot and release repositories

It is a common practice to publish snapshots and releases to different Maven repositories. A simple way to accomplish this is to configure the repository URL based on the project version. The following sample uses one URL for versions that end with "SNAPSHOT" and a different URL for the rest:

build.gradle.kts

```
publishing {
    repositories {
        maven {
            val releasesRepoUrl = layout.buildDirectory.dir("repos/releases")
            val snapshotsRepoUrl = layout.buildDirectory.dir("repos/snapshots")
            url = uri(if (version.toString().endsWith("SNAPSHOT"))
snapshotsRepoUrl else releasesRepoUrl)
        }
    }
}
```

build.gradle

```
publishing {
    repositories {
        maven {
            def releasesRepoUrl = layout.buildDirectory.dir('repos/releases')
            def snapshotsRepoUrl = layout.buildDirectory.dir('repos/snapshots')
            url = version.endsWith('SNAPSHOT') ? snapshotsRepoUrl :
releasesRepoUrl
        }
    }
}
```

Similarly, you can use a [project or system property](#) to decide which repository to publish to. The following example uses the release repository if the project property `release` is set, such as when a user runs `gradle -Prelease publish`:

build.gradle.kts

```
publishing {
    repositories {
        maven {
            val releasesRepoUrl = layout.buildDirectory.dir("repos/releases")
            val snapshotsRepoUrl = layout.buildDirectory.dir("repos/snapshots")
            url = uri(if (project.hasProperty("release")) releasesRepoUrl else
snapshotsRepoUrl)
        }
    }
}
```

build.gradle

```
publishing {
    repositories {
        maven {
            def releasesRepoUrl = layout.buildDirectory.dir('repos/releases')
            def snapshotsRepoUrl = layout.buildDirectory.dir('repos/snapshots')
            url = project.hasProperty('release') ? releasesRepoUrl :
snapshotsRepoUrl
        }
    }
}
```

== Publishing to Maven Local

For integration with a local Maven installation, it is sometimes useful to publish the module into the Maven local repository (typically at *<home directory of the current user>/.m2/repository*), along with its POM file and other metadata. In Maven parlance, this is referred to as 'installing' the module.

The Maven Publish Plugin makes this easy to do by automatically creating a `PublishToMavenLocal` task for each `MavenPublication` in the `publishing.publications` container. The task name follows the pattern of `publishPubNamePublicationToMavenLocal`. Each of these tasks is wired into the `publishToMavenLocal` aggregate task. You do not need to have `mavenLocal()` in your `publishing.repositories` section.

== Publishing Maven relocation information

When a project changes the `groupId` or `artifactId` (the *coordinates*) of an artifact it publishes, it is important to let users know where the new artifact can be found. Maven can help with that through the *relocation* feature. The way this works is that a project publishes an additional artifact under the old coordinates consisting only of a minimal *relocation POM*; that POM file specifies where the new artifact can be found. Maven repository browsers and build tools can then inform the user that the coordinates of an artifact have changed.

For this, a project adds an additional `MavenPublication` specifying a `MavenPomRelocation`:

build.gradle.kts

```
publishing {
    publications {
        // ... artifact publications

        // Specify relocation POM
        create<MavenPublication>("relocation") {
            pom {
                // Old artifact coordinates
                groupId = "com.example"
                artifactId = "lib"
                version = "2.0.0"

                distributionManagement {
                    relocation {
                        // New artifact coordinates
                        groupId = "com.new-example"
                        artifactId = "lib"
                        version = "2.0.0"
                        message = "groupId has been changed"
                    }
                }
            }
        }
    }
}
```

```
publishing {
    publications {
        // ... artifact publications

        // Specify relocation POM
        relocation(MavenPublication) {
            pom {
                // Old artifact coordinates
                groupId = "com.example"
                artifactId = "lib"
                version = "2.0.0"

                distributionManagement {
                    relocation {
                        // New artifact coordinates
                        groupId = "com.new-example"
                        artifactId = "lib"
                        version = "2.0.0"
                        message = "groupId has been changed"
                    }
                }
            }
        }
    }
}
```

Only the property which has changed needs to be specified under `relocation`, that is `artifactId` and / or `groupId`. All other properties are optional.

Specifying the `version` can be useful when the new artifact has a different version, for example because version numbering has started at 1.0.0 again.

A custom `message` allows explaining why the artifact coordinates have changed.

The relocation POM should be created for what would be the next version of the old artifact. For example when the artifact coordinates of `com.example:lib:1.0.0` are changed and the artifact with the new coordinates continues version numbering and is published as `com.new-example:lib:2.0.0`, then the relocation POM should specify a relocation from `com.example:lib:2.0.0` to `com.new-example:lib:2.0.0`.

A relocation POM only has to be published once, the build file configuration for it should be removed again once it has been published.

Note that a relocation POM is not suitable for all situations; when an artifact has been split into two or more separate artifacts then a relocation POM might not be helpful.

=== Retroactively publishing relocation information

It is possible to publish relocation information retroactively after the coordinates of an artifact have changed in the past, and no relocation information was published back then.

The same recommendations as described above apply. To ease migration for users, it is important to pay attention to the `version` specified in the relocation POM. The relocation POM should allow the user to move to the new artifact in one step, and then allow them to update to the latest version in a separate step. For example when for the coordinates of `com.new-example:lib:5.0.0` were changed in version 2.0.0, then ideally the relocation POM should be published for the old coordinates `com.example:lib:2.0.0` relocating to `com.new-example:lib:2.0.0`. The user can then switch from `com.example:lib` to `com.new-example` and then separately update from version 2.0.0 to 5.0.0, handling breaking changes (if any) step by step.

When relocation information is published retroactively, it is not necessary to wait for next regular release of the project, it can be published in the meantime. As mentioned above, the relocation information should then be removed again from the build file once the relocation POM has been published.

=== Avoiding duplicate dependencies

When only the coordinates of the artifact have changed, but package names of the classes inside the artifact have remained the same, dependency conflicts can occur. A project might (transitively) depend on the old artifact but at the same time also have a dependency on the new artifact which both contain the same classes, potentially with incompatible changes.

To detect such conflicting duplicate dependencies, capabilities can be published as part of the Gradle Module Metadata. For an example using a Java Library project, see declaring additional capabilities for a local component.

=== Performing a dry run

To verify that relocation information works as expected before publishing it to a remote repository, it can first be published to the local Maven repository. Then a local test Gradle or Maven project can be created which has the relocation artifact as dependency.

== Complete example

The following example demonstrates how to sign and publish a Java library including sources, Javadoc, and a customized POM:

build.gradle.kts

```kotlin
plugins {
    `java-library`
    `maven-publish`
    signing
}

group = "com.example"
version = "1.0"

java {
    withJavadocJar()
    withSourcesJar()
}

publishing {
    publications {
        create<MavenPublication>("mavenJava") {
            artifactId = "my-library"
            from(components["java"])
            versionMapping {
                usage("java-api") {
                    fromResolutionOf("runtimeClasspath")
                }
                usage("java-runtime") {
                    fromResolutionResult()
                }
            }
            pom {
                name = "My Library"
                description = "A concise description of my library"
                url = "http://www.example.com/library"
                properties = mapOf(
                    "myProp" to "value",
                    "prop.with.dots" to "anotherValue"
                )
                licenses {
                    license {
                        name = "The Apache License, Version 2.0"
                        url = "http://www.apache.org/licenses/LICENSE-2.0.txt"
                    }
                }
                developers {
                    developer {
                        id = "johnd"
                        name = "John Doe"
                        email = "john.doe@example.com"
                    }
                }
```

```
                    scm {
                        connection = "scm:git:git://example.com/my-library.git"
                        developerConnection = "scm:git:ssh://example.com/my-
library.git"
                        url = "http://example.com/my-library/"
                    }
                }
            }
        }
    repositories {
        maven {
            // change URLs to point to your repos, e.g. http://my.org/repo
            val releasesRepoUrl = uri(layout.buildDirectory.dir("repos/releases"))
            val snapshotsRepoUrl =
uri(layout.buildDirectory.dir("repos/snapshots"))
            url = if (version.toString().endsWith("SNAPSHOT")) snapshotsRepoUrl
else releasesRepoUrl
        }
    }
}

signing {
    sign(publishing.publications["mavenJava"])
}

tasks.javadoc {
    if (JavaVersion.current().isJava9Compatible) {
        (options as StandardJavadocDocletOptions).addBooleanOption("html5", true)
    }
}
```

build.gradle

```gradle
plugins {
    id 'java-library'
    id 'maven-publish'
    id 'signing'
}

group = 'com.example'
version = '1.0'

java {
    withJavadocJar()
    withSourcesJar()
}

publishing {
    publications {
        mavenJava(MavenPublication) {
            artifactId = 'my-library'
            from components.java
            versionMapping {
                usage('java-api') {
                    fromResolutionOf('runtimeClasspath')
                }
                usage('java-runtime') {
                    fromResolutionResult()
                }
            }
            pom {
                name = 'My Library'
                description = 'A concise description of my library'
                url = 'http://www.example.com/library'
                properties = [
                    myProp: "value",
                    "prop.with.dots": "anotherValue"
                ]
                licenses {
                    license {
                        name = 'The Apache License, Version 2.0'
                        url = 'http://www.apache.org/licenses/LICENSE-2.0.txt'
                    }
                }
                developers {
                    developer {
                        id = 'johnd'
                        name = 'John Doe'
                        email = 'john.doe@example.com'
                    }
                }
```

```
                scm {
                    connection = 'scm:git:git://example.com/my-library.git'
                    developerConnection = 'scm:git:ssh://example.com/my-
library.git'
                    url = 'http://example.com/my-library/'
                }
            }
        }
    }
    repositories {
        maven {
            // change URLs to point to your repos, e.g. http://my.org/repo
            def releasesRepoUrl = layout.buildDirectory.dir('repos/releases')
            def snapshotsRepoUrl = layout.buildDirectory.dir('repos/snapshots')
            url = version.endsWith('SNAPSHOT') ? snapshotsRepoUrl :
releasesRepoUrl
        }
    }
}

signing {
    sign publishing.publications.mavenJava
}


javadoc {
    if(JavaVersion.current().isJava9Compatible()) {
        options.addBooleanOption('html5', true)
    }
}
```

The result is that the following artifacts will be published:

- The POM: `my-library-1.0.pom`

- The primary JAR artifact for the Java component: `my-library-1.0.jar`

- The sources JAR artifact that has been explicitly configured: `my-library-1.0-sources.jar`

- The Javadoc JAR artifact that has been explicitly configured: `my-library-1.0-javadoc.jar`

The Signing Plugin is used to generate a signature file for each artifact. In addition, checksum files will be generated for all artifacts and signature files.

TIP	publishToMavenLocal` does not create checksum files in `$USER_HOME/.m2/repository`. If you want to verify that the checksum files are created correctly, or use them for later publishing, consider configuring a custom Maven repository with a `file://` URL and using that as the publishing target instead.

== Removal of deferred configuration behavior

Prior to Gradle 5.0, the `publishing {}` block was (by default) implicitly treated as if all the logic inside it was executed after the project is evaluated. This behavior caused quite a bit of confusion and was deprecated in Gradle 4.8, because it was the only block that behaved that way.

You may have some logic inside your publishing block or in a plugin that is depending on the deferred configuration behavior. For instance, the following logic assumes that the subprojects will be evaluated when the artifactId is set:

build.gradle.kts

```
subprojects {
    publishing {
        publications {
            create<MavenPublication>("mavenJava") {
                from(components["java"])
                artifactId = tasks.jar.get().archiveBaseName.get()
            }
        }
    }
}
```

build.gradle

```
subprojects {
    publishing {
        publications {
            mavenJava(MavenPublication) {
                from components.java
                artifactId = jar.archiveBaseName
            }
        }
    }
}
```

This kind of logic must now be wrapped in an `afterEvaluate {}` block.

build.gradle.kts

```
subprojects {
    publishing {
        publications {
            create<MavenPublication>("mavenJava") {
                from(components["java"])
                afterEvaluate {
                    artifactId = tasks.jar.get().archiveBaseName.get()
                }
            }
        }
    }
}
```

build.gradle

```
subprojects {
    publishing {
        publications {
            mavenJava(MavenPublication) {
                from components.java
                afterEvaluate {
                    artifactId = jar.archiveBaseName
                }
            }
        }
    }
}
```

= Ivy Publish Plugin

The Ivy Publish Plugin provides the ability to publish build artifacts in the Apache Ivy format, usually to a repository for consumption by other builds or projects. What is published is one or more artifacts created by the build, and an Ivy *module descriptor* (normally `ivy.xml`) that describes the artifacts and the dependencies of the artifacts, if any.

A published Ivy module can be consumed by Gradle (see Declaring Dependencies) and other tools that understand the Ivy format. You can learn about the fundamentals of publishing in Publishing Overview.

== Usage

To use the Ivy Publish Plugin, include the following in your build script:

build.gradle.kts

```
plugins {
    `ivy-publish`
}
```

build.gradle

```
plugins {
    id 'ivy-publish'
}
```

The Ivy Publish Plugin uses an extension on the project named `publishing` of type PublishingExtension. This extension provides a container of named publications and a container of named repositories. The Ivy Publish Plugin works with IvyPublication publications and IvyArtifactRepository repositories.

Tasks

generateDescriptorFileForPubNamePublication — **GenerateIvyDescriptor**

> Creates an Ivy descriptor file for the publication named *PubName,* populating the known metadata such as project name, project version, and the dependencies. The default location for the descriptor file is *build/publications/$pubName/ivy.xml*.

publishPubNamePublicationToRepoNameRepository — **PublishToIvyRepository**

> Publishes the *PubName* publication to the repository named *RepoName*. If you have a repository definition without an explicit name, *RepoName* will be "Ivy".

publish

> *Depends on*: All `publishPubNamePublicationToRepoNameRepository` tasks
>
> An aggregate task that publishes all defined publications to all defined repositories.

Publications

This plugin provides publications of type IvyPublication. To learn how to define and use publications, see the section on basic publishing.

There are four main things you can configure in an Ivy publication:

- A component — via IvyPublication.from(org.gradle.api.component.SoftwareComponent).
- Custom artifacts — via the IvyPublication.artifact(java.lang.Object) method. See IvyArtifact for the available configuration options for custom Ivy artifacts.
- Standard metadata like `module`, `organisation` and `revision`.
- Other contents of the module descriptor — via IvyPublication.descriptor(org.gradle.api.Action).

You can see all of these in action in the complete publishing example. The API documentation for `IvyPublication` has additional code samples.

Identity values for the published project

The generated Ivy module descriptor file contains an `<info>` element that identifies the module. The default identity values are derived from the following:

- `organisation` - Project.getGroup()
- `module` - Project.getName()
- `revision` - Project.getVersion()
- `status` - Project.getStatus()

- branch - (not set)

Overriding the default identity values is easy: simply specify the organisation, module or revision properties when configuring the IvyPublication. status and branch can be set via the descriptor property — see IvyModuleDescriptorSpec.

The descriptor property can also be used to add additional custom elements as children of the <info> element, like so:

build.gradle.kts

```kotlin
publishing {
    publications {
        create<IvyPublication>("ivy") {
            organisation = "org.gradle.sample"
            module = "project1-sample"
            revision = "1.1"
            descriptor.status = "milestone"
            descriptor.branch = "testing"
            descriptor.extraInfo("http://my.namespace", "myElement", "Some value")

            from(components["java"])
        }
    }
}
```

build.gradle

```groovy
publishing {
    publications {
        ivy(IvyPublication) {
            organisation = 'org.gradle.sample'
            module = 'project1-sample'
            revision = '1.1'
            descriptor.status = 'milestone'
            descriptor.branch = 'testing'
            descriptor.extraInfo 'http://my.namespace', 'myElement', 'Some value'

            from components.java
        }
    }
}
```

> **TIP** Certain repositories are not able to handle all supported characters. For example, the `:` character cannot be used as an identifier when publishing to a filesystem-backed repository on Windows.

Gradle will handle any valid Unicode character for `organisation`, `module` and `revision` (as well as the artifact's `name`, `extension` and `classifier`). The only values that are explicitly prohibited are `\`, `/` and any ISO control character. The supplied values are validated early during publication.

Customizing the generated module descriptor

At times, the module descriptor file generated from the project information will need to be tweaked before publishing. The Ivy Publish Plugin provides a DSL for that purpose. Please see IvyModuleDescriptorSpec in the DSL Reference for the complete documentation of available properties and methods.

The following sample shows how to use the most common aspects of the DSL:

build.gradle.kts

```
publications {
    create<IvyPublication>("ivyCustom") {
        descriptor {
            license {
                name = "The Apache License, Version 2.0"
                url = "http://www.apache.org/licenses/LICENSE-2.0.txt"
            }
            author {
                name = "Jane Doe"
                url = "http://example.com/users/jane"
            }
            description {
                text = "A concise description of my library"
                homepage = "http://www.example.com/library"
            }
        }
        versionMapping {
            usage("java-api") {
                fromResolutionOf("runtimeClasspath")
            }
            usage("java-runtime") {
                fromResolutionResult()
            }
        }
    }
}
```

```
publications {
    ivyCustom(IvyPublication) {
        descriptor {
            license {
                name = 'The Apache License, Version 2.0'
                url = 'http://www.apache.org/licenses/LICENSE-2.0.txt'
            }
            author {
                name = 'Jane Doe'
                url = 'http://example.com/users/jane'
            }
            description {
                text = 'A concise description of my library'
                homepage = 'http://www.example.com/library'
            }
        }
        versionMapping {
            usage('java-api') {
                fromResolutionOf('runtimeClasspath')
            }
            usage('java-runtime') {
                fromResolutionResult()
            }
        }
    }
}
```

In this example we are simply adding a 'description' element to the generated Ivy dependency descriptor, but this hook allows you to modify any aspect of the generated descriptor. For example, you could replace the version range for a dependency with the actual version used to produce the build.

You can also add arbitrary XML to the descriptor file via IvyModuleDescriptorSpec.withXml(org.gradle.api.Action), but you cannot use it to modify any part of the module identifier (organisation, module, revision).

| CAUTION | It is possible to modify the descriptor in such a way that it is no longer a valid Ivy module descriptor, so care must be taken when using this feature. |

=== Customizing dependencies versions

Two strategies are supported for publishing dependencies:

Declared versions (default)

This strategy publishes the versions that are defined by the build script author with the dependency declarations in the `dependencies` block. Any other kind of processing, for example through a rule changing the resolved version, will not be taken into account for the publication.

Resolved versions

This strategy publishes the versions that were resolved during the build, possibly by applying resolution rules and automatic conflict resolution. This has the advantage that the published versions correspond to the ones the published artifact was tested against.

Example use cases for resolved versions:

- A project uses dynamic versions for dependencies but prefers exposing the resolved version for a given release to its consumers.
- In combination with dependency locking, you want to publish the locked versions.
- A project leverages the rich versions constraints of Gradle, which have a lossy conversion to Ivy. Instead of relying on the conversion, it publishes the resolved versions.

This is done by using the `versionMapping` DSL method which allows to configure the VersionMappingStrategy:

```kotlin
publications {
    create<IvyPublication>("ivyCustom") {
        versionMapping {
            usage("java-api") {
                fromResolutionOf("runtimeClasspath")
            }
            usage("java-runtime") {
                fromResolutionResult()
            }
        }
    }
}
```

```groovy
publications {
    ivyCustom(IvyPublication) {
        versionMapping {
            usage('java-api') {
                fromResolutionOf('runtimeClasspath')
            }
            usage('java-runtime') {
                fromResolutionResult()
            }
        }
    }
}
```

In the example above, Gradle will use the versions resolved on the `runtimeClasspath` for dependencies declared in `api`, which are mapped to the `compile` configuration of Ivy. Gradle will also use the versions resolved on the `runtimeClasspath` for dependencies declared in `implementation`, which are mapped to the `runtime` configuration of Ivy. `fromResolutionResult()` indicates that Gradle should use the default classpath of a variant and `runtimeClasspath` is the default classpath of `java-runtime`.

== Repositories

This plugin provides repositories of type IvyArtifactRepository. To learn how to define and use repositories for publishing, see the section on basic publishing.

Here's a simple example of defining a publishing repository:

```
publishing {
    repositories {
        ivy {
            // change to point to your repo, e.g. http://my.org/repo
            url = uri(layout.buildDirectory.dir("repo"))
        }
    }
}
```

```
publishing {
    repositories {
        ivy {
            // change to point to your repo, e.g. http://my.org/repo
            url = layout.buildDirectory.dir("repo")
        }
    }
}
```

The two main things you will want to configure are the repository's:

- URL (required)
- Name (optional)

You can define multiple repositories as long as they have unique names within the build script. You may also declare one (and only one) repository without a name. That repository will take on an implicit name of "Ivy".

You can also configure any authentication details that are required to connect to the repository. See IvyArtifactRepository for more details.

== Complete example

The following example demonstrates publishing with a multi-project build. Each project publishes a Java component configured to also build and publish Javadoc and source code artifacts. The descriptor file is customized to include the project description for each project.

```
rootProject.name = "ivy-publish-java"
include("project1", "project2")
```

```
plugins {
    `kotlin-dsl`
}

repositories {
    gradlePluginPortal()
}
```

```kotlin
plugins {
    id("java-library")
    id("ivy-publish")
}

version = "1.0"
group = "org.gradle.sample"

repositories {
    mavenCentral()
}

java {
    withJavadocJar()
    withSourcesJar()
}

publishing {
    repositories {
        ivy {
            // change to point to your repo, e.g. http://my.org/repo
            url = uri("${rootProject.buildDir}/repo")
        }
    }
    publications {
        create<IvyPublication>("ivy") {
            from(components["java"])
            descriptor.description {
                text = providers.provider({ description })
            }
        }
    }
}
```

```kotlin
plugins {
    id("myproject.publishing-conventions")
}

description = "The first project"

dependencies {
    implementation("junit:junit:4.13")
    implementation(project(":project2"))
}
```

project2/build.gradle.kts

```kotlin
plugins {
    id("myproject.publishing-conventions")
}

description = "The second project"

dependencies {
    implementation("commons-collections:commons-collections:3.2.2")
}
```

settings.gradle

```
rootProject.name = 'ivy-publish-java'
include 'project1', 'project2'
```

buildSrc/build.gradle

```
plugins {
    id 'groovy-gradle-plugin'
}
```

buildSrc/src/main/groovy/myproject.publishing-conventions.gradle

```
plugins {
    id 'java-library'
    id 'ivy-publish'
}

version = '1.0'
group = 'org.gradle.sample'

repositories {
    mavenCentral()
}

java {
    withJavadocJar()
    withSourcesJar()
}

publishing {
    repositories {
        ivy {
            // change to point to your repo, e.g. http://my.org/repo
            url = "${rootProject.buildDir}/repo"
        }
    }
    publications {
        ivy(IvyPublication) {
            from components.java
            descriptor.description {
                text = providers.provider({ description })
            }
        }
    }
}
```

project1/build.gradle

```
plugins {
    id 'myproject.publishing-conventions'
}

description = 'The first project'

dependencies {
    implementation 'junit:junit:4.13'
    implementation project(':project2')
}
```

project2/build.gradle

```
plugins {
    id 'myproject.publishing-conventions'
}

description = 'The second project'

dependencies {
    implementation 'commons-collections:commons-collections:3.2.2'
}
```

The result is that the following artifacts will be published for each project:

- The Gradle Module Metadata file: `project1-1.0.module`.

- The Ivy module metadata file: `ivy-1.0.xml`.

- The primary JAR artifact for the Java component: `project1-1.0.jar`.

- The Javadoc and sources JAR artifacts of the Java component (because we configured `withJavadocJar()` and `withSourcesJar()`): `project1-1.0-javadoc.jar`, `project1-1.0-source.jar`.

== OPTIMIZING BUILD TIMES

= Improve the Performance of Gradle Builds

Build performance is critical to productivity. The longer builds take to complete, the more likely they'll disrupt your development flow. Builds run many times a day, so even small waiting periods add up. The same is true for Continuous Integration (CI) builds: the less time they take, the faster you can react to new issues and the more often you can experiment.

All this means that it's worth investing some time and effort into making your build as fast as possible. This section offers several ways to make a build faster. Additionally, you'll find details about what leads to build performance degradation, and how you can avoid it.

> **TIP** Want faster Gradle Builds? Register here for our Build Cache training session to learn how Develocity can speed up builds by up to 90%.

== Inspect your build

Before you make any changes, inspect your build with a build scan or profile report. A proper build inspection helps you understand:

- how long it takes to build your project

- which parts of your build are slow

Inspecting provides a comparison point to better understand the impact of the changes recommended on this page.

To best make use of this page:

1. Inspect your build.

2. Make a change.

3. Inspect your build again.

If the change improved build times, make it permanent. If you don't see an improvement, remove the change and try another.

== Update versions

=== Gradle

The Gradle team continuously improves the performance of Gradle builds. If you're using an old version of Gradle, you're missing out on the benefits of that work. Keeping up with Gradle version upgrades is low risk because the Gradle team ensures backwards compatibility between minor versions of Gradle. Staying up-to-date also makes transitioning to the next major version easier, since you'll get early deprecation warnings.

=== Java

Gradle runs on the Java Virtual Machine (JVM). Java performance improvements often benefit Gradle. For the best Gradle performance, use the latest version of Java.

=== Plugins

Plugin writers continuously improve the performance of their plugins. If you're using an old version of a plugin, you're missing out on the benefits of that work. The Android, Java, and Kotlin plugins in particular can significantly impact build performance. Update to the latest version of these plugins for performance improvements.

== Enable parallel execution

Most projects consist of more than one subproject. Usually, some of those subprojects are independent of one another; that is, they do not share state. Yet by default, Gradle only runs one task at a time. To execute tasks belonging to different subprojects in parallel, use the `parallel` flag:

```
$ gradle <task> --parallel
```

To execute project tasks in parallel by default, add the following setting to the `gradle.properties` file in the project root or your Gradle home:

gradle.properties

```
org.gradle.parallel=true
```

Parallel builds can significantly improve build times; how much depends on your project structure and how many dependencies you have between subprojects. A build whose execution time is dominated by a single subproject won't benefit much at all. Neither will a project with lots of inter-subproject dependencies. But most multi-subproject builds see a reduction in build times.

For more information about parallel builds, check out the parallel builds documentation.

=== Visualize parallelism with build scans

Build scans give you a visual timeline of task execution. In the following example build, you can see long-running tasks at the beginning and end of the build:
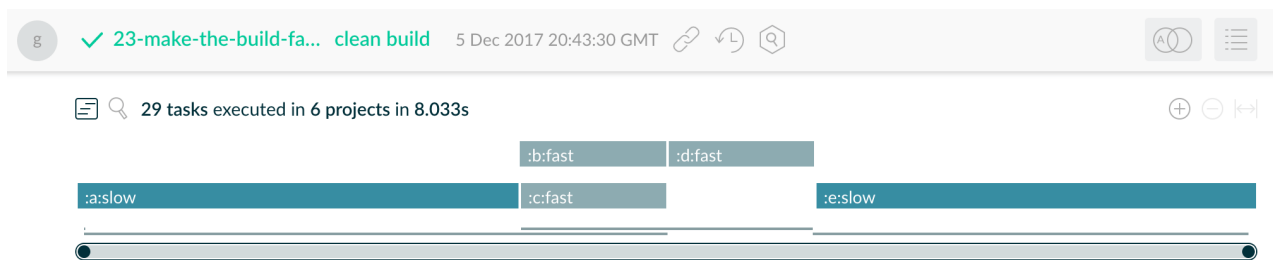
Figure 30. Bottleneck in parallel execution

Tweaking the build configuration to run the two slow tasks early on and in parallel reduces the overall build time from 8 seconds to 5 seconds:
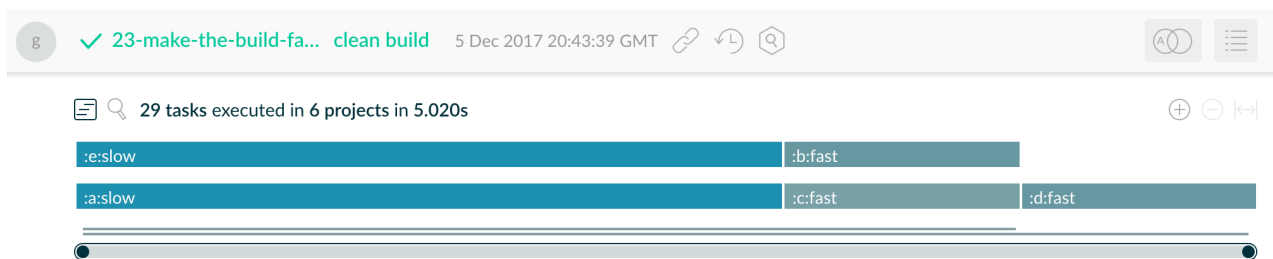
Figure 31. Optimized parallel execution

== Re-enable the Gradle Daemon

The Gradle Daemon reduces build times by:

- caching project information across builds

- running in the background so every Gradle build doesn't have to wait for JVM startup

- benefiting from continuous runtime optimization in the JVM

- watching the file system to calculate exactly what needs to be rebuilt before you run a build

Gradle enables the Daemon by default, but some builds override this preference. If your build disables the Daemon, you could see a significant performance improvement from enabling the daemon.

You can enable the Daemon at build time with the daemon flag:

```
$ gradle <task> --daemon
```

To enable the Daemon by default in older Gradle versions, add the following setting to the `gradle.properties` file in the project root or your Gradle home:

gradle.properties

```
org.gradle.daemon=true
```

On developer machines, you should see a significant performance improvement. On CI machines, long-lived agents benefit from the Daemon. But short-lived machines don't benefit much. Daemons automatically shut down on memory pressure in Gradle 3.0 and above, so it's always safe to leave the Daemon enabled.

== Enable the configuration cache

This feature has the following limitations:

- The configuration cache does not support all core Gradle plugins and features. Full support is a work in progress.
- Your build and the plugins you depend on might require changes to fulfill the requirements.
- IDE imports and syncs do not use the configuration cache.

You can cache the result of the configuration phase by enabling the configuration cache. When build configuration inputs remain the same across builds, the configuration cache allows Gradle to skip the configuration phase entirely.

Build configuration inputs include:

- Init scripts
- Settings scripts
- Build scripts
- System properties used during the configuration phase
- Gradle properties used during the configuration phase
- Environment variables used during the configuration phase
- Configuration files accessed using value suppliers such as providers
- `buildSrc` inputs, including build configuration inputs and source files

By default, Gradle does not use the configuration cache. To enable the configuration cache at build time, use the `configuration-cache` flag:

```
$ gradle <task> --configuration-cache
```

To enable the configuration cache by default, add the following setting to the `gradle.properties` file in the project root or your Gradle home:

gradle.properties

```
org.gradle.configuration-cache=true
```

For more information about the configuration cache, check out the configuration cache documentation.

=== Additional configuration cache benefits

The configuration cache enables additional benefits as well. When enabled, Gradle:

- Executes all tasks in parallel, even those in the same subproject.
- Caches dependency resolution results.

== Enable incremental build for custom tasks

Incremental build is a Gradle optimization that skips running tasks that have previously executed with the same inputs. If a task's inputs and its outputs have not changed since the last execution, Gradle skips that task.

Most built-in tasks provided by Gradle work with incremental build. To make a custom task compatible with incremental build, specify the inputs and outputs:

build.gradle.kts

```kotlin
tasks.register("processTemplatesAdHoc") {
    inputs.property("engine", TemplateEngineType.FREEMARKER)
    inputs.files(fileTree("src/templates"))
        .withPropertyName("sourceFiles")
        .withPathSensitivity(PathSensitivity.RELATIVE)
    inputs.property("templateData.name", "docs")
    inputs.property("templateData.variables", mapOf("year" to "2013"))
    outputs.dir(layout.buildDirectory.dir("genOutput2"))
        .withPropertyName("outputDir")

    doLast {
        // Process the templates here
    }
}
```

build.gradle

```groovy
tasks.register('processTemplatesAdHoc') {
    inputs.property('engine', TemplateEngineType.FREEMARKER)
    inputs.files(fileTree('src/templates'))
        .withPropertyName('sourceFiles')
        .withPathSensitivity(PathSensitivity.RELATIVE)
    inputs.property('templateData.name', 'docs')
    inputs.property('templateData.variables', [year: '2013'])
    outputs.dir(layout.buildDirectory.dir('genOutput2'))
        .withPropertyName('outputDir')

    doLast {
        // Process the templates here
    }
}
```

For more information about incremental builds, check out the [incremental build documentation](#).

=== Visualize incremental builds with build scan timelines

Look at the build scan timeline view to identify tasks that could benefit from incremental builds. This can also help you understand why tasks execute when you expect Gradle to skip them.
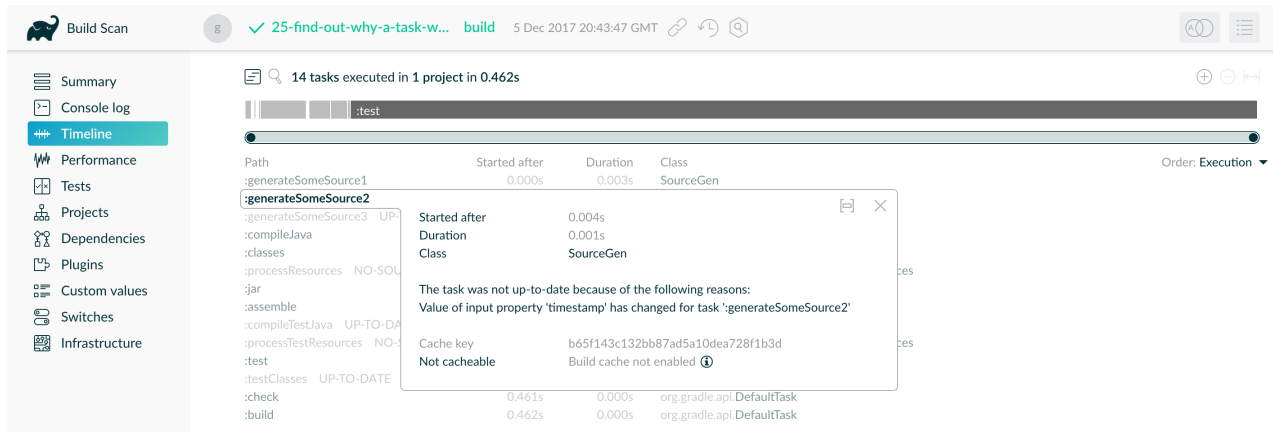
Figure 32. The timeline view can help with incremental build inspection

As you can see in the build scan above, the task was not up-to-date because one of its inputs (*"timestamp"*) changed, forcing the task to re-run.

Sort tasks by duration to find the slowest tasks in your project.

== Enable the build cache

The build cache is a Gradle optimization that stores task outputs for specific input. When you later run that same task with the same input, Gradle retrieves the output from the build cache instead of running the task again. By default, Gradle does not use the build cache. To enable the build cache at build time, use the `build-cache` flag:

```
$ gradle <task> --build-cache
```

To enable the build cache by default, add the following setting to the `gradle.properties` file in the project root or your Gradle home:

gradle.properties

```
org.gradle.caching=true
```

You can use a local build cache to speed up repeated builds on a single machine. You can also use a shared build cache to speed up repeated builds across multiple machines. Develocity provides one. Shared build caches can decrease build times for both CI and developer builds.

For more information about the build cache, check out the build cache documentation.

=== Visualize the build cache with build scans

Build scans can help you investigate build cache effectiveness. In the performance screen, the *"Build cache"* tab shows you statistics about:

- how many tasks interacted with a cache

- which cache was used

- transfer and pack/unpack rates for these cache entries
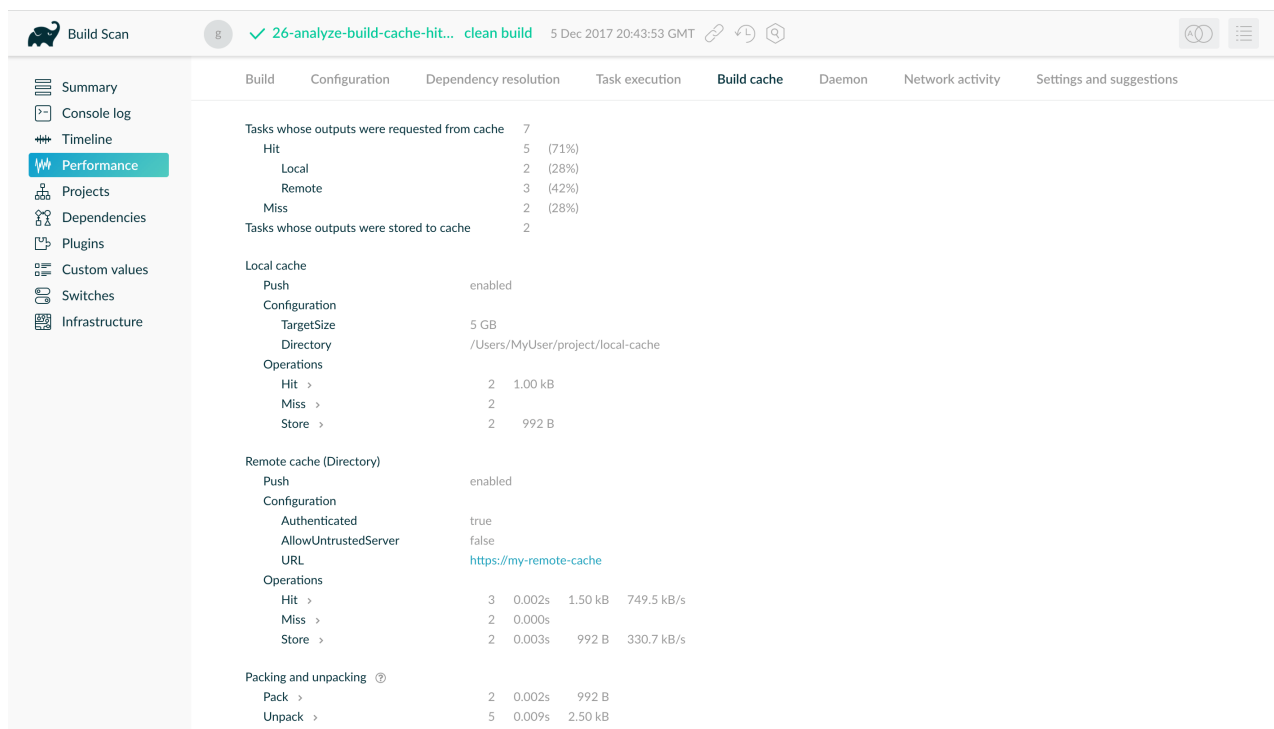
Figure 33. Inspecting the performance of the build cache for a build

The *"Task execution"* tab shows details about task cacheability. Click on a category to see a timeline screen that highlights tasks of that category.
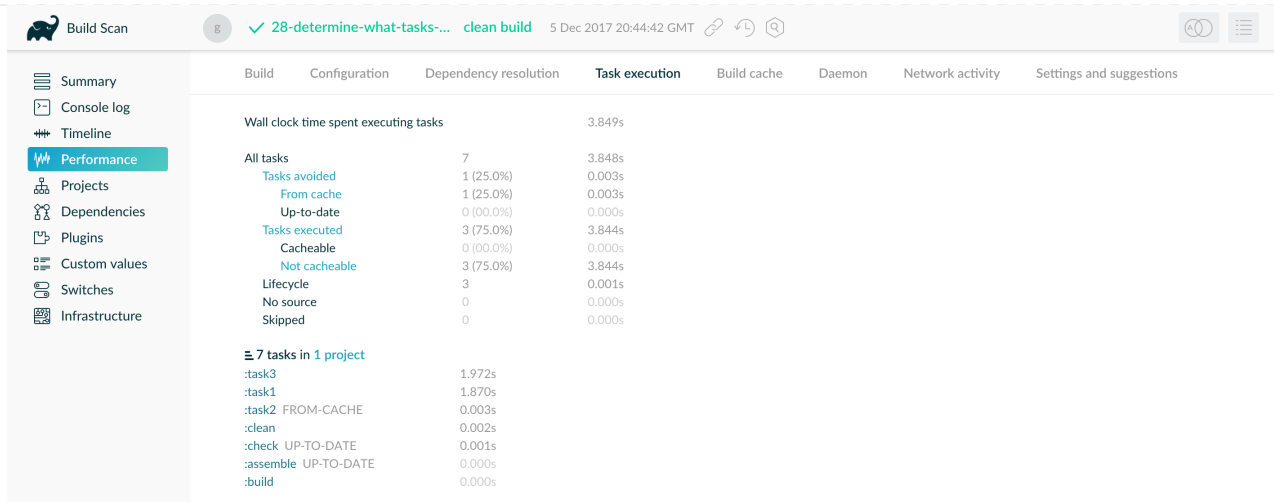
Figure 34. A task oriented view of performance
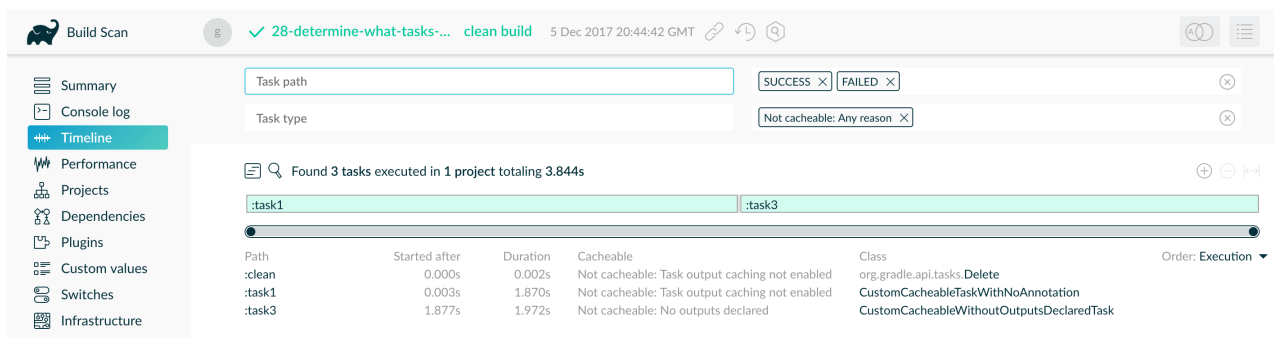
Figure 35. Timeline screen with 'not cacheable' tasks only

Sort by task duration on the timeline screen to highlight tasks with great time saving potential. The build scan above shows that `:task1` and `:task3` could be improved and made cacheable and shows why Gradle didn't cache them.

== Create builds for specific developer workflows

The fastest task is one that doesn't execute. If you can find ways to skip tasks you don't need to run, you'll end up with a faster build overall.

If your build includes multiple subprojects, create tasks to build those subprojects independently. This helps you get the most out of caching, since a change to one subproject won't force a rebuild for unrelated subprojects. And this helps reduce build times for teams that work on unrelated subprojects: there's no need for front-end developers to build the back-end subprojects every time they change the front-end. Documentation writers don't need to build front-end or back-end code even if the documentation lives in the same project as that code.

Instead, create tasks that match the needs of developers. You'll still have a single task graph for the whole project. Each group of users suggests a restricted view of the task graph: turn that view into a Gradle workflow that excludes unnecessary tasks.

Gradle provides several features to create these workflows:

- Assign tasks to appropriate groups

- Create *aggregate tasks*: tasks with no action that only depend on other tasks, such as

```
    assemble
```

- Defer configuration via `gradle.taskGraph.whenReady()` and others, so you can perform verification only when it's necessary

== Increase the heap size

By default, Gradle reserves 512MB of heap space for your build. This is plenty for most projects. However, some very large builds might need more memory to hold Gradle's model and caches. If this is the case for you, you can specify a larger memory requirement. Specify the following property in the `gradle.properties` file in your project root or your Gradle home:

gradle.properties

```
org.gradle.jvmargs=-Xmx2048M
```

To learn more, check out the JVM memory configuration documentation.

Optimize Configuration

As described in the build lifecycle chapter, a Gradle build goes through 3 phases: initialization, configuration, and execution. Configuration code always executes regardless of the tasks that run. As a result, any expensive work performed during configuration slows down every invocation. Even simple commands like `gradle help` and `gradle tasks`.

The next few subsections introduce techniques that can reduce time spent in the configuration phase.

> **NOTE** You can also enable the configuration cache to reduce the impact of a slow configuration phase. But even machines that use the cache still occasionally execute your configuration phase. As a result, you should make the configuration phase as fast as possible with these techniques.

Avoid expensive or blocking work

You should avoid time-intensive work in the configuration phase. But sometimes it can sneak into your build in non-obvious places. It's usually clear when you're encrypting data or calling remote services during configuration if that code is in a build file. But logic like this is more often found in plugins and occasionally custom task classes. Any expensive work in a plugin's `apply()` method or a tasks's constructor is a red flag.

Only apply plugins where they're needed

Every plugin and script that you apply to a project adds to the overall configuration time. Some plugins have a greater impact than others. That doesn't mean you should avoid using plugins, but you should take care to only apply them where they're needed. For example, it's easy to apply plugins to all subprojects via `allprojects {}` or `subprojects {}` even if not every project needs them.

In the above build scan example, you can see that the root build script applies the `script-a.gradle` script to 3 subprojects inside the build:
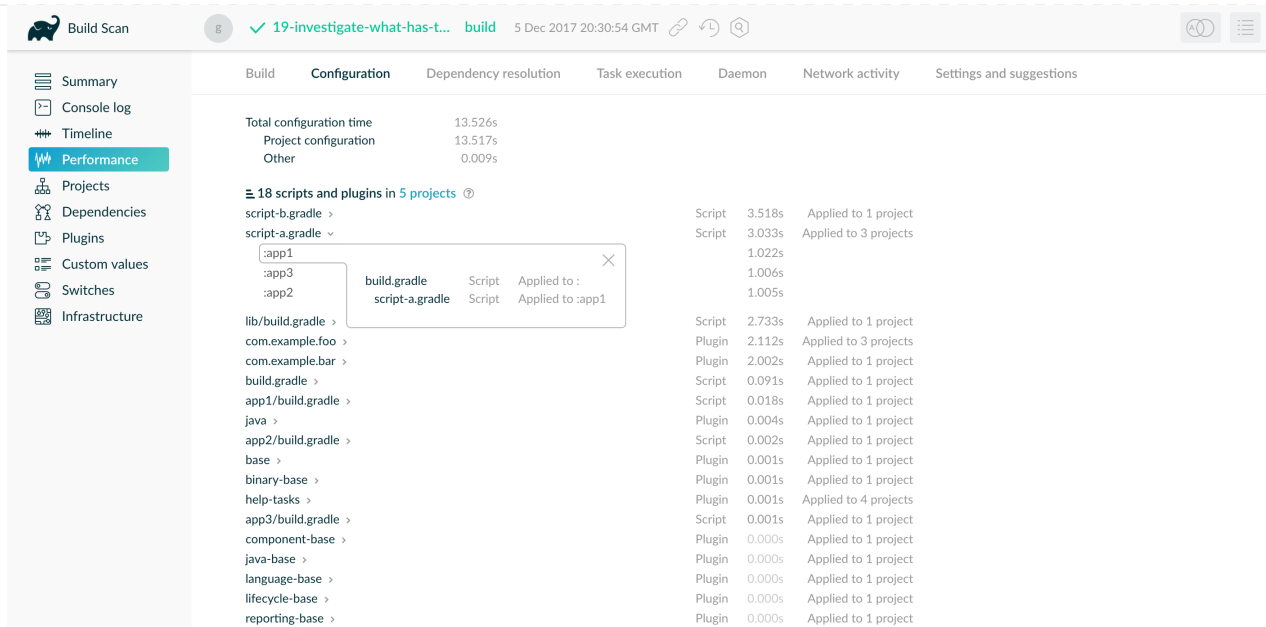
Figure 36. Showing the application of script-a.gradle to the build

This script takes 1 second to run. Since it applies to 3 subprojects, this script cumulatively delays the configuration phase by 3 seconds. In this situation, there are several ways to reduce the delay:

- If only one subproject uses the script, you could remove the script application from the other subprojects. This reduces the configuration delay by two seconds in each Gradle invocation.

- If multiple subprojects, but not all, use the script, you could refactor the script and all surrounding logic into a custom plugin located in `buildSrc`. Apply the custom plugin to only the relevant subprojects, reducing configuration delay and avoiding code duplication.

=== Statically compile tasks and plugins

Plugin and task authors often write Groovy for its concise syntax, API extensions to the JDK, and functional methods using closures. But Groovy syntax comes with the cost of dynamic interpretation. As a result, method calls in Groovy take more time and use more CPU than method calls in Java or Kotlin.

You can reduce this cost with static Groovy compilation: add the `@CompileStatic` annotation to your Groovy classes when you don't explicitly require dynamic features. If you need dynamic Groovy in a method, add the `@CompileDynamic` annotation to that method.

Alternatively, you can write plugins and tasks in a statically compiled language such as Java or Kotlin.

Warning: Gradle's Groovy DSL relies heavily on Groovy's dynamic features. To use static compilation in your plugins, switch to Java-like syntax.

The following example defines a task that copies files without dynamic features:

src/main/groovy/MyPlugin.groovy

```groovy
project.tasks.register('copyFiles', Copy) { Task t ->
    t.into(project.layout.buildDirectory.dir('output'))
    t.from(project.configurations.getByName('compile'))
}
```

This example uses the `register()` and `getByName()` methods available on all Gradle "domain object containers". Domain object containers include tasks, configurations, dependencies, extensions, and more. Some collections, such as `TaskContainer`, have dedicated types with extra methods like create, which accepts a task type.

When you use static compilation, an IDE can:

- quickly show errors related to unrecognised types, properties, and methods

- auto-complete method names

== Optimize Dependency resolution

Dependency resolution simplifies integrating third-party libraries and other dependencies into your projects. Gradle contacts remote servers to discover and download dependencies. You can optimize the way you reference dependencies to cut down on these remote server calls.

=== Avoid unnecessary and unused dependencies

Managing third-party libraries and their transitive dependencies adds a significant cost to project maintenance and build times.

Watch out for unused dependencies: when a third-party library stops being used by isn't removed from the dependency list. This happens frequently during refactors. You can use the Gradle Lint plugin to identify unused dependencies.

If you only use a small number of methods or classes in a third-party library, consider:

- implementing the required code yourself in your project

- copying the required code from the library (with attribution!) if it is open source

=== Optimize repository order

When Gradle resolves dependencies, it searches through each repository in the declared order. To reduce the time spent searching for dependencies, declare the repository hosting the largest number of your dependencies first. This minimizes the number of network requests required to resolve all dependencies.

=== Minimize repository count

Limit the number of declared repositories to the minimum possible for your build to work.

If you're using a custom repository server, create a virtual repository that aggregates several repositories together. Then, add only that repository to your build file.

=== Minimize dynamic and snapshot versions

Dynamic versions (e.g. "2.+"), and changing versions (snapshots) force Gradle to contact remote repositories to find new releases. By default, Gradle only checks once every 24 hours. But you can change this programmatically with the following settings:

- `cacheDynamicVersionsFor`

- `cacheChangingModulesFor`

If a build file or initialization script lowers these values, Gradle queries repositories more often. When you don't need the absolute latest release of a dependency every time you build, consider removing the custom values for these settings.

==== Find dynamic and changing versions with build scans

You can find all dependencies with dynamic versions via build scans:
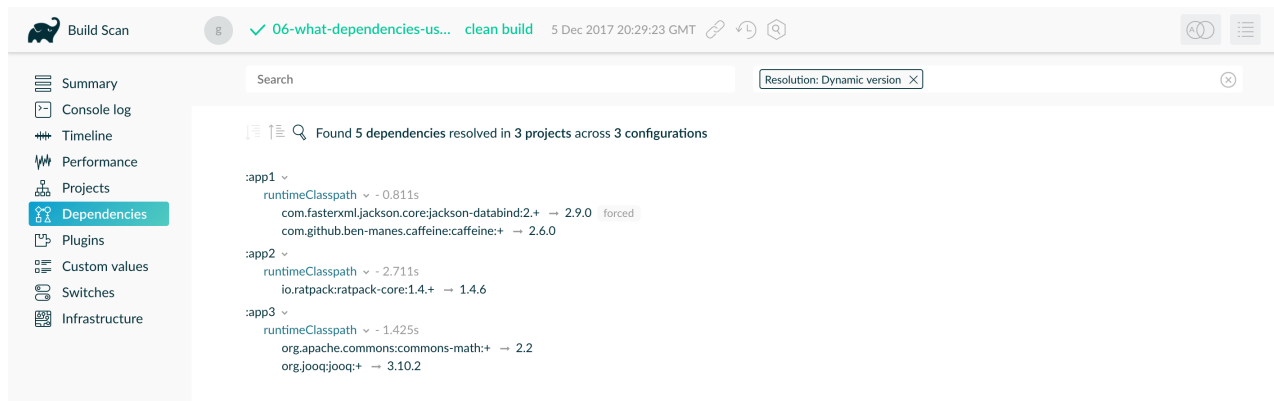
Figure 37. Find dependencies with dynamic versions

You may be able to use fixed versions like "1.2" and "3.0.3.GA" that allow Gradle to cache versions. If you must use dynamic and changing versions, tune the cache settings to best meet your needs.

=== Avoid dependency resolution during configuration

Dependency resolution is an expensive process, both in terms of I/O and computation. Gradle reduces the required network traffic through caching. But there is still a cost. Gradle runs the configuration phase on every build. If you trigger dependency resolution during the configuration phase, every build pays that cost.

==== Switch to declarative syntax

If you evaluate a configuration file, your project pays the cost of dependency resolution during configuration. Normally tasks evaluate these files, since you don't need the files until you're ready to do something with them in a task action. Imagine you're doing some debugging and want to display the files that make up a configuration. To implement this, you might inject a print statement:

build.gradle.kts

```kotlin
tasks.register<Copy>("copyFiles") {
    println(">> Compilation deps:
${configurations.compileClasspath.get().files.map { it.name }}")
    into(layout.buildDirectory.dir("output"))
    from(configurations.compileClasspath)
}
```

build.gradle

```groovy
tasks.register('copyFiles', Copy) {
    println ">> Compilation deps: ${configurations.compileClasspath.files.name}"
    into(layout.buildDirectory.dir('output'))
    from(configurations.compileClasspath)
}
```

The `files` property forces Gradle to resolve the dependencies. In this example, that happens during the configuration phase. Because the configuration phase runs on every build, all builds now pay the performance cost of dependency resolution. You can avoid this cost with a `doFirst()` action:

build.gradle.kts

```kotlin
tasks.register<Copy>("copyFiles") {
    into(layout.buildDirectory.dir("output"))
    // Store the configuration into a variable because referencing the project
from the task action
    // is not compatible with the configuration cache.
    val compileClasspath: FileCollection = configurations.compileClasspath.get()
    from(compileClasspath)
    doFirst {
        println(">> Compilation deps: ${compileClasspath.files.map { it.name }}")
    }
}
```

build.gradle

```groovy
tasks.register('copyFiles', Copy) {
    into(layout.buildDirectory.dir('output'))
    // Store the configuration into a variable because referencing the project
from the task action
    // is not compatible with the configuration cache.
    FileCollection compileClasspath = configurations.compileClasspath
    from(compileClasspath)
    doFirst {
        println ">> Compilation deps: ${compileClasspath.files.name}"
    }
}
```

Note that the `from()` declaration doesn't resolve the dependencies because you're using the dependency configuration itself as an argument, not the files. The `Copy` task resolves the configuration itself during task execution.

==== Visualize dependency resolution with build scans

The "Dependency resolution" tab on the performance page of a build scan shows dependency resolution time during the configuration and execution phases:
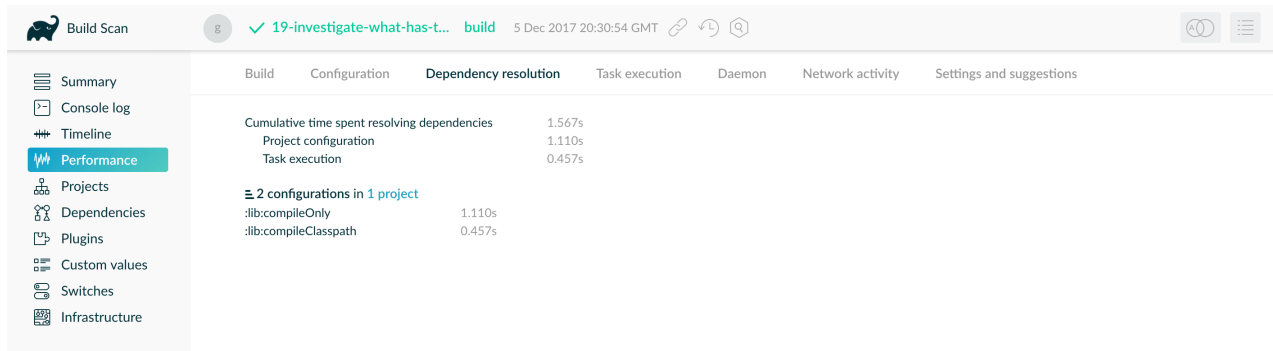
Figure 38. Dependency resolution at configuration time

Build scans provide another means of identifying this issue. Your build should spend 0 seconds resolving dependencies during *"project configuration"*. This example shows the build resolves dependencies too early in the lifecycle. You can also find a "Settings and suggestions" tab on the "Performance" page. This shows dependencies resolved during the configuration phase.

=== Remove or improve custom dependency resolution logic

Gradle allows users to model dependency resolution in the way that best suits them. Simple customizations, such as forcing specific versions of a dependency or substituting one dependency for another, don't have a big impact on dependency resolution times. More complex customizations, such as custom logic that downloads and parses POMs, can slow down dependency resolution signficantly.

Use build scans or profile reports to check that custom dependency resolution logic doesn't adversely affect dependency resolution times. This could be custom logic you have written yourself, or it could be part of a plugin.

=== Remove slow or unexpected dependency downloads

Slow dependency downloads can impact your overall build performance. Several things could cause this, including a slow internet connection or an overloaded repository server. On the "Performance" page of a build scan, you'll find a "Network Activity" tab. This tab lists information including:

- the time spent downloading dependencies

- the transfer rate of dependency downloads

- a list of downloads sorted by download time

In the following example, two slow dependency downloads took 20 and 40 seconds and slowed

down the overall performance of a build:
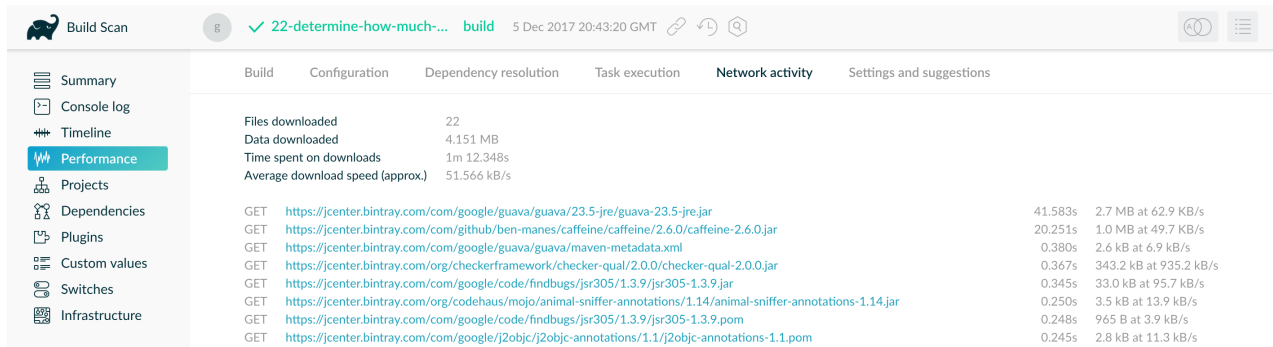
Figure 39. Identify slow dependency downloads

Check the download list for unexpected dependency downloads. For example, you might see a download caused by a dependency using a dynamic version.

Eliminate these slow or unexpected downloads by switching to a different repository or dependency.

== Optimize Java projects

The following sections apply only to projects that use the `java` plugin or another JVM language.

=== Optimize tests

Projects often spend much of their build time testing. These could be a mixture of unit and integration tests. Integration tests usually take longer. Build scans can help you identify the slowest tests. You can then focus on speeding up those tests.
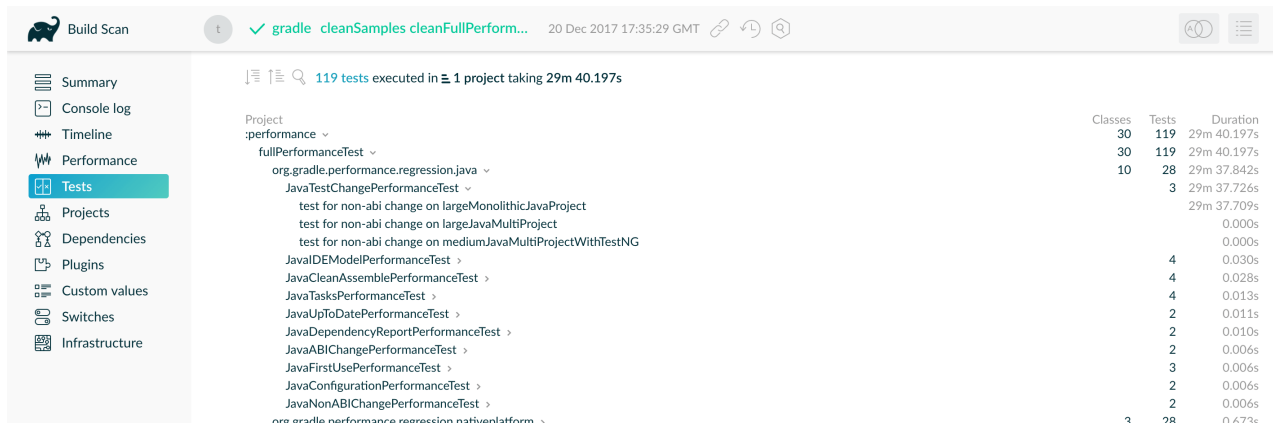
Figure 40. Tests screen, with tests by project, sorted by duration

The above build scan shows an interactive test report for all projects in which tests ran.

Gradle has several ways to speed up tests:

- Execute tests in parallel

- Fork tests into multiple processes

- Disable reports

Let's look at each of these in turn.

==== Execute tests in parallel

Gradle can run multiple test cases in parallel. To enable this feature, override the value of `maxParallelForks` on the relevant `Test` task. For the best performance, use some number less than or equal to the number of available CPU cores:

build.gradle.kts

```
tasks.withType<Test>().configureEach {
    maxParallelForks = (Runtime.getRuntime().availableProcessors() /
2).coerceAtLeast(1)
}
```

build.gradle

```
tasks.withType(Test).configureEach {
    maxParallelForks = Runtime.runtime.availableProcessors().intdiv(2) ?: 1
}
```

Tests in parallel must be independent. They should not share resources such as files or databases. If your tests do share resources, they could interfere with each other in random and unpredictable ways.

==== Fork tests into multiple processes

By default, Gradle runs all tests in a single forked VM. If there are a lot of tests, or some tests that consume lots of memory, your tests may take longer than you expect to run. You can increase the heap size, but garbage collection may slow down your tests.

Alternatively, you can fork a new test VM after a certain number of tests have run with the `forkEvery` setting:

build.gradle.kts

```
tasks.withType<Test>().configureEach {
    forkEvery = 100
}
```

build.gradle

```
tasks.withType(Test).configureEach {
    forkEvery = 100
}
```

WARNING	Forking a VM is an expensive operation. Setting too small a value here slows down testing.

==== Disable reports

Gradle automatically creates test reports regardless of whether you want to look at them. That report generation slows down the overall build. You may not need reports if:

- you only care if the tests succeeded (rather than why)

- you use build scans, which provide more information than a local report

To disable test reports, set `reports.html.required` and `reports.junitXml.required` to `false` in the `Test` task:

build.gradle.kts

```
tasks.withType<Test>().configureEach {
    reports.html.required = false
    reports.junitXml.required = false
}
```

build.gradle

```
tasks.withType(Test).configureEach {
    reports.html.required = false
    reports.junitXml.required = false
}
```

===== Conditionally enable reports

You might want to conditionally enable reports so you don't have to edit the build file to see them. To enable the reports based on a project property, check for the presence of a property before disabling reports:

```
tasks.withType<Test>().configureEach {
    if (!project.hasProperty("createReports")) {
        reports.html.required = false
        reports.junitXml.required = false
    }
}
```

```
tasks.withType(Test).configureEach {
    if (!project.hasProperty("createReports")) {
        reports.html.required = false
        reports.junitXml.required = false
    }
}
```

Then, pass the property with `-PcreateReports` on the command line to generate the reports.

```
$ gradle <task> -PcreateReports
```

Or configure the property in the `gradle.properties` file in the project root or your Gradle home:

gradle.properties

```
createReports=true
```

=== Optimize the compiler

The Java compiler is fast. But if you're compiling hundreds of Java classes, even a short compilation time adds up. Gradle offers a several optimizations for Java compilation:

- Run the compiler as a separate process
- Switch internal-only dependencies to implementation visibility

==== Run the compiler as a separate process

You can run the compiler as a separate process with the following configuration for any `JavaCompile` task:

build.gradle.kts

```
<task>.options.isFork = true
```

build.gradle

```
<task>.options.fork = true
```

To apply the configuration to *all* Java compilation tasks, you can `configureEach` java compilation task:

build.gradle.kts

```
tasks.withType<JavaCompile>().configureEach {
    options.isFork = true
}
```

build.gradle

```
tasks.withType(JavaCompile).configureEach {
    options.fork = true
}
```

Gradle reuses this process within the duration the build, so the forking overhead is minimal. By forking memory-intensive compilation into a separate process, we minimize garbage collection in the main Gradle process. Less garbage collection means that Gradle's infrastructure can run faster, especially when you also use parallel builds.

Forking compilation rarely impacts the performance of small projects. But you should consider it if a single task compiles more than a thousand source files together.

==== Switch internal-only dependencies to implementation visibility

> **NOTE**
> Only libraries can define `api` dependencies. Use the `java-library` plugin to define API dependencies in your libraries. Projects that use the `java` plugin cannot declare `api` dependencies.

Before Gradle 3.4, projects declared dependencies using the `compile` configuration. This exposed all of those dependencies to downstream projects. In Gradle 3.4 and above, you can separate downstream-facing `api` dependencies from internal-only `implementation` details. Implementation dependencies don't leak into the compile classpath of downstream projects. When implementation details change, Gradle only recompiles `api` dependencies.

build.gradle.kts

```
dependencies {
    api(project("my-utils"))
    implementation("com.google.guava:guava:21.0")
}
```

build.gradle

```
dependencies {
    api project('my-utils')
    implementation 'com.google.guava:guava:21.0'
}
```

This can significantly reduce the "ripple" of recompilations caused by a single change in large multi-project builds.

Improve the performance of older Gradle releases

Some projects cannot easily upgrade to a current Gradle version. While you should always upgrade Gradle to a recent version when possible, we recognize that it isn't always feasible for certain niche situations. In those select cases, check out these recommendations to optimize older versions of Gradle.

Enable the Daemon

Gradle 3.0 and above enable the Daemon by default. If you are using an older version, you should update to the latest version of Gradle. If you cannot update your Gradle version, you can enable the Daemon manually.

Use incremental compilation

Gradle can analyze dependencies down to the individual class level to recompile only the classes affected by a change. Gradle 4.10 and above enable incremental compilation by default. To enable incremental compilation by default in older Gradle versions, add the following setting to your `build.gradle` file:

build.gradle.kts

```
tasks.withType<JavaCompile>().configureEach {
    options.isIncremental = true
}
```

build.gradle

```
tasks.withType(JavaCompile).configureEach {
    options.incremental = true
}
```

=== Use compile avoidance

Often, updates only change internal implementation details of your code, like the body of a method. These updates are known as *ABI-compatible* changes: they have no impact on the binary interface of your project. In Gradle 3.4 and above, ABI-compatible changes no longer trigger recompiles of downstream projects. This especially improves build times in large multi-project builds with deep dependency chains.

Upgrade to a Gradle version above 3.4 to benefit from compile avoidance.

NOTE	If you use annotation processors, you need to explicitly declare them in order for compilation avoidance to work. To learn more, check out the compile avoidance documentation.

== Optimize Android projects

Everything on this page applies to Android builds, since Android builds use Gradle. Yet Android introduces unique opportunities for optimization. For more information, check out the Android team performance guide. You can also watch the accompanying talk from Google IO 2017.

= Configuration cache

== Introduction

The configuration cache is a feature that significantly improves build performance by caching the result of the configuration phase and reusing this for subsequent builds. Using the configuration cache, Gradle can skip the configuration phase entirely when nothing that affects the build configuration, such as build scripts, has changed. Gradle also applies performance improvements to task execution as well.

The configuration cache is conceptually similar to the build cache, but caches different information. The build cache takes care of caching the outputs and intermediate files of the build, such as task outputs or artifact transform outputs. The configuration cache takes care of caching the build configuration for a particular set of tasks. In other words, the configuration cache saves the output of the configuration phase, and the build cache saves the outputs of the execution phase.

This feature is currently not enabled by default. This feature has the following limitations:

- The configuration cache does not support all core Gradle plugins and features. Full support is a work in progress.

- Your build and the plugins you depend on might require changes to fulfil the requirements.

- IDE imports and syncs do not yet use the configuration cache.

How does it work?

When the configuration cache is enabled and you run Gradle for a particular set of tasks, for example by running `gradlew check`, Gradle checks whether a configuration cache entry is available for the requested set of tasks. If available, Gradle uses this entry instead of running the configuration phase. The cache entry contains information about the set of tasks to run, along with their configuration and dependency information.

The first time you run a particular set of tasks, there will be no entry in the configuration cache for these tasks and so Gradle will run the configuration phase as normal:

1. Run init scripts.

2. Run the settings script for the build, applying any requested settings plugins.

3. Configure and build the `buildSrc` project, if present.

4. Run the builds scripts for the build, applying any requested project plugins.

5. Calculate the task graph for the requested tasks, running any deferred configuration actions.

Following the configuration phase, Gradle writes a snapshot of the task graph to a new configuration cache entry, for later Gradle invocations. Gradle then loads the task graph from the configuration cache, so that it can apply optimizations to the tasks, and then runs the execution phase as normal. Configuration time will still be spent the first time you run a particular set of tasks. However, you should see build performance improvement immediately because tasks will run in parallel.

When you subsequently run Gradle with this same set of tasks, for example by running `gradlew check` again, Gradle will load the tasks and their configuration directly from the configuration cache and skip the configuration phase entirely. Before using a configuration cache entry, Gradle checks that none of the "build configuration inputs", such as build scripts, for the entry have changed. If a build configuration input has changed, Gradle will not use the entry and will run the configuration phase again as above, saving the result for later reuse.

Build configuration inputs include:

- Init scripts

- Settings scripts

- Build scripts

- System properties used during the configuration phase

- Gradle properties used during the configuration phase

- Environment variables used during the configuration phase

- Configuration files accessed using value suppliers such as providers

- `buildSrc` and plugin included build inputs, including build configuration inputs and source files.

Gradle uses its own optimized serialization mechanism and format to store the configuration

cache entries. It automatically serializes the state of arbitrary object graphs. If your tasks hold references to objects with simple state or of supported types you don't have anything to do to support the serialization.

As a fallback and to provide some aid in migrating existing tasks, some semantics of Java Serialization are supported. But it is not recommended relying on it, mostly for performance reasons.

Performance improvements

Apart from skipping the configuration phase, the configuration cache provides some additional performance improvements:

- All tasks run in parallel by default, subject to dependency constraints.
- Dependency resolution is cached.
- Configuration state and dependency resolution state is discarded from heap after writing the task graph. This reduces the peak heap usage required for a given set of tasks.

Configuration caching in action

[running help] | *configuration-cache/running-help.gif*

Using the configuration cache

It is recommended to get started with the simplest task invocation possible. Running `help` with the configuration cache enabled is a good first step:

```
 gradle --configuration-cache help
Calculating task graph as no cached configuration is available for tasks: help
...
BUILD SUCCESSFUL in 4s
1 actionable task: 1 executed
Configuration cache entry stored.
```

Running this for the first time, the configuration phase executes, calculating the task graph.

Then, run the same command again. This reuses the cached configuration:

```
 gradle --configuration-cache help
Reusing configuration cache.
...
BUILD SUCCESSFUL in 500ms
1 actionable task: 1 executed
Configuration cache entry reused.
```

If it succeeds on your build, congratulations, you can now try with more useful tasks. You should target your development loop. A good example is running tests after making incremental changes.

If any problem is found caching or reusing the configuration, an HTML report is generated to help you diagnose and fix the issues. The report also shows detected build configuration inputs like system properties, environment variables and value suppliers read during the configuration phase. See the [config_cache:troubleshooting] section below for more information.

Keep reading to learn how to tweak the configuration cache, manually invalidate the state if something goes wrong and use the configuration cache from an IDE.

Enabling the configuration cache

By default, Gradle does not use the configuration cache. To enable the cache at build time, use the `configuration-cache` flag:

```
 gradle --configuration-cache
```

You can also enable the cache persistently in a `gradle.properties` file using the `org.gradle.configuration-cache` property:

```
org.gradle.configuration-cache=true
```

If enabled in a `gradle.properties` file, you can override that setting and disable the cache at build time with the `no-configuration-cache` flag:

```
 gradle --no-configuration-cache
```

Ignoring problems

By default, Gradle will fail the build if any configuration cache problems are encountered. When gradually improving your plugin or build logic to support the configuration cache it can be useful to temporarily turn problems into warnings, with no guarantee that the build will work.

This can be done from the command line:

```
 gradle --configuration-cache-problems=warn
```

or in a `gradle.properties` file:

```
org.gradle.configuration-cache.problems=warn
```

Allowing a maximum number of problems

When configuration cache problems are turned into warnings, Gradle will fail the build if 512 problems are found by default.

This can be adjusted by specifying an allowed maximum number of problems on the command line:

```
❯ gradle -Dorg.gradle.configuration-cache.max-problems=5
```

or in a `gradle.properties` file:

```
org.gradle.configuration-cache.max-problems=5
```

=== Invalidating the cache

The configuration cache is automatically invalidated when inputs to the configuration phase change. However, certain inputs are not tracked yet, so you may have to manually invalidate the configuration cache when untracked inputs to the configuration phase change. This can happen if you ignored problems. See the [config_cache:requirements] and [config_cache:not_yet_implemented] sections below for more information.

The configuration cache state is stored on disk in a directory named `.gradle/configuration-cache` in the root directory of the Gradle build in use. If you need to invalidate the cache, simply delete that directory:

```
❯ rm -rf .gradle/configuration-cache
```

Configuration cache entries are checked periodically (at most every 24 hours) for whether they are still in use. They are deleted if they haven't been used for 7 days.

== Stable configuration cache

Working towards the stabilization of configuration caching we implemented some strictness behind a feature flag when it was considered too disruptive for early adopters.

You can enable that feature flag as follows:

settings.gradle.kts

```
enableFeaturePreview("STABLE_CONFIGURATION_CACHE")
```

settings.gradle

```
enableFeaturePreview "STABLE_CONFIGURATION_CACHE"
```

The `STABLE_CONFIGURATION_CACHE` feature flag enables the following:

Undeclared shared build service usage

> When enabled, tasks using a shared build service without declaring the requirement via the `Task.usesService` method will emit a deprecation warning.

In addition, when the configuration cache is not enabled but the feature flag is present, deprecations for the following configuration cache requirements are also enabled:

- Registering build listeners
- Using the `Project` object at execution time
- Using task extensions and conventions at execution time

It is recommended to enable it as soon as possible in order to be ready for when we remove the flag and make the linked features the default.

== IDE support

If you enable and configure the configuration cache from your `gradle.properties` file, then the configuration cache will be enabled when your IDE delegates to Gradle. There's nothing more to do.

`gradle.properties` is usually checked in to source control. If you don't want to enable the configuration cache for your whole team yet you can also enable the configuration cache from your IDE only as explained below.

Note that syncing a build from an IDE doesn't benefit from the configuration cache, only running tasks does.

=== IntelliJ based IDEs

In IntelliJ IDEA or Android Studio this can be done in two ways, either globally or per run configuration.

To enable it for the whole build, go to `Run > Edit configurations…`. This will open the IntelliJ IDEA or Android Studio dialog to configure Run/Debug configurations. Select `Templates > Gradle` and add the necessary system properties to the `VM options` field.

For example to enable the configuration cache, turning problems into warnings, add the following:

```
-Dorg.gradle.configuration-cache=true -Dorg.gradle.configuration
-cache.problems=warn
```

You can also choose to only enable it for a given run configuration. In this case, leave the `Templates > Gradle` configuration untouched and edit each run configuration as you see fit.

Combining these two ways you can enable globally and disable for certain run configurations,

> or the opposite.

You can use the [gradle-idea-ext-plugin](#) to configure IntelliJ run configurations from your build. This is a good way to enable the configuration cache only for the IDE.

=== Eclipse IDEs

In Eclipse IDEs you can enable and configure the configuration cache through Buildship in two ways, either globally or per run configuration.

To enable it globally, go to `Preferences > Gradle`. You can use the properties described above as system properties. For example to enable the configuration cache, turning problems into warnings, add the following JVM arguments:

- `-Dorg.gradle.configuration-cache=true`

- `-Dorg.gradle.configuration-cache.problems=warn`

To enable it for a given run configuration, go to `Run configurations…`, find the one you want to change, go to `Project Settings`, tick the `Override project settings` checkbox and add the same system properties as a `JVM argument`.

Combining these two ways you can enable globally and disable for certain run configurations, or the opposite.

== Supported plugins

The configuration cache is brand new and introduces new requirements for plugin implementations. As a result, both core Gradle plugins, and community plugins need to be adjusted. This section provides information about the current support in core Gradle plugins and community plugins.

=== Core Gradle plugins

Not all core Gradle plugins support configuration caching yet.

JVM languages and frameworks	Native languages	Packaging and distribution
⬜ Java	⬜ C++ Application	⬜ Application
⬜ Java Library	⬜ C++ Library	⬜ WAR
⬜ Java Platform	⬜ C++ Unit Test	⬜ EAR
⬜ Groovy	⬜ Swift Application	⬜ Maven Publish
⬜ Scala	⬜ Swift Library	⬜ Ivy Publish
⬜ ANTLR	⬜ XCTest	⬜ Distribution
		⬜ Java Library Distribution

Code analysis	IDE project files generation	Utility
⬡ Checkstyle	⬡ Eclipse	⬡ Base
⬡ CodeNarc	⬡ IntelliJ IDEA	⬡ Build Init
⬡ JaCoCo	⬡ Visual Studio	⬡ Signing
⬡ JaCoCo Report Aggregation	⬡ Xcode	⬡ Java Plugin Development
⬡ PMD		⬡ Groovy DSL Plugin Development
⬡ Test Report Aggregation		⬡ Kotlin DSL Plugin Development
		⬡ Project Report Plugin

⬡ Supported plugin

⬡ Partially supported plugin

⬡ Unsupported plugin

=== Community plugins

Please refer to issue gradle/gradle#13490 to learn about the status of community plugins.

== Troubleshooting

The following sections will go through some general guidelines on dealing with problems with the configuration cache. This applies to both your build logic and to your Gradle plugins.

Upon failure to serialize the state required to run the tasks, an HTML report of detected problems is generated. The Gradle failure output includes a clickable link to the report. This report is useful and allows you to drill down into problems, understand what is causing them.

Let's look at a simple example build script that contains a couple problems:

build.gradle.kts

```kotlin
tasks.register("someTask") {
    val destination = System.getProperty("someDestination") ①
    inputs.dir("source")
    outputs.dir(destination)
    doLast {
        project.copy { ②
            from("source")
            into(destination)
        }
    }
}
```

build.gradle

```groovy
tasks.register('someTask') {
    def destination = System.getProperty('someDestination') ①
    inputs.dir('source')
    outputs.dir(destination)
    doLast {
        project.copy { ②
            from 'source'
            into destination
        }
    }
}
```

① A system property read at configuration time

② Using the `Project` object at execution time

Running that task fails and print the following in the console:

```
⬡ gradle --configuration-cache someTask -DsomeDestination=dest
...
* What went wrong:
Configuration cache problems found in this build.

1 problem was found storing the configuration cache.
- Build file 'build.gradle': line 6: invocation of 'Task.project' at execution
time is unsupported.
  See
https://docs.gradle.org/0.0.0/userguide/configuration_cache.html#config_cache:requ
irements:use_project_during_execution

See the complete report at
file:///home/user/gradle/samples/build/reports/configuration-
cache/<hash>/configuration-cache-report.html
> Invocation of 'Task.project' by task ':someTask' at execution time is
unsupported.

* Try:
> Run with --stacktrace option to get the stack trace.
> Run with --info or --debug option to get more log output.
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

BUILD FAILED in 0s
1 actionable task: 1 executed
Configuration cache entry discarded with 1 problem.
```

The configuration cache entry was discarded because of the found problem failing the build.

Details can be found in the linked HTML report:

🐘   Learn more about the Gradle Configuration Cache.

Storing the configuration cache for someTask

1 build configuration input was found and will cause the cache to be discarded when its value change

1 problem was found

Build configuration inputs `1`   **Problems grouped by message** `1`   Problems grouped by location `1`

    > ✕ **invocation of** `Task.project` 📋 **at execution time is unsupported.** ⓘ

The report displays the set of problems twice. First grouped by problem message, then grouped by task. The former allows you to quickly see what classes of problems your build is facing. The latter allows you to quickly see which tasks are problematic. In both cases you can expand the tree in order to discover where the culprit is in the object graph.

The report also includes a list of detected build configuration inputs, such as environment variables, system properties and value suppliers that were read at configuration phase:

Problems displayed in the report have links to the corresponding requirement where you can find guidance on how to fix the problem or to the corresponding not yet implemented feature.

When changing your build or plugin to fix the problems you should consider testing your build logic with TestKit.

At this stage, you can decide to either [turn the problems into warnings](#) and continue exploring how your build reacts to the configuration cache, or fix the problems at hand.

Let's ignore the reported problem, and run the same build again twice to see what happens when reusing the cached problematic configuration:

```
⬚ gradle --configuration-cache --configuration-cache-problems=warn someTask
-DsomeDestination=dest
Calculating task graph as no cached configuration is available for tasks: someTask
> Task :someTask

1 problem was found storing the configuration cache.
- Build file 'build.gradle': line 6: invocation of 'Task.project' at execution
time is unsupported.
  See
https://docs.gradle.org/0.0.0/userguide/configuration_cache.html#config_cache:requ
irements:use_project_during_execution

See the complete report at
file:///home/user/gradle/samples/build/reports/configuration-
cache/<hash>/configuration-cache-report.html

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry stored with 1 problem.
⬚ gradle --configuration-cache --configuration-cache-problems=warn someTask
-DsomeDestination=dest
Reusing configuration cache.
> Task :someTask

1 problem was found reusing the configuration cache.
- Build file 'build.gradle': line 6: invocation of 'Task.project' at execution
time is unsupported.
  See
https://docs.gradle.org/0.0.0/userguide/configuration_cache.html#config_cache:requ
irements:use_project_during_execution

See the complete report at
file:///home/user/gradle/samples/build/reports/configuration-
cache/<hash>/configuration-cache-report.html

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry reused with 1 problem.
```

The two builds succeed reporting the observed problem, storing then reusing the configuration cache.

With the help of the links present in the console problem summary and in the HTML report we

can fix our problems. Here's a fixed version of the build script:

build.gradle.kts

```
abstract class MyCopyTask : DefaultTask() { ①

    @get:InputDirectory abstract val source: DirectoryProperty ②

    @get:OutputDirectory abstract val destination: DirectoryProperty ②

    @get:Inject abstract val fs: FileSystemOperations ③

    @TaskAction
    fun action() {
        fs.copy { ③
            from(source)
            into(destination)
        }
    }
}

tasks.register<MyCopyTask>("someTask") {
    val projectDir = layout.projectDirectory
    source = projectDir.dir("source")
    destination = projectDir.dir(System.getProperty("someDestination"))
}
```

```
abstract class MyCopyTask extends DefaultTask { ①

    @InputDirectory abstract DirectoryProperty getSource() ②

    @OutputDirectory abstract DirectoryProperty getDestination() ②

    @Inject abstract FileSystemOperations getFs() ③

    @TaskAction
    void action() {
        fs.copy { ③
            from source
            into destination
        }
    }
}

tasks.register('someTask', MyCopyTask) {
    def projectDir = layout.projectDirectory
    source = projectDir.dir('source')
    destination = projectDir.dir(System.getProperty('someDestination'))
}
```

① We turned our ad-hoc task into a proper task class,

② with inputs and outputs declaration,

③ and injected with the `FileSystemOperations` service, a supported replacement for `project.copy {}`.

Running the task twice now succeeds without reporting any problem and reuses the configuration cache on the second run:

```
❯ gradle --configuration-cache someTask -DsomeDestination=dest
Calculating task graph as no cached configuration is available for tasks: someTask
> Task :someTask

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry stored.
❯ gradle --configuration-cache someTask -DsomeDestination=dest
Reusing configuration cache.
> Task :someTask

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry reused.
```

But, what if we change the value of the system property?

```
❯ gradle --configuration-cache someTask -DsomeDestination=another
Calculating task graph as configuration cache cannot be reused because system
property 'someDestination' has changed.
> Task :someTask

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry stored.
```

The previous configuration cache entry could not be reused, and the task graph had to be calculated and stored again. This is because we read the system property at configuration time, hence requiring Gradle to run the configuration phase again when the value of that property changes. Fixing that is as simple as obtaining the provider of the system property and wiring it to the task input, without reading it at configuration time.

```kotlin
tasks.register<MyCopyTask>("someTask") {
    val projectDir = layout.projectDirectory
    source = projectDir.dir("source")
    destination = projectDir.dir(providers.systemProperty("someDestination")) ①
}
```

```groovy
tasks.register('someTask', MyCopyTask) {
    def projectDir = layout.projectDirectory
    source = projectDir.dir('source')
    destination = projectDir.dir(providers.systemProperty('someDestination')) ①
}
```

① We wired the system property provider directly, without reading it at configuration time.

With this simple change in place we can run the task any number of times, change the system property value, and reuse the configuration cache:

```
 gradle --configuration-cache someTask -DsomeDestination=dest
Calculating task graph as no cached configuration is available for tasks: someTask
> Task :someTask

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry stored.
 gradle --configuration-cache someTask -DsomeDestination=another
Reusing configuration cache.
> Task :someTask

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
Configuration cache entry reused.
```

We're now done with fixing the problems with this simple task.

Keep reading to learn how to adopt the configuration cache for your build or your plugins.

=== Declare a task incompatible with the configuration cache

It is possible to declare that a particular task is not compatible with the configuration cache via the Task.notCompatibleWithConfigurationCache() method.

Configuration cache problems found in tasks marked incompatible will no longer cause the build to fail.

And, when an incompatible task is scheduled to run, Gradle discards the configuration state at the end of the build. You can use this to help with migration, by temporarily opting out certain tasks that are difficult to change to work with the configuration cache.

Check the method documentation for more details.

== Adoption steps

An important prerequisite is to keep your Gradle and plugins versions up to date. The following explores the recommended steps for a successful adoption. It applies both to builds and plugins. While going through these steps, keep in mind the HTML report and the solutions explained in the requirements chapter below.

Start with `:help`

Always start by trying your build or plugin with the simplest task `:help`. This will exercise the minimal configuration phase of your build or plugin.

Progressively target useful tasks

Don't go with running `build` right away. You can also use `--dry-run` to discover more configuration time problems first.

When working on a build, progressively target your development feedback loop. For example, running tests after making some changes to the source code.

When working on a plugin, progressively target the contributed or configured tasks.

Explore by turning problems into warnings

Don't stop at the first build failure and turn problems into warnings to discover how your build and plugins behave. If a build fails, use the HTML report to reason about the reported problems related to the failure. Continue running more useful tasks.

This will give you a good overview of the nature of the problems your build and plugins are facing. Remember that when turning problems into warnings you might need to manually invalidate the cache in case of troubles.

Step back and fix problems iteratively

When you feel you know enough about what needs to be fixed, take a step back and start iteratively fixing the most important problems. Use the HTML report and this documentation to help you in this journey.

Start with problems reported when *storing* the configuration cache. Once fixed, you can rely on a valid cached configuration phase and move on to fixing problems reported when *loading* the configuration cache if any.

Report encountered issues

If you face a problem with a Gradle feature or with a Gradle core plugin that is not covered by this documentation, please report an issue on `gradle/gradle`.

If you face a problem with a community Gradle plugin, see if it is already listed at gradle/gradle#13490 and consider reporting the issue to the plugin's issue tracker.

A good way to report such issues is by providing information such as:

- a link to this very documentation,
- the plugin version you tried,
- the custom configuration of the plugin if any, or ideally a reproducer build,
- a description of what fails, for example problems with a given task
- a copy of the build failure,
- the self-contained `configuration-cache-report.html` file.

Test, test, test

Consider adding tests for your build logic. See the below section on testing your build logic for the configuration cache. This will help you while iterating on the required changes and prevent future regressions.

Roll it out to your team

Once you have your developer workflow working, for example running tests from the IDE, you can consider enabling it for your team. A faster turnaround when changing code and running tests could be worth it. You'll probably want to do this as an opt-in first.

If needed, turn problems into warnings and set the maximum number of allowed problems in your build `gradle.properties` file. Keep the configuration cache disabled by default. Let your team know they can opt-in by, for example, enabling the configuration cache on their IDE run configurations for the supported workflow.

Later on, when more workflows are working, you can flip this around. Enable the configuration cache by default, configure CI to disable it, and if required communicate the unsupported workflow(s) for which the configuration cache needs to be disabled.

=== Reacting to the configuration cache in the build

Build logic or plugin implementations can detect if the configuration cache is enabled for a given build, and react to it accordingly. The active status of the configuration cache is provided in the corresponding build feature. You can access it by injecting the `BuildFeatures` service into your code.

You can use this information to configure features of your plugin differently or to disable an optional feature that is not yet compatible. Another example involves providing additional guidance for your users, should they need to adjust their setup or be informed of temporary limitations.

=== Adopting changes in the configuration cache behavior

Gradle releases bring enhancements to the configuration cache, making it detect more cases of configuration logic interacting with the environment. Those changes improve the correctness of the cache by eliminating potential false cache hits. On the other hand, they impose stricter rules that plugins and build logic need to follow to be cached as often as possible.

Some of those configuration inputs may be considered "benign" if their results do not affect the configured tasks. Having new configuration misses because of them may be undesirable for the build users, and the suggested strategy for eliminating them is:

- Identify the configuration inputs causing the invalidation of the configuration cache with the help of the configuration cache report.
  - Fix undeclared configuration inputs accessed by the build logic of the project.
  - Report issues caused by third-party plugins to the plugin maintainers, and update the plugins once they get fixed.
- For some kinds of configuration inputs, it is possible to use the opt-out options that make Gradle fall back to the earlier behavior, omitting the inputs from detection. This temporary workaround is aimed to mitigate performance issues coming from out-of-date plugins.

It is possible to temporarily opt out of configuration input detection in the following cases:

- Since Gradle 8.1, using many APIs related to the file system is correctly tracked as

configuration inputs, including the file system checks, such as `File.exists()` or `File.isFile()`.

For the input tracking to ignore these file system checks on the specific paths, the Gradle property `org.gradle.configuration-cache.inputs.unsafe.ignore.file-system-checks`, with the list of the paths, relative to the root project directory and separated by `;`, can be used. To ignore multiple paths, use `*` to match arbitrary strings within one segment, or `**` across segments. Paths starting with `~/` are based on the user home directory. For example:

gradle.properties

```
org.gradle.configuration-cache.inputs.unsafe.ignore.file-system-checks=\
    ~/.third-party-plugin/*.lock;\
    ../../externalOutputDirectory/**;\
    build/analytics.json
```

- Before Gradle 8.4, some undeclared configuration inputs that were never used in the configuration logic could still be read when the task graph was serialized by the configuration cache. However, their changes would not invalidate the configuration cache afterward. Starting with Gradle 8.4, such undeclared configuration inputs are correctly tracked.

  To temporarily revert to the earlier behavior, set the Gradle property `org.gradle.configuration-cache.inputs.unsafe.ignore.in-serialization` to `true`.

Ignore configuration inputs sparingly, and only if they do not affect the tasks produced by the configuration logic. The support for these options will be removed in future releases.

== Testing your build logic

The Gradle TestKit (a.k.a. just TestKit) is a library that aids in testing Gradle plugins and build logic generally. For general guidance on how to use TestKit, see the dedicated chapter.

To enable configuration caching in your tests, you can pass the `--configuration-cache` argument to GradleRunner or use one of the other methods described in Enabling the configuration cache.

You need to run your tasks twice. Once to prime the configuration cache. Once to reuse the configuration cache.

src/test/kotlin/org/example/BuildLogicFunctionalTest.kt

```kotlin
@Test
fun `my task can be loaded from the configuration cache`() {

    buildFile.writeText("""
        plugins {
            id 'org.example.my-plugin'
        }
    """)

    runner()
        .withArguments("--configuration-cache", "myTask")        ①
        .build()

    val result = runner()
        .withArguments("--configuration-cache", "myTask")        ②
        .build()

    require(result.output.contains("Reusing configuration cache.")) ③
    // ... more assertions on your task behavior
}
```

```groovy
def "my task can be loaded from the configuration cache"() {
    given:
    buildFile << """
        plugins {
            id 'org.example.my-plugin'
        }
    """

    when:
    runner()
        .withArguments('--configuration-cache', 'myTask')    ①
        .build()

    and:
    def result = runner()
        .withArguments('--configuration-cache', 'myTask')    ②
        .build()

    then:
    result.output.contains('Reusing configuration cache.')    ③
    // ... more assertions on your task behavior
}
```

① First run primes the configuration cache.

② Second run reuses the configuration cache.

③ Assert that the configuration cache gets reused.

If problems with the configuration cache are found then Gradle will fail the build reporting the problems, and the test will fail.

A good testing strategy for a Gradle plugin is to run its whole test suite with the configuration cache enabled. This requires testing the plugin with a supported Gradle version.

If the plugin already supports a range of Gradle versions it might already have tests for multiple Gradle versions. In that case we recommend enabling the configuration cache starting with the Gradle version that supports it.

If this can't be done right away, using tests that run all tasks contributed by the plugin several times, for e.g. asserting the UP_TO_DATE and FROM_CACHE behavior, is also a good strategy.

== Requirements

In order to capture the state of the task graph to the configuration cache and reload it again in a later build, Gradle applies certain requirements to tasks and other build logic. Each of these requirements is treated as a configuration cache "problem" and fails the build if violations are present.

For the most part these requirements are actually surfacing some undeclared inputs. In other words, using the configuration cache is an opt-in to more strictness, correctness and reliability for all builds.

The following sections describe each of the requirements and how to change your build to fix the problems.

=== Certain types must not be referenced by tasks

There are a number of types that task instances must not reference from their fields. The same applies to task actions as closures such as `doFirst {}` or `doLast {}`.

These types fall into some categories as follows:

- Live JVM state types
- Gradle model types
- Dependency management types

In all cases the reason these types are disallowed is that their state cannot easily be stored or recreated by the configuration cache.

Live JVM state types (e.g. `ClassLoader`, `Thread`, `OutputStream`, `Socket` etc...) are simply disallowed. These types almost never represent a task input or output.

Gradle model types (e.g. `Gradle`, `Settings`, `Project`, `SourceSet`, `Configuration` etc...) are usually used to carry some task input that should be explicitly and precisely declared instead.

For example, if you reference a `Project` in order to get the `project.version` at execution time, you should instead directly declare the *project version* as an input to your task using a `Property<String>`. Another example would be to reference a `SourceSet` to later get the source files, the compilation classpath or the outputs of the source set. You should instead declare these as a `FileCollection` input and reference just that.

The same requirement applies to dependency management types with some nuances.

Some types, such as `Configuration` or `SourceDirectorySet`, don't make good task input parameters, as they hold a lot of irrelevant state, and it is better to model these inputs as something more precise. We don't intend to make these types serializable at all. For example, if you reference a `Configuration` to later get the resolved files, you should instead declare a `FileCollection` as an input to your task. In the same vein, if you reference a `SourceDirectorySet` you should instead declare a `FileTree` as an input to your task.

Referencing dependency resolution results is also disallowed (e.g. `ArtifactResolutionQuery`, `ResolvedArtifact`, `ArtifactResult` etc...). For example, if you reference some `ResolvedComponentResult` instances, you should instead declare a `Provider<ResolvedComponentResult>` as an input to your task. Such a provider can be obtained by invoking `ResolutionResult.getRootComponent()`. In the same vein, if you reference some `ResolvedArtifactResult` instances, you should instead use `ArtifactCollection.getResolvedArtifacts()` that returns a `Provider<Set<ResolvedArtifactResult>>` that can be mapped as an input to your task. The rule of thumb is that tasks must not reference *resolved* results, but lazy specifications instead, in order to do the dependency resolution at execution time.

Some types, such as `Publication` or `Dependency` are not serializable, but could be. We may, if necessary, allow these to be used as task inputs directly.

Here's an example of a problematic task type referencing a `SourceSet`:

build.gradle.kts

```kotlin
abstract class SomeTask : DefaultTask() {

    @get:Input lateinit var sourceSet: SourceSet ①

    @TaskAction
    fun action() {
        val classpathFiles = sourceSet.compileClasspath.files
        // ...
    }
}
```

build.gradle

```groovy
abstract class SomeTask extends DefaultTask {

    @Input SourceSet sourceSet ①

    @TaskAction
    void action() {
        def classpathFiles = sourceSet.compileClasspath.files
        // ...
    }
}
```

① this will be reported as a problem because referencing `SourceSet` is not allowed

The following is how it should be done instead:

build.gradle.kts

```kotlin
abstract class SomeTask : DefaultTask() {

    @get:InputFiles @get:Classpath
    abstract val classpath: ConfigurableFileCollection  ①

    @TaskAction
    fun action() {
        val classpathFiles = classpath.files
        // ...
    }
}
```

build.gradle

```groovy
abstract class SomeTask extends DefaultTask {

    @InputFiles @Classpath
    abstract ConfigurableFileCollection getClasspath()  ①

    @TaskAction
    void action() {
        def classpathFiles = classpath.files
        // ...
    }
}
```

① no more problems reported, we now reference the supported type `FileCollection`

In the same vein, if you encounter the same problem with an ad-hoc task declared in a script as follows:

build.gradle.kts

```
tasks.register("someTask") {
    doLast {
        val classpathFiles = sourceSets.main.get().compileClasspath.files ①
    }
}
```

build.gradle

```
tasks.register('someTask') {
    doLast {
        def classpathFiles = sourceSets.main.compileClasspath.files ①
    }
}
```

① this will be reported as a problem because the `doLast {}` closure is capturing a reference to the `SourceSet`

You still need to fulfil the same requirement, that is not referencing a disallowed type. Here's how the task declaration above can be fixed:

build.gradle.kts

```
tasks.register("someTask") {
    val classpath = sourceSets.main.get().compileClasspath ①
    doLast {
        val classpathFiles = classpath.files
    }
}
```

build.gradle

```
tasks.register('someTask') {
    def classpath = sourceSets.main.compileClasspath ①
    doLast {
        def classpathFiles = classpath.files
    }
}
```

① no more problems reported, the `doLast {}` closure now only captures `classpath` which is of the supported `FileCollection` type

Note that sometimes the disallowed type is indirectly referenced. For example, you could have a task reference some type from a plugin that is allowed. That type could reference another allowed type that in turn references a disallowed type. The hierarchical view of the object graph provided in the HTML reports for problems should help you pinpoint the offender.

=== Using the `Project` object

A task must not use any `Project` objects at execution time. This includes calling `Task.getProject()` while the task is running.

Some cases can be fixed in the same way as for disallowed types.

Often, similar things are available on both `Project` and `Task`. For example if you need a `Logger` in your task actions you should use `Task.logger` instead of `Project.logger`.

Otherwise, you can use injected services instead of the methods of `Project`.

Here's an example of a problematic task type using the `Project` object at execution time:

build.gradle.kts

```
abstract class SomeTask : DefaultTask() {
    @TaskAction
    fun action() {
        project.copy { ①
            from("source")
            into("destination")
        }
    }
}
```

build.gradle

```
abstract class SomeTask extends DefaultTask {
    @TaskAction
    void action() {
        project.copy { ①
            from 'source'
            into 'destination'
        }
    }
}
```

① this will be reported as a problem because the task action is using the `Project` object at execution time

The following is how it should be done instead:

build.gradle.kts

```kotlin
abstract class SomeTask : DefaultTask() {

    @get:Inject abstract val fs: FileSystemOperations ①

    @TaskAction
    fun action() {
        fs.copy {
            from("source")
            into("destination")
        }
    }
}
```

build.gradle

```groovy
abstract class SomeTask extends DefaultTask {

    @Inject abstract FileSystemOperations getFs() ①

    @TaskAction
    void action() {
        fs.copy {
            from 'source'
            into 'destination'
        }
    }
}
```

① no more problem reported, the injected `FileSystemOperations` service is supported as a replacement for `project.copy {}`

In the same vein, if you encounter the same problem with an ad-hoc task declared in a script as follows:

build.gradle.kts

```
tasks.register("someTask") {
    doLast {
        project.copy { ①
            from("source")
            into("destination")
        }
    }
}
```

build.gradle

```
tasks.register('someTask') {
    doLast {
        project.copy { ①
            from 'source'
            into 'destination'
        }
    }
}
```

① this will be reported as a problem because the task action is using the `Project` object at execution time

Here's how the task declaration above can be fixed:

build.gradle.kts

```
interface Injected {
    @get:Inject val fs: FileSystemOperations ①
}
tasks.register("someTask") {
    val injected = project.objects.newInstance<Injected>() ②
    doLast {
        injected.fs.copy { ③
            from("source")
            into("destination")
        }
    }
}
```

build.gradle

```groovy
interface Injected {
    @Inject FileSystemOperations getFs() ①
}
tasks.register('someTask') {
    def injected = project.objects.newInstance(Injected) ②
    doLast {
        injected.fs.copy { ③
            from 'source'
            into 'destination'
        }
    }
}
```

① services can't be injected directly in scripts, we need an extra type to convey the injection point

② create an instance of the extra type using `project.object` outside the task action

③ no more problem reported, the task action references `injected` that provides the `FileSystemOperations` service, supported as a replacement for `project.copy {}`

As you can see above, fixing ad-hoc tasks declared in scripts requires quite a bit of ceremony. It is a good time to think about extracting your task declaration as a proper task class as shown previously.

The following table shows what APIs or injected service should be used as a replacement for each of the `Project` methods.

Instead of:	Use:
`project.rootDir`	A task input or output property or a script variable to capture the result of using `project.rootDir` to calculate the actual parameter.
`project.projectDir`	A task input or output property or a script variable to capture the result of using `project.projectDir` to calculate the actual parameter.
`project.buildDir`	A task input or output property or a script variable to capture the result of using `project.buildDir` to calculate the actual parameter.
`project.name`	A task input or output property or a script variable to capture the result of using `project.name` to calculate the actual parameter.
`project.description`	A task input or output property or a script variable to capture the result of using `project.description` to calculate the actual parameter.
`project.group`	A task input or output property or a script variable to capture the result of using `project.group` to calculate the actual parameter.

Instead of:	Use:
`project.version`	A task input or output property or a script variable to capture the result of using `project.version` to calculate the actual parameter.
`project.properties`, `project.property(name)`, `project.hasProperty(name)`, `project.getProperty(name)` or `project.findProperty(name)`	Value providers for Gradle properties.
`project.logger`	Task.logger
`project.provider {}`	ProviderFactory.provider {}
`project.file(path)`	A task input or output property or a script variable to capture the result of using `project.file(file)` to calculate the actual parameter.
`project.uri(path)`	A task input or output property or a script variable to capture the result of using `project.uri(path)` to calculate the actual parameter. Otherwise, `File.toURI()` or some other JVM API can be used.
`project.relativePath(path)`	ProjectLayout.projectDirectory.file(path)
`project.files(paths)`	ObjectFactory.fileCollection().from(paths)
`project.fileTree(paths)`	ObjectFactory.fileTree().from(dir)
`project.zipTree(path)`	ArchiveOperations.zipTree(path)
`project.tarTree(path)`	ArchiveOperations.tarTree(path)
`project.resources`	A task input or output property or a script variable to capture the result of using `project.resource` to calculate the actual parameter.
`project.copySpec {}`	FileSystemOperations.copySpec {}
`project.copy {}`	FileSystemOperations.copy {}

Instead of:	Use:
`project.sync {}`	FileSystemOperations.sync {}
`project.delete {}`	FileSystemOperations.delete {}
`project.mkdir(path)`	The Kotlin, Groovy or Java API available to your build logic.
`project.exec {}`	ExecOperations.exec {}
`project.javaexec {}`	ExecOperations.javaexec {}
`project.ant {}`	Task.ant
`project.createAntBuilder()`	Task.ant

Accessing a task instance from another instance

Tasks should not directly access the state of another task instance. Instead, tasks should be connected using inputs and outputs relationships.

Note that this requirement makes it unsupported to write tasks that configure other tasks at execution time.

Sharing mutable objects When storing a task to the configuration cache, all objects directly or indirectly referenced through the task's fields are serialized. In most cases, deserialization preserves reference equality: if two fields `a` and `b` reference the same instance at configuration time, then upon deserialization they will reference the same instance again, so `a == b` (or `a === b` in Groovy and Kotlin syntax) still holds. However, for performance reasons, some classes, in particular `java.lang.String`, `java.io.File`, and many implementations of `java.util.Collection` interface, are serialized without preserving the reference equality. Upon deserialization, fields that referred to the object of such a class can refer to different but equal objects.

Let's look at a task that stores a user-defined object and an `ArrayList` in task fields.

build.gradle.kts

```kotlin
class StateObject {
    // ...
}

abstract class StatefulTask : DefaultTask() {
    @get:Internal
    var stateObject: StateObject? = null

    @get:Internal
    var strings: List<String>? = null
}


tasks.register<StatefulTask>("checkEquality") {
    val objectValue = StateObject()
    val stringsValue = arrayListOf("a", "b")

    stateObject = objectValue
    strings = stringsValue

    doLast { ①
        println("POJO reference equality: ${stateObject === objectValue}") ②
        println("Collection reference equality: ${strings === stringsValue}") ③
        println("Collection equality: ${strings == stringsValue}") ④
    }
}
```

build.gradle

```groovy
class StateObject {
    // ...
}

abstract class StatefulTask extends DefaultTask {
    @Internal
    StateObject stateObject

    @Internal
    List<String> strings
}


tasks.register("checkEquality", StatefulTask) {
    def objectValue = new StateObject()
    def stringsValue = ["a", "b"] as ArrayList<String>

    stateObject = objectValue
    strings = stringsValue

    doLast { ①
        println("POJO reference equality: ${stateObject === objectValue}") ②
        println("Collection reference equality: ${strings === stringsValue}") ③
        println("Collection equality: ${strings == stringsValue}") ④
    }
}
```

① `doLast` action captures the references from the enclosing scope. These captured references are also serialized to the configuration cache.

② Compare the reference to an object of user-defined class stored in the task field and the reference captured in the `doLast` action.

③ Compare the reference to `ArrayList` instance stored in the task field and the reference captured in the `doLast` action.

④ Check the equality of stored and captured lists.

Running the build without the configuration cache shows that reference equality is preserved in both cases.

```
⬡ gradle --no-configuration-cache checkEquality
> Task :checkEquality
POJO reference equality: true
Collection reference equality: true
Collection equality: true
```

However, with the configuration cache enabled, only the user-defined object references are the same. List references are different, though the referenced lists are equal.

```
⬡ gradle --configuration-cache checkEquality
> Task :checkEquality
POJO reference equality: true
Collection reference equality: false
Collection equality: true
```

In general, it isn't recommended to share mutable objects between configuration and execution phases. If you need to do this, you should always wrap the state in a class you define. There is no guarantee that the reference equality is preserved for standard Java, Groovy, and Kotlin types, or for Gradle-defined types.

Note that no reference equality is preserved between tasks: each task is its own "realm", so it is not possible to share objects between tasks. Instead, you can use a build service to wrap the shared state.

=== Accessing task extensions or conventions

Tasks should not access conventions and extensions, including extra properties, at execution time. Instead, any value that's relevant for the execution of the task should be modeled as a task property.

=== Using build listeners

Plugins and build scripts must not register any build listeners. That is listeners registered at configuration time that get notified at execution time. For example a `BuildListener` or a `TaskExecutionListener`.

These should be replaced by build services, registered to receive information about task execution if needed. Use dataflow actions to handle the build result instead of `buildFinished` listeners.

=== Running external processes

Plugin and build scripts should avoid running external processes at configuration time. In general, it is preferred to run external processes in tasks with properly declared inputs and outputs to avoid unnecessary work when the task is up-to-date. If necessary, only configuration-cache-compatible APIs should be used instead of Java and Groovy standard APIs or existing `ExecOperations`, `Project.exec`, `Project.javaexec`, and their likes in settings and init scripts. For simpler cases, when grabbing the output of the process is enough, providers.exec() and providers.javaexec() can be used:

build.gradle.kts

```kotlin
val gitVersion = providers.exec {
    commandLine("git", "--version")
}.standardOutput.asText.get()
```

build.gradle

```groovy
def gitVersion = providers.exec {
    commandLine("git", "--version")
}.standardOutput.asText.get()
```

For more complex cases a custom ValueSource implementation with injected `ExecOperations` can be used. This `ExecOperations` instance can be used at configuration time without restrictions.

build.gradle.kts

```kotlin
abstract class GitVersionValueSource : ValueSource<String,
ValueSourceParameters.None> {
    @get:Inject
    abstract val execOperations: ExecOperations

    override fun obtain(): String {
        val output = ByteArrayOutputStream()
        execOperations.exec {
            commandLine("git", "--version")
            standardOutput = output
        }
        return String(output.toByteArray(), Charset.defaultCharset())
    }
}
```

build.gradle

```groovy
abstract class GitVersionValueSource implements ValueSource<String,
ValueSourceParameters.None> {
    @Inject
    abstract ExecOperations getExecOperations()

    String obtain() {
        ByteArrayOutputStream output = new ByteArrayOutputStream()
        execOperations.exec {
            it.commandLine "git", "--version"
            it.standardOutput = output
        }
        return new String(output.toByteArray(), Charset.defaultCharset())
    }
}
```

The ValueSource implementation can then be used to create a provider with providers.of:

build.gradle.kts

```kotlin
val gitVersionProvider = providers.of(GitVersionValueSource::class) {}
val gitVersion = gitVersionProvider.get()
```

```
def gitVersionProvider = providers.of(GitVersionValueSource.class) {}
def gitVersion = gitVersionProvider.get()
```

In both approaches, if the value of the provider is used at configuration time then it will become a build configuration input. The external process will be executed for every build to determine if the configuration cache is up-to-date, so it is recommended to only call fast-running processes at configuration time. If the value changes then the cache is invalidated and the process will be run again during this build as part of the configuration phase.

=== Reading system properties and environment variables

Plugins and build scripts may read system properties and environment variables directly at configuration time with standard Java, Groovy, or Kotlin APIs or with the value supplier APIs. Doing so makes such variable or property a build configuration input, so changing the value invalidates the configuration cache. The configuration cache report includes a list of these build configuration inputs to help track them.

In general, you should avoid reading the value of system properties and environment variables at configuration time, to avoid cache misses when value changes. Instead, you can connect the `Provider` returned by providers.systemProperty() or providers.environmentVariable() to task properties.

Some access patterns that potentially enumerate all environment variables or system properties (for example, calling `System.getenv().forEach()` or using the iterator of its `keySet()`) are discouraged. In this case, Gradle cannot find out what properties are actual build configuration inputs, so every available property becomes one. Even adding a new property will invalidate the cache if this pattern is used.

Using a custom predicate to filter environment variables is an example of this discouraged pattern:

build.gradle.kts

```
val jdkLocations = System.getenv().filterKeys {
    it.startsWith("JDK_")
}
```

build.gradle

```
def jdkLocations = System.getenv().findAll {
    key, _ -> key.startsWith("JDK_")
}
```

The logic in the predicate is opaque to the configuration cache, so all environment variables are considered inputs. One way to reduce the number of inputs is to always use methods that query a concrete variable name, such as getenv(String), or getenv().get():

build.gradle.kts

```
val jdkVariables = listOf("JDK_8", "JDK_11", "JDK_17")
val jdkLocations = jdkVariables.filter { v ->
    System.getenv(v) != null
}.associate { v ->
    v to System.getenv(v)
}
```

build.gradle

```
def jdkVariables = ["JDK_8", "JDK_11", "JDK_17"]
def jdkLocations = jdkVariables.findAll { v ->
    System.getenv(v) != null
}.collectEntries { v ->
    [v, System.getenv(v)]
}
```

The fixed code above, however, is not exactly equivalent to the original as only an explicit list of variables is supported. Prefix-based filtering is a common scenario, so there are provider-based APIs to access system properties and environment variables:

build.gradle.kts

```
val jdkLocationsProvider = providers.environmentVariablesPrefixedBy("JDK_")
```

build.gradle

```
def jdkLocationsProvider = providers.environmentVariablesPrefixedBy("JDK_")
```

Note that the configuration cache would be invalidated not only when the value of the variable changes or the variable is removed but also when another variable with the matching prefix is added to the environment.

For more complex use cases a custom ValueSource implementation can be used. System properties and environment variables referenced in the code of the ValueSource do not become build configuration inputs, so any processing can be applied. Instead, the value of the ValueSource is recomputed each time the build runs and only if the value changes the configuration cache is invalidated. For example, a ValueSource can be used to get all environment variables with names containing the substring JDK:

build.gradle.kts

```
abstract class EnvVarsWithSubstringValueSource : ValueSource<Map<String, String>,
EnvVarsWithSubstringValueSource.Parameters> {
    interface Parameters : ValueSourceParameters {
        val substring: Property<String>
    }

    override fun obtain(): Map<String, String> {
        return System.getenv().filterKeys { key ->
            key.contains(parameters.substring.get())
        }
    }
}
val jdkLocationsProvider = providers.of(EnvVarsWithSubstringValueSource::class) {
    parameters {
        substring = "JDK"
    }
}
```

build.gradle

```groovy
abstract class EnvVarsWithSubstringValueSource implements ValueSource<Map<String,
String>, Parameters> {
    interface Parameters extends ValueSourceParameters {
        Property<String> getSubstring()
    }

    Map<String, String> obtain() {
        return System.getenv().findAll { key, _ ->
            key.contains(parameters.substring.get())
        }
    }
}
def jdkLocationsProvider = providers.of(EnvVarsWithSubstringValueSource.class) {
    parameters {
        substring = "JDK"
    }
}
```

=== Undeclared reading of files

Plugins and build scripts should not read files directly using the Java, Groovy or Kotlin APIs at configuration time. Instead, declare files as potential build configuration inputs using the value supplier APIs.

This problem is caused by build logic similar to this:

build.gradle.kts

```kotlin
val config = file("some.conf").readText()
```

build.gradle

```groovy
def config = file('some.conf').text
```

To fix this problem, read files using providers.fileContents() instead:

build.gradle.kts

```
val config = providers.fileContents(layout.projectDirectory.file("some.conf"))
    .asText
```

build.gradle

```
def config = providers.fileContents(layout.projectDirectory.file('some.conf'))
    .asText
```

In general, you should avoid reading files at configuration time, to avoid invalidating configuration cache entries when the file content changes. Instead, you can connect the `Provider` returned by [providers.fileContents()](#) to task properties.

Bytecode modifications and Java agent

To detect the configuration inputs, Gradle modifies the bytecode of classes on the build script classpath, like plugins and their dependencies. Gradle uses a Java agent to modify the bytecode. Integrity self-checks of some libraries may fail because of the changed bytecode or the agent's presence.

To work around this, you can use the [Worker API](#) with classloader or process isolation to encapsulate the library code. The bytecode of the worker's classpath is not modified, so the self-checks should pass. When process isolation is used, the worker action is executed in a separate worker process that doesn't have the Gradle Java agent installed.

In simple cases, when the libraries also provide command-line entry points (`public static void main()` method), you can also use the [JavaExec](#) task to isolate the library.

Handling of credentials and secrets

The configuration cache has currently no option to prevent storing secrets that are used as inputs, and so they might end up in the serialized configuration cache entry which, by default, is stored under `.gradle/configuration-cache` in your project directory.

To mitigate the risk of accidental exposure, Gradle encrypts the configuration cache. Gradle transparently generates a machine-specific secret key as required, caches it under the `GRADLE_USER_HOME` directory and uses it to encrypt the data in the project specific caches.

To enhance security further, make sure to:

- secure access to configuration cache entries;

- leverage `GRADLE_USER_HOME/gradle.properties` for storing secrets. The content of that file is not part of the configuration cache, only its fingerprint. If you store secrets in that file, care must be taken to protect access to the file content.

See [gradle/gradle#22618](#).

Providing an encryption key via `GRADLE_ENCRYPTION_KEY` environment variable

By default, Gradle automatically generates and manages the encryption key as a Java keystore stored under the `GRADLE_USER_HOME` directory.

For environments where this is undesirable (for instance, when the `GRADLE_USER_HOME` directory is shared across machines), you may provide Gradle with the exact encryption key to use when reading or writing the cached configuration data via the `GRADLE_ENCRYPTION_KEY` environment variable.

You must ensure that the same encryption key is consistently provided across multiple Gradle runs,

or else Gradle will not be able to reuse existing cached configurations.

Generating an encryption key that is compatible with GRADLE_ENCRYPTION_KEY

For Gradle to encrypt the configuration cache using a user-specified encryption key, you must run Gradle while having the GRADLE_ENCRYPTION_KEY environment variable set with a valid AES 128-bit key, encoded as a Base64 string.

One way of generating a Base64-encoded AES-128 key is by using a command like this:

```
 openssl enc -aes-128-cbc -P -base64 -pbkdf2 -nosalt -k YOUR-PASSPHRASE | grep key | cut -f 2 -d =
```

This command should work on Linux, Mac OS, or on Windows, if using a tool like Cygwin.

You can then use the Base64-encoded key produced by that command and set it as the value of the `GRADLE_ENCRYPTION_KEY` environment variable.

Not yet implemented

Support for using configuration caching with certain Gradle features is not yet implemented. Support for these features will be added in later Gradle releases.

Sharing the configuration cache

The configuration cache is currently stored locally only. It can be reused by hot or cold local Gradle daemons. But it can't be shared between developers or CI machines.

See gradle/gradle#13510.

Source dependencies

Support for source dependencies is not yet implemented. With the configuration cache enabled, no problem will be reported and the build will fail.

See gradle/gradle#13506.

Using a Java agent with builds run using TestKit

When running builds using TestKit, the configuration cache can interfere with Java agents, such as the Jacoco agent, that are applied to these builds.

See gradle/gradle#25979.

Fine-grained tracking of Gradle properties as build configuration inputs

Currently, all external sources of Gradle properties (`gradle.properties` in project directories and in the `GRADLE_USER_HOME`, environment variables and system properties that set properties, and properties specified with command-line flags) are considered build configuration inputs regardless of what properties are actually used at configuration time. These sources, however, are not included in the configuration cache report.

See gradle/gradle#20969.

=== Java Object Serialization

Gradle allows objects that support the Java Object Serialization protocol to be stored in the configuration cache.

The implementation is currently limited to serializable classes that implement the `java.io.Serializable` interface and define one of the following combination of methods:

- a `writeObject` method combined with a `readObject` method to control exactly which information to store;

- a `writeObject` method with no corresponding `readObject`; `writeObject` must eventually call `ObjectOutputStream.defaultWriteObject`;

- a `readObject` method with no corresponding `writeObject`; `readObject` must eventually call `ObjectInputStream.defaultReadObject`;

- a `writeReplace` method to allow the class to nominate a replacement to be written;

- a `readResolve` method to allow the class to nominate a replacement for the object just read;

The following *Java Object Serialization* features are **not** supported:

- serializable classes implementing the `java.io.Externalizable` interface; objects of such classes are discarded by the configuration cache during serialization and reported as problems;

- the `serialPersistentFields` member to explicitly declare which fields are serializable; the member, if present, is ignored; the configuration cache considers all but `transient` fields serializable;

- the following methods of `ObjectOutputStream` are not supported and will throw `UnsupportedOperationException`:

  - `reset()`, `writeFields()`, `putFields()`, `writeChars(String)`, `writeBytes(String)` and `writeUnshared(Any?)`.

- the following methods of `ObjectInputStream` are not supported and will throw `UnsupportedOperationException`:

  - `readLine()`, `readFully(ByteArray)`, `readFully(ByteArray, Int, Int)`, `readUnshared()`, `readFields()`, `transferTo(OutputStream)` and `readAllBytes()`.

- validations registered via `ObjectInputStream.registerValidation` are simply ignored;

- the `readObjectNoData` method, if present, is never invoked;

See gradle/gradle#13588.

=== Accessing top-level methods and variables of a build script at execution time

A common approach to reuse logic and data in a build script is to extract repeating bits into top-level methods and variables. However, calling such methods at execution time is not currently supported if the configuration cache is enabled.

For builds scripts written in Groovy, the task fails because the method cannot be found. The following snippet uses a top-level method in the `listFiles` task:

build.gradle

```groovy
def dir = file('data')

def listFiles(File dir) {
    dir.listFiles({ file -> file.isFile() } as FileFilter).name.sort()
}

tasks.register('listFiles') {
    doLast {
        println listFiles(dir)
    }
}
```

Running the task with the configuration cache enabled produces the following error:

```
Execution failed for task ':listFiles'.
> Could not find method listFiles() for arguments [/home/user/gradle/samples/data]
on task ':listFiles' of type org.gradle.api.DefaultTask.
```

To prevent the task from failing, convert the referenced top-level method to a static method within a class:

build.gradle

```groovy
def dir = file('data')

class Files {
    static def listFiles(File dir) {
        dir.listFiles({ file -> file.isFile() } as FileFilter).name.sort()
    }
}

tasks.register('listFilesFixed') {
    doLast {
        println Files.listFiles(dir)
    }
}
```

Build scripts written in Kotlin cannot store tasks that reference top-level methods or variables at execution time in the configuration cache at all. This limitation exists because the captured script object references cannot be serialized. The first run of the Kotlin version of the `listFiles` task fails with the configuration cache problem.

build.gradle.kts

```kotlin
val dir = file("data")

fun listFiles(dir: File): List<String> =
    dir.listFiles { file: File -> file.isFile }.map { it.name }.sorted()

tasks.register("listFiles") {
    doLast {
        println(listFiles(dir))
    }
}
```

To make the Kotlin version of this task compatible with the configuration cache, make the following changes:

build.gradle.kts

```kotlin
object Files { ①
    fun listFiles(dir: File): List<String> =
        dir.listFiles { file: File -> file.isFile }.map { it.name }.sorted()
}

tasks.register("listFilesFixed") {
    val dir = file("data") ②
    doLast {
        println(Files.listFiles(dir))
    }
}
```

① Define the method inside an object.

② Define the variable in a smaller scope.

See gradle/gradle#22879.

=== Using build services to invalidate the configuration cache

Currently, it is impossible to use a `BuildServiceProvider` or provider derived from it with `map` or `flatMap` as a parameter for the `ValueSource`, if the value of the `ValueSource` is accessed at configuration time. The same applies when such a `ValueSource` is obtained in a task that executes as part of the configuration phase, for example tasks of the `buildSrc` build or included builds contributing plugins. Note that using a `@ServiceReference` or storing `BuildServiceProvider` in an `@Internal`-annotated property of a task is safe. Generally speaking, this limitation makes it impossible to use a `BuildService` to invalidate the configuration cache.

See gradle/gradle#24085.

= Inspecting Gradle Builds

Gradle provides multiple ways to inspect your build:

- Profile with build scans

- Local profile reports

- Low level profiling

== What is a build scan?

Build scans are a persistent, shareable record of what happened when running a build. Build scans provide insights into your build that you can use to identify and fix performance bottlenecks.

In Gradle 4.3 and above, you can create a build scan using the `--scan` command line option:

```
$ gradle build --scan
```

For older Gradle versions, the Build Scan Plugin User Manual explains how to enable build scans.

At the end of your build, Gradle displays a URL where you can find your build scan:

```
BUILD SUCCESSFUL in 2s
4 actionable tasks: 4 executed

Publishing build scan...
https://gradle.com/s/e6ircx2wjbf7e
```

This section explains how to profile your build with build scans.

== Profile with build scans

The performance page can help use build scans to profile a build. To get there, click *"Performance"* in the left hand navigation menu or follow the "Explore performance" link on the build scan home page:

Figure 41. Performance page link on build scan home page

The performance page shows how long it took to complete different stages of a build. This page shows how long it took to:

- start up

- configure the build's projects

- resolve dependencies

- execute tasks

You also get details about environmental properties, such as whether a daemon was used or not.

Figure 42. Build scan performance page

In the above build scan, configuration takes over 13 seconds. Click on the *"Configuration"* tab to

break this stage into component parts, exposing the cause of the slowness.
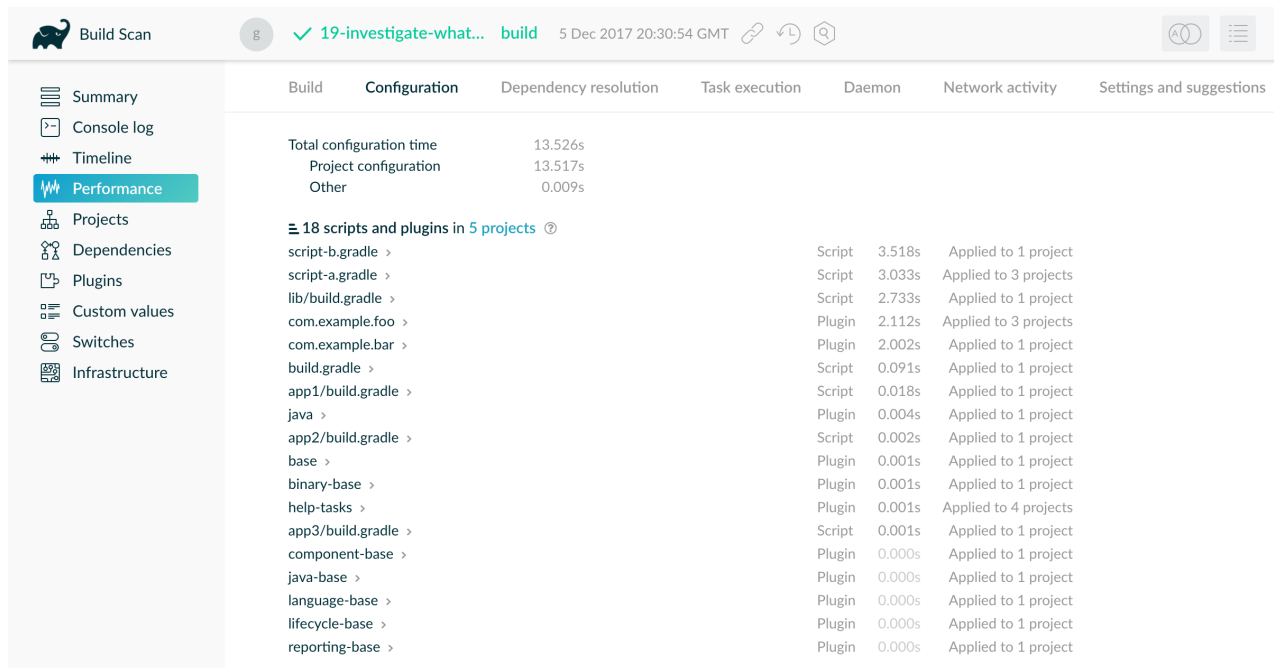
Figure 43. Build scan configuration breakdown

Here you can see the scripts and plugins applied to the project in descending order of how long they took to apply. The slowest plugin and script applications are good candidates for optimization. For example, the script `script-b.gradle` was applied once but took 3 seconds. Expand that row to see where the build applied this script.
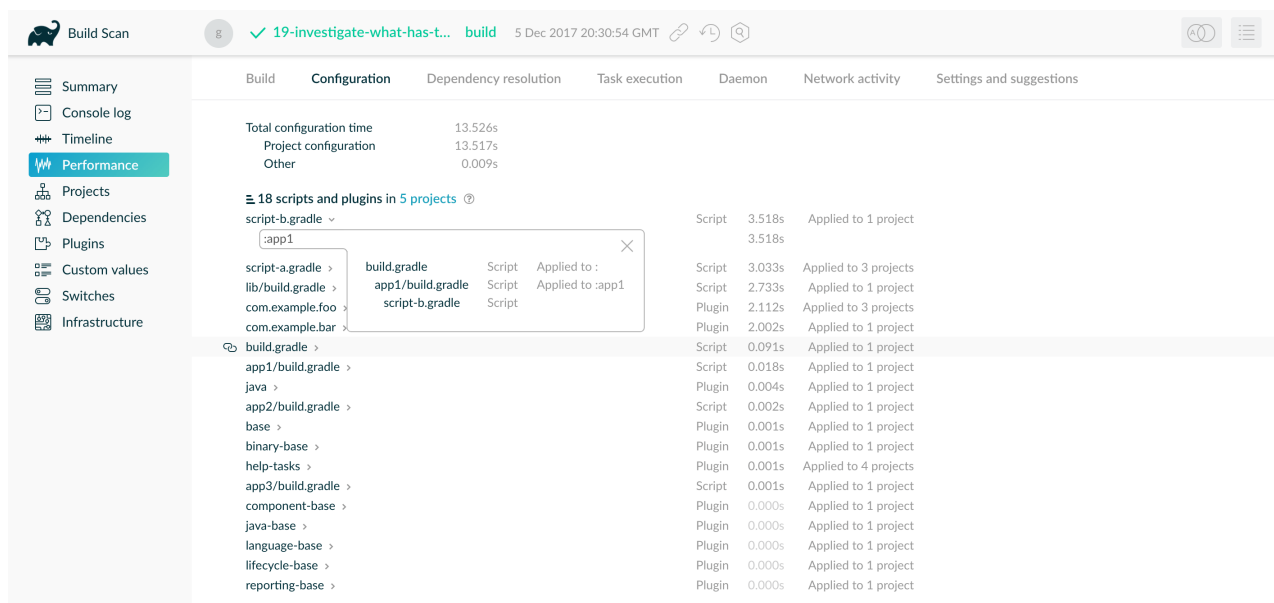
Figure 44. Showing the application of script-b.gradle to the build

You can see that subproject `:app1` applied the script once, from inside of that subproject's `build.gradle` file.

== Profile report

If you prefer not to use build scans, you can generate an HTML report in the `build/reports/profile` directory of your root project. To generate this report, use the `--profile` command-line option:

```
$ gradle --profile <tasks>
```

Each profile report has a timestamp in its name to avoid overwriting existing ones.

The report displays a breakdown of the time taken to run the build. However, this breakdown is not as detailed as a build scan. The following profile report shows the different categories available:

Figure 45. An example profile report

== Low level profiling

Sometimes your build can be slow even though your build scripts do everything right. This often comes down to inefficiencies in plugins and custom tasks or constrained resources. Use the Gradle Profiler to find these kinds of bottlenecks. With the Gradle Profiler, you can define scenarios like "Running 'assemble' after making an ABI-breaking change" and run your build several times to collect profiling data. Use the Profiler to produce build scans. Or combine it with method profilers like JProfiler and YourKit. These profilers can help you find inefficient algorithms in custom plugins. If you find that something in Gradle itself slows down your build, don't hesitate to send a profiler snapshot to performance@gradle.com.

== Performance categories

Both build scans and local profile reports break down build execution into the same categories. The following sections explain those categories.

=== Startup

This reflects Gradle's initialization time, which consists mostly of:

- JVM initialization and class loading

- Downloading the Gradle distribution if you're using the wrapper

- Starting the daemon if a suitable one isn't already running

- Executing Gradle initialization scripts

Even when a build execution has a long startup time, subsequent runs usually see a dramatic drop off in startup time. Persistently slow build startup times are usually the result of problems in your init scripts. Double check that the work you're doing there is necessary and performant.

=== Settings and *buildSrc*

After startup, Gradle initializes your project. Usually, Gradle only processes your settings file. If you have custom build logic in a `buildSrc` directory, Gradle also processes that logic. After building `buildSrc` once, Gradle considers it up to date. The up-to-date checks take significantly less time than logic processing. If your `buildSrc` phase takes too much time, consider breaking it out into a separate project. You can then add that project's JAR artifact as a dependency.

The settings file rarely contains code with significant I/O or computation. If you find that Gradle takes a long time to process it, use more traditional profiling methods, like the [the Gradle Profiler](), to determine the cause.

=== Loading projects

It normally doesn't take a significant amount of time to load projects, nor do you have any control over it. The time spent here is basically a function of the number of projects you have in your build.

== USING THE BUILD CACHE

= Build Cache

| TIP | Want to learn the tips and tricks top engineering teams use to keep builds fast and performant? [Register here]() for our Build Cache Training. |

== Overview

The Gradle *build cache* is a cache mechanism that aims to save time by reusing outputs produced by other builds. The build cache works by storing (locally or remotely) build outputs and allowing builds to fetch these outputs from the cache when it is determined that inputs have not changed, avoiding the expensive work of regenerating them.

A first feature using the build cache is *task output caching*. Essentially, task output caching leverages the same intelligence as [up-to-date checks]() that Gradle uses to avoid work when a previous local build has already produced a set of task outputs. But instead of being limited to

the previous build in the same workspace, task output caching allows Gradle to reuse task outputs from any earlier build in any location on the local machine. When using a shared build cache for task output caching this even works across developer machines and build agents.

Apart from tasks, artifact transforms can also leverage the build cache and re-use their outputs similarly to task output caching.

> **TIP** For a hands-on approach to learning how to use the build cache, start with reading through the use cases for the build cache and the follow up sections. It covers the different scenarios that caching can improve and has detailed discussions of the different caveats you need to be aware of when enabling caching for a build.

Enable the Build Cache

By default, the build cache is not enabled. You can enable the build cache in a couple of ways:

Run with `--build-cache` on the command-line
Gradle will use the build cache for this build only.

Put `org.gradle.caching=true` in your `gradle.properties`
Gradle will try to reuse outputs from previous builds for all builds, unless explicitly disabled with `--no-build-cache`.

When the build cache is enabled, it will store build outputs in the Gradle User Home. For configuring this directory or different kinds of build caches see Configure the Build Cache.

Task Output Caching

Beyond incremental builds described in up-to-date checks, Gradle can save time by reusing outputs from previous executions of a task by matching inputs to the task. Task outputs can be reused between builds on one computer or even between builds running on different computers via a build cache.

We have focused on the use case where users have an organization-wide remote build cache that is populated regularly by continuous integration builds. Developers and other continuous integration agents should load cache entries from the remote build cache. We expect that developers will not be allowed to populate the remote build cache, and all continuous integration builds populate the build cache after running the `clean` task.

For your build to play well with task output caching it must work well with the incremental build feature. For example, when running your build twice in a row all tasks with outputs should be `UP-TO-DATE`. You cannot expect faster builds or correct builds when enabling task output caching when this prerequisite is not met.

Task output caching is automatically enabled when you enable the build cache, see Enable the Build Cache.

What does it look like

Let us start with a project using the Java plugin which has a few Java source files. We run the build the first time.

```
> gradle --build-cache compileJava
:compileJava
:processResources
:classes
:jar
:assemble

BUILD SUCCESSFUL
```

We see the directory used by the local build cache in the output. Apart from that the build was the same as without the build cache. Let's clean and run the build again.

```
> gradle clean
:clean

BUILD SUCCESSFUL
```

```
> gradle --build-cache assemble
:compileJava FROM-CACHE
:processResources
:classes
:jar
:assemble

BUILD SUCCESSFUL
```

Now we see that, instead of executing the `:compileJava` task, the outputs of the task have been loaded from the build cache. The other tasks have not been loaded from the build cache since they are not cacheable. This is due to `:classes` and `:assemble` being lifecycle tasks and `:processResources` and `:jar` being Copy-like tasks which are not cacheable since it is generally faster to execute them.

== Cacheable tasks

Since a task describes all of its inputs and outputs, Gradle can compute a *build cache key* that uniquely defines the task's outputs based on its inputs. That build cache key is used to request previous outputs from a build cache or store new outputs in the build cache. If the previous build outputs have been already stored in the cache by someone else, e.g. your continuous integration server or other developers, you can avoid executing most tasks locally.

The following inputs contribute to the build cache key for a task in the same way that they do for up-to-date checks:

- The task type and its classpath

- The names of the output properties
- The names and values of properties annotated as described in the section called "Custom task types"
- The names and values of properties added by the DSL via TaskInputs
- The classpath of the Gradle distribution, buildSrc and plugins
- The content of the build script when it affects execution of the task

Task types need to opt-in to task output caching using the @CacheableTask annotation. Note that @CacheableTask is not inherited by subclasses. Custom task types are *not* cacheable by default.

=== Built-in cacheable tasks

Currently, the following built-in Gradle tasks are cacheable:

- Java toolchain: JavaCompile, Javadoc
- Groovy toolchain: GroovyCompile, Groovydoc
- Scala toolchain: ScalaCompile, `org.gradle.language.scala.tasks.PlatformScalaCompile` (removed), ScalaDoc
- Native toolchain: CppCompile, CCompile, SwiftCompile
- Testing: Test
- Code quality tasks: Checkstyle, CodeNarc, Pmd
- JaCoCo: JacocoReport
- Other tasks: AntlrTask, ValidatePlugins, WriteProperties

All other built-in tasks are currently not cacheable.

Some tasks, like Copy or Jar, usually do not make sense to make cacheable because Gradle is only copying files from one location to another. It also doesn't make sense to make tasks cacheable that do not produce outputs or have no task actions.

=== Third party plugins

There are third party plugins that work well with the build cache. The most prominent examples are the Android plugin 3.1+ and the Kotlin plugin 1.2.21+. For other third party plugins, check their documentation to find out whether they support the build cache.

=== Declaring task inputs and outputs

It is very important that a cacheable task has a complete picture of its inputs and outputs, so that the results from one build can be safely re-used somewhere else.

Missing task inputs can cause incorrect cache hits, where different results are treated as identical because the same cache key is used by both executions. Missing task outputs can cause build failures if Gradle does not completely capture all outputs for a given task. Wrongly declared task inputs can lead to cache misses especially when containing volatile data or

absolute paths. (See [the section called "Task inputs and outputs"](#) on what should be declared as inputs and outputs.)

NOTE	The task path is *not* an input to the build cache key. This means that tasks with different task paths can re-use each other's outputs as long as Gradle determines that executing them yields the same result.

In order to ensure that the inputs and outputs are properly declared use integration tests (for example using TestKit) to check that a task produces the same outputs for identical inputs and captures all output files for the task. We suggest adding tests to ensure that the task inputs are relocatable, i.e. that the task can be loaded from the cache into a different build directory (see [@PathSensitive](#)).

In order to handle volatile inputs for your tasks consider [configuring input normalization](#).

=== Marking tasks as non-cacheable by default

There are certain tasks that don't benefit from using the build cache. One example is a task that only moves data around the file system, like a `Copy` task. You can signify that a task is not to be cached by adding the `@DisableCachingByDefault` annotation to it. You can also give a human-readable reason for not caching the task by default. The annotation can be used on its own, or together with `@CacheableTask`.

NOTE	This annotation is only for documenting the reason behind not caching the task by default. Build logic can override this decision via the runtime API (see below).

== Enable caching of non-cacheable tasks

As we have seen, built-in tasks, or tasks provided by plugins, are cacheable if their class is annotated with the `Cacheable` annotation. But what if you want to make cacheable a task whose class is not cacheable? Let's take a concrete example: your build script uses a generic `NpmTask` task to create a JavaScript bundle by delegating to NPM (and running `npm run bundle`). This process is similar to a complex compilation task, but `NpmTask` is too generic to be cacheable by default: it just takes arguments and runs npm with those arguments.

The inputs and outputs of this task are simple to figure out. The inputs are the directory containing the JavaScript files, and the NPM configuration files. The output is the bundle file generated by this task.

=== Using annotations

We create a subclass of the `NpmTask` and use [annotations to declare the inputs and outputs](#).

When possible, it is better to use delegation instead of creating a subclass. That is the case for the built in `JavaExec`, `Exec`, `Copy` and `Sync` tasks, which have a method on `Project` to do the actual work.

If you're a modern JavaScript developer, you know that bundling can be quite long, and is worth caching. To achieve that, we need to tell Gradle that it's allowed to cache the output of

that task, using the @CacheableTask annotation.

This is sufficient to make the task cacheable on your own machine. However, input files are identified by default by their absolute path. So if the cache needs to be shared between several developers or machines using different paths, that won't work as expected. So we also need to set the path sensitivity. In this case, the relative path of the input files can be used to identify them.

Note that it is possible to override property annotations from the base class by overriding the getter of the base class and annotating that method.

build.gradle.kts

```kotlin
@CacheableTask                                               ①
abstract class BundleTask : NpmTask() {

    @get:Internal                                           ②
    override val args
        get() = super.args


    @get:InputDirectory
    @get:SkipWhenEmpty
    @get:PathSensitive(PathSensitivity.RELATIVE)            ③
    abstract val scripts: DirectoryProperty

    @get:InputFiles
    @get:PathSensitive(PathSensitivity.RELATIVE)            ④
    abstract val configFiles: ConfigurableFileCollection

    @get:OutputFile
    abstract val bundle: RegularFileProperty

    init {
        args.addAll("run", "bundle")
        bundle = projectLayout.buildDirectory.file("bundle.js")
        scripts = projectLayout.projectDirectory.dir("scripts")
        configFiles.from(projectLayout.projectDirectory.file("package.json"))
        configFiles.from(projectLayout.projectDirectory.file("package-lock.json"))
    }
}

tasks.register<BundleTask>("bundle")
```

build.gradle

```
@CacheableTask                                          ①
abstract class BundleTask extends NpmTask {

    @Override @Internal                                 ②
    ListProperty<String> getArgs() {
        super.getArgs()
    }

    @InputDirectory
    @SkipWhenEmpty
    @PathSensitive(PathSensitivity.RELATIVE)            ③
    abstract DirectoryProperty getScripts()

    @InputFiles
    @PathSensitive(PathSensitivity.RELATIVE)            ④
    abstract ConfigurableFileCollection getConfigFiles()

    @OutputFile
    abstract RegularFileProperty getBundle()

    BundleTask() {
        args.addAll("run", "bundle")
        bundle = projectLayout.buildDirectory.file("bundle.js")
        scripts = projectLayout.projectDirectory.dir("scripts")
        configFiles.from(projectLayout.projectDirectory.file("package.json"))
        configFiles.from(projectLayout.projectDirectory.file("package-lock.json"))
    }
}

tasks.register('bundle', BundleTask)
```

- (1) Add `@CacheableTask` to enable caching for the task.
- (2) Override the getter of a property of the base class to change the input annotation to `@Internal`.
- (3) (4) Declare the path sensitivity.

=== Using the runtime API

If for some reason you cannot create a new custom task class, it is also possible to make a task cacheable using the runtime API to declare the inputs and outputs.

For enabling caching for the task you need to use the TaskOutputs.cacheIf() method.

The declarations via the runtime API have the same effect as the annotations described above. Note that you cannot override file inputs and outputs via the runtime API. Input properties can be overridden by specifying the same property name.

build.gradle.kts

```
tasks.register<NpmTask>("bundle") {
    args = listOf("run", "bundle")

    outputs.cacheIf { true }

    inputs.dir(file("scripts"))
        .withPropertyName("scripts")
        .withPathSensitivity(PathSensitivity.RELATIVE)

    inputs.files("package.json", "package-lock.json")
        .withPropertyName("configFiles")
        .withPathSensitivity(PathSensitivity.RELATIVE)

    outputs.file(layout.buildDirectory.file("bundle.js"))
        .withPropertyName("bundle")
}
```

build.gradle

```
tasks.register('bundle', NpmTask) {
    args = ['run', 'bundle']

    outputs.cacheIf { true }

    inputs.dir(file("scripts"))
        .withPropertyName("scripts")
        .withPathSensitivity(PathSensitivity.RELATIVE)

    inputs.files("package.json", "package-lock.json")
        .withPropertyName("configFiles")
        .withPathSensitivity(PathSensitivity.RELATIVE)

    outputs.file(layout.buildDirectory.file("bundle.js"))
        .withPropertyName("bundle")
}
```

== Configure the Build Cache

You can configure the build cache by using the Settings.buildCache(org.gradle.api.Action) block in `settings.gradle`.

Gradle supports a `local` and a `remote` build cache that can be configured separately. When both build caches are enabled, Gradle tries to load build outputs from the local build cache first, and then tries the remote build cache if no build outputs are found. If outputs are found in the remote cache, they are also stored in the local cache, so next time they will be found locally. Gradle stores ("pushes") build outputs in any build cache that is enabled and has BuildCache.isPush() set to `true`.

By default, the local build cache has push enabled, and the remote build cache has push disabled.

The local build cache is pre-configured to be a DirectoryBuildCache and enabled by default. The remote build cache can be configured by specifying the type of build cache to connect to (BuildCacheConfiguration.remote(java.lang.Class)).

=== Built-in local build cache

The built-in local build cache, DirectoryBuildCache, uses a directory to store build cache artifacts. By default, this directory resides in the Gradle User Home, but its location is configurable.

Gradle will periodically clean-up the local cache directory by removing entries that have not been used recently to conserve disk space. How often Gradle will perform this clean-up is configurable as shown in the example below. Note that cache entries are cleaned-up regardless of the project they were produced by. If different projects configure this clean-up to run at different periods, the shortest period will clean-up cache entries for all projects. Therefore it is recommended to configure this setting globally in the init script. The Configuration use-cases section has an example of putting cache configuration in the init script.

For more details on the configuration options refer to the DSL documentation of DirectoryBuildCache. Here is an example of the configuration.

settings.gradle.kts

```
buildCache {
    local {
        directory = File(rootDir, "build-cache")
        removeUnusedEntriesAfterDays = 30
    }
}
```

settings.gradle

```
buildCache {
    local {
        directory = new File(rootDir, 'build-cache')
        removeUnusedEntriesAfterDays = 30
    }
}
```

=== Remote HTTP build cache

HttpBuildCache provides the ability read to and write from a remote cache via HTTP.

With the following configuration, the local build cache will be used for storing build outputs while the local and the remote build cache will be used for retrieving build outputs.

settings.gradle.kts

```
buildCache {
    remote<HttpBuildCache> {
        url = uri("https://example.com:8123/cache/")
    }
}
```

settings.gradle

```
buildCache {
    remote(HttpBuildCache) {
        url = 'https://example.com:8123/cache/'
    }
}
```

When attempting to load an entry, a `GET` request is made to `https://example.com:8123/cache/«cache-key»`. The response must have a `2xx` status and the cache entry as the body, or a `404 Not Found` status if the entry does not exist.

When attempting to store an entry, a `PUT` request is made to `https://example.com:8123/cache/«cache-key»`. Any `2xx` response status is interpreted as success. A `413 Payload Too Large` response may be returned to indicate that the payload is larger than the server will accept, which will not be treated as an error.

==== Specifying access credentials

HTTP Basic Authentication is supported, with credentials being sent preemptively.

settings.gradle.kts

```
buildCache {
    remote<HttpBuildCache> {
        url = uri("https://example.com:8123/cache/")
        credentials {
            username = "build-cache-user"
            password = "some-complicated-password"
        }
    }
}
```

settings.gradle

```
buildCache {
    remote(HttpBuildCache) {
        url = 'https://example.com:8123/cache/'
        credentials {
            username = 'build-cache-user'
            password = 'some-complicated-password'
        }
    }
}
```

==== Redirects

`3xx` redirecting responses will be followed automatically.

Servers must take care when redirecting `PUT` requests as only `307` and `308` redirect responses will be followed with a `PUT` request. All other redirect responses will be followed with a `GET` request, as per RFC 7231, without the entry payload as the body.

==== Network error handling

Requests that fail during request transmission, after having established a TCP connection, will be retried automatically.

This prevents temporary problems, such as connection drops, read or write timeouts, and low level network failures such as a connection resets, causing cache operations to fail and disabling the remote cache for the remainder of the build.

Requests will be retried up to 3 times. If the problem persists, the cache operation will fail and the remote cache will be disabled for the remainder of the build.

==== Using SSL

By default, use of HTTPS requires the server to present a certificate that is trusted by the build's Java runtime. If your server's certificate is not trusted, you can:

1. Update the trust store of your Java runtime to allow it to be trusted

2. Change the build environment to use an alternative trust store for the build runtime

3. Disable the requirement for a trusted certificate

The trust requirement can be disabled by setting HttpBuildCache.isAllowUntrustedServer() to `true`. Enabling this option is a security risk, as it allows any cache server to impersonate the intended server. It should only be used as a temporary measure or in very tightly controlled network environments.

settings.gradle.kts

```
buildCache {
    remote<HttpBuildCache> {
        url = uri("https://example.com:8123/cache/")
        isAllowUntrustedServer = true
    }
}
```

```
buildCache {
    remote(HttpBuildCache) {
        url = 'https://example.com:8123/cache/'
        allowUntrustedServer = true
    }
}
```

==== HTTP expect-continue

Use of HTTP Expect-Continue can be enabled. This causes upload requests to happen in two parts: first a check whether a body would be accepted, then transmission of the body if the server indicates it will accept it.

This is useful when uploading to cache servers that routinely redirect or reject upload requests, as it avoids uploading the cache entry just to have it rejected (e.g. the cache entry is larger than the cache will allow) or redirected. This additional check incurs extra latency when the server accepts the request, but reduces latency when the request is rejected or redirected.

Not all HTTP servers and proxies reliably implement Expect-Continue. Be sure to check that your cache server does support it before enabling.

To enable, set HttpBuildCache.isUseExpectContinue() to `true`.

settings.gradle.kts

```
buildCache {
    remote<HttpBuildCache> {
        url = uri("https://example.com:8123/cache/")
        isUseExpectContinue = true
    }
}
```

settings.gradle

```
buildCache {
    remote(HttpBuildCache) {
        url = 'https://example.com:8123/cache/'
        useExpectContinue = true
    }
}
```

=== Configuration use cases

The recommended use case for the remote build cache is that your continuous integration server populates it from clean builds while developers only load from it. The configuration would then look as follows.

settings.gradle.kts

```
val isCiServer = System.getenv().containsKey("CI")

buildCache {
    remote<HttpBuildCache> {
        url = uri("https://example.com:8123/cache/")
        isPush = isCiServer
    }
}
```

settings.gradle

```
boolean isCiServer = System.getenv().containsKey("CI")

buildCache {
    remote(HttpBuildCache) {
        url = 'https://example.com:8123/cache/'
        push = isCiServer
    }
}
```

It is also possible to configure the build cache from an init script, which can be used from the command line, added to your Gradle User Home or be a part of your custom Gradle distribution.

init.gradle.kts

```
gradle.settingsEvaluated {
    buildCache {
        // vvv Your custom configuration goes here
        remote<HttpBuildCache> {
            url = uri("https://example.com:8123/cache/")
        }
        // ^^^ Your custom configuration goes here
    }
}
```

init.gradle

```
gradle.settingsEvaluated { settings ->
    settings.buildCache {
        // vvv Your custom configuration goes here
        remote(HttpBuildCache) {
            url = 'https://example.com:8123/cache/'
        }
        // ^^^ Your custom configuration goes here
    }
}
```

Build cache, composite builds and `buildSrc`

Gradle's composite build feature allows including other complete Gradle builds into another. Such included builds will inherit the build cache configuration from the top level build, regardless of whether the included builds define build cache configuration themselves or not.

The build cache configuration present for any included build is effectively ignored, in favour of the top level build's configuration. This also applies to any `buildSrc` projects of any included builds.

The `buildSrc` directory is treated as an included build, and as such it inherits the build cache configuration from the top-level build.

| NOTE | This configuration precedence does not apply to plugin builds included through `pluginManagement` as these are loaded *before* the cache configuration itself. |

How to set up an HTTP build cache backend

Gradle provides a Docker image for a build cache node, which can connect with Develocity for centralized management. The cache node can also be used without a Develocity installation with restricted functionality.

Implement your own Build Cache

Using a different build cache backend to store build outputs (which is not covered by the built-in support for connecting to an HTTP backend) requires implementing your own logic for connecting to your custom build cache backend. To this end, custom build cache types can be registered via BuildCacheConfiguration.registerBuildCacheService(java.lang.Class, java.lang.Class).

Develocity includes a high-performance, easy to install and operate, shared build cache backend.

Use cases for the build cache

This section covers the different use cases for Gradle's build cache, from local-only development to caching task outputs across large teams.

Speed up developer builds with the local cache

Even when used by a single developer only, the build cache can be very useful. Gradle's *incremental build* feature helps to avoid work that is already done, but once you re-execute a task, any previous results are forgotten. When you are switching branches back and forth, the local results get rebuilt over and over again, even if you are building something that has already been built before. The build cache remembers the earlier build results, and greatly reduces the need to rebuild things when they have already been built locally. This can also extend to rebuilding different commits, like when running `git bisect`.

The local cache can also be useful when working with a project that has multiple variants, as

in the case of Android projects. Each variant has a number of tasks associated with it, and some of those task variant dimensions, despite having different names, can end up producing the same output. With the local cache enabled, reuse between task variants will happen automatically when applicable.

Share results between CI builds

The build cache can do more than go back-and-forth in time: it can also bridge physical distance between computers, allowing results generated on one machine to be re-used by another. A typical first step when introducing the build cache within a team is to enable it for builds running as part of *continuous integration* only. Using a shared HTTP build cache backend (such as [the one provided by Develocity](#)) can significantly reduce the work CI agents need to do. This translates into faster feedback for developers, and less money spent on the CI resources. Faster builds also mean fewer commits being part of each build, which makes debugging issues more efficient.

Beginning with the build cache on CI is a good first step as the environment on CI agents is usually more stable and predictable than developer machines. This helps to identify any possible issues with the build that may affect cacheability.

If you are subject to audit requirements regarding the artifacts you ship to your customers you may need to disable the build cache for certain builds. Develocity may help you with fulfilling these requirements while still using the build cache for all your builds. It allows you to easily find out which build produced an artifact coming from the build cache via build scans.

Accelerate developer builds by reusing CI results

When multiple developers work on the same project, they don't just need to build their own changes: whenever they pull from version control, they end up having to build each other's changes as well. Whenever a developer is working on something independent of the pulled changes, they can safely reuse outputs already generated on CI. Say, you're working on module

"A", and you pull in some changes to module "B" (which does not depend on your module). If those changes were already built in CI, you can download the task outputs for module "B" from the cache instead of generating them locally. A typical use case for this is when developers start their day, pull all changes from version control and then run their first build.

The changes don't need to be completely independent, either; we'll take a look at the strategies to reuse results when dependencies are involved in the section about the different forms of normalization.

== Combine remote results with local caching

You can utilize both a local and a remote cache for a compound effect. While loading results from a CI-filled remote cache helps to avoid work needed because of changes by other developers, the local cache can speed up switching branches and doing `git bisect`. On CI machines the local cache can act as a mirror of the remote cache, significantly reducing network usage.

== Share results between developers

Allowing developers to upload their results to a shared cache is possible, but not recommended. Developers can make changes to task inputs or outputs while the task is executing. They can do this unintentionally and without noticing, for example by making changes in their IDEs while a build is running. Currently, Gradle has no good way to defend against these changes, and will simply cache whatever is in the output directory once the task is finished. This again can lead to corrupted results being uploaded to the shared cache. This recommendation might change when Gradle has added the necessary safeguards against unintentional modification of task inputs and outputs.

If you want to share task output from incremental builds, i.e. non-clean builds, you have to make sure that all cacheable tasks are properly configured and implemented to deal with stale output. There are for example annotation processors that do not clean up stale files in the corresponding classes/resources directories. The cache is a great forcing function to fix these problems, which will also make your incremental builds much more reliable. At the same time, until you have confidence that the incremental build behavior is flawless, only use clean builds to upload content to the cache.

Build cache performance

The sole reason to use any build cache is to make builds faster. But how much faster can you go when using the cache? Measuring the impact is both important and complicated, as cache performance is determined by many factors. Performing measurements of the cache's impact can validate the extra effort (work, infrastructure) that is required to start using the cache. These measurements can later serve as baselines for future improvements, and to watch for signs of regressions.

> **NOTE** Proper configuration and maintenance of a build can improve caching performance in a big way.

Fully cached builds

The most straightforward way to get a feel for what the cache can do for you is to measure the difference between a non-cached build and a *fully cached* build. This will give you the theoretical limit of how fast builds with the cache can get, if everything you're trying to build has already been built. The easiest way to measure this is using the local cache:

1. Clean the cache directory to avoid any hits from previous builds (`rm -rf $GRADLE_USER_HOME/caches/build-cache-*`)

2. Run the build (e.g. `./gradlew --build-cache clean assemble`), so that all the results from cacheable tasks get stored in the cache.

3. Run the build again (e.g. `./gradlew --build-cache clean assemble`); depending on your build, you should see many of the tasks being retrieved from the cache.

4. Compare the execution time for the two builds

> **NOTE** You may encounter a few cached tasks even in the first of the two builds, where no previously cached results should be available. This can happen if you have tasks in your build that are configured to produce the same results from the same inputs; in such a case once one of these tasks has finished, Gradle will simply reuse its output for the rest of the tasks.

Normally, your *fully cached* build should be significantly faster than the `clean` build: this is the theoretical limit of how much time using the build cache can save on your particular build. You usually don't get the achievable performance gains on the first try, see finding problems with task output caching. As your build logic is evolving and changing it is also important to make sure that the cache effectiveness is not regressing. Build scans provide a detailed performance breakdown which show you how effectively your build is using the build cache:
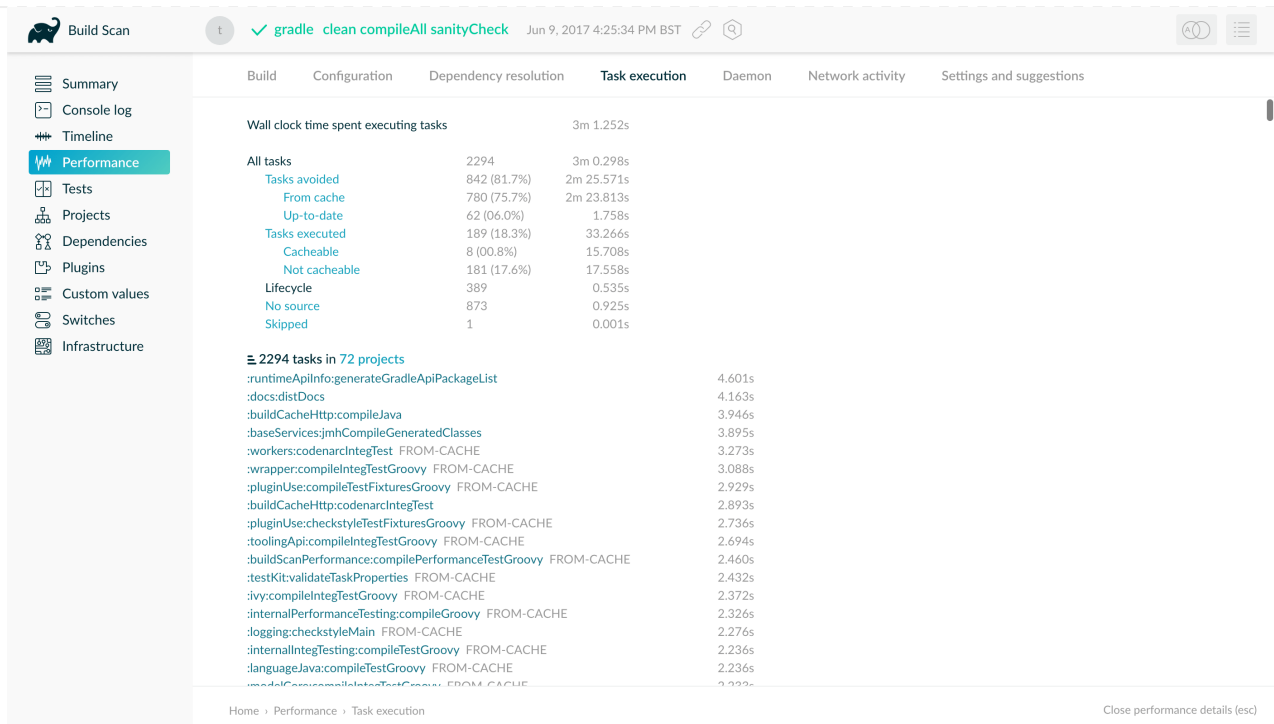
Fully cached builds occur in situations when developers check out the latest from version control and then build, for example to generate the latest sources they need in their IDE. The purpose of running most builds though is to process some new changes. The structure of the software being built (how many modules are there, how independent are its parts etc.), and the nature of the changes themselves ("big refactor in the core of the system" vs. "small change to a unit test" etc.) strongly influence the performance gains delivered by the build cache. As developers tend to submit different kinds of changes over time, caching performance is expected to vary with each change. As with any cache, the impact should therefore be measured over time.

In a setup where a team uses a shared cache backend, there are two locations worth measuring cache impact at: on CI and on developer machines.

== Cache impact on CI builds

The best way to learn about the impact of caching on CI is to set up the same builds with the cache enabled and disabled, and compare the results over time. If you have a single Gradle build step that you want to enable caching for, it's easy to compare the results using your CI system's built-in statistical tools.

Measuring complex pipelines may require more work or external tools to collect and process measurements. It's important to distinguish those parts of the pipeline that caching has no effect on, for example, the time builds spend waiting in the CI system's queue, or time taken by checking out source code from version control.

When using Develocity, you can use the Export API to access the necessary data and run your analytics. Develocity provides much richer data compared to what can be obtained from CI servers. For example, you can get insights into the execution of single tasks, how many tasks were retrieved from the cache, how long it took to download from the cache, the properties that were used to calculate the cache key and more. When using your CI servers built in functions, you can use statistic charts if you use Teamcity for your CI builds. Most of time you

will end up extracting data from your CI server via the corresponding REST API (see Jenkins remote access API and Teamcity REST API).

Typically, CI builds above a certain size include parallel sections to utilize multiple agents. With parallel pipelines you can measure the wall-clock time it takes for a set of changes to go from having been pushed to version control to being built, verified and deployed. The build cache's effect in this case can be measured in the reduction of the time developers have to wait for feedback from CI.

You can also measure the cumulative time your build agents spent building a changeset, which will give you a sense of the amount of work the CI infrastructure has to exert. The cache's effect here is less money spent on CI resources, as you don't need as many CI agents to maintain the same number of changes built.

If you want to look at the measurement for the Gradle build itself you can have a look at the blog post "Introducing the build cache".

== Measuring developer builds

Gradle's build cache can be very useful in reducing CI infrastructure cost and feedback time, but it usually has the biggest impact when developers can reuse cached results in their local builds. This is also the hardest to quantify for a number of reasons:

- developers run different builds

- developers can have different hardware, or have different settings

- developers run all kinds of other things on their machines that can slow them down

When using Develocity you can use the Export API to extract data about developer builds, too. You can then create statistics on how many tasks were cached per developer or build. You can even compare the times it took to execute the task vs loading it from the cache and then estimate the time saved per developer.

When using the Develocity build cache backend you should pay close attention to the hit rate in the admin UI. A rise in the hit rate there probably indicates better usage by developers:

Gradle Enterprise Build Cache

Usage summary

Last 24 hours

Node	Stored	Evicted	Hits	Misses	Hit Rate	Copy Ins	Copy Outs	Data Received	Data Sent
Built-in	24,839	18,799	933,884	28,649	97 %	0	1,519	4.66 GB	305.57 GB
California	103	0	39,502	113	99 %	1,387	0	359.84 MB	12.43 GB
Sydney	0	0	212	562	27 %	132	0	10.34 MB	14.15 MB
Totals	24,942	18,799	973,598	29,324	97 %	1,519	1,519	5.03 GB	318.02 GB

Last 7 days

Node	Stored	Evicted	Hits	Misses	Hit Rate	Copy Ins	Copy Outs	Data Received	Data Sent
Built-in	176,777	174,368	7,703,018	200,971	97 %	0	13,757	35.91 GB	2.55 TB
California	3,625	0	817,014	4,295	99 %	13,107	0	3.55 GB	257.25 GB
Sydney	0	0	927	945	49 %	650	0	69.47 MB	80.61 MB
Totals	180,402	174,368	8,520,959	206,211	97 %	13,757	13,757	39.53 GB	2.80 TB

Last 30 days

Node	Stored	Evicted	Hits	Misses	Hit Rate	Copy Ins	Copy Outs	Data Received	Data Sent

== Analyzing performance in build scans

Build scans provide a summary of all cache operations for a build via the *"Build cache"* section of the *"Performance"* page.

This page details which tasks were able to be avoided by cache hits, and which missed. It also indicates the hits and misses for the local and remote caches individually. For remote cache operations, the time taken to transfer artifacts to and from the cache is given, along with the transfer rate. This is particularly important for assessing the impact of network link quality on performance, as transfer times contribute to build time.

== Remote cache performance

Improving the network link between the build and the remote cache can significantly improve build cache performance. How to do this depends on the remote cache in use and your network environment.

The multi-node remote build cache provided by Develocity is a fast and efficient, purpose built, remote build cache. In particular, if your development team is geographically distributed, its replication features can significantly improve performance by allowing developers to use a cache that they have a good network link to. See the "Build Cache Replication" section of the Develocity Admin Manual for more information.

= Important concepts

How much of your build gets loaded from the cache depends on many factors. In this section you will see some of the tools that are essential for well-cached builds. Build scans are part of that toolchain and will be used throughout this guide.

== Build cache key

Artifacts in the build cache are uniquely identified by a build cache key. A build cache key is assigned to each cacheable task when running with the build cache enabled and is used for both loading and storing task outputs to the build cache. The following inputs contribute to the build cache key for a task:

- The task implementation
- The task action implementations
- The names of the output properties
- The names and values of task inputs

Two tasks can reuse their outputs by using the build cache if their associated build cache keys are the same.

== Repeatable task outputs

Assume that you have a code generator task as part of your build. When you have a fully up to date build and you clean and re-run the code generator task on the same code base it should generate *exactly the same output*, so anything that depends on that output will stay up-to-date.

It might also be that your code generator adds some extra information to its output that doesn't depend on its declared inputs, like a timestamp. In such a case re-executing the task *will* result in different code being generated (because the timestamp will be updated). Tasks that depend on the code generator's output will need to be re-executed.

When a task is cacheable, then the very nature of task output caching makes sure that the task will have the same outputs for a given set of inputs. Therefore, cacheable tasks should have repeatable task outputs. If they don't, then the result of executing the task and loading the task from the cache may be different, which can lead to hard-to-diagnose cache misses.

In some cases even well-trusted tools can produce non-repeatable outputs, and lead to cascading effects. One example is Oracle's Java compiler, which, due to a bug, was producing

different bytecode depending on the order source files to be compiled were presented to it. If you were using Oracle JDK 8u31 or earlier to compile code in the `buildSrc` subproject, this could lead to all of your custom tasks producing occasional cache misses, because of the difference in their classpaths (which include `buildSrc`).

The key here is that cacheable tasks should not use non-repeatable task outputs as an input.

== Stable task inputs

Having a task repeatedly produce the same output is not enough if its inputs keep changing all the time. Such unstable inputs can be supplied directly to the task. Consider a version number that includes a timestamp being added to the jar file's manifest:

build.gradle.kts

```
version = "3.2-${System.currentTimeMillis()}"

tasks.jar {
    manifest {
        attributes(mapOf("Implementation-Version" to project.version))
    }
}
```

build.gradle

```
version = "3.2-${System.currentTimeMillis()}"

tasks.named('jar') {
    manifest {
        attributes('Implementation-Version': project.version)
    }
}
```

In the above example the inputs for the `jar` task will be different for each build execution since this timestamp will continually change.

Another example for unstable inputs is the commit ID from version control. Maybe your version number is generated via `git describe` (and you include it in the jar manifest as shown above). Or maybe you include the commit hash directly in `version.properties` or a jar manifest attribute. Either way, the outputs produced by any tasks depending on such data will only be re-usable by builds running against the exact same commit.

Another common, but less obvious source of unstable inputs is when a task consumes the output of another task which produces non-repeatable results, such as the example before of a code generator that embeds timestamps in its output.

A task can only be loaded from the cache if it has stable task inputs. Unstable task inputs result in the task having a unique set of inputs for every build, which will always result in a cache miss.

== Better reuse via input normalization

Having stable inputs is crucial for cacheable tasks. However, achieving byte for byte identical inputs for each task can be challenging. In some cases sanitizing the output of a task to remove unnecessary information can be a good approach, but this also means that a task's output can only be normalized for a single purpose.

This is where input normalization comes into play. Input normalization is used by Gradle to determine if two task inputs are *essentially* the same. Gradle uses normalized inputs when doing up-to-date checks and when determining if a cached result can be re-used instead of executing the task. As input normalization is declared by the task *consuming* the data as input, different tasks can define different ways to normalize the same data.

When it comes to file inputs, Gradle can normalize the path of the files as well as their contents.

=== Path sensitivity and relocatability

When sharing cached results between computers, it's rare that everyone runs the build from the exact same location on their computers. To allow cached results to be shared even when builds are executed from different root directories, Gradle needs to understand which inputs can be relocated and which cannot.

Tasks having files as inputs can declare the parts of a file's path what are essential to them: this is called the *path sensitivity* of the input. Task properties declared with `ABSOLUTE` path sensitivity are considered non-relocatable. This is the default for properties not declaring path sensitivity, too.

For example, the class files produced by the Java compiler are dependent on the file names of the Java source files: renaming the source files with public classes in them would fail the build. Though moving the files around wouldn't have an effect on the result of the compilation, for incremental compilation the `JavaCompile` task relies on the relative path to find other classes in

the same package. Therefore, the path sensitivity for the sources of the `JavaCompile` task is `RELATIVE`. Because of this only the normalized (relative) paths of the Java source files are considered as inputs to the `JavaCompile` task.

NOTE	The Java compiler only respects the package declaration in the Java source files, not the relative path of the sources. As a consequence, path sensitivity for Java sources is `NAME_ONLY` and not `RELATIVE`.

=== Content normalization

==== Compile avoidance for Java

When it comes to the dependencies of a `JavaCompile` task (i.e. its *compile classpath),* only changes to the Application Binary Interface (ABI) of these dependencies require compilation to be executed. Gradle has a deep understanding of what a compile classpath is and uses a sophisticated normalization strategy for it. Task outputs can be re-used as long as the ABI of the classes on the compile classpath stays the same. This enables Gradle to avoid Java compilation by using incremental builds, or load results from the cache that were produced by different (but ABI-compatible) versions of dependencies. For more information on compile avoidance see the corresponding section.

==== Runtime classpath normalization

Similar to compile avoidance, Gradle also understands the concept of a runtime classpath, and uses tailored input normalization to avoid running e.g. tests. For runtime classpaths Gradle inspects the contents of jar files and ignores the timestamps and order of the entries in the jar file. This means that a rebuilt jar file would be considered the same runtime classpath input. For details on what level of understanding Gradle has for detecting changes to classpaths and what is considered as a classpath see this section.

===== Filtering runtime classpaths

For a runtime classpath it is possible to provide better insights to Gradle which files are essential to the input by configuring input normalization.

Given that you want to add a file `build-info.properties` to all your produced jar files which contains volatile information about the build, e.g. the timestamp when the build started or some ID to identify the CI job that published the artifact. This file is only used for auditing purposes, and has no effect on the outcome of running tests. Nonetheless, this file is part of the runtime classpath for the `test` task. Since the file changes on every build invocation, tests cannot be cached effectively. To fix this you can ignore `build-info.properties` on any runtime classpath by adding the following configuration to the build script in the *consuming* project:

build.gradle.kts

```kotlin
normalization {
    runtimeClasspath {
        ignore("build-info.properties")
    }
}
```

build.gradle

```groovy
normalization {
    runtimeClasspath {
        ignore 'build-info.properties'
    }
}
```

If adding such a file to your jar files is something you do for all of the projects in your build, and you want to filter this file for all consumers, you may wrap the configurations described above in an `allprojects {}` or `subprojects {}` block in the root build script.

The effect of this configuration would be that changes to `build-info.properties` would be ignored for both up-to-date checks and task output caching. All runtime classpath inputs for all tasks in the project where this configuration has been made will be affected. This will not change the runtime behavior of the `test` task — i.e. any test is still able to load `build-info.properties`, and the runtime classpath stays the same as before.

== The case against overlapping outputs

When two tasks write to the same output directory or output file, it is difficult for Gradle to determine which output belongs to which task. There are many edge cases, and executing the tasks in parallel cannot be done safely. For the same reason, Gradle cannot remove stale output files for these tasks. Tasks that have discrete, non-overlapping outputs can always be handled in a safe fashion by Gradle. For the aforementioned reasons, task output caching is automatically disabled for tasks whose output directories overlap with another task.

Build scans show tasks where caching was disabled due to overlapping outputs in the timeline:

== Reuse of outputs between different tasks

Some builds exhibit a surprising characteristic: even when executed against an empty cache, they produce tasks loaded from cache. How is this possible? Rest assured that this is completely normal.

When considering task outputs, Gradle only cares about the inputs to the task: the task type itself, input files and parameters etc., but it doesn't care about the task's name or which project it can be found in. Running `javac` will produce the same output regardless of the name of the `JavaCompile` task that invoked it. If your build includes two tasks that share every input, the

one executing later will be able to reuse the output produced by the first.

Having two tasks in the same build that do the same might sound like a problem to fix, but it is not necessarily something bad. For example, the Android plugin creates several tasks for each variant of the project; some of those tasks will potentially do the same thing. These tasks can safely reuse each other's outputs.

As discussed previously, you can use Develocity to diagnose the source build of these unexpected cache-hits.

== Non-cacheable tasks

You've seen quite a bit about cacheable tasks, which implies there are non-cacheable ones, too. If caching task outputs is as awesome as it sounds, why not cache every task?

There are tasks that are definitely worth caching: tasks that do complex, repeatable processing and produce moderate amounts of output. Compilation tasks are usually ideal candidates for caching. At the other end of the spectrum lie I/O-heavy tasks, like `Copy` and `Sync`. Moving files around locally typically cannot be sped up by copying them from a cache. Caching those tasks would even waste good resources by storing all those redundant results in the cache.

Most tasks are either obviously worth caching, or obviously not. For those in-between a good rule of thumb is to see if downloading results would be significantly faster than producing them locally.

= Caching Java projects

As of Gradle 4.0, the build tool fully supports caching plain Java projects. Built-in tasks for compiling, testing, documenting and checking the quality of Java code support the build cache out of the box.

== Java compilation

Caching Java compilation makes use of Gradle's deep understanding of compile classpaths. The mechanism avoids recompilation when dependencies change in a way that doesn't affect their application binary interfaces (ABI). Since the cache key is only influenced by the ABI of dependencies (and not by their implementation details like private types and method bodies), task output caching can also reuse compiled classes if they were produced by the same sources and ABI-equivalent dependencies.

For example, take a project with two modules: an application depending on a library. Suppose the latest version is already built by CI and uploaded to the shared cache. If a developer now modifies a method's body in the library, the library will need to be rebuilt on their computer. But they will be able to load the compiled classes for the application from the shared cache. Gradle can do this because the library used to compile the application on CI, and the modified library available locally share the same ABI.

=== Annotation processors

Compile avoidance works out of the box. There is one caveat though: when using annotation processors, Gradle uses the annotation processor classpath as an input. Unlike most compile

dependencies, in which only the ABI influences compilation, the *implementation* of annotation processors must be considered as an input to the compiler. For this reason Gradle will treat annotation processors as a *runtime* classpath, meaning less input normalization is taking place there. If Gradle detects an annotation processor on the compile classpath, the annotation processor classpath defaults to the compile classpath when not explicitly set, which in turn means the entire compile classpath is treated as a runtime classpath input.

For the example above this would mean the ABI extracted from the compile classpath would be unchanged, but the annotation processor classpath (because it's not treated with compile avoidance) would be different. Ultimately, the developer would end up having to recompile the application.

The easiest way to avoid this performance penalty is to not use annotation processors. However, if you need to use them, make sure you set the annotation processor classpath explicitly to include only the libraries needed for annotation processing. The section on Java compile avoidance describes how to do this.

Some common Java dependencies (such as Log4j 2.x) come bundled with annotation processors. If you use these dependencies, but do not leverage the features of the bundled annotation processors, it's best to disable annotation processing entirely. This can be done by setting the annotation processor classpath to an empty set.

== Unit test execution

The `Test` task used for test execution for JVM languages employs runtime classpath normalization for its classpath. This means that changes to order and timestamps in jars on the test classpath will not cause the task to be out-of-date or change the build cache key. For achieving stable task inputs you can also wield the power of filtering the runtime classpath.

== Integration test execution

Unit tests are easy to cache as they normally have no external dependencies. For integration tests the situation can be quite different, as they can depend on a variety of inputs outside of the test and production code. These external factors can be for example:

- operating system type and version,
- external tools being installed for the tests,
- environment variables and Java system properties,
- other services being up and running,
- a distribution of the software under test.

You need to be careful to declare these additional inputs for your integration test in order to avoid incorrect cache hits. For example, declaring the operating system in use by Gradle as an input to a `Test` task called `integTest` would work as follows:

build.gradle.kts

```
tasks.integTest {
    inputs.property("operatingSystem") {
        System.getProperty("os.name")
    }
}
```

build.gradle

```
tasks.named('integTest') {
    inputs.property("operatingSystem") {
        System.getProperty("os.name")
    }
}
```

=== Archives as inputs

It is common for the integration tests to depend on your packaged application. If this happens to be a zip or tar archive, then adding it as an input to the integration test task may lead to cache misses. This is because, as described in repeatable task outputs, rebuilding an archive often changes the metadata in the archive. You can depend on the exploded contents of the archive instead. See also the section on dealing with non-repeatable outputs.

=== Dealing with file paths

You will probably pass some information from the build environment to your integration test tasks by using system properties. Passing absolute paths will break relocatability of the integration test task.

build.gradle.kts

```
// Don't do this! Breaks relocatability!
tasks.integTest {
    systemProperty("distribution.location",
layout.buildDirectory.dir("dist").get().asFile.absolutePath)
}
```

build.gradle

```
// Don't do this! Breaks relocatability!
tasks.named('integTest') {
    systemProperty "distribution.location", layout.buildDirectory.dir('dist').get
().asFile.absolutePath
}
```

Instead of adding the absolute path directly as a system property, it is possible to add an annotated CommandLineArgumentProvider to the `integTest` task:

build.gradle.kts

```
abstract class DistributionLocationProvider : CommandLineArgumentProvider {   ①
    @get:InputDirectory
    @get:PathSensitive(PathSensitivity.RELATIVE)   ②
    abstract val distribution: DirectoryProperty

    override fun asArguments(): Iterable<String> =
        listOf("-
Ddistribution.location=${distribution.get().asFile.absolutePath}")   ③
}

tasks.integTest {
    jvmArgumentProviders.add(
        objects.newInstance<DistributionLocationProvider>().apply {   ④
            distribution = layout.buildDirectory.dir("dist")
        }
    )
}
```

build.gradle

```
abstract class DistributionLocationProvider implements CommandLineArgumentProvider
{  ①
    @InputDirectory
    @PathSensitive(PathSensitivity.RELATIVE)  ②
    abstract DirectoryProperty getDistribution()

    @Override
    Iterable<String> asArguments() {
        ["-Ddistribution.location=${distribution.get().asFile.absolutePath}"]  ③
    }
}

tasks.named('integTest') {
    jvmArgumentProviders.add(
        objects.newInstance(DistributionLocationProvider).tap {  ④
            distribution = layout.buildDirectory.dir('dist')
        }
    )
}
```

① Create a class implementing `CommandLineArgumentProvider`.

② Declare the inputs and outputs with the corresponding path sensitivity.

③ `asArguments` needs to return the JVM arguments passing the desired system properties to the test JVM.

④ Add an instance of the newly created class as JVM argument provider to the integration test task.[9]

=== Ignoring system properties

It may be necessary to ignore some system properties as inputs as they do not influence the outcome of the integration tests. In order to do so, add a CommandLineArgumentProvider to the `integTest` task:

```kotlin
abstract class CiEnvironmentProvider : CommandLineArgumentProvider {
    @get:Internal   ①
    abstract val agentNumber: Property<String>

    override fun asArguments(): Iterable<String> =
        listOf("-DagentNumber=${agentNumber.get()}")   ②
}

tasks.integTest {
    jvmArgumentProviders.add(
        objects.newInstance<CiEnvironmentProvider>().apply {   ③
            agentNumber =
providers.environmentVariable("AGENT_NUMBER").orElse("1")
        }
    )
}
```

```groovy
abstract class CiEnvironmentProvider implements CommandLineArgumentProvider {
    @Internal   ①
    abstract Property<String> getAgentNumber()

    @Override
    Iterable<String> asArguments() {
        ["-DagentNumber=${agentNumber.get()}"]   ②
    }
}

tasks.named('integTest') {
    jvmArgumentProviders.add(
        objects.newInstance(CiEnvironmentProvider).tap {   ③
            agentNumber = providers.environmentVariable("AGENT_NUMBER").orElse("1
")
        }
    )
}
```

① `@Internal` means that this property does not influence the output of the integration tests.

② The system properties for the actual test execution.

③ Add an instance of the newly created class as JVM argument provider to the integration test task.[9]

= Caching Android projects

While it is true that Android uses the Java toolchain as its foundation, there are nevertheless some significant differences from pure Java projects; these differences impact task cacheability. This is even more true for Android projects that include Kotlin source code (and therefore use the `kotlin-android` plugin).

== Disambiguation

This guide is about Gradle's build cache, but you may have also heard about the Android build cache. These are different things. The Android cache is internal to certain tasks in the Android plugin, and will eventually be removed in favor of native Gradle support.

== Why use the build cache?

The build cache can *significantly* improve build performance for Android projects, in many cases by 30-40%. Many of the compilation and assembly tasks provided by the Android Gradle Plugin are cacheable, and more are made so with each new iteration.

=== Faster CI builds

CI builds benefit particularly from the build cache. A typical CI build starts with a `clean`, which means that pre-existing build outputs are deleted and none of the tasks that make up the build will be `UP-TO-DATE`. However, it is likely that many of those tasks will have been run with exactly the same inputs in a prior CI build, populating the build cache; the outputs from those prior runs can safely be reused, resulting in dramatic build performance improvements.

=== Reusing CI builds for local development

When you sign into work at the start of your day, it's not unusual for your first task to be pulling the main branch and then running a build (Android Studio will probably do the latter, whether you ask it to or not). Assuming all merges to main are built on CI (a best practice!), you can expect this first local build of the day to enjoy a larger-than-typical benefit with Gradle's *remote cache*. CI already built this commit — why should you re-do that work?

=== Switching branches

During local development, it is not uncommon to switch branches several times per day. This defeats incremental build (i.e., `UP-TO-DATE` checks), but this issue is mitigated via use of the local build cache. You might run a build on Branch A, which will populate the local cache. You then switch to Branch B to conduct a code review, help a colleague, or address feedback on an open PR. You then switch back to Branch A to continue your original work. When you next build, all of the outputs previously built while working on Branch A can be reused from the cache, saving potentially a lot of time.

The Android Gradle Plugin and the Gradle Build Tool

The first thing you should always do when working to optimize your build is ensure you're on the latest stable, supported versions of the Android Gradle Plugin and the Gradle Build Tool. At the time of writing, they are 3.3.0 and 5.0, respectively. Each new version of these tools includes many performance improvements, not least of which is to the build cache.

Java and Kotlin compilation

The discussion above in "Caching Java projects" is equally relevant here, with the caveat that, for projects that include Kotlin source code, the Kotlin compiler does not currently support compile avoidance in the way that the Java compiler does.

Annotation processors and Kotlin

The advice above for pure Java projects also applies to Android projects. However, if you are using annotation processors (such as Dagger2 or Butterknife) in conjunction with Kotlin and the kotlin-kapt plugin, you should know that before Kotlin 1.3.30 kapt was not cached by default.

You can opt into it (which is recommended) by adding the following to build scripts:

build.gradle.kts

```
pluginManager.withPlugin("kotlin-kapt") {
    configure<KaptExtension> { useBuildCache = true }
}
```

build.gradle

```
plugins.withId("kotlin-kapt") {
    kapt.useBuildCache = true
}
```

Unit test execution

Unlike with unit tests in a pure Java project, the equivalent test task in an Android project (`AndroidUnitTest`) is not cacheable. The Google Team is working to make these tests cacheable. Please see this issue.

Instrumented test execution (i.e., Espresso tests)

Android instrumented tests (`DeviceProviderInstrumentTestTask`), often referred to as "Espresso" tests, are also not cacheable. The Google Android team is also working to make such tests cacheable. Please see this issue.

Lint

Users of Android's `Lint` task are well aware of the heavy performance penalty they pay for using it, but also know that it is indispensable for finding common issues in Android projects. Currently, this task is not cacheable. This task is planned to be cacheable with the release of Android Gradle Plugin 3.5. This is another reason to always use the latest version of the Android plugin!

The Fabric Plugin and Crashlytics

The Fabric plugin, which is used to integrate the Crashlytics crash-reporting tool (among others), is very popular, yet imposes some hefty performance penalties during the build process. This is due to the need for each version of your app to have a unique identifier so that it can be identified in the Crashlytics dashboard. In practice, the default behavior of Crashlytics is to treat "each version" as synonymous with "each build". This defeats incremental build, because each build will be unique. It also breaks the cacheability of certain tasks in the build, and for the same reason. This can be fixed by simply disabling Crashlytics in "debug" builds. You may find instructions for that in the Crashlytics documentation.

| NOTE | The fix described in the referenced documentation does not work directly if you are using the Kotlin DSL; see below for the workaround. |

Kotlin DSL

The fix described in the referenced documentation does not work directly if you are using the Kotlin DSL; this is due to incompatibilities between that Kotlin DSL and the Fabric plugin. There is a simple workaround for this, based on this advice from the Kotlin DSL primer.

Create a file, `fabric.gradle`, in the module where you apply the `io.fabric` plugin. This file (known as a script plugin), should have the following contents:

fabric.gradle

```
plugins.withId("com.android.application") { // or "com.android.library"
    android.buildTypes.debug.ext.enableCrashlytics = false
}
```

And then, in the module's `build.gradle.kts` file, apply this script plugin:

build.gradle.kts

```
apply(from = "fabric.gradle")
```

= Debugging and diagnosing cache misses

To make the most of task output caching, it is important that any necessary inputs to your tasks are specified correctly, while at the same time avoiding unneeded inputs. Failing to specify an input that affects the task's outputs can result in incorrect builds, while needlessly specifying inputs that do not affect the task's output can cause cache misses.

This chapter is about finding out why a cache miss happened. If you have a cache hit which you didn't expect we suggest to declare whatever change you expected to trigger the cache miss as an input to the task.

== Finding problems with task output caching

Below we describe a step-by-step process that should help shake out any problems with caching in your build.

=== Ensure incremental build works

First, make sure your build does the right thing without the cache. Run a build twice without enabling the Gradle build cache. The expected outcome is that all actionable tasks that produce file outputs are up-to-date. You should see something like this on the command-line:

```
$ ./gradlew clean --quiet ①
$ ./gradlew assemble ②

BUILD SUCCESSFUL
4 actionable tasks: 4 executed

$ ./gradlew assemble ③

BUILD SUCCESSFUL
4 actionable tasks: 4 up-to-date
```

① Make sure we start without any leftover results by running `clean` first.

② We are assuming your build is represented by running the `assemble` task in these examples, but you can substitute whatever tasks make sense for your build.

③ Run the build again without running `clean`.

NOTE	Tasks that have no outputs or no inputs will always be executed, but that shouldn't be a problem.

Use the methods as described below to diagnose and fix tasks that should be up-to-date but

aren't. If you find a task which is out of date, but no cacheable tasks depends on its outcome, then you don't have to do anything about it. The goal is to achieve stable task inputs for cacheable tasks.

=== In-place caching with the local cache

When you are happy with the up-to-date performance then you can repeat the experiment above, but this time with a clean build, and the build cache turned on. The goal with clean builds and the build cache turned on is to retrieve all cacheable tasks from the cache.

WARNING	When running this test make sure that you have no `remote` cache configured, and storing in the `local` cache is enabled. These are the default settings.

This would look something like this on the command-line:

```
$ rm -rf ~/.gradle/caches/build-cache-1 ①
$ ./gradlew clean --quiet ②
$ ./gradlew assemble --build-cache ③

BUILD SUCCESSFUL
4 actionable tasks: 4 executed

$ ./gradlew clean --quiet ④
$ ./gradlew assemble --build-cache ⑤

BUILD SUCCESSFUL
4 actionable tasks: 1 executed, 3 from cache
```

① We want to start with an empty local cache.

② Clean the project to remove any unwanted leftovers from previous builds.

③ Build it once to let it populate the cache.

④ Clean the project again.

⑤ Build it again: this time everything cacheable should load from the just populated cache.

You should see all cacheable tasks loaded from cache, while non-cacheable tasks should be executed.

Wall clock time spent executing tasks		0.111s
All tasks	11	0.110s
Tasks avoided	3 (75.0%)	0.103s
From cache	3 (75.0%)	0.103s
Up-to-date	0 (00.0%)	0.000s
Tasks executed	1 (25.0%)	0.004s
Cacheable	0 (00.0%)	0.000s
Not cacheable	1 (25.0%)	0.004s
Lifecycle	5	0.002s
No source	2	0.001s
Skipped	0	0.000s

≣ 11 tasks in 1 project

:compileTestJava FROM-CACHE		0.080s
:test FROM-CACHE		0.014s
:compileJava FROM-CACHE		0.009s
:jar		0.004s
:check UP-TO-DATE		0.001s
:processResources NO-SOURCE		0.001s
:testClasses UP-TO-DATE		0.001s
:assemble		0.000s
:build		0.000s
:classes UP-TO-DATE		0.000s
:processTestResources NO-SOURCE		0.000s

Home › Performance › Task execution   Close performance details (esc)

Again, use the below methods to diagnose and fix cacheability issues.

=== Testing cache relocatability

Once everything loads properly while building the same checkout with the local cache enabled, it's time to see if there are any *relocation problems.* A task is considered *relocatable* if its output can be reused when the task is executed in a different location. (More on this in path sensitivity and relocatability.)

> **NOTE** Tasks that should be relocatable but aren't are usually a result of absolute paths being present among the task's inputs.

To discover these problems, first check out the same commit of your project in two different directories on your machine. For the following example let's assume we have a checkout in `\~/checkout-1` and `\~/checkout-2`.

> **WARNING** Like with the previous test, you should have no `remote` cache configured, and storing in the `local` cache should be enabled.

```
$ rm -rf ~/.gradle/caches/build-cache-1 ①
$ cd ~/checkout-1 ②
$ ./gradlew clean --quiet ③
$ ./gradlew assemble --build-cache ④

BUILD SUCCESSFUL
4 actionable tasks: 4 executed

$ cd ~/checkout-2 ⑤
$ ./gradlew clean --quiet ⑥
$ ./gradlew clean assemble --build-cache ⑦

BUILD SUCCESSFUL
4 actionable tasks: 1 executed, 3 from cache
```

① Remove all entries in the local cache first.

② Go to the first checkout directory.

③ Clean the project to remove any unwanted leftovers from previous builds.

④ Run a build to populate the cache.

⑤ Go to the other checkout directory.

⑥ Clean the project again.

⑦ Run a build again.

You should see the exact same results as you saw with the previous in place caching test step.

=== Cross-platform tests

If your build passes the relocation test, it is in good shape already. If your build requires support for multiple platforms, it is best to see if the required tasks get reused between platforms, too. A typical example of cross-platform builds is when CI runs on Linux VMs, while developers use macOS or Windows, or a different variety or version of Linux.

To test cross-platform cache reuse, set up a `remote` cache (see share results between CI builds) and populate it from one platform and consume it from the other.

=== Incremental cache usage

After these experiments with fully cached builds, you can go on and try to make typical changes to your project and see if enough tasks are still cached. If the results are not satisfactory, you can think about restructuring your project to reduce dependencies between different tasks.

=== Evaluating cache performance over time

Consider recording execution times of your builds, generating graphs, and analyzing the results. Keep an eye out for certain patterns, like a build recompiling everything even though you expected compilation to be cached.

You can also make changes to your code base manually or automatically and check that the expected set of tasks is cached.

If you have tasks that are re-executing instead of loading their outputs from the cache, then it may point to a problem in your build. Techniques for debugging a cache miss are explained in the following section.

== Helpful data for diagnosing a cache miss

A cache miss happens when Gradle calculates a build cache key for a task which is different from any existing build cache key in the cache. Only comparing the build cache key on its own does not give much information, so we need to look at some finer grained data to be able to diagnose the cache miss. A list of all inputs to the computed build cache key can be found in the section on cacheable tasks.

From most coarse grained to most fine grained, the items we will use to compare two tasks are:

- Build cache keys
- Task and Task action implementations
  - classloader hash
  - class name
- Task output property names
- Individual task property input hashes
- Hashes of files which are part of task input properties

If you want information about the build cache key and individual input property hashes, use `-Dorg.gradle.caching.debug=true`:

```
$ ./gradlew :compileJava --build-cache -Dorg.gradle.caching.debug=true

.
.
.
Appending implementation to build cache key:
org.gradle.api.tasks.compile.JavaCompile_Decorated@470c67ec713775576db4e818e7a4c75
d
Appending additional implementation to build cache key:
org.gradle.api.tasks.compile.JavaCompile_Decorated@470c67ec713775576db4e818e7a4c75
d
Appending input value fingerprint for 'options' to build cache key:
e4eaee32137a6a587e57eea660d7f85d
Appending input value fingerprint for 'options.compilerArgs' to build cache key:
8222d82255460164427051d7537fa305
Appending input value fingerprint for 'options.debug' to build cache key:
f6d7ed39fe24031e22d54f3fe65b901c
Appending input value fingerprint for 'options.debugOptions' to build cache key:
a91a8430ae47b11a17f6318b53f5ce9c
Appending input value fingerprint for 'options.debugOptions.debugLevel' to build
cache key: f6bd6b3389b872033d462029172c8612
Appending input value fingerprint for 'options.encoding' to build cache key:
f6bd6b3389b872033d462029172c8612
.
.
.
Appending input file fingerprints for 'options.sourcepath' to build cache key:
5fd1e7396e8de4cb5c23dc6aadd7787a - RELATIVE_PATH{EMPTY}
Appending input file fingerprints for 'stableSources' to build cache key:
f305ada95aeae858c233f46fc1ec4d01 - RELATIVE_PATH{.../src/main/java=IGNORED / DIR,
.../src/main/java/Hello.java='Hello.java' / 9c306ba203d618dfbe1be83354ec211d}
Appending output property name to build cache key: destinationDir
Appending output property name to build cache key:
options.annotationProcessorGeneratedSourcesDirectory
Build cache key for task ':compileJava' is 8ebf682168823f662b9be34d27afdf77
```

The log shows e.g. which source files constitute the `stableSources` for the `compileJava` task. To find the actual differences between two builds you need to resort to matching up and comparing those hashes yourself.

TIP	Develocity already takes care of this for you; it lets you quickly diagnose a cache miss with the Build Scan™ Comparison tool.

== Diagnosing the reasons for a cache miss

Having the data from the last section at hand, you should be able to diagnose why the outputs of a certain task were not found in the build cache. Since you were expecting more tasks to be cached, you should be able to pinpoint a build which would have produced the artifact under question.

Before diving into how to find out why one task has not been loaded from the cache we should first look into which task caused the cache misses. There is a cascade effect which causes dependent tasks to be executed if one of the tasks earlier in the build is not loaded from the cache and has different outputs. Therefore, you should locate the first cacheable task which was executed and continue investigating from there. This can be done from the timeline view in a Build Scan™:

At first, you should check if the implementation of the task changed. This would mean checking the class names and classloader hashes for the task class itself and for each of its actions. If there is a change, this means that the build script, `buildSrc` or the Gradle version has changed.

A change in the output of `buildSrc` also marks all the logic added by your build as changed. Especially, custom actions added to cacheable tasks will be marked as changed. This can be problematic, see [section about `doFirst` and `doLast`](#).

If the implementation is the same, then you need to start comparing inputs between the two builds. There should be at least one different input hash. If it is a simple value property, then the configuration of the task changed. This can happen for example by

- changing the build script,

- conditionally configuring the task differently for CI or the developer builds,

- depending on a system property or an environment variable for the task configuration,

- or having an absolute path which is part of the input.

If the changed property is a file property, then the reasons can be the same as for the change of a value property. Most probably though a file on the filesystem changed in a way that Gradle detects a difference for this input. The most common case will be that the source code was changed by a check in. It is also possible that a file generated by a task changed, e.g. since it includes a timestamp. As described in Java version tracking, the Java version can also influence the output of the Java compiler. If you did not expect the file to be an input to the task, then it is possible that you should alter the configuration of the task to not include it. For example, having your integration test configuration including all the unit test classes as a dependency has the effect that all integration tests are re-executed when a unit test changes. Another option is that the task tracks absolute paths instead of relative paths and the location of the project directory changed on disk.

== Example

We will walk you through the process of diagnosing a cache miss. Let's say we have build A and build B and we expected all the test tasks for a sub-project sub1 to be cached in build B since only a unit test for another sub-project sub2 changed. Instead, all the tests for the sub-project have been executed. Since we have the cascading effect when we have cache misses, we need to find the task which caused the caching chain to fail. This can easily be done by filtering for all cacheable tasks which have been executed and then select the first one. In our case, it turns out that the tests for the sub-project internal-testing were executed even though there was no code change to this project. This means that the property classpath changed and some file on the runtime classpath actually did change. Looking deeper into this, we actually see that the inputs for the task processResources changed in that project, too. Finally, we find this in our build file:

build.gradle.kts

```
val currentVersionInfo = tasks.register<CurrentVersionInfo>("currentVersionInfo")
{
    version = project.version as String
    versionInfoFile = layout.buildDirectory.file("generated-
resources/currentVersion.properties")
}

sourceSets.main.get().output.dir(currentVersionInfo.map {
it.versionInfoFile.get().asFile.parentFile })

abstract class CurrentVersionInfo : DefaultTask() {
    @get:Input
    abstract val version: Property<String>

    @get:OutputFile
    abstract val versionInfoFile: RegularFileProperty

    @TaskAction
    fun writeVersionInfo() {
        val properties = Properties()
        properties.setProperty("latestMilestone", version.get())
        versionInfoFile.get().asFile.outputStream().use { out ->
            properties.store(out, null)
        }
    }
}
```

build.gradle

```
def currentVersionInfo = tasks.register('currentVersionInfo', CurrentVersionInfo)
{
    version = project.version
    versionInfoFile = layout.buildDirectory.file('generated-
resources/currentVersion.properties')
}

sourceSets.main.output.dir(currentVersionInfo.map { it.versionInfoFile.get()
.asFile.parentFile })

abstract class CurrentVersionInfo extends DefaultTask {
    @Input
    abstract Property<String> getVersion()

    @OutputFile
    abstract RegularFileProperty getVersionInfoFile()

    @TaskAction
    void writeVersionInfo() {
        def properties = new Properties()
        properties.setProperty('latestMilestone', version.get())
        versionInfoFile.get().asFile.withOutputStream { out ->
            properties.store(out, null)
        }
    }
}
```

Since properties files stored by Java's `Properties.store` method contain a timestamp, this will cause a change to the runtime classpath every time the build runs. In order to solve this problem see non-repeatable task outputs or use input normalization.

| NOTE | The compile classpath is not affected since compile avoidance ignores non-class files on the classpath. |

= Solving common problems

Small problems in a build, like forgetting to declare a configuration file as an input to your task, can be easily overlooked. The configuration file might change infrequently, or only change when some other (correctly tracked) input changes as well. The worst that could happen is that your task doesn't execute when it should. Developers can always re-run the build with `clean`, and "fix" their builds for the price of a slow rebuild. In the end nobody gets blocked in their work, and the incident is chalked up to "Gradle acting up again."

With cacheable tasks incorrect results are stored permanently, and can come back to haunt you later; re-running with `clean` won't help in this situation either. When using a shared cache, these problems even cross machine boundaries. In the example above, Gradle might end up loading a result for your task that was produced with a different configuration. Resolving these problems with the build therefore becomes even more important when task output caching is enabled.

Other issues with the build won't cause it to produce incorrect results, but will lead to unnecessary cache misses. In this chapter you will learn about some typical problems and ways to avoid them. Fixing these issues will have the added benefit that your build will stop "acting up," and developers can forget about running builds with `clean` altogether.

== System file encoding

Most Java tools use the system file encoding when no specific encoding is specified. This means that running the same build on machines with different file encoding can yield different outputs. Currently Gradle only tracks on a per-task basis that no file encoding has been specified, but it does not track the system encoding of the JVM in use. This can cause incorrect builds. You should always set the file system encoding to avoid these kind of problems.

| NOTE | Build scripts are compiled with the file encoding of the Gradle daemon. By default, the daemon uses the system file encoding, too. |

Setting the file encoding for the Gradle daemon mitigates both above problems by making sure that the encoding is the same across builds. You can do so in your `gradle.properties`:

gradle.properties

```
org.gradle.jvmargs=-Dfile.encoding=UTF-8
```

== Environment variable tracking

Gradle does not track changes in environment variables for tasks. For example for `Test` tasks it is completely possible that the outcome depends on a few environment variables. To ensure that only the right artifacts are re-used between builds, you need to add environment variables as inputs to tasks depending on them.

Absolute paths are often passed as environment variables, too. You need to pay attention what you add as an input to the task in this case. You would need to ensure that the absolute path is the same between machines. Most times it makes sense to track the file or the contents of the directory the absolute path points to. If the absolute path represents a tool being used it probably makes sense to track the tool version as an input instead.

For example, if you are using tools in your `Test` task called `integTest` which depend on the contents of the `LANG` variable you should do this:

build.gradle.kts

```
tasks.integTest {
    inputs.property("langEnvironment") {
        System.getenv("LANG")
    }
}
```

build.gradle

```
tasks.named('integTest') {
    inputs.property("langEnvironment") {
        System.getenv("LANG")
    }
}
```

If you add conditional logic to distinguish CI builds from local development builds, you have to ensure that this does not break the loading of task outputs from CI onto developer machines. For example, the following setup would break caching of `Test` tasks, since Gradle always detects the differences in custom task actions.

build.gradle.kts

```kotlin
if ("CI" in System.getenv()) {
    tasks.withType<Test>().configureEach {
        doFirst {
            println("Running test on CI")
        }
    }
}
```

build.gradle

```groovy
if (System.getenv().containsKey("CI")) {
    tasks.withType(Test).configureEach {
        doFirst {
            println "Running test on CI"
        }
    }
}
```

You should always add the action unconditionally:

build.gradle.kts

```kotlin
tasks.withType<Test>().configureEach {
    doFirst {
        if ("CI" in System.getenv()) {
            println("Running test on CI")
        }
    }
}
```

build.gradle

```
tasks.withType(Test).configureEach {
    doFirst {
        if (System.getenv().containsKey("CI")) {
            println "Running test on CI"
        }
    }
}
```

This way, the task has the same custom action on CI and on developer builds and its outputs can be re-used if the remaining inputs are the same.

Line endings

If you are building on different operating systems be aware that some version control systems convert line endings on check-out. For example, Git on Windows uses `autocrlf=true` by default which converts all line endings to `\r\n`. As a consequence, compilation outputs can't be re-used on Windows since the input sources are different. If sharing the build cache across multiple operating systems is important in your environment, then setting `autocrlf=false` across your build machines is crucial for optimal build cache usage.

Symbolic links

When using symbolic links, Gradle does not store the link in the build cache but the actual file contents of the destination of the link. As a consequence you might have a hard time when trying to reuse outputs which heavily use symbolic links. There currently is no workaround for this behavior.

For operating systems supporting symbolic links, the content of the destination of the symbolic link will be added as an input. If the operating system does not support symbolic links, the actual symbolic link file is added as an input. Therefore, tasks which have symbolic links as input files, e.g. `Test` tasks having symbolic link as part of its runtime classpath, will not be cached between Windows and Linux. If caching between operating systems is desired, symbolic links should not be checked into version control.

Java version tracking

Gradle tracks only the major version of Java as an input for compilation and test execution. Currently, it does *not* track the vendor nor the minor version. Still, the vendor and the minor version may influence the bytecode produced by compilation.

> **NOTE** If you're using Java Toolchains, the Java major version, the vendor (if specified) and implementation (if specified) will be tracked automatically as an input for compilation and test execution.

If you use different JVM vendors for compiling or running Java we strongly suggest that you add the vendor as an input to the corresponding tasks. This can be achieved by using the runtime API as shown in the following snippet.

build.gradle.kts

```
tasks.withType<AbstractCompile>().configureEach {
    inputs.property("java.vendor") {
        System.getProperty("java.vendor")
    }
}

tasks.withType<Test>().configureEach {
    inputs.property("java.vendor") {
        System.getProperty("java.vendor")
    }
}
```

build.gradle

```
tasks.withType(AbstractCompile).configureEach {
    inputs.property("java.vendor") {
        System.getProperty("java.vendor")
    }
}

tasks.withType(Test).configureEach {
    inputs.property("java.vendor") {
        System.getProperty("java.vendor")
    }
}
```

With respect to tracking the Java minor version there are different competing aspects: developers having cache hits and "perfect" results on CI. There are basically two situations when you may want to track the minor version of Java: for compilation and for runtime. In the case of compilation, there can sometimes be differences in the produced bytecode for different minor versions. However, the bytecode should still result in the same runtime behavior.

> **NOTE** | Java compile avoidance will treat this bytecode the same since it extracts the ABI.

Treating the minor number as an input can decrease the likelihood of a cache hit for developer builds. Depending on how standard development environments are across your team, it's common for many different Java minor version to be in use.

Even without tracking the Java minor version you may have cache misses for developers due to some locally compiled class files which constitute an input to test execution. If these outputs made it into the local build cache on this developers machine even a clean will not solve the situation. Therefore, the choice for tracking the Java minor version is between sometimes or never re-using outputs between different Java minor versions for test execution.

> **NOTE** | The compiler infrastructure provided by the JVM used to run Gradle is also used by the Groovy compiler. Therefore, you can expect differences in the bytecode of compiled Groovy classes for the same reasons as above and the same suggestions apply.

Avoid changing inputs external to your build

If your build is dependent on external dependencies like binary artifacts or dynamic data from a web page you need to make sure that these inputs are consistent throughout your infrastructure. Any variations across machines will result in cache misses.

Never re-release a non-changing binary dependency with the same version number but different contents: if this happens with a plugin dependency, you will never be able to explain why you don't see cache reuse between machines (it's because they have different versions of that artifact).

Using `SNAPSHOT`s or other changing dependencies in your build by design violates the stable task inputs principle. To use the build cache effectively, you should depend on fixed dependencies. You may want to look into dependency locking or switch to using composite builds instead.

The same is true for depending on volatile external resources, for example a list of released versions. One way of locking the changes would be to check the volatile resource into source control whenever it changes so that the builds only depend on the state in source control and not on the volatile resource itself.

Suggestions for authoring your build

Review usages of `doFirst` and `doLast`

Using `doFirst` and `doLast` from a build script on a cacheable task ties you to build script

changes since the implementation of the closure comes from the build script. If possible, you should use separate tasks instead.

Modifying input or output properties via the runtime API in `doFirst` is discouraged since these changes will not be detected for up-to-date checks and the build cache. Even worse, when the task does not execute, then the configuration of the task is actually different from when it executes. Instead of using `doFirst` for modifying the inputs consider using a separate task to configure the task under question - a so called configure task. E.g., instead of doing

build.gradle.kts

```
tasks.jar {
    val runtimeClasspath: FileCollection = configurations.runtimeClasspath.get()
    doFirst {
        manifest {
            val classPath = runtimeClasspath.map { it.name }.joinToString(" ")
            attributes("Class-Path" to classPath)
        }
    }
}
```

build.gradle

```
tasks.named('jar') {
    FileCollection runtimeClasspath = configurations.runtimeClasspath
    doFirst {
        manifest {
            def classPath = runtimeClasspath.collect { it.name }.join(" ")
            attributes('Class-Path': classPath)
        }
    }
}
```

do

build.gradle.kts

```kotlin
val configureJar = tasks.register("configureJar") {
    doLast {
        tasks.jar.get().manifest {
            val classPath = configurations.runtimeClasspath.get().map { it.name
}.joinToString(" ")
            attributes("Class-Path" to classPath)
        }
    }
}
tasks.jar { dependsOn(configureJar) }
```

build.gradle

```groovy
def configureJar = tasks.register('configureJar') {
    doLast {
        tasks.jar.manifest {
            def classPath = configurations.runtimeClasspath.collect { it.name }
.join(" ")
            attributes('Class-Path': classPath)
        }
    }
}

tasks.named('jar') { dependsOn(configureJar) }
```

Note that configuring a task from other task is not supported when using the configuration cache.
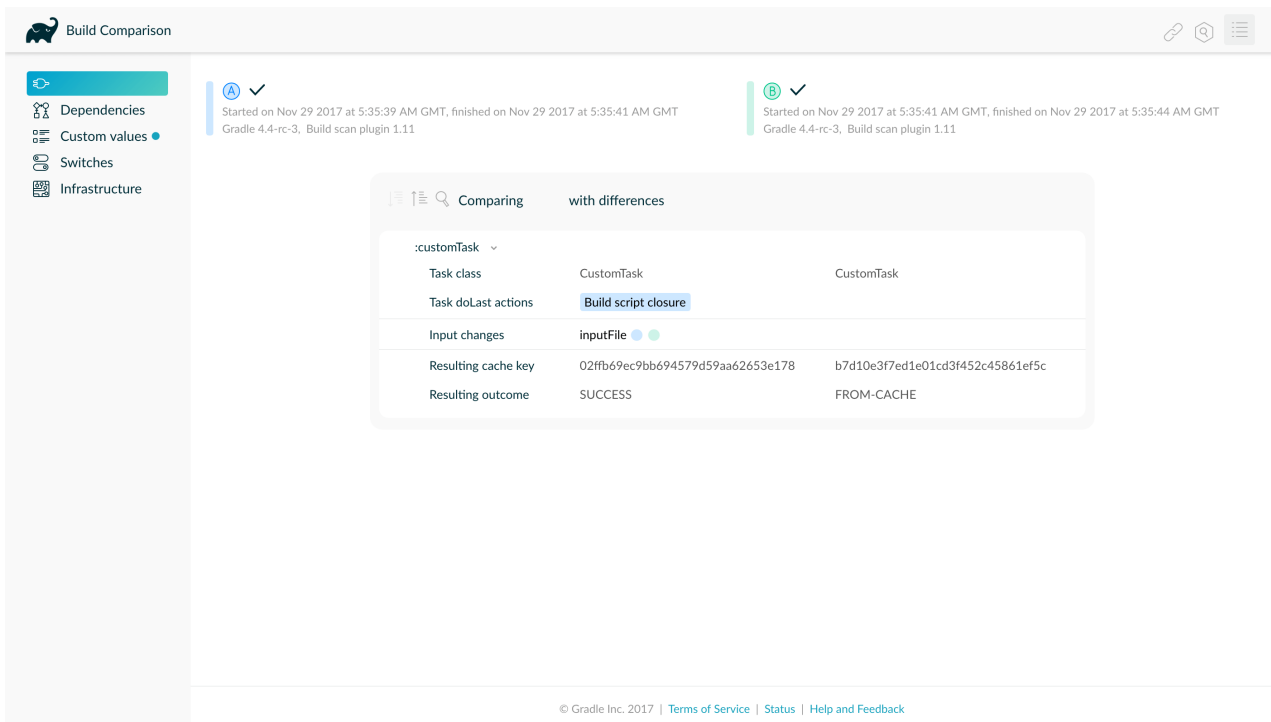
=== Build logic based on the outcome of a task

Do not base build logic on whether a task has been *executed*. In particular you should not assume that the output of a task can only change if it actually executed. Actually, loading the outputs from the build cache would also change them. Instead of relying on custom logic to deal with changes to input or output files you should leverage Gradle's built-in support by declaring the correct inputs and outputs for your tasks and leave it to Gradle to decide if the task actions should be executed. For the very same reason using `outputs.upToDateWhen` is discouraged and should be replaced by properly declaring the task's inputs.

=== Overlapping outputs

You already saw that overlapping outputs are a problem for task output caching. When you add new tasks to your build or re-configure built-in tasks make sure you do not create overlapping outputs for cacheable tasks. If you must you can add a `Sync` task which then would sync the merged outputs into the target directory while the original tasks remain cacheable.

Develocity will show tasks where caching was disabled for overlapping outputs in the timeline and in the task input comparison:

== Achieving stable task inputs

It is crucial to have stable task inputs for every cacheable task. In the following section you will learn about different situations which violate stable task inputs and look at possible solutions.

=== Volatile task inputs

If you use a volatile input like a timestamp as an input property for a task, then there is nothing Gradle can do to make the task cacheable. You should really think hard if the volatile data is really essential to the output or if it is only there for e.g. auditing purposes.

If the volatile input is essential to the output then you can try to make the task using the volatile input cheaper to execute. You can do this by splitting the task into two tasks - the first task doing the expensive work which is cacheable and the second task adding the volatile data to the output. In this way the output stays the same and the build cache can be used to avoid doing the expensive work. For example, for building a jar file the expensive part - Java compilation - is already a different task while the jar task itself, which is not cacheable, is cheap.

If it is not an essential part of the output, then you should not declare it as an input. As long as the volatile input does not influence the output then there is nothing else to do. Most times though, the input will be part of the output.

=== Non-repeatable task outputs

Having tasks which generate different outputs for the same inputs can pose a challenge for the effective use of task output caching as seen in repeatable task outputs. If the non-repeatable task output is not used by any other task then the effect is very limited. It basically means that loading the task from the cache might produce a different result than executing the same task locally. If the only difference between the outputs is a timestamp, then you can either accept the effect of the build cache or decide that the task is not cacheable after all.

Non-repeatable task outputs lead to non-stable task inputs as soon as another task depends on the non-repeatable output. For example, re-creating a jar file from the files with the same contents but different modification times yields a different jar file. Any other task depending on this jar file as an input file cannot be loaded from the cache when the jar file is rebuilt locally. This can lead to hard-to-diagnose cache misses when the consuming build is not a clean build or when a cacheable task depends on the output of a non-cacheable task. For example, when doing incremental builds it is possible that the artifact on disk which is considered up-to-date and the artifact in the build cache are different even though they are essentially the same. A task depending on this task output would then not be able to load outputs from the build cache since the inputs are not exactly the same.

As described in the stable task inputs section, you can either make the task outputs repeatable or use input normalization. You already learned about the possibilities with configurable input normalization.

Gradle includes some support for creating repeatable output for archive tasks. For tar and zip files Gradle can be configured to create reproducible archives. This is done by configuring e.g. the `Zip` task via the following snippet.

build.gradle.kts

```kotlin
tasks.register<Zip>("createZip") {
    isPreserveFileTimestamps = false
    isReproducibleFileOrder = true
    // ...
}
```

build.gradle

```groovy
tasks.register('createZip', Zip) {
    preserveFileTimestamps = false
    reproducibleFileOrder = true
    // ...
}
```

Another way to make the outputs repeatable is to activate caching for a task with non-repeatable outputs. If you can make sure that the same build cache is used for all builds then the task will always have the same outputs for the same inputs by design of the build cache. Going down this road can lead to different problems with cache misses for incremental builds as described above. Moreover, race conditions between different builds trying to store the same outputs in the build cache in parallel can lead to hard-to-diagnose cache misses. If possible, you should avoid going down that route.

=== Limit the effect of volatile data

If none of the described solutions for dealing with volatile data work for you, you should still be able to limit the effect of volatile data on effective use of the build cache. This can be done by adding the volatile data later to the outputs as described in the volatile task inputs section. Another option would be to move the volatile data so it affects fewer tasks. For example moving the dependency from the `compile` to the `runtime` configuration may already have quite an impact.

Sometimes it is also possible to build two artifacts, one containing the volatile data and another one containing a constant representation of the volatile data. The non-volatile output would be used e.g. for testing while the volatile one would be published to an external repository. While this conflicts with the Continuous Delivery "build artifacts once" principle it can sometimes be the only option.

== Custom and third party tasks

If your build contains custom or third party tasks, you should take special care that these don't influence the effectiveness of the build cache. Special care should also be taken for code generation tasks which may not have repeatable task outputs. This can happen if the code generator includes e.g. a timestamp in the generated files or depends on the order of the input files. Other pitfalls can be the use of `HashMap`s or other data structures without order guarantees in the task's code.

Some third party plugins can even influence cacheability of Gradle's built-in tasks. This can happen if they add inputs like absolute paths or volatile data to tasks via the runtime API. In the worst case this can lead to incorrect builds when the plugins try to depend on the outcome of a task and do not take `FROM-CACHE` into account.

== AUTHORING C++ / SWIFT BUILDS

= Building C++ projects

> **WARNING** The plugins described in this chapter are not compatible with the configuration cache.

Gradle uses a convention-over-configuration approach to building native projects. If you are coming from another native build system, these concepts may be unfamiliar at first, but they serve a purpose to simplify build script authoring.

We will look at C++ projects in detail in this chapter, but most of the topics will apply to other supported native languages as well. If you don't have much experience with building native projects with Gradle, take a look at the C++ tutorials for step-by-step instructions on how to build various types of basic C++ projects as well as some common use cases.

The C++ plugins covered in this chapter were introduced in 2018 and we recommend users to use those plugins over the older Native plugins that you may find references to.

== Introduction

The simplest build script for a C++ project applies the C++ application plugin or the C++ library plugin and optionally sets the project version:

build.gradle.kts

```
plugins {
    `cpp-application` // or `cpp-library`
}

version = "1.2.1"
```

build.gradle

```
plugins {
    id 'cpp-application' // or 'cpp-library'
}

version = '1.2.1'
```

By applying either of the C++ plugins, you get a whole host of features:

- `compileDebugCpp` and `compileReleaseCpp` tasks that compiles the C++ source files under *src/main/cpp* for the well-known debug and release build types, respectively.

- `linkDebug` and `linkRelease` tasks that link the compiled C++ object files into an executable for applications or shared library for libraries with shared linkage for the debug and release build types.

- `createDebug` and `createRelease` tasks that assemble the compiled C++ object files into a static library for libraries with static linkage for the debug and release build types.

For any non-trivial C++ project, you'll probably have some file dependencies and additional configuration specific to *your* project.

The C++ plugins also integrates the above tasks into the standard lifecycle tasks. The task that produces the development binary is attached to `assemble`. By default, the development binary is the debug variant.

The rest of the chapter explains the different ways to customize the build to your requirements when building libraries and applications.

== Introducing build variants

Native projects can typically produce several different binaries, such as debug or release ones, or ones that target particular platforms and processor architectures. Gradle manages this through the concepts of *dimensions* and *variants*.

A dimension is simply a category, where each category is orthogonal to the rest. For example, the "build type" dimension is a category that includes debug and release. The "architecture" dimension covers processor architectures like x86-64 and PowerPC.

A variant is a combination of values for these dimensions, consisting of exactly one value for each dimension. You might have a "debug x86-64" or a "release PowerPC" variant.

Gradle has built-in support for several dimensions and several values within each dimension. You can find a list of them in the native plugin reference chapter.

== Declaring your source files

Gradle's C++ support uses a `ConfigurableFileCollection` directly from the application or library script block to configure the set of sources to compile.

Libraries make a distinction between private (implementation details) and public (exported to consumer) headers.

You can also configure sources for each binary build for those cases where sources are compiled only on certain target machines.
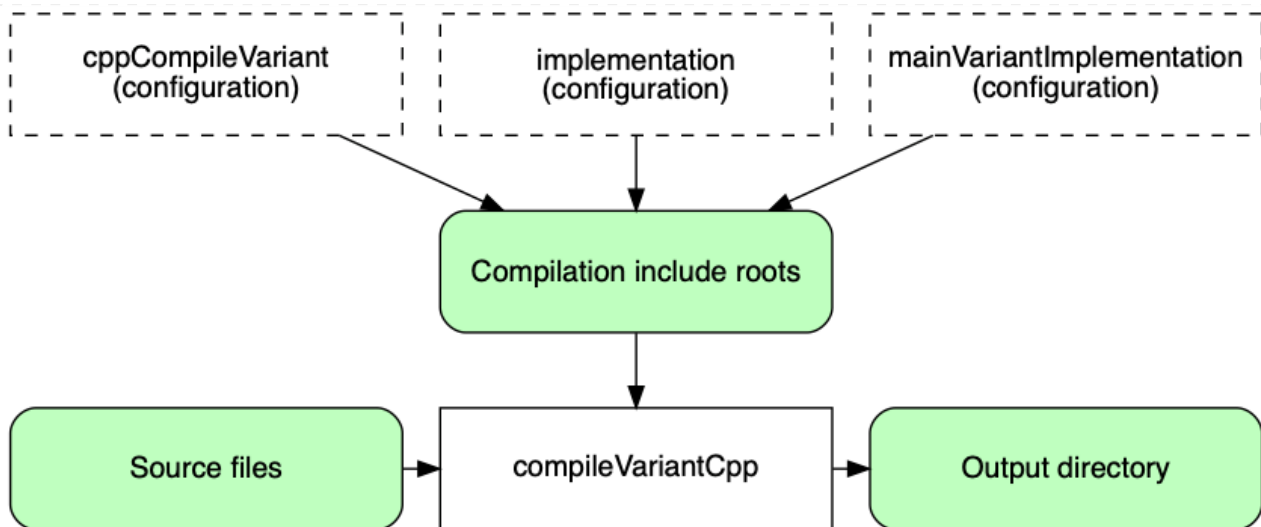
Figure 46. Sources and C++ compilation

Test sources are configured on each test suite script block. See [Testing C++ projects](#) chapter.

== Managing your dependencies

The vast majority of projects rely on other projects, so managing your project's dependencies is an important part of building any project. Dependency management is a big topic, so we will only focus on the basics for C++ projects here. If you'd like to dive into the details, check out the [introduction to dependency management](#).

Gradle provides support for consuming pre-built binaries from Maven repositories published by Gradle [10].

We will cover how to add dependencies between projects within a multi-build project.

Specifying dependencies for your C++ project requires two pieces of information:

- Identifying information for the dependency (project path, Maven GAV)
- What it's needed for, e.g. compilation, linking, runtime or all of the above.

This information is specified in a `dependencies {}` block of the C++ `application` or `library` script block. For example, to tell Gradle that your project requires library `common` to compile and link your production code, you can use the following fragment:

build.gradle.kts

```
application {
    dependencies {
        implementation(project(":common"))
    }
}
```

build.gradle

```
application {
    dependencies {
        implementation project(':common')
    }
}
```

The Gradle terminology for the three elements is as follows:

- *Configuration* (ex: `implementation`) - a named collection of dependencies, grouped together for a specific goal such as compiling or linking a module
- *Project reference* (ex: `project(':common')`) - the project referenced by the specified path

You can find a more comprehensive glossary of dependency management terms here.

As far as configurations go, the main ones of interest are:

- `implementation` - used for compilation, linking and runtime
- `cppCompileVariant` - for dependencies that are necessary to compile your production code but shouldn't be part of the linking or runtime process
- `nativeLinkVariant` - for dependencies that are necessary to link your code but shouldn't be part of the compilation or runtime process
- `nativeRuntimeVariant` - for dependencies that are necessary to run your component but shouldn't be part of the compilation or linking process

You can learn more about these and how they relate to one another in the native plugin reference chapter.

Be aware that the C++ Library Plugin creates an additional configuration — `api` — for dependencies that are required for compiling and linking both the module and any modules that depend on it.

We have only scratched the surface here, so we recommend that you read the dedicated dependency management chapters once you're comfortable with the basics of building C++ projects with Gradle.

Some common scenarios that require further reading include:

- Defining a custom Maven-compatible repository
- Declaring dependencies with changing (e.g. SNAPSHOT) and dynamic (range) versions
- Declaring a sibling project as a dependency
- Controlling transitive dependencies and their versions
- Testing your fixes to 3rd-party dependency via composite builds (a better alternative to publishing to and consuming from Maven Local)

You'll discover that Gradle has a rich API for working with dependencies — one that takes time to master, but is straightforward to use for common scenarios.

== Compiling and linking your code Compiling both your code can be trivially easy if you follow the conventions:

1. Put your source code under the *src/main/cpp* directory
2. Declare your compile dependencies in the `implementation` configurations (see the previous

section)

3. Run the `assemble` task

We recommend that you follow these conventions wherever possible, but you don't have to.

There are several options for customization, as you'll see next.

NOTE	All CppCompile tasks are incremental and cacheable.

=== Supported tool chain

Gradle offers the ability to execute the same build using different tool chains. When you build a native binary, Gradle will attempt to locate a tool chain installed on your machine that can build the binary. Gradle select the first tool chain that can build for the target operating system and architecture. In the future, Gradle will consider source and ABI compatibility when selecting a tool chain.

Gradle has general support for the three major tool chains on major operating system: Clang [11], GCC [12] and Visual C++ [13] (Windows-only). GCC and Clang installed using Macports and Homebrew have been reported to work fine, but this isn't tested continuously.

==== Windows

To build on Windows, install a compatible version of Visual Studio. The C++ plugins will discover the Visual Studio installations and select the latest version. There is no need to mess around with environment variables or batch scripts. This works fine from a Cygwin shell or the Windows command-line.

Alternatively, you can install Cygwin or MinGW with GCC. Clang is currently not supported.

==== macOS

To build on macOS, you should install Xcode. The C++ plugins will discover the Xcode installation using the system PATH.

The C++ plugins also work with GCC and Clang installed with Macports or Homebrew [14]. To use one of the Macports or Homebrew, you will need to add Macports/Homebrew to the system PATH.

==== Linux

To build on Linux, install a compatible version of GCC or Clang. The C++ plugins will discover GCC or Clang using the system PATH.

=== Customizing file and directory locations

Imagine you have a legacy library project that uses an *src* directory for the production code and private headers and *include* directory for exported headers. The conventional directory structure won't work, so you need to tell Gradle where to find the source and header files. You do that via the `application` or `library` script block.

Each component script block, as well as each binary, defines where it's source code resides. You can override the convention values by using the following syntax:

build.gradle.kts

```
library {
    source.from(file("src"))
    privateHeaders.from(file("src"))
    publicHeaders.from(file("include"))
}
```

build.gradle

```
library {
    source.from file('src')
    privateHeaders.from file('src')
    publicHeaders.from file('include')
}
```

Now Gradle will only search directly in *src* for the source and private headers and in *include* for public headers.

=== Changing compiler and linker options

Most of the compiler and linker options are accessible through the corresponding task, such as compileVariantCpp, linkVariant and createVariant. These tasks are of type CppCompile, LinkSharedLibrary and CreateStaticLibrary respectively. Read the task reference for an up-to-date and comprehensive list of the options.

For example, if you want to change the warning level generated by the compiler for all variants, you can use this configuration:

```kotlin
tasks.withType(CppCompile::class.java).configureEach {
    // Define a preprocessor macro for every binary
    macros.put("NDEBUG", null)

    // Define a compiler options
    compilerArgs.add("-W3")

    // Define toolchain-specific compiler options
    compilerArgs.addAll(toolChain.map { toolChain ->
        when (toolChain) {
            is Gcc, is Clang -> listOf("-O2", "-fno-access-control")
            is VisualCpp -> listOf("/Zi")
            else -> listOf()
        }
    })
}
```

```groovy
tasks.withType(CppCompile).configureEach {
    // Define a preprocessor macro for every binary
    macros.put("NDEBUG", null)

    // Define a compiler options
    compilerArgs.add '-W3'

    // Define toolchain-specific compiler options
    compilerArgs.addAll toolChain.map { toolChain ->
        if (toolChain in [ Gcc, Clang ]) {
            return ['-O2', '-fno-access-control']
        } else if (toolChain in VisualCpp) {
            return ['/Zi']
        }
        return []
    }
}
```

It's also possible to find the instance for a specific variant through the `BinaryCollection` on the `application` or `library` script block:

```kotlin
application {
    binaries.configureEach(CppStaticLibrary::class.java) {
        // Define a preprocessor macro for every binary
        compileTask.get().macros.put("NDEBUG", null)

        // Define a compiler options
        compileTask.get().compilerArgs.add("-W3")

        // Define toolchain-specific compiler options
        when (toolChain) {
            is Gcc, is Clang -> compileTask.get().compilerArgs.addAll(listOf("-
O2", "-fno-access-control"))
            is VisualCpp -> compileTask.get().compilerArgs.add("/Zi")
        }
    }
}
```

```groovy
application {
    binaries.configureEach(CppStaticLibrary) {
        // Define a preprocessor macro for every binary
        compileTask.get().macros.put("NDEBUG", null)

        // Define a compiler options
        compileTask.get().compilerArgs.add '-W3'

        // Define toolchain-specific compiler options
        if (toolChain in [ Gcc, Clang ]) {
            compileTask.get().compilerArgs.addAll(['-O2', '-fno-access-control'])
        } else if (toolChain in VisualCpp) {
            compileTask.get().compilerArgs.add('/Zi')
        }
    }
}
```

=== Selecting target machines

By default, Gradle will attempt to create a C++ binary variant for the host operating system and architecture. It is possible to override this by specifying the set of `TargetMachine` on the `application` or `library` script block:

```
application {
    targetMachines = listOf(machines.windows.x86, machines.windows.x86_64,
machines.macOS.x86_64, machines.linux.x86_64)
}
```

build.gradle

```
application {
    targetMachines = [
        machines.linux.x86_64,
        machines.windows.x86, machines.windows.x86_64,
        machines.macOS.x86_64
    ]
}
```

Packaging and publishing

How you package and potentially publish your C++ project varies greatly in the native world. Gradle comes with defaults, but custom packaging can be implemented without any issues.

- Executable files are published directly to Maven repositories.
- Shared and static library files are published directly to Maven repositories along with a zip of the public headers.
- For applications, Gradle also supports installing and running the executable with all of its shared library dependencies in a known location.

Cleaning the build

The C++ Application and Library Plugins add a `clean` task to you project by using the base plugin. This task simply deletes everything in the `layout.buildDirectory` directory, hence why you should always put files generated by the build in there. The task is an instance of Delete and you can change what directory it deletes by setting its `dir` property.

Building C++ libraries

The unique aspect of library projects is that they are used (or "consumed") by other C++ projects. That means the dependency metadata published with the binaries and headers — in the form of Gradle Module Metadata — is crucial. In particular, consumers of your library should be able to distinguish between two different types of dependencies: those that are only required to compile your library and those that are also required to compile the consumer.

Gradle manages this distinction via the C++ Library Plugin, which introduces an *api* configuration in addition to the *implementation* once covered in this chapter. If the types from a dependency appear as unresolved symbols of the static library or within the public headers then that dependency is exposed via your library's public API and should, therefore, be added to the *api* configuration. Otherwise, the dependency is an internal implementation detail and should be added to *implementation*.

If you're unsure of the difference between an API and implementation dependency, the C++ Library Plugin chapter has a detailed explanation. In addition, you can see a basic, practical example of building a C++ library in the corresponding sample.

Building C++ applications

See the C++ Application Plugin chapter for more details, but here's a quick summary of what you get:

- `install` create a directory containing everything needed to run it
- Shell and Windows Batch scripts to start the application

You can see a basic example of building a C++ application in the corresponding sample.

Testing in C++ projects

> **WARNING**   The C++ testing support is not compatible with the configuration cache.

Testing in the native ecosystem takes many forms.

There are different testing libraries and frameworks, as well as many different types of test. All need to be part of the build, whether they are executed frequently or infrequently. This chapter is dedicated to explaining how Gradle handles differing requirements between and within builds, with significant coverage of how it integrates with the executable-based testing frameworks, such as Google Test.

Testing C++ projects in Gradle is fairly limited when compared to Testing in Java & JVM projects. In this chapter, we explain the ways to control how tests are run (Test execution).

But first, we look at the basics of native testing in Gradle.

== The basics

All C++ testing revolves around a single task type: RunTestExecutable. This runs a single test executable built with any testing framework and asserts the execution was successful using the exit code of the executable. The test case results aren't collected and no reports are generated.

In order to operate, the RunTestExecutable task type requires just one piece of information:

- Where to find the built test executable (property: RunTestExecutable.getExecutable())

When you're using the C++ Unit Test Plugin you will automatically get the following:

- A dedicated unitTest extension for configuring test component and its variants
- A `run` task of type RunTestExecutable that runs the test executable

The test plugins configure the required pieces of information appropriately. In addition, they attach the `run` task to the `check` lifecycle task. It also create the `testImplementation` dependency configuration. Dependencies that are only needed for test compilation, linking and runtime may be added to this configuration. The `unitTest` script block behave similarly to a `application` or `library` script block.

The RunTestExecutable task has many configuration options. We cover a number of them in the rest of the chapter.

== Test execution

Gradle executes tests in a separate ('forked') process.

You can control how the test process is launched via several properties on the RunTestExecutable task, including the following:

`ignoreFailures` - **default: false**
    If this property is `true`, Gradle will continue with the project's build once the tests have completed, even if some of them have failed. Note that, by default, RunTestExecutable task

type always executes every test that it detects, irrespective of this setting.

See [RunTestExecutable](#) for details on all the available configuration options.

= Building Swift projects

WARNING	The plugins described in this chapter are not compatible with the [configuration cache](#).

Gradle uses a convention-over-configuration approach to building native projects. If you are coming from another native build system, these concepts may be unfamiliar at first, but they serve a purpose to simplify build script authoring.

We will look at Swift projects in detail in this chapter, but most of the topics will apply to other supported native languages as well.

== Introduction

The simplest build script for a Swift project applies the Swift application plugin or the Swift library plugin and optionally sets the project version:

build.gradle.kts

```kotlin
plugins {
    `swift-application` // or `swift-library`
}

version = "1.2.1"
```

build.gradle

```groovy
plugins {
    id 'swift-application' // or 'swift-library'
}

version = '1.2.1'
```

By applying either of the Swift plugins, you get a whole host of features:

- `compileDebugSwift` and `compileReleaseSwift` tasks that compiles the Swift source files under *src/main/swift* for the well-known debug and release build types, respectively.

- `linkDebug` and `linkRelease` tasks that link the compiled Swift object files into an executable for applications or shared library for libraries with shared linkage for the debug and release build types.

- `createDebug` and `createRelease` tasks that assemble the compiled Swift object files into a static library for libraries with static linkage for the debug and release build types.

For any non-trivial Swift project, you'll probably have some file dependencies and additional configuration specific to *your* project.

The Swift plugins also integrates the above tasks into the standard lifecycle tasks. The task that produces the development binary is attached to `assemble`. By default, the development binary is the debug variant.

The rest of the chapter explains the different ways to customize the build to your requirements when building libraries and applications.

== Introducing build variants

Native projects can typically produce several different binaries, such as debug or release ones, or ones that target particular platforms and processor architectures. Gradle manages this through the concepts of *dimensions* and *variants*.

A dimension is simply a category, where each category is orthogonal to the rest. For example, the "build type" dimension is a category that includes debug and release. The "architecture" dimension covers processor architectures like x86-64 and x86.

A variant is a combination of values for these dimensions, consisting of exactly one value for each dimension. You might have a "debug x86-64" or a "release x86" variant.

Gradle has built-in support for several dimensions and several values within each dimension. You can find a list of them in the native plugin reference chapter.

== Declaring your source files

Gradle's Swift support uses a `ConfigurableFileCollection` directly from the application or library script block to configure the set of sources to compile.

Libraries make a distinction between private (implementation details) and public (exported to consumer) headers.

You can also configure sources for each binary build for those cases where sources are compiled only on certain target machines.
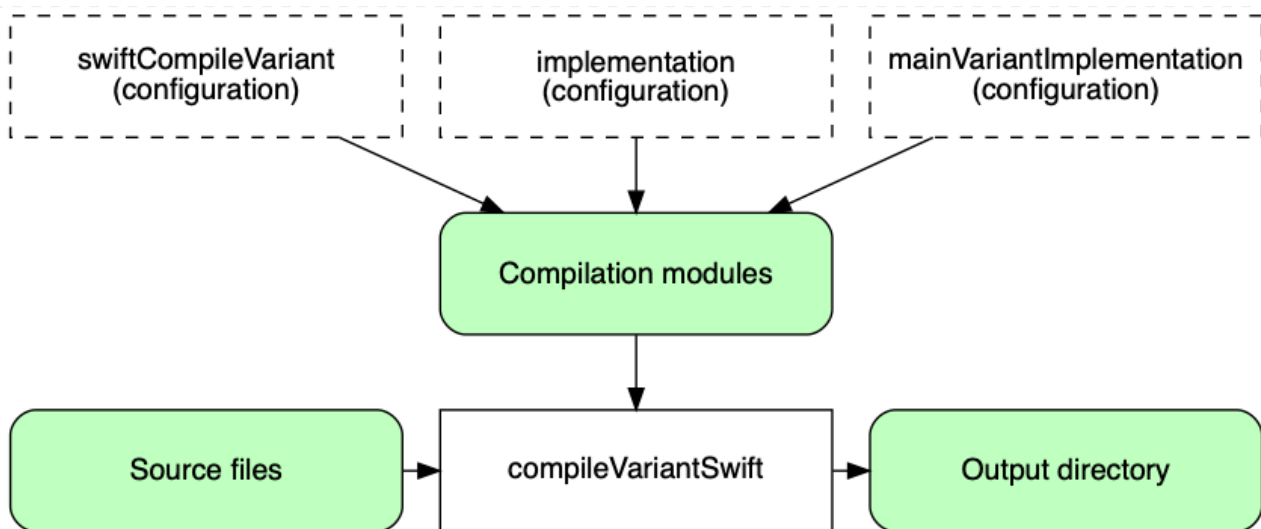
Figure 47. Sources and Swift compilation

== Managing your dependencies

The vast majority of projects rely on other projects, so managing your project's dependencies is an important part of building any project. Dependency management is a big topic, so we will only focus on the basics for Swift projects here. If you'd like to dive into the details, check out the introduction to dependency management.

Gradle provides support for consuming pre-built binaries from Maven repositories published by Gradle [15].

We will cover how to add dependencies between projects within a multi-build project.

Specifying dependencies for your Swift project requires two pieces of information:

* Identifying information for the dependency (project path, Maven GAV)
* What it's needed for, e.g. compilation, linking, runtime or all of the above.

This information is specified in a `dependencies {}` block of the Swift `application` or `library` script block. For example, to tell Gradle that your project requires library `common` to compile and link your production code, you can use the following fragment:

build.gradle.kts

```
application {
    dependencies {
        implementation(project(":common"))
    }
}
```

build.gradle

```
application {
    dependencies {
        implementation project(':common')
    }
}
```

The Gradle terminology for the three elements is as follows:

- *Configuration* (ex: `implementation`) - a named collection of dependencies, grouped together for a specific goal such as compiling or linking a module

- *Project reference* (ex: `project(':common')`) - the project referenced by the specified path

You can find a more comprehensive glossary of dependency management terms [here](.).

As far as configurations go, the main ones of interest are:

- `implementation` - used for compilation, linking and runtime

- `swiftCompileVariant` - for dependencies that are necessary to compile your production code but shouldn't be part of the linking or runtime process

- `nativeLinkVariant` - for dependencies that are necessary to link your code but shouldn't be part of the compilation or runtime process

- `nativeRuntimeVariant` - for dependencies that are necessary to run your component but shouldn't be part of the compilation or linking process

You can learn more about these and how they relate to one another in the [native plugin reference chapter](.).

Be aware that the [Swift Library Plugin](.) creates an additional configuration — `api` — for dependencies that are required for compiling and linking both the module and any modules that depend on it.

We have only scratched the surface here, so we recommend that you read the [dedicated dependency management chapters](.) once you're comfortable with the basics of building Swift projects with Gradle.

Some common scenarios that require further reading include:

- Defining a custom [Maven-compatible](.) repository

- Declaring dependencies with [changing](.) (e.g. SNAPSHOT) and [dynamic](.) (range) versions

- Declaring a sibling [project as a dependency](.)

- [Controlling transitive dependencies and their versions](.)

- Testing your fixes to 3rd-party dependency via [composite builds](.) (a better alternative to publishing to and consuming from [Maven Local](.))

You'll discover that Gradle has a rich API for working with dependencies — one that takes time to master, but is straightforward to use for common scenarios.

== Compiling and linking your code Compiling both your code can be trivially easy if you follow the conventions:

1. Put your source code under the *src/main/swift* directory

2. Declare your compile dependencies in the `implementation` configurations (see the previous

section)

3. Run the `assemble` task

We recommend that you follow these conventions wherever possible, but you don't have to.

There are several options for customization, as you'll see next.

> **NOTE** All SwiftCompile tasks are incremental and cacheable.

=== Supported tool chain

Gradle support the official Swift tool chain for macOS and Linux. When you build a native binary, Gradle will attempt to locate a tool chain installed on your machine that can build the binary. Gradle select the first tool chain that can build for the target operating system, architecture and Swift language support.

> **NOTE** For Linux users, Gradle will discover the tool chain using the system PATH.

=== Customizing file and directory locations

Imagine you are migrating a library project that follows the Swift Package Manager layout (e.g. `Sources/ModuleName` directory for the production code). The conventional directory structure won't work, so you need to tell Gradle where to find the source files. You do that via the `application` or `library` script block.

Each component script block, as well as each binary, defines where it's source code resides. You can override the convention values by using the following syntax:

build.gradle.kts

```
extensions.configure<SwiftLibrary> {
    source.from(file("Sources/Common"))
}
```

build.gradle

```
library {
    source.from file('src')
}
```

Now Gradle will only search directly in *Sources/Common* for the source.

=== Changing compiler and linker options

Most of the compiler and linker options are accessible through the corresponding task, such as compileVariantSwift, linkVariant and createVariant. These tasks are of type SwiftCompile, LinkSharedLibrary and CreateStaticLibrary respectively. Read the task reference for an up-to-date and comprehensive list of the options.

For example, if you want to change the warning level generated by the compiler for all variants, you can use this configuration:

build.gradle.kts

```
tasks.withType(SwiftCompile::class.java).configureEach {
    // Define a preprocessor macro for every binary
    macros.add("NDEBUG")

    // Define a compiler options
    compilerArgs.add("-O")
}
```

build.gradle

```
tasks.withType(SwiftCompile).configureEach {
    // Define a preprocessor macro for every binary
    macros.add("NDEBUG")

    // Define a compiler options
    compilerArgs.add '-O'
}
```

It's also possible to find the instance for a specific variant through the BinaryCollection on the application or library script block:

```kotlin
application {
    binaries.configureEach(SwiftStaticLibrary::class.java) {
        // Define a preprocessor macro for every binary
        compileTask.get().macros.add("NDEBUG")

        // Define a compiler options
        compileTask.get().compilerArgs.add("-O")
    }
}
```

build.gradle

```groovy
application {
    binaries.configureEach(SwiftStaticLibrary) {
        // Define a preprocessor macro for every binary
        compileTask.get().macros.add("NDEBUG")

        // Define a compiler options
        compileTask.get().compilerArgs.add '-O'
    }
}
```

=== Selecting target machines

By default, Gradle will attempt to create a Swift binary variant for the host operating system and architecture. It is possible to override this by specifying the set of `TargetMachine` on the `application` or `library` script block:

build.gradle.kts

```kotlin
application {
    targetMachines = listOf(machines.linux.x86_64, machines.macOS.x86_64)
}
```

build.gradle

```
application {
    targetMachines = [
        machines.linux.x86_64,
        machines.macOS.x86_64
    ]
}
```

Packaging and publishing

How you package and potentially publish your Swift project varies greatly in the native world. Gradle comes with defaults, but custom packaging can be implemented without any issues.

- Executable files are published directly to Maven repositories.
- Shared and static library files are published directly to Maven repositories along with a zip of the public headers.
- For applications, Gradle also supports installing and running the executable with all of its shared library dependencies in a known location.

Cleaning the build

The Swift Application and Library Plugins add a `clean` task to you project by using the base plugin. This task simply deletes everything in the `layout.buildDirectory` directory, hence why you should always put files generated by the build in there. The task is an instance of Delete and you can change what directory it deletes by setting its `dir` property.

Building Swift libraries

The unique aspect of library projects is that they are used (or "consumed") by other Swift projects. That means the dependency metadata published with the binaries and headers — in the form of Gradle Module Metadata — is crucial. In particular, consumers of your library should be able to distinguish between two different types of dependencies: those that are only required to compile your library and those that are also required to compile the consumer.

Gradle manages this distinction via the Swift Library Plugin, which introduces an *api* configuration in addition to the *implementation* once covered in this chapter. If the types from a dependency appear as unresolved symbols of the static library or within the public headers then that dependency is exposed via your library's public API and should, therefore, be added to the *api* configuration. Otherwise, the dependency is an internal implementation detail and should be added to *implementation.*

If you're unsure of the difference between an API and implementation dependency, the Swift Library Plugin chapter has a detailed explanation. In addition, you can see a basic, practical example of building a Swift library in the corresponding sample.

Building Swift applications

See the Swift Application Plugin chapter for more details, but here's a quick summary of what you get:

- `install` create a directory containing everything needed to run it
- Shell and Windows Batch scripts to start the application

You can see a basic example of building a Swift application in the corresponding sample.

Testing in Swift projects

WARNING	The Swift testing support is not compatible with the configuration cache.

Testing in the native ecosystem is a rich subject matter. There are many different testing libraries and frameworks, as well as many different types of test. All need to be part of the build, whether they are executed frequently or infrequently. This chapter is dedicated to explaining how Gradle handles differing requirements between and within builds, with significant coverage of how it integrates with XCTest on both macOS and Linux.

It explains: - Ways to control how the tests are run (Test execution) - How to select specific tests to run (Test filtering) - What test reports are generated and how to influence the process (Test reporting) - How Gradle finds tests to run (Test detection)

But first, we look at the basics of native testing in Gradle.

== The basics

Gradle supports deep integration with XCTest testing framework for the Swift language and revolves around the XCTest task type. This runs a collection of test cases using the Xcode XCTest on macOS or the open source Swift core library alternative on Linux and collates the results. You can then turn those results into a report via an instance of the TestReport task type.

In order to operate, the XCTest task type requires three pieces of information: - Where to find the built testable bundle (on macOS) or executable (on Linux) (property: XCTest.getTestInstalledDirectory()) - The run script for executing the bundle or executable (property: XCTest.getRunScriptFile()) - The working directory to execution the bundle or executable (property: XCTest.getWorkingDirectory())

When you're using the XCTest Plugin you will automatically get the following: - A dedicated `xctest` extension of type SwiftXCTestSuite for configuring test component and its variants - A `xcTest` task of type XCTest that runs those unit tests - A testable bundle or executable linked with the main component's object files

The test plugins configure the required pieces of information appropriately. In addition, they attach the `xcTest` or `run` task to the `check` lifecycle task. It also create the `testImplementation` dependency configuration. Dependencies that are only needed for test compilation, linking and runtime may be added to this configuration. The `xctest` script block behave similarly to a `application` or `library` script block.

The XCTest task has many configuration options. We cover a significant number of them in the rest of the chapter.

== Test execution

Gradle executes tests in a separate ('forked') process.

You can control how the test process is launched via several properties on the XCTest task, including the following:

ignoreFailures - default: false

> If this property is `true`, Gradle will continue with the project's build once the tests have completed, even if some of them have failed. Note that, by default, both task type always executes every test that it detects, irrespective of this setting.

testLogging - default: not set

> This property represents a set of options that control which test events are logged and at what level. You can also configure other logging behavior via this property. Set TestLoggingContainer for more detail.

See XCTest for details on all the available configuration options.

== Test filtering It's a common requirement to run subsets of a test suite, such as when you're fixing a bug or developing a new test case. Gradle provides filtering to do this. You can select tests to run based on:

- A simple class name or method name, e.g. `SomeTest`, `SomeTest.someMethod`
- '*' wildcard matching

You can enable filtering either in the build script or via the `--tests` command-line option. Here's an example of some filters that are applied every time the build runs:

build.gradle.kts

```
xctest {
    binaries.configureEach {
        runTask.get().filter.includeTestsMatching("SomeIntegTest.*") // or
`"Testing.SomeIntegTest.*"` on macOS
    }
}
```

build.gradle

```
xctest {
    binaries.configureEach {
        runTask.get().configure {
            // include all tests from test class
            filter.includeTestsMatching "SomeIntegTest.*" // or
`"Testing.SomeIntegTest.*"` on macOS
        }
    }
}
```

For more details and examples of declaring filters in the build script, please see the TestFilter reference.

The command-line option is especially useful to execute a single test method. It is also possible to supply multiple `--tests` options, all of whose patterns will take effect. The following sections have several examples of using command-line option.

NOTE	The test filtering only support XCTest compatible filters at the moment. It means the same filter will differ between macOS and Linux. On macOS, the bundle base name needs to be prepended to the filter, e.g. `TestBundle.SomeTest`, `TestBundle.SomeTest.someMethod` See the Simple name pattern section below for more information about valid filtering pattern.

The following section looks at the specific cases of simple class/method names.

=== Simple name pattern

Gradle support simple class name, or a class name + method name test filtering. For example, the following command lines run either all or exactly one of the tests in the `SomeTestClass` test case:

```
# Executes all tests in SomeTestClass
gradle xcTest --tests SomeTestClass
# or `gradle xcTest --tests TestBundle.SomeTestClass` on macOS

# Executes a single specified test in SomeTestClass
gradle xcTest --tests TestBundle.SomeTestClass.someSpecificMethod
# or `gradle xcTest --tests TestBundle.SomeTestClass.someSpecificMethod` on macOS
```

You can also combine filters defined at the command line with continuous build to re-execute a subset of tests immediately after every change to a production or test source file. The following executes all tests in the 'SomeTestClass' test class whenever a change triggers the tests to run:

```
gradle test --continuous --tests SomeTestClass
```

== Test reporting The XCTest task generates the following results by default:

- An HTML test report

- XML test results in a format compatible with the Ant JUnit report task - one that is supported by many other tools, such as CI servers

- An efficient binary format of the results used by the `XCTest` task to generate the other formats

In most cases, you'll work with the standard HTML report, which automatically includes the result from your `XCTest` tasks.

There is also a standalone TestReport task type that you can use to generate a custom HTML test report. All it requires are a value for `destinationDir` and the test results you want included in the report. Here is a sample which generates a combined report for the unit tests from all subprojects:

buildSrc/src/main/kotlin/myproject.xctest-conventions.gradle.kts

```kotlin
plugins {
    id("xctest")
}

extensions.configure<SwiftXCTestSuite>() {
    binaries.configureEach {
        // Disable the test report for the individual test task
        runTask.get().reports.html.required = false
    }
}

configurations.create("binaryTestResultsElements") {
    isCanBeResolved = false
    isCanBeConsumed = true
    attributes {
        attribute(Category.CATEGORY_ATTRIBUTE,
objects.named(Category.DOCUMENTATION))
        attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named("test-report-data"))
    }
    tasks.withType<XCTest>() {
        outgoing.artifact(binaryResultsDirectory)
    }
}
```

build.gradle.kts

```
plugins {
    `reporting-base`
}

val testReportData by configurations.creating {
    isCanBeConsumed = false
    attributes {
        attribute(Category.CATEGORY_ATTRIBUTE,
objects.named(Category.DOCUMENTATION))
        attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named("test-report-data"))
    }
}

dependencies {
    testReportData(project(":core"))
    testReportData(project(":util"))
}

tasks.register<TestReport>("testReport") {
    destinationDirectory = reporting.baseDirectory.dir("allTests")
    // Use test results from testReportData configuration
    testResults.from(testReportData)
}
```

buildSrc/src/main/groovy/myproject.xctest-conventions.gradle

```groovy
plugins {
    id 'xctest'
}

xctest {
    binaries.configureEach {
        runTask.get().configure {
            // Disable the test report for the individual test task
            reports.html.required = false
        }
    }
}

// Share the test report data to be aggregated for the whole project
configurations {
    binaryTestResultsElements {
        canBeResolved = false
        attributes {
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.DOCUMENTATION))
            attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named(DocsType, 'test-
report-data'))
        }
        tasks.withType(XCTest).configureEach {
            outgoing.artifact(it.binaryResultsDirectory)
        }
    }
}
```

```gradle
// A resolvable configuration to collect test reports data
plugins {
    id 'reporting-base'
}

configurations {
    testReportData {
        canBeConsumed = false
        attributes {
            attribute(Category.CATEGORY_ATTRIBUTE, objects.named(Category,
Category.DOCUMENTATION))
            attribute(DocsType.DOCS_TYPE_ATTRIBUTE, objects.named(DocsType, 'test-
report-data'))
        }
    }
}

dependencies {
    testReportData project(':core')
    testReportData project(':util')
}

tasks.register('testReport', TestReport) {
    destinationDirectory = reporting.baseDirectory.dir('allTests')
    // Use test results from testReportData configuration
    testResults.from(configurations.testReportData)
}
```

In this example, we use a convention plugin `myproject.xctest-conventions` to expose the test results from a project to Gradle's variant aware dependency management engine.

The plugin declares a consumable `binaryTestResultsElements` configuration that represents the binary test results of the `test` task. In the aggregation project's build file, we declare the `testReportData` configuration and depend on all of the projects that we want to aggregate the results from. Gradle will automatically select the binary test result variant from each of the subprojects instead of the project's jar file. Lastly, we add a `testReport` task that aggregates the test results from the `testResultsDirs` property, which contains all of the binary test results resolved from the `testReportData` configuration.

You should note that the TestReport type combines the results from multiple test tasks and needs to aggregate the results of individual test classes. This means that it a given test class is executed by multiple test tasks, then the test report will include executions of that class, but it can be hard to distinguish individual executions of that class and their output.

== NATIVE PROJECTS USING THE SOFTWARE MODEL

= Building native software

CAUTION	The software model is being retired and the plugins mentioned in this chapter will eventually be deprecated and removed. We recommend new projects looking to build C++ applications and libraries use the newer replacement plugins.
WARNING	The native plugins described in this chapter are not compatible with the configuration cache.

The native software plugins add support for building native software components, such as executables or shared libraries, from code written in C++, C and other languages. While many excellent build tools exist for this space of software development, Gradle offers developers its trademark power and flexibility together with dependency management practices more traditionally found in the JVM development space.

The native software plugins make use of the Gradle software model.

== Features

The native software plugins provide:

- Support for building native libraries and applications on Windows, Linux, macOS and other platforms.
- Support for several source languages.
- Support for building different variants of the same software, for different architectures, operating systems, or for any purpose.
- Incremental parallel compilation, precompiled headers.
- Dependency management between native software components.

- Unit test execution.

- Generate Visual studio solution and project files.

- Deep integration with various tool chain, including discovery of installed tool chains.

== Supported languages

The following source languages are currently supported:

- C

- C++

- Objective-C

- Objective-C++

- Assembly

- Windows resources

== Tool chain support

Gradle offers the ability to execute the same build using different tool chains. When you build a native binary, Gradle will attempt to locate a tool chain installed on your machine that can build the binary. You can fine tune exactly how this works, see Tool chain support for details.

The following tool chains are supported:

Operating System	Tool Chain	Notes
Linux	GCC	
Linux	Clang	
macOS	XCode	Uses the Clang tool chain bundled with XCode.
Windows	Visual C++	Windows XP and later, Visual C++ 2010/2012/2013/2015/2017/2019.
Windows	GCC with Cygwin 32 and Cygwin 64	Windows XP and later.
Windows	GCC with MinGW and MinGW64	Windows XP and later.

The following tool chains are unofficially supported. They generally work fine, but are not tested continuously:

Operating System	Tool Chain	Notes
macOS	GCC from Macports	
macOS	Clang from Macports	
UNIX-like	GCC	

Operating System	Tool Chain	Notes
UNIX-like	Clang	

Tool chain installation

> **NOTE** Note that if you are using GCC then you currently need to install support for C++, even if you are not building from C++ source. This restriction will be removed in a future Gradle version.

To build native software, you will need to have a compatible tool chain installed:

Windows

To build on Windows, install a compatible version of Visual Studio. The native plugins will discover the Visual Studio installations and select the latest version. There is no need to mess around with environment variables or batch scripts. This works fine from a Cygwin shell or the Windows command-line.

Alternatively, you can install Cygwin with GCC or MinGW. Clang is currently not supported.

macOS

To build on macOS, you should install XCode. The native plugins will discover the XCode installation using the system PATH.

The native plugins also work with GCC and Clang bundled with Macports. To use one of the Macports tool chains, you will need to make the tool chain the default using the `port select` command and add Macports to the system PATH.

Linux

To build on Linux, install a compatible version of GCC or Clang. The native plugins will discover GCC or Clang using the system PATH.

Native software model

The native software model builds on the base Gradle software model.

To build native software using Gradle, your project should define one or more *native components*. Each component represents either an executable or a library that Gradle should build. A project can define any number of components. Gradle does not define any components by default.

For each component, Gradle defines a *source set* for each language that the component can be built from. A source set is essentially just a set of source directories containing source files. For example, when you apply the `c` plugin and define a library called `helloworld`, Gradle will define, by default, a source set containing the C source files in the `src/helloworld/c` directory. It will use these source files to build the `helloworld` library. This is described in more detail below.

For each component, Gradle defines one or more *binaries* as output. To build a binary, Gradle will take the source files defined for the component, compile them as appropriate for the source language, and link the result into a binary file. For an executable component, Gradle can produce executable binary files. For a library component, Gradle can produce both static and shared library binary files. For example, when you define a library called `helloworld` and build on Linux, Gradle will, by default, produce `libhelloworld.so` and `libhelloworld.a` binaries.

In many cases, more than one binary can be produced for a component. These binaries may vary based on the tool chain used to build, the compiler/linker flags supplied, the dependencies provided, or additional source files provided. Each native binary produced for a component is referred to as a *variant*. Binary variants are discussed in detail below.

== Parallel Compilation

Gradle uses the single build worker pool to concurrently compile and link native components, by default. No special configuration is required to enable concurrent building.

By default, the worker pool size is determined by the number of available processors on the build machine (as reported to the build JVM). To explicitly set the number of workers use the `--max-workers` command-line option or `org.gradle.workers.max` system property. There is generally no need to change this setting from its default.

The build worker pool is shared across all build tasks. This means that when using parallel project execution, the maximum number of concurrent individual compilation operations does not increase. For example, if the build machine has 4 processing cores and 10 projects are compiling in parallel, Gradle will only use 4 total workers, not 40.

== Building a library

To build either a static or shared native library, you define a library component in the `components` container. The following sample defines a library called `hello`:

=== Example: Defining a library component

build.gradle

```
model {
    components {
        hello(NativeLibrarySpec)
    }
}
```

A library component is represented using NativeLibrarySpec. Each library component can produce at least one shared library binary (SharedLibraryBinarySpec) and at least one static library binary (StaticLibraryBinarySpec).

== Building an executable

To build a native executable, you define an executable component in the `components` container. The following sample defines an executable called `main`:

=== Example: Defining executable components

build.gradle

```
model {
    components {
        main(NativeExecutableSpec) {
            sources {
                c.lib library: "hello"
            }
        }
    }
}
```

An executable component is represented using NativeExecutableSpec. Each executable component can produce at least one executable binary (NativeExecutableBinarySpec).

For each component defined, Gradle adds a FunctionalSourceSet with the same name. Each of these functional source sets will contain a language-specific source set for each of the languages supported by the project.

== Assembling or building dependents

Sometimes, you may need to *assemble* (compile and link) or *build* (compile, link and test) a component or binary and its *dependents* (things that depend upon the component or binary). The native software model provides tasks that enable this capability. First, the *dependent components* report gives insight about the relationships between each component. Second, the *build and assemble dependents* tasks allow you to assemble or build a component and its dependents in one step.

In the following example, the build file defines `OpenSSL` as a dependency of `libUtil` and `libUtil` as a dependency of `LinuxApp` and `WindowsApp`. Test suites are treated similarly. Dependents can be thought of as reverse dependencies.
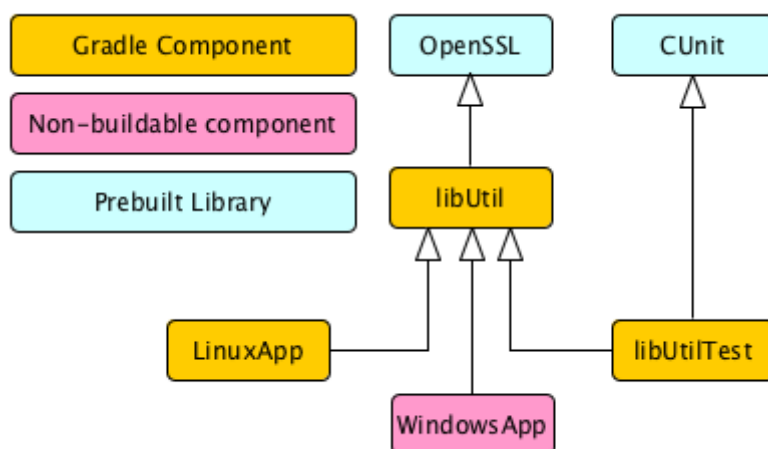
Figure 48. Dependent Components Example

NOTE	By following the dependencies backwards, you can see `LinuxApp` and `WindowsApp` are *dependents* of `libUtil`. When `libUtil` is changed, Gradle will need to recompile or relink `LinuxApp` and `WindowsApp`.

When you *assemble* dependents of a component, the component and all of its dependents are compiled and linked, including any test suite binaries. Gradle's up-to-date checks are used to only compile or link if something has changed. For instance, if you have changed source files in a way that do not affect the headers of your project, Gradle will be able to skip compilation for dependent components and only need to re-link with the new library. Tests are not run when assembling a component.

When you *build* dependents of a component, the component and all of its dependent binaries are compiled, linked *and checked.* Checking components means running any check task including executing any test suites, so tests *are* run when building a component.

In the following sections, we will demonstrate the usage of the `assembleDependents*`, `buildDependents*` and `dependentComponents` tasks with a sample build that contains a CUnit test suite. The build script for the sample is the following:

=== Example: Sample build

```
plugins {
    id 'c'
    id 'cunit-test-suite'
}

model {
    flavors {
        passing
        failing
    }
    platforms {
        x86 {
            if (operatingSystem.macOsX) {
                architecture "x64"
            } else {
                architecture "x86"
            }
        }
    }
    components {
        operators(NativeLibrarySpec) {
            targetPlatform "x86"
        }
    }
    testSuites {
        operatorsTest(CUnitTestSuiteSpec) {
            testing $.components.operators
        }
    }
}
```

=== Dependent components report

Gradle provides a report that you can run from the command-line that shows a graph of components in your project and components that depend upon them. The following is an example of running `gradle dependentComponents` on the sample project:

=== Example: Dependent components report

Output of `gradle dependentComponents`

```
> gradle dependentComponents

> Task :dependentComponents


------------------------------------------------------------
Root project 'cunit'
------------------------------------------------------------

operators - Components that depend on native library 'operators'
+--- operators:failingSharedLibrary
+--- operators:failingStaticLibrary
+--- operators:passingSharedLibrary
\--- operators:passingStaticLibrary

Some test suites were not shown, use --test-suites or --all to show them.

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

NOTE	See DependentComponentsReport API documentation for more details.

By default, non-buildable binaries and test suites are hidden from the report. The `dependentComponents` task provides options that allow you to see all dependents by using the `--all` option:

=== Example: Dependent components report

```
> gradle dependentComponents --all

> Task :dependentComponents

------------------------------------------------------------
Root project 'cunit'
------------------------------------------------------------

operators - Components that depend on native library 'operators'
+--- operators:failingSharedLibrary
+--- operators:failingStaticLibrary
|     \--- operatorsTest:failingCUnitExe (t)
+--- operators:passingSharedLibrary
\--- operators:passingStaticLibrary
      \--- operatorsTest:passingCUnitExe (t)

operatorsTest - Components that depend on Cunit test suite 'operatorsTest'
+--- operatorsTest:failingCUnitExe (t)
\--- operatorsTest:passingCUnitExe (t)

(t) - Test suite binary

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

Here is the corresponding report for the `operators` component, showing dependents of all its binaries:

=== Example: Report of components that depends on the operators component

Output of `gradle dependentComponents --component operators`

```
> gradle dependentComponents --component operators

> Task :dependentComponents

------------------------------------------------------------
Root project 'cunit'
------------------------------------------------------------

operators - Components that depend on native library 'operators'
+--- operators:failingSharedLibrary
+--- operators:failingStaticLibrary
+--- operators:passingSharedLibrary
\--- operators:passingStaticLibrary

Some test suites were not shown, use --test-suites or --all to show them.

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

Here is the corresponding report for the `operators` component, showing dependents of all its binaries, including test suites:

=== Example: Report of components that depends on the operators component, including test suites

Output of `gradle dependentComponents --test-suites --component operators`

```
> gradle dependentComponents --test-suites --component operators

> Task :dependentComponents

------------------------------------------------------------
Root project 'cunit'
------------------------------------------------------------

operators - Components that depend on native library 'operators'
+--- operators:failingSharedLibrary
+--- operators:failingStaticLibrary
|    \--- operatorsTest:failingCUnitExe (t)
+--- operators:passingSharedLibrary
\--- operators:passingStaticLibrary
     \--- operatorsTest:passingCUnitExe (t)

(t) - Test suite binary

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

Furthermore, the `--non-binaries` option shows non-buildable binaries in the report, `--no-non-buildable` hides them. Similarly, the `--test-suites` option shows test suites and `--no-test-suites` hides them. The option `--no-all` hides both non-buildable binaries and test suites from the report.

=== Assembling dependents

For each NativeBinarySpec, Gradle will create a task named `assembleDependents${component.name}${binary.variant}` that *assembles* (compile and link) the binary and all of its dependent binaries.

For each NativeComponentSpec, Gradle will create a task named `assembleDependents${component.name}` that *assembles* all the binaries of the component and all of their dependent binaries.

For example, to assemble the dependents of the "passing" flavor of the "static" library binary of the "operators" component, you would run the `assembleDependentsOperatorsPassingStaticLibrary` task:

=== Example: Assemble components that depends on the passing/static binary of the operators component

Output of `gradle assembleDependentsOperatorsPassingStaticLibrary --max-workers=1`

```
> gradle assembleDependentsOperatorsPassingStaticLibrary --max-workers=1
> Task :compileOperatorsTestPassingCUnitExeOperatorsC
> Task :operatorsTestCUnitLauncher
> Task :compileOperatorsTestPassingCUnitExeOperatorsTestC
> Task :compileOperatorsTestPassingCUnitExeOperatorsTestCunitLauncher
> Task :linkOperatorsTestPassingCUnitExe
> Task :operatorsTestPassingCUnitExe
> Task :assembleDependentsOperatorsTestPassingCUnitExe
> Task :compileOperatorsPassingStaticLibraryOperatorsC
> Task :createOperatorsPassingStaticLibrary
> Task :operatorsPassingStaticLibrary
> Task :assembleDependentsOperatorsPassingStaticLibrary

BUILD SUCCESSFUL in 0s
7 actionable tasks: 7 executed
```

In the output above, the targeted binary gets assembled as well as the test suite binary that depends on it.

You can also assemble *all* of the dependents of a component (i.e. of all its binaries/variants) using the corresponding component task, e.g. `assembleDependentsOperators`. This is useful if you have many combinations of build types, flavors and platforms and want to assemble all of them.

=== Building dependents

For each NativeBinarySpec, Gradle will create a task named `buildDependents${component.name}${binary.variant}` that *builds* (compile, link and check) the binary and all of its dependent binaries.

For each NativeComponentSpec, Gradle will create a task named `buildDependents${component.name}` that *builds* all the binaries of the component and all of their dependent binaries.

For example, to build the dependents of the "passing" flavor of the "static" library binary of the "operators" component, you would run the `buildDependentsOperatorsPassingStaticLibrary` task:

=== Example: Build components that depends on the passing/static binary of the operators component

Output of `gradle buildDependentsOperatorsPassingStaticLibrary --max-workers=1`

```
> gradle buildDependentsOperatorsPassingStaticLibrary --max-workers=1
> Task :compileOperatorsTestPassingCUnitExeOperatorsC
> Task :operatorsTestCUnitLauncher
> Task :compileOperatorsTestPassingCUnitExeOperatorsTestC
> Task :compileOperatorsTestPassingCUnitExeOperatorsTestCunitLauncher
> Task :linkOperatorsTestPassingCUnitExe
> Task :operatorsTestPassingCUnitExe
> Task :installOperatorsTestPassingCUnitExe
> Task :runOperatorsTestPassingCUnitExe
> Task :checkOperatorsTestPassingCUnitExe
> Task :buildDependentsOperatorsTestPassingCUnitExe
> Task :compileOperatorsPassingStaticLibraryOperatorsC
> Task :createOperatorsPassingStaticLibrary
> Task :operatorsPassingStaticLibrary
> Task :buildDependentsOperatorsPassingStaticLibrary

BUILD SUCCESSFUL in 0s
9 actionable tasks: 9 executed
```

In the output above, the targeted binary as well as the test suite binary that depends on it are built and the test suite has run.

You can also build *all* of the dependents of a component (i.e. of all its binaries/variants) using the corresponding component task, e.g. `buildDependentsOperators`.

== Tasks

For each NativeBinarySpec that can be produced by a build, a single *lifecycle task* is constructed that can be used to create that binary, together with a set of other tasks that do the actual work of compiling, linking or assembling the binary.

`${component.name}Executable`

    Component Type

        NativeExecutableSpec

Native Binary Type

NativeExecutableBinarySpec

Location of created binary

${project.layout.buildDirectory}/**exe/**${component.name}/${component.name}

${component.name}SharedLibrary

Component Type

NativeLibrarySpec

Native Binary Type

SharedLibraryBinarySpec

Location of created binary

${project.layout.buildDirectory}/**libs/**${component.name}/**shared/lib**
${component.name}**.so**

${component.name}StaticLibrary

Component Type

NativeLibrarySpec

Native Binary Type

StaticLibraryBinarySpec

Location of created binary

${project.layout.buildDirectory}/**libs/**${component.name}/**static/**${component.name}**.a**

=== Check tasks

For each NativeBinarySpec that can be produced by a build, a single *check task* is constructed
that can be used to assemble and check that binary.

check${component.name}Executable

Component Type

NativeExecutableSpec

Native Binary Type

NativeExecutableBinarySpec

check${component.name}SharedLibrary

Component Type

NativeLibrarySpec

Native Binary Type

SharedLibraryBinarySpec

check${component.name}StaticLibrary

Component Type

[NativeLibrarySpec](#)

Native Binary Type

[SharedLibraryBinarySpec](#)

The built-in `check` task depends on all the *check tasks* for binaries in the project. Without either [CUnit](#) or [GoogleTest](#) plugins, the binary check task only depends on the *lifecycle task* that assembles the binary, see [Native tasks](#).

When the [CUnit](#) or [GoogleTest](#) plugins are applied, the task that executes the test suites for a component are automatically wired to the appropriate *check task*.

You can also add custom check tasks as follows:

=== Example: Adding a custom check task

build.gradle

```
plugins {
    id "cpp"
}
// You don't need to apply the plugin below if you're already using CUnit or
GoogleTest support
apply plugin: TestingModelBasePlugin

tasks.register('myCustomCheck') {
    doLast {
        println 'Executing my custom check'
    }
}

model {
    components {
        hello(NativeLibrarySpec) {
            binaries.all {
                // Register our custom check task to all binaries of this
component

                checkedBy $.tasks.myCustomCheck
            }
        }
    }
}
```

Now, running `check` or any of the *check tasks* for the `hello` binaries will run the custom check task:

=== Example: Running checks for a given binary

```
> gradle checkHelloSharedLibrary

> Task :myCustomCheck
Executing my custom check

> Task :checkHelloSharedLibrary

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

=== Working with shared libraries

For each executable binary produced, the `cpp` plugin provides an `install${binary.name}` task, which creates a development install of the executable, along with the shared libraries it requires. This allows you to run the executable without needing to install the shared libraries in their final locations.

== Finding out more about your project

Gradle provides a report that you can run from the command-line that shows some details about the components and binaries that your project produces. To use this report, just run `gradle components`. Below is an example of running this report for one of the sample projects:

=== Example: The components report

Output of `gradle components`

```
> gradle components

> Task :components


------------------------------------------------------------
Root project 'cpp'
------------------------------------------------------------

Native library 'hello'
----------------------

Source sets
    C++ source 'hello:cpp'
        srcDir: src/hello/cpp

Binaries
    Shared library 'hello:sharedLibrary'
        build using task: :helloSharedLibrary
        build type: build type 'debug'
        flavor: flavor 'default'
        target platform: platform 'current'
        tool chain: Tool chain 'clang' (Clang)
```

```
            shared library file: build/libs/hello/shared/libhello.dylib
        Static library 'hello:staticLibrary'
            build using task: :helloStaticLibrary
            build type: build type 'debug'
            flavor: flavor 'default'
            target platform: platform 'current'
            tool chain: Tool chain 'clang' (Clang)
            static library file: build/libs/hello/static/libhello.a

Native executable 'main'
------------------------

Source sets
    C++ source 'main:cpp'
        srcDir: src/main/cpp

Binaries
    Executable 'main:executable'
        build using task: :mainExecutable
        install using task: :installMainExecutable
        build type: build type 'debug'
        flavor: flavor 'default'
        target platform: platform 'current'
        tool chain: Tool chain 'clang' (Clang)
        executable file: build/exe/main/main

Note: currently not all plugins register their components, so some components may
not be visible here.

BUILD SUCCESSFUL in 0s
1 actionable task: 1 executed
```

== Language support

Presently, Gradle supports building native software from any combination of source languages listed below. A native binary project will contain one or more named `FunctionalSourceSet` instances (e.g. 'main', 'test', etc), each of which can contain `LanguageSourceSet`s containing source files, one for each language.

- C
- C++
- Objective-C
- Objective-C++
- Assembly
- Windows resources

=== C++ sources

C++ language support is provided by means of the `'cpp'` plugin.

=== Example: The 'cpp' plugin

build.gradle

```
plugins {
    id 'cpp'
}
```

C++ sources to be included in a native binary are provided via a CppSourceSet, which defines a set of C++ source files and optionally a set of exported header files (for a library). By default, for any named component the CppSourceSet contains `.cpp` source files in `src/${name}/cpp`, and header files in `src/${name}/headers`.

While the `cpp` plugin defines these default locations for each CppSourceSet, it is possible to extend or override these defaults to allow for a different project layout.

=== Example: C++ source set

build.gradle

```
sources {
    cpp {
        source {
            srcDir "src/source"
            include "**/*.cpp"
        }
    }
}
```

For a library named 'main', header files in `src/main/headers` are considered the "public" or "exported" headers. Header files that should not be exported should be placed inside the `src/main/cpp` directory (though be aware that such header files should always be referenced in a manner relative to the file including them).

=== C sources

C language support is provided by means of the `'c'` plugin.

=== Example: The 'c' plugin

build.gradle

```
plugins {
    id 'c'
}
```

C sources to be included in a native binary are provided via a CSourceSet, which defines a set of C source files and optionally a set of exported header files (for a library). By default, for any

named component the CSourceSet contains `.c` source files in `src/${name}/c`, and header files in `src/${name}/headers`.

While the `c` plugin defines these default locations for each CSourceSet, it is possible to extend or override these defaults to allow for a different project layout.

=== Example: C source set

build.gradle

```
sources {
    c {
        source {
            srcDir "src/source"
            include "**/*.c"
        }
        exportedHeaders {
            srcDir "src/include"
        }
    }
}
```

For a library named 'main', header files in `src/main/headers` are considered the "public" or "exported" headers. Header files that should not be exported should be placed inside the `src/main/c` directory (though be aware that such header files should always be referenced in a manner relative to the file including them).

=== Assembler sources

Assembly language support is provided by means of the `'assembler'` plugin.

=== Example: The 'assembler' plugin

build.gradle

```
plugins {
    id 'assembler'
}
```

Assembler sources to be included in a native binary are provided via a AssemblerSourceSet, which defines a set of Assembler source files. By default, for any named component the AssemblerSourceSet contains `.s` source files under `src/${name}/asm`.

=== Objective-C sources

Objective-C language support is provided by means of the `'objective-c'` plugin.

=== Example: The 'objective-c' plugin

```
plugins {
    id 'objective-c'
}
```

Objective-C sources to be included in a native binary are provided via a ObjectiveCSourceSet, which defines a set of Objective-C source files. By default, for any named component the ObjectiveCSourceSet contains `.m` source files under `src/${name}/objectiveC`.

=== Objective-C++ sources

Objective-C++ language support is provided by means of the `'objective-cpp'` plugin.

=== Example: The 'objective-cpp' plugin

build.gradle

```
plugins {
    id 'objective-cpp'
}
```

Objective-C++ sources to be included in a native binary are provided via a ObjectiveCppSourceSet, which defines a set of Objective-C++ source files. By default, for any named component the ObjectiveCppSourceSet contains `.mm` source files under `src/${name}/objectiveCpp`.

== Configuring the compiler, assembler and linker

Each binary to be produced is associated with a set of compiler and linker settings, which include command-line arguments as well as macro definitions. These settings can be applied to all binaries, an individual binary, or selectively to a group of binaries based on some criteria.

=== Example: Settings that apply to all binaries

build.gradle

```
model {
    binaries {
        all {
            // Define a preprocessor macro for every binary
            cppCompiler.define "NDEBUG"

            // Define toolchain-specific compiler and linker options
            if (toolChain in Gcc) {
                cppCompiler.args "-O2", "-fno-access-control"
                linker.args "-Xlinker", "-S"
            }
            if (toolChain in VisualCpp) {
                cppCompiler.args "/Zi"
                linker.args "/DEBUG"
            }
        }
    }
}
```

Each binary is associated with a particular NativeToolChain, allowing settings to be targeted based on this value.

It is easy to apply settings to all binaries of a particular type:

=== Example: Settings that apply to all shared libraries

build.gradle

```
// For any shared library binaries built with Visual C++,
// define the DLL_EXPORT macro
model {
    binaries {
        withType(SharedLibraryBinarySpec) {
            if (toolChain in VisualCpp) {
                cCompiler.args "/Zi"
                cCompiler.define "DLL_EXPORT"
            }
        }
    }
}
```

Furthermore, it is possible to specify settings that apply to all binaries produced for a particular `executable` or `library` component:

=== Example: Settings that apply to all binaries produced for the 'main' executable component

```
model {
    components {
        main(NativeExecutableSpec) {
            targetPlatform "x86"
            binaries.all {
                if (toolChain in VisualCpp) {
                    sources {
                        platformAsm(AssemblerSourceSet) {
                            source.srcDir "src/main/asm_i386_masm"
                        }
                    }
                    assembler.args "/Zi"
                } else {
                    sources {
                        platformAsm(AssemblerSourceSet) {
                            source.srcDir "src/main/asm_i386_gcc"
                        }
                    }
                    assembler.args "-g"
                }
            }
        }
    }
}
```

The example above will apply the supplied configuration to all `executable` binaries built.

Similarly, settings can be specified to target binaries for a component that are of a particular type: e.g. all shared libraries for the main library component.

=== Example: Settings that apply only to shared libraries produced for the 'main' library component

build.gradle

```
model {
    components {
        main(NativeLibrarySpec) {
            binaries.withType(SharedLibraryBinarySpec) {
                // Define a preprocessor macro that only applies to shared
libraries
                cppCompiler.define "DLL_EXPORT"
            }
        }
    }
}
```

== Windows Resources

When using the VisualCpp tool chain, Gradle is able to compile Window Resource (`rc`) files and link them into a native binary. This functionality is provided by the `'windows-resources'` plugin.

=== Example: The 'windows-resources' plugin

build.gradle

```
plugins {
    id 'windows-resources'
}
```

Windows resources to be included in a native binary are provided via a WindowsResourceSet, which defines a set of Windows Resource source files. By default, for any named component the WindowsResourceSet contains `.rc` source files under `src/${name}/rc`.

As with other source types, you can configure the location of the windows resources that should be included in the binary.

=== Example: Configuring the location of Windows resource sources

build-resource-only-dll.gradle

```
sources {
    rc {
        source {
            srcDirs "src/hello/rc"
        }
        exportedHeaders {
            srcDirs "src/hello/headers"
        }
    }
}
```

You are able to construct a resource-only library by providing Windows Resource sources with no other language sources, and configure the linker as appropriate:

=== Example: Building a resource-only dll

```
model {
    components {
        helloRes(NativeLibrarySpec) {
            binaries.all {
                rcCompiler.args "/v"
                linker.args "/noentry", "/machine:x86"
            }
            sources {
                rc {
                    source {
                        srcDirs "src/hello/rc"
                    }
                    exportedHeaders {
                        srcDirs "src/hello/headers"
                    }
                }
            }
        }
    }
}
```

The example above also demonstrates the mechanism of passing extra command-line arguments to the resource compiler. The `rcCompiler` extension is of type PreprocessingTool.

== Library Dependencies

Dependencies for native components are binary libraries that export header files. The header files are used during compilation, with the compiled binary dependency being used during linking and execution. Header files should be organized into subdirectories to prevent clashes of commonly named headers. For instance, if your `mylib` project has a `logging.h` header, it will make it less likely the wrong header is used if you include it as `"mylib/logging.h"` instead of `"logging.h"`.

=== Dependencies within the same project

A set of sources may depend on header files provided by another binary component within the same project. A common example is a native executable component that uses functions provided by a separate native library component.

Such a library dependency can be added to a source set associated with the `executable` component:

=== Example: Providing a library dependency to the source set

build.gradle

```
sources {
    cpp {
        lib library: "hello"
    }
}
```

Alternatively, a library dependency can be provided directly to the `NativeExecutableBinarySpec` for the `executable`.

=== Example: Providing a library dependency to the binary

build.gradle

```
model {
    components {
        hello(NativeLibrarySpec) {
            sources {
                c {
                    source {
                        srcDir "src/source"
                        include "**/*.c"
                    }
                    exportedHeaders {
                        srcDir "src/include"
                    }
                }
            }
        }
        main(NativeExecutableSpec) {
            sources {
                cpp {
                    source {
                        srcDir "src/source"
                        include "**/*.cpp"
                    }
                }
            }
            binaries.all {
                // Each executable binary produced uses the 'hello' static library
  binary
                lib library: 'hello', linkage: 'static'
            }
        }
    }
}
```

=== Project Dependencies

For a component produced in a different Gradle project, the notation is similar.

=== Example: Declaring project dependencies

lib/build.gradle

```
plugins {
    id 'cpp'
}

model {
    components {
        main(NativeLibrarySpec)
    }

    // For any shared library binaries built with Visual C++,
    // define the DLL_EXPORT macro
    binaries {
        withType(SharedLibraryBinarySpec) {
            if (toolChain in VisualCpp) {
                cppCompiler.define "DLL_EXPORT"
            }
        }
    }
}
```

exe/build.gradle

```
plugins {
    id 'cpp'
}

model {
    components {
        main(NativeExecutableSpec) {
            sources {
                cpp {
                    lib project: ':lib', library: 'main'
                }
            }
        }
    }
}
```

== Precompiled Headers

Precompiled headers are a performance optimization that reduces the cost of compiling widely used headers multiple times. This feature *precompiles* a header such that the compiled object file can be reused when compiling each source file rather than recompiling the header each time. This support is available for C, C++, Objective-C, and Objective-C++ builds.

To configure a precompiled header, first a header file needs to be defined that includes all of the headers that should be precompiled. It must be specified as the first included header in every source file where the precompiled header should be used. It is assumed that this header file, and any headers it contains, make use of header guards so that they can be included in an idempotent manner. If header guards are not used in a header file, it is possible the header could be compiled more than once and could potentially lead to a broken build.

=== Example: Creating a precompiled header file

src/hello/headers/pch.h

```
#ifndef PCH_H
#define PCH_H
#include <iostream>
#include "hello.h"
#endif
```

=== Example: Including a precompiled header file in a source file

src/hello/cpp/hello.cpp

```
#include "pch.h"

void LIB_FUNC Greeter::hello () {
    std::cout << "Hello world!" << std::endl;
}
```

Precompiled headers are specified on a source set. Only one precompiled header file can be specified on a given source set and will be applied to all source files that declare it as the first include. If a source files does not include this header file as the first header, the file will be compiled in the normal manner (without making use of the precompiled header object file). The string provided should be the same as that which is used in the "#include" directive in the source files.

=== Example: Configuring a precompiled header

build.gradle

```
model {
    components {
        hello(NativeLibrarySpec) {
            sources {
                cpp {
                    preCompiledHeader "pch.h"
                }
            }
        }
    }
}
```

A precompiled header must be included in the same way for all files that use it. Usually, this means the header file should exist in the source set "headers" directory or in a directory included on the compiler include path.

Native Binary Variants

For each executable or library defined, Gradle is able to build a number of different native binary variants. Examples of different variants include debug vs release binaries, 32-bit vs 64-bit binaries, and binaries produced with different custom preprocessor flags.

Binaries produced by Gradle can be differentiated on build type, platform, and flavor. For each of these 'variant dimensions', it is possible to specify a set of available values as well as target each component at one, some or all of these. For example, a plugin may define a range of support platforms, but you may choose to only target Windows-x86 for a particular component.

Build types

A `build type` determines various non-functional aspects of a binary, such as whether debug information is included, or what optimisation level the binary is compiled with. Typical build types are 'debug' and 'release', but a project is free to define any set of build types.

Example: Defining build types

build.gradle

```
model {
    buildTypes {
        debug
        release
    }
}
```

If no build types are defined in a project, then a single, default build type called 'debug' is added.

For a build type, a Gradle project will typically define a set of compiler/linker flags per tool chain.

Example: Configuring debug binaries

```groovy
model {
    binaries {
        all {
            if (toolChain in Gcc && buildType == buildTypes.debug) {
                cppCompiler.args "-g"
            }
            if (toolChain in VisualCpp && buildType == buildTypes.debug) {
                cppCompiler.args '/Zi'
                cppCompiler.define 'DEBUG'
                linker.args '/DEBUG'
            }
        }
    }
}
```

NOTE	At this stage, it is completely up to the build script to configure the relevant compiler/linker flags for each build type. Future versions of Gradle will automatically include the appropriate debug flags for any 'debug' build type, and may be aware of various levels of optimisation as well.

=== Platform

An executable or library can be built to run on different operating systems and cpu architectures, with a variant being produced for each platform. Gradle defines each OS/architecture combination as a NativePlatform, and a project may define any number of platforms. If no platforms are defined in a project, then a single, default platform 'current' is added.

Presently, a `Platform` consists of a defined operating system and architecture. As we continue to develop the native binary support in Gradle, the concept of Platform will be extended to include things like C-runtime version, Windows SDK, ABI, etc. Sophisticated builds may use the extensibility of Gradle to apply additional attributes to each platform, which can then be queried to specify particular includes, preprocessor macros or compiler arguments for a native binary.

=== Example: Defining platforms

build.gradle

```
model {
    platforms {
        x86 {
            architecture "x86"
        }
        x64 {
            architecture "x86_64"
        }
        itanium {
            architecture "ia-64"
        }
    }
}
```

For a given variant, Gradle will attempt to find a NativeToolChain that is able to build for the target platform. Available tool chains are searched in the order defined. See the tool chains section below for more details.

=== Flavor

Each component can have a set of named `flavors`, and a separate binary variant can be produced for each flavor. While the `build type` and `target platform` variant dimensions have a defined meaning in Gradle, each project is free to define any number of flavors and apply meaning to them in any way.

An example of component flavors might differentiate between 'demo', 'paid' and 'enterprise' editions of the component, where the same set of sources is used to produce binaries with different functions.

=== Example: Defining flavors

```
model {
    flavors {
        english
        french
    }
    components {
        hello(NativeLibrarySpec) {
            binaries.all {
                if (flavor == flavors.french) {
                    cppCompiler.define "FRENCH"
                }
            }
        }
    }
}
```

In the example above, a library is defined with a 'english' and 'french' flavor. When compiling the 'french' variant, a separate macro is defined which leads to a different binary being produced.

If no flavor is defined for a component, then a single default flavor named 'default' is used.

=== Selecting the build types, platforms and flavors for a component

For a default component, Gradle will attempt to create a native binary variant for each and every combination of `buildType` and `flavor` defined for the project. It is possible to override this on a per-component basis, by specifying the set of `targetBuildTypes` and/or `targetFlavors`. By default, Gradle will build for the default platform, see above, unless specified explicitly on a per-component basis by specifying a set of `targetPlatforms`.

=== Example: Targeting a component at particular platforms

build.gradle

```
model {
    components {
        hello(NativeLibrarySpec) {
            targetPlatform "x86"
            targetPlatform "x64"
        }
        main(NativeExecutableSpec) {
            targetPlatform "x86"
            targetPlatform "x64"
            sources {
                cpp.lib library: 'hello', linkage: 'static'
            }
        }
    }
}
```

Here you can see that the TargetedNativeComponent.targetPlatform(java.lang.String) method is used to specify a platform that the `NativeExecutableSpec` named `main` should be built for.

A similar mechanism exists for selecting TargetedNativeComponent.targetBuildTypes(java.lang.String…) and TargetedNativeComponent.targetFlavors(java.lang.String…).

=== Building all possible variants

When a set of build types, target platforms, and flavors is defined for a component, a NativeBinarySpec model element is created for every possible combination of these. However, in many cases it is not possible to build a particular variant, perhaps because no tool chain is available to build for a particular platform.

If a binary variant cannot be built for any reason, then the NativeBinarySpec associated with that variant will not be `buildable`. It is possible to use this property to create a task to generate all possible variants on a particular machine.

=== Example: Building all possible variants

build.gradle

```
model {
    tasks {
        buildAllExecutables(Task) {
            dependsOn $.binaries.findAll { it.buildable }
        }
    }
}
```

== Tool chains

A single build may utilize different tool chains to build variants for different platforms. To this end, the core 'native-binary' plugins will attempt to locate and make available supported tool chains. However, the set of tool chains for a project may also be explicitly defined, allowing additional cross-compilers to be configured as well as allowing the install directories to be specified.

=== Defining tool chains

The supported tool chain types are:

- Gcc
- Clang
- VisualCpp

=== Example: Defining tool chains

build.gradle

```
model {
    toolChains {
        visualCpp(VisualCpp) {
            // Specify the installDir if Visual Studio cannot be located
            // installDir "C:/Apps/Microsoft Visual Studio 10.0"
        }
        gcc(Gcc) {
            // Uncomment to use a GCC install that is not in the PATH
            // path "/usr/bin/gcc"
        }
        clang(Clang)
    }
}
```

Each tool chain implementation allows for a certain degree of configuration (see the API documentation for more details).

=== Using tool chains

It is not necessary or possible to specify the tool chain that should be used to build. For a given variant, Gradle will attempt to locate a NativeToolChain that is able to build for the target platform. Available tool chains are searched in the order defined.

| NOTE | When a platform does not define an architecture or operating system, the default target of the tool chain is assumed. So if a platform does not define a value for `operatingSystem`, Gradle will find the first available tool chain that can build for the specified `architecture`. |

The core Gradle tool chains are able to target the following architectures out of the box. In each case, the tool chain will target the current operating system. See the next section for information on cross-compiling for other operating systems.

Tool Chain	Architectures
GCC	x86, x86_64, arm64 (macOS Only)
Clang	x86, x86_64, arm64 (macOS only)
Visual C++	x86, x86_64, ia-64

So for GCC running on linux, the supported target platforms are 'linux/x86' and 'linux/x86_64'. For GCC running on Windows via Cygwin, platforms 'windows/x86' and 'windows/x86_64' are supported. (The Cygwin POSIX runtime is not yet modelled as part of the platform, but will be in the future.)

If no target platforms are defined for a project, then all binaries are built to target a default platform named 'current'. This default platform does not specify any `architecture` or `operatingSystem` value, hence using the default values of the first available tool chain.

Gradle provides a *hook* that allows the build author to control the exact set of arguments passed to a tool chain executable. This enables the build author to work around any limitations in Gradle, or assumptions that Gradle makes. The arguments hook should be seen as a 'last-resort' mechanism, with preference given to truly modelling the underlying domain.

=== Example: Reconfigure tool arguments

```
model {
    toolChains {
        visualCpp(VisualCpp) {
            eachPlatform {
                cppCompiler.withArguments { args ->
                    args << "-DFRENCH"
                }
            }
        }
        clang(Clang) {
            eachPlatform {
                cCompiler.withArguments { args ->
                    Collections.replaceAll(args, "CUSTOM", "-DFRENCH")
                }
                linker.withArguments { args ->
                    args.remove "CUSTOM"
                }
                staticLibArchiver.withArguments { args ->
                    args.remove "CUSTOM"
                }
            }
        }
    }
}
```

=== Cross-compiling with GCC

Cross-compiling is possible with the Gcc and Clang tool chains, by adding support for additional target platforms. This is done by specifying a target platform for a toolchain. For each target platform a custom configuration can be specified.

=== Example: Defining target platforms

build.gradle

```
model {
    toolChains {
        gcc(Gcc) {
            target("arm"){
                cppCompiler.withArguments { args ->
                    args << "-m32"
                }
                linker.withArguments { args ->
                    args << "-m32"
                }
            }
            target("sparc")
        }
    }
    platforms {
        arm {
            architecture "arm"
        }
        sparc {
            architecture "sparc"
        }
    }
    components {
        main(NativeExecutableSpec) {
            targetPlatform "arm"
            targetPlatform "sparc"
        }
    }
}
```

== Visual Studio IDE integration

Gradle has the ability to generate Visual Studio project and solution files for the native components defined in your build. This ability is added by the `visual-studio` plugin. For a multi-project build, all projects with native components (and the root project) should have this plugin applied.

When the `visual-studio` plugin is applied to the root project, a task named `visualStudio` is created, which will generate a Visual Studio solution file containing all components in the build. This solution will include a Visual Studio project for each component, as well as configuring each component to build using Gradle.

A task named `openVisualStudio` is also created by the `visual-studio` plugin when the project is the root project. This task generates the Visual Studio solution and then opens the solution in Visual Studio. This means you can simply run `gradlew openVisualStudio` from the root project to generate and open the Visual Studio solution in one convenient step.

The content of the generated visual studio files can be modified via API hooks, provided by the

`visualStudio` extension. Take a look at the 'visual-studio' sample, or see VisualStudioExtension.getProjects() and VisualStudioRootExtension.getSolution() in the API documentation for more details.

CUnit support

The Gradle `cunit` plugin provides support for compiling and executing CUnit tests in your native-binary project. For each NativeExecutableSpec and NativeLibrarySpec defined in your project, Gradle will create a matching CUnitTestSuiteSpec component, named `${component.name}Test`.

CUnit sources

Gradle will create a CSourceSet named 'cunit' for each CUnitTestSuiteSpec component in the project. This source set should contain the cunit test files for the component under test. Source files can be located in the conventional location (`src/${component.name}Test/cunit`) or can be configured like any other source set.

Gradle initialises the CUnit test registry and executes the tests, utilising some generated CUnit launcher sources. Gradle will expect and call a function with the signature `void gradle_cunit_register()` that you can use to configure the actual CUnit suites and tests to execute.

Example: Registering CUnit tests

suite_operators.c

```
#include <CUnit/Basic.h>
#include "gradle_cunit_register.h"
#include "test_operators.h"

int suite_init(void) {
    return 0;
}

int suite_clean(void) {
    return 0;
}

void gradle_cunit_register() {
    CU_pSuite pSuiteMath = CU_add_suite("operator tests", suite_init,
suite_clean);
    CU_add_test(pSuiteMath, "test_plus", test_plus);
    CU_add_test(pSuiteMath, "test_minus", test_minus);
}
```

NOTE	Due to this mechanism, your CUnit sources may not contain a `main` method since this will clash with the method provided by Gradle.

Building CUnit executables

A CUnitTestSuiteSpec component has an associated NativeExecutableSpec or NativeLibrarySpec component. For each NativeBinarySpec configured for the main component, a matching CUnitTestSuiteBinarySpec will be configured on the test suite component. These test suite binaries can be configured in a similar way to any other binary instance:

=== Example: Configuring CUnit tests

build.gradle

```
model {
    binaries {
        withType(CUnitTestSuiteBinarySpec) {
            lib library: "cunit", linkage: "static"

            if (flavor == flavors.failing) {
                cCompiler.define "PLUS_BROKEN"
            }
        }
    }
}
```

NOTE	Both the CUnit sources provided by your project and the generated launcher require the core CUnit headers and libraries. Presently, this library dependency must be provided by your project for each CUnitTestSuiteBinarySpec.

=== Running CUnit tests

For each CUnitTestSuiteBinarySpec, Gradle will create a task to execute this binary, which will run all of the registered CUnit tests. Test results will be found in the ${build.dir}/test-results directory.

=== Example: Running CUnit tests

build.gradle

```
plugins {
    id 'c'
    id 'cunit-test-suite'
}

model {
    flavors {
        passing
        failing
    }
    platforms {
        x86 {
            if (operatingSystem.macOsX) {
                architecture "x64"
```

```
        } else {
            architecture "x86"
        }
    }
}
repositories {
    libs(PrebuiltLibraries) {
        cunit {
            headers.srcDir "libs/cunit/2.1-2/include"
            binaries.withType(StaticLibraryBinary) {
                staticLibraryFile =
                    file("libs/cunit/2.1-2/lib/" +
                        findCUnitLibForPlatform(targetPlatform))
            }
        }
    }
}
components {
    operators(NativeLibrarySpec) {
        targetPlatform "x86"
    }
}
testSuites {
    operatorsTest(CUnitTestSuiteSpec) {
        testing $.components.operators
    }
}
}
model {
    binaries {
        withType(CUnitTestSuiteBinarySpec) {
            lib library: "cunit", linkage: "static"

            if (flavor == flavors.failing) {
                cCompiler.define "PLUS_BROKEN"
            }
        }
    }
}
```

Output of `gradle -q runOperatorsTestFailingCUnitExe`

```
> gradle -q runOperatorsTestFailingCUnitExe

There were test failures:
  1. /home/user/gradle/samples/src/operatorsTest/c/test_plus.c:6  - plus(0, -2) ==
-2
  2. /home/user/gradle/samples/src/operatorsTest/c/test_plus.c:7  - plus(2, 2) ==
4

FAILURE: Build failed with an exception.

* What went wrong:
Execution failed for task ':runOperatorsTestFailingCUnitExe'.
> There were failing tests. See the results at:
file:///home/user/gradle/samples/build/test-results/operatorsTest/failing/

* Try:
> Run with --stacktrace option to get the stack trace.
> Run with --info or --debug option to get more log output.
> Run with --scan to get full insights.
> Get more help at https://help.gradle.org.

BUILD FAILED in 0s
```

The current support for CUnit is quite rudimentary. Plans for future integration include:

- Allow tests to be declared with Javadoc-style annotations.

- Improved HTML reporting, similar to that available for JUnit.

- Real-time feedback for test execution.

- Support for additional test frameworks.

GoogleTest support

The Gradle `google-test` plugin provides support for compiling and executing GoogleTest tests in your native-binary project. For each NativeExecutableSpec and NativeLibrarySpec defined in your project, Gradle will create a matching GoogleTestTestSuiteSpec component, named `${component.name}Test`.

GoogleTest sources

Gradle will create a CppSourceSet named 'cpp' for each GoogleTestTestSuiteSpec component in the project. This source set should contain the GoogleTest test files for the component under test. Source files can be located in the conventional location (`src/${component.name}Test/cpp`) or can be configured like any other source set.

Building GoogleTest executables

A GoogleTestTestSuiteSpec component has an associated NativeExecutableSpec or NativeLibrarySpec component. For each NativeBinarySpec configured for the main component, a matching GoogleTestTestSuiteBinarySpec will be configured on the test suite component. These test suite binaries can be configured in a similar way to any other binary instance:

Example: Registering GoogleTest tests

build.gradle

```
model {
    binaries {
        withType(GoogleTestTestSuiteBinarySpec) {
            lib library: "googleTest", linkage: "static"

            if (flavor == flavors.failing) {
                cppCompiler.define "PLUS_BROKEN"
            }

            if (targetPlatform.operatingSystem.linux) {
                cppCompiler.args '-pthread'
                linker.args '-pthread'

                if (toolChain instanceof Gcc || toolChain instanceof Clang) {
                    // Use C++03 with the old ABIs, as this is what the googletest
    binaries were built with
                    cppCompiler.args '-std=c++03', '-D_GLIBCXX_USE_CXX11_ABI=0'
                    linker.args '-std=c++03'
                }
            }
        }
    }
}
```

NOTE	The GoogleTest sources provided by your project require the core GoogleTest headers and libraries. Presently, this library dependency must be provided by your project for each GoogleTestTestSuiteBinarySpec.

=== Running GoogleTest tests

For each GoogleTestTestSuiteBinarySpec, Gradle will create a task to execute this binary, which will run all of the registered GoogleTest tests. Test results will be found in the `${build.dir}/test-results` directory.

The current support for GoogleTest is quite rudimentary. Plans for future integration include:

- Improved HTML reporting, similar to that available for JUnit.

- Real-time feedback for test execution.

- Support for additional test frameworks.

= Implementing model rules in a plugin

Rule based configuration will be deprecated. New plugins should not use this concept. Instead, use the standard approach described in the Writing Custom Plugins chapter.

A plugin can define rules by extending RuleSource and adding methods that define the rules. The plugin class can either extend RuleSource directly or can implement Plugin and include a nested RuleSource subclass.

Refer to the API docs for RuleSource for more details.

== Applying additional rules

A rule method annotated with Rules can apply a RuleSource to a target model element.

== **GRADLE ON CI**

= Executing Gradle builds on Jenkins

| **TIP** | Top engineering teams using Jenkins have been able to reduce CI build time by up to 90% by using the Gradle Build Cache. Register here for our Build Cache training session to learn how your team can achieve similar results. |

Building Gradle projects doesn't stop with the developer's machine. Continuous Integration (CI) has been a long-established practice for running a build for every single change committed to version control to tighten the feedback loop.

In this guide, we'll discuss how to configure Jenkins for a typical Gradle project.

== What you'll need

- A text editor
- A command prompt
- The Java Development Kit (JDK), version 1.7 or higher
- A Jenkins installation (setup steps explained in this post)

== Setup a typical project

As example, this guide is going to focus on a Java-based project. More specifically, a Gradle plugin written in Java and tested with Spek. First, we'll get the project set up on your local machine before covering the same steps on CI.

Just follow these steps:

=== Clone the Gradle Site Plugin repository

```
$ git clone https://github.com/gradle/gradle-site-plugin.git
Cloning into 'gradle-site-plugin'...
$ cd gradle-site-plugin
```

=== Build the project

As a developer of a Java project, you'll typical want to compile the source code, run the tests

and assemble the JAR artifact. That's no different for Gradle plugins. The following command achieves exactly that:

```
$ ./gradlew build

BUILD SUCCESSFUL
14 actionable tasks: 14 executed
```

The project provides the Gradle Wrapper as part of the repository. It is a recommended practice for any Gradle project as it enables your project to built on CI without having to install the Gradle runtime.

=== Build scan integration

The sample project is equipped with support for generating build scans. Running the build with the command line option `--scan` renders a link in the console.

```
$ ./gradlew build --scan

Publishing build scan...
https://gradle.com/s/7mtynxxmesdio
```

The following section will describe how to build the project with the help of Jenkins.

== Setup Jenkins

Jenkins is one of the most prominent players in the field. In the course of this section, you'll learn how to set up Jenkins, configure a job to pull the source code from GitHub and run the Gradle build.

=== Install and start Jenkins

On the Jenkins website you can pick from a variety of distributions. This post uses the runnable WAR file. A simple Java command brings up the Jenkins server.

```
$ wget https://mirrors.jenkins.io/war-stable/latest/jenkins.war
$ java -jar jenkins.war
```

In the browser, navigate to `localhost` with port `8080` to render the Jenkins dashboard. You will be asked to set up an new administration user and which plugins to install.

=== Installation of plugins

Confirm to install the recommended plugins when starting Jenkins for the first time. Under "Manage Jenkins > Manage Plugins" ensure that you have the following two plugins installed.

- Git plugin

- Gradle plugin

Next, we can set up the job for building the project.

== Create a Jenkins job

Setting up a new Gradle job can be achieved with just a couple of clicks. From the left navigation bar select "New Item > Freestyle project". Enter a new name for the project. We'll pick "gradle-site-plugin" for the project.

Select the radio button "Git" in the section "Source Code Management". Enter the URL of the GitHub repository: `https://github.com/gradle/gradle-site-plugin.git`.

Furthermore, create a "Build step" in the section "Build" by selecting "Invoke Gradle script". As mentioned before, we'll want to use the Wrapper to execute the build. In the "Tasks" input box enter the `build` and use the "Switches" `--scan -s` to generate a build scan and render a stack trace in case of a build failure.

=== Execute the job

Save the configuration of job and execute an initial build by triggering the "Build Now" button.

The build should finish successfully and render a "Gradle Build Scan" icon that brings you directly to the build scan for the given build.

There are various options to trigger Jenkins builds continuously: from polling the repository periodically, to building on a set schedule, or via callback URL.

== Further reading

You can learn more about advanced Jenkins usage through these resources:

- Using credentials with Jenkins
- Pipeline as code with Jenkins
- Modelling a Continuous Deployment pipeline for a Spring Boot application

== Summary

Executing Gradle builds on CI can be set up and configured with just a handful of steps. The benefit of receiving fast feedback clearly speaks for itself. If you are not using Jenkins, no problem, many CI products tightly integrate with Gradle as a first-class citizen.

= Executing Gradle builds on TeamCity

TIP	Top engineering teams using TeamCity have been able to reduce CI build time by up to 90% by using the Gradle Build Cache. Register here for our Build Cache training session to learn how your team can achieve similar results.

Building Gradle projects doesn't stop with the developer's machine. Continuous Integration (CI) has been a long-established practice for running a build for every single change committed to version control to tighten the feedback loop.

In this guide, we'll discuss how to configure TeamCity for a typical Gradle project.

== What you'll need

- A command prompt

- The Java Development Kit (JDK), version 1.8 or higher

- A TeamCity installation (setup steps explained in this guide)

== Setup a typical project

For demonstration purposes, this guide is going to focus on building a Java-based project; however, this setup will work with any Gradle-compatible project. More specifically, a Gradle plugin written in Java and tested with Spek. First, we'll get the project set up on your local machine before covering the same steps on CI.

Just follow these steps:

=== Clone the Gradle Site Plugin repository

```
$ git clone https://github.com/gradle/gradle-site-plugin.git
Cloning into 'gradle-site-plugin'...
$ cd gradle-site-plugin
```

=== Build the project

As a developer of a Java project, you'll typical want to compile the source code, run the tests and assemble the JAR artifact. That's no different for Gradle plugins. The following command achieves exactly that:

```
$ ./gradlew build

BUILD SUCCESSFUL
14 actionable tasks: 14 executed
```

The project provides the Gradle Wrapper as part of the repository. It is a recommended practice for any Gradle project as it enables your project to built on CI without having to install the Gradle runtime.

=== Build scan integration

The sample project is equipped with support for generating build scans. Running the build with the command line option `--scan` renders a link in the console.

```
$ ./gradlew build --scan
Publishing build scan...
https://gradle.com/s/7mtynxxmesdio
```

== Setup TeamCity

JetBrains TeamCity is a powerful and user-friendly Continuous Integration and Deployment server that works out of the box. JetBrains offers several licensing options that allow you to scale TeamCity to your needs. In this setup, we'll use TeamCity Professional, a free fully functional edition suitable for average projects. In the course of this section, you'll learn how to set up TeamCity, create a build configuration to pull the source code from GitHub and run the Gradle build.

=== Install and start TeamCity

On the TeamCity website you can pick from a variety of distributions. This post uses TeamCity bundled with Tomcat servlet container and covers the evaluation setup of a TeamCity server and a default build agent running on the same machine.

1. Make sure you have JRE or JDK installed and the JAVA_HOME environment variable is pointing to the Java installation directory. Oracle Java 1.8 JDK is required.

2. Download TeamCity .tar.gz distribution. Unpack the `TeamCity<version number>.tar.gz` archive, for example, using the WinZip, WinRar or a similar utility under Windows, or the following command under Linux or macOS:

```
tar xfz TeamCity<version number>.tar.gz
```

3. Start the TeamCity server and one default agent at the same time, using the runAll script provided in the <TeamCity home>/bin directory, e.g.

```
runAll.sh start
```

4. To access the TeamCity Web UI, navigate to `http://localhost:8111/`. Follow the defaults of the TeamCity setup. You will be asked to set up a new administration user.

Next, we can set up the project and run a build in TeamCity.

== Create a TeamCity build

Setting up a new Gradle build in TeamCity requires just a few clicks: TeamCity comes bundled with a Gradle plugin, so you do not need to install plugins additionally. However, it is recommended that you install the TeamCity Build Scan plugin.

On the **Administration | Projects** page click *Create project*, use the option *From the repository URL* and enter the URL of the GitHub repository: `https://github.com/gradle/gradle-site-plugin.git`.

Follow the *Create Project* wizard, it will prompt for the project and build configuration name and automatically detect build steps. Select the automatically Gradle build step and click *Use selected*:

The build step is added to the build configuration:

Click *Edit*, on the page that opens click *Advanced options*. Using the Wrapper to execute the build is considered good practice with Gradle, and on automatic detection this option is selected by default. We'll want to generate a build scan, so we'll enter the `--scan` option in *Additional Gradle command line parameters* field.

Save the settings and we're ready to run the build.

=== Run the build in TeamCity Click the *Run* button in the right top corner:

TeamCity will start the build and you'll be able to view the build progress by clicking *Build Configuration Home*. When the build is finished, you can review the build results by clicking the build number link:

You can view the tests right here in TeamCity:

The information on parameters and environment of the build is available on the *Parameters*

tab of the build results.

If you installed the TeamCity Build Scan plugin, you will see a link to the build scan in the Build Results view:

Otherwise, the link to the build scan for the given build is available in the build log:

There are various options to trigger TeamCity builds continuously: from polling the repository periodically, to building on a set schedule, or via post-commit hook.

== Further reading

You can learn more about advanced TeamCity usage through these resources:

- Build chains and dependencies
- Remote run and pre-tested commit

More information is available in TeamCity documentation. Follow the TeamCity blog for the latest news.

== Summary

Executing Gradle builds on CI can be set up and configured with just a handful of steps. The benefit of receiving fast feedback clearly speaks for itself. If you are not using TeamCity, no problem, many CI products tightly integrate with Gradle as a first-class citizen.

Executing Gradle builds on GitHub Actions

TIP	Top engineering teams using GitHub Actions have been able to reduce CI build time by up to 90% by using the Gradle Build Cache. Register here for our Build Cache training session to learn how your team can achieve similar results.

Building Gradle projects doesn't stop with the developer's machine. Continuous Integration (CI) has been a long-established practice for running a build for every single change committed to version control to tighten the feedback loop.

In this guide, we'll discuss how to configure GitHub Actions for a Gradle project hosted on GitHub.

Introduction

GitHub Actions is a cloud-based CI solution provider built directly into GitHub, making it an excellent choice for projects hosted on GitHub.

Using the Gradle Build Action makes it simple to integrate any Gradle project into a GitHub Actions workflow.

What you'll need

- A text editor
- A command prompt
- The Java Development Kit (JDK), version 1.8 or higher
- A local Gradle installation, to initialize a new Gradle project
- A GitHub account
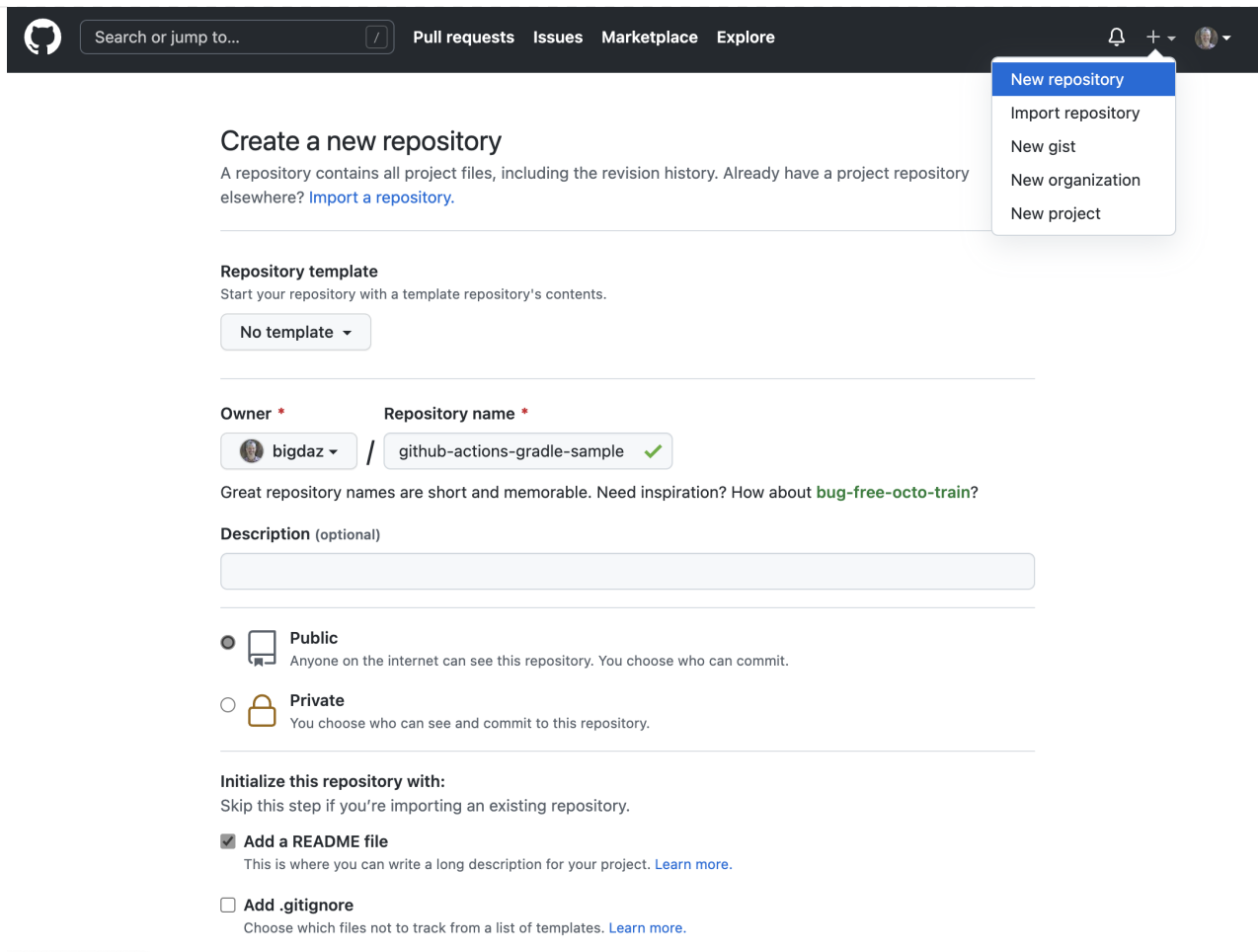
Setup a Gradle project on GitHub

If you have an existing Gradle project hosted on GitHub, then you can skip this step and move directly to Configure GitHub Actions.

If not, follow these step to initialize a new Gradle project on GitHub.

Create a new GitHub repository for your project

Via the GitHub user interface, create a new repository named `github-actions-gradle-sample`.

=== Clone the repository locally

```
$ git clone git@github.com:<YOUR-GITHUB-USER>/github-actions-gradle-sample.git
Cloning into 'github-actions-gradle-sample'...
$ cd github-actions-gradle-sample
```

=== Initialize the Gradle project and commit to the repository

Use `gradle init` to create a fresh Gradle project. You can choose any of the available options during `init`, but we recommend choosing "library" as the project type.

Once the project is generated, commit the changes and push to the repository.

```
$ gradle init
$ git add .
$ git commit -m "Initial commit"
$ git push
```

=== Enable Build Scan™ publishing

Gradle Build Scans are a great way to view your build results, and provide valuable insights into your build. In order to publish Build Scans from GitHub Actions, you'll need to pre-approve the Terms & Conditions.

To do so, add the following content to the top of your `settings.gradle[.kts]` file. The "CI" environment variable is set by GitHub Actions:

```
plugins {
    id("com.gradle.enterprise") version("3.16")
}

gradleEnterprise {
    if (System.getenv("CI") != null) {
        buildScan {
            publishAlways()
            termsOfServiceUrl = "https://gradle.com/terms-of-service"
            termsOfServiceAgree = "yes"
        }
    }
}
```

=== Test building the project

The project uses the Gradle Wrapper for building the project. It is a recommended practice for any Gradle project as it enables your project to built on CI without having to install the Gradle runtime.

Before asking GitHub Actions to build your project, it's useful to ensure that it builds locally. Adding the "CI" environment variable will emulate running the build on GitHub Actions.

The following command achieves that:

```
$ CI=true ./gradlew build

BUILD SUCCESSFUL

Publishing build scan...
https://gradle.com/s/7mtynxxmesdio
```

If the build works as expected, commit the changes and push to the repository.

```
$ git commit -a -m "Publish Build Scans from GitHub Actions"
$ git push
```

== Configure GitHub Actions

You can create a GitHub Actions workflow by adding a `.github/workflows/<workflow-name>.yml` file to your repository. This workflow definition file contains all relevant instructions for building the project on GitHub Actions.

The following workflow file instructs GitHub Actions to build your Gradle project using the

Gradle Wrapper, executed by the default Java distribution for GitHub Actions. Create a new file named `.github/workflows/build-gradle-project.yml` with the following content, and push it to the GitHub repository.

```
name: Build Gradle project

on:
  push:

jobs:
  build-gradle-project:
    runs-on: ubuntu-latest
    steps:
    - name: Checkout project sources
      uses: actions/checkout@v3
    - name: Setup Gradle
      uses: gradle/gradle-build-action@v2
    - name: Run build with Gradle Wrapper
      run: ./gradlew build
```

Commit the changes and push to the repository:
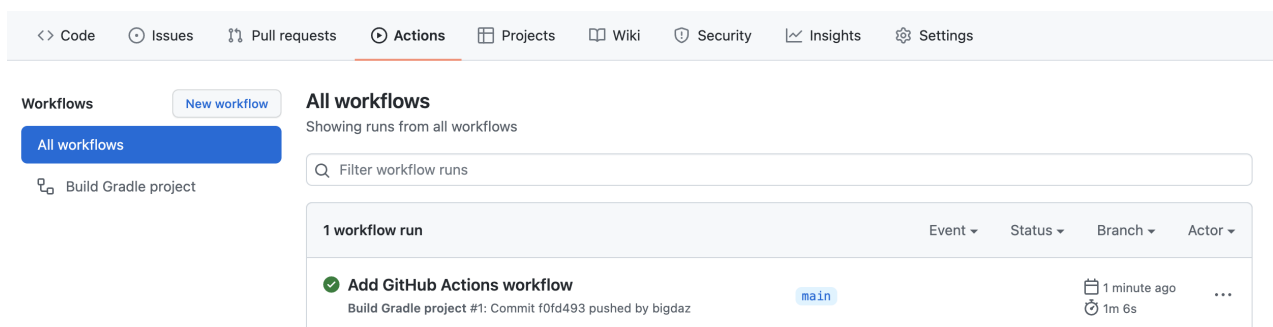
```
$ git add .
$ git commit -m "Add GitHub Actions workflow"
$ git push
```

== View the GitHub Actions results

Once this workflow file is pushed, you should immediately see the workflow execution in the GitHub Actions page for your repository (eg https://github.com/gradle/gradle/actions). Any subsequent push to the repository will trigger the workflow to run.

=== List all runs of the GitHub Actions workflow

The main actions page can be filtered to list all runs for a GitHub Actions workflow.

=== See the results for GitHub Actions workflow run

Clicking on the link for a workflow run will show the details of the workflow run, including a

link to the build scan produced for the build.

| NOTE | Configuring build scans is especially helpful on cloud CI systems like GitHub Actions because it has additional environment and test results information that are difficult to obtain otherwise. |

=== View the details for Jobs and Steps in the workflow

Finally, you can view the details for the individual workflow Jobs and each Step defined for a Job:

== Enable caching of downloaded artifacts

The gradle-build-action used by this workflow will enable saving and restoring of the Gradle User Home directory in the built-in GitHub Actions cache. This will speed up your GitHub Actions build by avoiding the need to re-download Gradle versions and project dependencies, as well as re-using state from the previous workflow execution.

Details about what entries are saved/restored from the cache can be viewed in the `Post Setup Gradle` step:

== Further reading

Learn more about building Gradle projects with GitHub Actions:

- GitHub Actions documentation

- Use and configuration of the gradle-build-action

== Summary

Executing Gradle builds on CI can be set up and configured with just a handful of steps. The benefit of receiving fast feedback clearly speaks for itself. GitHub Actions provides a simple, convenient mechanism to setup CI for any Gradle project hosted on GitHub.

= Executing Gradle builds on Travis CI

> **TIP**
> Top engineering teams using Travis CI have been able to reduce CI build time by up to 90% by using the Gradle Build Cache. Register here for our Build Cache training session to learn how your team can achieve similar results.

Building Gradle projects doesn't stop with the developer's machine. Continuous Integration (CI) has been a long-established practice for running a build for every single change committed to version control to tighten the feedback loop.

In this guide, we'll discuss how to configure Travis CI for a typical Gradle project.

== What you'll need

- A text editor

- A command prompt
- The Java Development Kit (JDK), version 1.8 or higher

== Setup a typical project

As example, this guide is going to focus on a Java-based project. More specifically, a Gradle plugin written in Java and tested with Spek. First, we'll get the project set up on your local machine before covering the same steps on CI.

Just follow these steps:

=== Clone the Gradle Site Plugin repository

```
$ git clone https://github.com/gradle/gradle-site-plugin.git
Cloning into 'gradle-site-plugin'...
$ cd gradle-site-plugin
```

=== Build the project

As a developer of a Java project, you'll typical want to compile the source code, run the tests and assemble the JAR artifact. That's no different for Gradle plugins. The following command achieves exactly that:

```
$ ./gradlew build

BUILD SUCCESSFUL
14 actionable tasks: 14 executed
```

The project provides the Gradle Wrapper as part of the repository. It is a recommended practice for any Gradle project as it enables your project to built on CI without having to install the Gradle runtime.

=== Build scan integration

The sample project is equipped with support for generating build scans. Running the build with the command line option --scan renders a link in the console.

```
$ ./gradlew build --scan
Publishing build scan...
https://gradle.com/s/7mtynxxmesdio
```

The following section will describe how to build the project with the help of Travis CI.

== Configure Travis CI

Travis CI is a free, cloud-based CI solution provider making it an excellent choice for open source projects. You can build any project as long as it is hosted on GitHub as a public

repository. Travis CI doesn't not provide built-in options to post-process produced artifacts of the build e.g. host the JAR file or the HTML test reports. You will have to use external services (like S3) to transfer the files.

=== Create the configuration file

Travis CI requires you to check in a configuration file with your source code named `.travis.yml`. This file contains all relevant instructions for building the project.

The following configuration file tells Travis CI to build a Java project with JDK 8, skip the usual default execution step, and run the Gradle build with the Wrapper.

```
language: java
install: skip

os: linux
dist: trusty
jdk: oraclejdk8

script:
  - ./gradlew build --scan -s
```

Select the project from the Travis CI profile. After activating the repository from the dashboard, the project is ready to be built with every single commit.

| NOTE | Configuring build scans is especially helpful on cloud CI systems like Travis CI because it has additional environment and test results information that are difficult to obtain otherwise. |

=== Enable caching of downloaded artifacts

Gradle's dependency management mechanism resolves declared modules and their corresponding artifacts from a binary repository. Once downloaded, the files will be re-used from the cache. You need to tell Travis CI explicitly that you want to store and use the Gradle cache and Wrapper for successive invocations of the build.

```
before_cache:
  - rm -f  $HOME/.gradle/caches/modules-2/modules-2.lock
  - rm -fr $HOME/.gradle/caches/*/plugin-resolution/

cache:
  directories:
    - $HOME/.gradle/caches/
    - $HOME/.gradle/wrapper/
```

=== Further reading

You can learn more about advanced Travis CI usage through these resources:

- Encrypting sensitive data

- Modelling a pipeline with build stages

== Summary

Executing Gradle builds on CI can be set up and configured with just a handful of steps. The benefit of receiving fast feedback clearly speaks for itself. If you are not using Travis CI, no problem, many CI products tightly integrate with Gradle as a first-class citizen.

== **REFERENCE**

= A Groovy Build Script Primer

Ideally, a Groovy build script looks mostly like configuration: setting some properties of the project, configuring dependencies, declaring tasks, and so on. That configuration is based on Groovy language constructs. This primer aims to explain what those constructs are and — most importantly — how they relate to Gradle's API documentation.

== The `Project` object

As Groovy is an object-oriented language based on Java, its properties and methods apply to objects. In some cases, the object is implicit — particularly at the top level of a build script, i.e. not nested inside a {} block.

Consider this fragment of build script, which contains an unqualified property and block:

```
version = '1.0.0.GA'

configurations {
    ...
}
```

Both `version` and `configurations {}` are part of org.gradle.api.Project.

This example reflects how every Groovy build script is backed by an implicit instance of `Project`. If you see an unqualified element and you don't know where it's defined, always

check the `Project` API documentation to see if that's where it's coming from.

CAUTION	Avoid using Groovy MetaClass programming techniques in your build scripts. Gradle provides its own API for adding dynamic runtime properties. Use of Groovy-specific metaprogramming can cause builds to retain large amounts of memory between builds that will eventually cause the Gradle daemon to run out-of-memory.

Properties

```
<obj>.<name>                // Get a property value
<obj>.<name> = <value>      // Set a property to a new value
"$<name>"                   // Embed a property value in a string
"${<obj>.<name>}"           // Same as previous (embedded value)
```

Examples

```
version = '1.0.1'
myCopyTask.description = 'Copies some files'

file("$projectDir/src")
println "Destination: ${myCopyTask.destinationDir}"
```

A property represents some state of an object. The presence of an `=` sign is a clear indicator that you're looking at a property. Otherwise, a qualified name — it begins with `<obj>.` — without any other decoration is also a property.

If the name is unqualified, then it may be one of the following:

- A task instance with that name.

- A property on Project.

- An extra property defined elsewhere in the project.

- A property of an implicit object within a block.

- A local variable defined earlier in the build script.

Note that plugins can add their own properties to the `Project` object. The API documentation lists all the properties added by core plugins. If you're struggling to find where a property comes from, check the documentation for the plugins that the build uses.

TIP	When referencing a project property in your build script that is added by a non-core plugin, consider prefixing it with `project.` — it's clear then that the property belongs to the project object.

Properties in the API documentation

The Groovy DSL reference shows properties as they are used in your build scripts, but the Javadocs only display methods. That's because properties are implemented as methods behind the scenes:

- A property can be *read* if there is a method named `get<PropertyName>` with zero arguments that returns the same type as the property.

- A property can be *modified* if there is a method named `set<PropertyName>` with one argument that has the same type as the property and a return type of `void`.

Note that property names usually start with a lower-case letter, but that letter is upper case in the method names. So the getter method `getProjectVersion()` corresponds to the property `projectVersion`. This convention does not apply when the name begins with at least two upper-case letters, in which case there is not change in case. For example, `getRAM()` corresponds to the property `RAM`.

Examples

```
project.getVersion()
project.version

project.setVersion('1.0.1')
project.version = '1.0.1'
```

== Methods

```
<obj>.<name>()              // Method call with no arguments
<obj>.<name>(<arg>, <arg>)  // Method call with multiple arguments
<obj>.<name> <arg>, <arg>   // Method call with multiple args (no parentheses)
```

Examples

```
myCopyTask.include '**/*.xml', '**/*.properties'

ext.resourceSpec = copySpec()   // `copySpec()` comes from `Project`

file('src/main/java')
println 'Hello, World!'
```

A method represents some behavior of an object, although Gradle often uses methods to configure the state of objects as well. Methods are identifiable by their arguments or empty parentheses. Note that parentheses are sometimes required, such as when a method has zero arguments, so you may find it simplest to always use parentheses.

| NOTE | Gradle has a convention whereby if a method has the same name as a collection-based property, then the method *appends* its values to that collection. |

== Blocks

Blocks are also [methods](#), just with specific types for the last argument.

```
<obj>.<name> {
    ...
}

<obj>.<name>(<arg>, <arg>) {
    ...
}
```

Examples

```
plugins {
    id 'java-library'
}

configurations {
    assets
}

sourceSets {
    main {
        java {
            srcDirs = ['src']
        }
    }
}

dependencies {
    implementation project(':util')
}
```

Blocks are a mechanism for configuring multiple aspects of a build element in one go. They also provide a way to nest configuration, leading to a form of structured data.

There are two important aspects of blocks that you should understand:

1. They are implemented as methods with specific signatures.

2. They can change the target ("delegate") of unqualified methods and properties.

Both are based on Groovy language features and we explain them in the following sections.

=== Block method signatures

You can easily identify a method as the implementation behind a block by its signature, or more specifically, its argument types. If a method corresponds to a block:

- It must have at least one argument.

- The *last* argument must be of type `groovy.lang.Closure` or [org.gradle.api.Action](#).

For example, Project.copy(Action) matches these requirements, so you can use the syntax:

```
copy {
    into layout.buildDirectory.dir("tmp")
    from 'custom-resources'
}
```

That leads to the question of how `into()` and `from()` work. They're clearly methods, but where would you find them in the API documentation? The answer comes from understanding object *delegation*.

=== Delegation

The section on properties lists where unqualified properties might be found. One common place is on the `Project` object. But there is an alternative source for those unqualified properties and methods inside a block: the block's *delegate object*.

To help explain this concept, consider the last example from the previous section:

```
copy {
    into layout.buildDirectory.dir("tmp")
    from 'custom-resources'
}
```

All the methods and properties in this example are unqualified. You can easily find `copy()` and `layout` in the `Project` API documentation, but what about `into()` and `from()`? These are resolved against the delegate of the `copy {}` block. What is the type of that delegate? You'll need to check the API documentation for that.

There are two ways to determine the delegate type, depending on the signature of the block method:

- For `Action` arguments, look at the type's parameter.

  In the example above, the method signature is `copy(Action<? super CopySpec>)` and it's the bit inside the angle brackets that tells you the delegate type — CopySpec in this case.

- For `Closure` arguments, the documentation will explicitly say in the description what type is being configured or what type the delegate it (different terminology for the same thing).

Hence you can find both `into()` and `from()` on `CopySpec`. You might even notice that both of those methods have variants that take an `Action` as their last argument, which means you can use block syntax with them.

All new Gradle APIs declare an `Action` argument type rather than `Closure`, which makes it very easy to pick out the delegate type. Even older APIs have an `Action` variant in addition to the old `Closure` one.

== Local variables

```
def <name> = <value>        // Untyped variable
<type> <name> = <value>     // Typed variable
```

Examples

```
def i = 1
String errorMsg = 'Failed, because reasons'
```

Local variables are a Groovy construct — unlike extra properties — that can be used to share values within a build script.

Avoid using local variables in the root of the project, i.e. as pseudo project properties. They cannot be read outside of the build script and Gradle has no knowledge of them.

Within a narrower context — such as configuring a task — local variables can occasionally be helpful.

= Gradle Kotlin DSL Primer

Gradle's Kotlin DSL provides an alternative syntax to the traditional Groovy DSL with an enhanced editing experience in supported IDEs, with superior content assist, refactoring, documentation, and more. This chapter provides details of the main Kotlin DSL constructs and how to use it to interact with the Gradle API.

> **TIP** If you are interested in migrating an existing Gradle build to the Kotlin DSL, please also check out the dedicated migration section.

== Prerequisites

- The embedded Kotlin compiler is known to work on Linux, macOS, Windows, Cygwin, FreeBSD and Solaris on x86-64 architectures.

- Knowledge of Kotlin syntax and basic language features is very helpful. The Kotlin reference documentation and Kotlin Koans will help you to learn the basics.

- Use of the plugins {} block to declare Gradle plugins significantly improves the editing experience and is highly recommended.

== IDE support

The Kotlin DSL is fully supported by IntelliJ IDEA and Android Studio. Other IDEs do not yet provide helpful tools for editing Kotlin DSL files, but you can still import Kotlin-DSL-based builds and work with them as usual.

Table 33. IDE support matrix

	Build import	Syntax highlighting [1]	Semantic editor [2]
IntelliJ IDEA	⬚	⬚	⬚
Android Studio	⬚	⬚	⬚
Eclipse IDE	⬚	⬚	⬚
CLion	⬚	⬚	⬚
Apache NetBeans	⬚	⬚	⬚
Visual Studio Code [(LSP)]	⬚	⬚	⬚
Visual Studio	⬚	⬚	⬚

1 Kotlin syntax highlighting in Gradle Kotlin DSL scripts

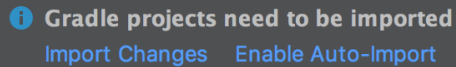2 code completion, navigation to sources, documentation, refactorings etc… in Gradle Kotlin DSL scripts

As mentioned in the limitations, you must import your project from the Gradle model to get content-assist and refactoring tools for Kotlin DSL scripts in IntelliJ IDEA.

Builds with slow configuration time might affect the IDE responsiveness, so please check out the performance section to help resolve such issues.
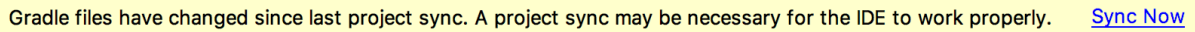
=== Automatic build import vs. automatic reloading of script dependencies

Both IntelliJ IDEA and Android Studio — which is derived from IntelliJ IDEA — will detect when you make changes to your build logic and offer two suggestions:

1. Import the whole build again

2. Reload script dependencies when editing a build script

We recommend that you *disable automatic build import*, but *enable automatic reloading of script dependencies*. That way you get early feedback while editing Gradle scripts and control over when the whole build setup gets synchronized with your IDE.

=== Troubleshooting

The IDE support is provided by two components:

- The Kotlin Plugin used by IntelliJ IDEA/Android Studio

- Gradle

The level of support varies based on the versions of each.

If you run into trouble, the first thing you should try is running `./gradlew tasks` from the command line to see whether your issue is limited to the IDE. If you encounter the same problem from the command line, then the issue is with the build rather than the IDE integration.

If you can run the build successfully from the command line but your script editor is complaining, then you should try restarting your IDE and invalidating its caches.

If the above doesn't work and you suspect an issue with the Kotlin DSL script editor, you can:

- Run `./gradle tasks` to get more details

- Check the logs in one of these locations:

  - `$HOME/Library/Logs/gradle-kotlin-dsl` on Mac OS X

  - `$HOME/.gradle-kotlin-dsl/log` on Linux

  - `$HOME/AppData/Local/gradle-kotlin-dsl/log` on Windows

- Open an issue on the Gradle issue tracker, including as much detail as you can.

From version 5.1 onwards, the log directory is cleaned up automatically. It is checked periodically (at most every 24 hours) and log files are deleted if they haven't been used for 7 days.

If the above isn't enough to pinpoint the problem, you can enable the `org.gradle.kotlin.dsl.logging.tapi` system property in your IDE. This will cause the Gradle Daemon to log extra information in its log file located in `$HOME/.gradle/daemon`. In IntelliJ IDEA this can be done by opening `Help > Edit Custom VM Options…` and adding `-Dorg.gradle.kotlin.dsl.logging.tapi=true`.

For IDE problems outside of the Kotlin DSL script editor, please open issues in the corresponding IDE's issue tracker:

- JetBrains's IDEA issue tracker,

- Google's Android Studio issue tracker.

Lastly, if you face problems with Gradle itself or with the Kotlin DSL, please open issues on the Gradle issue tracker.

== Kotlin DSL scripts

Just like the Groovy-based equivalent, the Kotlin DSL is implemented on top of Gradle's Java API. Everything you can read in a Kotlin DSL script is Kotlin code compiled and executed by Gradle. Many of the objects, functions and properties you use in your build scripts come from the Gradle API and the APIs of the applied plugins.

| **TIP** | You can use the Kotlin DSL reference search functionality to drill through the available members. |

=== Script file names

- Groovy DSL script files use the `.gradle` file name extension.
- Kotlin DSL script files use the `.gradle.kts` file name extension.

To activate the Kotlin DSL, simply use the `.gradle.kts` extension for your build scripts in place of `.gradle`. That also applies to the settings file — for example `settings.gradle.kts` — and initialization scripts.

Note that you can mix Groovy DSL build scripts with Kotlin DSL ones, i.e. a Kotlin DSL build script can apply a Groovy DSL one and each project in a multi-project build can use either one.

We recommend that you apply the following conventions to get better IDE support:

- Name settings scripts (or any script that is backed by a Gradle `Settings` object) according to the pattern `*.settings.gradle.kts` — this includes script plugins that are applied from settings scripts

- Name initialization scripts according to the pattern `*.init.gradle.kts` or simply `init.gradle.kts`.

This is so that the IDE knows what type of object "backs" the script, be it Project, Settings or Gradle.

=== Implicit imports

All Kotlin DSL build scripts have implicit imports consisting of:

- The default Gradle API imports
- The Kotlin DSL API, which is all types within the following packages:
    - `org.gradle.kotlin.dsl`
    - `org.gradle.kotlin.dsl.plugins.dsl`
    - `org.gradle.kotlin.dsl.precompile`

Avoid using internal Kotlin DSL APIs

Use of internal Kotlin DSL APIs in plugins and build scripts has the potential to break builds when either Gradle or plugins change. The Kotlin DSL API extends the Gradle public API with the types listed in the corresponding API docs that are in the packages listed above (but not subpackages of those).

=== Compilation warnings

Gradle Kotlin DSL scripts are compiled by Gradle during the configuration phase of your build. Deprecation warnings found by the Kotlin compiler are reported on the console when compiling the scripts.

```
> Configure project :
w: build.gradle.kts:4:5: 'getter for uploadTaskName: String!' is deprecated.
Deprecated in Java
```

It is possible to configure your build to fail on any warning emitted during script compilation by setting the `org.gradle.kotlin.dsl.allWarningsAsErrors` Gradle property to `true`:

```
# gradle.properties
org.gradle.kotlin.dsl.allWarningsAsErrors=true
```

== Type-safe model accessors

The Groovy DSL allows you to reference many elements of the build model by name, even when they are defined at runtime. Think named configurations, named source sets, and so on. For example, you can get hold of the `implementation` configuration via `configurations.implementation`.

The Kotlin DSL replaces such dynamic resolution with type-safe model accessors that work with model elements contributed by plugins.

=== Understanding when type-safe model accessors are available

The Kotlin DSL currently supports type-safe model accessors for any of the following that are contributed by plugins:

- Dependency and artifact configurations (such as `implementation` and `runtimeOnly` contributed by the Java Plugin)

- Project extensions and conventions (such as `sourceSets`)

- Extensions on the `dependencies` and `repositories` containers

- Elements in the `tasks` and `configurations` containers

- Elements in project-extension containers (for example the source sets contributed by the Java Plugin that are added to the `sourceSets` container)

- Extensions on each of the above

Only the main project build scripts and precompiled project script plugins have type-safe model accessors. Initialization scripts, settings scripts, script plugins do not. These limitations will be removed in a future Gradle release.

The set of type-safe model accessors available is calculated right before evaluating the script body, immediately after the `plugins {}` block. Any model elements contributed after that point do not work with type-safe model accessors. For example, this includes any configurations you might define in your own build script. However, this approach does mean that you can use type-safe accessors for any model elements that are contributed by plugins that are *applied by parent projects*.

The following project build script demonstrates how you can access various configurations, extensions and other elements using type-safe accessors:

```
plugins {
    `java-library`
}

dependencies {                                    ①
    api("junit:junit:4.13")
    implementation("junit:junit:4.13")
    testImplementation("junit:junit:4.13")
}

configurations {                                  ①
    implementation {
        resolutionStrategy.failOnVersionConflict()
    }
}

sourceSets {                                      ②
    main {                                        ③
        java.srcDir("src/core/java")
    }
}

java {                                            ④
    sourceCompatibility = JavaVersion.VERSION_11
    targetCompatibility = JavaVersion.VERSION_11
}

tasks {
    test {                                        ⑤
        testLogging.showExceptions = true
        useJUnit()
    }
}
```

① Uses type-safe accessors for the `api`, `implementation` and `testImplementation` dependency configurations contributed by the [Java Library Plugin](#)

② Uses an accessor to configure the `sourceSets` project extension

③ Uses an accessor to configure the `main` source set

④ Uses an accessor to configure the `java` source for the `main` source set

⑤ Uses an accessor to configure the `test` task

Your IDE knows about the type-safe accessors, so it will include them in its suggestions.

This will happen both at the top level of your build scripts — most plugin extensions are added to the `Project` object — and within the blocks that configure an extension.

Note that accessors for elements of containers such as `configurations`, `tasks` and `sourceSets` leverage Gradle's configuration avoidance APIs. For example, on `tasks` they are of type `TaskProvider<T>` and provide a lazy reference and lazy configuration of the underlying task. Here are some examples that illustrate the situations in which configuration avoidance applies:

```
tasks.test {
    // lazy configuration
}

// Lazy reference
val testProvider: TaskProvider<Test> = tasks.test

testProvider {
    // lazy configuration
}

// Eagerly realized Test task, defeat configuration avoidance if done out of a
lazy context
val test: Test = tasks.test.get()
```

For all other containers than `tasks`, accessors for elements are of type `NamedDomainObjectProvider<T>` and provide the same behavior.

=== Understanding what to do when type-safe model accessors are not available

Consider the sample build script shown above that demonstrates the use of type-safe accessors. The following sample is exactly the same except that is uses the `apply()` method to apply the plugin. The build script can not use type-safe accessors in this case because the `apply()` call happens in the body of the build script. You have to use other techniques instead, as demonstrated here:

build.gradle.kts

```kotlin
apply(plugin = "java-library")

dependencies {
    "api"("junit:junit:4.13")
    "implementation"("junit:junit:4.13")
    "testImplementation"("junit:junit:4.13")
}

configurations {
    "implementation" {
        resolutionStrategy.failOnVersionConflict()
    }
}

configure<SourceSetContainer> {
    named("main") {
        java.srcDir("src/core/java")
    }
}

configure<JavaPluginExtension> {
    sourceCompatibility = JavaVersion.VERSION_11
    targetCompatibility = JavaVersion.VERSION_11
}

tasks {
    named<Test>("test") {
        testLogging.showExceptions = true
    }
}
```

Type-safe accessors are unavailable for model elements contributed by the following:

- Plugins applied via the `apply(plugin = "id")` method

- The project build script

- Script plugins, via `apply(from = "script-plugin.gradle.kts")`

- Plugins applied via cross-project configuration

You also can not use type-safe accessors in Binary Gradle plugins implemented in Kotlin.

If you can't find a type-safe accessor, *fall back to using the normal API* for the corresponding types. To do that, you need to know the names and/or types of the configured model elements. We'll now show you how those can be discovered by looking at the above script in detail.

==== Artifact configurations

The following sample demonstrates how to reference and configure artifact configurations without type accessors:

build.gradle.kts

```
apply(plugin = "java-library")

dependencies {
    "api"("junit:junit:4.13")
    "implementation"("junit:junit:4.13")
    "testImplementation"("junit:junit:4.13")
}

configurations {
    "implementation" {
        resolutionStrategy.failOnVersionConflict()
    }
}
```

The code looks similar to that for the type-safe accessors, except that the configuration names are string literals in this case. You can use string literals for configuration names in dependency declarations and within the `configurations {}` block.

The IDE won't be able to help you discover the available configurations in this situation, but you can look them up either in the corresponding plugin's documentation or by running `gradle dependencies`.

==== Project extensions and conventions

Project extensions and conventions have both a name and a unique type, but the Kotlin DSL only needs to know the type in order to configure them. As the following sample shows for the `sourceSets {}` and `java {}` blocks from the original example build script, you can use the `configure<T>()` function with the corresponding type to do that:

build.gradle.kts

```
apply(plugin = "java-library")

configure<SourceSetContainer> {
    named("main") {
        java.srcDir("src/core/java")
    }
}

configure<JavaPluginExtension> {
    sourceCompatibility = JavaVersion.VERSION_11
    targetCompatibility = JavaVersion.VERSION_11
}
```

Note that `sourceSets` is a Gradle extension on `Project` of type `SourceSetContainer` and `java` is an extension on `Project` of type `JavaPluginExtension`.

You can discover what extensions and conventions are available either by looking at the documentation for the applied plugins or by running `gradle kotlinDslAccessorsReport`, which prints the Kotlin code necessary to access the model elements contributed by all the applied plugins. The report provides both names and types. As a last resort, you can also check a plugin's source code, but that shouldn't be necessary in the majority of cases.

Note that you can also use the `the<T>()` function if you only need a reference to the extension or convention without configuring it, or if you want to perform a one-line configuration, like so:

```
the<SourceSetContainer>()["main"].srcDir("src/core/java")
```

The snippet above also demonstrates one way of configuring the elements of a project extension that is a container.

==== Elements in project-extension containers

Container-based project extensions, such as `SourceSetContainer`, also allow you to configure the elements held by them. In our sample build script, we want to configure a source set named `main` within the source set container, which we can do by using the named() method in place of an accessor, like so:

build.gradle.kts

```
apply(plugin = "java-library")

configure<SourceSetContainer> {
    named("main") {
        java.srcDir("src/core/java")
    }
}
```

All elements within a container-based project extension have a name, so you can use this technique in all such cases.

As for project extensions and conventions themselves, you can discover what elements are present in any container by either looking at the documentation of the applied plugins or by running `gradle kotlinDslAccessorsReport`. And as a last resort, you may be able to view the plugin's source code to find out what it does, but that shouldn't be necessary in the majority of cases.

==== Tasks

Tasks are not managed through a container-based project extension, but they are part of a container that behaves in a similar way. This means that you can configure tasks in the same way as you do for source sets, as you can see in this example:

build.gradle.kts

```
apply(plugin = "java-library")

tasks {
    named<Test>("test") {
        testLogging.showExceptions = true
    }
}
```

We are using the Gradle API to refer to the tasks by name and type, rather than using accessors. Note that it's necessary to specify the type of the task explicitly, otherwise the script won't compile because the inferred type will be `Task`, not `Test`, and the `testLogging` property is specific to the `Test` task type. You can, however, omit the type if you only need to configure properties or to call methods that are common to all tasks, i.e. they are declared on the `Task` interface.

One can discover what tasks are available by running `gradle tasks`. You can then find out the type of a given task by running `gradle help --task <taskName>`, as demonstrated here:

```
⬡ ./gradlew help --task test
...
Type
     Test (org.gradle.api.tasks.testing.Test)
```

Note that the IDE can assist you with the required imports, so you only need the simple names of the types, i.e. without the package name part. In this case, there's no need to import the `Test` task type as it is part of the Gradle API and is therefore imported implicitly.

=== About conventions

Some of the Gradle core plugins expose configurability with the help of a so-called *convention* object. These serve a similar purpose to — and have now been superseded by — *extensions*. Conventions are deprecated. Please avoid using convention objects when writing new plugins.

As seen above, the Kotlin DSL provides accessors only for convention objects on `Project`. There are situations that require you to interact with a Gradle plugin that uses convention objects on other types. The Kotlin DSL provides the `withConvention(T::class) {}` extension function to do this:

build.gradle.kts

```
sourceSets {
    main {
        withConvention(CustomSourceSetConvention::class) {
            someOption = "some value"
        }
    }
}
```

This technique is primarily necessary for source sets added by language plugins that have yet to be migrated to extensions.

Multi-project builds

As with single-project builds, you should try to use the `plugins {}` block in your multi-project builds so that you can use the type-safe accessors. Another consideration with multi-project builds is that you won't be able to use type-safe accessors when configuring subprojects within the root build script or with other forms of cross configuration between projects. We discuss both topics in more detail in the following sections.

Applying plugins

You can declare your plugins within the subprojects to which they apply, but we recommend that you also declare them within the root project build script. This makes it easier to keep plugin versions consistent across projects within a build. The approach also improves the performance of the build.

The Using Gradle plugins chapter explains how you can declare plugins in the root project build script with a version and then apply them to the appropriate subprojects' build scripts. What follows is an example of this approach using three subprojects and three plugins. Note how the root build script only declares the community plugins as the Java Library Plugin is tied to the version of Gradle you are using:

settings.gradle.kts

```kotlin
rootProject.name = "multi-project-build"
include("domain", "infra", "http")
```

build.gradle.kts

```kotlin
plugins {
    id("com.github.johnrengelman.shadow") version "7.1.2" apply false
    id("io.ratpack.ratpack-java") version "1.8.2" apply false
}
```

domain/build.gradle.kts

```kotlin
plugins {
    `java-library`
}

dependencies {
    api("javax.measure:unit-api:1.0")
    implementation("tec.units:unit-ri:1.0.3")
}
```

infra/build.gradle.kts

```kotlin
plugins {
    `java-library`
    id("com.github.johnrengelman.shadow")
}

shadow {
    applicationDistribution.from("src/dist")
}

tasks.shadowJar {
    minimize()
}
```

http/build.gradle.kts

```
plugins {
    java
    id("io.ratpack.ratpack-java")
}

dependencies {
    implementation(project(":domain"))
    implementation(project(":infra"))
    implementation(ratpack.dependency("dropwizard-metrics"))
}

application {
    mainClass = "example.App"
}

ratpack.baseDir = file("src/ratpack/baseDir")
```

If your build requires additional plugin repositories on top of the Gradle Plugin Portal, you should declare them in the `pluginManagement {}` block in your `settings.gradle.kts` file, like so:

settings.gradle.kts

```
pluginManagement {
    repositories {
        mavenCentral()
        gradlePluginPortal()
    }
}
```

Plugins fetched from a source other than the Gradle Plugin Portal can only be declared via the `plugins {}` block if they are published with their plugin marker artifacts.

NOTE	At the time of writing, all versions of the Android Plugin for Gradle up to 3.2.0 present in the `google()` repository lack plugin marker artifacts.

If those artifacts are missing, then you can't use the `plugins {}` block. You must instead fall back to declaring your plugin dependencies using the `buildscript {}` block in the root project build script. Here's an example of doing that for the Android Plugin:

settings.gradle.kts

```
include("lib", "app")
```

build.gradle.kts

```
buildscript {
    repositories {
        google()
        gradlePluginPortal()
    }
    dependencies {
        classpath("com.android.tools.build:gradle:7.3.0")
    }
}
```

lib/build.gradle.kts

```
plugins {
    id("com.android.library")
}

android {
    // ...
}
```

app/build.gradle.kts

```
plugins {
    id("com.android.application")
}

android {
    // ...
}
```

This technique is not that different from what Android Studio produces when creating a new build. The main difference is that the subprojects' build scripts in the above sample declare their plugins using the `plugins {}` block. This means that you can use type-safe accessors for the model elements that they contribute.

Note that you can't use this technique if you want to apply such a plugin either to the root project build script of a multi-project build (rather than solely to its subprojects) or to a single-project build. You'll need to use a different approach in those cases that we detail in another section.

=== Cross-configuring projects

Cross project configuration is a mechanism by which you can configure a project from another project's build script. A common example is when you configure subprojects in the root project build script.

Taking this approach means that you won't be able to use type-safe accessors for model elements contributed by the plugins. You will instead have to rely on string literals and the standard Gradle APIs.

As an example, let's modify the Java/Ratpack sample build to fully configure its subprojects from the root project build script:

settings.gradle.kts

```
rootProject.name = "multi-project-build"
include("domain", "infra", "http")
```

build.gradle.kts

```kotlin
import com.github.jengelman.gradle.plugins.shadow.ShadowExtension
import com.github.jengelman.gradle.plugins.shadow.tasks.ShadowJar
import ratpack.gradle.RatpackExtension

plugins {
    id("com.github.johnrengelman.shadow") version "7.1.2" apply false
    id("io.ratpack.ratpack-java") version "1.8.2" apply false
}

project(":domain") {
    apply(plugin = "java-library")
    repositories { mavenCentral() }
    dependencies {
        "api"("javax.measure:unit-api:1.0")
        "implementation"("tec.units:unit-ri:1.0.3")
    }
}


project(":infra") {
    apply(plugin = "java-library")
    apply(plugin = "com.github.johnrengelman.shadow")
    configure<ShadowExtension> {
        applicationDistribution.from("src/dist")
    }
    tasks.named<ShadowJar>("shadowJar") {
        minimize()
    }
}

project(":http") {
    apply(plugin = "java")
    apply(plugin = "io.ratpack.ratpack-java")
    repositories { mavenCentral() }
    val ratpack = the<RatpackExtension>()
    dependencies {
        "implementation"(project(":domain"))
        "implementation"(project(":infra"))
        "implementation"(ratpack.dependency("dropwizard-metrics"))
        "runtimeOnly"("org.slf4j:slf4j-simple:1.7.25")
    }
    configure<JavaApplication> {
        mainClass = "example.App"
    }
    ratpack.baseDir = file("src/ratpack/baseDir")
}
```

Note how we're using the `apply()` method to apply the plugins since the `plugins {}` block doesn't work in this context. We are also using standard APIs instead of type-safe accessors to configure tasks, extensions and conventions — an approach that we discussed in more detail elsewhere.

== When you can't use the `plugins {}` block

Plugins fetched from a source other than the Gradle Plugin Portal may or may not be usable with the `plugins {}` block. It depends on how they have been published and, specifically, whether they have been published with the necessary plugin marker artifacts.

For example, the Android Plugin for Gradle is not published to the Gradle Plugin Portal and — at least up to version 3.2.0 of the plugin — the metadata required to resolve the artifacts for a given plugin identifier is not published to the Google repository.

If your build is a multi-project build and you don't need to apply such a plugin to your *root* project, then you can get round this issue using the technique described above. For any other situation, keep reading.

When publishing plugins, please use Gradle's built-in Gradle Plugin Development Plugin.

It automates the publication of the metadata necessary to make your plugins usable with the `plugins {}` block.

We will show you in this section how to apply the Android Plugin to a single-project build or the root project of a multi-project build. The goal is to instruct your build on how to map the `com.android.application` plugin identifier to a resolvable artifact. This is done in two steps:

- Add a plugin repository to the build's settings script
- Map the plugin ID to the corresponding artifact coordinates

You accomplish both steps by configuring a `pluginManagement {}` block in the build's settings script. To demonstrate, the following sample adds the `google()` repository — where the Android plugin is published — to the repository search list, and uses a `resolutionStrategy {}` block to map the `com.android.application` plugin ID to the `com.android.tools.build:gradle:<version>` artifact available in the `google()` repository:

settings.gradle.kts

```
pluginManagement {
    repositories {
        google()
        gradlePluginPortal()
    }
    resolutionStrategy {
        eachPlugin {
            if(requested.id.namespace == "com.android") {
                useModule("com.android.tools.build:gradle:${requested.version}")
            }
        }
    }
}
```

build.gradle.kts

```
plugins {
    id("com.android.application") version "7.3.0"
}

android {
    // ...
}
```

In fact, the above sample will work for all `com.android.*` plugins that are provided by the specified module. That's because the packaged module contains the details of which plugin ID maps to which plugin implementation class, using the properties-file mechanism described in the Writing Custom Plugins chapter.

See the Plugin Management section of the Gradle user manual for more information on the `pluginManagement {}` block and what it can be used for.

== Working with container objects

The Gradle build model makes heavy use of container objects (or just "containers"). For example, both `configurations` and `tasks` are container objects that contain `Configuration` and `Task` objects respectively. Community plugins also contribute containers, like the `android.buildTypes` container contributed by the Android Plugin.

The Kotlin DSL provides several ways for build authors to interact with containers. We look at each of those ways next, using the `tasks` container as an example.

| TIP | Note that you can leverage the type-safe accessors described in another section if you are configuring existing elements on supported containers. That section also describes which containers support type-safe accessors. |

=== Using the container API

All containers in Gradle implement NamedDomainObjectContainer<DomainObjectType>. Some of them can contain objects of different types and implement PolymorphicDomainObjectContainer<BaseType>. The simplest way to interact with containers is through these interfaces.

The following sample demonstrates how you can use the named() method to configure existing tasks and the register() method to create new ones.

build.gradle.kts

```
tasks.named("check")                        ①
tasks.register("myTask1")                    ②

tasks.named<JavaCompile>("compileJava")  ③
tasks.register<Copy>("myCopy1")             ④

tasks.named("assemble") {                   ⑤
    dependsOn(":myTask1")
}
tasks.register("myTask2") {                 ⑥
    description = "Some meaningful words"
}

tasks.named<Test>("test") {                 ⑦
    testLogging.showStackTraces = true
}
tasks.register<Copy>("myCopy2") {           ⑧
    from("source")
    into("destination")
}
```

① Gets a reference of type `Task` to the existing task named `check`

② Registers a new untyped task named `myTask1`

③ Gets a reference to the existing task named `compileJava` of type `JavaCompile`

④ Registers a new task named `myCopy1` of type `Copy`

⑤ Gets a reference to the existing (untyped) task named `assemble` and configures it — you can only configure properties and methods that are available on `Task` with this syntax

⑥ Registers a new untyped task named `myTask2` and configures it — you can only configure properties and methods that are available on `Task` in this case

⑦ Gets a reference to the existing task named `test` of type `Test` and configures it — in this case you have access to the properties and methods of the specified type

⑧ Registers a new task named `myCopy2` of type `Copy` and configures it

NOTE	The above sample relies on the configuration avoidance APIs. If you need or want to eagerly configure or register container elements, simply replace `named()` with `getByName()` and `register()` with `create()`.

=== Using Kotlin delegated properties

Another way to interact with containers is via Kotlin delegated properties. These are particularly useful if you need a reference to a container element that you can use elsewhere in the build. In addition, Kotlin delegated properties can easily be renamed via IDE refactoring.

The following sample does the exact same things as the one in the previous section, but it uses delegated properties and reuses those references in place of string-literal task paths:

build.gradle.kts

```kotlin
val check by tasks.existing
val myTask1 by tasks.registering

val compileJava by tasks.existing(JavaCompile::class)
val myCopy1 by tasks.registering(Copy::class)

val assemble by tasks.existing {
    dependsOn(myTask1)   ①
}
val myTask2 by tasks.registering {
    description = "Some meaningful words"
}

val test by tasks.existing(Test::class) {
    testLogging.showStackTraces = true
}
val myCopy2 by tasks.registering(Copy::class) {
    from("source")
    into("destination")
}
```

① Uses the reference to the `myTask1` task rather than a task path

The above rely on configuration avoidance APIs. If you need to eagerly configure or register container elements simply replace `existing()` with `getting()` and `registering()` with `creating()`.

=== Configuring multiple container elements together

When configuring several elements of a container one can group interactions in a block in order to avoid repeating the container's name on each interaction. The following example uses a combination of type-safe accessors, the container API and Kotlin delegated properties:

build.gradle.kts

```
tasks {
    test {
        testLogging.showStackTraces = true
    }
    val myCheck by registering {
        doLast { /* assert on something meaningful */ }
    }
    check {
        dependsOn(myCheck)
    }
    register("myHelp") {
        doLast { /* do something helpful */ }
    }
}
```

== Working with runtime properties

Gradle has two main sources of properties that are defined at runtime: *project properties* and *extra properties*. The Kotlin DSL provides specific syntax for working with these types of properties, which we look at in the following sections.

=== Project properties

The Kotlin DSL allows you to access project properties by binding them via Kotlin delegated properties. Here's a sample snippet that demonstrates the technique for a couple of project properties, one of which *must* be defined:

build.gradle.kts

```
val myProperty: String by project   ①
val myNullableProperty: String? by project ②
```

① Makes the `myProperty` project property available via a `myProperty` delegated property — the project property must exist in this case, otherwise the build will fail when the build script attempts to use the `myProperty` value

② Does the same for the `myNullableProperty` project property, but the build won't fail on using the `myNullableProperty` value as long as you check for null (standard Kotlin rules for null safety apply)

The same approach works in both settings and initialization scripts, except you use `by settings` and `by gradle` respectively in place of `by project`.

=== Extra properties

Extra properties are available on any object that implements the ExtensionAware interface. Kotlin DSL allows you to access extra properties and create new ones via delegated properties, using any of the `by extra` forms demonstrated in the following sample:

build.gradle.kts

```
val myNewProperty by extra("initial value")   ①
val myOtherNewProperty by extra { "calculated initial value" }   ②

val myProperty: String by extra   ③
val myNullableProperty: String? by extra   ④
```

① Creates a new extra property called `myNewProperty` in the current context (the project in this case) and initializes it with the value `"initial value"`, which also determines the property's *type*

② Create a new extra property whose initial value is calculated by the provided lambda

③ Binds an existing extra property from the current context (the project in this case) to a `myProperty` reference

④ Does the same as the previous line but allows the property to have a null value

This approach works for all Gradle scripts: project build scripts, script plugins, settings scripts and initialization scripts.

You can also access extra properties on a root project from a subproject using the following syntax:

my-sub-project/build.gradle.kts

```
val myNewProperty: String by rootProject.extra   ①
```

① Binds the root project's `myNewProperty` extra property to a reference of the same name

Extra properties aren't just limited to projects. For example, `Task` extends `ExtensionAware`, so you can attach extra properties to tasks as well. Here's an example that defines a new `myNewTaskProperty` on the `test` task and then uses that property to initialize another task:

build.gradle.kts

```
tasks {
    test {
        val reportType by extra("dev")   ①
        doLast {
            // Use 'suffix' for post processing of reports
        }
    }

    register<Zip>("archiveTestReports") {
        val reportType: String by test.get().extra   ②
        archiveAppendix = reportType
        from(test.get().reports.html.destination)
    }
}
```

① Creates a new `reportType` extra property on the `test` task

② Makes the `test` task's `reportType` extra property available to configure the `archiveTestReports` task

If you're happy to use eager configuration rather than the configuration avoidance APIs, you could use a single, "global" property for the report type, like this:

build.gradle.kts

```
tasks.test.doLast { ... }

val testReportType by tasks.test.get().extra("dev")   ①

tasks.create<Zip>("archiveTestReports") {
    archiveAppendix = testReportType   ②
    from(test.get().reports.html.destination)
}
```

① Creates and initializes an extra property on the `test` task, binding it to a "global" property

② Uses the "global" property to initialize the `archiveTestReports` task

There is one last syntax for extra properties that we should cover, one that treats `extra` as a map. We recommend against using this in general as you lose the benefits of Kotlin's type checking and it prevents IDEs from providing as much support as they could. However, it is more succinct than the delegated properties syntax and can reasonably be used if you only need to set the value of an extra property without referencing it later.

Here's a simple example demonstrating how to set and read extra properties using the map syntax:

build.gradle.kts

```
extra["myNewProperty"] = "initial value"   ①

tasks.create("myTask") {
    doLast {
        println("Property: ${project.extra["myNewProperty"]}")   ②
    }
}
```

① Creates a new project extra property called `myNewProperty` and sets its value

② Reads the value from the project extra property we created — note the `project.` qualifier on `extra[⋯]`, otherwise Gradle will assume we want to read an extra property from the *task*

== Kotlin lazy property assignment

Gradle's Kotlin DSL supports lazy property assignment using the `=` operator . Lazy property assignment reduces the verbosity for Kotlin DSL when lazy properties are used. It works for properties that are publicly seen as `final` (without a setter) and have type `Property` or `ConfigurableFileCollection`. Since properties have to be `final`, our general recommendation is not to implement custom setters for properties with lazy types and, if possible, implement such properties via an abstract getter.

Using the `=` operator is the preferred way to call `set()` in the Kotlin DSL.

build.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}

abstract class WriteJavaVersionTask : DefaultTask() {
    @get:Input
    abstract val javaVersion: Property<String>
    @get:OutputFile
    abstract val output: RegularFileProperty

    @TaskAction
    fun execute() {
        output.get().asFile.writeText("Java version: ${javaVersion.get()}")
    }
}

tasks.register<WriteJavaVersionTask>("writeJavaVersion") {
    javaVersion.set("17") ①
    javaVersion = "17" ②
    javaVersion = java.toolchain.languageVersion.map { it.toString() } ③
    output = layout.buildDirectory.file("writeJavaVersion/javaVersion.txt")
}
```

① Set value with the `.set()` method

② Set value with lazy property assignment using the `=` operator

③ The `=` operator can be used also for assigning lazy values

=== IDE support

Lazy property assignment is supported from IntelliJ 2022.3 and from Android Studio Giraffe.

== The Kotlin DSL Plugin

The Kotlin DSL Plugin provides a convenient way to develop Kotlin-based projects that contribute build logic. That includes buildSrc projects, included builds and Gradle plugins.

The plugin achieves this by doing the following:

- Applies the Kotlin Plugin, which adds support for compiling Kotlin source files.
- Adds the `kotlin-stdlib`, `kotlin-reflect` and `gradleKotlinDsl()` dependencies to the `compileOnly` and `testImplementation` configurations, which allows you to make use of those Kotlin libraries and the Gradle API in your Kotlin code.
- Configures the Kotlin compiler with the same settings that are used for Kotlin DSL scripts, ensuring consistency between your build logic and those scripts:
  - adds Kotlin compiler arguments,
  - registers the SAM-with-receiver Kotlin compiler plugin.
- Enables support for precompiled script plugins.

Avoid specifying a version for the `kotlin-dsl` plugin

Each Gradle release is meant to be used with a specific version of the `kotlin-dsl` plugin and compatibility between arbitrary Gradle releases and `kotlin-dsl` plugin versions is not guaranteed. Using an unexpected version of the `kotlin-dsl` plugin in a build will emit a warning and can cause hard to diagnose problems.

This is the basic configuration you need to use the plugin:

buildSrc/build.gradle.kts

```
plugins {
    `kotlin-dsl`
}

repositories {
    // The org.jetbrains.kotlin.jvm plugin requires a repository
    // where to download the Kotlin compiler dependencies from.
    mavenCentral()
}
```

The Kotlin DSL Plugin leverages Java Toolchains. By default the code will target Java 8. You can change that by defining a Java toolchain to be used by the project:

buildSrc/src/main/kotlin/myproject.java-conventions.gradle.kts

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
    }
}
```

buildSrc/src/main/groovy/myproject.java-conventions.gradle

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(11)
    }
}
```

== The embedded Kotlin

Gradle embeds Kotlin in order to provide support for Kotlin-based scripts.

=== Kotlin versions

Gradle ships with `kotlin-compiler-embeddable` plus matching versions of `kotlin-stdlib` and `kotlin-reflect` libraries. For details see the Kotlin section of Gradle's compatibility matrix. The `kotlin` package from those modules is visible through the Gradle classpath.

The compatibility guarantees provided by Kotlin apply for both backward and forward compatibility.

==== Backward compatibility

Our approach is to only do backwards-breaking Kotlin upgrades on a major Gradle release. We will always clearly document which Kotlin version we ship and announce upgrade plans before a major release.

Plugin authors who want to stay compatible with older Gradle versions need to limit their API usage to a subset that is compatible with these old versions. It's not really different from any other new API in Gradle. E.g. if we introduce a new API for dependency resolution and a plugin wants to use that API, then they either need to drop support for older Gradle versions or they need to do some clever organization of their code to only execute the new code path on newer versions.

==== Forward compatibility

The biggest issue is the compatibility between the external `kotlin-gradle-plugin` version and the `kotlin-stdlib` version shipped with Gradle. More generally, between any plugin that transitively depends on `kotlin-stdlib` and its version shipped with Gradle. As long as the combination is compatible everything should work. This will become less of an issue as the language matures.

=== Kotlin compiler arguments

These are the Kotlin compiler arguments used for compiling Kotlin DSL scripts and Kotlin sources and scripts in a project that has the `kotlin-dsl` plugin applied:

`-java-parameters`

Generate metadata for Java >= 1.8 reflection on method parameters. See Kotlin/JVM compiler options in the Kotlin documentation for more information.

`-Xjvm-default=all`

Makes all non-abstract members of Kotlin interfaces default for the Java classes implementing them. This is to provide a better interoperability with Java and Groovy for plugins written in Kotlin. See Default methods in interfaces in the Kotlin documentation for more information.

`-Xsam-conversions=class`

Sets up the implementation strategy for SAM (single abstract method) conversion to always generate anonymous classes, instead of using the `invokedynamic` JVM instruction. This is to provide a better support for configuration cache and incremental build. See KT-44912 in the Kotlin issue tracker for more information.

`-Xjsr305=strict`

Sets up Kotlin's Java interoperability to strictly follow JSR-305 annotations for increased null safety. See Calling Java code from Kotlin in the Kotlin documentation for more information.

== Interoperability

When mixing languages in your build logic, you may have to cross language boundaries. An extreme example would be a build that uses tasks and plugins that are implemented in Java, Groovy and Kotlin, while also using both Kotlin DSL and Groovy DSL build scripts.

Quoting the Kotlin reference documentation:

> Kotlin is designed with Java Interoperability in mind. Existing Java code can be called from Kotlin in a natural way, and Kotlin code can be used from Java rather smoothly as well.

Both calling Java from Kotlin and calling Kotlin from Java are very well covered in the Kotlin reference documentation.

The same mostly applies to interoperability with Groovy code. In addition, the Kotlin DSL provides several ways to opt into Groovy semantics, which we look at next.

=== Static extensions

Both the Groovy and Kotlin languages support extending existing classes via Groovy Extension modules and Kotlin extensions.

To call a Kotlin extension function from Groovy, call it as a static function, passing the receiver as the first parameter:

build.gradle

```
TheTargetTypeKt.kotlinExtensionFunction(receiver, "parameters", 42, aReference)
```

Kotlin extension functions are package-level functions and you can learn how to locate the name of the type declaring a given Kotlin extension in the Package-Level Functions section of the Kotlin reference documentation.

To call a Groovy extension method from Kotlin, the same approach applies: call it as a static function passing the receiver as the first parameter. Here's an example:

build.gradle.kts

```
TheTargetTypeGroovyExtension.groovyExtensionMethod(receiver, "parameters", 42,
aReference)
```

Named parameters and default arguments

Both the Groovy and Kotlin languages support named function parameters and default arguments, although they are implemented very differently. Kotlin has fully-fledged support for both, as described in the Kotlin language reference under named arguments and default arguments. Groovy implements named arguments in a non-type-safe way based on a `Map<String, ?>` parameter, which means they cannot be combined with default arguments. In other words, you can only use one or the other in Groovy for any given method.

Calling Kotlin from Groovy

To call a Kotlin function that has named arguments from Groovy, just use a normal method call with positional parameters. There is no way to provide values by argument name.

To call a Kotlin function that has default arguments from Groovy, always pass values for all the function parameters.

Calling Groovy from Kotlin

To call a Groovy function with named arguments from Kotlin, you need to pass a `Map<String, ?>`, as shown in this example:

build.gradle.kts

```
groovyNamedArgumentTakingMethod(mapOf(
    "parameterName" to "value",
    "other" to 42,
    "and" to aReference))
```

To call a Groovy function with default arguments from Kotlin, always pass values for all the parameters.

=== Groovy closures from Kotlin

You may sometimes have to call Groovy methods that take Closure arguments from Kotlin code. For example, some third-party plugins written in Groovy expect closure arguments.

NOTE	Gradle plugins written in any language should prefer the type `Action<T>` type in place of closures. Groovy closures and Kotlin lambdas are automatically mapped to arguments of that type.

In order to provide a way to construct closures while preserving Kotlin's strong typing, two helper methods exist:

- `closureOf<T> {}`
- `delegateClosureOf<T> {}`

Both methods are useful in different circumstances and depend upon the method you are passing the `Closure` instance into.

Some plugins expect simple closures, as with the Bintray plugin:

build.gradle.kts

```
bintray {
    pkg(closureOf<PackageConfig> {
        // Config for the package here
    })
}
```

In other cases, like with the Gretty Plugin when configuring farms, the plugin expects a delegate closure:

build.gradle.kts

```
farms {
    farm("OldCoreWar", delegateClosureOf<FarmExtension> {
        // Config for the war here
    })
}
```

There sometimes isn't a good way to tell, from looking at the source code, which version to use. Usually, if you get a `NullPointerException` with `closureOf<T> {}`, using `delegateClosureOf<T> {}` will resolve the problem.

These two utility functions are useful for *configuration closures*, but some plugins might expect Groovy closures for other purposes. The `KotlinClosure0` to `KotlinClosure2` types allows adapting Kotlin functions to Groovy closures with more flexibility.

build.gradle.kts

```
somePlugin {

    // Adapt parameter-less function
    takingParameterLessClosure(KotlinClosure0({
        "result"
    }))

    // Adapt unary function
    takingUnaryClosure(KotlinClosure1<String, String>({
        "result from single parameter $this"
    }))

    // Adapt binary function
    takingBinaryClosure(KotlinClosure2<String, String, String>({ a, b ->
        "result from parameters $a and $b"
    }))
}
```

=== The Kotlin DSL Groovy Builder

If some plugin makes heavy use of Groovy metaprogramming, then using it from Kotlin or Java or any statically-compiled language can be very cumbersome.

The Kotlin DSL provides a `withGroovyBuilder {}` utility extension that attaches the Groovy metaprogramming semantics to objects of type `Any`. The following example demonstrates several features of the method on the object `target`:

build.gradle.kts

```
target.withGroovyBuilder {                                      ①

    // GroovyObject methods available                           ②
    if (hasProperty("foo")) { /*...*/ }
    val foo = getProperty("foo")
    setProperty("foo", "bar")
    invokeMethod("name", arrayOf("parameters", 42, aReference))

    // Kotlin DSL utilities
    "name"("parameters", 42, aReference)                        ③
        "blockName" {                                           ④
            // Same Groovy Builder semantics on `blockName`
        }
    "another"("name" to "example", "url" to "https://example.com/") ⑤
}
```

① The receiver is a GroovyObject and provides Kotlin helpers

② The `GroovyObject` API is available

③ Invoke the `methodName` method, passing some parameters

④ Configure the `blockName` property, maps to a `Closure` taking method invocation

⑤ Invoke `another` method taking named arguments, maps to a Groovy named arguments `Map<String, ?>` taking method invocation

=== Using a Groovy script

Another option when dealing with problematic plugins that assume a Groovy DSL build script is to configure them in a Groovy DSL build script that is applied from the main Kotlin DSL build script:

dynamic-groovy-plugin-configuration.gradle

```
native {                                                        ①
    dynamic {
        groovy as Usual
    }
}
```

build.gradle.kts

```
plugins {
    id("dynamic-groovy-plugin") version "1.0"                ②
}
apply(from = "dynamic-groovy-plugin-configuration.gradle")   ③
```

① The Groovy script uses dynamic Groovy to configure plugin

② The Kotlin build script requests and applies the plugin

③ The Kotlin build script applies the Groovy script

== Limitations

- The Kotlin DSL is known to be slower than the Groovy DSL on first use, for example with clean checkouts or on ephemeral continuous integration agents. Changing something in the *buildSrc* directory also has an impact as it invalidates build-script caching. The main reason for this is the slower script compilation for Kotlin DSL.

- In IntelliJ IDEA, you must import your project from the Gradle model in order to get content assist and refactoring support for your Kotlin DSL build scripts.

- Kotlin DSL script compilation avoidance has known issues. If you encounter problems, it can be disabled by setting the `org.gradle.kotlin.dsl.scriptCompilationAvoidance` system property to `false`.

- The Kotlin DSL will not support the `model {}` block, which is part of the discontinued Gradle Software Model.

If you run into trouble or discover a suspected bug, please report the issue in the Gradle issue tracker.

= Migrating build logic from Groovy to Kotlin :figure-caption!: :example-caption!: :plugin-portal: https://plugins.gradle.org/ :kotlin-reference: https://kotlinlang.org/docs/reference/ :kotlin-tutorials: https://kotlinlang.org/tutorials/ :gradle-issues: https://github.com/gradle/gradle/issues/

This section will walk you through converting your Groovy-based Gradle build scripts to Kotlin.

Gradle's newer Kotlin DSL provides a pleasant editing experience in supported IDEs: content-assist, refactoring, documentation, and more.
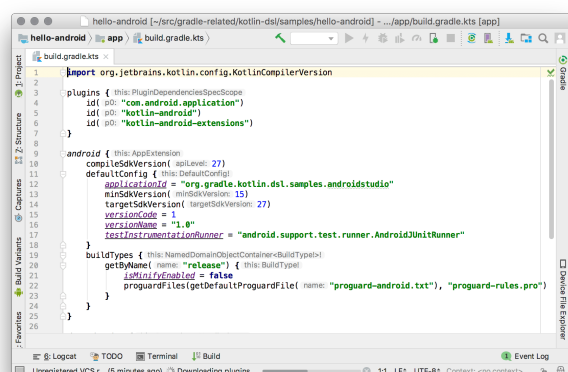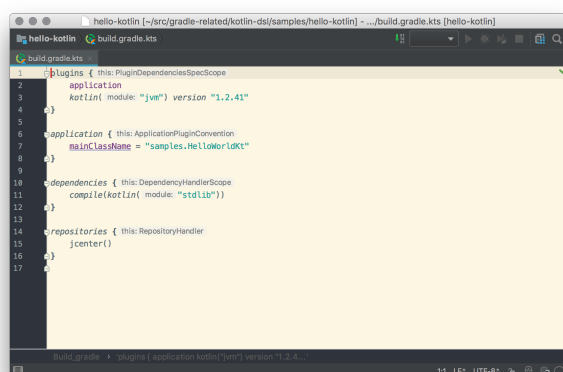
Please also read the Gradle Kotlin DSL Primer to learn the specificities, limitations and usage of the Gradle Kotlin DSL.

The rest of the user manual contain build script excerpts that demonstrate both the Groovy DSL and the Kotlin DSL. This is the best place where to find how to do this and what with each DSL ; and it covers all Gradle features from using plugins to customizing the dependency resolution behavior.

== Before you start migrating

Please read: It's helpful to understand the following important information *before you migrate*:

- Using the latest versions of Gradle, applied plugins, and your IDE should be your first move.

- Kotlin DSL is fully supported in Intellij IDEA and Android Studio. Other IDEs, such as Eclipse or NetBeans, do not yet provide helpful tools for editing Gradle Kotlin DSL files, however, importing and working with Kotlin DSL-based builds work as usual.

- In IntelliJ IDEA, you must import your project from the Gradle model to get content-assist and refactoring tools for Kotlin DSL scripts.

- There are some situations where the Kotlin DSL is slower. First use, on clean checkouts or ephemeral CI agents for example, are known to be slower. The same applies to the scenario in which something in the *buildSrc* directory changes, which invalidates build-script caching. Builds with slow configuration time might affect the IDE responsiveness, please check out the documentation on Gradle performance.

- You must run Gradle with Java 8 or higher. Java 7 is not supported.

- The embedded Kotlin compiler is known to work on Linux, macOS, Windows, Cygwin, FreeBSD and Solaris on x86-64 architectures.

- Knowledge of Kotlin syntax and basic language features is very helpful. The Kotlin reference documentation and Kotlin Koans should be useful to you.

- Use of the `plugins {}` block to declare Gradle plugins significantly improves the editing experience, and is highly recommended. Consider adopting it in your Groovy build scripts before converting them to Kotlin.

- The Kotlin DSL will not support `model {}` elements. This is part of the discontinued Gradle Software Model.

- Enabling the incubating configuration on demand feature is not recommended as it can lead to very hard-to-diagnose problems.

Read more in the Gradle Kotlin DSL Primer.

If you run to trouble or a suspected bug, please take advantage of the `gradle/gradle` issue tracker.

You don't have to migrate all at once! Both Groovy and Kotlin-based build scripts can `apply` other scripts of either language. You can find inspiration for any Gradle features not covered in the Kotlin DSL samples.

== Prepare your Groovy scripts

Some simple Kotlin and Groovy language differences can make converting scripts tedious:

- Groovy strings can be quoted with single quotes `'string'` or double quotes `"string"` whereas Kotlin requires double quotes `"string"`.

- Groovy allows to omit parentheses when invoking functions whereas Kotlin always requires the parentheses.

- The Gradle Groovy DSL allows to omit the `=` assignment operator when assigning properties whereas Kotlin always requires the assignment operator.

As a first migration step, it is recommended to prepare your Groovy build scripts by

- unifying quotes using double quotes,

- disambiguating function invocations and property assignments (using respectively parentheses and assignment operator).

The former can easily be done by searching for `'` and replacing by `"`. For example,

Example 90. build.gradle

```
group 'com.acme'
dependencies {
    implementation 'com.acme:example:1.0'
}
```

becomes:

Example 91. build.gradle

```
group "com.acme"
dependencies {
    implementation "com.acme:example:1.0"
}
```

The next step is a bit more involved as it may not be trivial to distinguish function invocations and property assignments in a Groovy script. A good strategy is to make all ambiguous statements property assignments first and then fix the build by turning the failing ones to function invocations.

For example,

Example 92. build.gradle

```
group "com.acme"
dependencies {
    implementation "com.acme:example:1.0"
}
```

becomes:

Example 93. build.gradle

```
group = "com.acme"                              ①
dependencies {
    implementation("com.acme:example:1.0")  ②
}
```

① Property assignment

② Function invocation

While staying valid Groovy, it is now unambiguous and close to the Kotlin syntax, making it easier to then rename the script to turn it into a Gradle Kotlin DSL script.

It is important to note that while Groovy extra properties can be modified using an object's `ext` property, in Kotlin they are modified using the `extra` property. It is important to look at each object and update the build scripts accordingly.

You can find an example in the [userguide](#).

== Script file naming

| NOTE | Groovy DSL script files use the `.gradle` file name extension. Kotlin DSL script files use the `.gradle.kts` file name extension. |

To use the Kotlin DSL, simply name your files `build.gradle.kts` instead of `build.gradle`.

The [settings file](#), `settings.gradle`, can also be renamed `settings.gradle.kts`.

In a multi-project build, you can have some modules using the Groovy DSL (with `build.gradle`) and others using the Kotlin DSL (with `build.gradle.kts`).

On top of that, apply the following conventions for better IDE support:

- Name scripts that are applied to `Settings` according to the pattern `*.settings.gradle.kts`,

- Name [init scripts](#) according to the pattern `*.init.gradle.kts`.

== Applying plugins

Just like with the Groovy DSL, there are two ways to apply Gradle plugins:

- [declaratively, using the `plugins {}` block](#),

- [imperatively, using the legacy `apply(..)` functions](#).

Here's an example using the declarative `plugins {}` block:

build.gradle.kts

```
plugins {
    java
    jacoco
    `maven-publish`
    id("org.springframework.boot") version "2.7.8"
}
```

build.gradle

```
plugins {
    id 'java'
    id 'jacoco'
    id 'maven-publish'
    id 'org.springframework.boot' version '2.7.8'
}
```

The Kotlin DSL provides property extensions for all Gradle core plugins, as shown above with the `java`, `jacoco` or `maven-publish` declaration.

Third party plugins can be applied the same way as with the Groovy DSL. Except for the double quotes and parentheses. You can also apply core plugins with that style. But the statically-typed accessors are recommended since they are type-safe and will be autocompleted by your IDE.

You can also use the imperative `apply` syntax, but then non-core plugins must be included on the classpath of the build script:

build.gradle.kts

```
buildscript {
    repositories {
        gradlePluginPortal()
    }
    dependencies {
        classpath("org.springframework.boot:spring-boot-gradle-plugin:2.7.8")
    }
}

apply(plugin = "java")
apply(plugin = "jacoco")
apply(plugin = "org.springframework.boot")
```

build.gradle

```
buildscript {
    repositories {
        gradlePluginPortal()
    }
    dependencies {
        classpath('org.springframework.boot:spring-boot-gradle-plugin:2.7.8')
    }
}

apply plugin: 'java'
apply plugin: 'jacoco'
apply plugin: 'org.springframework.boot'
```

We strongly recommend that you use the `plugins {}` block in preference to the `apply()` function.

The declarative nature of the `plugins {}` block enables the Kotlin DSL to provide type-safe accessors to the extensions, configurations and other features contributed by the applied plugins, which makes it easy for IDEs to discover the details of the plugins' models and makes them easy to configure.
See the `plugins {}` block documentation in the Gradle user manual for more information.

== Configuring plugins

Many plugins come with extensions to configure them. If those plugins are applied using the declarative `plugins {}` block, then Kotlin extension functions are made available to configure their extension, the same way as in Groovy. The following sample shows how this works for the Jacoco Plugin.

build.gradle.kts

```
plugins {
    jacoco
}

jacoco {
    toolVersion = "0.8.1"
}
```

```
plugins {
    id 'jacoco'
}

jacoco {
    toolVersion = '0.8.1'
}
```

By contrast, if you use the imperative `apply()` function to apply a plugin, then you will have to use the `configure<T>()` function to configure that plugin. The following sample shows how this works for the Checkstyle Plugin by explicitly declaring the plugin's extension class — `CheckstyleExtension` — in the `configure<T>()` function:

build.gradle.kts

```
apply(plugin = "checkstyle")

configure<CheckstyleExtension> {
    maxErrors = 10
}
```

build.gradle

```
apply plugin: "checkstyle"

checkstyle {
    maxErrors = 10
}
```

Again, we strongly recommend that you apply plugins declaratively via the `plugins {}` block.

Knowing what plugin-provided extensions are available

Because your IDE knows about the configuration elements that a plugin provides, it will include those elements when you ask your IDE for suggestions. This will happen both at the top level of your build scripts — most plugin extensions are added to the `Project` object — and within an extension's configuration block.

You can also run the `:kotlinDslAccessorsReport` task to learn about the extensions contributed by all applied plugins. It prints the Kotlin code you can use to access those extensions and provides the name and type of the accessor methods.

If the plugin you want to configure relies on `groovy.lang.Closure` in its method signatures or uses other dynamic Groovy semantics, more work will be required to configure that plugin from a Kotlin DSL build script. See the interoperability section of the Gradle Kotlin DSL documentation for more information on how to call Groovy code from Kotlin code or to keep that plugin's configuration in a Groovy script.

Plugins also contribute tasks that you may want to configure directly. This topic is covered in the [configuring-tasks] section below.

Keeping build scripts declarative

To get the most benefits of the Gradle Kotlin DSL you should strive to keep your build scripts declarative. The main thing to remember here is that in order to get type-safe accessors, plugins must be applied before the body of build scripts.

It is strongly recommended to read about configuring plugins with the Gradle Kotlin DSL in the Gradle user manual.

If your build is a multi-project build, like mostly all **Android** builds for example, please also read the subsequent section about multi-project builds.

Finally, there are strategies to use the `plugins {}` block with plugins that aren't published with the correct metadata, such as the **Android** Gradle Plugin.

== Configuration avoidance

Gradle 4.9 introduced a new API for creating and configuring tasks in build scripts and plugins. The intent is for this new API to eventually replace the existing API.

> One of the major differences between the existing and new Gradle Tasks API is whether or not Gradle spends the time to create `Task` instances and run configuration code. The new API allows Gradle to delay or completely avoid configuring tasks that will never be executed in a build. For example, when compiling code, Gradle does not need to configure tasks that run tests.

See the *Evolving the Gradle API to reduce configuration time* blog post and the Task

Configuration Avoidance chapter in the user manual for more information.

The Gradle Kotlin DSL embraces configuration avoidance by making the type-safe model accessors leverage the new APIs and providing DSL constructs to make them easier to use. Rest assured, the whole Gradle API remains available.

== Configuring tasks

The syntax for configuring tasks is where the Groovy and Kotlin DSLs start to differ significantly.

build.gradle.kts

```
tasks.jar {
    archiveFileName = "foo.jar"
}
```

build.gradle

```
tasks.jar {
    archiveFileName = 'foo.jar'
}
```

Note that in Kotlin the `tasks.jar {}` notation leverage the configuration avoidance API and defer the configuration of the `jar` task.

If the type-safe task accessor `tasks.jar` isn't available, see the configuring plugins section above, you can fallback to using the `tasks` container API. The Kotlin flavor of the following sample is strictly equivalent to the one using the type-safe accessor above:

build.gradle.kts

```
tasks.named<Jar>("jar") {
    archiveFileName = "foo.jar"
}
```

```
tasks.named('jar') {
    archiveFileName = 'foo.jar'
}
```

Note that since Kotlin is a statically typed language, it is necessary to specify the type of the task explicitly. Otherwise, the script will not compile because the inferred type will be `Task`, not `Jar`, and the `archiveName` property is specific to the `Jar` task type.

If configuration avoidance is getting in your way migrating and you want to eagerly configure a task just like Groovy you can do so by using the eager configuration API on the `tasks` container:

build.gradle.kts

```
tasks.getByName<Jar>("jar") {
    archiveFileName = "foo.jar"
}
```

build.gradle

```
tasks.getByName('jar') {
    archiveFileName = 'foo.jar'
}
```

Working with containers in the Gradle Kotlin DSL is documented in detail here.

Knowing the type of a task

If you don't know what type a task has, then you can find that information out via the built-in `help` task. Simply pass it the name of the task you're interested in using the `--task` option, like so:

```
 ./gradlew help --task jar
...
Type
    Jar (org.gradle.api.tasks.bundling.Jar)
```

Let's bring all this together by running through a quick worked example that configures the `bootJar` and `bootRun` tasks of a Spring Boot project:

build.gradle.kts

```
plugins {
    java
    id("org.springframework.boot") version "2.7.8"
}

tasks.bootJar {
    archiveFileName = "app.jar"
    mainClass = "com.example.demo.Demo"
}

tasks.bootRun {
    mainClass = "com.example.demo.Demo"
    args("--spring.profiles.active=demo")
}
```

```
plugins {
    id 'java'
    id 'org.springframework.boot' version '2.7.8'
}

tasks.bootJar {
    archiveFileName = 'app.jar'
    mainClass = 'com.example.demo.Demo'
}

tasks.bootRun {
    mainClass = 'com.example.demo.Demo'
    args '--spring.profiles.active=demo'
}
```

This is pretty self explanatory. The main difference is that the task configuration automatically becomes lazy when using the Kotlin DSL accessors.

Now, for the sake of the example, let's look at the same configuration applied using the API instead of the type-safe accessors that may not be available depending on the build logic structure, see the corresponding documentation in the Gradle user manual for more information.

We first determine the types of the `bootJar` and `bootRun` tasks via the `help` task:

```
 ./gradlew help --task bootJar
...
Type
     BootJar (org.springframework.boot.gradle.tasks.bundling.BootJar)
```

```
 ./gradlew help --task bootRun
...
Type
     BootRun (org.springframework.boot.gradle.tasks.run.BootRun)
```

Now that we know the types of the two tasks, we can import the relevant types — `BootJar` and `BootRun` — and configure the tasks as required. Note that the IDE can assist us with the required imports, so we only need the simple names, i.e. without the full packages. Here's the resulting build script, complete with imports:

build.gradle.kts

```kotlin
import org.springframework.boot.gradle.tasks.bundling.BootJar
import org.springframework.boot.gradle.tasks.run.BootRun

// TODO:Finalize Upload Removal - Issue #21439
plugins {
    java
    id("org.springframework.boot") version "2.7.8"
}

tasks.named<BootJar>("bootJar") {
    archiveFileName = "app.jar"
    mainClass = "com.example.demo.Demo"
}

tasks.named<BootRun>("bootRun") {
    mainClass = "com.example.demo.Demo"
    args("--spring.profiles.active=demo")
}
```

build.gradle

```groovy
plugins {
    id 'java'
    id 'org.springframework.boot' version '2.7.8'
}

tasks.named('bootJar') {
    archiveFileName = 'app.jar'
    mainClass = 'com.example.demo.Demo'
}

tasks.named('bootRun') {
    mainClass = 'com.example.demo.Demo'
    args '--spring.profiles.active=demo'
}
```

== Creating tasks

Creating tasks can be done using the script top-level function named `task(···)`:

build.gradle.kts

```
task("greeting") {
    doLast { println("Hello, World!") }
}
```

build.gradle

```
task greeting {
    doLast { println 'Hello, World!' }
}
```

Note that the above eagerly configures the created task with both Groovy and Kotlin DSLs.

Registering or creating tasks can also be done on the `tasks` container, respectively using the `register(⋯)` and `create(⋯)` functions as shown here:

build.gradle.kts

```
tasks.register("greeting") {
    doLast { println("Hello, World!") }
}
```

build.gradle

```
tasks.register('greeting') {
    doLast { println('Hello, World!') }
}
```

build.gradle.kts

```
tasks.create("greeting") {
    doLast { println("Hello, World!") }
}
```

build.gradle

```
tasks.create('greeting') {
    doLast { println('Hello, World!') }
}
```

The samples above create untyped, ad-hoc tasks, but you will more commonly want to create tasks of a specific type. This can also be done using the same `register()` and `create()` methods. Here's an example that creates a new task of type `Zip`:

build.gradle.kts

```
tasks.register<Zip>("docZip") {
    archiveFileName = "doc.zip"
    from("doc")
}
```

build.gradle

```
tasks.register('docZip', Zip) {
    archiveFileName = 'doc.zip'
    from 'doc'
}
```

build.gradle.kts

```
tasks.create<Zip>("docZip") {
    archiveFileName = "doc.zip"
    from("doc")
}
```

```
tasks.create(name: 'docZip', type: Zip) {
    archiveFileName = 'doc.zip'
    from 'doc'
}
```

== Configurations and dependencies

Declaring dependencies in existing configurations is similar to the way it's done in Groovy build scripts, as you can see in this example:

build.gradle.kts

```
plugins {
    `java-library`
}
dependencies {
    implementation("com.example:lib:1.1")
    runtimeOnly("com.example:runtime:1.0")
    testImplementation("com.example:test-support:1.3") {
        exclude(module = "junit")
    }
    testRuntimeOnly("com.example:test-junit-jupiter-runtime:1.3")
}
```

build.gradle

```
plugins {
    id 'java-library'
}
dependencies {
    implementation 'com.example:lib:1.1'
    runtimeOnly 'com.example:runtime:1.0'
    testImplementation('com.example:test-support:1.3') {
        exclude(module: 'junit')
    }
    testRuntimeOnly 'com.example:test-junit-jupiter-runtime:1.3'
}
```

Each configuration contributed by an applied plugin is also available as a member of the `configurations` container, so you can reference it just like any other configuration.

Knowing what configurations are available

The easiest way to find out what configurations are available is by asking your IDE for suggestions within the `configurations` container.

You can also use the `:kotlinDslAccessorsReport` task, which prints the Kotlin code for accessing the configurations contributed by applied plugins and provides the names for all of those accessors.

Note that if you do not use the `plugins {}` block to apply your plugins, then you won't be able to configure the dependency configurations provided by those plugins in the usual way. Instead, you will have to use string literals for the configuration names, which means you won't get IDE support:

build.gradle.kts

```
apply(plugin = "java-library")
dependencies {
    "implementation"("com.example:lib:1.1")
    "runtimeOnly"("com.example:runtime:1.0")
    "testImplementation"("com.example:test-support:1.3") {
        exclude(module = "junit")
    }
    "testRuntimeOnly"("com.example:test-junit-jupiter-runtime:1.3")
}
```

build.gradle

```
apply plugin: 'java-library'
dependencies {
    implementation 'com.example:lib:1.1'
    runtimeOnly 'com.example:runtime:1.0'
    testImplementation('com.example:test-support:1.3') {
        exclude(module: 'junit')
    }
    testRuntimeOnly 'com.example:test-junit-jupiter-runtime:1.3'
}
```

This is just one more reason to use the `plugins {}` block whenever you can!

=== Custom configurations and dependencies

Sometimes you need to create your own configurations and attach dependencies to them. The following example declares two new configurations:

- `db`, to which we add a PostgreSQL dependency

- `integTestImplementation`, which is configured to extend the `testImplementation` configuration and to which we add a different dependency

build.gradle.kts

```
val db by configurations.creating
val integTestImplementation by configurations.creating {
    extendsFrom(configurations["testImplementation"])
}

dependencies {
    db("org.postgresql:postgresql")
    integTestImplementation("com.example:integ-test-support:1.3")
}
```

build.gradle

```
configurations {
    db
    integTestImplementation {
        extendsFrom testImplementation
    }
}

dependencies {
    db 'org.postgresql:postgresql'
    integTestImplementation 'com.example:integ-test-support:1.3'
}
```

Note that we can only use the `db(…)` and `integTestImplementation(…)` notation within the `dependencies {}` block in the above example because both configurations are declared as delegated properties beforehand via the `creating()` method. If the configurations were defined elsewhere, you could only reference them either by first creating delegating properties via `configurations` — as opposed to `configurations.creating()` — or by using string literals within the `dependencies {}` block. The following example demonstrates both approaches:

build.gradle.kts

```
// get the existing 'testRuntimeOnly' configuration
val testRuntimeOnly by configurations

dependencies {
    testRuntimeOnly("com.example:test-junit-jupiter-runtime:1.3")
    "db"("org.postgresql:postgresql")
    "integTestImplementation"("com.example:integ-test-support:1.3")
}
```

Migration strategies

As we've seen above, both scripts using the Kotlin DSL and those using the Groovy DSL can participate in the same build. In addition, Gradle plugins from the *buildSrc* directory, an included build or an external location can be implemented using any JVM language. This makes it possible to migrate a build progressively, piece by piece, without blocking your team.

Two approaches to migrations stand out:

- Migrating the existing syntax of your build to Kotlin, bit by bit, while retaining the structure — what we call a *mechanical migration*
- Restructuring your build logic towards Gradle best practices and switching to Kotlin DSL as part of that effort

Both approaches are viable. A mechanical migration will be enough for simple builds. A complex and highly dynamic build may require some restructuring anyway, so in such cases reimplementing build logic to follow Gradle best practice makes sense.

Since applying Gradle best practices will make your builds easier to use and faster, we recommend that you migrate all projects in that way eventually, but it makes sense to focus on the projects that have to be restructured first and those that would benefit most from the improvements.

Also consider that the more parts of your build logic rely on the dynamic aspects of Groovy, the harder they will be to use from the Kotlin DSL. You'll find recipes on how to cross the dynamic boundaries from static Kotlin in the interoperability section of the Gradle Kotlin DSL documentation, regardless of where the dynamic Groovy build logic resides.

There are two key best practices that make it easier to work within the static context of the Kotlin DSL:

- Using the `plugins {}` block
- Putting local build logic in the build's *buildSrc* directory

The `plugins {}` block is about keeping your build scripts declarative in order to get the best out of the Kotlin DSL.

Utilizing the *buildSrc project* is about organizing your build logic into shared local plugins and conventions that are easily testable and provide good IDE support.

Kotlin DSL build structure samples

Depending on your build structure you might be interested in the following user manual chapters:

- The Writing Build Scripts chapter demonstrates the use of `apply(from = "")` to modularize build scripts.
- The Multi-project Builds chapter demonstrates various multi-project build structures.

- The Developing Custom Gradle Plugins and Gradle Kotlin DSL Primer chapters demonstrate how to develop custom Gradle plugins.
- The Composing builds chapter demonstrates how to use Composite Builds.

Interoperability

When mixing languages in your build logic, you may have to cross language boundaries. An extreme example would be a build that uses tasks and plugins that are implemented in Java, Groovy and Kotlin, while also using both Kotlin DSL and Groovy DSL build scripts.

Quoting the Kotlin reference documentation:

> Kotlin is designed with Java Interoperability in mind. Existing Java code can be called from Kotlin in a natural way, and Kotlin code can be used from Java rather smoothly as well.

Both calling Java from Kotlin and calling Kotlin from Java are very well covered in the Kotlin reference documentation.

The same mostly applies to interoperability with Groovy code. In addition, the Kotlin DSL provides several ways to opt into Groovy semantics.

On the Gradle Kotlin DSL and interoperability

Please find detailed documentation in the interoperability section of the Gradle Kotlin DSL Primer.

Gradle Plugin Reference

This page contains links and short descriptions for all the core plugins provided by Gradle itself.

JVM languages and frameworks

Java

   Provides support for building any type of Java project.

Java Library

   Provides support for building a Java library.

Java Platform

   Provides support for building a Java platform.

Groovy

   Provides support for building any type of Groovy project.

Scala

   Provides support for building any type of Scala project.

ANTLR

Provides support for generating parsers using ANTLR.

JVM Test Suite

Provides support for modeling and configuring multiple test suite invocations.

Test Report Aggregation

Aggregates the results of multiple Test task invocations (potentially spanning multiple Gradle projects) into a single HTML report.

== Native languages

C++ Application

Provides support for building C++ applications on Windows, Linux, and macOS.

C++ Library

Provides support for building C++ libraries on Windows, Linux, and macOS.

C++ Unit Test

Provides support for building and running C++ executable-based tests on Windows, Linux, and macOS.

Swift Application

Provides support for building Swift applications on Linux and macOS.

Swift Library

Provides support for building Swift libraries on Linux and macOS.

XCTest

Provides support for building and running XCTest-based tests on Linux and macOS.

== Packaging and distribution

Application

Provides support for building JVM-based, runnable applications.

WAR

Provides support for building and packaging WAR-based Java web applications.

EAR

Provides support for building and packaging Java EE applications.

Maven Publish

Provides support for publishing artifacts to Maven-compatible repositories.

Ivy Publish

Provides support for publishing artifacts to Ivy-compatible repositories.

Distribution

Makes it easy to create ZIP and tarball distributions of your project.

Java Library Distribution

Provides support for creating a ZIP distribution of a Java library project that includes its runtime dependencies.

== Code analysis

Checkstyle

Performs quality checks on your project's Java source files using Checkstyle and generates associated reports.

PMD

Performs quality checks on your project's Java source files using PMD and generates associated reports.

JaCoCo

Provides code coverage metrics for your Java project using JaCoCo.

JaCoCo Report Aggregation

Aggregates the results of multiple JaCoCo code coverage reports (potentially spanning multiple Gradle projects) into a single HTML report.

CodeNarc

Performs quality checks on your Groovy source files using CodeNarc and generates associated reports.

== IDE integration

Eclipse

Generates Eclipse project files for the build that can be opened by the IDE. This set of plugins can also be used to fine tune Buildship's import process for Gradle builds.

IntelliJ IDEA

Generates IDEA project files for the build that can be opened by the IDE. It can also be used to fine tune IDEA's import process for Gradle builds.

Visual Studio

Generates Visual Studio solution and project files for build that can be opened by the IDE.

Xcode

Generates Xcode workspace and project files for the build that can be opened by the IDE.

== Utility

Base

Provides common lifecycle tasks, such as `clean`, and other features common to most builds.

Build Init

Generates a new Gradle build of a specified type, such as a Java library. It can also generate a build script from a Maven POM — see Migrating from Maven to Gradle for more details.

Signing

Provides support for digitally signing generated files and artifacts.

Plugin Development

Makes it easier to develop and publish a Gradle plugin.

Project Report Plugin

Helps to generate reports containing useful information about your build.

= Gradle & Third-party Tools

Gradle can be integrated with many different third-party tools such as IDEs and continuous integration platforms. Here we look at some of the more common ones as well as how to integrate your own tool with Gradle.

== IDEs

Android Studio

As a variant of IntelliJ IDEA, Android Studio has built-in support for importing and building Gradle projects. You can also use the IDEA Plugin for Gradle to fine-tune the import process if that's necessary.

This IDE also has an extensive user guide to help you get the most out of the IDE and Gradle.

Eclipse

If you want to work on a project within Eclipse that has a Gradle build, you should use the Eclipse Buildship plugin. This will allow you to import and run Gradle builds. If you need to fine tune the import process so that the project loads correctly, you can use the Eclipse Plugins for Gradle. See the associated release announcement for details on what fine tuning you can do.

IntelliJ IDEA

IDEA has built-in support for importing Gradle projects. If you need to fine tune the import process so that the project loads correctly, you can use the IDEA Plugin for Gradle.

NetBeans

Built-in support for Gradle in Apache NetBeans

Visual Studio

For developing C++ projects, Gradle comes with a Visual Studio plugin.

Xcode

For developing C++ projects, Gradle comes with a Xcode plugin.

CLion

JetBrains supports building C++ projects with Gradle.

== Continuous integration

We have dedicated guides showing you how to integrate a Gradle project with the following CI platforms:

- Jenkins
- TeamCity
- Travis CI

Even if you don't use one of the above, you can almost certainly configure your CI platform to use the Gradle Wrapper scripts.

== How to integrate with Gradle

There are two main ways to integrate a tool with Gradle:

- The Gradle build uses the tool
- The tool executes the Gradle build

The former case is typically implemented as a Gradle plugin. The latter can be accomplished by embedding Gradle through the Tooling API as described below.

== Embedding Gradle using the Tooling API

=== Introduction to the Tooling API

Gradle provides a programmatic API called the Tooling API, which you can use for embedding Gradle into your own software. This API allows you to execute and monitor builds and to query Gradle about the details of a build. The main audience for this API is IDE, CI server, other UI authors; however, the API is open for anyone who needs to embed Gradle in their application.

- Gradle TestKit uses the Tooling API for functional testing of your Gradle plugins.
- Eclipse Buildship uses the Tooling API for importing your Gradle project and running tasks.
- IntelliJ IDEA uses the Tooling API for importing your Gradle project and running tasks.

=== Tooling API Features

A fundamental characteristic of the Tooling API is that it operates in a version independent way. This means that you can use the same API to work with builds that use different versions of Gradle, including versions that are newer or older than the version of the Tooling API that you are using. The Tooling API is Gradle wrapper aware and, by default, uses the same Gradle version as that used by the wrapper-powered build.

Some features that the Tooling API provides:

- Query the details of a build, including the project hierarchy and the project dependencies, external dependencies (including source and Javadoc jars), source directories and tasks of each project.

- Execute a build and listen to stdout and stderr logging and progress messages (e.g. the messages shown in the 'status bar' when you run on the command line).

- Execute a specific test class or test method.

- Receive interesting events as a build executes, such as project configuration, task execution or test execution.

- Cancel a build that is running.

- Combine multiple separate Gradle builds into a single composite build.

- The Tooling API can download and install the appropriate Gradle version, similar to the wrapper.

- The implementation is lightweight, with only a small number of dependencies. It is also a well-behaved library, and makes no assumptions about your classloader structure or logging configuration. This makes the API easy to embed in your application.

=== Tooling API and the Gradle Build Daemon

The Tooling API always uses the Gradle daemon. This means that subsequent calls to the Tooling API, be it model building requests or task executing requests will be executed in the same long-living process. Gradle Daemon contains more details about the daemon, specifically information on situations when new daemons are forked.

=== Quickstart

As the Tooling API is an interface for developers, the Javadoc is the main documentation for it.

To use the Tooling API, add the following repository and dependency declarations to your build script:

build.gradle.kts

```
repositories {
    maven { url = uri("https://repo.gradle.org/gradle/libs-releases") }
}

dependencies {
    implementation("org.gradle:gradle-tooling-api:$toolingApiVersion")
    // The tooling API need an SLF4J implementation available at runtime, replace
this with any other implementation
    runtimeOnly("org.slf4j:slf4j-simple:1.7.10")
}
```

build.gradle

```
repositories {
    maven { url 'https://repo.gradle.org/gradle/libs-releases' }
}

dependencies {
    implementation "org.gradle:gradle-tooling-api:$toolingApiVersion"
    // The tooling API need an SLF4J implementation available at runtime, replace
this with any other implementation
    runtimeOnly 'org.slf4j:slf4j-simple:1.7.10'
}
```

The main entry point to the Tooling API is the GradleConnector. You can navigate from there to find code samples and explore the available Tooling API models. You can use GradleConnector.connect() to create a ProjectConnection. A `ProjectConnection` connects to a single Gradle project. Using the connection you can execute tasks, tests and retrieve models relative to this project.

=== Compatibility of Java and Gradle versions

The following components should be considered when implementing Gradle integration: the Tooling API version, The JVM running the Tooling API client (i.e. the IDE process), the JVM running the Gradle daemon, and the Gradle version.

The Tooling API itself is a Java library published as part of the Gradle release. Each Gradle release has a corresponding Tooling API version with the same version number.

The Tooling API classes are loaded into the client's JVM, so they should have a matching version. The current version of the Tooling API library is compiled with Java 8 compatibility.

The JVM running the Tooling API client and the one running the daemon can be different. At the same time, classes that are sent to the build via custom build actions need to be targeted to the lowest supported Java version. The JVM versions supported by Gradle is version-specific. The upper bound is defined in the compatibility matrix. The rule for the lower bound is the following:

- Gradle 3.x and 4.x require a minimum version of Java 7.

- Gradle 5 and above require a minimum version of Java 8.

The Tooling API version is guaranteed to support running builds with all Gradle versions for the last five major releases. For example, the Tooling API 8.0 release is compatible with Gradle versions >= 3.0. Besides, the Tooling API is guaranteed to be compatible with future Gradle releases for the current and the next major. This means, for example, that the 8.1 version of the Tooling API will be able to run Gradle 9.x builds and *might* break with Gradle 10.0.

== **LICENSE INFORMATION**

= License Information

== Gradle Documentation

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== Gradle Build Scan Plugin

Use of the build scan plugin is subject to Gradle's Terms of Service.

[2] You might be wondering why there is neither an import for the `StopExecutionException` nor do we access it via its fully qualified name. The reason is, that Gradle adds a set of default imports to your script (see Default imports).

[3] In Groovy you can execute Strings. To learn more about executing external processes with Groovy have a look in 'Groovy in Action' 9.3.2 or at the Groovy wiki

[4] The JUnit wiki contains a detailed description on how to work with JUnit categories: https://github.com/junit-team/junit/wiki/Categories.

[5] The TestNG documentation contains more details about test groups: http://testng.org/doc/documentation-main.html#test-groups.

[6] The TestNG documentation contains more details about test ordering when working with `testng.xml` files: http://testng.org/doc/documentation-main.html#testng-xml.

[7] Gradle uses the same conventions as introduced by Russel Winder's Gant tool.

[8] See Automatic configuration of Scala classpath.

[9] The `CommandLineArgumentProvider` in this example is implemented as a managed type.

[10] Unfortunately, Conan and Nuget repositories aren't yet supported as core features

[11] Installed with Xcode on macOS

[12] Installed through Cygwin and MinGW for 32- and 64-bits architecture on Windows

[13] Installed with Visual Studio 2010 to 2019

[14] Macports and Homebrew installation of GCC and Clang is not officially supported

[15] Unfortunately, Cocoapods repositories aren't yet supported as core features