Android Studio Koala Essentials

Kotlin Edition

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2. Setting up an Android Studio Development Environment

Before any work can begin on developing an Android application, the first step is to configure a computer system to act as the development platform. This involves several steps consisting of installing the Android Studio Integrated Development Environment (IDE), including the Android Software Development Kit (SDK), the Kotlin plug-in and the OpenJDK Java development environment.

This chapter will cover the steps necessary to install the requisite components for Android application development on Windows, macOS, and Linux-based systems.

2.1 System requirements

Android application development may be performed on any of the following system types:

- Windows 8/10/11 64-bit
- macOS 10.14 or later running on Intel or Apple silicon
- Chrome OS device with Intel i5 or higher
- Linux systems with version 2.31 or later of the GNU C Library (glibc)
- Minimum of 8GB of RAM
- Approximately 8GB of available disk space
- 1280 x 800 minimum screen resolution

2.2 Downloading the Android Studio package

Most of the work involved in developing applications for Android will be performed using the Android Studio environment. The content and examples in this book were created based on Android Studio Koala Feature Drop 2024.1.2 using the Android API 35 SDK (Vanilla Ice Cream), which, at the time of writing, are the latest stable releases.

Android Studio is, however, subject to frequent updates, so a newer version may have been released since this book was published.

The latest release of Android Studio may be downloaded from the primary download page, which can be found at the following URL:

https://developer.android.com/studio/index.html

If this page provides instructions for downloading a newer version of Android Studio, there may be differences between this book and the software. A web search for “Android Studio Koala Feature Drop” should provide the option to download the older version if these differences become a problem. Alternatively, visit the following web page to find Android Studio Koala Feature Drop in the archives:

https://developer.android.com/studio/archive

2.3 Installing Android Studio

Once downloaded, the exact steps to install Android Studio differ depending on the operating system on which the installation is performed.

2.3.1 Installation on Windows

Locate the downloaded Android Studio installation executable file (named *android-studio-<version>-windows.exe*) in a Windows Explorer window and double-click on it to start the installation process, clicking the *Yes* button in the User Account Control dialog if it appears.

Once the Android Studio setup wizard appears, work through the various screens to configure the installation to meet your requirements in terms of the file system location into which Android Studio should be installed. When prompted to select the components to install, ensure that the *Android Studio* and *Android Virtual Device* options are both selected.

Although there are no strict rules on where Android Studio should be installed on the system, the remainder of this book will assume that the installation was performed into *C:\Program Files\Android\Android Studio* and that the Android SDK packages have been installed into the user's *AppData\Local\Android\sdk* sub-folder. Once the options have been configured, click the *Install* button to complete the installation process.

2.3.2 Installation on macOS

Android Studio for macOS is downloaded as a disk image (.dmg) file. Once the *android-studio-<version>-mac.dmg* file has been downloaded, locate it in a Finder window and double-click on it to open it, as shown in Figure 2-1:

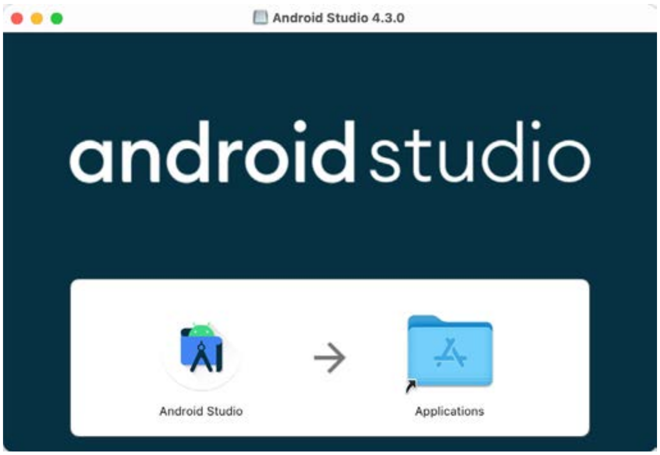

Figure 2-1

To install the package, drag the Android Studio icon and drop it onto the Applications folder. The Android Studio package will then be installed into the Applications folder of the system, a process that will typically take a few seconds to complete.

To launch Android Studio, locate the executable in the Applications folder using a Finder window and double-click on it.

For future, easier access to the tool, drag the Android Studio icon from the Finder window and drop it onto the dock.

2.3.3 Installation on Linux

Having downloaded the Linux Android Studio package, open a terminal window, change directory to the location where Android Studio is to be installed, and execute the following command:

```
tar xvfz /<path to package>/android-studio-<version>-linux.tar.gz
```

Note that the Android Studio bundle will be installed into a subdirectory named *android-studio.* Therefore, assuming that the above command was executed in */home/demo*, the software packages will be unpacked into */home/demo/android-studio.*

To launch Android Studio, open a terminal window, change directory to the *android-studio/bin* sub-directory, and execute the following command:

```
./studio.sh
```

2.4 Installing additional Android SDK packages

When you launch Android Studio, the Welcome to Android Studio screen will appear as shown below:

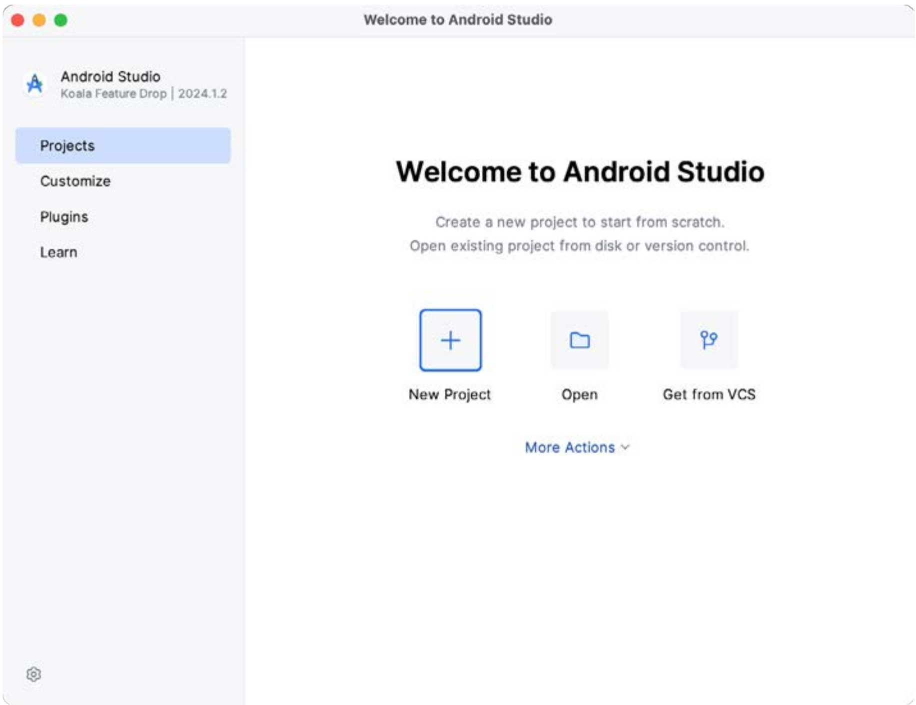

Figure 2-2

The steps performed so far have installed the Android Studio IDE and the current set of default Android SDK packages. Before proceeding, it is worth taking some time to verify which packages are installed and to install any missing or updated packages.

This task can be performed by clicking on the *More Actions* link within the welcome dialog and selecting the *SDK Manager* option from the drop-down menu. Once invoked, the *Android SDK* screen of the Settings dialog will appear as shown in Figure 2-3:

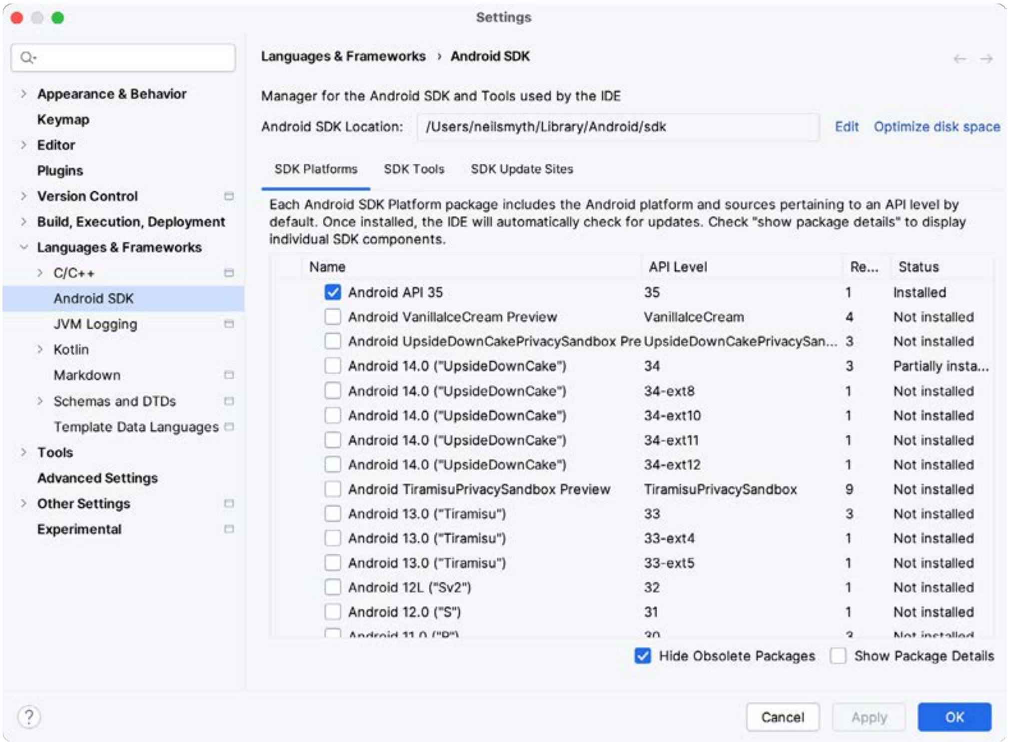

Figure 2-3

Google pairs each release of Android Studio with a maximum supported Application Programming Interface (API) level of the Android SDK. In the case of Android Studio Koala Feature Drop, this is Android Vanilla Ice Cream (API Level 35). This information can be confirmed using the following link:

https://developer.android.com/studio/releases#api-level-support

Immediately after installing Android Studio for the first time, it is likely that only the latest supported version of the Android SDK has been installed. To install older versions of the Android SDK, select the checkboxes corresponding to the versions and click the *Apply* button. The rest of this book assumes that the Android Vanilla Ice Cream (API Level 35) SDK is installed.

Most of the examples in this book will support older versions of Android as far back as Android 8.0 (Oreo). This ensures that the apps run on a wide range of Android devices. Within the list of SDK versions, enable the checkbox next to Android 8.0 (Oreo) and click the Apply button. Click the OK button to install the SDK in the resulting confirmation dialog. Subsequent dialogs will seek the acceptance of licenses and terms before performing the installation. Click Finish once the installation is complete.

It is also possible that updates will be listed as being available for the latest SDK. To access detailed information about the packages that are ready to be updated, enable the *Show Package Details* option located in the lower right-hand corner of the screen. This will display information similar to that shown in Figure 2-4:

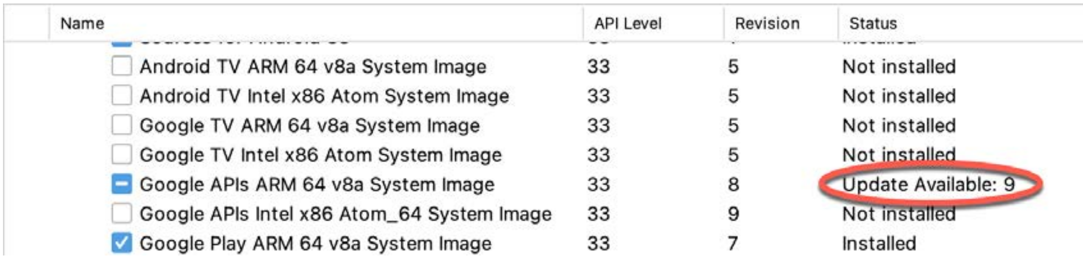

Figure 2-4

The above figure highlights the availability of an update. To install the updates, enable the checkbox to the left of the item name and click the *Apply* button.

In addition to the Android SDK packages, several tools are also installed for building Android applications. To view the currently installed packages and check for updates, remain within the SDK settings screen and select the SDK Tools tab as shown in Figure 2-5:

Figure 2-5

Within the Android SDK Tools screen, make sure that the following packages are listed as *Installed* in the Status column:

- Android SDK Build-tools
- Android Emulator
- Android SDK Platform-tools
- Google Play Services
- Intel x86 Emulator Accelerator (HAXM installer)*
- Google USB Driver (Windows only)
- Layout Inspector image server for API 31-35

*Note that the Intel x86 Emulator Accelerator (HAXM installer) requires an Intel processor with VT-x support enabled. It cannot be installed on Apple silicon-based Macs or AMD-based PCs.

If any of the above packages are listed as *Not Installed* or requiring an update, select the checkboxes next to those packages and click the *Apply* button to initiate the installation process. If the HAXM emulator settings dialog appears, select the recommended memory allocation:

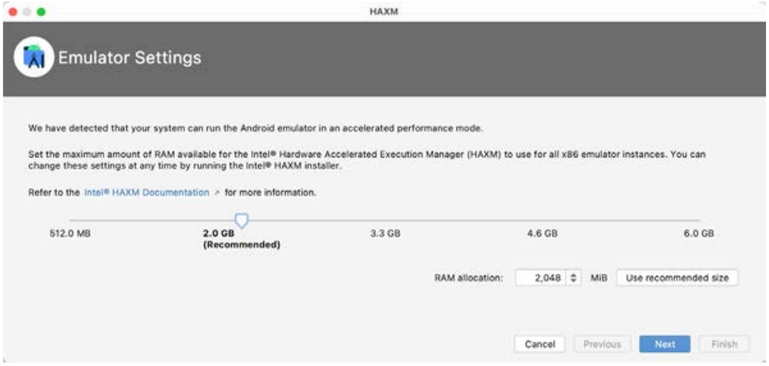

Figure 2-6

Once the installation is complete, review the package list and ensure that the selected packages are listed as *Installed* in the *Status* column. If any are listed as *Not installed,* make sure they are selected and click the *Apply* button again.

2.5 Installing the Android SDK Command-line Tools

Android Studio includes tools that allow some tasks to be performed from your operating system command line. To install these tools on your system, open the SDK Manager, select the SDK Tools tab, and locate the *Android SDK Command-line Tools (latest)* package as shown in Figure 2-7:

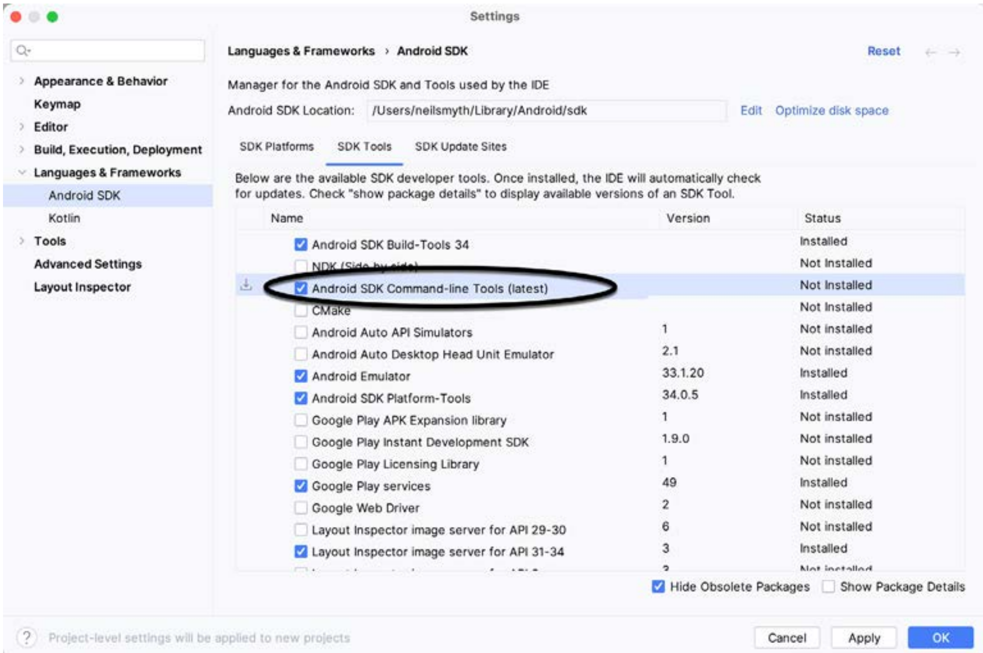

Figure 2-7

If the command-line tools package is not already installed, enable it and click Apply, followed by OK to complete the installation. When the installation completes, click Finish and close the SDK Manager dialog.

For the operating system on which you are developing to be able to find these tools, it will be necessary to add them to the system's *PATH* environment variable.

Regardless of your operating system, you will need to configure the PATH environment variable to include the following paths (where <*path_to_android_sdk_installation*> represents the file system location into which you installed the Android SDK):

```
<path_to_android_sdk_installation>/sdk/cmdline-tools/latest/bin
<path_to_android_sdk_installation>/sdk/platform-tools
```

You can identify the location of the SDK on your system by launching the SDK Manager and referring to the *Android SDK Location:* field located at the top of the settings panel, as highlighted in Figure 2-8:

Figure 2-8

Once the location of the SDK has been identified, the steps to add this to the PATH variable are operating system dependent:

2.5.1 Windows 8.1

1. On the start screen, move the mouse to the bottom right-hand corner of the screen and select Search from the resulting menu. In the search box, enter Control Panel. When the Control Panel icon appears in the results area, click on it to launch the tool on the desktop.

2. Within the Control Panel, use the Category menu to change the display to Large Icons. From the list of icons, select the one labeled System.

3. In the Environment Variables dialog, locate the Path variable in the System variables list, select it, and click the *Edit…* button. Using the *New* button in the edit dialog, add two new entries to the path. For example, assuming the Android SDK was installed into *C:\Users\demo\AppData\Local\Android\Sdk*, the following entries would need to be added:

```
C:\Users\demo\AppData\Local\Android\Sdk\cmdline-tools\latest\bin
C:\Users\demo\AppData\Local\Android\Sdk\platform-tools
```

4. Click OK in each dialog box and close the system properties control panel.

Open a command prompt window by pressing Windows + R on the keyboard and entering *cmd* into the Run dialog. Within the Command Prompt window, enter:

```
echo %Path%
```

The returned path variable value should include the paths to the Android SDK platform tools folders. Verify that the *platform-tools* value is correct by attempting to run the *adb* tool as follows:

```
adb
```

The tool should output a list of command-line options when executed.

Similarly, check the *tools* path setting by attempting to run the AVD Manager command-line tool (don't worry if the avdmanager tool reports a problem with Java - this will be addressed later):

```
avdmanager
```

If a message similar to the following message appears for one or both of the commands, it is most likely that an incorrect path was appended to the Path environment variable:

```
'adb' is not recognized as an internal or external command,
operable program or batch file.
```

2.5.2 Windows 10

Right-click on the Start menu, select Settings from the resulting menu and enter "Edit the system environment variables" into the *Find a setting* text field. In the System Properties dialog, click the *Environment Variables...* button. Follow the steps outlined for Windows 8.1 starting from step 3.

2.5.3 Windows 11

Right-click on the Start icon located in the taskbar and select Settings from the resulting menu. When the Settings dialog appears, scroll down the list of categories and select the "About" option. In the About screen, select *Advanced system settings* from the Related links section. When the System Properties window appears, click the *Environment Variables...* button. Follow the steps outlined for Windows 8.1 starting from step 3.

2.5.4 Linux

This configuration can be achieved on Linux by adding a command to the *.bashrc* file in your home directory (specifics may differ depending on the particular Linux distribution in use). Assuming that the Android SDK bundle package was installed into */home/demo/Android/sdk*, the export line in the *.bashrc* file would read as follows:

```
export PATH=/home/demo/Android/sdk/platform-tools:/home/demo/Android/sdk/cmdline-tools/latest/bin:/home/demo/android-studio/bin:$PATH
```

Note also that the above command adds the *android-studio/bin* directory to the PATH variable. This will enable the *studio.sh* script to be executed regardless of the current directory within a terminal window.

2.5.5 macOS

Several techniques may be employed to modify the $PATH environment variable on macOS. Arguably the cleanest method is to add a new file in the */etc/paths.d* directory containing the paths to be added to $PATH. Assuming an Android SDK installation location of */Users/demo/Library/Android/sdk*, the path may be configured by creating a new file named *android-sdk* in the */etc/paths.d* directory containing the following lines:

```
/Users/demo/Library/Android/sdk/cmdline-tools/latest/bin
/Users/demo/Library/Android/sdk/platform-tools
```

Note that since this is a system directory, it will be necessary to use the *sudo* command when creating the file. For example:

```
sudo vi /etc/paths.d/android-sdk
```

2.6 Android Studio memory management

Android Studio is a large and complex software application with many background processes. Although Android Studio has been criticized in the past for providing less than optimal performance, Google has made significant performance improvements in recent releases and continues to do so with each new version. These improvements include allowing the user to configure the amount of memory used by both the Android Studio IDE and the background processes used to build and run apps. This allows the software to take advantage of systems with larger amounts of RAM.

If you are running Android Studio on a system with sufficient unused RAM to increase these values (this feature is only available on 64-bit systems with 5GB or more of RAM) and find that Android Studio performance appears to be degraded, it may be worth experimenting with these memory settings. Android Studio may also notify you that performance can be increased via a dialog similar to the one shown below:

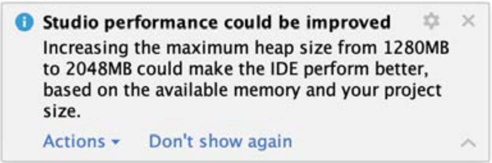

Figure 2-9

To view and modify the current memory configuration, select the *File -> Settings...* main menu option (*Android Studio -> Settings...* on macOS) and, in the resulting dialog, select *Appearance & Behavior* followed by the *Memory Settings* option listed under *System Settings* in the left-hand navigation panel, as illustrated in Figure 2-10 below:

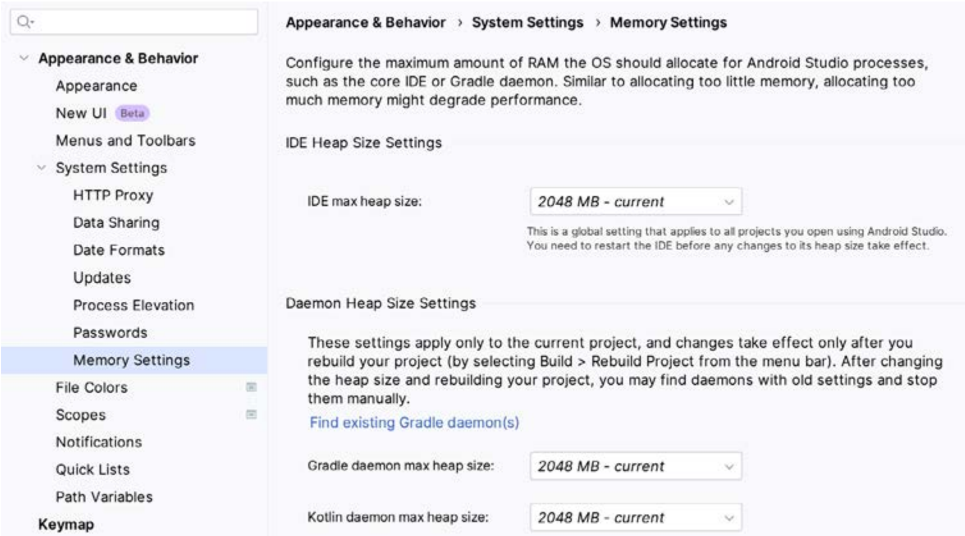

Figure 2-10

When changing the memory allocation, be sure not to allocate more memory than necessary or than your system can spare without slowing down other processes.

The IDE heap size setting adjusts the memory allocated to Android Studio and applies regardless of the currently loaded project. On the other hand, when a project is built and run from within Android Studio, several background processes (referred to as daemons) perform the task of compiling and running the app. When compiling and running large and complex projects, build time could be improved by adjusting the daemon heap settings. Unlike the IDE heap settings, these daemon settings apply only to the current project and can only be accessed when a project is open in Android Studio. To display the SDK Manager from within an open project, select the *Tools -> SDK Manager...* menu option from the main menu.

2.7 Updating Android Studio and the SDK

From time to time, new versions of Android Studio and the Android SDK are released. New versions of the SDK are installed using the Android SDK Manager. Android Studio will typically notify you when an update is ready to be installed.

To manually check for Android Studio updates, use the *Help -> Check for Updates...* menu option from the Android Studio main window (*Android Studio -> Check for Updates...* on macOS).

2.8 Summary

Before beginning the development of Android-based applications, the first step is to set up a suitable development environment. This consists of the Android SDKs and Android Studio IDE (which also includes the OpenJDK development environment). This chapter covers the steps necessary to install these packages on Windows, macOS, and Linux.

Chapter 3

3. Creating an Example Android App in Android Studio

The preceding chapters of this book have explained how to configure an environment suitable for developing Android applications using the Android Studio IDE. Before moving on to slightly more advanced topics, now is a good time to validate that all required development packages are installed and functioning correctly. The best way to achieve this goal is to create an Android application and compile and run it. This chapter will cover creating an Android application project using Android Studio. Once the project has been created, a later chapter will explore using the Android emulator environment to perform a test run of the application.

3.1 About the Project

The project created in this chapter takes the form of a rudimentary currency conversion calculator (so simple, in fact, that it only converts from dollars to euros and does so using an estimated conversion rate). The project will also use one of the most basic Android Studio project templates. This simplicity allows us to introduce some key aspects of Android app development without overwhelming the beginner by introducing too many concepts, such as the recommended app architecture and Android architecture components, at once. When following the tutorial in this chapter, rest assured that the techniques and code used in this initial example project will be covered in much greater detail later.

3.2 Creating a New Android Project

The first step in the application development process is to create a new project within the Android Studio environment. Begin, therefore, by launching Android Studio so that the "Welcome to Android Studio" screen appears as illustrated in Figure 3-1:

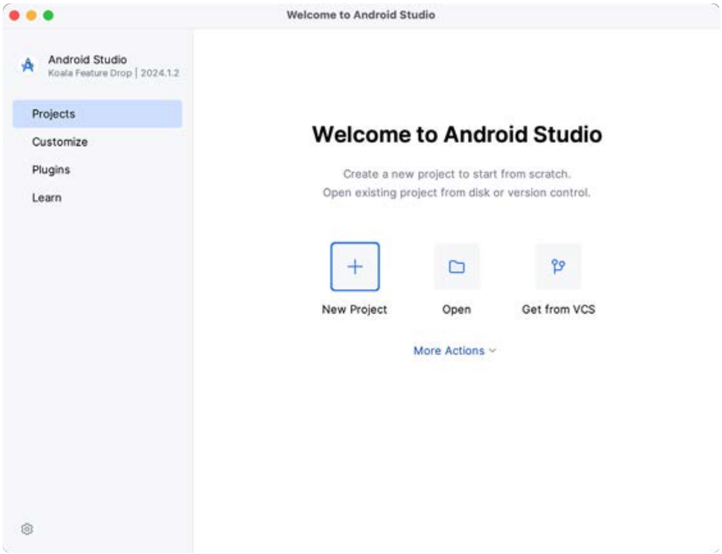

Figure 3-1

Once this window appears, Android Studio is ready for a new project to be created. To create the new project, click on the *New Project* option to display the first screen of the *New Project* wizard.

3.3 Creating an Activity

The next step is to define the type of initial activity to be created for the application. Options are available to create projects for Phone and Tablet, Wear OS, Television, or Automotive. A range of different activity types is available when developing Android applications, many of which will be covered extensively in later chapters. For this example, however, select the *Phone and Tablet* option from the Templates panel, followed by the option to create an *Empty Views Activity.* The Empty Views Activity option creates a template user interface consisting of a single TextView object.

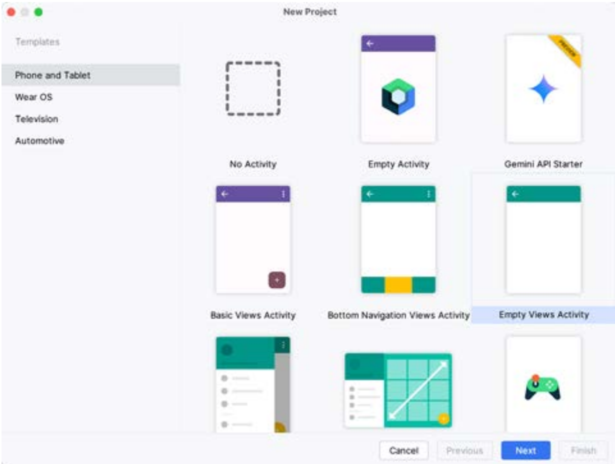

Figure 3-2

With the Empty Views Activity option selected, click *Next* to continue with the project configuration.

3.4 Defining the Project and SDK Settings

In the project configuration window (Figure 3-3), set the *Name* field to *AndroidSample*. The application name is the name by which the application will be referenced and identified within Android Studio and is also the name that would be used if the completed application were to go on sale in the Google Play store.

The *Package name* uniquely identifies the application within the Android application ecosystem. Although this can be set to any string that uniquely identifies your app, it is traditionally based on the reversed URL of your domain name followed by the application's name. For example, if your domain is *www.mycompany.com*, and the application has been named *AndroidSample*, then the package name might be specified as follows:

```
com.mycompany.androidsample
```

If you do not have a domain name, you can enter any other string into the Company Domain field, or you may use *example.com* for testing, though this will need to be changed before an application can be published:

```
com.example.androidsample
```

The *Save location* setting will default to a location in the folder named *AndroidStudioProjects* located in your home directory and may be changed by clicking on the folder icon to the right of the text field containing the current path setting.

Set the minimum SDK setting to API 26 (Oreo; Android 8.0). This minimum SDK will be used in most projects created in this book unless a necessary feature is only available in a more recent version. The objective here is to build an app using the latest Android SDK while retaining compatibility with devices running older versions of Android (in this case, as far back as Android 8.0). The text beneath the Minimum SDK setting will outline the percentage of Android devices currently in use on which the app will run. Click on the *Help me choose* button (highlighted in Figure 3-3) to see a full breakdown of the various Android versions still in use:

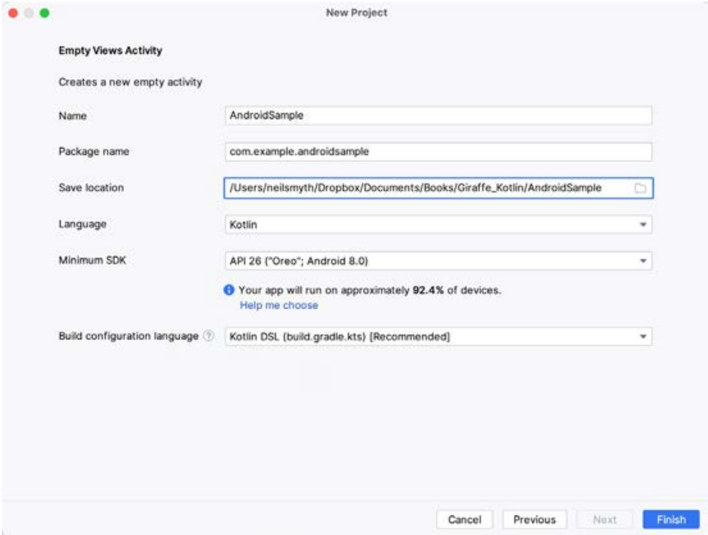

Figure 3-3

Finally, change the *Language* menu to *Kotlin* and select *Kotlin DSL (build.gradle.kts)* as the build configuration language before clicking *Finish* to create the project.

3.5 Modifying the Example Application

Once the project has been created, the main window will appear containing our AndroidSample project, as illustrated in Figure 3-4 below:

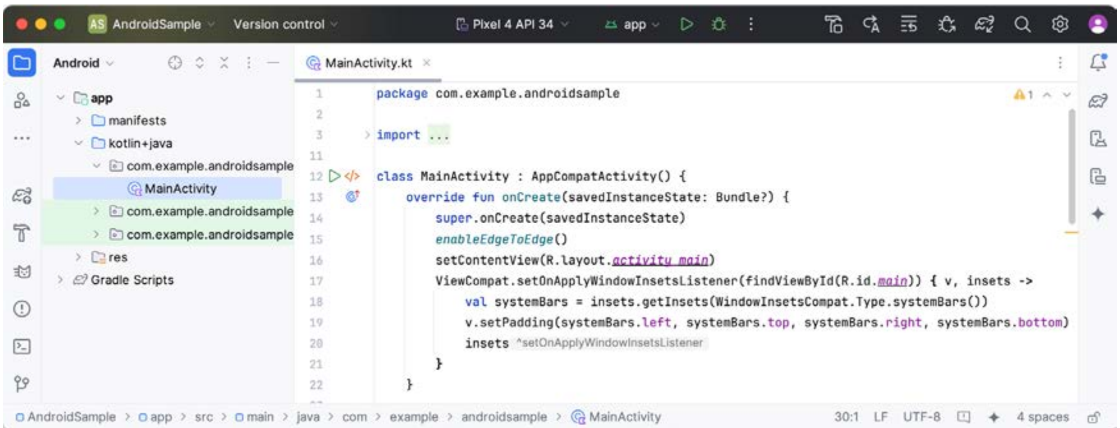

Figure 3-4

The newly created project and references to associated files are listed in the *Project* tool window on the left side of the main project window. The Project tool window has several modes in which information can be displayed. By default, this panel should be in *Android* mode. This setting is controlled by the menu at the top of the panel as highlighted in Figure 3-5. If the panel is not currently in Android mode, use the menu to switch mode:

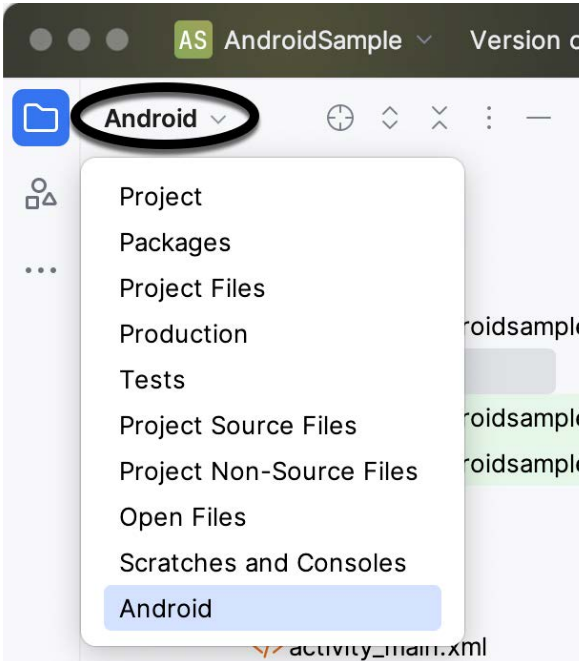

Figure 3-5

3.6 Modifying the User Interface

The user interface design for our activity is stored in a file named *activity_main.xml* which, in turn, is located under *app* -> *res* -> *layout* in the Project tool window file hierarchy. Once located in the Project tool window, double-click on the file to load it into the user interface Layout Editor tool, which will appear in the center panel of the Android Studio main window:

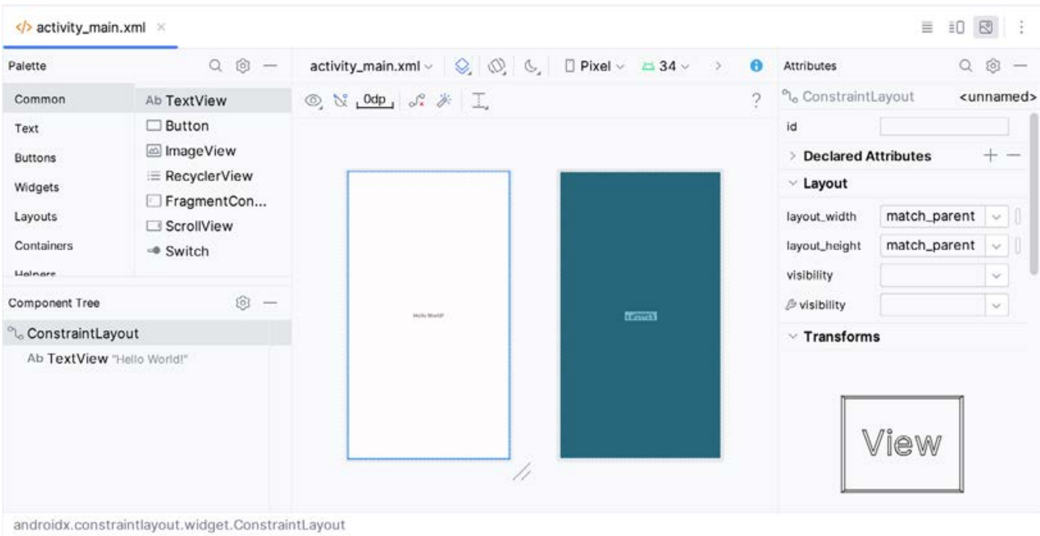

Figure 3-6

In the toolbar across the top of the Layout Editor window is a menu (currently set to *Pixel* in the above figure) which is reflected in the visual representation of the device within the Layout Editor panel. A range of other device options are available by clicking on this menu.

Use the System UI Mode button () to turn Night mode on and off for the device screen layout. To change the orientation of the device representation between landscape and portrait, use the drop-down menu showing the  icon.

As we can see in the device screen, the content layout already includes a label that displays a “Hello World!” message. Running down the left-hand side of the panel is a palette containing different categories of user interface components that may be used to construct a user interface, such as buttons, labels, and text fields. However, it should be noted that not all user interface components are visible to the user. One such category consists of *layouts*. Android supports a variety of layouts that provide different levels of control over how visual user interface components are positioned and managed on the screen. Though it is difficult to tell from looking at the visual representation of the user interface, the current design has been created using a ConstraintLayout. This can be confirmed by reviewing the information in the *Component Tree* panel, which, by default, is located in the lower left-hand corner of the Layout Editor panel and is shown in Figure 3-7:

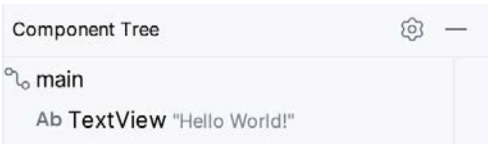

Figure 3-7

As we can see from the component tree hierarchy, the user interface layout consists of a ConstraintLayout parent called *main* and a TextView child object.

Before proceeding, check that the Layout Editor’s Autoconnect mode is enabled. This means that as components are added to the layout, the Layout Editor will automatically add constraints to ensure the components are correctly positioned for different screen sizes and device orientations (a topic that will be covered in much greater detail in future chapters). The Autoconnect button appears in the Layout Editor toolbar and is represented by a U-shaped icon. When disabled, the icon appears with a diagonal line through it (Figure 3-8). If necessary, re-enable Autoconnect mode by clicking on this button.

Figure 3-8

The next step in modifying the application is to add some additional components to the layout, the first of which will be a Button for the user to press to initiate the currency conversion.

The Palette panel consists of two columns, with the left-hand column containing a list of view component categories. The right-hand column lists the components contained within the currently selected category. In Figure 3-9, for example, the Button view is currently selected within the Buttons category:

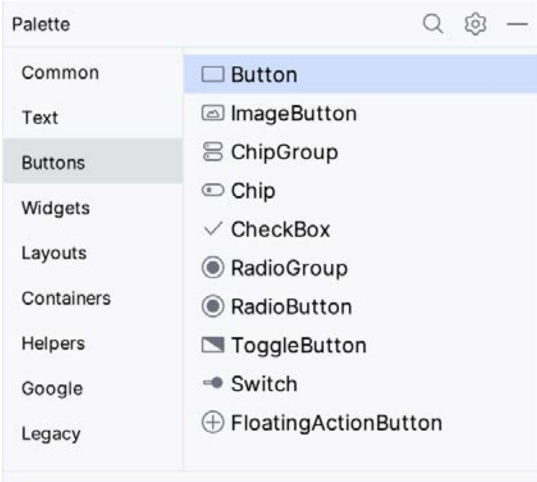

Figure 3-9

Click and drag the *Button* object from the Buttons list and drop it in the horizontal center of the user interface design so that it is positioned beneath the existing TextView widget:

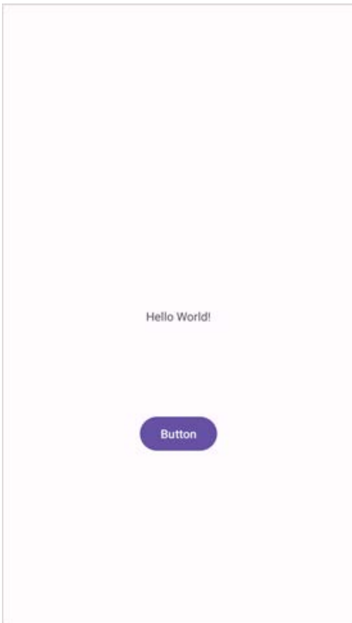

Figure 3-10

The next step is to change the text currently displayed by the Button component. The panel located to the right of the design area is the Attributes panel. This panel displays the attributes assigned to the currently selected component in the layout. Within this panel, locate the *text* property in the Common Attributes section and change the current value from "Button" to "Convert", as shown in Figure 3-11:

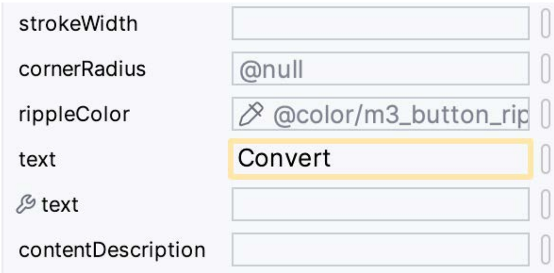

Figure 3-11

The second text property with a wrench next to it allows a text property to be set, which only appears within the Layout Editor tool but is not shown at runtime. This is useful for testing how a visual component and the layout will behave with different settings without running the app repeatedly.

Just in case the Autoconnect system failed to set all of the layout connections, click on the Infer Constraints button (Figure 3-12) to add any missing constraints to the layout:

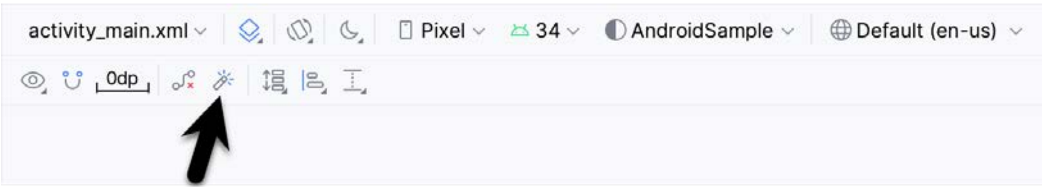

Figure 3-12

It is important to explain the warning button in the top right-hand corner of the Layout Editor tool, as indicated in Figure 3-13. This warning indicates potential problems with the layout. For details on any problems, click on the button:

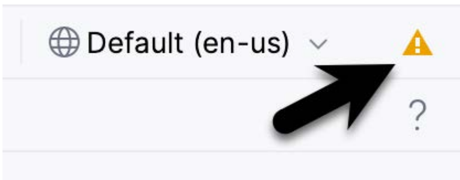

Figure 3-13

When clicked, the Problems tool window (Figure 3-14) will appear, describing the nature of the problems:

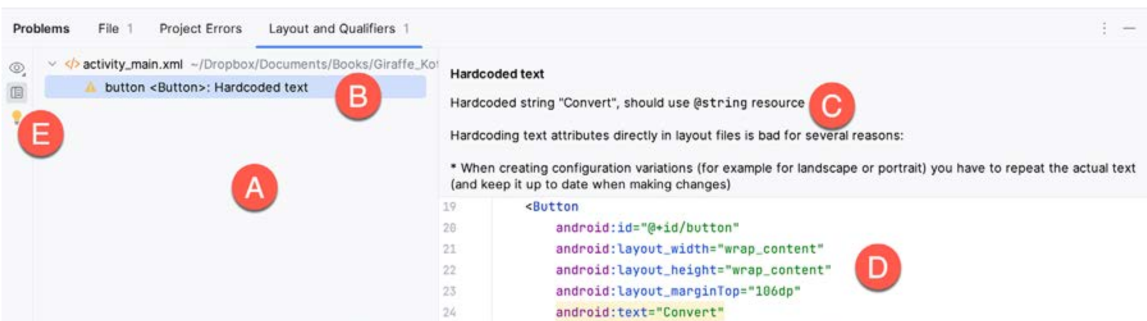

Figure 3-14

This tool window is divided into two panels. The left panel (marked A in the above figure) lists issues detected within the layout file. In our example, only the following problem is listed:

```
button <Button>: Hardcoded text
```

When an item is selected from the list (B), the right-hand panel will update to provide additional detail on the problem (C). In this case, the explanation reads as follows:

```
Hardcoded string "Convert", should use @string resource
```

The tool window also includes a preview editor (D), allowing manual corrections to be made to the layout file.

This I18N message informs us that a potential issue exists concerning the future internationalization of the project ("I18N" comes from the fact that the word "internationalization" begins with an "I", ends with an "N" and has 18 letters in between). The warning reminds us that attributes and values such as text strings should be stored as *resources* wherever possible when developing Android applications. Doing so enables changes to the appearance of the application to be made by modifying resource files instead of changing the application source code. This can be especially valuable when translating a user interface to a different spoken language. If all of the text in a user interface is contained in a single resource file, for example, that file can be given to a translator, who will then perform the translation work and return the translated file for inclusion in the application. This enables multiple languages to be targeted without the necessity for any source code changes to be made. In this instance, we are going to create a new resource named *convert_string* and assign to it the string "Convert".

Begin by clicking on the Show Quick Fixes button (E) and selecting the *Extract string resource* option from the menu, as shown in Figure 3-15:

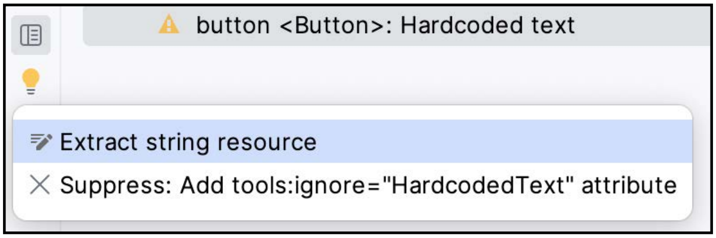

Figure 3-15

After selecting this option, the *Extract Resource* panel (Figure 3-16) will appear. Within this panel, change the resource name field to *convert_string* and leave the resource value set to *Convert* before clicking on the OK button:

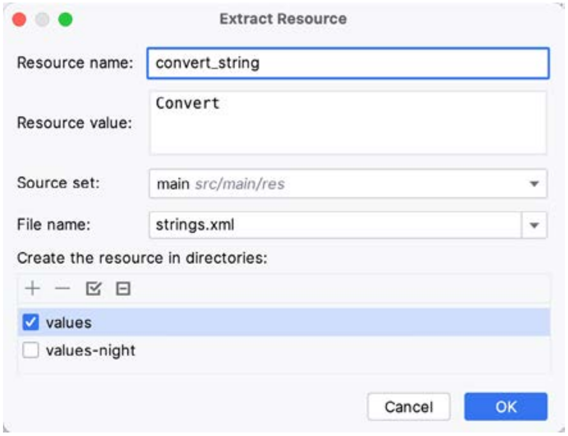

Figure 3-16

The next widget to be added is an EditText widget, into which the user will enter the dollar amount to be converted. From the Palette panel, select the Text category and click and drag a Number (Decimal) component onto the layout so that it is centered horizontally and positioned above the existing TextView widget. With the widget selected, use the Attributes tools window to set the *hint* property to "dollars". Click on the warning icon and extract the string to a resource named *dollars_hint*.

The code written later in this chapter will need to access the dollar value entered by the user into the EditText field. It will do this by referencing the id assigned to the widget in the user interface layout. The default id assigned to the widget by Android Studio can be viewed and changed from within the Attributes tool window when the widget is selected in the layout, as shown in Figure 3-17:

Figure 3-17

Change the id to *dollarText* and, in the Rename dialog, click on the *Refactor* button. This ensures that any references elsewhere within the project to the old id are automatically updated to use the new id:

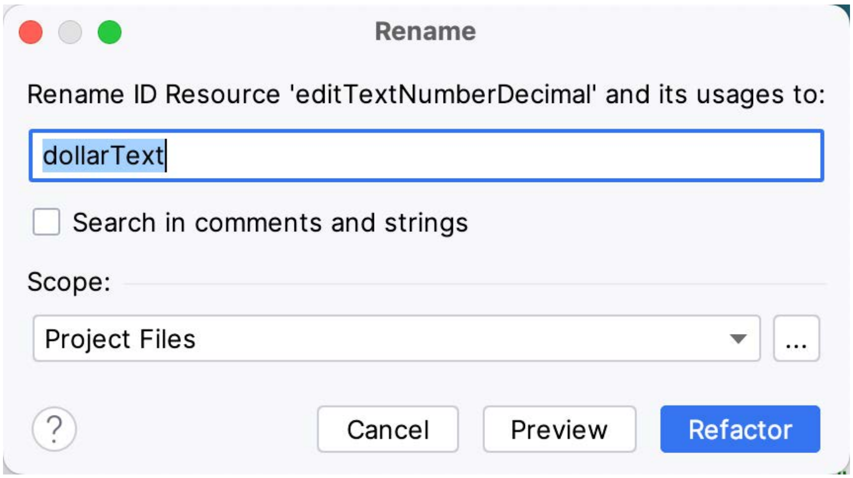

Figure 3-18

Repeat the steps to set the id of the TextView widget to *textView*, if necessary.

Add any missing layout constraints by clicking on the *Infer Constraints* button. At this point, the layout should resemble that shown in Figure 3-19:

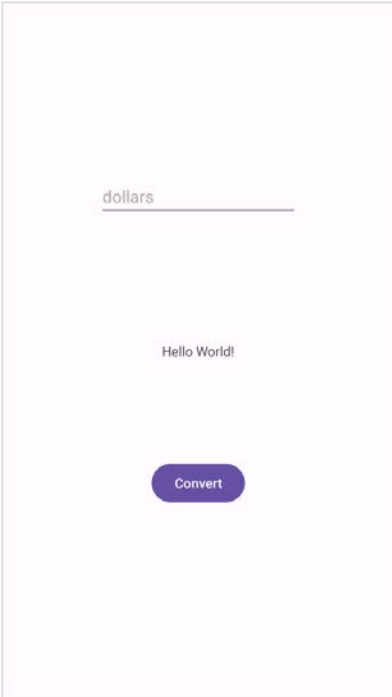

Figure 3-19

3.7 Reviewing the Layout and Resource Files

Before moving on to the next step, we will look at some internal aspects of user interface design and resource handling. In the previous section, we changed the user interface by modifying the *activity_main.xml* file using the Layout Editor tool. In fact, all that the Layout Editor was doing was providing a user-friendly way to edit the underlying XML content of the file. In practice, there is no reason why you cannot modify the XML directly to make user interface changes, and, in some instances, this may actually be quicker than using the Layout Editor tool. In the top right-hand corner of the Layout Editor panel are the View Modes buttons marked A through C in Figure 3-20 below:

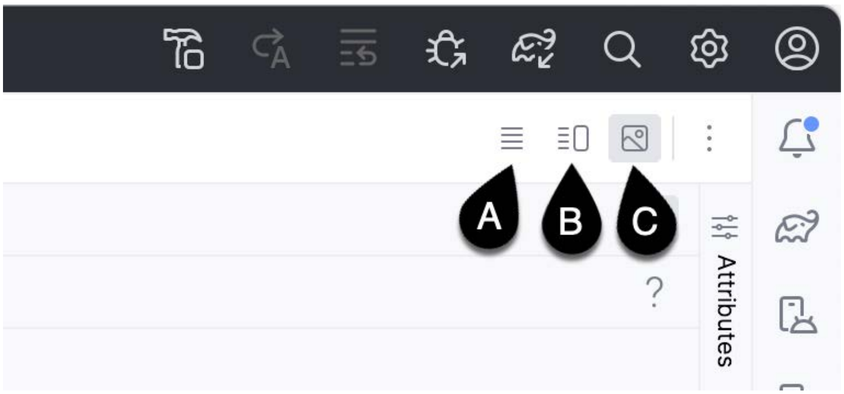

Figure 3-20

By default, the editor will be in *Design* mode (button C), whereby only the visual representation of the layout is displayed. In *Code* mode (A), the editor will display the XML for the layout, while in *Split* mode (B), both the layout and XML are displayed, as shown in Figure 3-21:

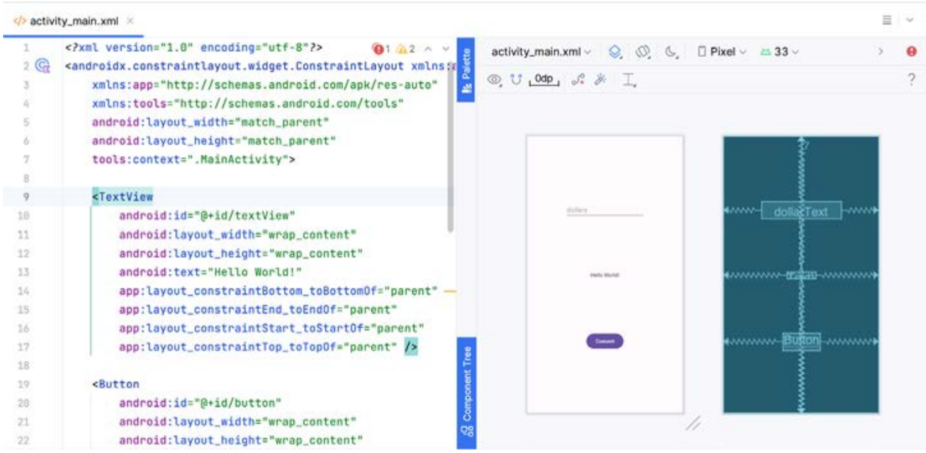

Figure 3-21

The button to the left of the View Modes button (marked B in Figure 3-20 above) is used to toggle between Code and Split modes quickly.

As can be seen from the structure of the XML file, the user interface consists of the ConstraintLayout component, which in turn, is the parent of the TextView, Button, and EditText objects. We can also see, for example, that the *text* property of the Button is set to our *convert_string* resource. Although complexity and content vary, all user interface layouts are structured in this hierarchical, XML-based way.

As changes are made to the XML layout, these will be reflected in the layout canvas. The layout may also be modified visually from within the layout canvas panel, with the changes appearing in the XML listing. To see this in action, switch to Split mode and modify the XML layout to change the background color of the ConstraintLayout to a shade of red as follows:

```
<?xml version="1.0" encoding="utf-8"?>
<androidx.constraintlayout.widget.ConstraintLayout xmlns:android="http://schemas.
android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:id="@+id/main"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context=".MainActivity"
    android:background="#ff2438" >
.
.
</androidx.constraintlayout.widget.ConstraintLayout>
```

Note that the layout color changes in real-time to match the new setting in the XML file. Note also that a small red square appears in the XML editor's left margin (also called the *gutter*) next to the line containing the color setting. This is a visual cue to the fact that the color red has been set on a property. Clicking on the red square will display a color chooser allowing a different color to be selected:

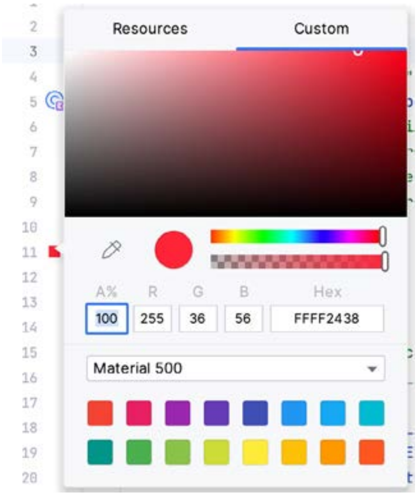

Figure 3-22

Before proceeding, delete the background property from the layout file so that the background returns to the default setting.

Finally, use the Project panel to locate the *app* -> *res* -> *values* -> *strings.xml* file and double-click on it to load it into the editor. Currently, the XML should read as follows:

```
<resources>
    <string name="app_name">AndroidSample</string>
    <string name="convert_string">Convert</string>
    <string name="dollars_hint">dollars</string>
</resources>
```

To demonstrate resources in action, change the string value currently assigned to the *convert_string* resource to "Convert to Euros" and then return to the Layout Editor tool by selecting the tab for the layout file in the editor panel. Note that the layout has picked up the new resource value for the string.

There is also a quick way to access the value of a resource referenced in an XML file. With the Layout Editor tool in Split or Code mode, click on the "@string/convert_string" property setting so that it highlights, and then press Ctrl-B on the keyboard (Cmd-B on macOS). Android Studio will subsequently open the *strings.xml* file and take you to the line in that file where this resource is declared. Use this opportunity to revert the string resource to the original "Convert" text and to add the following additional entry for a string resource that will be referenced later in the app code:

```
<resources>
    <string name="app_name">AndroidSample</string>
    <string name="convert_string">Convert</string>
    <string name="dollars_hint">dollars</string>
    <string name="no_value_string">No Value</string>
</resources>
```

Resource strings may also be edited using the Android Studio Translations Editor by clicking on the *Open editor* link in the top right-hand corner of the editor window. This will display the Translation Editor in the main panel of the Android Studio window:

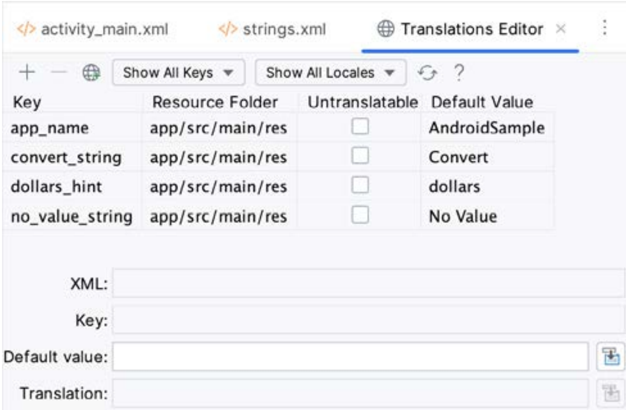

Figure 3-23

This editor allows the strings assigned to resource keys to be edited and for translations for multiple languages to be managed.

3.8 Adding Interaction

The final step in this example project is to make the app interactive so that when the user enters a dollar value into the EditText field and clicks the convert button, the converted euro value appears on the TextView. This involves the implementation of some event handling on the Button widget. Specifically, the Button needs to be configured so that a method in the app code is called when an *onClick* event is triggered. Event handling can be implemented in several ways and is covered in a later chapter entitled *"An Overview and Example of Android Event Handling"*. Return the layout editor to Design mode, select the Button widget in the layout editor, refer to the Attributes tool window, and specify a method named *convertCurrency* as shown below:

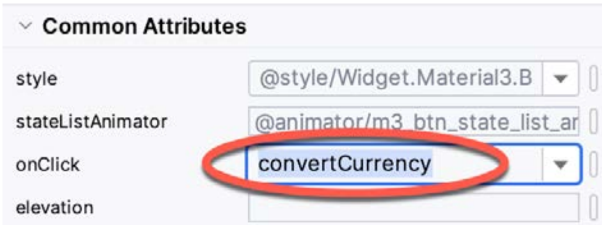

Figure 3-24

Next, double-click on the *MainActivity.kt* file in the Project tool window (*app -> kotlin+java -> <package name> -> MainActivity*) to load it into the code editor and add the code for the *convertCurrency* method to the class file so that it reads as follows, noting that it is also necessary to import some additional Android packages:

```
package com.example.androidsample

import android.os.Bundle
import androidx.activity.enableEdgeToEdge
import androidx.appcompat.app.AppCompatActivity
import androidx.core.view.ViewCompat
import androidx.core.view.WindowInsetsCompat
import android.view.View
import android.widget.EditText
import android.widget.TextView
```

```
class MainActivity : AppCompatActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
.
.
        }
    }

    fun convertCurrency(view: View) {
        val dollarText: EditText = findViewById(R.id.dollarText)
        val textView: TextView = findViewById(R.id.textView)

        if (dollarText.text.isNotEmpty()) {
            val dollarValue = dollarText.text.toString().toFloat()
            val euroValue = dollarValue * 0.85f
            textView.text = euroValue.toString()
        } else {
            textView.text = getString(R.string.no_value_string)
        }
    }
}
```

The method begins by obtaining references to the EditText and TextView objects by making a call to a method named findViewById, passing through the id assigned within the layout file. A check is then made to ensure that the user has entered a dollar value, and if so, that value is extracted, converted from a String to a floating point value, and converted to euros. Finally, the result is displayed on the TextView widget.

If any of this is unclear, rest assured that these concepts will be covered in greater detail in later chapters. In particular, the topic of accessing widgets from within code using findByViewId and an introduction to an alternative technique referred to as *view binding* will be covered in the chapter entitled *"An Overview of Android View Binding"*.

3.9 Summary

While not excessively complex, several steps are involved in setting up an Android development environment. Having performed those steps, it is worth working through an example to ensure the environment is correctly installed and configured. In this chapter, we have created an example application and then used the Android Studio Layout Editor tool to modify the user interface layout. In doing so, we explored the importance of using resources wherever possible, particularly string values, and briefly touched on layouts. Next, we looked at the underlying XML used to store Android application user interface designs.

Finally, an onClick event was added to a Button connected to a method implemented to extract the user input from the EditText component, convert it from dollars to euros and then display the result on the TextView.

With the app ready for testing, the steps necessary to set up an emulator for testing purposes will be covered in detail in the next chapter.

Chapter 6

6. A Tour of the Android Studio User Interface

While it is tempting to plunge into running the example application created in the previous chapter, it involves using aspects of the Android Studio user interface, which are best described in advance.

Android Studio is a powerful and feature-rich development environment that is, to a large extent, intuitive to use. That being said, taking the time now to gain familiarity with the layout and organization of the Android Studio user interface will shorten the learning curve in later chapters of the book. With this in mind, this chapter will provide an overview of the various areas and components of the Android Studio environment.

6.1 The Welcome Screen

The welcome screen (Figure 6-1) is displayed any time that Android Studio is running with no projects currently open (open projects can be closed at any time by selecting the *File -> Close Project* menu option). If Android Studio was previously exited while a project was still open, the tool will bypass the welcome screen the next time it is launched, automatically opening the previously active project.

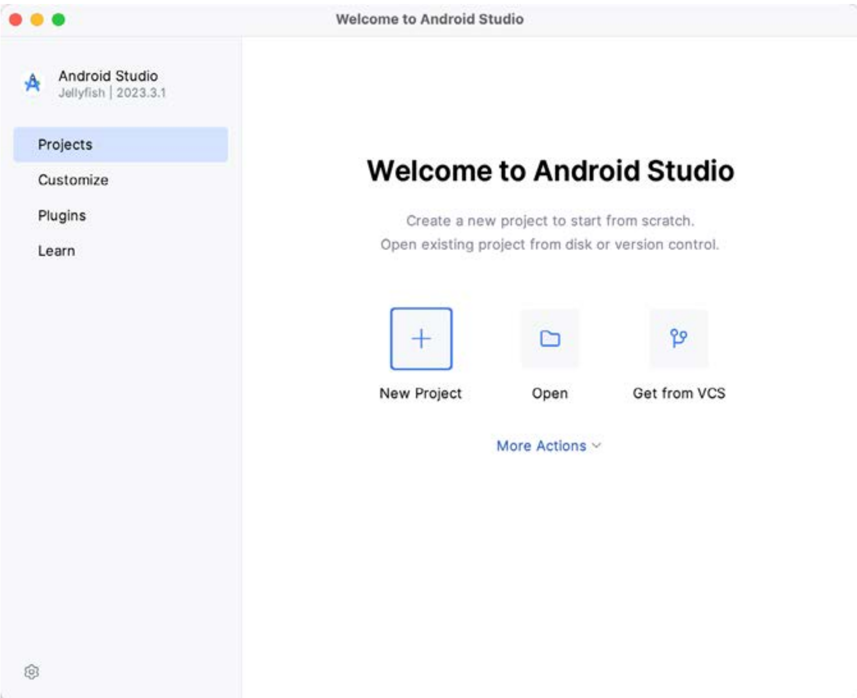

Figure 6-1

In addition to a list of recent projects, the welcome screen provides options for performing tasks such as opening and creating projects, along with access to projects currently under version control. In addition, the *Customize* screen provides options to change the theme and font settings used by both the IDE and the editor. Android

Studio plugins may be viewed, installed, and managed using the *Plugins* option.

Additional options are available by selecting the More Actions link or using the menu shown in Figure 6-2 when the list of recent projects replaces the More Actions link:

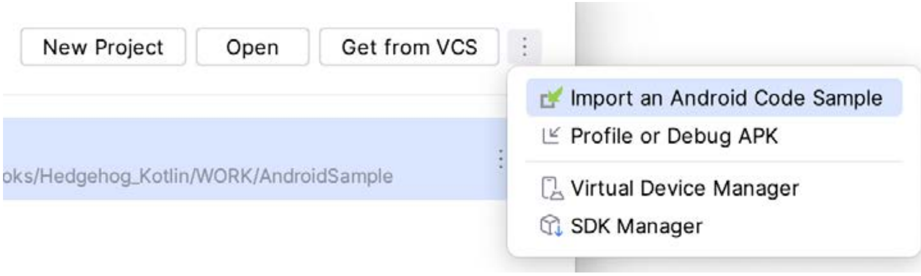

Figure 6-2

6.2 The Menu Bar

The Android Studio main window will appear when a new project is created, or an existing one is opened. When multiple projects are open simultaneously, each will be assigned its own main window. The precise configuration of the window will vary depending on the operating system Android Studio is running on and which tools and panels were displayed the last time the project was open. The appearance, for example, of the main menu bar will differ depending on the host operating system. On macOS, Android Studio follows the standard convention of placing the menu bar along the top edge of the desktop, as illustrated in Figure 6-3:

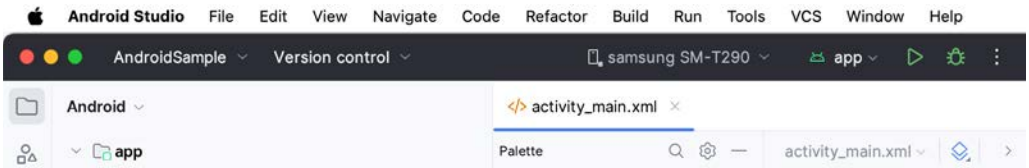

Figure 6-3

When Android Studio is running on Windows or Linux, however, the main menu is accessed via the button highlighted in Figure 6-4:

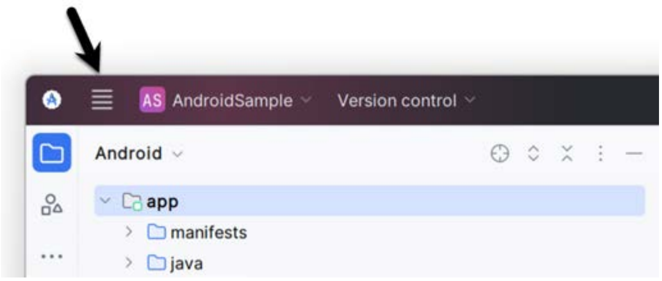

Figure 6-4

6.3 The Main Window

Once a project is open, the Android Studio main window will typically resemble that of Figure 6-5:

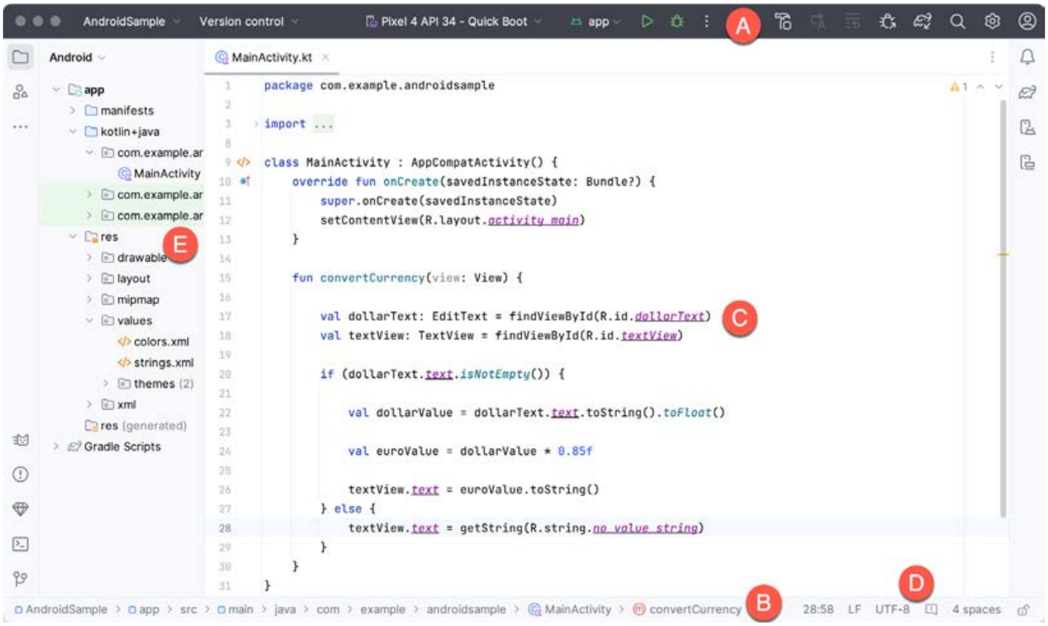

Figure 6-5

The various elements of the main window can be summarized as follows:

A – Toolbar – A selection of shortcuts to frequently performed actions. The toolbar buttons provide quick access to a select group of menu bar actions. The toolbar can be customized by right-clicking on the bar and selecting the *Customize Toolbar…* menu option. The toolbar menu shown in Figure 6-6 provides a convenient way to perform tasks such as creating and opening projects and switching between windows when multiple projects are open:

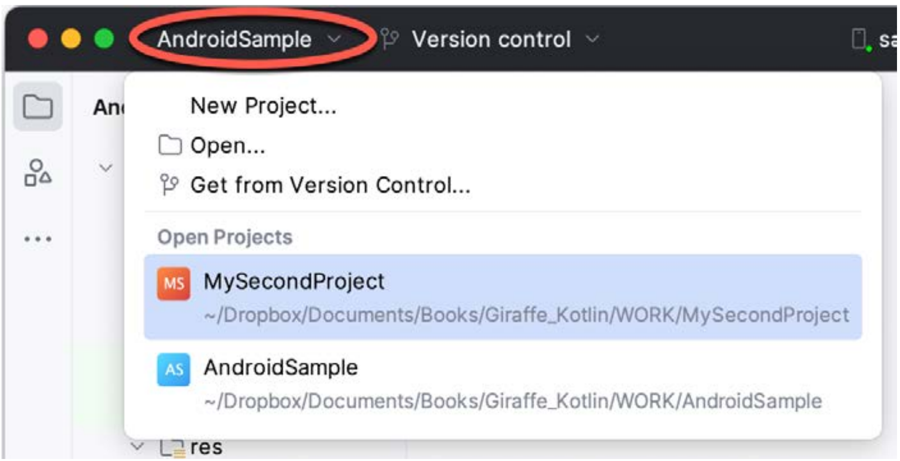

Figure 6-6

B – Navigation Bar – The navigation bar provides a convenient way to move around the files and folders that make up the project. Clicking on an element in the navigation bar will drop down a menu listing the sub-folders and files at that location, ready for selection. Similarly, clicking on a class name displays a menu listing methods contained within that class:

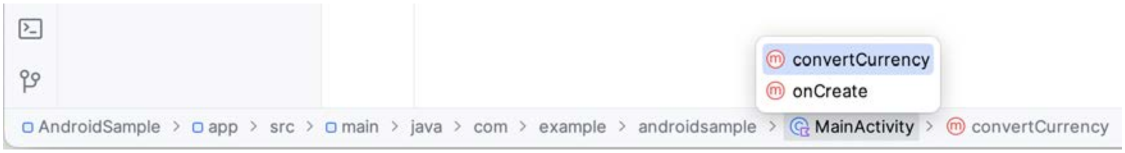

Figure 6-7

Select a method from the list to be taken to the corresponding location within the code editor. You can hide, display, and change the position of this bar using the *View -> Appearance -> Navigation Bar* menu option.

C – Editor Window – The editor window displays the content of the file on which the developer is currently working. When multiple files are open, each file is represented by a tab located along the top edge of the editor, as shown in Figure 6-8:

Figure 6-8

D – Status Bar – The status bar displays informational messages about the project and the activities of Android Studio. Hovering over items in the status bar will display a description of that field. Many fields are interactive, allowing users to click to perform tasks or obtain more detailed status information.

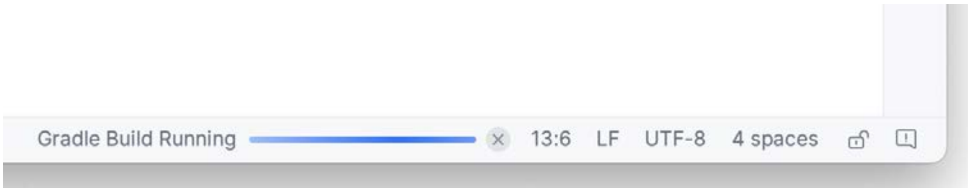

Figure 6-9

The widgets displayed in the status bar can be changed using the *View -> Appearance -> Status Bar Widgets* menu.

E – Project Tool Window – The project tool window provides a hierarchical overview of the project file structure allowing navigation to specific files and folders to be performed. The toolbar can be used to display the project in several different ways. The default setting is the *Android* view which is the mode primarily used in the remainder of this book.

The project tool window is just one of many available tools within the Android Studio environment.

6.4 The Tool Windows

In addition to the project view tool window, Android Studio also includes many other windows, which, when enabled, are displayed *tool window bars* that appear along the left and right edges of the main window and contain buttons for showing and hiding each of the tool windows. Figure 6-10 shows typical tool window bar configurations, though the buttons and their positioning may differ for your Android Studio installation.

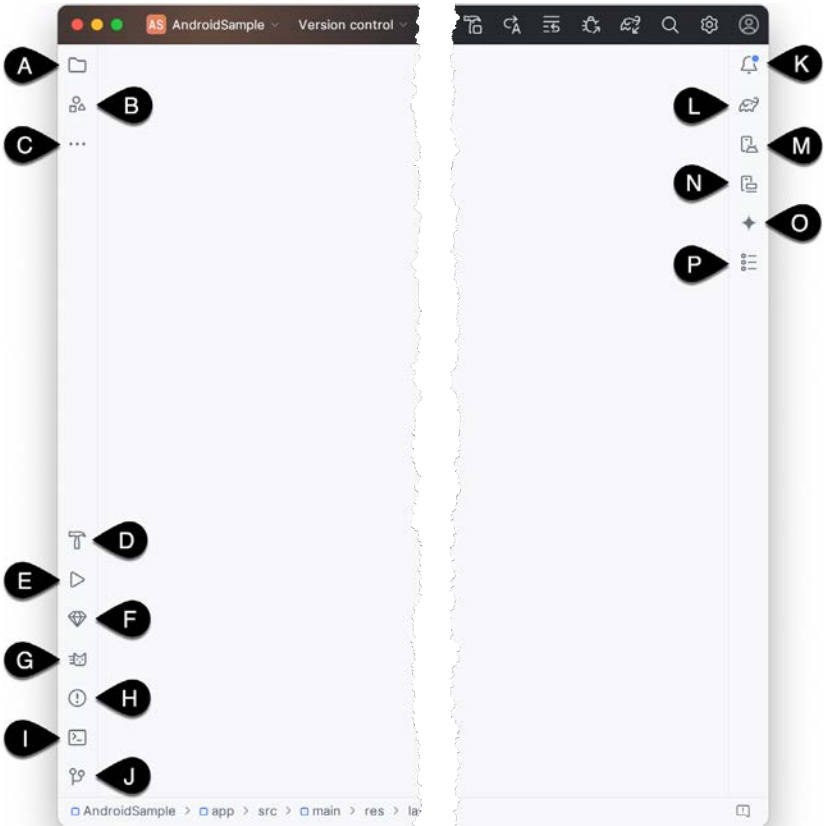

Figure 6-10

Clicking on a button will display the corresponding tool window, while a second click will hide the window. The location of a button in a tool window bar indicates the side of the window against which the window will appear when displayed. These positions can be changed by clicking and dragging the buttons to different locations in other window toolbars.

Android Studio offers a wide range of tool windows, the most commonly used of which are as follows:

- **Project (A)** – The project view provides an overview of the file structure that makes up the project allowing for quick navigation between files. Generally, double-clicking on a file in the project view will cause that file to be loaded into the appropriate editing tool.
- **Resource Manager (B)** - A tool for adding and managing resources and assets within the project, such as images, colors, and layout files.
- **More Tool Windows (C)** - Displays a menu containing additional tool windows not currently displayed in a tool window bar. When a tool window is selected from this menu, it will appear as a button in a tool window bar.
- **Build (D)** - Displays a real-time view of each process step while Android Studio builds the current project.
- **Run (E)** – The run tool window becomes available when an application is currently running and provides a view of the results of the run together with options to stop or restart a running process. If an application fails to install and run on a device or emulator, this window typically provides diagnostic information about the problem.

- **App Quality Insights (F)** - Provides access to the cloud-based Firebase app quality and crash analytics platform.
- **Logcat (G)** – The Logcat tool window provides access to the monitoring log output from a running application and options for taking screenshots and videos of the application and stopping and restarting a process.
- **Problems (H)** - A central location to view all of the current errors or warnings within the project. Double-clicking on an item in the problem list will take you to the problem file and location.
- **Terminal (I)** – Provides access to a terminal window on the system on which Android Studio is running. On Windows systems, this is the Command Prompt interface, while on Linux and macOS systems, this takes the form of a Terminal prompt.
- **Version Control (J)** - This tool window is used when the project files are under source code version control, allowing access to Git repositories and code change history.
- **Notifications (K)** - Android Studio occasionally displays notification popups for events such as project build completion or the successful launch of an app on a device or emulator. The Notifications tool window provides a central location to review the notification history.
- **Gradle (L)** – The Gradle tool window provides a view of the Gradle tasks that make up the project build configuration. The window lists the tasks involved in compiling the various elements of the project into an executable application. Right-click on a top-level Gradle task and select the *Open Gradle Config* menu option to load the Gradle build file for the current project into the editor. Gradle will be covered in greater detail later in this book.
- **Device Manager (M)** - Provides access to the Device Manager tool window where physical Android device connections and emulators may be added, removed, and managed.
- **Running Devices (N)** - Contains the AVD emulator if the option has been enabled to run the emulator in a tool window as outlined in the chapter entitled *"Creating an Android Virtual Device (AVD) in Android Studio"*.
- **Gemini (O)** - Android Studio's AI powered coding assistant. Currently in preview, this tool helps you develop your app by providing coding suggestions and solutions.
- **Assistant (P)** - Display the Assistant panel, the content of which will differ depending on which Android Studio feature you are currently using.
- **App Inspection** - Provides access to the Database and Background Task inspectors. The Database Inspector allows you to inspect, query, and modify your app's databases while running. The Background Task Inspector allows background worker tasks created using WorkManager to be monitored and managed.
- **Bookmarks** – The Bookmarks tool window provides quick access to bookmarked files and code lines. For example, right-clicking on a file in the project view allows access to an Add to Bookmarks menu option. Similarly, you can bookmark a line of code in a source file by moving the cursor to that line and pressing the F11 key (F3 on macOS). All bookmarked items can be accessed through this tool window.
- **Build Variants** – The build variants tool window provides a quick way to configure different build targets for the current application project (for example, different builds for debugging and release versions of the application or multiple builds to target different device categories).
- **Device File Explorer** – Available via the *View -> Tool Windows -> Device File Explorer* menu, this tool window provides direct access to the filesystem of the currently connected Android device or emulator, allowing the filesystem to be browsed and files copied to the local filesystem.

- **Layout Inspector** - Provides a visual 3D rendering of the hierarchy of components that make up a user interface layout.
- **Structure** – The structure tool provides a high-level view of the structure of the source file currently displayed in the editor. This information includes a list of items such as classes, methods, and variables in the file. Selecting an item from the structure list will take you to that location in the source file in the editor window.
- **TODO** – As the name suggests, this tool provides a place to review items that have yet to be completed on the project. Android Studio compiles this list by scanning the source files that make up the project to look for comments that match specified TODO patterns. These patterns can be reviewed and changed by opening the Settings dialog and navigating to the *TODO* entry listed under *Editor*.

6.5 The Tool Window Menus

Each tool window has its own toolbar along the top edge. The menu buttons within these toolbars vary from one tool to the next, though all tool windows contain an Options menu (marked A in Figure 6-11):

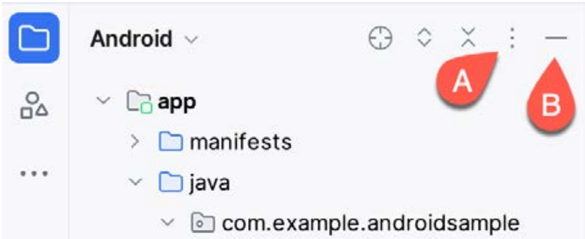

Figure 6-11

The Options menu allows various aspects of the window to be changed. Figure 6-12, for example, shows the Options menu for the Project tool window. Settings are available, for example, to undock a window and to allow it to float outside of the boundaries of the Android Studio main window, and to move and resize the tool panel:

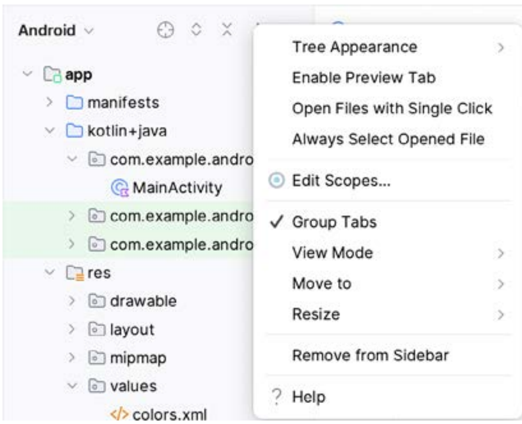

Figure 6-12

All tool windows also include a far-right button on the toolbar (marked B in Figure 6-11 above), providing an additional way to hide the tool window from view. A search of the items within a tool window can be performed by giving that window focus by clicking on it and then typing the search term (for example, the name of a file in the Project tool window). A search box will appear in the window's toolbar, and items matching the search highlighted.

6.6 Android Studio Keyboard Shortcuts

Android Studio includes many keyboard shortcuts to save time when performing common tasks. A complete keyboard shortcut keymap listing can be viewed and printed from within the Android Studio project window by selecting the *Help -> Keyboard Shortcuts PDF* menu option. You may also list and modify the keyboard shortcuts by opening the Settings dialog and clicking on the Keymap entry, as shown in Figure 6-13 below:

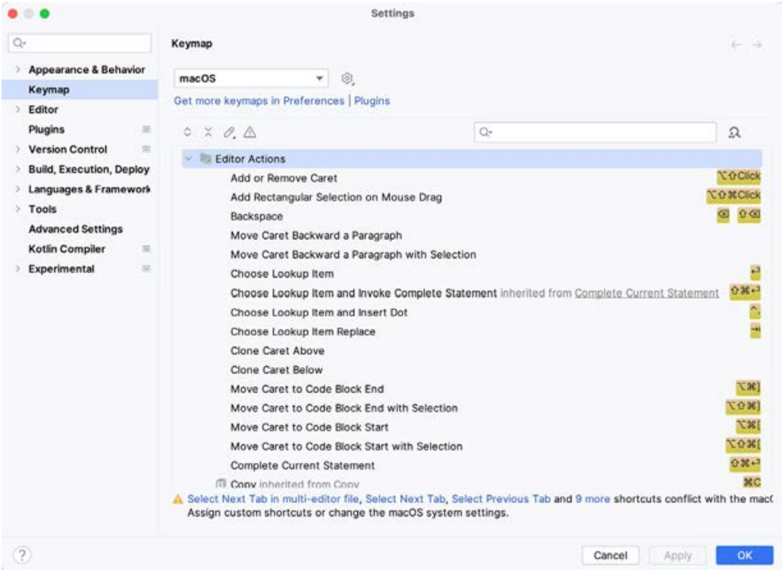

Figure 6-13

6.7 Switcher and Recent Files Navigation

Another useful mechanism for navigating within the Android Studio main window involves using the *Switcher*. Accessed via the Ctrl-Tab keyboard shortcut, the switcher appears as a panel listing both the tool windows and currently open files (Figure 6-14).

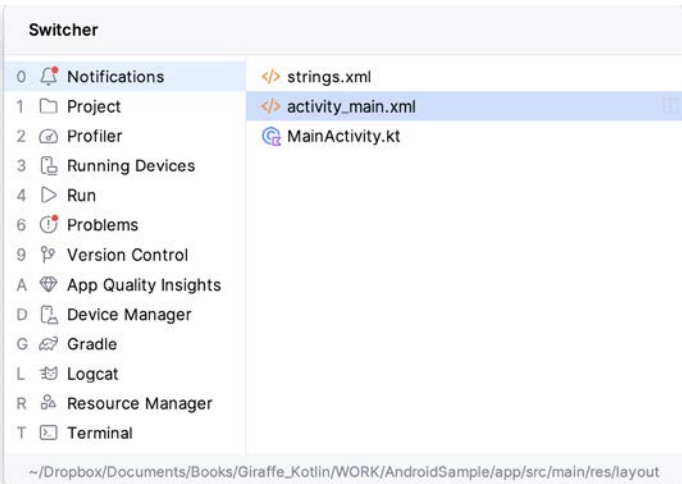

Figure 6-14

Once displayed, the switcher will remain visible as long as the Ctrl key remains depressed. Repeatedly tapping the Tab key while holding down the Ctrl key will cycle through the various selection options while releasing the

Ctrl key causes the currently highlighted item to be selected and displayed within the main window.

In addition to the Switcher, the Recent Files panel provides navigation to recently opened files (Figure 6-15). This can be accessed using the Ctrl-E keyboard shortcut (Cmd-E on macOS). Once displayed, either the mouse pointer can be used to select an option, or the keyboard arrow keys can be used to scroll through the file name and tool window options. Pressing the Enter key will select the currently highlighted item:

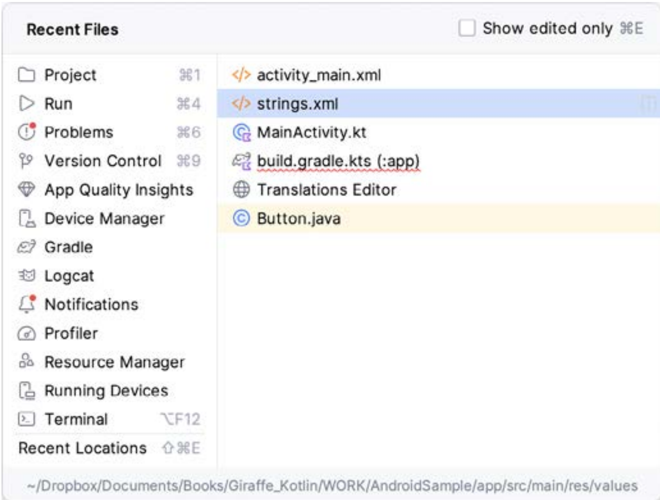

Figure 6-15

6.8 Changing the Android Studio Theme

The overall theme of the Android Studio environment may be changed using the Settings dialog. Once the settings dialog is displayed, select the *Appearance & Behavior* option in the left-hand panel, followed by *Appearance*. Then, change the setting of the *Theme* menu before clicking on the *OK* button. The themes available will depend on the platform but usually include options such as Light, IntelliJ, Windows, High Contrast, and Darcula. Figure 6-16 shows an example of the main window with the Dark theme selected:

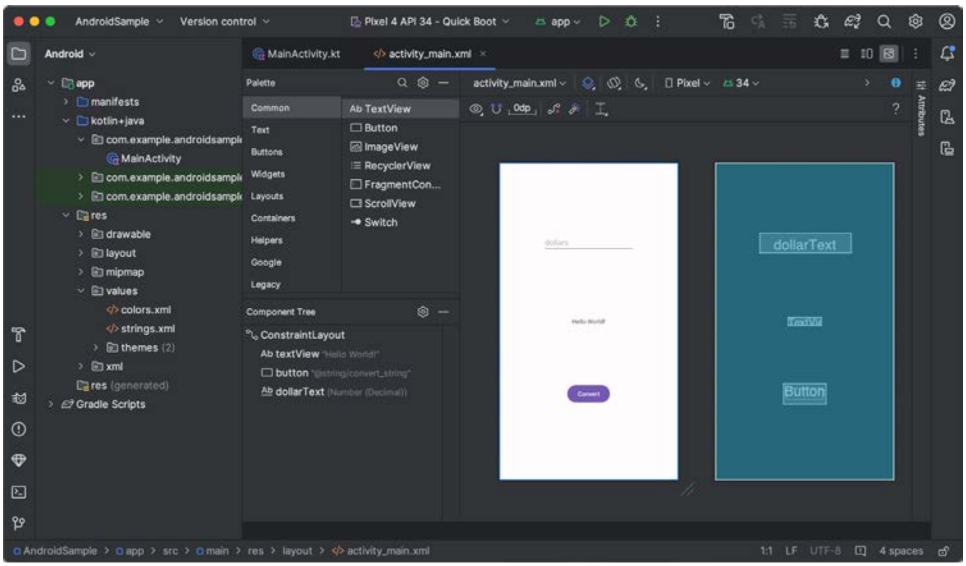

Figure 6-16

To synchronize the Android Studio theme with the operating system light and dark mode setting, enable the *Sync with OS* option and use the drop-down menu to control which theme to use for each mode:

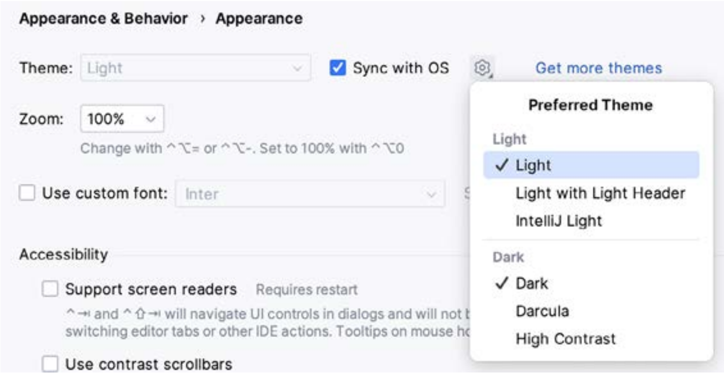

Figure 6-17

Hundreds of additional themes are available for download in the Android Studio Marketplace, which can be accessed by clicking on the *Get more themes* link.

6.9 Summary

The primary elements of the Android Studio environment consist of the welcome screen and main window. Each open project is assigned its own main window, which, in turn, consists of a menu bar, toolbar, editing and design area, status bar, and a collection of tool windows. Tool windows appear on the sides of the main window.

There are very few actions within Android Studio that cannot be triggered via a keyboard shortcut. A keymap of default keyboard shortcuts can be accessed at any time from within the Android Studio main window.

Chapter 41

41. Modern Android App Architecture with Jetpack

For many years, Google did not recommend a specific approach to building Android apps other than to provide tools and development kits while letting developers decide what worked best for a particular project or individual programming style. That changed in 2017 with the introduction of the Android Architecture Components, which, in turn, became part of Android Jetpack when it was released in 2018.

This chapter provides an overview of the concepts of Jetpack, Android app architecture recommendations, and some key architecture components. Once the basics have been covered, these topics will be covered in more detail and demonstrated through practical examples in later chapters.

41.1 What is Android Jetpack?

Android Jetpack consists of Android Studio, the Android Architecture Components, the Android Support Library, and a set of guidelines recommending how an Android App should be structured. The Android Architecture Components are designed to make it quicker and easier to perform common tasks when developing Android apps while also conforming to the key principle of the architectural guidelines.

While all Android Architecture Components will be covered in this book, this chapter will focus on the key architectural guidelines and the ViewModel, LiveData, and Lifecycle components while introducing Data Binding and Repositories.

Before moving on, it is important to understand that the Jetpack approach to app development is optional. While highlighting some of the shortcomings of other techniques that have gained popularity over the years, Google stopped short of completely condemning those approaches to app development. Google is taking the position that while there is no right or wrong way to develop an app, there is a recommended way.

41.2 The "Old" Architecture

In the chapter entitled *"Creating an Example Android App in Android Studio*", an Android project was created consisting of a single activity that contained all of the code for presenting and managing the user interface together with the back-end logic of the app. Until the introduction of Jetpack, the most common architecture followed this paradigm with apps consisting of multiple activities (one for each screen within the app), with each activity class to some degree mixing user interface and back-end code.

This approach led to a range of problems related to the lifecycle of an app (for example, an activity is destroyed and recreated each time the user rotates the device leading to the loss of any app data that had not been saved to some form of persistent storage) as well as issues such as inefficient navigation involving launching a new activity for each app screen accessed by the user.

41.3 Modern Android Architecture

At the most basic level, Google now advocates single-activity apps where different screens are loaded as content within the same activity.

Modern architecture guidelines also recommend separating different areas of responsibility within an app into entirely separate modules (a concept referred to as "separation of concerns"). One of the keys to this approach is the ViewModel component.

41.4 The ViewModel Component

The purpose of ViewModel is to separate the user interface-related data model and logic of an app from the code responsible for displaying and managing the user interface and interacting with the operating system. When designed this way, an app will consist of one or more UI Controllers, such as an activity, together with ViewModel instances responsible for handling the data those controllers need.

The ViewModel only knows about the data model and corresponding logic. It knows nothing about the user interface and does not attempt to directly access or respond to events relating to views within the user interface. When a UI controller needs data to display, it asks the ViewModel to provide it. Similarly, when the user enters data into a view within the user interface, the UI controller passes it to the ViewModel for handling.

This separation of responsibility addresses the issues relating to the lifecycle of UI controllers. Regardless of how often the UI controller is recreated during the lifecycle of an app, the ViewModel instances remain in memory, thereby maintaining data consistency. For example, a ViewModel used by an activity will remain in memory until the activity finishes, which, in the single activity app, is not until the app exits.

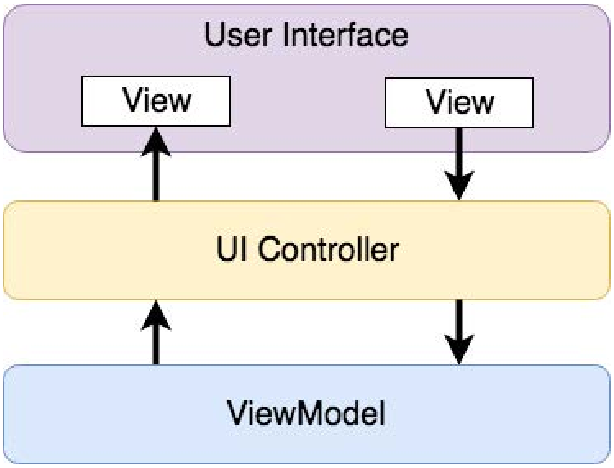

Figure 41-1

41.5 The LiveData Component

Consider an app that displays real-time data, such as the current price of a financial stock. The app could use a stock price web service to continuously update the data model within the ViewModel with the latest information. This real-time data is of use only if it is displayed to the user promptly. There are only two ways that the UI controller can ensure that the latest data is displayed in the user interface. One option is for the controller to continuously check with the ViewModel to determine if the data has changed since it was last displayed. However, the problem with this approach is that it could be more efficient. To maintain the real-time nature of the data feed, the UI controller would have to run on a loop, continuously checking for the data to change.

A better solution would be for the UI controller to receive a notification when a specific data item within a ViewModel changes. This is made possible by using the LiveData component. LiveData is a data holder that allows a value to become *observable*. In basic terms, an observable object can notify other objects when changes to its data occur, thereby solving the problem of ensuring that the user interface always matches the data within the ViewModel.

This means, for example, that a UI controller interested in a ViewModel value can set up an observer, which will, in turn, be notified when that value changes. In our hypothetical application, for example, the stock price would be wrapped in a LiveData object within the ViewModel, and the UI controller would assign an observer to the value, declaring a method to be called when the value changes. When triggered by data change, this method will read the updated value from the ViewModel and use it to update the user interface.

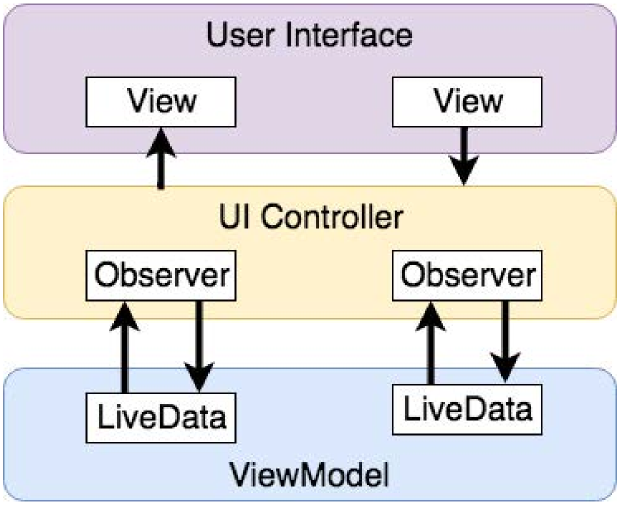

Figure 41-2

A LiveData instance may also be declared as mutable, allowing the observing entity to update the underlying value held within the LiveData object. The user might, for example, enter a value in the user interface that needs to overwrite the value stored in the ViewModel.

Another of the key advantages of using LiveData is that it is aware of the *lifecycle state* of its observers. If, for example, an activity contains a LiveData observer, the corresponding LiveData object will know when the activity's lifecycle state changes and respond accordingly. If the activity is paused (perhaps the app is put into the background), the LiveData object will stop sending events to the observer. Suppose the activity has just started or resumes after being paused. In that case, the LiveData object will send a LiveData event to the observer so that the activity has the most up-to-date value. Similarly, the LiveData instance will know when the activity is destroyed and remove the observer to free up resources.

So far, we've only talked about UI controllers using observers. In practice, however, an observer can be used within any object that conforms to the Jetpack approach to lifecycle management.

41.6 ViewModel Saved State

Android allows the user to place an active app in the background and return to it after performing other tasks on the device (including running other apps). When a device runs low on resources, the operating system will rectify this by terminating background app processes, starting with the least recently used app. However, when the user returns to the terminated background app, it should appear in the same state as when it was placed in the background, regardless of whether it was terminated. In terms of the data associated with a ViewModel, this can be implemented using the ViewModel Saved State module. This module allows values to be stored in the app's *saved state* and restored in case of system-initiated process termination. This topic will be covered later in the *"An Android ViewModel Saved State Tutorial"* chapter.

41.7 LiveData and Data Binding

Android Jetpack includes the Data Binding Library, which allows data in a ViewModel to be mapped directly to specific views within the XML user interface layout file. In the AndroidSample project created earlier, code had to be written to obtain references to the EditText and TextView views and to set and get the text properties to reflect data changes. Data binding allows the LiveData value stored in the ViewModel to be referenced directly within the XML layout file avoiding the need to write code to keep the layout views updated.

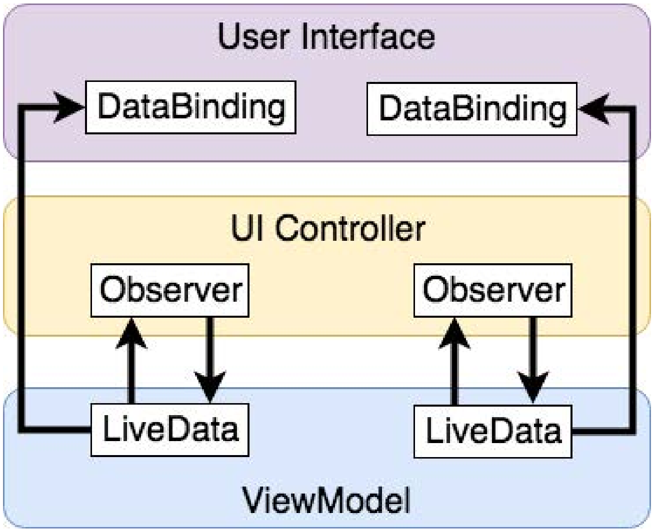

Figure 41-3

Data binding will be covered in greater detail, starting with the chapter *"An Overview of Android Jetpack Data Binding"*.

41.8 Android Lifecycles

The duration from when an Android component is created to the point that it is destroyed is called the *lifecycle*. During this lifecycle, the component will change between different lifecycle states, usually under the operating system's control and in response to user actions. An activity, for example, will begin in the *initialized* state before transitioning to the *created* state. Once the activity runs, it will switch to the *started* state, from which it will cycle through various states, including *created*, *started*, *resumed*, and *destroyed*.

Many Android Framework classes and components allow other objects to access their current state. *Lifecycle observers* may also be used so that an object receives a notification when the lifecycle state of another object changes. The ViewModel component uses this technique behind the scenes to identify when an observer has restarted or been destroyed. This functionality is not limited to Android framework and architecture components. It may also be built into any other classes using a set of lifecycle components included with the architecture components.

Objects that can detect and react to lifecycle state changes in other objects are said to be *lifecycle-aware*. In contrast, objects that provide access to their lifecycle state are called *lifecycle owners*. The chapter entitled *"Working with Android Lifecycle-Aware Components"* will cover Lifecycles in greater detail.

41.9 Repository Modules

If a ViewModel obtains data from one or more external sources (such as databases or web services, it is important to separate the code involved in handling those data sources from the ViewModel class. Failure to do this would, after all, violate the separation of concerns guidelines. To avoid mixing this functionality with the ViewModel, Google's architecture guidelines recommend placing this code in a separate *Repository* module.

A repository is not an Android architecture component but a Kotlin class created by the app developer that is responsible for interfacing with the various data sources. The class then provides an interface to the ViewModel, allowing that data to be stored in the model.

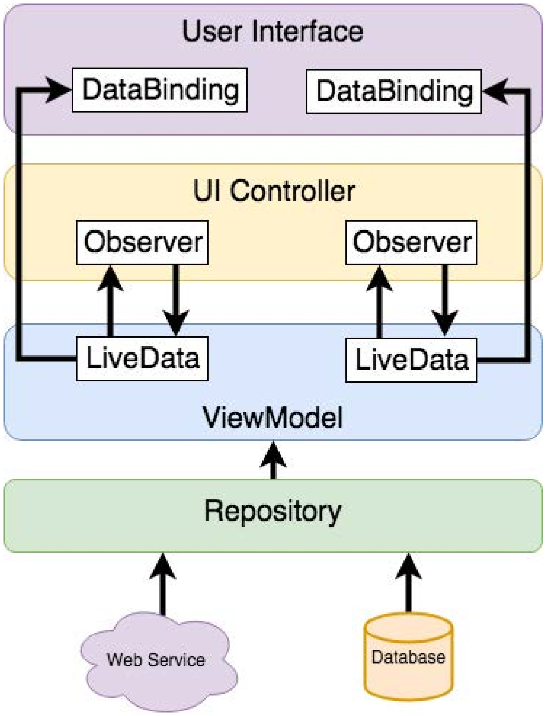

Figure 41-4

41.10 Summary

Until recently, Google has tended not to recommend any particular approach to structuring an Android app. That has now changed with the introduction of Android Jetpack, consisting of tools, components, libraries, and architecture guidelines. Google now recommends that an app project be divided into separate modules, each responsible for a particular area of functionality, otherwise known as "separation of concerns".

In particular, the guidelines recommend separating the view data model of an app from the code responsible for handling the user interface. In addition, the code responsible for gathering data from data sources such as web services or databases should be built into a separate repository module instead of being bundled with the view model.

Android Jetpack includes the Android Architecture Components, designed to make developing apps that conform to the recommended guidelines easier. This chapter has introduced the ViewModel, LiveData, and Lifecycle components. These will be covered in more detail, starting with the next chapter. Other architecture components not mentioned in this chapter will be covered later in the book.

Chapter 42

42. An Android ViewModel Tutorial

The previous chapter introduced the fundamental concepts of Android Jetpack and outlined the basics of modern Android app architecture. Jetpack defines a set of recommendations describing how an Android app project should be structured while providing a set of libraries and components that make it easier to conform to these guidelines to develop reliable apps with less coding and fewer errors.

To help reinforce and clarify the information provided in the previous chapter, this chapter will step through creating an example app project that uses the ViewModel component. The next chapter will further enhance this example by including LiveData and data binding support.

42.1 About the Project

In the chapter entitled *"Creating an Example Android App in Android Studio"*, a project named AndroidSample was created in which all of the code for the app was bundled into the main Activity class file. In the following chapter, an AVD emulator was created and used to run the app. While the app was running, we experienced first-hand the problems that occur when developing apps in this way when the data displayed on a TextView widget was lost during a device rotation.

This chapter will implement the same currency converter app, using the ViewModel component and following the Google app architecture guidelines to avoid Activity lifecycle complications.

42.2 Creating the ViewModel Example Project

When the AndroidSample project was created, the Empty Views Activity template was chosen as the basis for the project. However, the Basic Views Template template will be used for this project.

Select the *New Project* option from the welcome screen and, within the resulting new project dialog, choose the *Basic Views Activity* template before clicking on the Next button.

Enter *ViewModelDemo* into the Name field and specify *com.ebookfrenzy.viewmodeldemo* as the package name. Before clicking on the Finish button, change the Minimum API level setting to API 26: Android 8.0 (Oreo) and the Language menu to Kotlin.

42.3 Removing Unwanted Project Elements

As outlined in the *"A Guide to the Android Studio Layout Editor Tool"*, the Basic Views Activity template includes features not required by all projects. Before adding the ViewModel to the project, we first need to remove the navigation features, the second content fragment, and the floating action button as follows:

1. Double-click on the *activity_main.xml* layout file in the Project tool window, select the floating action button, and tap the keyboard delete key to remove the object from the layout.

2. Edit the *MainActivity.kt* file and remove the floating action button code from the onCreate method as follows:

```
override fun onCreate(savedInstanceState: Bundle?) {
.
.
    binding.fab.setOnClickListener { view ->
```

```
        Snackbar.make(view, "Replace with your own action", Snackbar.LENGTH_LONG)
            .setAnchorView(R.id.fab)
            .setAction("Action", null).show()
    }
}
```

3. Within the Project tool window, navigate to and double-click on the *app -> res -> navigation -> nav_graph.xml* file to load it into the navigation editor.

4. Within the editor, select the SecondFragment entry in the graph panel and tap the keyboard delete key to remove it from the graph.

5. Locate and delete the *SecondFragment.kt* and *fragment_second.xml* files.

6. The final task is to remove some code from the FirstFragment class so that the Button view no longer navigates to the now non-existent second fragment when clicked. Edit the *FirstFragment.kt* file and remove the code from the *onViewCreated()* method so that it reads as follows:

```
override fun onViewCreated(view: View, savedInstanceState: Bundle?) {
    super.onViewCreated(view, savedInstanceState)

    binding.buttonFirst.setOnClickListener {
        findNavController().navigate(R.id.action_FirstFragment_to_SecondFragment)
    }
}
```

42.4 Designing the Fragment Layout

The next step is to design the layout of the fragment. First, locate the *fragment_first.xml* file in the Project tool window and double-click on it to load it into the layout editor. Once the layout has loaded, select and delete the existing Button, TextView, and ConstraintLayout components. Next, right-click on the NestedScrollView instance in the Component Tree panel and select the *Convert NestedScrollView to ConstraintLayout* menu option as shown in Figure 42-1, and accept the default settings in the resulting dialog:

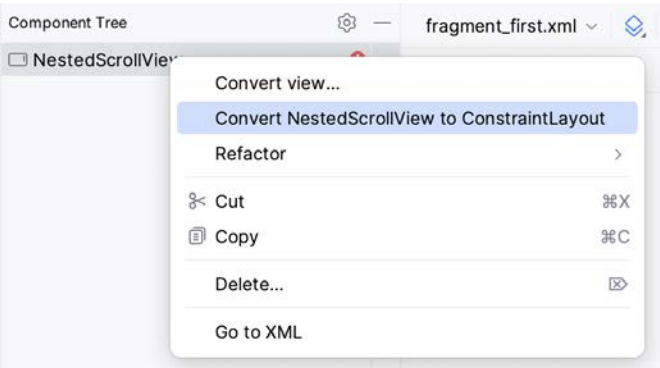

Figure 42-1

Select the converted ConstraintLayout component and use the Attributes tool window to change the id to *constraintLayout*.

Add a new TextView, position it in the center of the layout, and change the id to *resultText*. Next, drag a Number (Decimal) view from the palette and position it above the existing TextView. With the view selected in the layout, refer to the Attributes tool window and change the id to *dollarText*.

Drag a Button widget onto the layout to position it below the TextView, and change the text attribute to read "Convert". With the button still selected, change the id property to *convertButton*. At this point, the layout should resemble that illustrated in Figure 42-2 (note that the three views have been constrained using a vertical chain):

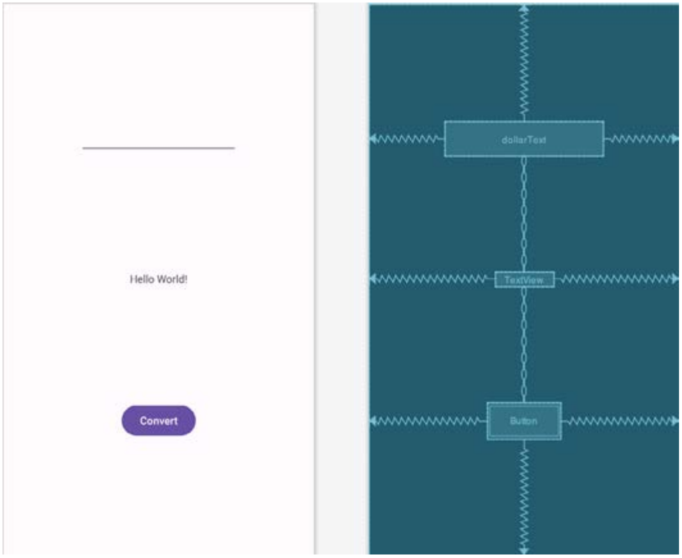

Figure 42-2

Finally, click on the warning icon in the top right-hand corner of the layout editor and convert the hard-coded strings to resources.

42.5 Implementing the View Model

With the user interface layout completed, the data model for the app needs to be created within the view model. Begin by locating the *com.ebookfrenzy.viewmodeldemo* entry in the Project tool window, right-clicking on it, and selecting the *New -> Kotlin Class/File* menu option. Name the new class MainViewModel and press the keyboard enter key. Edit the new class file so that it reads as follows:

```
package com.ebookfrenzy.viewmodeldemo

import androidx.lifecycle.ViewModel

class MainViewModel : ViewModel() {

    private val rate = 0.74f
    private var dollarText = ""
    private var result: Float = 0f

    fun setAmount(value: String) {
        this.dollarText = value
        result = value.toFloat() * rate
    }
```

```
    fun getResult(): Float {
        return result
    }
}
```

The class declares variables to store the current dollar string value and the converted amount together with getter and setter methods to provide access to those data values. When called, the *setAmount()* method takes the current dollar amount as an argument and stores it in the local *dollarText* variable. The dollar string value is converted to a floating point number, multiplied by a fictitious exchange rate, and the resulting euro value is stored in the *result* variable. The *getResult()* method, on the other hand, returns the current value assigned to the *result* variable.

42.6 Associating the Fragment with the View Model

There needs to be some way for the fragment to obtain a reference to the ViewModel to access the model and observe data changes. A Fragment or Activity maintains references to the ViewModels on which it relies for data using an instance of the ViewModelProvider class.

A ViewModelProvider instance is created using the ViewModelProvider class from within the Fragment. When called, the class initializer is passed a reference to the current Fragment or Activity and returns a ViewModelProvider instance as follows:

```
val viewModelProvider = ViewModelProvider(this)
```

Once the ViewModelProvider instance has been created, an index value can be used to request a specific ViewModel class. The provider will then either create a new instance of that ViewModel class or return an existing instance, for example:

```
val viewModel = ViewModelProvider(this)[MyViewModel::class.java]
```

Edit the *FirstFragment.kt* file and override the *onCreate()* method to set up the ViewModelProvider:

```
.
.
import androidx.lifecycle.ViewModelProvider
.
.
class FirstFragment : Fragment() {
.
.
    private lateinit var viewModel: MainViewModel

    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        viewModel = ViewModelProvider(this)[MainViewModel::class.java]
    }
.
.
```

With access to the model view, code can now be added to the Fragment to begin working with the data model.

42.7 Modifying the Fragment

The fragment class needs to be updated to react to button clicks and interact with the data values stored in the ViewModel. The class will also need references to the three views in the user interface layout to react to button clicks, extract the current dollar value, and display the converted currency amount.

In the chapter entitled *"Creating an Example Android App in Android Studio"*, the onClick property of the Button widget was used to designate the method to be called when the user clicks the button. Unfortunately, this property can only call methods on an Activity and cannot be used to call a method in a Fragment. To overcome this limitation, we must add some code to the Fragment class to set up an onClick listener on the button. This can be achieved in the *onViewCreated()* lifecycle method in the *FirstFragment.kt* file as outlined below:

```
override fun onViewCreated(view: View, savedInstanceState: Bundle?) {
    super.onViewCreated(view, savedInstanceState)

    binding.convertButton.setOnClickListener {

    }
}
```

With the listener added, any code placed within the *onClick()* method will be called whenever the user clicks the button.

42.8 Accessing the ViewModel Data

When the button is clicked, the *onClick()* method needs to read the current value from the EditText view, confirm that the field is not empty, and then call the *setAmount()* method of the ViewModel instance. The method will then need to call the ViewModel's *getResult()* method and display the converted value on the TextView widget.

Since LiveData has yet to be used in the project, it will also be necessary to get the latest result value from the ViewModel each time the Fragment is created.

Remaining in the *FirstFragment.kt* file, implement these requirements as follows in the *onViewCreated()* method:

```
.
.
override fun onViewCreated(view: View, savedInstanceState: Bundle?) {
    super.onViewCreated(view, savedInstanceState)

    binding.resultText.text = viewModel.getResult().toString()

    binding.convertButton.setOnClickListener {
        if (binding.dollarText.text.isNotEmpty()) {
            viewModel.setAmount(binding.dollarText.text.toString())
            binding.resultText.text = viewModel.getResult().toString()
        } else {
            binding.resultText.text = "No Value"
        }
    }
}
```

42.9 Testing the Project

With this project development phase completed, build and run the app on the simulator or a physical device, enter a dollar value, and click the Convert button. The converted amount should appear on the TextView, indicating that the UI controller and ViewModel re-structuring is working as expected.

When the original AndroidSample app was run, rotating the device caused the value displayed on the *resultText* TextView widget to be lost. Repeat this test now with the ViewModelDemo app and note that the current euro value is retained after the rotation. This is because the ViewModel remained in memory as the Fragment was destroyed and recreated, and code was added to the *onViewCreated()* method to update the TextView with the result data value from the ViewModel each time the Fragment re-started.

While this is an improvement on the original AndroidSample app, much more can be done to simplify the project by using LiveData and data binding, both of which are the topics of the next chapters.

42.10 Summary

In this chapter, we revisited the AndroidSample project created earlier in the book and created a new version of the project structured to comply with the Android Jetpack architectural guidelines. The example project also demonstrated the use of ViewModels to separate data handling from user interface-related code. Finally, the chapter showed how the ViewModel approach avoids problems handling Fragment and Activity lifecycles.

Chapter 63

63. An Introduction to Kotlin Coroutines

When an Android application is first started, the runtime system creates a single thread in which all components will run by default. This thread is generally referred to as the *main thread*. The primary role of the main thread is to handle the user interface in terms of event handling and interaction with views in the user interface. Any additional components started within the application will, by default, also run on the main thread.

Any code within an application that performs a time-consuming task using the main thread will cause the entire application to appear to lock up until the task is completed. This typically results in the operating system displaying an "Application is not responding" warning to the user. This is far from the desired behavior for any application. Fortunately, Kotlin provides a lightweight alternative in the form of Coroutines. This chapter will introduce Coroutines, including terminology such as dispatchers, coroutine scope, suspend functions, coroutine builders, and structured concurrency. The chapter will also explore channel-based communication between coroutines.

63.1 What are Coroutines?

Coroutines are blocks of code that execute asynchronously without blocking the thread from which they are launched. Coroutines can be implemented without worrying about building complex AsyncTask implementations or directly managing multiple threads. Because of the way they are implemented, coroutines are much more efficient and less resource intensive than using traditional multi-threading options. Coroutines also make for code that is much easier to write, understand and maintain since it allows code to be written sequentially without having to write callbacks to handle thread-related events and results.

Although a relatively recent addition to Kotlin, there is nothing new or innovative about coroutines. Coroutines, in one form or another, have existed in programming languages since the 1960s and are based on a model known as Communicating Sequential Processes (CSP). Though it does so efficiently, Kotlin still uses multi-threading behind the scenes.

63.2 Threads vs. Coroutines

A problem with threads is that they are a finite resource and expensive in terms of CPU capabilities and system overhead. In the background, much work is involved in creating, scheduling, and destroying a thread. Although modern CPUs can run large numbers of threads, the actual number of threads that can be run in parallel at any one time is limited by the number of CPU cores (though newer CPUs have 8 cores, most Android devices contain CPUs with 4 cores). When more threads are required than there are CPU cores, the system has to perform thread scheduling to decide how the execution of these threads is to be shared between the available cores.

To avoid these overheads, instead of starting a new thread for each coroutine and destroying it when the coroutine exits, Kotlin maintains a pool of active threads and manages how coroutines are assigned to those threads. When an active coroutine is suspended, the Kotlin runtime saves it, and another coroutine resumes to take its place. When the coroutine is resumed, it is restored to an existing unoccupied thread within the pool to continue executing until it either completes or is suspended. Using this approach, a limited number of threads are used efficiently to execute asynchronous tasks with the potential to perform large numbers of concurrent tasks without the inherent performance degeneration that would occur using standard multi-threading.

63.3 Coroutine Scope

All coroutines must run within a specific scope, allowing them to be managed as groups instead of as individual ones. This is particularly important when canceling and cleaning up coroutines, for example, when a Fragment or Activity is destroyed, and ensuring that coroutines do not "leak" (in other words, continue running in the background when the app no longer needs them). By assigning coroutines to a scope, they can, for example, all be canceled in bulk when they are no longer needed.

Kotlin and Android provide built-in scopes and the option to create custom scopes using the CoroutineScope class. The built-in scopes can be summarized as follows:

- **GlobalScope** – GlobalScope is used to launch top-level coroutines tied to the entire application lifecycle. Since this has the potential for coroutines in this scope to continue running when not needed (for example, when an Activity exits), use of this scope is not recommended for Android applications. Coroutines running in GlobalScope are considered to be using *unstructured concurrency*.

- **ViewModelScope** – Provided specifically for ViewModel instances when using the Jetpack architecture ViewModel component. Coroutines launched in this scope from within a ViewModel instance are automatically canceled by the Kotlin runtime system when the corresponding ViewModel instance is destroyed.

- **LifecycleScope** - Every lifecycle owner has associated with it a LifecycleScope. This scope is canceled when the corresponding lifecycle owner is destroyed, making it particularly useful for launching coroutines from within activities and fragments.

For all other requirements, a custom scope will likely be used. The following code, for example, creates a custom scope named *myCoroutineScope*:

```
private val myCoroutineScope = CoroutineScope(Dispatchers.Main)
```

The coroutineScope declares the dispatcher that will be used to run coroutines (though this can be overridden) and must be referenced each time a coroutine is started if it is to be included within the scope. All of the running coroutines in a scope can be canceled via a call to the *cancel()* method of the scope instance:

```
myCoroutineScope.cancel()
```

63.4 Suspend Functions

A suspend function is a special type of Kotlin function that contains the code of a coroutine. It is declared using the Kotlin *suspend* keyword, which indicates to Kotlin that the function can be paused and resumed later, allowing long-running computations to execute without blocking the main thread.

The following is an example suspend function:

```
suspend fun mySlowTask() {
    // Perform long-running tasks here
}
```

63.5 Coroutine Dispatchers

Kotlin maintains threads for different types of asynchronous activity, and when launching a coroutine, it will be necessary to select the appropriate dispatcher from the following options:

- **Dispatchers.Main** – Runs the coroutine on the main thread and is suitable for coroutines that need to make changes to the UI and as a general-purpose option for performing lightweight tasks.

- **Dispatchers.IO** – Recommended for coroutines that perform network, disk, or database operations.

- **Dispatchers.Default** – Intended for CPU-intensive tasks such as sorting data or performing complex calculations.

The dispatcher is responsible for assigning coroutines to appropriate threads and suspending and resuming the coroutine during its lifecycle. In addition to the predefined dispatchers, it is also possible to create dispatchers for your own custom thread pools.

63.6 Coroutine Builders

The coroutine builders bring together all of the components covered so far and launch the coroutines so that they start executing. For this purpose, Kotlin provides the following six builders:

- **launch** – Starts a coroutine without blocking the current thread and does not return a result to the caller. Use this builder when calling a suspend function from within a traditional function and when the results of the coroutine do not need to be handled (sometimes referred to as "fire and forget" coroutines).
- **async** – Starts a coroutine and allows the caller to wait for a result using the await() function without blocking the current thread. Use async when you have multiple coroutines that need to run in parallel. The async builder can only be used from within another suspend function.
- **withContext** – Allows a coroutine to be launched in a different context from that used by the parent coroutine. Using this builder, a coroutine running using the Main context could launch a child coroutine in the Default context. The withContext builder also provides a useful alternative to async when returning results from a coroutine.
- **coroutineScope** – The coroutineScope builder is ideal for situations where a suspend function launches multiple coroutines that will run in parallel and where some action must occur only when all the coroutines reach completion. If those coroutines are launched using the coroutineScope builder, the calling function will not return until all child coroutines have completed. When using coroutineScope, a failure in any coroutine will cancel all other coroutines.
- **supervisorScope** – Similar to the coroutineScope outlined above, except that a failure in one child does not result in the cancellation of the other coroutines.
- **runBlocking** - Starts a coroutine and blocks the current thread until the coroutine reaches completion. This is typically the exact opposite of what is wanted from coroutines but is useful for testing code and when integrating legacy code and libraries. Otherwise to be avoided.

63.7 Jobs

Each call to a coroutine builder, such as launch or async, returns a Job instance which can, in turn, be used to track and manage the lifecycle of the corresponding coroutine. Subsequent builder calls from within the coroutine create new Job instances, which will become children of the immediate parent Job, forming a parent-child relationship tree where canceling a parent Job will recursively cancel all its children. Canceling a child does not, however, cancel the parent, though an uncaught exception within a child created using the launch builder may result in the cancellation of the parent (this is not the case for children created using the async builder, which encapsulates the exception in the result returned to the parent).

The status of a coroutine can be identified by accessing the isActive, isCompleted, and isCancelled properties of the associated Job object. In addition to these properties, several methods are also available on a Job instance. For example, a Job and all of its children may be canceled by calling the cancel() method of the Job object, while a call to the *cancelChildren()* method will cancel all child coroutines.

The *join()* method can be called to suspend the coroutine associated with the job until all of its child jobs have completed. To perform this task and cancel the Job once all child jobs have completed, call the *cancelAndJoin()*

method.

This hierarchical Job structure, together with coroutine scopes, form the foundation of structured concurrency, which aims to ensure that coroutines do not run longer than required without manually keeping references to each coroutine.

63.8 Coroutines – Suspending and Resuming

It helps to see some coroutine examples in action to understand coroutine suspension better. To start with, let's assume a simple Android app containing a button that, when clicked, calls a function named *startTask()*. This function calls a suspend function named *performSlowTask()* using the Main coroutine dispatcher. The code for this might read as follows:

```
private val myCoroutineScope = CoroutineScope(Dispatchers.Main)

fun startTask(view: View) {
    myCoroutineScope.launch(Dispatchers.Main) {
        performSlowTask()
    }
}
```

In the above code, a custom scope is declared and referenced in the call to the launch builder, which, in turn, calls the *performSlowTask()* suspend function. Since *startTask()* is not a suspend function, the coroutine must be started using the launch builder instead of the async builder.

Next, we can declare the *performSlowTask()* suspend function as follows:

```
suspend fun performSlowTask() {
    Log.i(TAG, "performSlowTask before")
    delay(5_000) // simulates long-running task
    Log.i(TAG, "performSlowTask after")
}
```

As implemented, all the function does is output diagnostic messages before and after performing a 5-second delay, simulating a long-running task. While the 5-second delay is in effect, the user interface will continue to be responsive because the main thread is not being blocked. To understand why it helps to explore what is happening behind the scenes.

First, the *startTask()* function is executed and launches the *performSlowTask()* suspend function as a coroutine. This function then calls the Kotlin *delay()* function passing through a time value. The built-in Kotlin *delay()* function is implemented as a suspend function, so it is also launched as a coroutine by the Kotlin runtime environment. The code execution has now reached what is referred to as a suspend point which will cause the *performSlowTask()* coroutine to be suspended while the delay coroutine is running. This frees up the thread on which *performSlowTask()* was running and returns control to the main thread so that the UI is unaffected.

Once the *delay()* function reaches completion, the suspended coroutine will be resumed and restored to a thread from the pool where it can display the Log message and return to the *startTask()* function.

When working with coroutines in Android Studio suspend points within the code editor are marked as shown in the figure below:

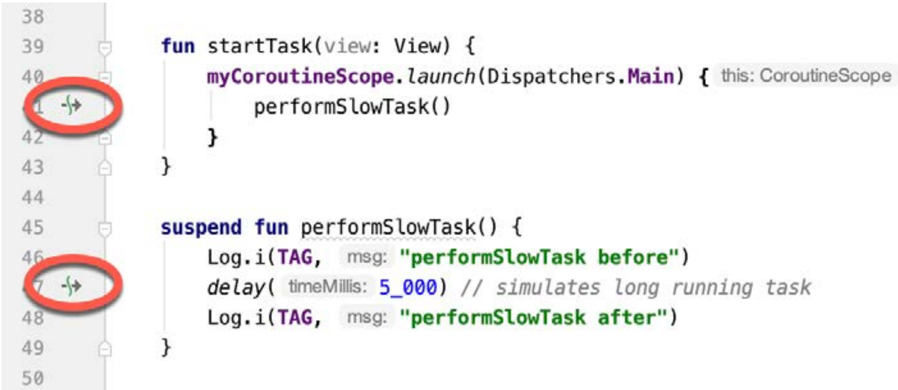

Figure 63-1

63.9 Returning Results from a Coroutine

The above example ran a suspend function as a coroutine but did not demonstrate how to return results. However, suppose the *performSlowTask()* function is required to return a string value to be displayed to the user via a TextView object.

To do this, we must rewrite the suspend function to return a Deferred object. A Deferred object is a commitment to provide a value at some point in the future. By calling the *await()* function on the Deferred object, the Kotlin runtime will deliver the value when the coroutine returns it. The code in our *startTask()* function might, therefore, be rewritten as follows:

```
fun startTask(view: View) {

    coroutineScope.launch(Dispatchers.Main) {
        statusText.text = performSlowTask().await()
    }
}
```

The problem now is that we are having to use the launch builder to start the coroutine since *startTask()* is not a suspend function. As outlined earlier in this chapter, it is only possible to return results when using the async builder. To get around this, we have to adapt the suspend function to use the async builder to start another coroutine that returns a Deferred result:

```
suspend fun performSlowTask(): Deferred<String> =
    coroutineScope.async(Dispatchers.Default) {
        Log.i(TAG, "performSlowTask before")
        delay(5_000)
        Log.i(TAG, "performSlowTask after")
    return@async "Finished"
}
```

When the app runs, the "Finished" result string will be displayed on the TextView object when the *performSlowTask()* coroutine completes. Once again, the wait for the result will occur in the background without blocking the main thread.

63.10 Using withContext

As we have seen, coroutines are launched within a specified scope and using a specific dispatcher. By default, any child coroutines will inherit the same dispatcher as that used by the parent. Consider the following code designed to call multiple functions from within a suspend function:

```
fun startTask(view: View) {

    coroutineScope.launch(Dispatchers.Main) {
        performTasks()
    }
}

suspend fun performTasks() {
    performTask1()
    performTask2()
    performTask3()
}

suspend fun performTask1() {
    Log.i(TAG, "Task 1 ${Thread.currentThread().name}")
}

suspend fun performTask2() {
    Log.i(TAG, "Task 2 ${Thread.currentThread().name}")
}

suspend fun performTask3 () {
    Log.i(TAG, "Task 3 ${Thread.currentThread().name}")
}
```

Since the *performTasks()* function was launched using the Main dispatcher, all three functions will default to the main thread. To prove this, the functions have been written to output the name of the thread in which they are running. On execution, the Logcat panel will contain the following output:

```
Task 1 main
Task 2 main
Task 3 main
```

However, imagine that the *performTask2()* function performs network-intensive operations more suited to the IO dispatcher. This can easily be achieved using the withContext launcher, which allows the context of a coroutine to be changed while still staying in the same coroutine scope. The following change switches the *performTask2()* coroutine to an IO thread:

```
suspend fun performTasks() {
    performTask1()
    withContext(Dispatchers.IO) { performTask2() }
    performTask3()
}
```

When executed, the output will read as follows, indicating that the Task 2 coroutine is no longer on the main thread:

```
Task 1 main
Task 2 DefaultDispatcher-worker-1
```

```
Task 3 main
```

The withContext builder also provides an interesting alternative to using the async builder and the Deferred object *await()* call when returning a result. Using withContext, the code from the previous section can be rewritten as follows:

```
fun startTask(view: View) {

    coroutineScope.launch(Dispatchers.Main) {
          statusText.text = performSlowTask()
    }
}

suspend fun performSlowTask(): String =
    withContext(Dispatchers.Main) {
        Log.i(TAG, "performSlowTask before")
        delay(5_000)
        Log.i(TAG, "performSlowTask after")

        return@withContext "Finished"
    }
}
```

63.11 Coroutine Channel Communication

Channels provide a simple way to implement communication between coroutines, including streams of data. In the simplest form, this involves the creation of a Channel instance and calling the *send()* method to send the data. Once sent, transmitted data can be received in another coroutine via a call to the *receive()* method of the same Channel instance.

The following code, for example, passes six integers from one coroutine to another:

```
.
.
import kotlinx.coroutines.channels.*
.
.
val channel = Channel<Int>()

suspend fun channelDemo() {
    coroutineScope.launch(Dispatchers.Main) { performTask1() }
    coroutineScope.launch(Dispatchers.Main) { performTask2() }
}

suspend fun performTask1() {
    (1..6).forEach {
        channel.send(it)
    }
}
```

```
suspend fun performTask2() {
    repeat(6) {
        Log.d(TAG, "Received: ${channel.receive()}")
    }
}
```

When executed, the following logcat output will be generated:

```
Received: 1
Received: 2
Received: 3
Received: 4
Received: 5
Received: 6
```

63.12 Summary

Kotlin coroutines provide a simpler and more efficient approach to performing asynchronous tasks than traditional multi-threading. Coroutines allow asynchronous tasks to be implemented in a structured way without implementing the callbacks associated with typical thread-based tasks. This chapter has introduced the basic concepts of coroutines, including jobs, scope, builders, suspend functions, structured concurrency, and channel-based communication.

Chapter 80

80. An Android Picture-in-Picture Tutorial

Following the previous chapters, this chapter will take the existing VideoPlayer project and enhance it to add Picture-in-Picture support, including detecting PiP mode changes and adding a PiP action designed to display information about the currently running video.

80.1 Adding Picture-in-Picture Support to the Manifest

The first step in adding PiP support to an Android app project is to enable it within the project Manifest file. Open the *manifests -> AndroidManifest.xml* file and modify the activity element to enable PiP support:

```
.
.
<activity
   android:name=".MainActivity"
   android:supportsPictureInPicture="true"
   android:configChanges="screenSize|smallestScreenSize|screenLayout|orientation"
   android:exported="true">
     <intent-filter>
         <action android:name="android.intent.action.MAIN" />
         <category android:name="android.intent.category.LAUNCHER" />
     </intent-filter>
</activity>
.
.
```

80.2 Adding a Picture-in-Picture Button

As currently designed, the layout for the VideoPlayer activity consists solely of a VideoView instance. As currently designed, the layout for the VideoPlayer activity consists solely of a VideoView instance. A button will now be added to the layout to switch to PiP mode. Load the *activity_main.xml* file into the layout editor and drag a Button object from the palette onto the layout so that it is positioned as shown in Figure 80-1:

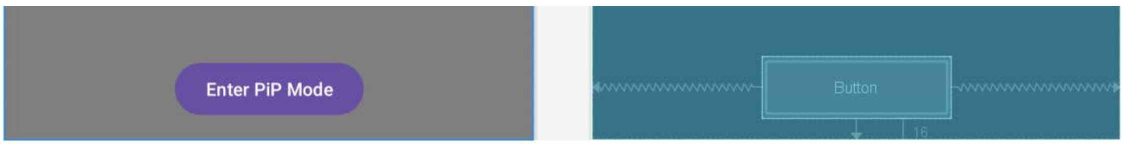

Figure 80-1

Change the text on the button to read "Enter PiP Mode" and extract the string to a resource named *enter_pip_mode*. Before moving on to the next step, change the ID of the button to *pipButton* and configure the onClick attribute to call a method named *enterPipMode*.

80.3 Entering Picture-in-Picture Mode

The *enterPipMode* onClick callback method must now be added to the *MainActivity.kt* class file. Locate this file, open it in the code editor, and add this method as follows:

```
.
.
import android.app.PictureInPictureParams
import android.util.Rational
import android.view.View
import android.content.res.Configuration
.
.
fun enterPipMode(view: View) {

    val rational = Rational(binding.videoView1.width,
            binding.videoView1.height)

    val params = PictureInPictureParams.Builder()
            .setAspectRatio(rational)
            .build()

    binding.pipButton.visibility = View.INVISIBLE
    binding.videoView1.setMediaController(null)
    enterPictureInPictureMode(params)
}
```

The method begins by obtaining a reference to the Button view, then creates a Rational object containing the width and height of the VideoView. A set of Picture-in-Picture parameters is then created using the PictureInPictureParams Builder, passing through the Rational object as the aspect ratio for the video playback. Since the button does not need to be visible while the video is in PiP mode, it is invisible. The video playback controls are also hidden, so the video view will be unobstructed while in PiP mode.

Compile and run the app on a device or emulator running Android version 8 or newer and wait for video playback to begin before clicking on the PiP mode button. The video playback should minimize and appear in the PiP window as shown in Figure 80-2:

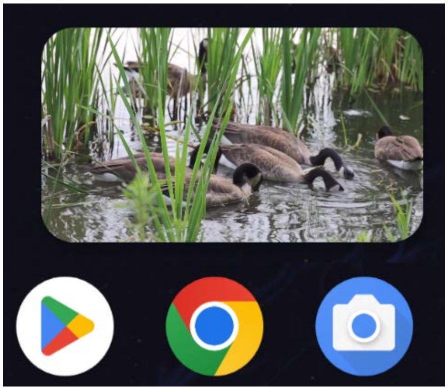

Figure 80-2

Click in the PiP window, then click within the full-screen mode markers that appear in the center of the window. Although the activity returns to full-screen mode, the button and media playback controls remain hidden.

Clearly, some code must be added to the project to detect when PiP mode changes occur within the activity.

80.4 Detecting Picture-in-Picture Mode Changes

As discussed in the previous chapter, PiP mode changes are detected by overriding the *onPictureInPictureModeChanged()* method within the affected activity. n this case, the method must be written to detect whether the activity is entering or exiting PiP mode and to take appropriate action to re-activate the PiP button and the playback controls. Remaining within the *MainActivity.kt* file, add this method now:

```
override fun onPictureInPictureModeChanged(
       isInPictureInPictureMode: Boolean, newConfig: Configuration) {
    super.onPictureInPictureModeChanged(isInPictureInPictureMode, newConfig)
    if (isInPictureInPictureMode) {

    } else {
        binding.pipButton.visibility = View.VISIBLE
        binding.videoView1.setMediaController(mediaController)
    }
}
```

When the method is called, it is passed a Boolean value indicating whether the activity is now in PiP mode. The code in the above method checks this value to decide whether to show the PiP button and to re-activate the playback controls.

80.5 Adding a Broadcast Receiver

The final step in the project is to add an action to the PiP window. The purpose of this action is to display a Toast message containing the name of the currently playing video. This will require some communication between the PiP window and the activity. One of the simplest ways to achieve this is to implement a broadcast receiver within the activity and use a pending intent to broadcast a message from the PiP window to the activity. Each time the activity enters PiP mode, these steps must be performed, so code must be added to the *onPictureInPictureModeChanged()* method. Locate this method now and begin by adding some code to create an intent filter and initialize the broadcast receiver:

```
.
.
import android.content.BroadcastReceiver
import android.content.Context
import android.content.Intent
import android.content.IntentFilter
import android.widget.Toast

class MainActivity : AppCompatActivity() {
.
.
    private val receiver: BroadcastReceiver? = null
.
.
override fun onPictureInPictureModeChanged(
```

```
      isInPictureInPictureMode: Boolean, newConfig: Configuration) {
    super.onPictureInPictureModeChanged(isInPictureInPictureMode, newConfig)
    if (isInPictureInPictureMode) {
        val filter = IntentFilter()
        filter.addAction(
                "com.ebookfrenzy.videoplayer.VIDEO_INFO")

        val receiver = object : BroadcastReceiver() {
            override fun onReceive(context: Context,
                                   intent: Intent) {
                Toast.makeText(context,
                        "Favorite Home Movie Clips",
                        Toast.LENGTH_LONG).show()
            }
        }

        registerReceiver(receiver, filter, Context.RECEIVER_EXPORTED)
    } else {
        binding.pipButton.visibility = View.VISIBLE
        binding.videoView1.setMediaController(mediaController)

        receiver?.let {
            unregisterReceiver(it)
        }
    }
}
```

80.6 Adding the PiP Action

With the broadcast receiver implemented, the next step is to create a RemoteAction object configured with an image to represent the action within the PiP window.

For this example, an image icon file named *ic_info_24dp.xml* will be used. This file can be found in the *project_icons* folder of the source code download archive available from the following URL:

https://www.payloadbooks.com/product/koalakotlin/

Locate this icon file and copy and paste it into the *app* -> *res* -> *drawables* folder within the Project tool window:

Figure 80-3

The next step is to create an Intent that will be sent to the broadcast receiver. This intent then needs to be wrapped up within a PendingIntent object, allowing the intent to be triggered later when the user taps the action button in the PiP window.

Edit the *MainActivity.kt* file to add a method to create the Intent and PendingIntent objects as follows:

```
.
.
import android.app.PendingIntent
import android.app.PendingIntent.FLAG_IMMUTABLE
.
.
class MainActivity : AppCompatActivity() {

    private val REQUEST_CODE = 101
.
.
    private fun createPipAction() {

        val actionIntent = Intent("com.ebookfrenzy.videoplayer.VIDEO_INFO")

        val pendingIntent = PendingIntent.getBroadcast(this@MainActivity,
                REQUEST_CODE, actionIntent, FLAG_IMMUTABLE)
    }
}
```

Now that both the Intent object and the PendingIntent instance in which it is contained have been created, a RemoteAction object needs to be created containing the icon to appear in the PiP window and the PendingIntent object. Remaining within the *createPipAction()* method, add this code as follows:

```
.
.
import android.app.RemoteAction
import android.graphics.drawable.Icon
.
.
private fun createPipAction() {

    val actions = ArrayList<RemoteAction>()

    val actionIntent = Intent("com.ebookfrenzy.videoplayer.VIDEO_INFO")

    val pendingIntent = PendingIntent.getBroadcast(this@MainActivity,
            REQUEST_CODE, actionIntent, FLAG_IMMUTABLE)

    val icon = Icon.createWithResource(this, R.drawable.ic_info_24dp)

    val remoteAction = RemoteAction(icon, "Info", "Video Info", pendingIntent)
```

```
    actions.add(remoteAction)
}
```

Now a PictureInPictureParams object containing the action needs to be created and the parameters applied so that the action appears within the PiP window:

```
private fun createPipAction() {

    val actions = ArrayList<RemoteAction>()

    val actionIntent = Intent("com.ebookfrenzy.videoplayer.VIDEO_INFO")

    val pendingIntent = PendingIntent.getBroadcast(this@MainActivity,
            REQUEST_CODE, actionIntent, FLAG_IMMUTABLE)

    val icon =
    Icon.createWithResource(this,
        R.drawable.ic_info_24dp)

    val remoteAction = RemoteAction(icon, "Info",
    "Video Info", pendingIntent)

    actions.add(remoteAction)

    val params = PictureInPictureParams.Builder()
                    .setActions(actions)
                    .build()

    setPictureInPictureParams(params)
}
```

The final task before testing the action is to make a call to the *createPipAction()* method when the activity enters PiP mode:

```
override fun onPictureInPictureModeChanged(
        isInPictureInPictureMode: Boolean, newConfig: Configuration) {
    super.onPictureInPictureModeChanged(isInPictureInPictureMode, newConfig)
.
.
        registerReceiver(receiver, filter, Context.RECEIVER_EXPORTED)
        createPipAction()
    } else {
        pipButton.visibility = View.VISIBLE
        videoView1.setMediaController(mediaController)
.
.
```

80.7 Testing the Picture-in-Picture Action

Rerun the app and place the activity into PiP mode. Tap on the PiP window so that the new action button appears, as shown in Figure 80-4:

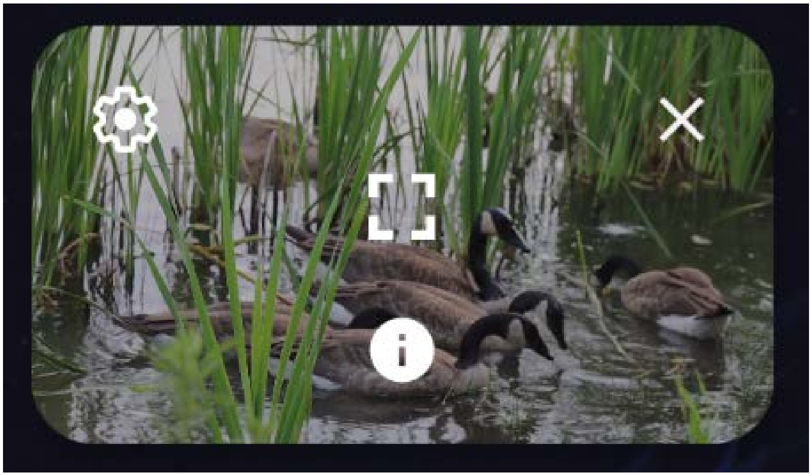

Figure 80-4

Click on the action button and wait for the Toast message to appear, displaying the name of the video:

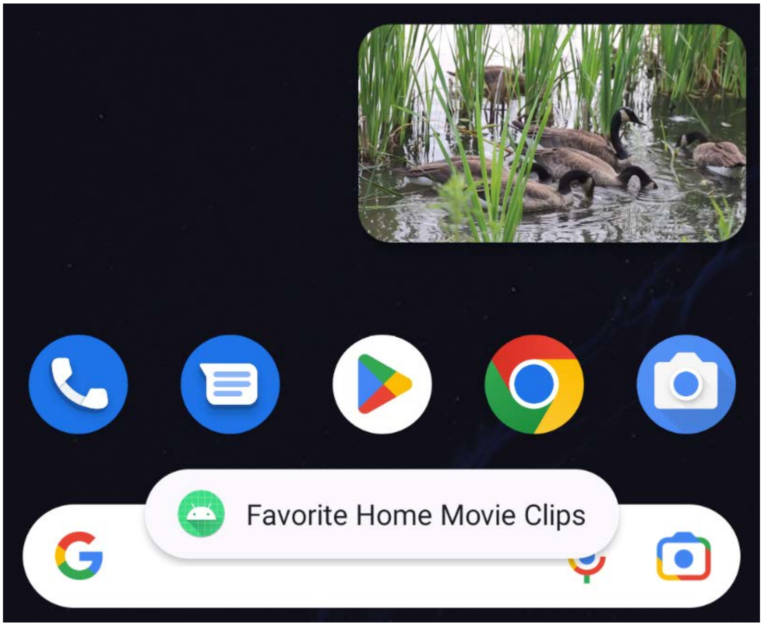

Figure 80-5

80.8 Summary

This chapter has demonstrated the addition of Picture-in-Picture support to an Android Studio app project, including enabling and entering PiP mode and implementing a PiP action. This included using a broadcast receiver and pending intents to implement communication between the PiP window and the activity.

Chapter 93

93. An Overview of Android In-App Billing

n the early days of mobile applications for operating systems such as Android and iOS, the most common method for earning revenue was to charge an upfront fee to download and install the application. Another revenue opportunity was soon introduced by embedding advertising within applications. The most common and lucrative option is to charge the user for purchasing items from within the application after installing it. This typically takes the form of access to a higher level in a game, acquiring virtual goods or currency, or subscribing to premium content in the digital edition of a magazine or newspaper.

Google supports integrating in-app purchasing through the Google Play In-App Billing API and the Play Console. This chapter will provide an overview of in-app billing and outline how to integrate in-app billing into your Android projects. Once these topics have been explored, the next chapter will walk you through creating an example app that includes in-app purchasing features.

93.1 Preparing a Project for In-App Purchasing

Building in-app purchasing into an app will require a Google Play Developer Console account, details of which were covered previously in the *"Creating, Testing and Uploading an Android App Bundle"* chapter. You must also register a Google merchant account. These settings can be found by navigating to *Setup -> Payments profile* in the Play Console. Note that merchant registration is not available in all countries. For details, refer to the following page:

https://support.google.com/googleplay/android-developer/answer/9306917

The app must then be uploaded to the console and enabled for in-app purchasing. However, the console will not activate in-app purchasing support for an app unless the Google Play Billing Library has been added to the module-level *build.gradle.kts* file:

```
dependencies {
.
.
    implementation(libs.billingclient.ktx)
.
.
}
```

Once the build file has been modified and the app bundle uploaded to the console, the next step is to add in-app products or subscriptions for the user to purchase.

93.2 Creating In-App Products and Subscriptions

Products and subscriptions are created and managed using the options listed beneath the Monetize section of the Play Console navigation panel, as highlighted in Figure 93-1 below:

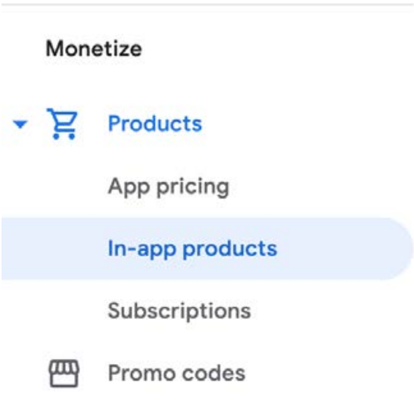

Figure 93-1

Each product or subscription needs an ID, title, description, and pricing information. Purchases fall into the categories of *consumable* (the item must be purchased each time it is required by the user, such as virtual currency in a game), *non-consumable* (only needs to be purchased once by the user, such as content access), and *subscription*-based. Consumable and non-consumable products are collectively referred to as *managed products*.

Subscriptions are useful for selling an item that needs to be renewed regularly, such as access to news content or the premium features of an app. When creating a subscription, a *base plan* specifies the price, renewal period (monthly, annually, etc.), and whether the subscription auto-renews. Users can also be given discount offers and the option of pre-purchasing a subscription.

93.3 Billing Client Initialization

Communication between your app and the Google Play Billing Library is handled by a BillingClient instance. In addition, BillingClient includes a set of methods that can be called to perform both synchronous and asynchronous billing-related activities. When the billing client is initialized, it will need to be provided with a reference to a PurchasesUpdatedListener callback handler. The client will call this handler to notify your app of the results of any purchasing activity. To avoid duplicate notifications, it is recommended to have only one BillingClient instance per app.

A BillingClient instance can be created using the *newBuilder()* method, passing through the current activity or fragment context. The purchase update handler is then assigned to the client via the *setListener()* method:

```
private val purchasesUpdatedListener =
    PurchasesUpdatedListener { billingResult, purchases ->
        if (billingResult.responseCode ==
            BillingClient.BillingResponseCode.OK
            && purchases != null
        ) {
            for (purchase in purchases) {
                // Process the purchases
            }
        } else if (billingResult.responseCode ==
            BillingClient.BillingResponseCode.USER_CANCELED
        ) {
            // Purchase canceled by the user
        } else {
```

```
            // Handle errors here
        }
    }

billingClient = BillingClient.newBuilder(this)
    .setListener(purchasesUpdatedListener)
    .enablePendingPurchases(
        PendingPurchasesParams.newBuilder()
            .enableOneTimeProducts().build()
    )
    .build()
```

93.4 Connecting to the Google Play Billing Library

After successfully creating the Billing Client, the next step is initializing a connection to the Google Play Billing Library. A call must be made to the *startConnection()* method of the billing client instance to establish this connection. Since the connection is performed asynchronously, a BillingClientStateListener must be implemented to receive a callback indicating whether the connection was successful. Code should also be added to override the *onBillingServiceDisconnected()* method. This is called if the connection to the Billing Library is lost and can be used to report the problem to the user and retry the connection.

Once the setup and connection tasks are complete, the BillingClient instance will make a call to the *onBillingSetupFinished()* method, which can be used to check that the client is ready:

```
billingClient.startConnection(object : BillingClientStateListener {
    override fun onBillingSetupFinished(
        billingResult: BillingResult
    ) {
        if (billingResult.responseCode ==
            BillingClient.BillingResponseCode.OK
        ) {
            // Connection successful
        } else {
            // Connection failed
        }
    }

    override fun onBillingServiceDisconnected() {
        // Connection to billing service lost
    }
})
```

93.5 Querying Available Products

Once the billing environment is initialized and ready to go, the next step is to request the details of the products or subscriptions available for purchase. This is achieved by making a call to the *queryProductDetailsAsync()* method of the BillingClient and passing through an appropriately configured QueryProductDetailsParams instance containing the product ID and type (ProductType.SUBS for a subscription or ProductType.INAPP for a managed product):

```
val queryProductDetailsParams = QueryProductDetailsParams.newBuilder()
```

```
    .setProductList(
        ImmutableList.of(
            QueryProductDetailsParams.Product.newBuilder()
                .setProductId(productId)
                .setProductType(
                    BillingClient.ProductType.INAPP
                )
                .build()
        )
    )
    .build()

billingClient.queryProductDetailsAsync(
    queryProductDetailsParams
) { billingResult, productDetailsList ->
    if (!productDetailsList.isEmpty()) {
        // Process list of matching products
    } else {
        // No product matches found
    }
}
```

The *queryProductDetailsAsync()* method is passed a ProductDetailsResponseListener handler (in this case, in the form of a lambda code block) which, in turn, is called and passed a list of ProductDetail objects containing information about the matching products. For example, we can call methods on these objects to get information such as the product name, title, description, price, and offer details.

93.6 Starting the Purchase Process

Once a product or subscription has been queried and selected for purchase by the user, the purchase process is ready to be launched. We do this by calling the *launchBillingFlow()* method of the BillingClient, passing through as arguments the current activity and a BillingFlowParams instance configured with the ProductDetail object for the purchased item.

```
val billingFlowParams = BillingFlowParams.newBuilder()
    .setProductDetailsParamsList(
        ImmutableList.of(
            BillingFlowParams.ProductDetailsParams.newBuilder()
                .setProductDetails(productDetails)
                .build()
        )
    )
    .build()

billingClient.launchBillingFlow(this, billingFlowParams)
```

The success or otherwise of the purchase operation will be reported via a call to the PurchasesUpdatedListener callback handler outlined earlier in the chapter.

93.7 Completing the Purchase

When purchases are successful, the PurchasesUpdatedListener handler will be passed a list containing a Purchase object for each item. You can verify that the item has been purchased by calling the *getPurchaseState()* method of the Purchase instance as follows:

```
if (purchase.getPurchaseState() == Purchase.PurchaseState.PURCHASED) {
    // Purchase completed.
} else if (purchase.getPurchaseState() == Purchase.PurchaseState.PENDING) {
    // Payment is still pending
}
```

Note that your app will only support pending purchases if a call is made to the *enablePendingPurchases()* method during initialization. A pending purchase will remain so until the user completes the payment process.

When the purchase of a non-consumable item is complete, it must be acknowledged to prevent a refund from being issued to the user. This requires the *purchase token* for the item, which is obtained via a call to the *getPurchaseToken()* method of the Purchase object. This token is used to create an AcknowledgePurchaseParams instance and an AcknowledgePurchaseResponseListener handler. Managed product purchases and subscriptions are acknowledged by calling the BillingClient's *acknowledgePurchase()* method as follows:

```
billingClient.acknowledgePurchase(acknowledgePurchaseParams,
                             acknowledgePurchaseResponseListener);
val acknowledgePurchaseParams = AcknowledgePurchaseParams.newBuilder()
    .setPurchaseToken(purchase.purchaseToken)
    .build()

val acknowledgePurchaseResponseListener = AcknowledgePurchaseResponseListener {
    // Check acknowledgement result
}

billingClient.acknowledgePurchase(
    acknowledgePurchaseParams,
    acknowledgePurchaseResponseListener
)
```

For consumable purchases, you will need to notify Google Play when the item has been consumed so that it is available to be repurchased by the user. This requires a configured ConsumeParams instance containing a purchase token and a call to the billing client's *consumePurchase()* method:

```
val consumeParams = ConsumeParams.newBuilder()
    .setPurchaseToken(purchase.purchaseToken)
    .build()

coroutineScope.launch {
    val result = billingClient.consumePurchase(consumeParams)

    if (result.billingResult.responseCode ==
                     BillingClient.BillingResponseCode.OK) {
        // Purchase successfully consumed
    }
```

```
}
```

93.8 Querying Previous Purchases

When working with in-app billing, checking whether a user has already purchased a product or subscription is a common requirement. A list of all the user's previous purchases of a specific type can be generated by calling the *queryPurchasesAsync()* method of the BillingClient instance and implementing a PurchaseResponseListener. The following code, for example, obtains a list of all previously purchased items that have not yet been consumed:

```
val queryPurchasesParams = QueryPurchasesParams.newBuilder()
    .setProductType(BillingClient.ProductType.INAPP)
    .build()

billingClient.queryPurchasesAsync(
    queryPurchasesParams,
    purchasesListener
)
.
.
private val purchasesListener =
    PurchasesResponseListener { billingResult, purchases ->

        if (!purchases.isEmpty()) {
            // Access existing active purchases
        } else {
            // No
        }
    }
```

To obtain a list of active subscriptions, change the ProductType value from INAPP to SUBS.

Alternatively, to obtain a list of the most recent purchases for each product, make a call to the BillingClient *queryPurchaseHistoryAsync()* method:

```
val queryPurchaseHistoryParams = QueryPurchaseHistoryParams.newBuilder()
    .setProductType(BillingClient.ProductType.INAPP)
    .build()

billingClient.queryPurchaseHistoryAsync(queryPurchaseHistoryParams) {
billingResult, historyList ->
    // Process purchase history list
}
```

93.9 Summary

In-app purchases provide a way to generate revenue from within Android apps by selling virtual products and subscriptions to users. This chapter explored managed products and subscriptions and explained the difference between consumable and non-consumable products. In-app purchasing support is added to an app using the Google Play In-app Billing Library. It involves creating and initializing a billing client on which methods are called to perform tasks such as making purchases, listing available products, and consuming existing purchases. The next chapter contains a tutorial demonstrating the addition of in-app purchases to an Android Studio project.

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