Android Studio Bumble Bee Essentials

Kotlin Edition
# Table of Contents

1. Introduction ......................................................................................................................... 1  
   1.1 Downloading the Code Samples ...................................................................................... 1  
   1.2 Feedback ......................................................................................................................... 2  
   1.3 Errata ............................................................................................................................... 2  

2. Setting up an Android Studio Development Environment .................................................. 3  
   2.1 System Requirements ....................................................................................................... 3  
   2.2 Downloading the Android Studio Package ....................................................................... 3  
   2.3 Installing Android Studio .................................................................................................. 4  
      2.3.1 Installation on Windows .............................................................................................. 4  
      2.3.2 Installation on macOS ................................................................................................. 4  
      2.3.3 Installation on Linux .................................................................................................... 5  
   2.4 The Android Studio Setup Wizard .................................................................................... 5  
   2.5 Installing Additional Android SDK Packages ................................................................. 6  
   2.6 Making the Android SDK Tools Command-line Accessible ............................................ 9  
      2.6.1 Windows 8.1 .............................................................................................................. 9  
      2.6.2 Windows 10 ............................................................................................................... 10  
      2.6.3 Windows 11 ............................................................................................................... 10  
      2.6.4 Linux ......................................................................................................................... 10  
      2.6.5 macOS ..................................................................................................................... 10  
   2.7 Android Studio Memory Management .............................................................................. 11  
   2.8 Updating Android Studio and the SDK ............................................................................ 12  
   2.9 Summary ......................................................................................................................... 12  

3. Creating an Example Android App in Android Studio ......................................................... 13  
   3.1 About the Project ................................................................................................................. 13  
   3.2 Creating a New Android Project ....................................................................................... 13  
   3.3 Creating an Activity ........................................................................................................... 14  
   3.4 Defining the Project and SDK Settings ............................................................................. 14  
   3.5 Modifying the Example Application ................................................................................. 15  
   3.6 Modifying the User Interface ............................................................................................. 16  
   3.7 Reviewing the Layout and Resource Files ....................................................................... 21  
   3.8 Adding the Kotlin Extensions Plugin ................................................................................. 24  
   3.9 Adding Interaction ............................................................................................................ 25  
   3.10 Summary ......................................................................................................................... 26  

4. Creating an Android Virtual Device (AVD) in Android Studio ............................................ 27  
   4.1 About Android Virtual Devices ........................................................................................... 27  
   4.2 Starting the Emulator ......................................................................................................... 28  
   4.3 Running the Application in the AVD ............................................................................... 29  
   4.4 Running on Multiple Devices ........................................................................................... 31  
   4.5 Stopping a Running Application ....................................................................................... 31  
   4.6 Supporting Dark Theme .................................................................................................... 32  
   4.7 Running the Emulator in a Separate Window .................................................................... 33
Table of Contents

12.13 Type Casting and Type Checking ................................................. 93
12.12 The Elvis Operator ........................................................................ 93
12.11 Late Initialization (lateinit) ............................................................ 92
12.10 Nullable Types and the let Function .............................................. 91
12.9 Not-Null Assertion .......................................................................... 91
12.8 The Safe Call Operator .................................................................... 90
12.7 Nullable Type .................................................................................. 90
12.6 Type Annotations and Type Inference ............................................ 89
12.5 Data Types are Objects ................................................................... 88
12.4 Equality Operators ......................................................................... 97
12.3 Boolean Logical Operators .............................................................. 97
12.2 The Basic Assignment Operator ..................................................... 95
12.1 Expression Syntax in Kotlin .............................................................. 95
12.1.3 Boolean Data Type ...................................................................... 86
12.1.4 Character Data Type ................................................................... 86
12.1.5 String Data Type ......................................................................... 86
12.1.6 Escape Sequences ....................................................................... 87
12.1.2 The for-in Statement ................................................................... 103
12.1.1 The Kotlin for-in Statement ......................................................... 103
12.1 Breaking from Loops ....................................................................... 105
12.1.5 The continue Statement ............................................................... 106
12.1.4 Breaking from Loops ................................................................... 105
12.1.3 The do ... while loop ................................................................. 104
12.1.2 The while Loop .......................................................................... 104
12.1.1 The Kotlin while loop ................................................................. 103
12.1 Loopy Control flow ......................................................................... 103
12.1.6 Escape Sequences ....................................................................... 87
12.1.4 Character Data Type ................................................................... 86
12.1.3 Boolean Data Type ...................................................................... 86
12.1.2 The Basic Assignment Operator ..................................................... 95
12.1.1 Expression Syntax in Kotlin .............................................................. 95

13. Kotlin Operators and Expressions ...................................................... 95

13.1 Expression Syntax in Kotlin .............................................................. 95
13.2 The Basic Assignment Operator ..................................................... 95
13.3 Kotlin Arithmetic Operators ............................................................. 96
13.4 Augmented Assignment Operators ................................................ 96
13.5 Increment and Decrement Operators ............................................. 96
13.6 Equality Operators ......................................................................... 97
13.7 Boolean Logical Operators .............................................................. 97
13.8 Range Operator ............................................................................... 98
13.9 Bitwise Operators ............................................................................ 98
13.9.1 Bitwise Inversion ......................................................................... 98
13.9.2 Bitwise AND ................................................................................ 99
13.9.3 Bitwise OR .................................................................................. 99
13.9.4 Bitwise XOR .............................................................................. 99
13.9.5 Bitwise Left Shift ....................................................................... 100
13.9.6 Bitwise Right Shift ..................................................................... 100
13.10 Summary ....................................................................................... 101

14. Kotlin Control Flow ......................................................................... 103

14.1 Loopy Control flow ......................................................................... 103
14.1.1 The Kotlin for-in Statement ......................................................... 103
14.1.2 The while Loop .......................................................................... 104
14.1.3 The do ... while loop ................................................................. 105
14.1.4 Breaking from Loops ................................................................... 105
14.1.5 The continue Statement ............................................................... 106
14.1.6 Break and Continue Labels ........................................................... 106
14.2 Conditional Control Flow ................................................................. 107
14.2.1 Using the if Expressions .............................................................. 107
14.2.2 Using if ... else ... Expressions .................................................. 108
14.2.3 Using if ... else if ... Expressions ............................................... 108
14.2.4 Using the when Statement ........................................................... 108
14.3 Summary ......................................................................................... 109
Table of Contents

19.2 Android Process States ................................................................. 139
  19.2.1 Foreground Process .............................................................. 140
  19.2.2 Visible Process ....................................................................... 140
  19.2.3 Service Process ...................................................................... 140
  19.2.4 Background Process ............................................................. 140
  19.2.5 Empty Process ....................................................................... 141
19.3 Inter-Process Dependencies .......................................................... 141
19.4 The Activity Lifecycle ................................................................. 141
19.5 The Activity Stack ................................................................. 141
19.6 Activity States ............................................................................ 142
19.7 Configuration Changes ............................................................... 142
19.8 Handling State Change ............................................................... 143
19.9 Summary ................................................................................... 143

20. Handling Android Activity State Changes ............................................. 145
  20.1 New vs. Old Lifecycle Techniques .............................................. 145
  20.2 The Activity and Fragment Classes ........................................... 145
  20.3 Dynamic State vs. Persistent State ........................................... 147
  20.4 The Android Lifecycle Methods .............................................. 147
  20.5 Lifetimes .................................................................................. 149
  20.6 Foldable Devices and Multi-Resume ......................................... 150
  20.7 Disabling Configuration Change Restarts .................................... 150
  20.8 Lifecycle Method Limitations ............................................... 150
  20.9 Summary ................................................................................ 151

21. Android Activity State Changes by Example ...................................... 153
  21.1 Creating the State Change Example Project ............................... 153
  21.2 Designing the User Interface ...................................................... 154
  21.3 Overriding the Activity Lifecycle Methods ............................... 154
  21.4 Filtering the Logcat Panel .......................................................... 156
  21.5 Running the Application ............................................................ 157
  21.6 Experimenting with the Activity ................................................. 157
  21.7 Summary ................................................................................ 159

22. Saving and Restoring the State of an Android Activity ................. 161
  22.1 Saving Dynamic State ............................................................... 161
  22.2 Default Saving of User Interface State ...................................... 161
  22.3 The Bundle Class ..................................................................... 162
  22.4 Saving the State ...................................................................... 163
  22.5 Restoring the State ................................................................. 164
  22.6 Testing the Application ............................................................ 164
  22.7 Summary ................................................................................ 164

23. Understanding Android Views, View Groups and Layouts ............... 165
  23.1 Designing for Different Android Devices .................................... 165
  23.2 Views and View Groups ............................................................ 165
  23.3 Android Layout Managers ......................................................... 165
  23.4 The View Hierarchy ................................................................. 167
  23.5 Creating User Interfaces ........................................................... 168
  23.6 Summary ................................................................................ 168

   25.1 How ConstraintLayout Works.............................................................................. 187
         25.1.1 Constraints.......................................................................................... 187
         25.1.2 Margins .............................................................................................. 188
         25.1.3 Opposing Constraints.......................................................................... 188
         25.1.4 Constraint Bias ................................................................................... 189
         25.1.5 Chains .................................................................................................. 190
         25.1.6 Chain Styles ...................................................................................... 190
   25.2 Baseline Alignment .......................................................................................... 191
   25.3 Configuring Widget Dimensions ...................................................................... 191
   25.4 Guideline Helper ........................................................................................... 192
   25.5 Group Helper .................................................................................................. 192
   25.6 Barrier Helper ................................................................................................ 192
   25.7 Flow Helper ................................................................................................... 194
   25.8 Ratios ............................................................................................................ 195
   25.9 ConstraintLayout Advantages ....................................................................... 195
   25.10 ConstraintLayout Availability ...................................................................... 196
   25.11 Summary ....................................................................................................... 196

   26.1 Design and Layout Views ................................................................................ 197
   26.2 Autoconnect Mode .......................................................................................... 198
   26.3 Inference Mode ............................................................................................... 199
   26.4 Manipulating Constraints Manually ................................................................ 199
   26.5 Adding Constraints in the Inspector ................................................................. 200
   26.6 Viewing Constraints in the Attributes Window .............................................. 201
   26.7 Deleting Constraints ...................................................................................... 202
   26.8 Adjusting Constraint Bias .............................................................................. 202
   26.9 Understanding ConstraintLayout Margins ................................................... 203
   26.10 The Importance of Opposing Constraints and Bias .................................... 204
   26.11 Configuring Widget Dimensions .................................................................. 206
   26.12 Design Time Tools Positioning .................................................................... 207
# Table of Contents

26.13 Adding Guidelines ................................................................. 208
26.14 Adding Barriers ........................................................................ 210
26.15 Adding a Group ........................................................................ 211
26.16 Working with the Flow Helper .................................................. 212
26.17 Widget Group Alignment and Distribution ................................. 213
26.18 Converting other Layouts to ConstraintLayout .......................... 214
26.19 Summary .................................................................................. 214

27. Working with ConstraintLayout Chains and Ratios in Android Studio ......................................................... 215

27.1 Creating a Chain ........................................................................ 215
27.2 Changing the Chain Style .......................................................... 217
27.3 Spread Inside Chain Style .......................................................... 217
27.4 Packed Chain Style ..................................................................... 218
27.5 Packed Chain Style with Bias ...................................................... 218
27.6 Weighted Chain ......................................................................... 218
27.7 Working with Ratios ................................................................. 219
27.8 Summary ..................................................................................... 221

28. An Android Studio Layout Editor ConstraintLayout Tutorial ................................................................. 223

28.1 An Android Studio Layout Editor Tool Example ............................................. 223
28.2 Creating a New Activity ................................................................... 223
28.3 Preparing the Layout Editor Environment ............................................... 225
28.4 Adding the Widgets to the User Interface .............................................. 226
28.5 Adding the Constraints ....................................................................... 229
28.6 Testing the Layout ............................................................................ 230
28.7 Using the Layout Inspector .............................................................. 231
28.8 Summary ....................................................................................... 232


29.1 Manually Creating an XML Layout ................................................ 233
29.2 Manual XML vs. Visual Layout Design ............................................. 236
29.3 Summary ....................................................................................... 236

30. Managing Constraints using Constraint Sets ......................................................... 237

30.1 Kotlin Code vs. XML Layout Files ................................................... 237
30.2 Creating Views ............................................................................... 237
30.3 View Attributes ............................................................................. 238
30.4 Constraint Sets ............................................................................ 238
30.4.1 Establishing Connections ............................................................ 238
30.4.2 Applying Constraints to a Layout ............................................... 238
30.4.3 Parent Constraint Connections .................................................... 238
30.4.4 Sizing Constraints ...................................................................... 239
30.4.5 Constraint Bias ........................................................................ 239
30.4.6 Alignment Constraints .............................................................. 239
30.4.7 Copying and Applying Constraint Sets ........................................... 239
30.4.8 ConstraintLayout Chains ............................................................ 239
30.4.9 Guidelines ................................................................................ 240
30.4.10 Removing Constraints .............................................................. 240
30.4.11 Scaling .................................................................................... 240
30.4.12 Rotation .................................................................................. 241
30.5 Summary ..................................................................................... 241
# Table of Contents

31. **An Android ConstraintSet Tutorial** .............................................................. 243  
   31.1 Creating the Example Project in Android Studio ............................................. 243  
   31.2 Adding Views to an Activity ........................................................................... 243  
   31.3 Setting View Attributes ................................................................................. 244  
   31.4 Creating View IDs ......................................................................................... 245  
   31.5 Configuring the Constraint Set ...................................................................... 246  
   31.6 Adding the EditText View ........................................................................... 247  
   31.7 Converting Density Independent Pixels (dp) to Pixels (px) ......................... 248  
   31.8 Summary ....................................................................................................... 249  

32. **A Guide to using Apply Changes in Android Studio** ..................................... 251  
   32.1 Introducing Apply Changes ........................................................................... 251  
   32.2 Understanding Apply Changes Options ......................................................... 251  
   32.3 Using Apply Changes .................................................................................... 252  
   32.4 Configuring Apply Changes Fallback Settings ............................................. 253  
   32.5 An Apply Changes Tutorial ......................................................................... 253  
   32.6 Using Apply Code Changes ......................................................................... 253  
   32.7 Using Apply Changes and Restart Activity ................................................. 254  
   32.8 Using Run App ............................................................................................. 254  
   32.9 Summary ..................................................................................................... 254  

33. **An Overview and Example of Android Event Handling** ................................ 255  
   33.1 Understanding Android Events ..................................................................... 255  
   33.2 Using the android:onClick Resource ........................................................... 255  
   33.3 Event Listeners and Callback Methods ....................................................... 256  
   33.4 An Event Handling Example ....................................................................... 256  
   33.5 Designing the User Interface ...................................................................... 257  
   33.6 The Event Listener and Callback Method .................................................. 258  
   33.7 Consuming Events ....................................................................................... 259  
   33.8 Summary ..................................................................................................... 260  

34. **Android Touch and Multi-touch Event Handling** ....................................... 261  
   34.1 Intercepting Touch Events .......................................................................... 261  
   34.2 The MotionEvent Object ............................................................................ 262  
   34.3 Understanding Touch Actions ..................................................................... 262  
   34.4 Handling Multiple Touches .......................................................................... 262  
   34.5 An Example Multi-Touch Application ......................................................... 263  
   34.6 Designing the Activity User Interface .......................................................... 263  
   34.7 Implementing the Touch Event Listener ...................................................... 263  
   34.8 Running the Example Application ............................................................... 266  
   34.9 Summary .................................................................................................... 266  

35. **Detecting Common Gestures Using the Android Gesture Detector Class** ........ 267  
   35.1 Implementing Common Gesture Detection .................................................. 267  
   35.2 Creating an Example Gesture Detection Project ......................................... 268  
   35.3 Implementing the Listener Class .................................................................. 268  
   35.4 Creating the GestureDetectorCompat Instance ....................................... 270  
   35.5 Implementing the onTouchEvent() Method ............................................... 270  
   35.6 Testing the Application ............................................................................... 271  
   35.7 Summary .................................................................................................... 271
# Table of Contents

45. Working with Android Lifecycle-Aware Components ................................................................. 341  
45.1 Lifecycle Awareness .................................................................................................................. 341  
45.2 Lifecycle Owners ...................................................................................................................... 341  
45.3 Lifecycle Observers .................................................................................................................. 342  
45.4 Lifecycle States and Events ...................................................................................................... 342  
45.5 Summary .................................................................................................................................. 343  

46. An Android Jetpack Lifecycle Awareness Tutorial ........................................................................ 345  
46.1 Creating the Example Lifecycle Project .................................................................................... 345  
46.2 Creating a Lifecycle Observer .................................................................................................... 345  
46.3 Adding the Observer .................................................................................................................. 346  
46.4 Testing the Observer .................................................................................................................. 347  
46.5 Creating a Lifecycle Owner ....................................................................................................... 347  
46.6 Testing the Custom Lifecycle Owner ....................................................................................... 349  
46.7 Summary .................................................................................................................................. 349  

47. An Overview of the Navigation Architecture Component .......................................................... 351  
47.1 Understanding Navigation ....................................................................................................... 351  
47.2 Declaring a Navigation Host ..................................................................................................... 352  
47.3 The Navigation Graph .............................................................................................................. 354  
47.4 Accessing the Navigation Controller ...................................................................................... 355  
47.5 Triggering a Navigation Action ............................................................................................... 355  
47.6 Passing Arguments .................................................................................................................... 356  
47.7 Summary .................................................................................................................................. 356  

48. An Android Jetpack Navigation Component Tutorial ................................................................... 357  
48.1 Creating the NavigationDemo Project ....................................................................................... 357  
48.2 Adding Navigation to the Build Configuration ......................................................................... 357  
48.3 Creating the Navigation Graph Resource File ......................................................................... 358  
48.4 Declaring a Navigation Host .................................................................................................... 359  
48.5 Adding Navigation Destinations ............................................................................................... 361  
48.6 Designing the Destination Fragment Layouts .......................................................................... 362  
48.7 Adding an Action to the Navigation Graph .............................................................................. 363  
48.8 Implement the OnFragmentInteractionListener ...................................................................... 365  
48.9 Adding View Binding Support to the Destination Fragments .................................................. 366  
48.10 Triggering the Action .............................................................................................................. 366  
48.11 Passing Data Using Safeargs .................................................................................................. 367  
48.12 Summary ................................................................................................................................ 370  

49. An Introduction to MotionLayout .................................................................................................. 371  
49.1 An Overview of MotionLayout ................................................................................................. 371  
49.2 MotionLayout ............................................................................................................................ 371  
49.3 MotionScene .............................................................................................................................. 371  
49.4 Configuring ConstraintSets ...................................................................................................... 372  
49.5 Custom Attributes ..................................................................................................................... 373
49.6 Triggering an Animation ................................................................. 374
49.7 Arc Motion .................................................................................. 376
49.8 Keyframes .................................................................................. 376
  49.8.1 Attribute Keyframes ................................................................. 376
  49.8.2 Position Keyframes ................................................................. 377
49.9 Time Linearity ............................................................................ 380
49.10 KeyTrigger ............................................................................... 380
49.11 Cycle and Time Cycle Keyframes ................................................. 381
49.12 Starting an Animation from Code .................................................. 381
49.13 Summary .................................................................................. 382

50. An Android MotionLayout Editor Tutorial ............................................ 383

  50.1 Creating the MotionLayoutDemo Project ......................................... 383
  50.2 ConstraintLayout to MotionLayout Conversion .................................. 383
  50.3 Configuring Start and End Constraints ........................................... 385
  50.4 Previewing the MotionLayout Animation ........................................ 387
  50.5 Adding an OnClick Gesture .......................................................... 388
  50.6 Adding an Attribute Keyframe to the Transition .............................. 389
  50.7 Adding a CustomAttribute to a Transition ....................................... 392
  50.8 Adding Position Keyframes .......................................................... 393
  50.9 Summary .................................................................................. 396

51. A MotionLayout KeyCycle Tutorial .................................................... 397

  51.1 An Overview of Cycle Keyframes ................................................. 397
  51.2 Using the Cycle Editor ............................................................... 401
  51.3 Creating the KeyCycleDemo Project ............................................. 402
  51.4 Configuring the Start and End Constraints ..................................... 402
  51.5 Creating the Cycles ................................................................. 404
  51.6 Previewing the Animation .......................................................... 406
  51.7 Adding the KeyFrameSet to the MotionScene ................................. 406
  51.8 Summary .................................................................................. 408

52. Working with the Floating Action Button and Snackbar ....................... 409

  52.1 The Material Design ................................................................. 409
  52.2 The Design Library ................................................................. 409
  52.3 The Floating Action Button (FAB) .................................................. 409
  52.4 The Snackbar ........................................................................... 410
  52.5 Creating the Example Project ..................................................... 411
  52.6 Reviewing the Project ............................................................... 411
  52.7 Removing Navigation Features ................................................... 412
  52.8 Changing the Floating Action Button .......................................... 413
  52.9 Adding an Action to the Snackbar .............................................. 414
  52.10 Summary .............................................................................. 414

53. Creating a Tabbed Interface using the TabLayout Component ............... 415

  53.1 An Introduction to the ViewPager2 ............................................ 415
  53.2 An Overview of the TabLayout Component ................................ 415
  53.3 Creating the TabLayoutDemo Project ......................................... 416
  53.4 Creating the First Fragment ....................................................... 416
  53.5 Duplicating the Fragments ........................................................ 418
  53.6 Adding the TabLayout and ViewPager2 ..................................... 419
Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>53.7 Creating the Pager Adapter</td>
<td>420</td>
</tr>
<tr>
<td>53.8 Performing the Initialization Tasks</td>
<td>421</td>
</tr>
<tr>
<td>53.9 Testing the Application</td>
<td>423</td>
</tr>
<tr>
<td>53.10 Customizing the TabLayout</td>
<td>423</td>
</tr>
<tr>
<td>53.11 Summary</td>
<td>424</td>
</tr>
<tr>
<td>54. Working with the RecyclerView and CardView Widgets</td>
<td>425</td>
</tr>
<tr>
<td>54.1 An Overview of the RecyclerView</td>
<td>425</td>
</tr>
<tr>
<td>54.2 An Overview of the CardView</td>
<td>427</td>
</tr>
<tr>
<td>54.3 Summary</td>
<td>428</td>
</tr>
<tr>
<td>55. An Android RecyclerView and CardView Tutorial</td>
<td>429</td>
</tr>
<tr>
<td>55.1 Creating the CardDemo Project</td>
<td>429</td>
</tr>
<tr>
<td>55.2 Modifying the Basic Activity Project</td>
<td>429</td>
</tr>
<tr>
<td>55.3 Designing the CardView Layout</td>
<td>430</td>
</tr>
<tr>
<td>55.4 Adding the Recyclerview</td>
<td>431</td>
</tr>
<tr>
<td>55.5 Adding the Image Files</td>
<td>431</td>
</tr>
<tr>
<td>55.6 Creating the RecyclerViewAdapter</td>
<td>431</td>
</tr>
<tr>
<td>55.7 Initializing the RecyclerView Component</td>
<td>433</td>
</tr>
<tr>
<td>55.8 Testing the Application</td>
<td>434</td>
</tr>
<tr>
<td>55.9 Responding to Card Selections</td>
<td>435</td>
</tr>
<tr>
<td>55.10 Summary</td>
<td>436</td>
</tr>
<tr>
<td>56. A Layout Editor Sample Data Tutorial</td>
<td>437</td>
</tr>
<tr>
<td>56.1 Adding Sample Data to a Project</td>
<td>437</td>
</tr>
<tr>
<td>56.2 Using Custom Sample Data</td>
<td>441</td>
</tr>
<tr>
<td>56.3 Summary</td>
<td>444</td>
</tr>
<tr>
<td>57. Working with the AppBar and Collapsing Toolbar Layouts</td>
<td>445</td>
</tr>
<tr>
<td>57.1 The Anatomy of an AppBar</td>
<td>445</td>
</tr>
<tr>
<td>57.2 The Example Project</td>
<td>446</td>
</tr>
<tr>
<td>57.3 Coordinating the RecyclerView and Toolbar</td>
<td>446</td>
</tr>
<tr>
<td>57.4 Introducing the Collapsing Toolbar Layout</td>
<td>448</td>
</tr>
<tr>
<td>57.5 Changing the Title and Scrim Color</td>
<td>451</td>
</tr>
<tr>
<td>57.6 Summary</td>
<td>452</td>
</tr>
<tr>
<td>58. An Android Studio Primary/Detail Flow Tutorial</td>
<td>453</td>
</tr>
<tr>
<td>58.1 The Primary/Detail Flow</td>
<td>453</td>
</tr>
<tr>
<td>58.2 Creating a Primary/Detail Flow Activity</td>
<td>454</td>
</tr>
<tr>
<td>58.3 Modifying the Primary/Detail Flow Template</td>
<td>455</td>
</tr>
<tr>
<td>58.4 Changing the Content Model</td>
<td>455</td>
</tr>
<tr>
<td>58.5 Changing the Detail Pane</td>
<td>457</td>
</tr>
<tr>
<td>58.6 Modifying the WebsiteDetailFragment Class</td>
<td>458</td>
</tr>
<tr>
<td>58.7 Modifying the WebsiteListFragment Class</td>
<td>459</td>
</tr>
<tr>
<td>58.8 Adding Manifest Permissions</td>
<td>459</td>
</tr>
<tr>
<td>58.9 Running the Application</td>
<td>460</td>
</tr>
<tr>
<td>58.10 Summary</td>
<td>460</td>
</tr>
<tr>
<td>59. An Overview of Android Intents</td>
<td>461</td>
</tr>
<tr>
<td>59.1 An Overview of Intents</td>
<td>461</td>
</tr>
<tr>
<td>59.2 Explicit Intents</td>
<td>461</td>
</tr>
<tr>
<td>59.3 Returning Data from an Activity</td>
<td>462</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>60.1</td>
<td>Creating the Explicit Intent Example Application</td>
</tr>
<tr>
<td>60.2</td>
<td>Designing the User Interface Layout for MainActivity</td>
</tr>
<tr>
<td>60.3</td>
<td>Creating the Second Activity Class</td>
</tr>
<tr>
<td>60.4</td>
<td>Designing the User Interface Layout for SecondActivity</td>
</tr>
<tr>
<td>60.5</td>
<td>Reviewing the Application Manifest File</td>
</tr>
<tr>
<td>60.6</td>
<td>Creating the Intent</td>
</tr>
<tr>
<td>60.7</td>
<td>Extracting Intent Data</td>
</tr>
<tr>
<td>60.8</td>
<td>Launching SecondActivity as a Sub-Activity</td>
</tr>
<tr>
<td>60.9</td>
<td>Returning Data from a Sub-Activity</td>
</tr>
<tr>
<td>60.10</td>
<td>Testing the Application</td>
</tr>
<tr>
<td>60.11</td>
<td>Summary</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.1</td>
<td>Creating the Android Studio Implicit Intent Example Project</td>
<td>479</td>
</tr>
<tr>
<td>61.2</td>
<td>Designing the User Interface</td>
<td>479</td>
</tr>
<tr>
<td>61.3</td>
<td>Creating the Implicit Intent</td>
<td>480</td>
</tr>
<tr>
<td>61.4</td>
<td>Adding a Second Matching Activity</td>
<td>481</td>
</tr>
<tr>
<td>61.5</td>
<td>Adding the Web View to the UI</td>
<td>481</td>
</tr>
<tr>
<td>61.6</td>
<td>Obtaining the Intent URL</td>
<td>482</td>
</tr>
<tr>
<td>61.7</td>
<td>Modifying the MyWebView Project Manifest File</td>
<td>483</td>
</tr>
<tr>
<td>61.8</td>
<td>Installing the MyWebView Package on a Device</td>
<td>484</td>
</tr>
<tr>
<td>61.9</td>
<td>Testing the Application</td>
<td>485</td>
</tr>
<tr>
<td>61.10</td>
<td>Manually Enabling the Link</td>
<td>485</td>
</tr>
<tr>
<td>61.11</td>
<td>Automatic Link Verification</td>
<td>487</td>
</tr>
<tr>
<td>61.12</td>
<td>Summary</td>
<td>489</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.1</td>
<td>An Overview of Broadcast Intents</td>
<td>491</td>
</tr>
<tr>
<td>62.2</td>
<td>An Overview of Broadcast Receivers</td>
<td>492</td>
</tr>
<tr>
<td>62.3</td>
<td>Obtaining Results from a Broadcast</td>
<td>493</td>
</tr>
<tr>
<td>62.4</td>
<td>Sticky Broadcast Intents</td>
<td>493</td>
</tr>
<tr>
<td>62.5</td>
<td>The Broadcast Intent Example</td>
<td>494</td>
</tr>
<tr>
<td>62.6</td>
<td>Creating the Example Application</td>
<td>494</td>
</tr>
<tr>
<td>62.7</td>
<td>Creating and Sending the Broadcast Intent</td>
<td>494</td>
</tr>
<tr>
<td>62.8</td>
<td>Creating the Broadcast Receiver</td>
<td>495</td>
</tr>
<tr>
<td>62.9</td>
<td>Registering the Broadcast Receiver</td>
<td>496</td>
</tr>
<tr>
<td>62.10</td>
<td>Testing the Broadcast Example</td>
<td>497</td>
</tr>
<tr>
<td>62.11</td>
<td>Listening for System Broadcasts</td>
<td>497</td>
</tr>
<tr>
<td>62.12</td>
<td>Summary</td>
<td>497</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.1</td>
<td>What are Coroutines?</td>
<td>499</td>
</tr>
<tr>
<td>63.2</td>
<td>Threads vs Coroutines</td>
<td>499</td>
</tr>
</tbody>
</table>
Table of Contents

63.3 Coroutine Scope ................................................................. 500
63.4 Suspend Functions ............................................................ 500
63.5 Coroutine Dispatchers ....................................................... 500
63.6 Coroutine Builders .......................................................... 501
63.7 Jobs .................................................................................. 501
63.8 Coroutines – Suspending and Resuming .............................. 502
63.9 Returning Results from a Coroutine ................................. 503
63.10 Using withContext .......................................................... 503
63.11 Coroutine Channel Communication ................................. 505
63.12 Summary ....................................................................... 506

64. An Android Kotlin Coroutines Tutorial ............................... 507
64.1 Creating the Coroutine Example Application ...................... 507
64.2 Adding Coroutine Support to the Project ......................... 507
64.3 Designing the User Interface ............................................. 507
64.4 Implementing the SeekBar ................................................ 509
64.5 Adding the Suspend Function ............................................. 509
64.6 Implementing the launchCoroutines Method .................... 510
64.7 Testing the App ............................................................... 511
64.8 Summary ....................................................................... 511

65. An Overview of Android Services ....................................... 513
65.1 Started Services ............................................................... 513
65.2 Intent Service ................................................................. 513
65.3 Bound Service ............................................................... 514
65.4 The Anatomy of a Service ................................................ 514
65.5 Controlling Destroyed Service Restart Options ................. 515
65.6 Declaring a Service in the Manifest File ............................ 515
65.7 Starting a Service Running on System Startup .................. 516
65.8 Summary ....................................................................... 516

66. Implementing an Android Started Service – A Worked Example ........................................... 517
66.1 Creating the Example Project ........................................... 517
66.2 Designing the User Interface ............................................. 517
66.3 Creating the Service Class ............................................... 517
66.4 Adding the Service to the Manifest File ............................ 519
66.5 Starting the Service ........................................................ 519
66.6 Testing the IntentService Example ................................... 520
66.7 Using the Service Class ..................................................... 520
66.8 Creating the New Service ................................................ 521
66.9 Launching the Service ..................................................... 522
66.10 Running the Application ................................................ 522
66.11 Using a Coroutine for the Service Task ......................... 523
66.12 Summary ....................................................................... 524

67. Android Local Bound Services – A Worked Example ....................................................... 525
67.1 Understanding Bound Services ....................................... 525
67.2 Bound Service Interaction Options ................................. 525
67.3 A Local Bound Service Example ..................................... 525
67.4 Adding a Bound Service to the Project ......................... 526
67.5 Implementing the Binder ............................................... 526
67.6 Binding the Client to the Service ................................................................. 528
67.7 Completing the Example .............................................................................. 529
67.8 Testing the Application .................................................................................. 531
67.9 Summary ......................................................................................................... 531

68. Android Remote Bound Services – A Worked Example ............................. 533
   68.1 Client to Remote Service Communication ............................................... 533
   68.2 Creating the Example Application ........................................................... 533
   68.3 Designing the User Interface ................................................................. 533
   68.4 Implementing the Remote Bound Service ............................................... 534
   68.5 Configuring a Remote Service in the Manifest File ............................... 535
   68.6 Launching and Binding to the Remote Service ...................................... 535
   68.7 Sending a Message to the Remote Service ............................................ 537
   68.8 Summary ..................................................................................................... 537

69. An Android Notifications Tutorial ................................................................. 539
   69.1 An Overview of Notifications ................................................................. 539
   69.2 Creating the NotifyDemo Project ............................................................ 541
   69.3 Designing the User Interface ................................................................. 541
   69.4 Creating the Second Activity ................................................................. 541
   69.5 Creating a Notification Channel ............................................................ 542
   69.6 Creating and Issuing a Notification ....................................................... 544
   69.7 Launching an Activity from a Notification ............................................ 546
   69.8 Adding Actions to a Notification ............................................................ 548
   69.9 Bundled Notifications ............................................................................ 548
   69.10 Summary ................................................................................................ 550

70. An Android Direct Reply Notification Tutorial .......................................... 551
   70.1 Creating the DirectReply Project ............................................................ 551
   70.2 Designing the User Interface ................................................................. 551
   70.3 Creating the Notification Channel .......................................................... 552
   70.4 Building the RemoteInput Object .......................................................... 553
   70.5 Creating the PendingIntent ................................................................. 554
   70.6 Creating the Reply Action ..................................................................... 554
   70.7 Receiving Direct Reply Input ................................................................. 556
   70.8 Updating the Notification ..................................................................... 556
   70.9 Summary .................................................................................................. 558

71. Foldable Devices and Multi-Window Support .............................................. 559
   71.1 Foldables and Multi-Window Support .................................................... 559
   71.2 Using a Foldable Emulator ..................................................................... 560
   71.3 Entering Multi-Window Mode ............................................................... 561
   71.4 Enabling and using Freeform Support ................................................... 562
   71.5 Checking for Freeform Support .............................................................. 562
   71.6 Enabling Multi-Window Support in an App ......................................... 562
   71.7 Specifying Multi-Window Attributes .................................................... 563
   71.8 Detecting Multi-Window Mode in an Activity ...................................... 564
   71.9 Receiving Multi-Window Notifications ................................................. 564
   71.10 Launching an Activity in Multi-Window Mode ...................................... 565
   71.11 Configuring Freeform Activity Size and Position .................................. 565
   71.12 Summary ............................................................................................... 566
Table of Contents

72. An Overview of Android SQLite Databases ................................................................. 567
   72.1 Understanding Database Tables ............................................................................. 567
   72.2 Introducing Database Schema .......................................................................... 567
   72.3 Columns and Data Types ..................................................................................... 567
   72.4 Database Rows ...................................................................................................... 568
   72.5 Introducing Primary Keys ...................................................................................... 568
   72.6 What is SQLite? ...................................................................................................... 568
   72.7 Structured Query Language (SQL) ....................................................................... 568
   72.8 Trying SQLite on an Android Virtual Device (AVD) ........................................... 569
   72.9 The Android Room Persistence Library ............................................................... 571
   72.10 Summary ............................................................................................................ 571

73. The Android Room Persistence Library ..................................................................... 573
   73.1 Revisiting Modern App Architecture ..................................................................... 573
   73.2 Key Elements of Room Database Persistence ...................................................... 573
       73.2.1 Repository ....................................................................................................... 574
       73.2.2 Room Database ............................................................................................... 574
       73.2.3 Data Access Object (DAO) .............................................................................. 574
       73.2.4 Entities ............................................................................................................. 574
       73.2.5 SQLite Database ............................................................................................... 574
   73.3 Understanding Entities ......................................................................................... 575
   73.4 Data Access Objects ............................................................................................. 577
   73.5 The Room Database ............................................................................................. 578
   73.6 The Repository ..................................................................................................... 579
   73.7 In-Memory Databases .......................................................................................... 580
   73.8 Database Inspector ............................................................................................... 580
   73.9 Summary .............................................................................................................. 581

74. An Android TableLayout and TableRow Tutorial ..................................................... 583
   74.1 The TableLayout and TableRow Layout Views ..................................................... 583
   74.2 Creating the Room Database Project ................................................................. 584
   74.3 Converting to a LinearLayout .............................................................................. 584
   74.4 Adding the TableLayout to the User Interface .................................................... 585
   74.5 Configuring the TableRows ................................................................................ 586
   74.6 Adding the Button Bar to the Layout ................................................................. 587
   74.7 Adding the RecyclerView .................................................................................... 588
   74.8 Adjusting the Layout Margins .............................................................................. 589
   74.9 Summary ............................................................................................................ 589

75. An Android Room Database and Repository Tutorial .............................................. 591
   75.1 About the RoomDemo Project ............................................................................. 591
   75.2 Modifying the Build Configuration ..................................................................... 591
   75.3 Building the Entity ............................................................................................... 592
   75.4 Creating the Data Access Object ....................................................................... 593
   75.5 Adding the Room Database ................................................................................. 594
   75.6 Adding the Repository ....................................................................................... 595
   75.7 Modifying the ViewModel ................................................................................... 598
   75.8 Creating the Product Item Layout ..................................................................... 599
   75.9 Adding the RecyclerView Adapter ................................................................. 600
   75.10 Preparing the Main Fragment .......................................................................... 601
Table of Contents

81. Making Runtime Permission Requests in Android ................................................................. 639
  81.1 Understanding Normal and Dangerous Permissions ......................................................... 639
  81.2 Creating the Permissions Example Project ................................................................. 641
  81.3 Checking for a Permission ............................................................................................... 641
  81.4 Requesting Permission at Runtime .................................................................................. 642
  81.5 Providing a Rationale for the Permission Request .......................................................... 644
  81.6 Testing the Permissions App ........................................................................................... 645
  81.7 Summary ......................................................................................................................... 646

82. Android Audio Recording and Playback using MediaPlayer and MediaRecorder ............... 647
  82.1 Playing Audio .................................................................................................................. 647
  82.2 Recording Audio and Video using the MediaRecorder Class .............................................. 648
  82.3 About the Example Project ............................................................................................. 649
  82.4 Creating the AudioApp Project ....................................................................................... 649
  82.5 Designing the User Interface ........................................................................................... 649
  82.6 Checking for Microphone Availability ............................................................................. 650
  82.7 Initializing the Activity ..................................................................................................... 650
  82.8 Implementing the recordAudio() Method ......................................................................... 652
  82.9 Implementing the stopAudio() Method ............................................................................ 652
  82.10 Implementing the playAudio() method .......................................................................... 653
  82.11 Configuring and Requesting Permissions ....................................................................... 653
  82.12 Testing the Application .................................................................................................. 656
  82.13 Summary ....................................................................................................................... 656

83. Printing with the Android Printing Framework .................................................................... 657
  83.1 The Android Printing Architecture .................................................................................... 657
  83.2 The Print Service Plugins ............................................................................................... 657
  83.3 Google Cloud Print ........................................................................................................... 658
  83.4 Printing to Google Drive .................................................................................................. 658
  83.5 Save as PDF ...................................................................................................................... 659
  83.6 Printing from Android Devices ........................................................................................ 659
  83.7 Options for Building Print Support into Android Apps ..................................................... 660
    83.7.1 Image Printing .............................................................................................................. 660
    83.7.2 Creating and Printing HTML Content ............................................................................ 661
    83.7.3 Printing a Web Page .................................................................................................... 662
    83.7.4 Printing a Custom Document ....................................................................................... 663
  83.8 Summary ......................................................................................................................... 663

84. An Android HTML and Web Content Printing Example ................................................... 665
  84.1 Creating the HTML Printing Example Application ......................................................... 665
  84.2 Printing Dynamic HTML Content ................................................................................... 665
  84.3 Creating the Web Page Printing Example ..................................................................... 668
  84.4 Removing the Floating Action Button ............................................................................. 668
  85.1 An Overview of Android Custom Document Printing ........................................................ 675
  85.2 Preparing the Custom Document Printing Project .............................................................. 676
  85.3 Creating the Custom Print Adapter ..................................................................................... 677
  85.4 Implementing the onLayout() Callback Method ................................................................. 678
  85.5 Implementing the onWrite() Callback Method ................................................................. 681
  85.6 Checking a Page is in Range ............................................................................................. 683
  85.7 Drawing the Content on the Page Canvas ......................................................................... 684
  85.8 Starting the Print Job ........................................................................................................ 686
  85.9 Testing the Application ..................................................................................................... 687
  85.10 Summary .......................................................................................................................... 687

86. An Introduction to Android App Links ................................................................................. 689
  86.1 An Overview of Android App Links .................................................................................. 689
  86.2 App Link Intent Filters .................................................................................................... 689
  86.3 Handling App Link Intents ............................................................................................... 690
  86.4 Associating the App with a Website .................................................................................. 690
  86.5 Summary .......................................................................................................................... 691

87. An Android Studio App Links Tutorial ................................................................................ 693
  87.1 About the Example App .................................................................................................... 693
  87.2 The Database Schema ...................................................................................................... 693
  87.3 Loading and Running the Project ...................................................................................... 694
  87.4 Adding the URL Mapping ............................................................................................... 695
  87.5 Adding the Intent Filter .................................................................................................. 698
  87.6 Adding Intent Handling Code .......................................................................................... 698
  87.7 Testing the App ................................................................................................................ 701
  87.8 Creating the Digital Asset Links File ............................................................................... 701
  87.9 Testing the App Link ...................................................................................................... 702
  87.10 Summary ........................................................................................................................ 702

88. An Android Biometric Authentication Tutorial ................................................................... 703
  88.1 An Overview of Biometric Authentication ...................................................................... 703
  88.2 Creating the Biometric Authentication Project ............................................................... 703
  88.3 Configuring Device Fingerprint Authentication .............................................................. 704
  88.4 Adding the BiometricPermission to the Manifest File .................................................... 704
  88.5 Designing the User Interface ............................................................................................ 705
  88.6 Adding a Toast Convenience Method .............................................................................. 705
  88.7 Checking the Security Settings ........................................................................................ 706
  88.8 Configuring the Authentication Callbacks ...................................................................... 707
  88.9 Adding the CancellationSignal ....................................................................................... 708
  88.10 Starting the Biometric Prompt ....................................................................................... 708
  88.11 Testing the Project ......................................................................................................... 709
# Table of Contents

**89. Creating, Testing and Uploading an Android App Bundle** .......................................................... 711

- 89.1 The Release Preparation Process ................................................................................................ 711
- 89.2 Android App Bundles .................................................................................................................. 711
- 89.3 Register for a Google Play Developer Console Account ............................................................... 712
- 89.4 Configuring the App in the Console ............................................................................................. 713
- 89.5 Enabling Google Play App Signing ............................................................................................... 714
- 89.6 Creating a Keystore File ................................................................................................................ 714
- 89.7 Creating the Android App Bundle ................................................................................................ 716
- 89.8 Generating Test APK Files .......................................................................................................... 717
- 89.9 Uploading the App Bundle to the Google Play Developer Console ............................................ 718
- 89.10 Exploring the App Bundle .......................................................................................................... 719
- 89.11 Managing Testers ....................................................................................................................... 720
- 89.12 Rolling the App Out for Testing .................................................................................................. 720
- 89.13 Uploading New App Bundle Revisions ...................................................................................... 721
- 89.14 Analyzing the App Bundle File .................................................................................................. 722
- 89.15 Summary ..................................................................................................................................... 722

**90. An Overview of Android Dynamic Feature Modules** ................................................................ 725

- 90.1 An Overview of Dynamic Feature Modules ................................................................................ 725
- 90.2 Dynamic Feature Module Architecture ....................................................................................... 725
- 90.3 Creating a Dynamic Feature Module .......................................................................................... 726
- 90.4 Converting an Existing Module for Dynamic Delivery ............................................................... 728
- 90.5 Working with Dynamic Feature Modules .................................................................................... 731
- 90.6 Handling Large Dynamic Feature Modules .............................................................................. 732
- 90.7 Summary ...................................................................................................................................... 733

**91. An Android Studio Dynamic Feature Tutorial** ............................................................................. 735

- 91.1 Creating the DynamicFeature Project ......................................................................................... 735
- 91.2 Adding Dynamic Feature Support to the Project ........................................................................ 735
- 91.3 Designing the Base Activity User Interface ................................................................................. 736
- 91.4 Adding the Dynamic Feature Module ......................................................................................... 737
- 91.5 Reviewing the Dynamic Feature Module .................................................................................... 738
- 91.6 Adding the Dynamic Feature Activity .......................................................................................... 739
- 91.7 Implementing the launchIntent() Method .................................................................................... 742
- 91.8 Uploading the App Bundle for Testing ......................................................................................... 743
- 91.9 Implementing the installFeature() Method ............................................................................... 744
- 91.10 Adding the Update Listener ....................................................................................................... 745
- 91.11 Using Deferred Installation ........................................................................................................ 748
- 91.12 Removing a Dynamic Module .................................................................................................... 748
- 91.13 Summary .................................................................................................................................... 748

**92. Working with Material Design 3 Theming** ................................................................................... 749

- 92.1 Material Design 2 vs Material Design 3 ...................................................................................... 749
- 92.2 Understanding Material Design Theming .................................................................................... 749
- 92.3 Material Design 2 Theming .......................................................................................................... 751
- 92.4 Material Design 3 Theming .......................................................................................................... 752
- 92.5 Building a Custom Theme ........................................................................................................... 753
- 92.6 Summary ...................................................................................................................................... 753

**93. A Material Design 3 Theming and Dynamic Color Tutorial** .......................................................... 755
# Table of Contents

93.1 Creating the ThemeDemo Project ................................................................. 755
93.2 Designing the User Interface ................................................................. 755
93.3 Migrating to Material Design 3 ............................................................. 757
93.4 Building a New Theme ........................................................................... 758
93.5 Adding the Theme to the Project ......................................................... 759
93.6 Enabling Dynamic Color Support ......................................................... 760
93.7 Summary ................................................................................................. 761

94. An Overview of Gradle in Android Studio .............................................. 763

94.1 An Overview of Gradle ........................................................................... 763
94.2 Gradle and Android Studio ..................................................................... 763
  94.2.1 Sensible Defaults ............................................................................. 763
  94.2.2 Dependencies ............................................................................... 763
  94.2.3 Build Variants .............................................................................. 764
  94.2.4 Manifest Entries ............................................................................ 764
  94.2.5 APK Signing ................................................................................. 764
  94.2.6 ProGuard Support ....................................................................... 764
94.3 The Property and Settings Gradle Build File ........................................ 764
94.4 The Top-level Gradle Build File ............................................................ 765
94.5 Module Level Gradle Build Files .......................................................... 766
94.6 Configuring Signing Settings in the Build File ....................................... 768
94.7 Running Gradle Tasks from the Command-line ..................................... 769
94.8 Summary ................................................................................................. 770

Index .................................................................................................................. 771
1. Introduction

Fully updated for Android Studio Bumble Bee, the goal of this book is to teach the skills necessary to develop Android-based applications using the Kotlin programming language.

Beginning with the basics, this book provides an outline of the steps necessary to set up an Android development and testing environment followed by an introduction to programming in Kotlin including data types, control flow, functions, lambdas and object-oriented programming.

An overview of Android Studio is included covering areas such as tool windows, the code editor and the Layout Editor tool. An introduction to the architecture of Android is followed by an in-depth look at the design of Android applications and user interfaces using the Android Studio environment.

Chapters are also included covering the Android Architecture Components including view models, lifecycle management, Room database access, the Database Inspector, app navigation, live data, and data binding.

More advanced topics such as intents are also covered, as are touch screen handling, gesture recognition, and the recording and playback of audio. This edition of the book also covers printing, transitions, cloud-based file storage, and foldable device support.

The concepts of material design are also covered in detail, including the use of floating action buttons, Snackbars, tabbed interfaces, card views, navigation drawers, and collapsing toolbars.

Other key features of Android Studio Bumble Bee and Android are also covered in detail including the Layout Editor, the ConstraintLayout and ConstraintSet classes, MotionLayout Editor, view binding, constraint chains, barriers, and direct reply notifications.

Chapters also cover advanced features of Android Studio such as App Links, Dynamic Delivery, Gradle build configuration, and submitting apps to the Google Play Developer Console.

Assuming you already have some programming experience, are ready to download Android Studio and the Android SDK, have access to a Windows, Mac, or Linux system, and have ideas for some apps to develop, you are ready to get started.

1.1 Downloading the Code Samples

The source code and Android Studio project files for the examples contained in this book are available for download at:


The steps to load a project from the code samples into Android Studio are as follows:

1. From the Welcome to Android Studio dialog, click on the Open button option.

2. In the project selection dialog, navigate to and select the folder containing the project to be imported and click on OK.
Introduction

1.2 Feedback
We want you to be satisfied with your purchase of this book. If you find any errors in the book, or have any comments, questions or concerns please contact us at feedback@ebookfrenzy.com.

1.3 Errata
While we make every effort to ensure the accuracy of the content of this book, it is inevitable that a book covering a subject area of this size and complexity may include some errors and oversights. Any known issues with the book will be outlined, together with solutions, at the following URL:

https://www.ebookfrenzy.com/errata/bumblebeekotlin.html

If you find an error not listed in the errata, please let us know by emailing our technical support team at feedback@ebookfrenzy.com. They are there to help you and will work to resolve any problems you may encounter.
2. Setting up an Android Studio Development Environment

Before any work can begin on the development of 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) which also includes the Android Software Development Kit (SDK), the Kotlin plug-in and 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 (see below)
- Approximately 8GB of available disk space
- 1280 x 800 minimum screen resolution

Although Android Studio will run on computers with 8GB of RAM, performance will be greatly improved on systems containing more memory. This is particularly an issue if you plan to test your apps using the Android Virtual Device emulator (AVD).

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 Bumble Bee 2021.1.1 using the Android API 32 SDK which, at the time of writing, are the current versions.

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:


If this page provides instructions for downloading a newer version of Android Studio it is important to note that there may be some minor differences between this book and the software. A web search for “Android Studio Bumble Bee” should provide the option to download the older version if these differences become a problem.
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 being 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 and whether or not it should be made available to other users of the system. When prompted to select the components to install, make sure that the Android Studio and Android Virtual Device options are all 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 \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 on the Install button to begin the installation process.

On versions of Windows with a Start menu, the newly installed Android Studio can be launched from the entry added to that menu during the installation. The executable may be pinned to the taskbar for easy access by navigating to the Android Studio\bin directory, right-clicking on the studio64 executable, and selecting the Pin to Taskbar menu option (on Windows 11 this option can be found by selecting Show more options from the menu).

2.3.2 Installation on macOS

Android Studio for macOS is downloaded in the form of 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:

![Android Studio on macOS](image)

Figure 2-1

To install the package, simply 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.
Setting up an Android Studio Development Environment

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:

```
unzip /<path to package>/android-studio-ide-<version>-linux.zip
```

Note that the Android Studio bundle will be installed into a subdirectory named `android-studio`. Assuming, therefore, 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
```

When running on a 64-bit Linux system, it may be necessary to install some 32-bit support libraries before Android Studio will run. On Ubuntu these libraries can be installed using the following command:

```
sudo apt-get install libc6:i386 libncurses5:i386 libstdc++6:i386 lib32z1 libbz2-1.0:i386
```

On Red Hat and Fedora-based 64-bit systems, use the following command:

```
sudo yum install zlib.i686 ncurses-libs.i686 bzip2-libs.i686
```

2.4 The Android Studio Setup Wizard

If you are installing Android Studio for the first time the initial dialog that appears once the setup process starts may resemble that shown in Figure 2-2 below:

![Android Studio Setup Wizard](image)

**Figure 2-2**

If this dialog appears, click the Next button to display the SDK Components Setup dialog (Figure 2-3). Within this dialog, make sure that the Android SDK option is selected along with the latest API package before clicking on the Next button:
After clicking Next, Android Studio will download and install the Android SDK and tools.

If you have previously installed an earlier version of Android Studio, the first time that this new version is launched, a dialog may appear providing the option to import settings from a previous Android Studio version. If you have settings from a previous version and would like to import them into the latest installation, select the appropriate option and location. Alternatively, indicate that you do not need to import any previous settings and click on the OK button to proceed.

After these initial setup steps have been taken, click the Finish button to display the Welcome to Android Studio screen:

2.5 Installing Additional Android SDK Packages

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 Preferences dialog will appear as shown in Figure 2-5:
Immediately after installing Android Studio for the first time, it is likely that only the latest released version of the Android SDK has been installed. To install older versions of the Android SDK simply select the checkboxes corresponding to the versions and click on the **Apply** button.

Most of the examples in this book will support older versions of Android as far back as Android 8.0 (Oreo). This is to ensure 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 on the **Apply** button. In the resulting confirmation dialog click on the OK button to install the SDK. 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 2-6:

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 on 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 2-7:
Within the Android SDK Tools screen, make sure that the following packages are listed as \textit{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 S

Note the Intel x86 Emulator Accelerator (HAXM installer) cannot be installed on Apple silicon-based Macs.

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

Once the installation is complete, review the package list and make sure that the selected packages are now listed as \textit{Installed} in the \textit{Status} column. If any are listed as \textit{Not installed}, make sure they are selected and click on the \textit{Apply} button again.
2.6 Making the Android SDK Tools Command-line Accessible

Most of the time, the underlying tools of the Android SDK will be accessed from within the Android Studio environment. That being said, however, there will also be instances where it will be useful to be able to invoke those tools from a command prompt or terminal window. 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 operating system, the PATH variable needs to be configured to include the following paths (where <path_to_android_sdk_installation> represents the file system location into which the Android SDK was installed):

<path_to_android_sdk_installation>/sdk/tools
<path_to_android_sdk_installation>/sdk/tools/bin
<path_to_android_sdk_installation>/sdk/platform-tools

The location of the SDK on your system can be identified 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 2-9:

![Figure 2-9](image)

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

2.6.1 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 on the Edit… button. Using the New button in the edit dialog, add three 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\platform-tools
   C:\Users\demo\AppData\Local\Android\Sdk\tools
   C:\Users\demo\AppData\Local\Android\Sdk\tools\bin

4. Click on 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:

```bash
echo %Path%
```

The returned path variable value should include the paths to the Android SDK platform tools folders. Verify that
Setting up an Android Studio Development Environment

the `platform-tools` value is correct by attempting to run the `adb` tool as follows:

```bash
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):

```bash
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.
```

### 2.6.2 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.

### 2.6.3 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 on the `Environment Variables...` button. Follow the steps outlined for Windows 8.1 starting from step 3.

### 2.6.4 Linux

On Linux, this configuration can typically be achieved 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:

```bash
export PATH=/home/demo/Android/sdk/platform-tools:/home/demo/Android/sdk/tools:/home/demo/Android/sdk/tools/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.

### 2.6.5 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:

```bash
/Users/demo/Library/Android/sdk/tools
/Users/demo/Library/Android/sdk/tools/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:

```bash
sudo vi /etc/paths.d/android-sdk
```
2.7 Android Studio Memory Management

Android Studio is a large and complex software application that consists of 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 2-10

To view and modify the current memory configuration, select the File -> Settings... (Android Studio -> Preferences... on macOS) menu option and, in the resulting dialog, select the Memory Settings option listed under System Settings in the left-hand navigation panel as illustrated in Figure 2-11 below.

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.

Figure 2-11
Setting up an Android Studio Development Environment

The IDE memory setting adjusts the memory allocated to Android Studio and applies regardless of the currently loaded project. When a project is built and run from within Android Studio, on the other hand, a number of 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 may potentially be improved by adjusting the daemon heap settings. Unlike the IDE heap settings, these settings apply only to the current project and can only be accessed when a project is open in Android Studio.

2.8 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).

2.9 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). In this chapter, we have covered the steps necessary to install these packages on Windows, macOS, and Linux.
3. Creating an Example Android App in Android Studio

The preceding chapters of this book have covered the steps necessary to configure an environment suitable for the development of Android applications using the Android Studio IDE. Before moving on to slightly more advanced topics, now is a good time to validate that all of the 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 the creation of an Android application project using Android Studio. Once the project has been created, a later chapter will explore the use of 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 make use of one of the most basic of Android Studio project templates. This simplicity allows us to introduce some of the key aspects of Android app development without overwhelming the beginner by trying to introduce 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 all of the techniques and code used in this initial example project will be covered in much greater detail in later chapters.

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:

![Welcome to Android Studio](image)

Figure 3-1

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

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

With the Empty 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 is used to uniquely identify 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 name of the application. 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 the purposes of 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: Android 8.0 (Oreo). This is the minimum SDK that will be used in most of the 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 also 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:

Finally, change the Language menu to Kotlin and click on Finish to initiate the project creation process.

3.5 Modifying the Example Application

At this point, Android Studio has created a minimal example application project and opened the main window.

The newly created project and references to associated files are listed in the Project tool window located on the left-hand side of the main project window. The Project tool window has a number of 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:
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 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:

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 wide range of other device options are available for selection by clicking on this menu.

To change the orientation of the device representation between landscape and portrait simply use the drop down menu immediately to the left of the device selection menu showing the icon.

As can be seen 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. It should be noted, however, that not all user interface components are obviously 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:

![Component Tree](image)

Figure 3-7

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

Before proceeding, also 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 make sure 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 magnet icon. When disabled the magnet appears with a diagonal line through it (Figure
3-8). If necessary, re-enable Autoconnect mode by clicking on this button.

![Autoconnect](image)

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:

![Palette](image)

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:
The next step is to change the text that is 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](image)

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 the way in which a visual component and the layout will behave with different settings without having to run 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](image)
At this point it is important to explain the warning button located in the top right-hand corner of the Layout Editor tool as indicated in Figure 3-13. Obviously, this is indicating potential problems with the layout. For details on any problems, click on the button:

![Default (en-us) ▼](image)

**Figure 3-13**

When clicked, a panel (Figure 3-14) will appear describing the nature of the problems and offering some possible corrective measures:

![Issue Explanation Panel](image)

**Figure 3-14**

Currently, the only warning listed reads as follows:

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

This I18N message is informing us that a potential issue exists with regard to 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 is reminding us that when developing Android applications, attributes and values such as text strings should be stored in the form of resources wherever possible. 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”.

Click on the Fix button in the Issue Explanation panel to display the Extract Resource panel (Figure 3-15). 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.
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 3-16:

Add any missing layout constraints by clicking on the Infer constraints button. At this point the layout should resemble that shown in Figure 3-18:
3.7 Reviewing the Layout and Resource Files

Before moving on to the next step, we are going to look at some of the internal aspects of user interface design and resource handling. In the previous section, we made some changes to 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 three buttons as highlighted in Figure 3-19 below:

![Figure 3-19](image)

By default, the editor will be in Design mode whereby just the visual representation of the layout is displayed. The left-most button will switch to Code mode to display the XML for the layout, while the middle button enters Split mode where both the layout and XML are displayed, as shown in Figure 3-20:
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 varying in complexity and content, 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
<?xml version="1.0" encoding="utf-8"?>
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context=".MainActivity"
    android:background="#ff2438" />
```

Note that the color of the layout changes in real-time to match the new setting in the XML file. Note also that a small red square appears in the left-hand margin (also referred to as the gutter) of the XML editor 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:
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:

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

As a demonstration of 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 back 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:

```xml
<resources>
  <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. To open this editor, right-click on the app -> res -> values -> strings.xml file and select the Open editor menu option. This will display the Translation Editor in the main panel of the Android Studio window:
Creating an Example Android App in Android Studio

![Figure 3-22](image-url)

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

### 3.8 Adding the Kotlin Extensions Plugin

The next section will add some code to the project so that a currency conversion occurs when the button is tapped and the result displayed to the user. Before adding this code, however, we first need to add a plugin to the project build configuration which will make it easier for us to reference the user interface widgets from within the Kotlin code. To do this, begin by opening the module level `build.gradle` file located in the project tool window (`app -> Gradle Scripts -> build.gradle (Module: AndroidSample.app)`) as shown in :

![Figure 3-23](image-url)

Once opened, modify the plugins section so that it reads as follows:

```groovy
plugins {
    id 'com.android.application'
    id 'org.jetbrains.kotlin.android'
    id '-extensions'
}
```

Finally, click on the **Sync Now** link highlighted in below to commit the change and update the project:
3.9 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 a number of different ways and is covered in detail 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:

Note that the text field for the onClick property is now highlighted with a red border to warn us that the button has been configured to call a method which does not yet exist. To address this, double-click on the MainActivity.kt file in the Project tool window (app -> 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:

```kotlin
package com.example.androidsample

import androidx.appcompat.app.AppCompatActivity
import android.os.Bundle
import android.view.View
import kotlinx.android.synthetic.main.activity_main.*
class MainActivity : AppCompatActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)
        // Method body
    }
}
```

This code imports the necessary Android packages and defines the MainActivity class. The `onCreate` method is overridden to set the content view to the activity_main layout. The body of the method is currently empty, but it will be filled in as we add the event handling code for the convert button.
fun convertCurrency(view: View) {

    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 checking the text property of the dollarText EditText view to make sure that it is not empty (in other words that the user has entered a dollar value). If a value has not been entered, a "No Value" string is displayed on the TextView using the string resource declared earlier in the chapter. If, on the other hand, a dollar amount has been entered, it is converted into a floating point value and the equivalent euro value calculated. This floating point value is then converted into a string and displayed on the TextView. If any of this is unclear, rest assured that these concepts will be covered in greater detail in later chapters.

3.10 Summary

While not excessively complex, a number of steps are involved in setting up an Android development environment. Having performed those steps, it is worth working through an example to make sure 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 in the case of string values, and briefly touched on the topic of layouts. Next we looked at the underlying XML that is used to store the user interface designs of Android applications.

Finally, an onClick event was added to a Button connected to a method that was implemented to extract the user input from the EditText component, convert 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.
4. Creating an Android Virtual Device (AVD) in Android Studio

Although the Android Studio Preview panel allows us to see the layout we are designing and test basic functionality using interactive mode, it be will necessary to compile and run an entire app to fully test that it works. An Android application may be tested by installing and running it either on a physical device or in an Android Virtual Device (AVD) emulator environment. Before an AVD can be used, it must first be created and configured to match the specifications of a particular device model. In this chapter, we will work through the creation of such a virtual device using the Pixel 4 phone as a reference example.

4.1 About Android Virtual Devices

AVDs are essentially emulators that allow Android applications to be tested without the necessity to install the application on a physical Android-based device. An AVD may be configured to emulate a variety of hardware features including options such as screen size, memory capacity, and the presence or otherwise of features such as a camera, GPS navigation support, or an accelerometer. As part of the standard Android Studio installation, several emulator templates are installed allowing AVDs to be configured for a range of different devices. Custom configurations may be created to match any physical Android device by specifying properties such as processor type, memory capacity, and the size and pixel density of the screen.

An AVD session can appear either as a separate window or embedded within the Android Studio window.

New AVDs are created and managed using the Android Virtual Device Manager, which may be used either in command-line mode or with a more user-friendly graphical user interface. To create a new AVD, the first step is to launch the AVD Manager. This can be achieved from within the Android Studio environment by selecting the Tools -> Device Manager menu option from within the main window.

Once launched, the manager will appear as a tool window as shown in Figure 4-1:

![Figure 4-1](image_url)

To add a new AVD, begin by making sure that the Virtual tab is selected before clicking on the Create device
Creating an Android Virtual Device (AVD) in Android Studio

button to open the Virtual Device Configuration dialog:

**Figure 4-2**

Within the dialog, perform the following steps to create a Pixel 4 compatible emulator:

1. From the Category panel, select the Phone option to display the list of available Android phone AVD templates.

2. Select the Pixel 4 device option and click Next.

3. On the System Image screen, select the latest version of Android. Note that if the system image has not yet been installed a Download link will be provided next to the Release Name. Click this link to download and install the system image before selecting it. If the image you need is not listed, click on the x86 Images (or ARM images if you are running a Mac with Apple Silicon) and Other images tabs to view alternative lists.

4. Click Next to proceed and enter a descriptive name (for example Pixel 4 API 32) into the name field or simply accept the default name.

5. Click Finish to create the AVD.

6. With the AVD created, the Device Manager may now be closed. If future modifications to the AVD are necessary, simply re-open the Device Manager, select the AVD from the list, and click on the pencil icon in the Actions column to edit the settings.

**4.2 Starting the Emulator**

To perform a test run of the newly created AVD emulator, simply select the emulator from the Device Manager and click on the launch button (the triangle in the Actions column). The emulator will appear embedded into the main Android Studio window and begin the startup process. The amount of time it takes for the emulator to start will depend on the configuration of both the AVD and the system on which it is running:
Creating an Android Virtual Device (AVD) in Android Studio

4.3 Running the Application in the AVD

With an AVD emulator configured, the example AndroidSample application created in the earlier chapter now can be compiled and run. With the AndroidSample project loaded into Android Studio, make sure that the newly created Pixel 4 AVD is displayed in the device menu (marked A in Figure 4-5 below), then either click on the run button represented by a green triangle (B), select the Run -> Run 'app' menu option or use the Ctrl-R
Creating an Android Virtual Device (AVD) in Android Studio

keyboard shortcut:

Figure 4-5

The device menu (A) may be used to select a different AVD instance or physical device as the run target, and also to run the app on multiple devices. The menu also provides access to the Device Manager as well as device connection configuration and troubleshooting options:

Figure 4-6

Once the application is installed and running, the user interface for the first fragment will appear within the emulator (a fragment is a reusable section of an Android project typically consisting of a user interface layout and some code, a topic which will be covered later in the chapter entitled “An Introduction to Android Fragments”):

Figure 4-7
Creating an Android Virtual Device (AVD) in Android Studio

If the activity does not automatically launch, check to see if the launch icon has appeared among the apps on the emulator. If it has, simply click on it to launch the application. Once the run process begins, the Run tool window will become available. The Run tool window will display diagnostic information as the application package is installed and launched. Figure 4-8 shows the Run tool window output from a typical successful application launch:

![Figure 4-8](image)

If problems are encountered during the launch process, the Run tool window will provide information that will hopefully help to isolate the cause of the problem.

Assuming that the application loads into the emulator and runs as expected, we have safely verified that the Android development environment is correctly installed and configured. With the app now running, try performing a temperature conversion to verify that the app works as intended.

4.4 Running on Multiple Devices

The run menu shown in Figure 4-6 above includes an option to run the app on multiple emulators and devices in parallel. When selected, this option displays the dialog shown in Figure 4-9 providing a list of both the AVDs configured on the system and any attached physical devices. Enable the checkboxes next to the emulators or devices to be targeted before clicking on the Run button:

![Figure 4-9](image)

After the Run button is clicked, Android Studio will launch the app on the selected emulators and devices.

4.5 Stopping a Running Application

To stop a running application, simply click on the stop button located in the main toolbar as shown in Figure 4-10:

![Figure 4-10](image)

An app may also be terminated using the Run tool window. Begin by displaying the Run tool window using the window bar button that becomes available when the app is running. Once the Run tool window appears, click
4.6 Supporting Dark Theme

Android 10 introduced the much-awaited dark theme, support for which is enabled by default in Android Studio app projects. To test dark theme in the AVD emulator, open the Settings app within the running Android instance in the emulator. Within the Settings app, choose the *Display* category and enable the *Dark theme* option as shown in Figure 4-12 so that the screen background turns black:

With dark theme enabled, run the AndroidSample app and note that it appears using a dark theme including a black background and a purple background color on the button as shown in Figure 4-13:

Return to the Settings app and turn off Dark theme mode before continuing.
4.7 Running the Emulator in a Separate Window

So far in this chapter, we have only used the emulator as a tool window embedded within the main Android Studio window. To run the emulator in a separate window, select the File -> Settings... menu option (Android Studio -> Preferences... on macOS), navigate to Tools -> Emulator in the left-hand navigation panel of the preferences dialog, and disable the Launch in a tool window option:

![Tools > Emulator][1]

With the option disabled, click the Apply button followed by OK to commit the change, then exit the current emulator session by clicking on the close button on the tab marked B in Figure 4-3 above.

Run the sample app once again, at which point the emulator will appear as a separate window as shown below:

![Figure 4-15][2]
Creating an Android Virtual Device (AVD) in Android Studio

The choice of standalone or tool window mode is a matter of personal preference. If you prefer the emulator running in a tool window, return to the settings screen and re-enable the *Launch in a tool window* option. Before committing to standalone mode, however, keep in mind that the emulator tool window may also be detached from the main Android Studio window by clicking on the settings button (represented by the gear icon) in the tool emulator toolbar and selecting the *View Mode -> Float* menu option:

![Figure 4-16](image)

### 4.8 Enabling the Device Frame

The emulator can be configured to appear with (Figure 4-17) or without the device frame (Figure 4-15).

![Figure 4-17](image)

To change the setting, open the Device Manager, select the AVD from the list, and click on the pencil icon in the Actions column to edit the settings. In the settings screen, locate and change the *Enable Device Frame* option:
As previously discussed, in addition to the graphical user interface it is also possible to create a new AVD directly from the command-line. This is achieved using the `avdmanager` tool in conjunction with some command-line options. Once initiated, the tool will prompt for additional information before creating the new AVD.

The `avdmanager` tool requires access to the Java Runtime Environment (JRE) to run. If, when attempting to run `avdmanager`, an error message appears indicating that the `java` command cannot be found, the command prompt or terminal window within which you are running the command can be configured to use the OpenJDK environment bundled with Android Studio. Begin by identifying the location of the OpenJDK JRE as follows:

1. Launch Android Studio and open the ComposeDemo project created earlier in the book.
2. Select the File -> Settings... menu option (Android Studio -> Preferences... on macOS).
3. Navigate to the Build, Execution, Deployment section and select the Gradle option listed under the Build Tools category.
4. Click on the Gradle JDK setting and make a note of the path for Android Studio default JDK:

On Windows, execute the following command within the command prompt window from which `avdmanager` is to be run (where `<path to jre>` is replaced by the path copied from the Project Structure dialog above):

```
set JAVA_HOME=<path to jre>
```

On macOS or Linux, execute the following command:

```
export JAVA_HOME="<path to jre>"
```

If you expect to use the `avdmanager` tool frequently, follow the environment variable steps for your operating system.
Creating an Android Virtual Device (AVD) in Android Studio

system outlined in the chapter entitled "Setting up an Android Studio Development Environment" to configure JAVA_HOME on a system-wide basis.

Assuming that the system has been configured such that the Android SDK tools directory is included in the PATH environment variable, a list of available targets for the new AVD may be obtained by issuing the following command in a terminal or command window:

```
avdmanager list targets
```

The resulting output from the above command will contain a list of Android SDK versions that are available on the system. For example:

```
Available Android targets:

id: 1 or "android-29"
  Name: Android API 29
  Type: Platform
  API level: 29
  Revision: 1

id: 2 or "android-26"
  Name: Android API 26
  Type: Platform
  API level: 26
  Revision: 1
```

The avdmanager tool also allows new AVD instances to be created from the command-line. For example, to create a new AVD named myAVD using the target ID for the Android API level 29 device using the x86 ABI, the following command may be used:

```
avdmanager create avd -n myAVD -k "system-images;android-29;google_apis_playstore;x86"
```

The avdmanager tool will create the new AVD to the specifications required for a basic Android 8 device, also providing the option to create a custom configuration to match the specification of a specific device if required.

Once a new AVD has been created from the command-line, it may not show up in the Android Device Manager tool until the Refresh button is clicked.

In addition to the creation of new AVDs, several other tasks may be performed from the command-line. For example, a list of currently available AVDs may be obtained using the list avd command-line arguments:

```
avdmanager list avd
```

```
Available Android Virtual Devices:

  Name: Pixel_XL_API_28_No_Play
  Device: pixel_xl (Google)
  Path: /Users/neilsmyth/.android/avd/Pixel_XL_API_28_No_Play.avd
  Target: Google APIs (Google Inc.)
    Based on: Android API 28 Tag/ABI: google_apis/x86
  Skin: pixel_xl_silver
  Sdcard: 512M
```

Similarly, to delete an existing AVD, simply use the delete option as follows:
4.10 Android Virtual Device Configuration Files

By default, the files associated with an AVD are stored in the .android/avd sub-directory of the user's home directory, the structure of which is as follows (where <avd name> is replaced by the name assigned to the AVD):

<avd name>.avd/config.ini
<avd name>.avd/userdata.img
<avd name>.ini

The config.ini file contains the device configuration settings such as display dimensions and memory specified during the AVD creation process. These settings may be changed directly within the configuration file and will be adopted by the AVD when it is next invoked.

The <avd name>.ini file contains a reference to the target Android SDK and the path to the AVD files. Note that a change to the image.sysdir value in the config.ini file will also need to be reflected in the target value of this file.

4.11 Moving and Renaming an Android Virtual Device

The current name or the location of the AVD files may be altered from the command-line using the avdmanager tool's move avd argument. For example, to rename an AVD named Pixel4 to Pixel4a, the following command may be executed:

avdmanager move avd -n Pixel4 -r Pixel4a

To physically relocate the files associated with the AVD, the following command syntax should be used:

avdmanager move avd -n <avd name> -p <path to new location>

For example, to move an AVD from its current file system location to /tmp/Pixel4Test:

avdmanager move avd -n Pixel4 -p /tmp/Pixel4Test

Note that the destination directory must not already exist before executing the command to move an AVD.

4.12 Summary

A typical application development process follows a cycle of coding, compiling, and running in a test environment. Android applications may be tested on either a physical Android device or using an Android Virtual Device (AVD) emulator. AVDs are created and managed using the Android Studio Device Manager tool which may be used either as a command-line tool or via a graphical user interface. When creating an AVD to simulate a specific Android device model, the virtual device should be configured with a hardware specification matching that of the physical device.

The AVD emulator session may be displayed as a standalone window or embedded into the main Android Studio user interface.
5. Using and Configuring the Android Studio AVD Emulator

Before the next chapter explores testing on physical Android devices, this chapter will take some time to provide an overview of the Android Studio AVD emulator and highlight many of the configuration features that are available to customize the environment in both standalone and tool window modes.

5.1 The Emulator Environment

When launched in standalone mode, the emulator displays an initial splash screen during the loading process. Once loaded, the main emulator window appears containing a representation of the chosen device type (in the case of Figure 5-1 this is a Pixel 4 device):

Positioned along the right-hand edge of the window is the toolbar providing quick access to the emulator controls and configuration options.

5.2 Emulator Toolbar Options

The emulator toolbar (Figure 5-2) provides access to a range of options relating to the appearance and behavior of the emulator environment.
Each button in the toolbar has associated with it a keyboard accelerator which can be identified either by hovering the mouse pointer over the button and waiting for the tooltip to appear or via the help option of the extended controls panel.

Though many of the options contained within the toolbar are self-explanatory, each option will be covered for the sake of completeness:

- **Exit / Minimize** – The uppermost ‘x’ button in the toolbar exits the emulator session when selected while the ‘-’ option minimizes the entire window.

- **Power** – The Power button simulates the hardware power button on a physical Android device. Clicking and releasing this button will lock the device and turn off the screen. Clicking and holding this button will initiate the device “Power off” request sequence.

- **Volume Up / Down** – Two buttons that control the audio volume of playback within the simulator environment.

- **Rotate Left/Right** – Rotates the emulated device between portrait and landscape orientations.

- **Take Screenshot** – Takes a screenshot of the content currently displayed on the device screen. The captured image is stored at the location specified in the Settings screen of the extended controls panel as outlined later in this chapter.

- **Zoom Mode** – This button toggles in and out of zoom mode, details of which will be covered later in this chapter.

- **Back** – Performs the standard Android “Back” navigation to return to a previous screen.

- **Home** – Displays the device home screen.

- **Overview** – Simulates selection of the standard Android “Overview” navigation which displays the currently running apps on the device.
• **Fold Device** – Simulates the folding and unfolding of a foldable device. This option is only available if the emulator is running a foldable device system image.

• **Extended Controls** – Displays the extended controls panel, allowing for the configuration of options such as simulated location and telephony activity, battery strength, cellular network type, and fingerprint identification.

5.3 Working in Zoom Mode

The zoom button located in the emulator toolbar switches in and out of zoom mode. When zoom mode is active the toolbar button is depressed and the mouse pointer appears as a magnifying glass when hovering over the device screen. Clicking the left mouse button will cause the display to zoom in relative to the selected point on the screen, with repeated clicking increasing the zoom level. Conversely, clicking the right mouse button decreases the zoom level. Toggling the zoom button off reverts the display to the default size.

Clicking and dragging while in zoom mode will define a rectangular area into which the view will zoom when the mouse button is released.

While in zoom mode the visible area of the screen may be panned using the horizontal and vertical scrollbars located within the emulator window.

5.4 Resizing the Emulator Window

The size of the emulator window (and the corresponding representation of the device) can be changed at any time by clicking and dragging on any of the corners or sides of the window.

5.5 Extended Control Options

The extended controls toolbar button displays the panel illustrated in Figure 5-3. By default, the location settings will be displayed. Selecting a different category from the left-hand panel will display the corresponding group of controls:

![Extended Controls Panel](image)

Figure 5-3
5.5.1 Location

The location controls allow simulated location information to be sent to the emulator in the form of decimal or sexigesimal coordinates. Location information can take the form of a single location, or a sequence of points representing movement of the device, the latter being provided via a file in either GPS Exchange (GPX) or Keyhole Markup Language (KML) format. Alternatively, the integrated Google Maps panel may be used to visually select single points or travel routes.

5.5.2 Displays

In addition to the main display shown within the emulator screen, the Displays option allows additional displays to be added running within the same Android instance. This can be useful for testing apps for dual-screen devices such as the Microsoft Surface Duo. These additional screens can be configured to be any required size and appear within the same emulator window as the main screen.

5.5.3 Cellular

The type of cellular connection being simulated can be changed within the cellular settings screen. Options are available to simulate different network types (CSM, EDGE, HSDPA, etc) in addition to a range of voice and data scenarios such as roaming and denied access.

5.5.4 Battery

A variety of battery state and charging conditions can be simulated on this panel of the extended controls screen, including battery charge level, battery health, and whether the AC charger is currently connected.

5.5.5 Camera

The emulator simulates a 3D scene when the camera is active. This takes the form of the interior of a virtual building through which you can navigate by holding down the Option key (Alt on Windows) while using the mouse pointer and keyboard keys when recording video or before taking a photo within the emulator. This extended configuration option allows different images to be uploaded for display within the virtual environment.

5.5.6 Phone

The phone extended controls provide two very simple but useful simulations within the emulator. The first option allows for the simulation of an incoming call from a designated phone number. This can be of particular use when testing how an app handles high-level interrupts of this nature.

The second option allows the receipt of text messages to be simulated within the emulator session. As in the real world, these messages appear within the Message app and trigger the standard notifications within the emulator.

5.5.7 Directional Pad

A directional pad (D-Pad) is an additional set of controls either built into an Android device or connected externally (such as a game controller) that provides directional controls (left, right, up, down). The directional pad settings allow D-Pad interaction to be simulated within the emulator.

5.5.8 Microphone

The microphone settings allow the microphone to be enabled and virtual headset and microphone connections to be simulated. A button is also provided to launch the Voice Assistant on the emulator.

5.5.9 Fingerprint

Many Android devices are now supplied with built-in fingerprint detection hardware. The AVD emulator makes it possible to test fingerprint authentication without the need to test apps on a physical device containing a fingerprint sensor. Details on how to configure fingerprint testing within the emulator will be covered in detail later in this chapter.
5.5.10 Virtual Sensors

The virtual sensors option allows the accelerometer and magnetometer to be simulated to emulate the effects of the physical motion of a device such as rotation, movement, and tilting through yaw, pitch and roll settings.

5.5.11 Snapshots

Snapshots contain the state of the currently running AVD session to be saved and rapidly restored making it easy to return the emulator to an exact state. Snapshots are covered in later in this chapter.

5.5.12 Record and Playback

Allows the emulator screen and audio to be recorded and saved in either WebM or animated GIF format.

5.5.13 Google Play

If the emulator is running a version of Android with Google Play Services installed, this option displays the current Google Play version and provides the option to update the emulator to the latest version.

5.5.14 Settings

The settings panel provides a small group of configuration options. Use this panel to choose a darker theme for the toolbar and extended controls panel, specify a file system location into which screenshots are to be saved, configure OpenGL support levels, and configure the emulator window to appear on top of other windows on the desktop.

5.5.15 Help

The Help screen contains three sub-panels containing a list of keyboard shortcuts, links to access the emulator online documentation, file bugs and send feedback, and emulator version information.

5.6 Working with Snapshots

When an emulator starts for the very first time it performs a cold boot much like a physical Android device when it is powered on. This cold boot process can take some time to complete as the operating system loads and all the background processes are started. To avoid the necessity of going through this process every time the emulator is started, the system is configured to automatically save a snapshot (referred to as a quick-boot snapshot) of the emulator’s current state each time it exits. The next time the emulator is launched, the quick-boot snapshot is loaded into memory and execution resumes from where it left off previously, allowing the emulator to restart in a fraction of the time needed for a cold boot to complete.

The Snapshots screen of the extended controls panel can be used to store additional snapshots at any point during the execution of the emulator. This saves the exact state of the entire emulator allowing the emulator to be restored to the exact point in time that the snapshot was taken. From within the screen, snapshots can be taken using the Take Snapshot button (marked A in Figure 5-4). To restore an existing snapshot, select it from the list (B) and click the run button (C) located at the bottom of the screen. Options are also provided to edit (D) the snapshot name and description and to delete (E) the currently selected snapshot:
Using and Configuring the Android Studio AVD Emulator

Figure 5-4
The Settings option (F) provides the option to configure the automatic saving of quick-boot snapshots (by default the emulator will ask whether to save the quick boot snapshot each time the emulator exits) and to reload the most recent snapshot. To force an emulator session to perform a cold boot instead of using a previous quick-boot snapshot, open the AVD Manager (Tools -> AVD Manager), click on the down arrow in the Actions column for the emulator and select the Cold Boot Now menu option.

Figure 5-5

5.7 Configuring Fingerprint Emulation
The emulator allows up to 10 simulated fingerprints to be configured and used to test fingerprint authentication within Android apps. To configure simulated fingerprints begin by launching the emulator, opening the Settings app, and selecting the Security & Location option.

Within the Security settings screen, select the Use fingerprint option. On the resulting information screen click on the Next button to proceed to the Fingerprint setup screen. Before fingerprint security can be enabled a backup screen unlocking method (such as a PIN) must be configured. Click on the Fingerprint + PIN button and, when prompted, choose not to require the PIN on device startup. Enter and confirm a suitable PIN and complete the PIN entry process by accepting the default notifications option.

Proceed through the remaining screens until the Settings app requests a fingerprint on the sensor. At this point display the extended controls dialog, select the Fingerprint category in the left-hand panel and make sure that
Finger 1 is selected in the main settings panel:

Click on the Touch the Sensor button to simulate Finger 1 touching the fingerprint sensor. The emulator will report the successful addition of the fingerprint:

To add additional fingerprints click on the Add Another button and select another finger from the extended controls panel menu before clicking on the Touch the Sensor button once again.

5.8 The Emulator in Tool Window Mode

As outlined in the previous chapter ("Creating an Android Virtual Device (AVD) in Android Studio"), Android Studio can be configured to launch the emulator as an embedded tool window so that it does not appear in a separate window. When running in this mode, the same controls available in standalone mode are provided in the toolbar as shown in Figure 5-8:
Using and Configuring the Android Studio AVD Emulator

![Emulator: Pixel 2 XL API 31 900MB](image)

Figure 5-8

From left to right, these buttons perform the following tasks (details of which match those for standalone mode):
- Power
- Volume Up
- Volume Down
- Rotate Left
- Rotate Right
- Back
- Home
- Overview
- Screenshot
- Snapshots
- Extended Controls

5.9 Summary

Android Studio contains an Android Virtual Device emulator environment designed to make it easier to test applications without the need to run on a physical Android device. This chapter has provided a brief tour of the emulator and highlighted key features that are available to configure and customize the environment to simulate different testing conditions.
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, doing so 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 considerably shorten the learning curve in later chapters of the book. With this in mind, this chapter will provide an initial overview of the various areas and components that make up 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 by-pass the welcome screen next time it is launched, automatically opening the previously active project.

In addition to a list of recent projects, the welcome screen provides a range of 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 via the Plugins option.

Additional options are available by clicking on the menu button as shown in Figure 6-2:
6.2 The Main Window

When a new project is created, or an existing one opened, the Android Studio main window will appear. When multiple projects are open simultaneously, each will be assigned its own main window. The precise configuration of the window will vary depending on which tools and panels were displayed the last time the project was open, but will typically resemble that of Figure 6-3.

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

A – Menu Bar – Contains a range of menus for performing tasks within the Android Studio environment.

B – Toolbar – A selection of shortcuts to frequently performed actions. The toolbar buttons provide quicker access to a select group of menu bar actions. The toolbar can be customized by right-clicking on the bar and selecting the Customize Menus and Toolbars… menu option. If the toolbar is not visible, it can be displayed using the View -> Appearance -> Toolbar menu option.

C – 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. Select a method from the list to be taken to the corresponding location within the code editor. Hide and display this bar using the View -> Appearance -> Navigation Bar menu option.
**D – Editor Window** – The editor window displays the content of the file on which the developer is currently working. What gets displayed in this location, however, is subject to context. When editing code, for example, the code editor will appear. When working on a user interface layout file, on the other hand, the user interface Layout Editor tool will appear. When multiple files are open, each file is represented by a tab located along the top edge of the editor as shown in Figure 6-4.

![Figure 6-4](image)

**E – Status Bar** – The status bar displays informational messages about the project and the activities of Android Studio together with the tools menu button located in the far left corner. Hovering over items in the status bar will provide a description of that field. Many fields are interactive, allowing the user to click to perform tasks or obtain more detailed status information.

**F – 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 a number of 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 a number of tool windows available within the Android Studio environment.

### 6.3 The Tool Windows

In addition to the project view tool window, Android Studio also includes a number of other windows which, when enabled, are displayed along the bottom and sides of the main window. The tool window quick access menu can be accessed by hovering the mouse pointer over the button located in the far left-hand corner of the status bar (Figure 6-5) without clicking the mouse button.

![Figure 6-5](image)

Selecting an item from the quick access menu will cause the corresponding tool window to appear within the main window.

Alternatively, a set of *tool window bars* can be displayed by clicking on the quick access menu icon in the status bar. These bars appear along the left, right and bottom edges of the main window (as indicated by the arrows in...
A Tour of the Android Studio User Interface

Figure 6-6) and contain buttons for showing and hiding each of the tool windows. When the tool window bars are displayed, a second click on the button in the status bar will hide them.

Clicking on a button will display the corresponding tool window while a second click will hide the window. Buttons prefixed with a number (for example 1: Project) indicate that the tool window may also be displayed by pressing the Alt key on the keyboard (or the Command key for macOS) together with the corresponding number.

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 tool bars.

Each tool window has its own toolbar along the top edge. The buttons within these toolbars vary from one tool to the next, though all tool windows contain a settings option, represented by the cog icon, which allows various aspects of the window to be changed. Figure 6-7 shows the settings menu for the project view tool window. Options 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.

All of the windows also include a far right button on the toolbar providing an additional way to hide the tool window from view. A search of the items within a tool window can be performed simply by giving that window focus by clicking in 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 tool bar and items matching the search highlighted.

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

- **App Inspector** - Provides access to the Database and Background Task inspectors. The Database Inspector allows you to inspect, query, and modify your app’s databases while the app is running. The Background Task Inspector allows background worker tasks created using WorkManager to be monitored and managed.

- **Build** - The build tool window displays information about the build process while a project is being compiled and packaged and displays details of any errors encountered.

- **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.

- **Device Manager** - Provides access to the Device Manager tool window where physical Android device connections and emulators may be added, removed, and managed.

- **Emulator** - 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”.

- **Event Log** – The event log window displays messages relating to events and activities performed within Android Studio. The successful build of a project, for example, or the fact that an application is now running will be reported within this tool window.

- **Favorites** – A variety of project items can be added to the favorites list. Right-clicking on a file in the project view, for example, provides access to an Add to Favorites menu option. Similarly, a method in a source file can be added as a favorite by right-clicking on it in the Structure tool window. Anything added to a Favorites list can be accessed through this Favorites tool window.

- **Gradle** – The Gradle tool window provides a view of the Gradle tasks that make up the project build configuration. The window lists the tasks that are 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.

- **Layout Inspector** - Provides a visual 3D rendering of the hierarchy of components that make up a user interface layout.

- **Logcat** – The Logcat tool window provides access to the monitoring log output from a running application in addition to options for taking screenshots and videos of the application and stopping and restarting a process.

- **Problems** - A central location in which 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.

- **Profiler** – The Android Profiler tool window provides real-time monitoring and analysis tools for identifying performance issues within running apps, including CPU, memory and network usage. This option becomes available when an app is currently running.

- **Project** – 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
A Tour of the Android Studio User Interface

loaded into the appropriate editing tool.

- **Resource Manager** - A tool for adding and managing resources and assets such as images, colors, and layout files contained with the project.

- **Run** – 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 is failing to install and run on a device or emulator, this window will typically provide diagnostic information relating to the problem.

- **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.

- **Terminal** – 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.

- **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 selecting the File -> Settings… menu option (Android Studio -> Preferences… on macOS) and navigating to the TODO page listed under Editor.

### 6.4 Android Studio Keyboard Shortcuts

Android Studio includes an abundance of keyboard shortcuts designed to save time when performing common tasks. A full keyboard shortcut keymap listing can be viewed and printed from within the Android Studio project window by selecting the Help -> Keymap Reference menu option. You may also list and modify the keyboard shortcuts by selecting the File -> Settings… menu option (Android Studio -> Preferences… on macOS) and clicking on the Keymap entry as shown in Figure 6-8 below:

![Figure 6-8](image-url)
6.5 Switcher and Recent Files Navigation

Another useful mechanism for navigating within the Android Studio main window involves the use of 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 6-9).

Once displayed, the switcher will remain visible for 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, navigation to recently opened files is provided by the Recent Files panel (Figure 6-10). 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, alternatively, the keyboard arrow keys used to scroll through the file name and tool window options. Pressing the Enter key will select the currently highlighted item.

6.6 Changing the Android Studio Theme

The overall theme of the Android Studio environment may be changed either from the welcome screen using the Configure -> Settings option, or via the File -> Settings... menu option (Android Studio -> Preferences... on macOS) of the main window.
Once the settings dialog is displayed, select the *Appearance & Behavior* option followed by *Appearance* in the left-hand panel and then change the setting of the *Theme* menu before clicking on the *Apply* button. The themes available will depend on the platform but usually include options such as Light, IntelliJ, Windows, High Contrast and Darcula. Figure 6-11 shows an example of the main window with the Darcula theme selected:

![Figure 6-11](image)

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 6-12](image)

### 6.7 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 and bottom edges of the main window and can be accessed either using the quick access menu located in the status bar, or via the optional tool window bars.

There are very few actions within Android Studio which 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.
7. Testing Android Studio Apps on a Physical Android Device

While much can be achieved by testing applications using an Android Virtual Device (AVD), there is no substitute for performing real-world application testing on a physical Android device and there are some Android features that are only available on physical Android devices.

Communication with both AVD instances and connected Android devices is handled by the Android Debug Bridge (ADB). In this chapter, we explain how to configure the adb environment to enable application testing on an Android device with macOS, Windows, and Linux-based systems.

7.1 An Overview of the Android Debug Bridge (ADB)

The primary purpose of the ADB is to facilitate interaction between a development system, in this case, Android Studio, and both AVD emulators and Android devices to run and debug applications. ADB allows you to connect to devices either over a WiFi network or directly using a USB cable.

The ADB consists of a client, a server process running in the background on the development system, and a daemon background process running in either AVDs or real Android devices such as phones and tablets.

The ADB client can take a variety of forms. For example, a client is provided in the form of a command-line tool named `adb` located in the Android SDK `platform-tools` sub-directory. Similarly, Android Studio also has a built-in client.

A variety of tasks may be performed using the `adb` command-line tool. For example, a listing of currently active virtual or physical devices may be obtained using the `devices` command-line argument. The following command output indicates the presence of an AVD on the system but no physical devices:

```
$ adb devices
List of devices attached
emulator-5554   device
```

7.2 Enabling USB Debugging ADB on Android Devices

Before ADB can connect to an Android device, that device must first be configured to allow the connection. On phone and tablet devices running Android 6.0 or later, the steps to achieve this are as follows:

1. Open the Settings app on the device and select the About tablet or About phone option (on some versions of Android this can be found on the System page of the Settings app).

2. On the About screen, scroll down to the Build number field (Figure 7-1) and tap on it seven times until a message appears indicating that developer mode has been enabled. If the Build number is not listed on the About screen it may be available via the Software information option. Alternatively, unfold the Advanced section of the list if available.
Testing Android Studio Apps on a Physical Android Device

3. Return to the main Settings screen and note the appearance of a new option titled Developer options (on newer versions of Android this option is listed on the System settings screen). Select this option and on the resulting screen, locate the USB debugging option as illustrated in Figure 7-2:

4. Enable the USB debugging option and tap the Allow button when confirmation is requested.

At this point, the device is now configured to accept debugging connections from adb on the development system over a USB connection. All that remains is to configure the development system to detect the device when it is attached. While this is a relatively straightforward process, the steps involved differ depending on whether the development system is running Windows, macOS, or Linux. Note that the following steps assume that the Android SDK platform-tools directory is included in the operating system PATH environment variable as described in the chapter entitled “Setting up an Android Studio Development Environment”.

7.2.1 macOS ADB Configuration

To configure the ADB environment on a macOS system, connect the device to the computer system using a USB cable, open a terminal window and execute the following command to restart the adb server:

```bash
$ adb kill-server
$ adb start-server
* daemon not running. starting it now on port 5037 *
* daemon started successfully *
```

Once the server is successfully running, execute the following command to verify that the device has been detected:

```bash
$ adb devices
List of devices attached
74CE00600000001 offline
```

If the device is listed as offline, go to the Android device and check for the presence of the dialog shown in Figure 7-3 seeking permission to Allow USB debugging. Enable the checkbox next to the option that reads Always allow from this computer, before clicking on OK.
7.2.2 Windows ADB Configuration

The first step in configuring a Windows-based development system to connect to an Android device using ADB is to install the appropriate USB drivers on the system. The USB drivers to install will depend on the model of the Android Device. If you have a Google device such as a Pixel phone, then it will be necessary to install and configure the Google USB Driver package on your Windows system. Detailed steps to achieve this are outlined on the following web page:


For Android devices not supported by the Google USB driver, it will be necessary to download the drivers provided by the device manufacturer. A listing of drivers together with download and installation information can be obtained online at:


With the drivers installed and the device now being recognized as the correct device type, open a Command Prompt window and execute the following command:

adb devices

This command should output information about the connected device similar to the following:

List of devices attached
HT4CTJT01906       offline

If the device is listed as offline or unauthorized, go to the device display and check for the dialog shown in Figure 7-3 seeking permission to Allow USB debugging. Enable the checkbox next to the option that reads Always allow from this computer, before clicking on OK. Repeating the adb devices command should now list the device as being ready:

List of devices attached
HT4CTJT01906       device

If the device is not listed, execute the following commands to restart the ADB server:

adb kill-server
adb start-server
Testing Android Studio Apps on a Physical Android Device

If the device is still not listed, try executing the following command:

```
android update adb
```

Note that it may also be necessary to reboot the system.

### 7.2.3 Linux adb Configuration

For this chapter, we will once again use Ubuntu Linux as a reference example in terms of configuring adb on Linux to connect to a physical Android device for application testing.

Physical device testing on Ubuntu Linux requires the installation of a package named `android-tools-adb` which, in turn, requires that the Android Studio user be a member of the `plugdev` group. This is the default for user accounts on most Ubuntu versions and can be verified by running the `id` command. If the plugdev group is not listed, run the following command to add your account to the group:

```
sudo usermod -aG plugdev $LOGNAME
```

After the group membership requirement has been met, the `android-tools-adb` package can be installed by executing the following command:

```
sudo apt-get install android-tools-adb
```

Once the above changes have been made, reboot the Ubuntu system. Once the system has restarted, open a Terminal window, start the adb server and check the list of attached devices:

```
$ adb start-server
* daemon not running. starting it now on port 5037 *
* daemon started successfully *
$ adb devices
List of devices attached
015d41d4454bf80c        offline
```

If the device is listed as `offline` or `unauthorized`, go to the Android device and check for the dialog shown in Figure 7-3 seeking permission to `Allow USB debugging`.

### 7.3 Resolving USB Connection Issues

If you are unable to successfully connect to the device using the above steps, display the run target menu (Figure 7-4) and select the `Troubleshoot Device Connections` option:

![Figure 7-4](image)

The connection assistant will scan for devices and report problems and possible solutions.
7.4 Enabling Wireless Debugging on Android Devices

Follow steps 1 through 3 from section 7.2 above, this time enabling the Wireless Debugging option as shown in Figure 7-5:

![Figure 7-5](image)

Next, tap the above Wireless debugging entry to display the screen shown in Figure 7-6:

![Figure 7-6](image)

If the device you are using has a camera, select **Pair device with QR code**, otherwise select the **Pair device with pairing code** option. Depending on your selection, the Settings app will either start a camera session or display a pairing code as shown in Figure 7-7:

![Figure 7-7](image)

With an option selected, return to Android Studio and select the **Pair Devices Using WiFi** option from the run target menu as illustrated in Figure 7-8:
In the pairing dialog, select either Pair using QR code or Pair using pairing code depending on your previous selection in the Settings app on the device:

Either scan the QR code using the Android device or enter the pairing code displayed on the device screen into the Android Studio dialog (Figure 7-10) to complete the pairing process:

If the pairing process fails, try rebooting both the development system and Android device and try again.
7.5 Testing the adb Connection

Assuming that the adb configuration has been successful on your chosen development platform, the next step is to try running the test application created in the chapter entitled “Creating an Example Android App in Android Studio” on the device. Launch Android Studio, open the AndroidSample project, and verify that the device appears in the device selection menu as highlighted in Figure 7-11:

![Figure 7-11](image)

Select the device from the list and click on the run button (the green arrow button located immediately to the right of the device menu) to install and run the app.

7.6 Summary

While the Android Virtual Device emulator provides an excellent testing environment, it is important to keep in mind that there is no real substitute for making sure an application functions correctly on a physical Android device. This, after all, is where the application will be used in the real world.

By default, however, the Android Studio environment is not configured to detect Android devices as a target testing device. It is necessary, therefore, to perform some steps to be able to load applications directly onto an Android device from within the Android Studio development environment either via a USB cable or over a WiFi network. The exact steps to achieve this goal differ depending on the development platform being used. In this chapter, we have covered those steps for Linux, macOS, and Windows-based platforms.
8. The Basics of the Android Studio Code Editor

Developing applications for Android involves a considerable amount of programming work which, by definition, involves typing, reviewing and modifying lines of code. It should come as no surprise that the majority of a developer’s time spent using Android Studio will typically involve editing code within the editor window.

The modern code editor needs to go far beyond the original basics of typing, deleting, cutting and pasting. Today the usefulness of a code editor is generally gauged by factors such as the amount by which it reduces the typing required by the programmer, ease of navigation through large source code files and the editor's ability to detect and highlight programming errors in real-time as the code is being written. As will become evident in this chapter, these are just a few of the areas in which the Android Studio editor excels.

While not an exhaustive overview of the features of the Android Studio editor, this chapter aims to provide a guide to the key features of the tool. Experienced programmers will find that some of these features are common to most code editors available today, while a number are unique to this particular editing environment.

8.1 The Android Studio Editor

The Android Studio editor appears in the center of the main window when a Java, Kotlin, XML or other text based file is selected for editing. Figure 8-1, for example, shows a typical editor session with a Kotlin source code file loaded:

![Figure 8-1](image-url)
The Basics of the Android Studio Code Editor

The elements that comprise the editor window can be summarized as follows:

A – Document Tabs – Android Studio is capable of holding multiple files open for editing at any one time. As each file is opened, it is assigned a document tab displaying the file name in the tab bar located along the top edge of the editor window. A small drop-down menu will appear in the far right-hand corner of the tab bar when there is insufficient room to display all of the tabs. Clicking on this menu will drop down a list of additional open files. A wavy red line underneath a file name in a tab indicates that the code in the file contains one or more errors that need to be addressed before the project can be compiled and run.

Switching between files is simply a matter of clicking on the corresponding tab or using the Alt-Left and Alt-Right keyboard shortcuts. Navigation between files may also be performed using the Switcher mechanism (accessible via the Ctrl-Tab keyboard shortcut).

To detach an editor panel from the Android Studio main window so that it appears in a separate window, click on the tab and drag it to an area on the desktop outside of the main window. To return the editor to the main window, click on the file tab in the separated editor window and drag and drop it onto the original editor tab bar in the main window.

B – The Editor Gutter Area - The gutter area is used by the editor to display informational icons and controls. Some typical items, among others, which appear in this gutter area are debugging breakpoint markers, controls to fold and unfold blocks of code, bookmarks, change markers and line numbers. Line numbers are switched on by default but may be disabled by right-clicking in the gutter and selecting the Show Line Numbers menu option.

C – Code Structure Location - This bar at the bottom of the editor displays the current position of the cursor as it relates to the overall structure of the code. In the following figure, for example, the bar indicates that the convertCurrency method is currently being edited, and that this method is contained within the MainActivity class.

![Figure 8-2](image)

Double-clicking an element within the bar will move the cursor to the corresponding location within the code file. For example, double-clicking on the convertCurrency entry will move the cursor to the top of the convertCurrency method within the source code. Similarly clicking on the MainActivity entry will drop down a list of available code navigation points for selection:

![Figure 8-3](image)

D – The Editor Area – This is the main area where the code is displayed, entered and edited by the user. Later sections of this chapter will cover the key features of the editing area in detail.

E – The Validation and Marker Sidebar – Android Studio incorporates a feature referred to as “on-the-fly code analysis”. What this essentially means is that as you are typing code, the editor is analyzing the code to check for warnings and syntax errors. The indicators at the top of the validation sidebar will update in real-time to indicate the number of errors and warnings found as code is added. Clicking on this indicator will display a popup containing a summary of the issues found with the code in the editor as illustrated in Figure 8-4:
The Basics of the Android Studio Code Editor

The up and down arrows may be used to move between the error locations within the code. A green check mark indicates that no warnings or errors have been detected.

The sidebar also displays markers at the locations where issues have been detected using the same color coding. Hovering the mouse pointer over a marker when the line of code is visible in the editor area will display a popup containing a description of the issue:

```
Too many arguments for public open fun show(): Unit defined in com.google.android.material.snackbar.Snackbar
Unresolved reference: null
Create abstract property 'null'
More actions...
```

Hovering the mouse pointer over a marker for a line of code which is currently scrolled out of the viewing area of the editor will display a “lens” overlay containing the block of code where the problem is located (Figure 8-6) allowing it to be viewed without the necessity to scroll to that location in the editor:

```
override fun onOptionsItemSelected(item: MenuItem): Boolean {
    // Handle action bar item clicks here. The action bar will
    // automatically handle clicks on the Home/Up button, so long
    // as you specify a parent activity in AndroidManifest.xml.
    return when (item.itemId) {
        R.id.action_settings -> true
        else -> super.onOptionsItemSelected(item) { [Unresolved reference: i] Expecting an element
```

It is also worth noting that the lens overlay is not limited to warnings and errors in the sidebar. Hovering over any part of the sidebar will result in a lens appearing containing the code present at that location within the source file.

**F - The Status Bar** – Though the status bar is actually part of the main window, as opposed to the editor, it does contain some information about the currently active editing session. This information includes the current position of the cursor in terms of lines and characters and the encoding format of the file (UTF-8, ASCII etc.). Clicking on these values in the status bar allows the corresponding setting to be changed. Clicking on the line number, for example, displays the Go to Line dialog.

Having provided an overview of the elements that comprise the Android Studio editor, the remainder of this chapter will explore the key features of the editing environment in more detail.

### 8.2 Splitting the Editor Window

By default, the editor will display a single panel showing the content of the currently selected file. A particularly useful feature when working simultaneously with multiple source code files is the ability to split the editor into multiple panes. To split the editor, right-click on a file tab within the editor window and select either the Split Vertically or Split Horizontally menu option. Figure 8-7, for example, shows the splitter in action with the editor...
The Basics of the Android Studio Code Editor

split into three panels:

![Figure 8-7](image)

The orientation of a split panel may be changed at any time by right-clicking on the corresponding tab and selecting the Change Splitter Orientation menu option. Repeat these steps to unsplit a single panel, this time selecting the Unsplit option from the menu. All of the split panels may be removed by right-clicking on any tab and selecting the Unsplit All menu option.

Window splitting may be used to display different files, or to provide multiple windows onto the same file, allowing different areas of the same file to be viewed and edited concurrently.

8.3 Code Completion

The Android Studio editor has a considerable amount of built-in knowledge of Kotlin programming syntax and the classes and methods that make up the Android SDK, as well as knowledge of your own code base. As code is typed, the editor scans what is being typed and, where appropriate, makes suggestions with regard to what might be needed to complete a statement or reference. When a completion suggestion is detected by the editor, a panel will appear containing a list of suggestions. In Figure 8-8, for example, the editor is suggesting possibilities for the beginning of a String declaration:

![Figure 8-8](image)

If none of the auto completion suggestions are correct, simply keep typing and the editor will continue to refine the suggestions where appropriate. To accept the top most suggestion, simply press the Enter or Tab key on the keyboard. To select a different suggestion, use the arrow keys to move up and down the list, once again using the
Enter or Tab key to select the highlighted item.

Completion suggestions can be manually invoked using the Ctrl-Space keyboard sequence. This can be useful when changing a word or declaration in the editor. When the cursor is positioned over a word in the editor, that word will automatically highlight. Pressing Ctrl-Space will display a list of alternate suggestions. To replace the current word with the currently highlighted item in the suggestion list, simply press the Tab key.

In addition to the real-time auto completion feature, the Android Studio editor also offers a system referred to as Smart Completion. Smart completion is invoked using the Shift-Ctrl-Space keyboard sequence and, when selected, will provide more detailed suggestions based on the current context of the code. Pressing the Shift-Ctrl-Space shortcut sequence a second time will provide more suggestions from a wider range of possibilities.

Code completion can be a matter of personal preference for many programmers. In recognition of this fact, Android Studio provides a high level of control over the auto completion settings. These can be viewed and modified by selecting the File -> Settings… menu option (or Android Studio -> Preferences… on macOS) and choosing Editor -> General -> Code Completion from the settings panel as shown in Figure 8-9:

![Figure 8-9](image)

8.4 Statement Completion

Another form of auto completion provided by the Android Studio editor is statement completion. This can be used to automatically fill out the parentheses and braces for items such as methods and loop statements. Statement completion is invoked using the Shift-Ctrl-Enter (Shift-Cmd-Enter on macOS) keyboard sequence. Consider for example the following code:

```kotlin
fun myMethod()
```

Having typed this code into the editor, triggering statement completion will cause the editor to automatically add the braces to the method:

```kotlin
fun myMethod() {
}
```
8.5 Parameter Information

It is also possible to ask the editor to provide information about the argument parameters accepted by a method. With the cursor positioned between the brackets of a method call, the Ctrl-P (Cmd-P on macOS) keyboard sequence will display the parameters known to be accepted by that method, with the most likely suggestion highlighted in bold:

```kotlin
val myButtonText: String = myString.format()
```

Figure 8-10

8.6 Parameter Name Hints

The code editor may be configured to display parameter name hints within method calls. Figure 8-11, for example, highlights the parameter name hints within the calls to the `make()` and `setAction()` methods of the Snackbar class:

```kotlin
fab.setOnClickListener { view ->
    Snackbar.make(view, text: "Replace with your own action", SnackBar.LENGTH_LONG)
}
```

Figure 8-11

The settings for this mode may be configured by selecting the `File -> Settings` menu (Android Studio -> Preferences on macOS) option followed by `Editor -> Inlay Hints -> Kotlin` in the left-hand panel. On the resulting screen, select the Parameter Hints item from the list and enable or disable the Show parameter hints option. To adjust the hint settings, click on the `Exclude list...` link and make any necessary adjustments.

8.7 Code Generation

In addition to completing code as it is typed the editor can, under certain conditions, also generate code for you. The list of available code generation options shown in Figure 8-12 can be accessed using the Alt-Insert (Cmd-N on macOS) keyboard shortcut when the cursor is at the location in the file where the code is to be generated.

![Code Generation Options](image)

Figure 8-12

For the purposes of an example, consider a situation where we want to be notified when an Activity in our project is about to be destroyed by the operating system. As will be outlined in a later chapter of this book, this can be achieved by overriding the `onStop()` lifecycle method of the Activity superclass. To have Android Studio
generate a stub method for this, simply select the Override Methods… option from the code generation list and select the onStop() method from the resulting list of available methods:

![Figure 8-13](image)

Having selected the method to override, clicking on OK will generate the stub method at the current cursor location in the Kotlin source file as follows:

```kotlin
override fun onStop() {
    super.onStop()
}
```

### 8.8 Code Folding

Once a source code file reaches a certain size, even the most carefully formatted and well organized code can become overwhelming and difficult to navigate. Android Studio takes the view that it is not always necessary to have the content of every code block visible at all times. Code navigation can be made easier through the use of the code folding feature of the Android Studio editor. Code folding is controlled using markers appearing in the editor gutter at the beginning and end of each block of code in a source file. Figure 8-14, for example, highlights the start and end markers for a method declaration which is not currently folded:

![Figure 8-14](image)

Clicking on either of these markers will fold the statement such that only the signature line is visible as shown in Figure 8-15:
To unfold a collapsed section of code, simply click on the ‘+’ marker in the editor gutter. To see the hidden code without unfolding it, hover the mouse pointer over the “{…}” indicator as shown in Figure 8-16. The editor will then display the lens overlay containing the folded code block:

```kotlin
override fun onCreateOptionsMenuMenu(menu: Menu): Boolean {

    // Inflate the menu; this adds items to the action bar if it is present.
    menuInflater.inflate(R.menu.menu_android_sample, menu)

    return true
}
```

All of the code blocks in a file may be folded or unfolded using the Ctrl-Shift-Plus and Ctrl-Shift-Minus keyboard sequences.

By default, the Android Studio editor will automatically fold some code when a source file is opened. To configure the conditions under which this happens, select File -> Settings… (Android Studio -> Preferences… on macOS) and choose the Editor -> General -> Code Folding entry in the resulting settings panel (Figure 8-17):

8.9 Quick Documentation Lookup

Context sensitive Kotlin and Android documentation can be accessed by placing the cursor over the declaration for which documentation is required and pressing the Ctrl-Q keyboard shortcut (Ctrl-J on macOS). This will display a popup containing the relevant reference documentation for the item. Figure 8-18, for example, shows the documentation for the Android Menu class.
Once displayed, the documentation popup can be moved around the screen as needed.

8.10 Code Reformatting

In general, the Android Studio editor will automatically format code in terms of indenting, spacing and nesting of statements and code blocks as they are added. In situations where lines of code need to be reformatted (a common occurrence, for example, when cutting and pasting sample code from a website), the editor provides a source code reformatting feature which, when selected, will automatically reformat code to match the prevailing code style.

To reformat source code, press the Ctrl-Alt-L (Cmd-Opt-L on macOS) keyboard shortcut sequence. To display the Reformat Code dialog (Figure 8-19) use the Ctrl-Alt-Shift-L (Cmd-Opt-Shift-L on macOS). This dialog provides the option to reformat only the currently selected code, the entire source file currently active in the editor or only code that has changed as the result of a source code control update.

8.11 Finding Sample Code

The Android Studio editor provides a way to access sample code relating to the currently highlighted entry within the code listing. This feature can be useful for learning how a particular Android class or method is used. To find sample code, highlight a method or class name in the editor, right-click on it and select the Find Sample Code menu option. The Find Sample Code panel (Figure 8-20) will appear beneath the editor with a list of matching samples. Selecting a sample from the list will load the corresponding code into the right-hand panel:
8.12 Live Templates

As you write Android code you will find that there are common constructs that are used frequently. For example, a common requirement is to display a popup message to the user using the Android Toast class. Live templates are a collection of common code constructs that can be entered into the editor by typing the initial characters followed by a special key (set to the Tab key by default) to insert template code. To experience this in action, type toast in the code editor followed by the Tab key and Android Studio will insert the following code at the cursor position ready for editing:

```java
Toast.makeText(, "", Toast.LENGTH_SHORT).show()
```

To list and edit existing templates, change the special key, or add your own templates, open the Preferences dialog and select Live Templates from the Editor section of the left-hand navigation panel:

![Figure 8-21](image)

Add, remove, duplicate or reset templates using the buttons marked A in Figure 8-21 above. To modify a template, select it from the list (B) and change the settings in the panel marked C.

8.13 Summary

The Android Studio editor goes to great length to reduce the amount of typing needed to write code and to make that code easier to read and navigate. In this chapter we have covered a number of the key editor features including code completion, code generation, editor window splitting, code folding, reformatting, documentation lookup and live templates.
Chapter 9

9. An Overview of the Android Architecture

So far in this book, steps have been taken to set up an environment suitable for the development of Android applications using Android Studio. An initial step has also been taken into the process of application development through the creation of an Android Studio application project.

Before delving further into the practical matters of Android application development, however, it is important to gain an understanding of some of the more abstract concepts of both the Android SDK and Android development in general. Gaining a clear understanding of these concepts now will provide a sound foundation on which to build further knowledge.

Starting with an overview of the Android architecture in this chapter, and continuing in the next few chapters of this book, the goal is to provide a detailed overview of the fundamentals of Android development.

9.1 The Android Software Stack

Android is structured in the form of a software stack comprising applications, an operating system, run-time environment, middle-ware, services and libraries. This architecture can, perhaps, best be represented visually as outlined in Figure 9-1. Each layer of the stack, and the corresponding elements within each layer, are tightly integrated and carefully tuned to provide the optimal application development and execution environment for mobile devices. The remainder of this chapter will work through the different layers of the Android stack, starting at the bottom with the Linux Kernel.

![Figure 9-1](image)

Applications
- Native Android Apps
- Third Party Apps

Application Framework
- Activity Manager
- Window Manager
- Notification Manager
- View System
- Location Manager
- Package Manager
- Resource Manager
- Content Providers

Libraries
- SQLite
- WebKit
- OpenGL ES
- FreeType
- Surface Manager
- Media Framework
- SSL
- SQL
- ld

Android Runtime (ART)

Linux Kernel
- Display Driver
- WiFi Driver
- Audio Drivers
- Binder (IPC) Drivers
- Camera Driver
- Power Management
- Process Management
- Memory Management

Figure 9-1
9.2 The Linux Kernel

Positioned at the bottom of the Android software stack, the Linux Kernel provides a level of abstraction between the device hardware and the upper layers of the Android software stack. Based on Linux version 2.6, the kernel provides preemptive multitasking, low-level core system services such as memory, process and power management in addition to providing a network stack and device drivers for hardware such as the device display, WiFi and audio.

The original Linux kernel was developed in 1991 by Linus Torvalds and was combined with a set of tools, utilities and compilers developed by Richard Stallman at the Free Software Foundation to create a full operating system referred to as GNU/Linux. Various Linux distributions have been derived from these basic underpinnings such as Ubuntu and Red Hat Enterprise Linux.

It is important to note, however, that Android uses only the Linux kernel. That said, it is worth noting that the Linux kernel was originally developed for use in traditional computers in the form of desktops and servers. In fact, Linux is now most widely deployed in mission critical enterprise server environments. It is a testament to both the power of today’s mobile devices and the efficiency and performance of the Linux kernel that we find this software at the heart of the Android software stack.

9.3 Android Runtime – ART

When an Android app is built within Android Studio it is compiled into an intermediate bytecode format (referred to as DEX format). When the application is subsequently loaded onto the device, the Android Runtime (ART) uses a process referred to as Ahead-of-Time (AOT) compilation to translate the bytecode down to the native instructions required by the device processor. This format is known as Executable and Linkable Format (ELF).

Each time the application is subsequently launched, the ELF executable version is run, resulting in faster application performance and improved battery life.

This contrasts with the Just-in-Time (JIT) compilation approach used in older Android implementations whereby the bytecode was translated within a virtual machine (VM) each time the application was launched.

9.4 Android Libraries

In addition to a set of standard Java development libraries (providing support for such general purpose tasks as string handling, networking and file manipulation), the Android development environment also includes the Android Libraries. These are a set of Java-based libraries that are specific to Android development. Examples of libraries in this category include the application framework libraries in addition to those that facilitate user interface building, graphics drawing and database access.

A summary of some key core Android libraries available to the Android developer is as follows:

- **android.app** – Provides access to the application model and is the cornerstone of all Android applications.
- **android.content** – Facilitates content access, publishing and messaging between applications and application components.
- **android.database** – Used to access data published by content providers and includes SQLite database management classes.
- **android.graphics** – A low-level 2D graphics drawing API including colors, points, filters, rectangles and canvases.
- **android.hardware** – Presents an API providing access to hardware such as the accelerometer and light sensor.
An Overview of the Android Architecture

- **android.opengl** – A Java interface to the OpenGL ES 3D graphics rendering API.

- **android.os** – Provides applications with access to standard operating system services including messages, system services and inter-process communication.

- **android.media** – Provides classes to enable playback of audio and video.

- **android.net** – A set of APIs providing access to the network stack. Includes android.net.wifi, which provides access to the device’s wireless stack.

- **android.print** – Includes a set of classes that enable content to be sent to configured printers from within Android applications.

- **android.provider** – A set of convenience classes that provide access to standard Android content provider databases such as those maintained by the calendar and contact applications.

- **android.text** – Used to render and manipulate text on a device display.

- **android.util** – A set of utility classes for performing tasks such as string and number conversion, XML handling and date and time manipulation.

- **android.view** – The fundamental building blocks of application user interfaces.

- **android.widget** – A rich collection of pre-built user interface components such as buttons, labels, list views, layout managers, radio buttons etc.

- **android.webkit** – A set of classes intended to allow web-browsing capabilities to be built into applications.

Having covered the Java-based libraries in the Android runtime, it is now time to turn our attention to the C/C++ based libraries contained in this layer of the Android software stack.

### 9.4.1 C/C++ Libraries

The Android runtime core libraries outlined in the preceding section are Java-based and provide the primary APIs for developers writing Android applications. It is important to note, however, that the core libraries do not perform much of the actual work and are, in fact, essentially Java “wrappers” around a set of C/C++ based libraries. When making calls, for example, to the android.opengl library to draw 3D graphics on the device display, the library actually ultimately makes calls to the OpenGL ES C++ library which, in turn, works with the underlying Linux kernel to perform the drawing tasks.

C/C++ libraries are included to fulfill a wide and diverse range of functions including 2D and 3D graphics drawing, Secure Sockets Layer (SSL) communication, SQLite database management, audio and video playback, bitmap and vector font rendering, display subsystem and graphic layer management and an implementation of the standard C system library (libc).

In practice, the typical Android application developer will access these libraries solely through the Java based Android core library APIs. If direct access to these libraries is needed, this can be achieved using the Android Native Development Kit (NDK), the purpose of which is to call the native methods of non-Java or Kotlin programming languages (such as C and C++) from within Java code using the Java Native Interface (JNI).

### 9.5 Application Framework

The Application Framework is a set of services that collectively form the environment in which Android applications run and are managed. This framework implements the concept that Android applications are constructed from reusable, interchangeable and replaceable components. This concept is taken a step further in that an application is also able to publish its capabilities along with any corresponding data so that they can be
An Overview of the Android Architecture

found and reused by other applications.

The Android framework includes the following key services:

- **Activity Manager** – Controls all aspects of the application lifecycle and activity stack.
- **Content Providers** – Allows applications to publish and share data with other applications.
- **Resource Manager** – Provides access to non-code embedded resources such as strings, color settings and user interface layouts.
- **Notifications Manager** – Allows applications to display alerts and notifications to the user.
- **View System** – An extensible set of views used to create application user interfaces.
- **Package Manager** – The system by which applications are able to find out information about other applications currently installed on the device.
- **Telephony Manager** – Provides information to the application about the telephony services available on the device such as status and subscriber information.
- **Location Manager** – Provides access to the location services allowing an application to receive updates about location changes.

9.6 Applications

Located at the top of the Android software stack are the applications. These comprise both the native applications provided with the particular Android implementation (for example web browser and email applications) and the third party applications installed by the user after purchasing the device.

9.7 Summary

A good Android development knowledge foundation requires an understanding of the overall architecture of Android. Android is implemented in the form of a software stack architecture consisting of a Linux kernel, a runtime environment and corresponding libraries, an application framework and a set of applications. Applications are predominantly written in Java or Kotlin and compiled down to bytecode format within the Android Studio build environment. When the application is subsequently installed on a device, this bytecode is compiled down by the Android Runtime (ART) to the native format used by the CPU. The key goals of the Android architecture are performance and efficiency, both in application execution and in the implementation of reuse in application design.