Building
Mobile Applications

CS 346 Application
Development

Smartphone Design

- Smartphones as personal, portable computing.
- Originally a mashup of other devices.
  - “An iPod, a phone, an internet communicator”.
  - Mobile phone category evolved over 2-3 years.
- What makes them unique?
  - Touch-screens! Touch input, customizable output.
  - Optimized for simple, ad hoc interaction.
  - A single device for all your needs (data).
- Design concerns
  - Processing efficiency, battery life.
  - Security! Applications needed to be sandboxed.

The first iPhone, introduced in Jan 2007, and available for sale in June of that year. Apple sold more than 6 million phones before replacing this model with the iPhone 3G in 2008.

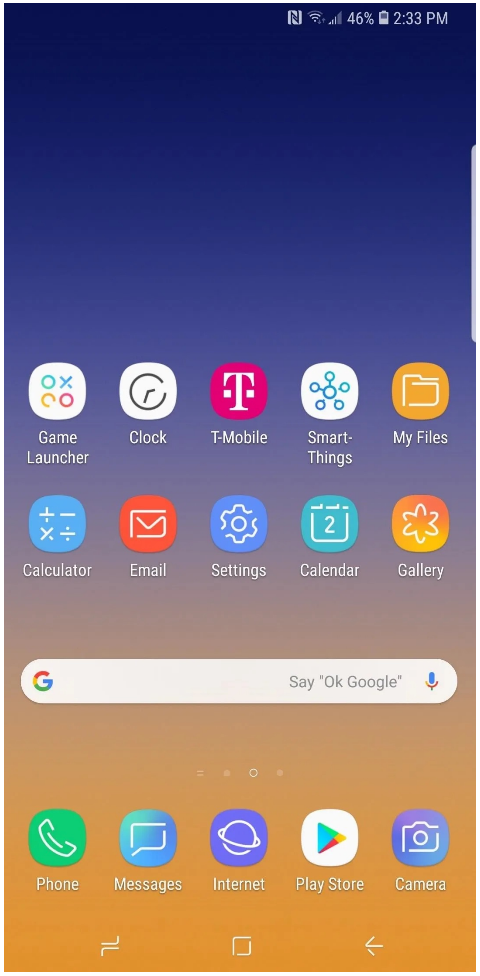
Android

- History of Android
  - Founded by Andy Rubin 2003 to build a camera OS.
  - Pivoted to phone OS 2004, sold to Google in 2005.
  - By Dec 2006 Google was testing phones w. keyboards.
  - Redesigned for touch-screens before phones launched.
- Android is the world's "most popular OS".
  - Based on Linux kernel; portions are open source.
  - Ships on different devices e.g., TV boxes, phones.
  - "Billions of Android devices" have been shipped.

The first Android phone was the HTC Dream, which launched in October 2008 – approximately 18 months after the first iPhone.

Android Features

- Graphical User Interface
  - Applications presented as pages of icons.
  - An application usually runs full-screen.
    - Forward/backward screen navigation within an application.
    - Navigate through running applications.
  - Custom UI displays
    - Side-by-side applications, Live-regions
- Tight integration with Google applications
  - Gmail, Google docs, other services.
  - Google search, “Ok Google” voice chat.
- Wider range of hardware
  - Many vendors, who produce a wider range of devices.



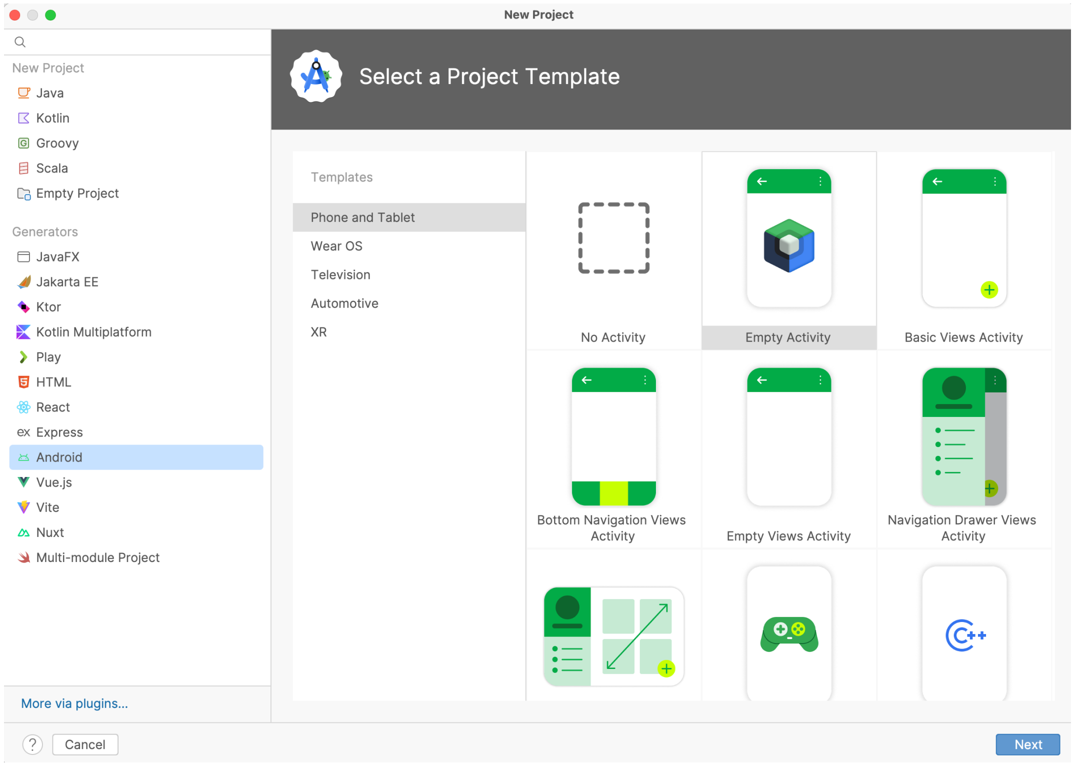
Getting Started

How to create an Android project.

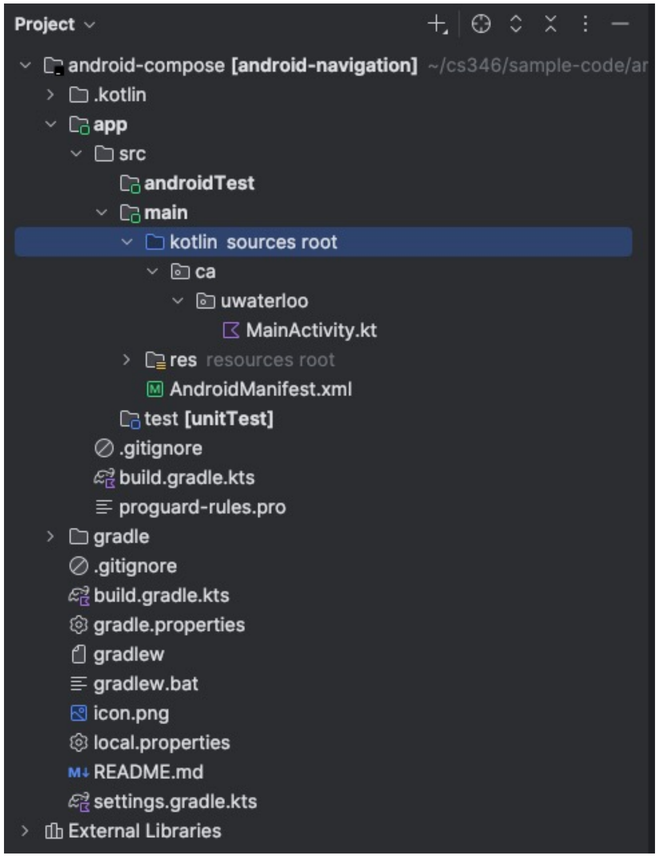
Step 1: Create a Project

An Android project is just a Gradle project with specific dependencies.

- Requires an IDE with the Android plugin installed.
- IntelliJ IDEA or Android Studio are both fine.



Step 2: Check the directory structure



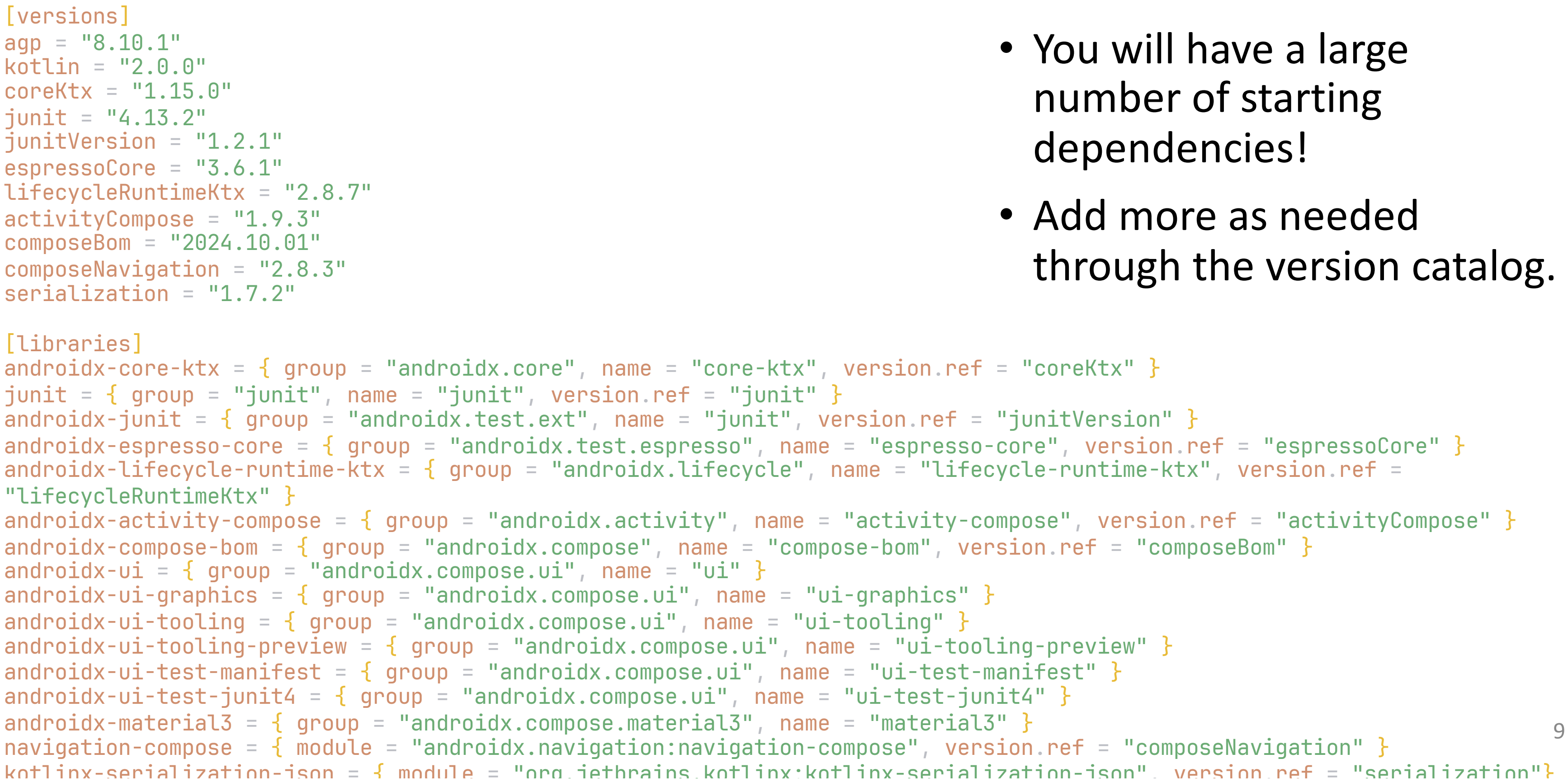
```
android-compose [android-navigation] ~/cs346/sample-code/ar
  .kotlin
  app
    src
      androidTest
      main
        kotlin sources root
          ca
            uwaterloo
              MainActivity.kt
        res resources root
        AndroidManifest.xml
      test [unitTest]
    .gitignore
    build.gradle.kts
    proguard-rules.pro
  gradle
  .gitignore
  build.gradle.kts
  gradle.properties
  gradlew
  gradlew.bat
  icon.png
  local.properties
  README.md
  settings.gradle.kts
External Libraries
```

An Android project should be runnable after you walk through the creation wizard.

Same general structure as any other Gradle project.

- Some additional configuration files.
- Some changes when we run and test code.
- TBD in a few slides.

Step 3: Dependencies



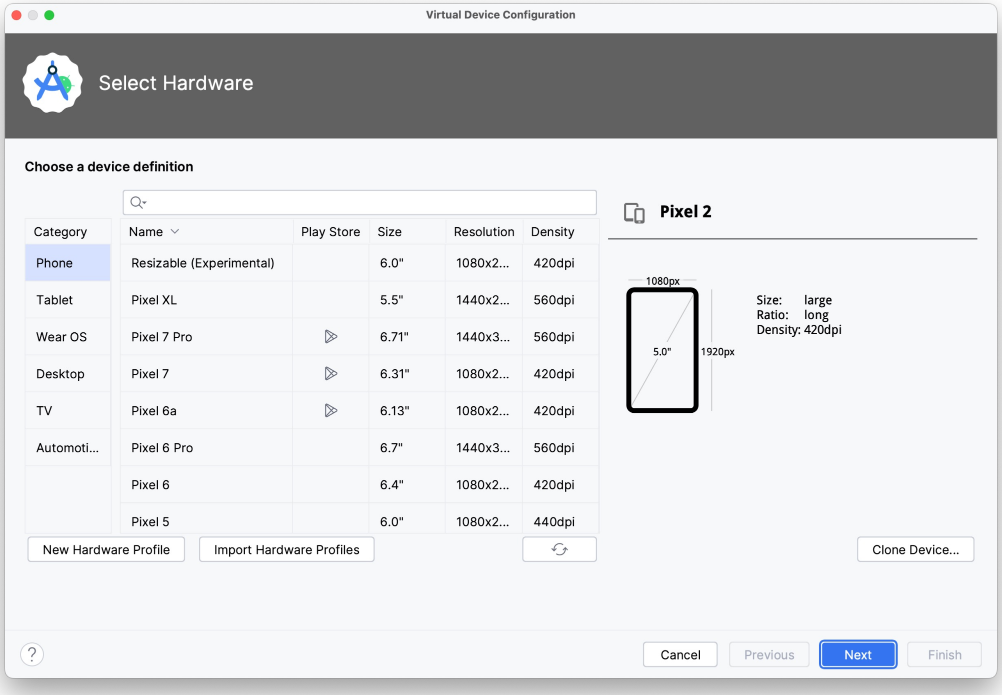
```
[versions]
agp = "8.10.1"
kotlin = "2.0.0"
coreKtx = "1.15.0"
junit = "4.13.2"
junitVersion = "1.2.1"
espressoCore = "3.6.1"
lifecycleRuntimeKtx = "2.8.7"
activityCompose = "1.9.3"
composeBom = "2024.10.01"
composeNavigation = "2.8.3"
serialization = "1.7.2"

[libraries]
androidx-core-ktx = { group = "androidx.core", name = "core-ktx", version.ref = "coreKtx" }
junit = { group = "junit", name = "junit", version.ref = "junit" }
androidx-junit = { group = "androidx.test.ext", name = "junit", version.ref = "junitVersion" }
androidx-espresso-core = { group = "androidx.test.espresso", name = "espresso-core", version.ref = "espressoCore" }
androidx-lifecycle-runtime-ktx = { group = "androidx.lifecycle", name = "lifecycle-runtime-ktx", version.ref =
"lifecycleRuntimeKtx" }
androidx-activity-compose = { group = "androidx.activity", name = "activity-compose", version.ref = "activityCompose" }
androidx-compose-bom = { group = "androidx.compose", name = "compose-bom", version.ref = "composeBom" }
androidx-ui = { group = "androidx.compose.ui", name = "ui" }
androidx-ui-graphics = { group = "androidx.compose.ui", name = "ui-graphics" }
androidx-ui-tooling = { group = "androidx.compose.ui", name = "ui-tooling" }
androidx-ui-tooling-preview = { group = "androidx.compose.ui", name = "ui-tooling-preview" }
androidx-ui-test-manifest = { group = "androidx.compose.ui", name = "ui-test-manifest" }
androidx-ui-test-junit4 = { group = "androidx.compose.ui", name = "ui-test-junit4" }
androidx-material3 = { group = "androidx.compose.material3", name = "material3" }
navigation-compose = { module = "androidx.navigation:navigation-compose", version.ref = "composeNavigation" }
kotlinx-serialization-json = { module = "org.jetbrains.kotlinx:kotlinx-serialization-json", version.ref = "serialization"}
```

- You will have a large number of starting dependencies!
- Add more as needed through the version catalog.

Running on a virtual device

DEMO!



Virtual Device Configuration

Select Hardware

Choose a device definition

Category
Phone
Tablet
Wear OS
Desktop
TV
Automoti...

Name	Play Store	Size	Resolution	Density
Resizable (Experimental)		6.0"	1080x2...	420dpi
Pixel XL		5.5"	1440x2...	560dpi
Pixel 7 Pro	▷	6.71"	1440x3...	560dpi
Pixel 7	▷	6.31"	1080x2...	420dpi
Pixel 6a	▷	6.13"	1080x2...	420dpi
Pixel 6 Pro		6.7"	1440x3...	560dpi
Pixel 6		6.4"	1080x2...	420dpi
Pixel 5		6.0"	1080x2...	440dpi

Pixel 2

Size: large
Ratio: long
Density: 420dpi

Tools > Android > Android Device Manager

Architecture

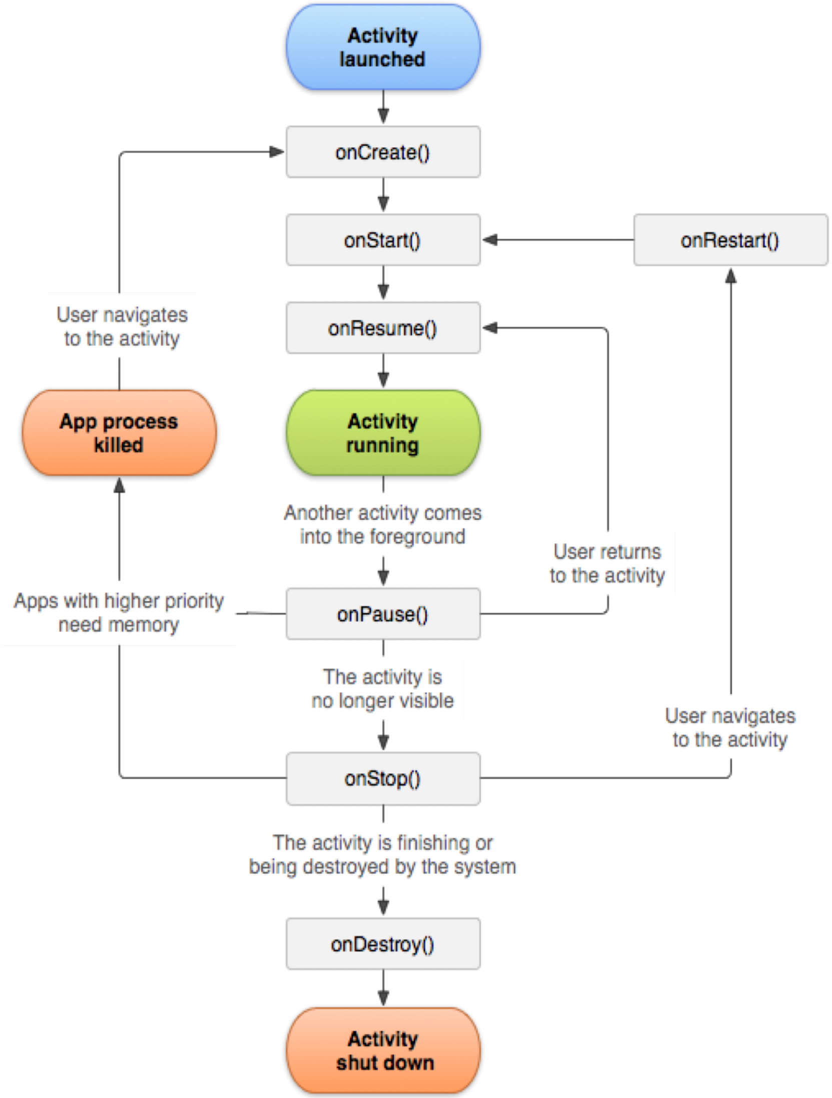
How is Android designed?

Application Design

A typical Android application contains multiple components, including some combination of:

Component	Description
Activities	Screens, each with its own state and lifecycle.
Fragments	Portions of a screen that can be managed separately.
Services	Provides long-running operations in the background.
Content Providers	Shares data with other applications.
Broadcast Receivers	Listens for system events e.g., phone call, airplane mode.

These components are registered with the OS, and applications can request to use each other’s components e.g., you can use an existing `camera` component instead of creating one.


Activity launched
onCreate()
onStart()
onRestart()
onResume()
User navigates to the activity
App process killed
Activity running
Another activity comes into the foreground
User returns to the activity
Apps with higher priority need memory
onPause()
The activity is no longer visible
User navigates to the activity
onStop()
The activity is finishing or being destroyed by the system
onDestroy()
Activity shut down

Key takeaway: your application needs to support being paused or stopped (typically by saving data for later).

Activity Lifecycle

There are three key loops that these phases attempt to capture:

- **The entire lifetime of an activity** happens between the first call to `onCreate(Bundle)` through to a single final call to `onDestroy()`. Setup is done in `onCreate()`, and resources are released by `onDestroy()`.
- **The visible lifetime of an activity** happens between a call to `onStart()` until a corresponding call to `onStop()`. During this time the user can see the activity on-screen, though it may not be in the foreground.
- **The foreground lifetime of an activity** happens between a call to `onResume()` until a corresponding call to `onPause()`. During this time the activity is in visible, active and interacting with the user. An activity can frequently go between the resumed and paused states e.g. sleeping.

Warning: Data loss on rotation ⚠

- Activities can be restarted when
  - The OS decides that it needs to reclaim resources (*uncommon*),
  - You rotate the device (*common!*)
- Restarting activities means relaunching and losing data.
- How do you avoid this?
  - Save and restore data manually
    - Override the onPause() and onResume() methods and manage a Bundle of data.
  - Use a ViewModel as a base class for your custom ViewModel.
    - Android will automatically save and restore VM data!!
    - https://developer.android.com/topic/libraries/architecture/viewmodel

Application Structure

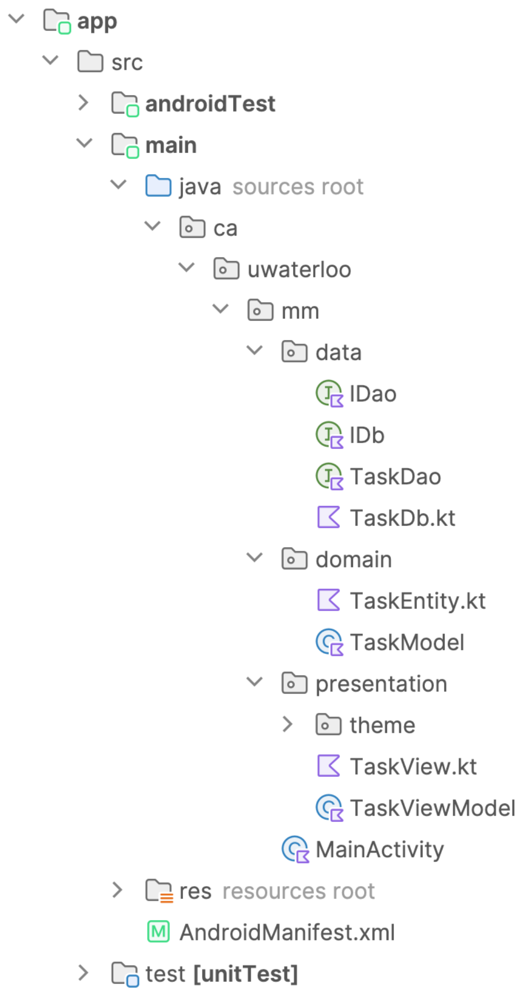
What does it look like again?

Project Structure

Your application structure should look the same as discussed in the Architecture lecture, with data/, domain/ and presentation/ layers.

Differences compared to a desktop application:

- Your entry point is the `MainActivity` class.
- `Manifest` file describes your project structure.
- Android stores resources in the `res` folder structure. There is an API to load them.



```
app
  src
    androidTest
    main
      java  sources root
        ca
          uwaterloo
            mm
              data
                IDao
                IDb
                TaskDao
                TaskDb.kt
              domain
                TaskEntity.kt
                TaskModel
              presentation
                theme
                TaskView.kt
                TaskViewModel
              MainActivity
      res  resources root
      AndroidManifest.xml
    test [unitTest]
```

MainActivity

MainActivity.kt

```kotlin
class MainActivity : ComponentActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        enableEdgeToEdge()

        val database= getRoomDatabase(this)
        val taskModel = TaskModel(database.taskDao())
        val viewModel = TaskViewModel(taskModel)

        setContent {
            MMTheme {
                TaskView(viewModel) // top-level View/Composable
            }
        }
    }
}
```

MainActivity is a class that extends ComponentActivity.

Activities have built-in methods that mirror their lifecycle: onCreate(), onStart(), onStop() and so on.

The onCreate() method is the first method that is called when the MainActivity is instantiated and serves as the entry point for your application.

GitHub: demos > mm-android

Application Manifest

Every Android project has a single `AndroidManifest.xml` file

This is an XML file that describes your application structure.

- It lists components and properties required to compile, install and run your application. e.g.,
  - Identifies the `MainActivity` which launches on startup i.e., `main` method.
  - Identifies the name and icon to use for your application.
  - Location of resources to include.
  - Permissions that the application requires

- See [Application Manifest Overview]()

You can probably ignore this file UNLESS you need permissions (file system, network)

AndroidManifest.xml

```xml
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
          xmlns:tools="http://schemas.android.com/tools">

    <application
            android:allowBackup="true"
            android:dataExtractionRules="@xml/data_extraction_rules"
            android:fullBackupContent="@xml/backup_rules"
            android:icon="@mipmap/ic_launcher"
            android:label="@string/app_name"
            android:roundIcon="@mipmap/ic_launcher_round"
            android:supportsRtl="true"
            android:theme="@style/Theme.Mmandroid"
            tools:targetApi="31">
        <activity
                android:name="ca.uwaterloo.mm.MainActivity"
                android:exported="true"
                android:label="@string/app_name"
                android:theme="@style/Theme.Mmandroid">
            <intent-filter>
                <action android:name="android.intent.action.MAIN"/>

                <category android:name="android.intent.category.LAUNCHER"/>
            </intent-filter>
        </activity>
    </application>

</manifest>
```

GitHub: demos > mm-android

Activity: View relationship

We use View classes for screens. How do they relate to Activities?

1. Each View is an Activity (early-Android).
   - Every screen is represented by a corresponding Activity.
   - You would use an Intent (message to the OS) to swap between them.
   - This is not recommended! It’s very slow. ❌
2. You fewer Activities, each is configurable using Fragments (old Android)
   - You have few Activities, but each one is composed of pieces called Fragments.
   - You write logic to load the Activity, then load suitable fragments.
   - Not recommended! Faster, but still generally very slow. ❌
3. One Activity, and you just choose your View to show (new Android)
   - Use your MainActivity as a container. Each view is a single top-level composable!
   - Navigation code/libraries just chooses which View to launch. ✓

presentation/
TaskView.kt

```
@Composable
fun TaskView(viewModel: TaskViewModel) {
    val items by viewModel.getAll().collectAsState(initial = emptyList())

    Scaffold(
        topBar = {
            Toolbar(
                addHandler = { viewModel.showAddDialog = true },
                editHandler = { viewModel.showEditDialog = true },
                deleteHandler = {
                    val task = viewModel.selectedTask ?: return@Toolbar
                    viewModel.delete(task)
                    viewModel.selectedTask = null
                }
            )
        },
        bottomBar = {  },
    ) { padding ->
        Box(
            modifier = Modifier.fillMaxSize().padding(padding)
        ) {
            if (items.isEmpty() && !viewModel.showAddDialog && !viewModel.showEditDialog) {
                Text(
                    "No tasks available. Add a task using the + button.",
                    modifier = Modifier.align(Alignment.Center).padding(16.dp)
                )
            } else {
              // …
            }
```

The presentation layer communicates with the domain layer. i.e. TaskViewModel and TaskEntity classes.

None of this is Android-specific; it’s straight Compose code.

```kotlin
/*
 * Android ViewModel
 * This class holds state for our Application Composable function.
 * The built-in ViewModel survives screen rotation automatically.
 */

class TaskViewModel(val taskModel: TaskModel) : ViewModel() {
    var selectedTask by mutableStateOf<Task?>(null)
    var showAddDialog by mutableStateOf(false)
    var showEditDialog by mutableStateOf(false)

    fun getAll(): Flow<List<Task>> {
        return taskModel.getAll()
    }

    fun getById(id: Int): Task {
        return runBlocking {
            taskModel.getById(id)
        }
    }

fun deleteAll() {
    viewModelScope.launch {
        taskModel.deleteAll()
    }
}

// …
```

```
domain/
  TaskViewModel.kt
```

The domain layer communicates with the data layer.

None of this code is Android specific.

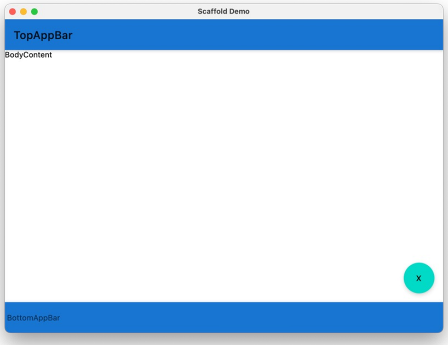
We’ll review the application in more detail in the database lecture.

GitHub: demos > mm-android

Android Composables

What Compose functionality is specific to mobile development?

Composable: Scaffold



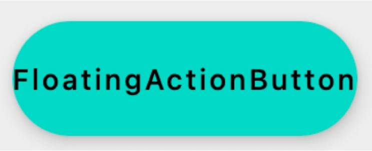
```
@Composable
fun ScaffoldDemo() {
    val materialBlue700= Color(0xFF1976D2)
    val scaffoldState = rememberScaffoldState(rememberDrawerState(DrawerValue.Open))
    Scaffold(
          scaffoldState = scaffoldState,
          topBar = {
              TopAppBar(title = {Text(“TopAppBar")}, backgroundColor = materialBlue700)
          },
          floatingActionButtonPosition = FabPosition.End,
          floatingActionButton = { FloatingActionButton(onClick = {}){Text(“X”)} },
          drawerContent = { Text(text = "drawerContent") },
          content = { Text("BodyContent") },
          bottomBar = {
              BottomAppBar(backgroundColor = materialBlue700) {Text(“BottomAppBar”)}
          }
    )
}
```

Composable: Image

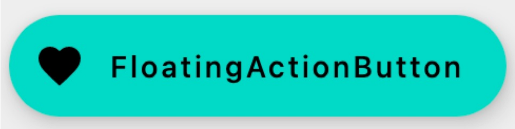
```
@Composable
fun ImageResourceDemo() {
    val image: Painter = painterResource(id = R.drawable.composelogo)
    Image(painter = image,contentDescription = "")
}
```

Composable: Floating Action Buttons

```
@Composable
fun FloatingActionButtonDemo() {
    FloatingActionButton(onClick = { /*do something*/}) {
        Text("FloatingActionButton")
    }
}
```

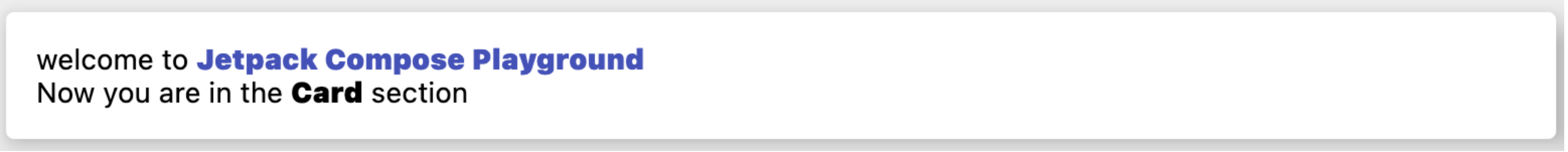


```
@Composable
fun ExtendedFloatingActionButtonDemo() {
    ExtendedFloatingActionButton(
        icon = { Icon(Icons.Filled.Favorite,"") },
        text = { Text("FloatingActionButton") },
        onClick = { /*do something*/ },
        elevation = FloatingActionButtonDefaults.elevation(8.dp)
    )
}
```



Composable: Card

```
@Composable
fun CardDemo() {
    Card(
        modifier = Modifier.fillMaxWidth().padding(15.dp).clickable{ },
        elevation = 10.dp
    ) {
        Column(modifier = Modifier.padding(15.dp)) {
            Text("Jetpack Compose Playground")
            Text("Now you are in the Card section")
       }
    }
}
```



welcome to **Jetpack Compose Playground**
Now you are in the **Card** section

Finding More Composables

All of the other composables work as well! The amazing thing about Compose is that you can copy/paste composables between platforms.

List of Composables
https://developer.android.com/reference/kotlin/androidx/compose/material/package-summary

Sample Code
https://foso.github.io/Jetpack-Compose-Playground/
https://developer.android.com/jetpack/compose/components

Managing State

Android-specific issues.

What is unique about Android?

The OS has control over applications at a deep level.

  - Application components only communicate through the OS via intents.
  - The OS can launch and control specific application components.
    - e.g., Your application can use a Photo Capture screen from a different application.

- The OS was designed around devices with very limited resources.
  - Rotating the device will cause the UI to be reloaded. ⚠
    - Pre-compose? The UI was completely reloaded, and UI state is lost.
    - Compose? This forces recomposition.
  - The OS may terminate your application if it needs resources. ⚠
    - You need to handle this as well, otherwise you will lose data!

Managing Compose State

```
@Composable
fun ChatBubble(
  message: Message
) {
  var showDetails by rememberSaveable { mutableStateOf(false) }

  ClickableText(
        text = AnnotatedString(message.content),
        onClick = { showDetails = !showDetails }
  )

  if (showDetails) {
        Text(message.timestamp)
  }
}
```

This keyword will retain state across activity and process recreation.

Caveats

`rememberSaveable` stores data in a Bundle

- this is a special Android specific data structure to hold values.
- It only works for primitives!

To store anything more complex, you may need additional APIs.

- e.g., making a class Parcelable.
- See Ways to store state

Interactivity

Handling screen events, key presses.

Interaction Styles

What types of interaction do we need to support on a mobile device?

1. Multi-touch for primary input.
    - Tapping on widgets to activate e.g. touch a text widget to enter text; touch a button to activate it.
    - Dragging and other gestures.
2. Keyboard input as secondary.
    - Soft-keyboard (on-screen).

Multi-touch Widgets

This is *exactly* the same as desktop. You override the handler functions for the widgets, providing it with a lambda function that is executed when the event fires.

```
FloatingActionButton(onClick = { /* something */ }) {
    Text("FloatingActionButton")
}
```

Touch Gestures

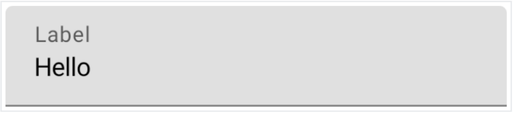
You can apply gesture modifiers to make the composable listen to gestures.

```
var log by remember { mutableStateOf("") }
Column {
   Box(
        Modifier
            .size(100.dp)
            .background(Color.Red)
            .pointerInput(Unit) {
                detectTapGestures { log = "Tap!" }
                detectDragGestures { _, _ -> log = "Dragging" }
            }
    )
}
```

Key Gestures

```
@Composable
fun SimpleFilledTextFieldSample() {
    var text by remember { mutableStateOf("Hello") }

    TextField(
        value = text,
        onValueChange = { text = it },
        label = { Text("Label") }
    )
}
```

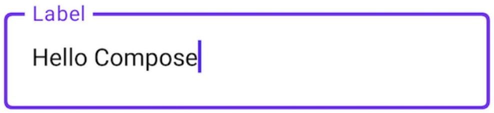


Label

Hello

```
@Composable
fun SimpleOutlinedTextFieldSample() {
    var text by remember { mutableStateOf("") }

    OutlinedTextField(
        value = text,
        onValueChange = { text = it },
        label = { Text("Label") }
    )
}
```



Label

Hello Compose

Reference

- Google. 2025. Android Developer Portal.
- Google. 2025. Compose Lifecycle.
- Google. 2025. Guide to App Architecture.
- Google. 2025. State and Jetpack Compose.