CMPS 312

Flutter Fundamentals

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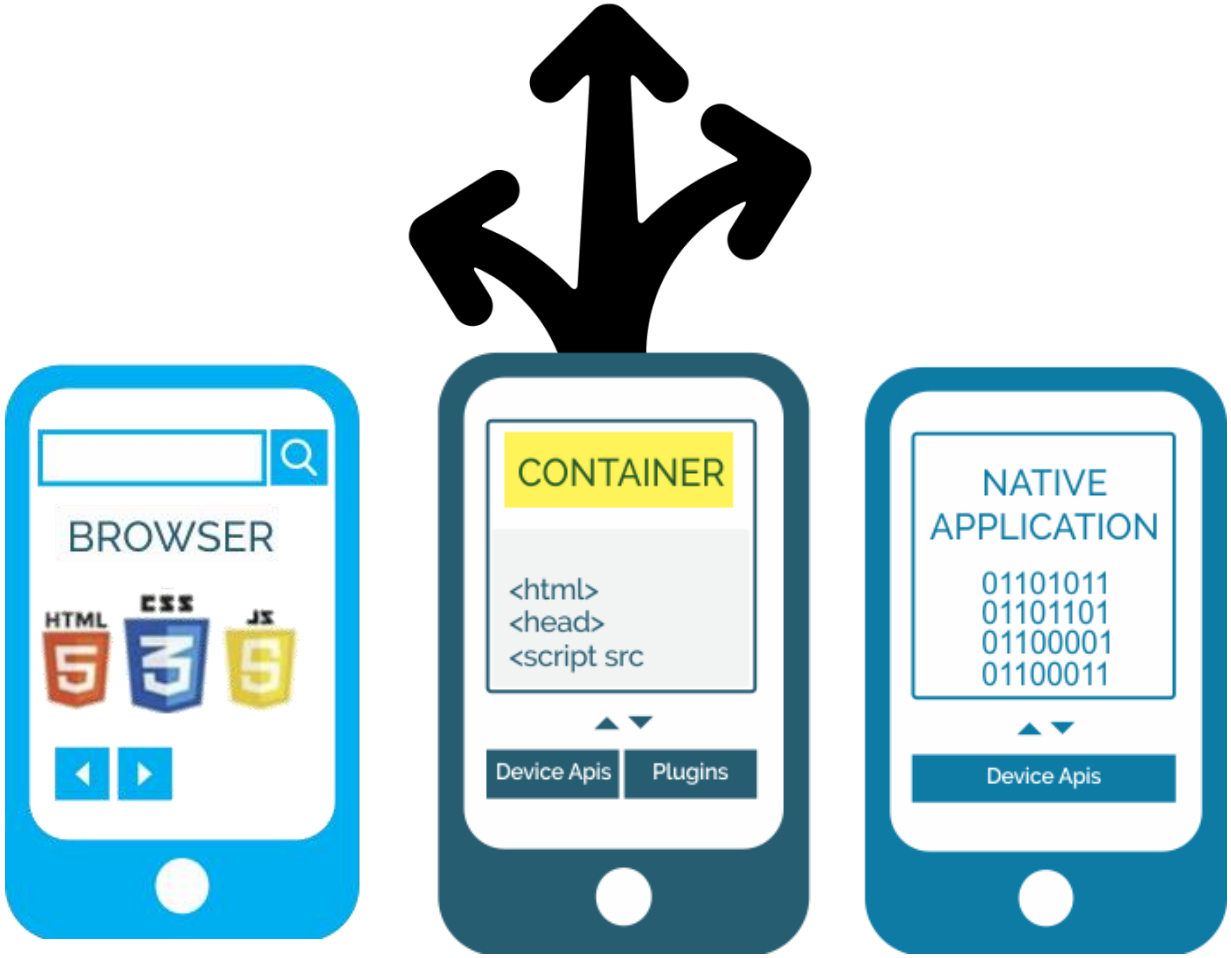
CSE@QU

Outline

1. Mobile Development Approaches
2. Introduction to Flutter
3. Flutter Key Concepts
4. Widgets (UI Components)
5. Layouts
6. State

Mobile Development Approaches



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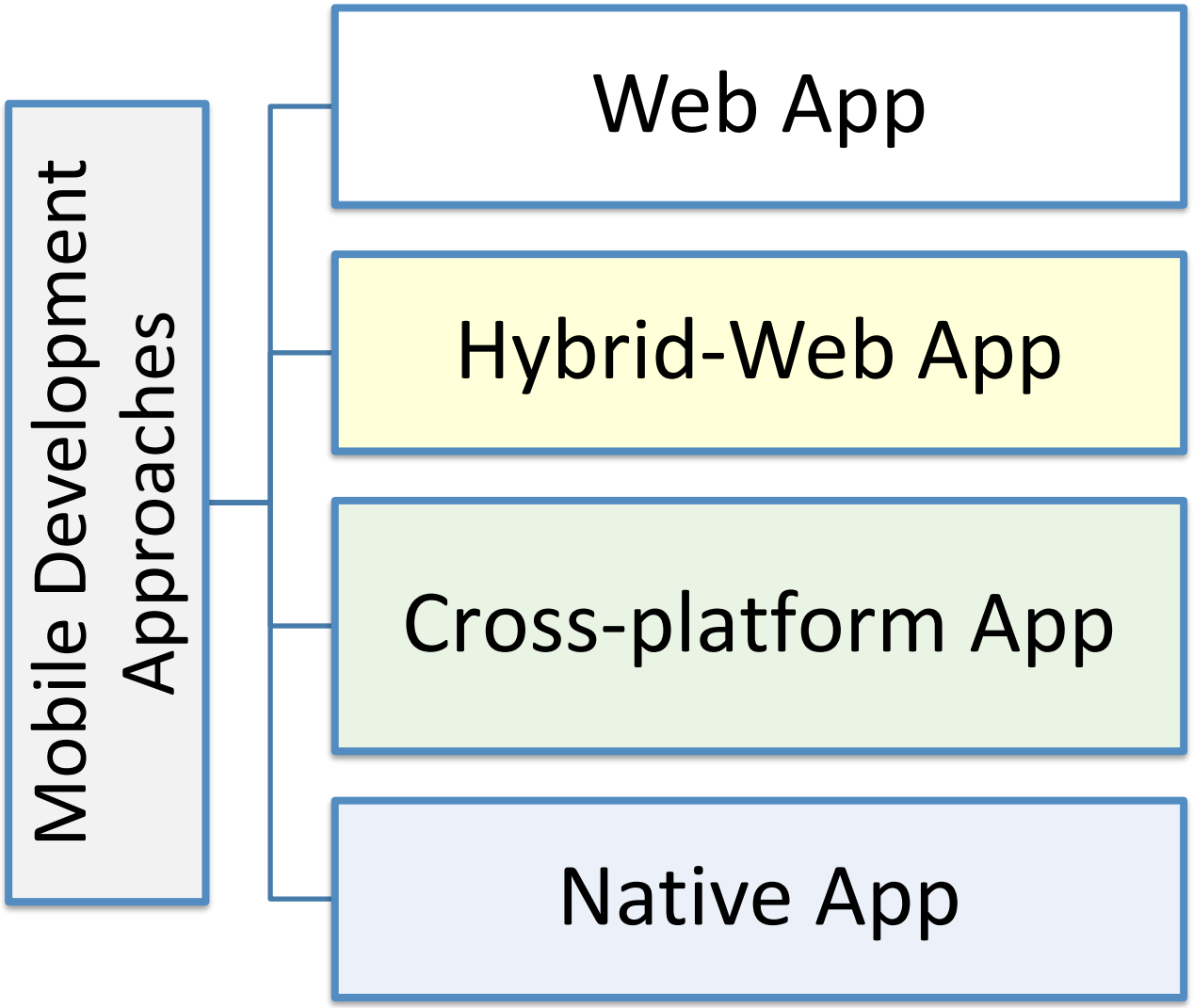
Mobile Development Approaches



Web App

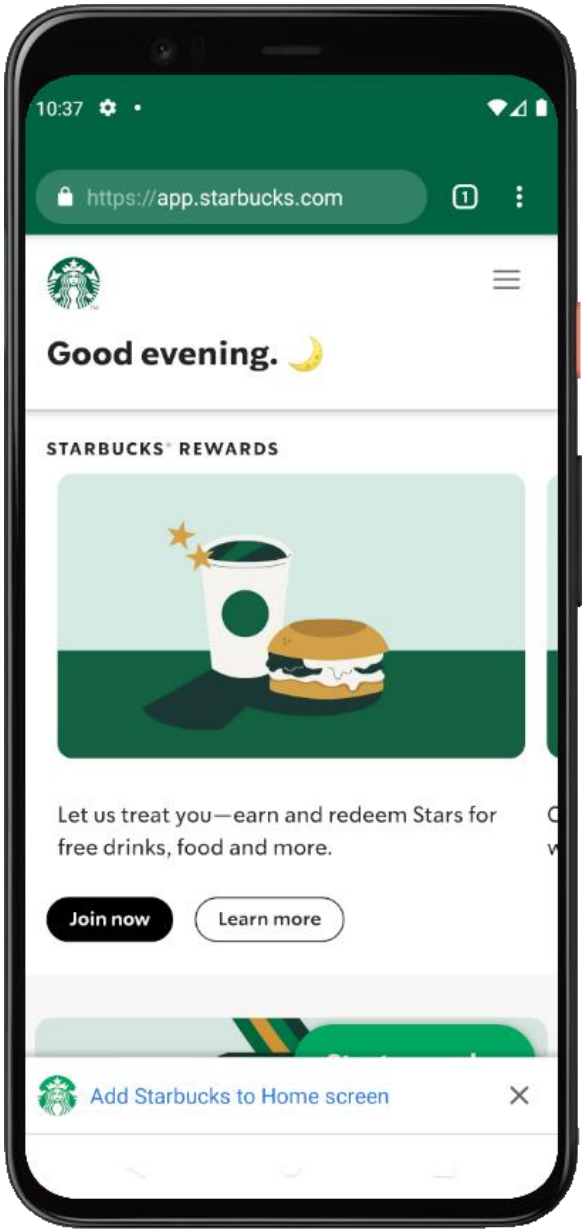
- Responsive Web app adapted to any screen size
- Can be added to Home screen & can work on any platform
- Experience feels like a native app

✓ Can work offline, provide limited access to device's features, such as camera, microphone, location, and notifications

– Slower performance (Run inside a WebView)

– Least access to hardware, sensors, OS

– Not available from the app stores



Hybrid-Web App

- Hybrid-Web Apps: apps blend
  - Mobile-optimized UI components (written using HTML, CSS, and JavaScript) with
  - Native modules or **bridge plugins** for accessing Camera, Geolocation, Bluetooth and other services

✓ Lower development costs (Single codebase)

✓ Multiplatform - Write once, run anywhere

✓ Downloadable from app stores

– Slower performance (not suitable for CPU-intensive apps such as 3D games)

– Highly dependent on libraries and frameworks

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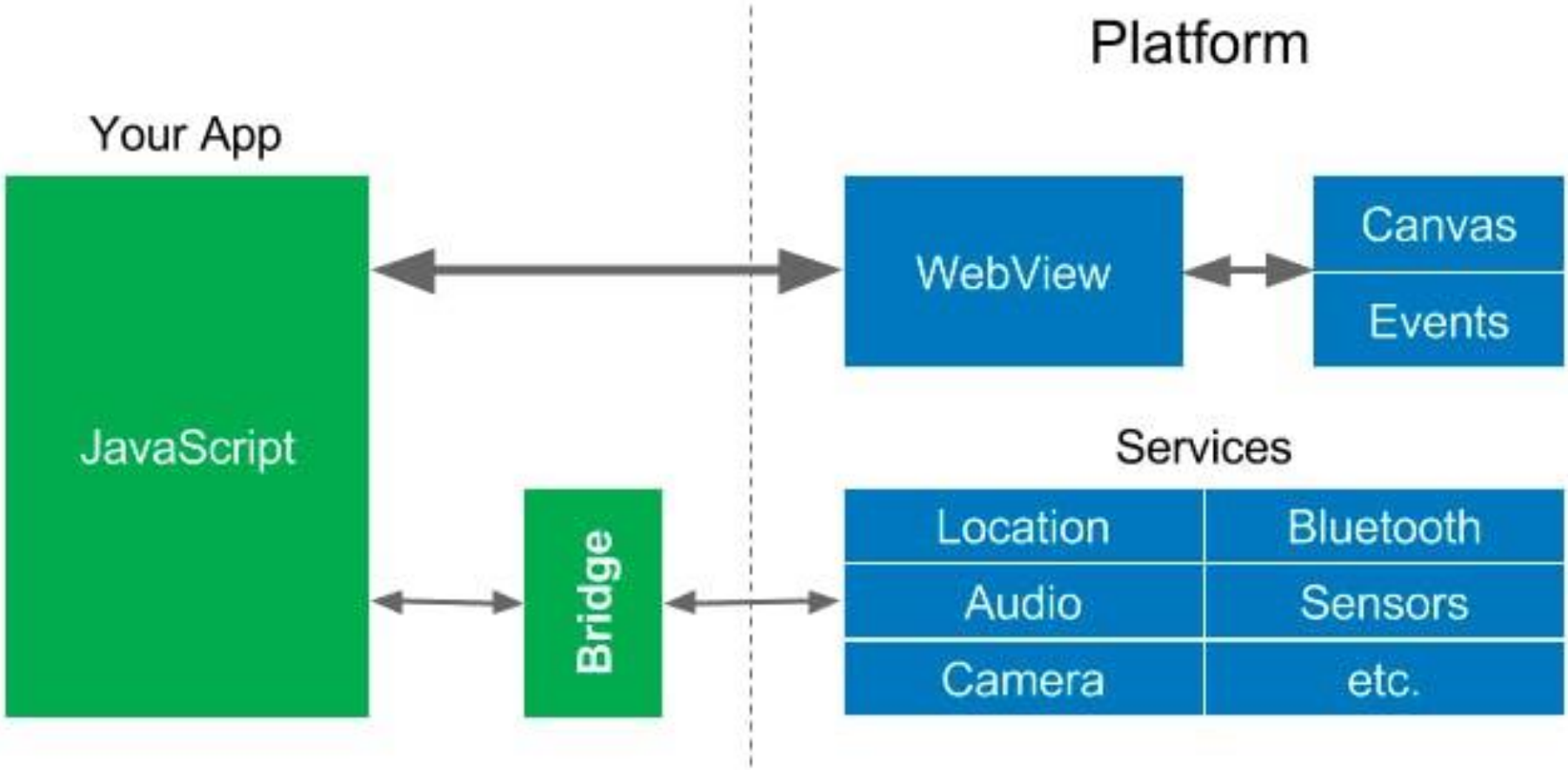
Hybrid-Web App

- App runs inside a **WebView** responsible for UI Rendering
- App access the platform services via a **bridge**



https://wajahatkarim.com/2019/11/how-is-flutter-different-from-native-web-view-and-other-cross-platform-frameworks/

Cross-platform App

- Cross-platform mobile development frameworks can be used to build native-looking apps for multiple platforms, such as Android and iOS, using a single codebase

✓ Lower development costs (Multiplatform utilizing a single codebase)

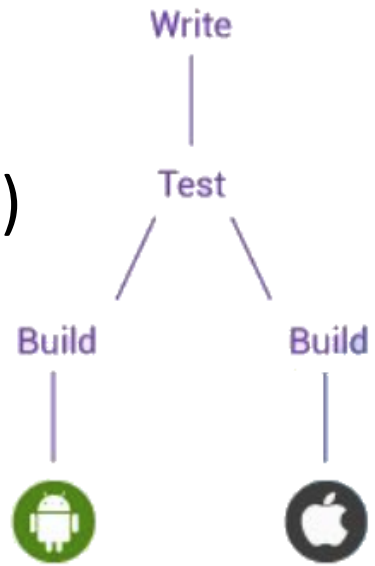
✓ Leverage existing skillset (JavaScript, React, Dart)

✓ UI performance is almost as fast as native

✓ Downloadable from app stores

– Highly dependent on libraries and frameworks

– Delayed update to latest native APIs



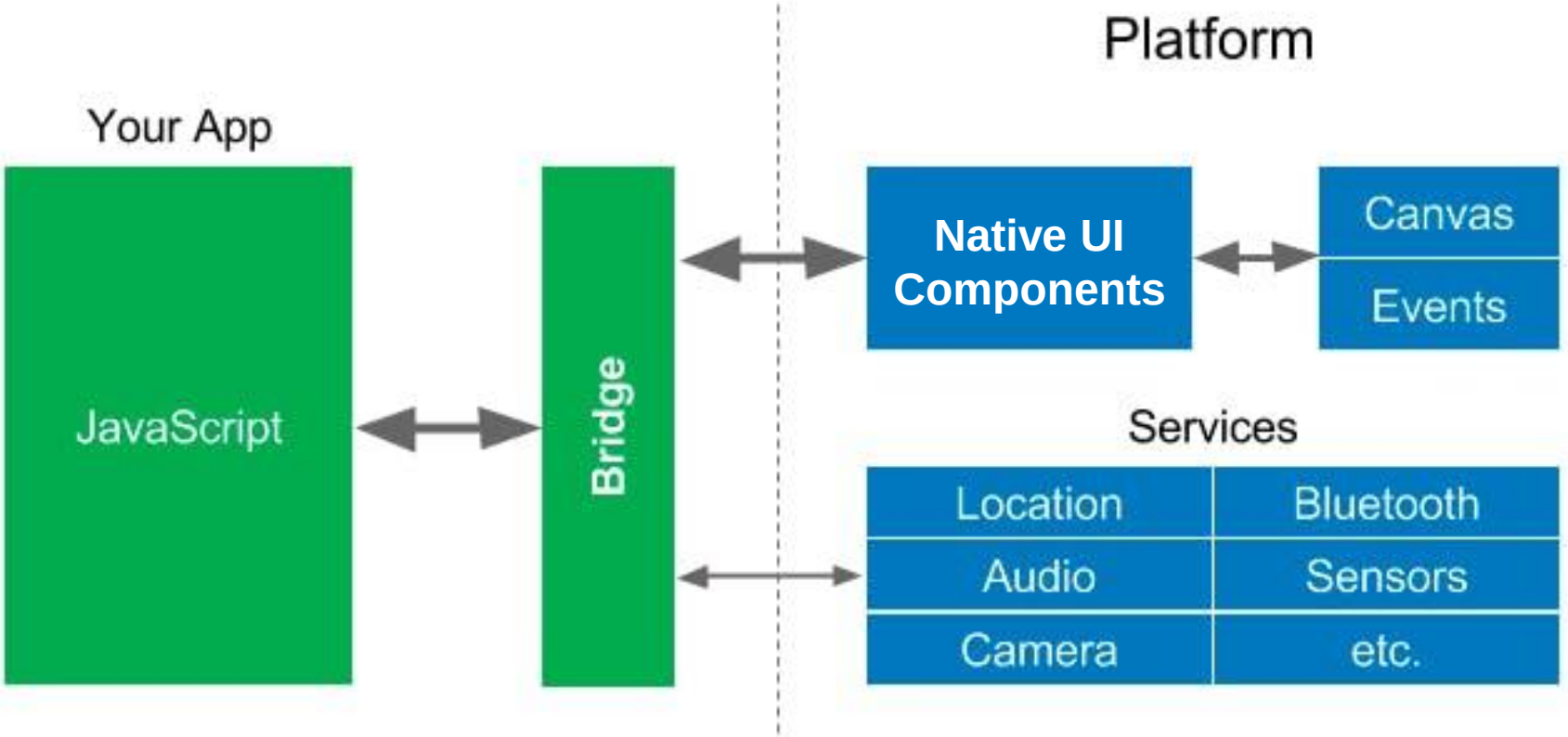
Flutter

React Native

Kotlin Multiplatform

React Native Compiles JavaScript UI components into equivalent **native UI** elements

- Remaining code doesn't get compiled, instead runs in a separate JavaScript thread
- App interact with UI and access the platform services via a **bridge**



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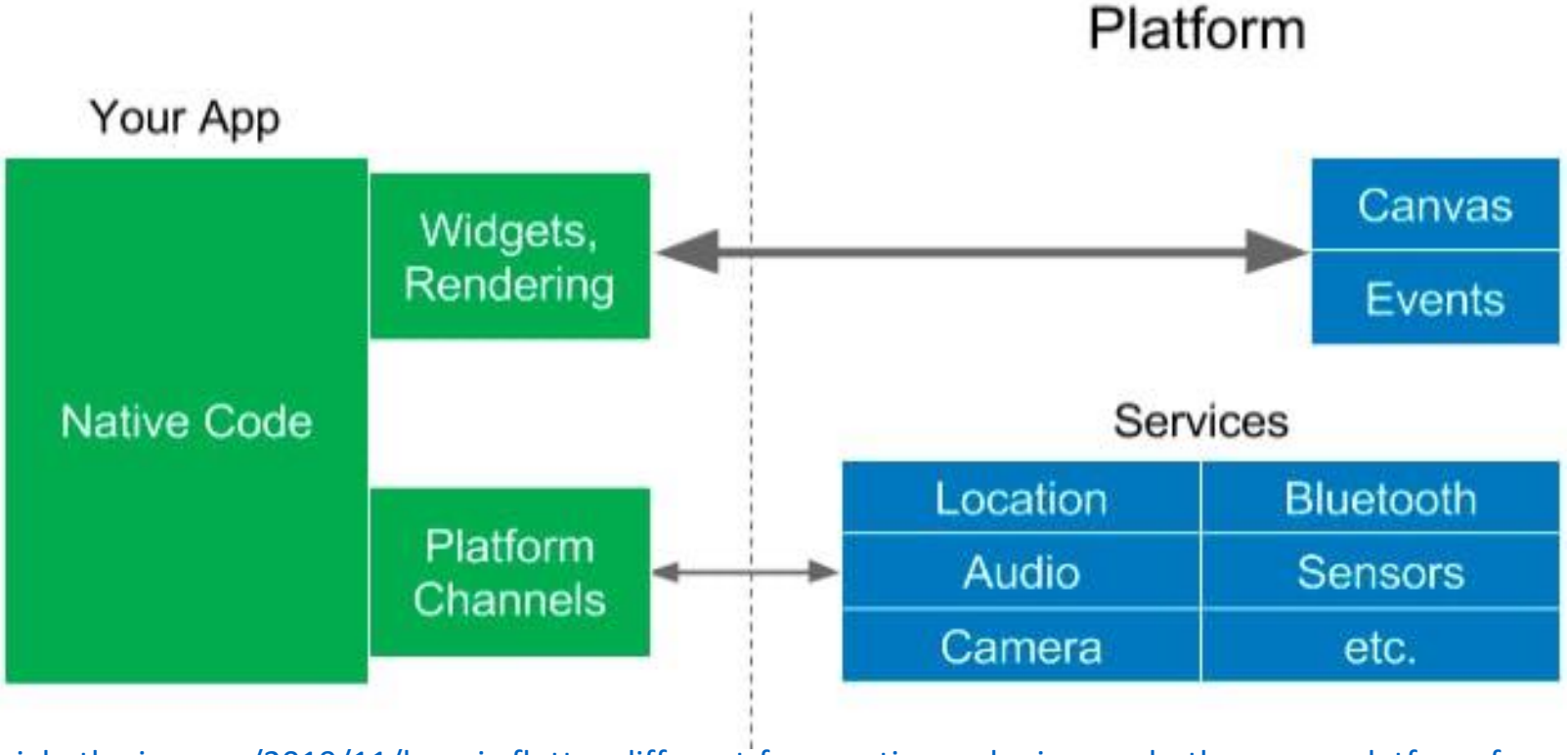
Flutter

- Flutter App (written in Dart) is **compiled into native code**, UI uses Flutter own custom widgets rendered by the framework's **graphics engine Impeller or Skia** to work across devices.
- App uses Platform Channels to access the platform services



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Native App

- Uses platform-specific (Android/iOS) UI components and API

✓ Access to all native APIs, hardware, sensors, & OS

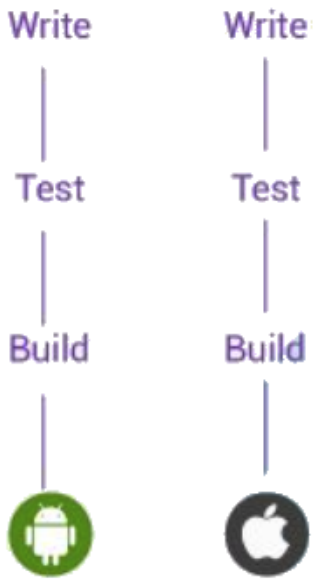
- No third-party dependencies

✓ Fast **performance** as it run directly on OS

✓ High-quality User Experience (UX)

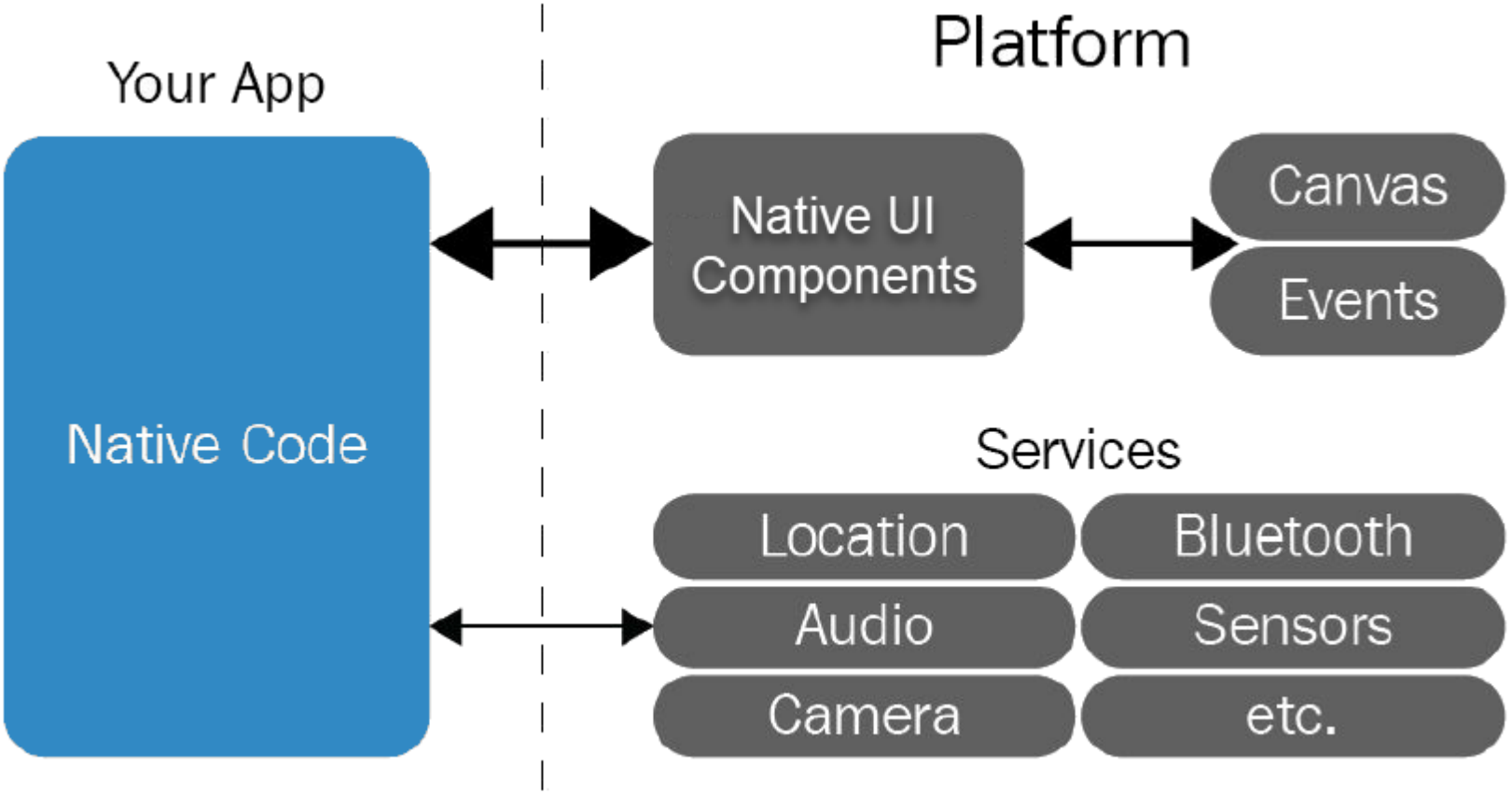
– No codebase reuse

– High dev cost and longer time to market: requires **multiple code bases** and teams



Native Android/iOS Platforms

The **app** has direct access to the platform services



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Introduction to Flutter

Flutter

- Flutter is a **UI toolkit** (including Widgets, Rendering Engine and DevTools) for building applications for mobile, web, and desktop from a single codebase.
- A **declarative component-based programming model**
  - UI is built using composable widgets
    - Each widget define a piece the app's UI programmatically by **describing WHAT to see** (layout/ look and feel) **NOT HOW**
    - Compiler takes care of the HOW and constructs UI elements
  - As state changes the UI automatically updates (Reactive UI)

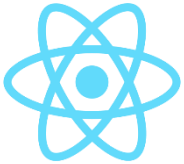
  (without imperatively mutating UI components)
- Inspired by/similar to other declarative UI frameworks such as React and Jetpack Compose

Declarative UI is a major trend

- Describe WHAT to see NOT HOW

Flutter: Google's UI toolkit for building natively compiled applications for mobile, web and desktop from a single codebase

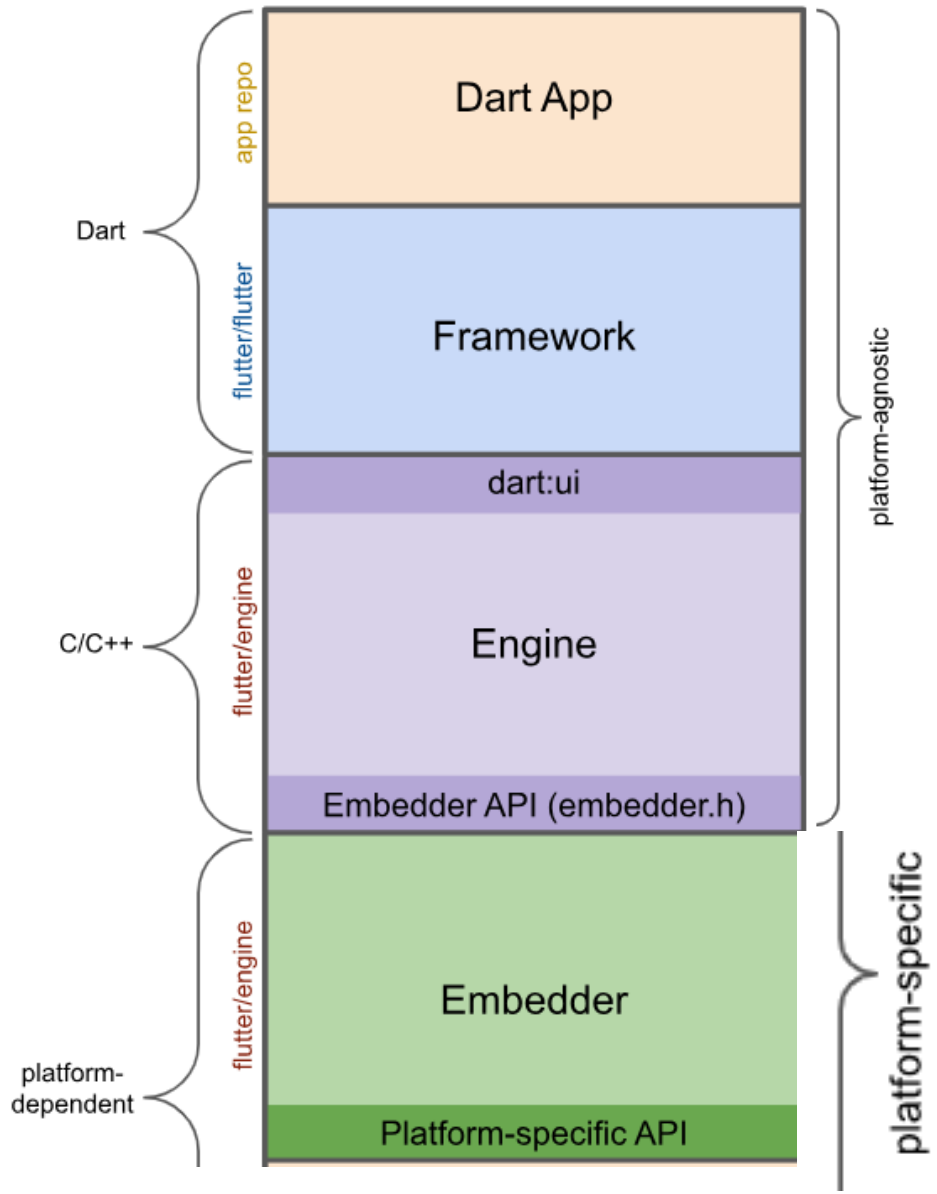
SwiftUI: Apple’s declarative framework for creating apps that run on iOS



React: A JavaScript library for building user interfaces

Jetpack Compose: a **toolkit** for building native Android UI

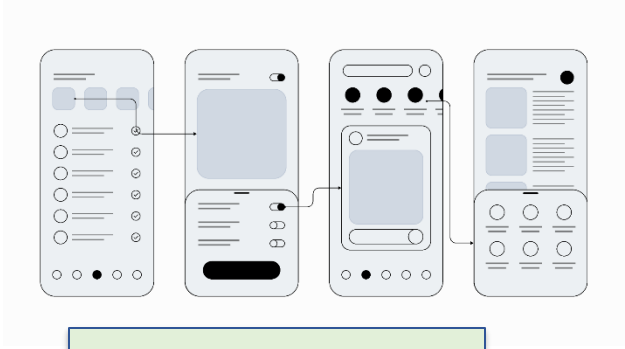
Flutter Software Stack

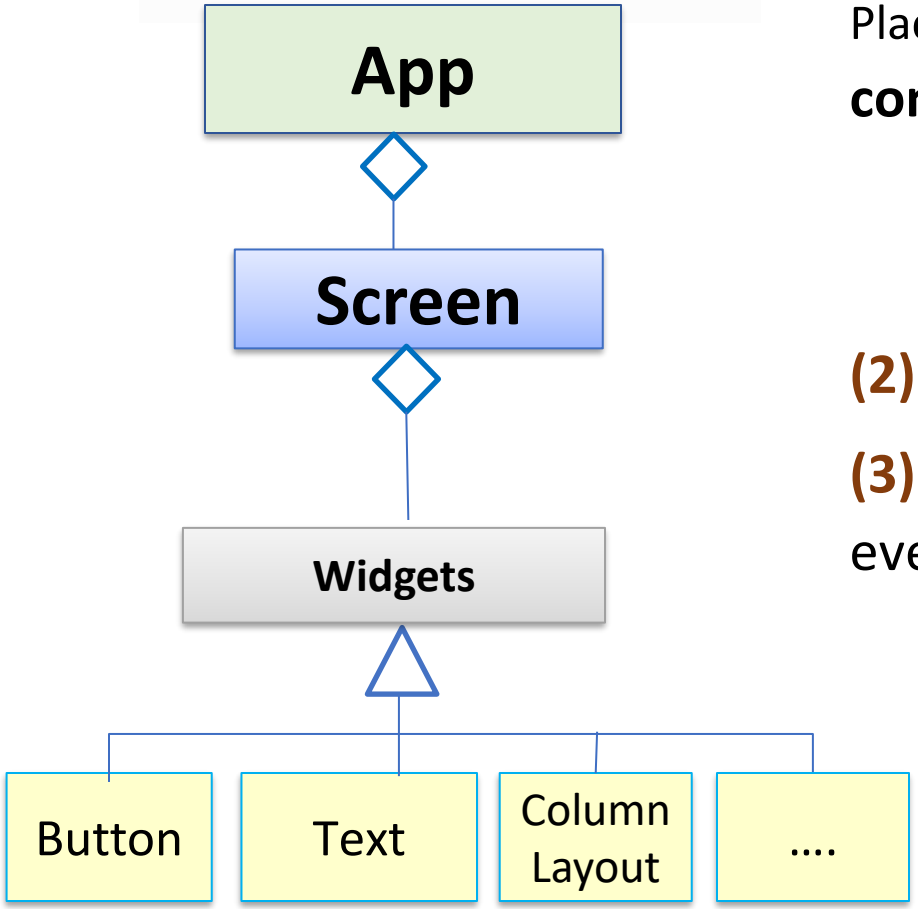


1. **Dart App**: composes widgets into the desired UI
   - Implements business logic
2. **Framework**: provides widgets and higher-level API to build apps
3. **Flutter engine** is responsible for rendering the UI and processing platform events such as touch gestures and keyboard inputs
4. **Embedder** acts as a bridge that handles interaction between the native OS and system resources. More info

Flutter Key Concepts

Declarative UI Programming Model





- App is composed of one or more **screens** (also called pages). A **screen** has:

(1) Widgets (UI Components)

Placed in a **Layout** widgets that acts as a **container** for UI Components

- Layout decides the size and position of widgets placed in it

(2) State objects that provides the data to the UI

(3) Event Handlers to respond to the UI events

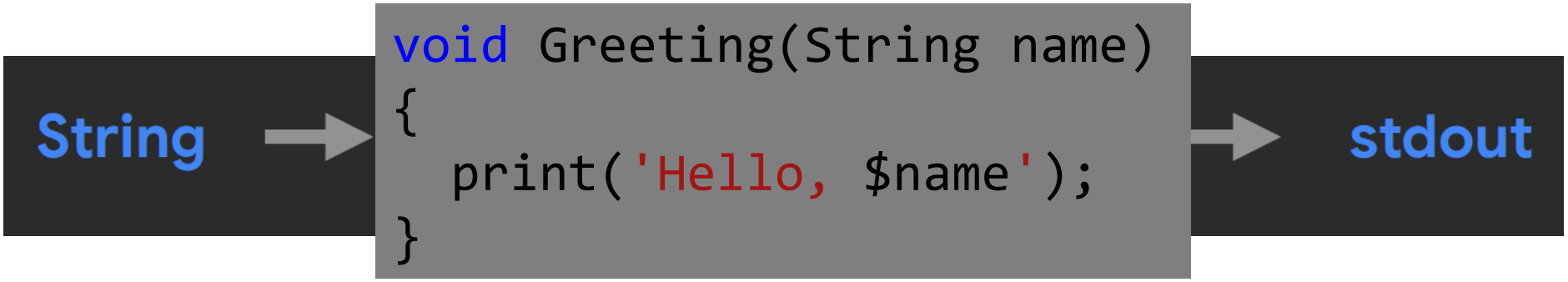
- Widgets **raise Events** when the user interacts with them (such as a Pressed event is raised when a button is pressed)
- Connecting user interactions (like button presses) to app behavior

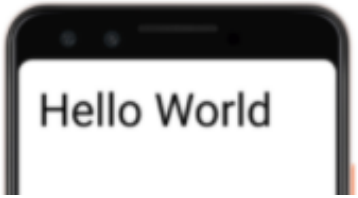
How to define a piece of UI?

- UI is **composed** of small reusable **components** called widgets
- **Widget:** a class that extends StatelessWidget or StatefulWidget depending on whether it manages internal state
  - Each component renders a portion of the UI, transforming the app's data (state) into visual elements
- **UI = f(state) : UI is a visual representation of state** (e.g., display a tweet and associated comments)

- **State-Driven UI Updates**
  - State changes trigger automatic update of the UI

Stateless Widget



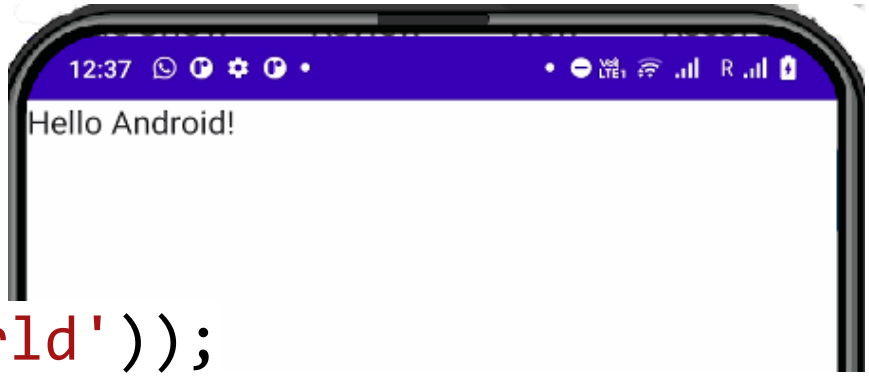



```dart
class Greeting extends StatelessWidget {
  final String name;
  const Greeting(this.name);

  @override
  Widget build(BuildContext context) {
    return Text('Hello, $name');
  }
}
```

Greeting class uses the input data to render a Text widget on the screen

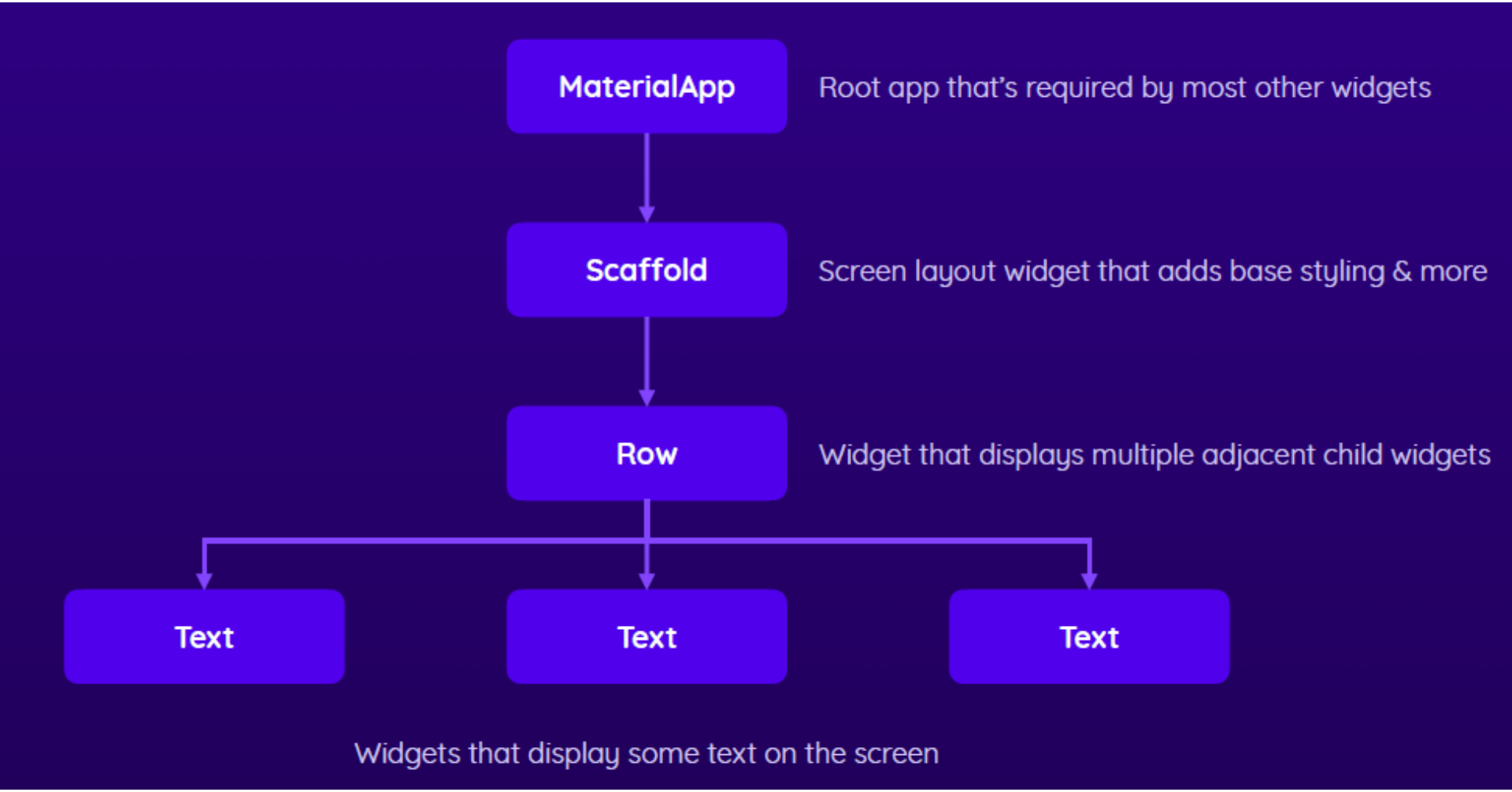
App Entry Point

- The `main()` function is the app entry point
  - Inside it you call the `runApp()` function to launch the app and display the UI on the screen
  - `runApp()` takes a widget (the root widget) and displays the app UI
  - The root widget can be anything, but typically it's a `MaterialApp`, which is a pre-built app structure, including theming, navigation, and more




```
void main() {
  runApp(const Greeting('World'));
}
```

Widget Tree


MaterialApp
Root app that's required by most other widgets
Scaffold
Screen layout widget that adds base styling & more
Row
Widget that displays multiple adjacent child widgets
Text
Text
Text
Widgets that display some text on the screen

BuildContext

- `BuildContext` represents the location of a widget within the widget tree, serving as a link between the widget and its surrounding environment. It plays a critical role in giving the widget access to:
  - **Theme**: used to customize the app's look and feel, such as colors, fonts.
  - **MediaQuery**: provides information about the screen size, device orientation to enable responsive UI that adapt to different screen sizes
  - **Navigator**: used for navigating between screens

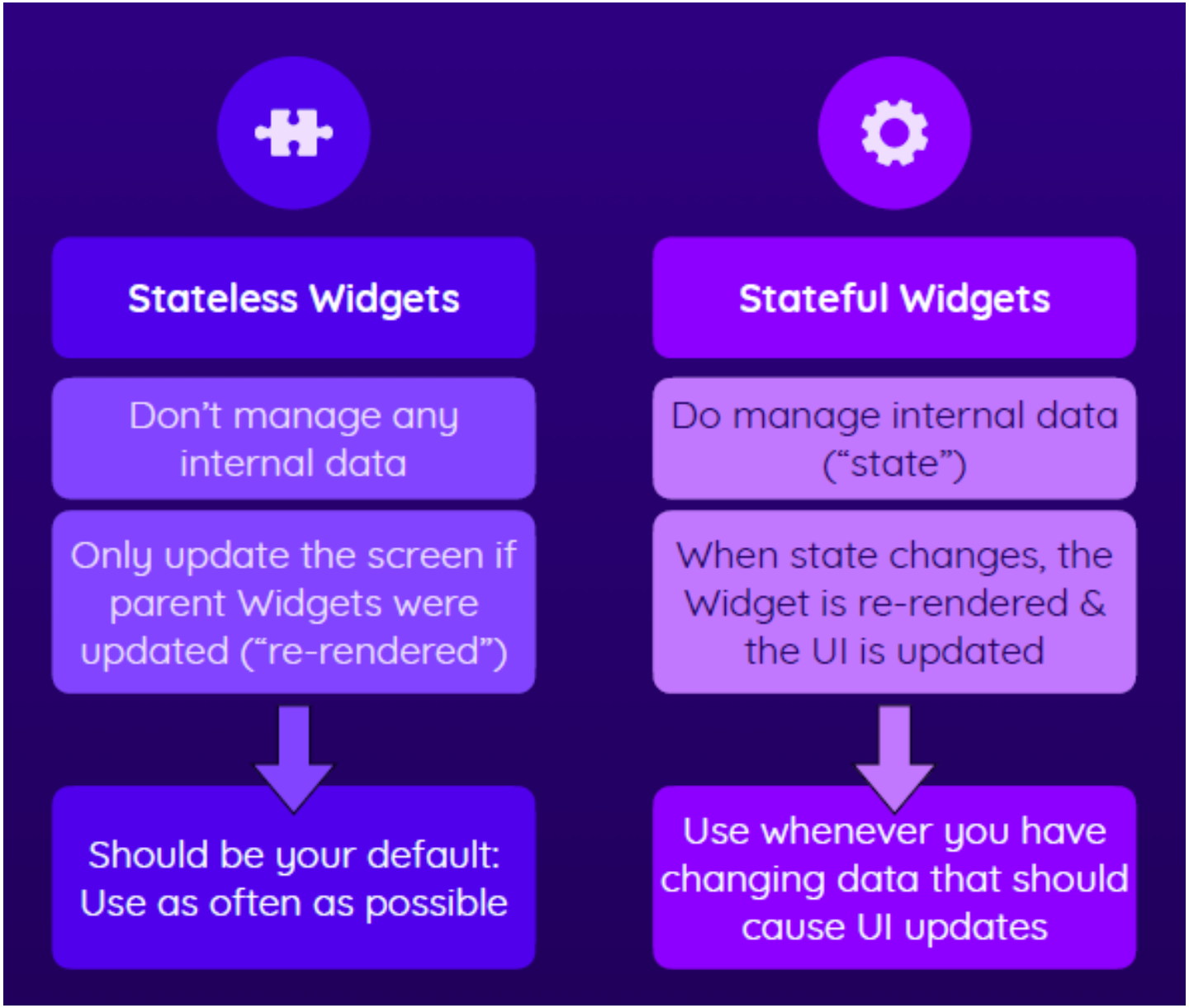
BuildContext usage example

```
class Greeting extends StatelessWidget {
  final String name;

  const Greeting(this.name);

  @override
  Widget build(BuildContext context) {
    return Text(
      'Hello, $name',
      // Using context to access theme data
      style: Theme.of(context).textTheme.headlineLarge,
    );
  }
}
```

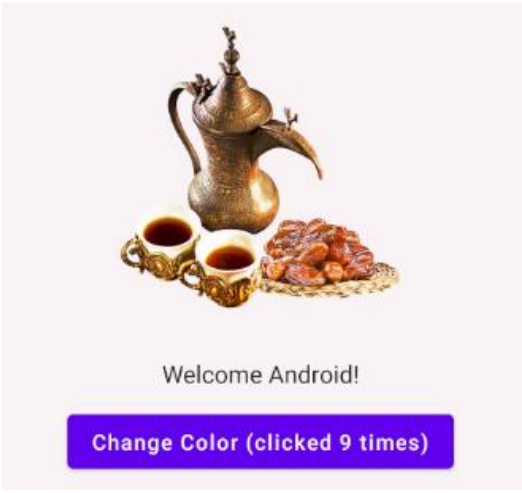
Stateless vs Stateful widgets

- A stateless widget doesn't hold any state
  - The caller controls and manages the state
- Stateful widget holds **mutable state**, which can be modified using **setState()** to trigger a rebuild

Stateless vs Stateful



UI = Composition of Widgets

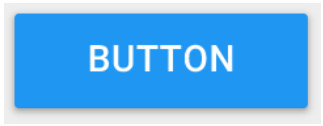


- The top-level widget describes the UI by calling other widgets and passing them the appropriate data

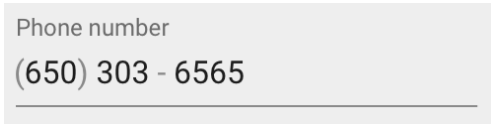
```
@Composable
fun WelcomeScreen() {
    var userName by remember { mutableStateOf( value: "Android") }
    Column { this: ColumnScope
        NameEditor(name = userName, nameChange = { newName -> userName = newName })
        Welcome(userName)
    }
}

@Composable
fun NameEditor(name: String, nameChange: (String) -> Unit) {...}

@Composable
fun Welcome(name: String) {...}
```

Widgets

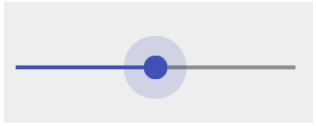
Button



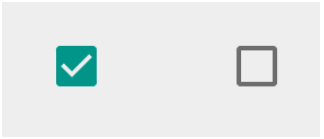
TextField



Slider

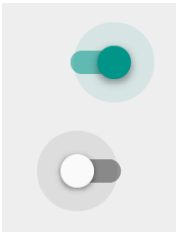


CheckBox



RadioButton

Switch



See more details in slides
'05 Widgets-Layouts'

Full list available at link

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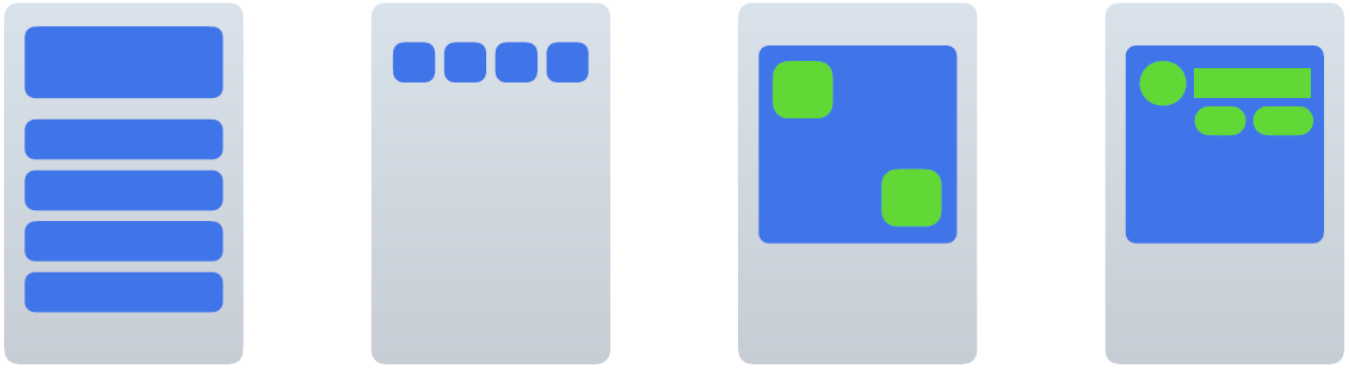
Layouts

- Use a Layout to size & **position** UI elements on the screen
- **`Row`** - position elements horizontally
- **`Column`** - position elements vertically
- **`Stack`** - stack elements on top of each other
- Many more…



Column | Row | Stack | Other Layouts

See more details in slides '05 Widgets-Layouts' & this link

Column and Row

`Column()` & `Row()` can be used to place **multiple child widgets next to each other**

`Column()`

Main Axis: **Vertical** Axis

Cross Axis: Horizontal Axis

By default, occupies the **entire available height** but **only the width required** by its content (children)

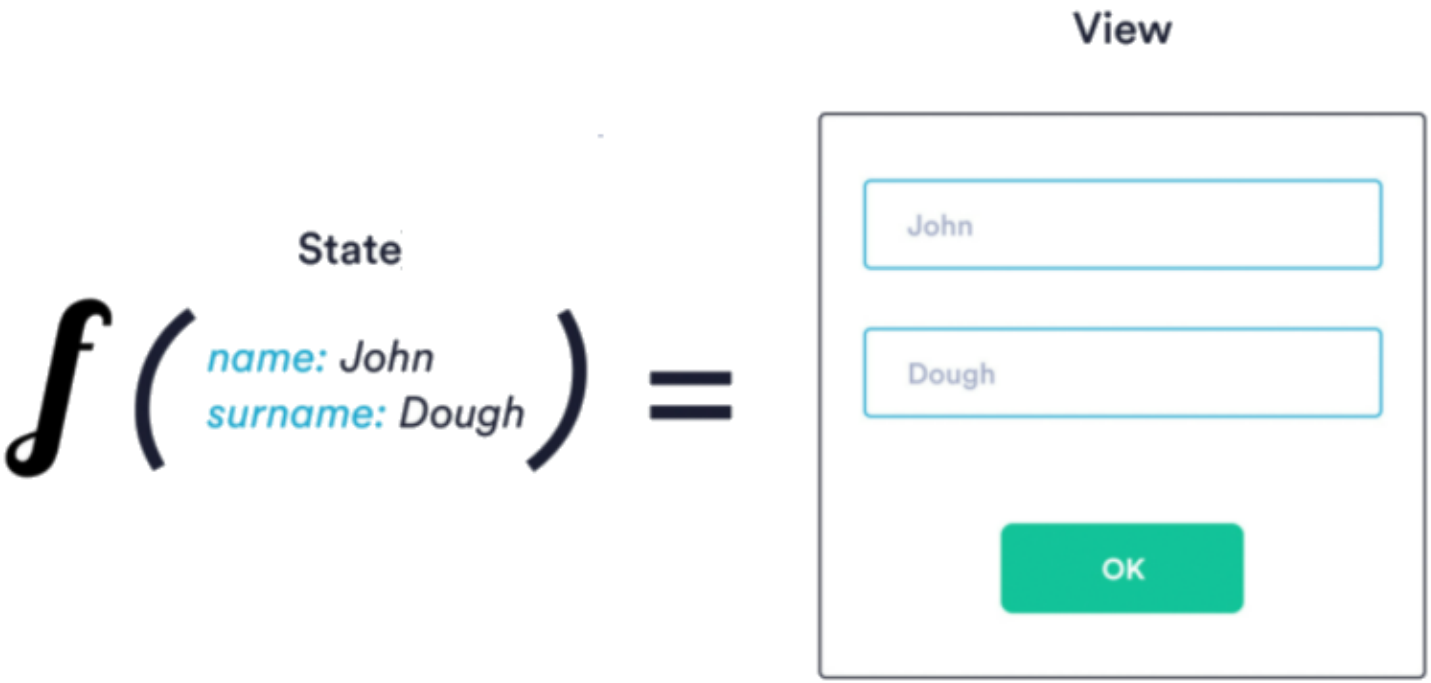
`Row()`

Main Axis: **Horizontal** Axis

Cross Axis: Vertical Axis

By default, occupies the **entire available width** but **only the height required** by its content (children)

State



https://developer.android.com/jetpack/compose/state

State

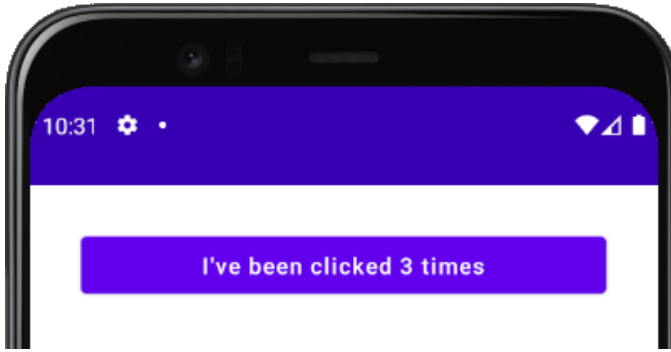
- State = any value that can change overtime
- State variables must be declared in class that extends **State** base class
  - They should be changed inside `setState`(…) method that act as **Change Notifiers** to notify Flutter runtime
  -  Any change of a state variable (inside `setState` method) will trigger the **recomposition** of any widgets that **reads** the state variable

  => UI is **auto-updated** to reflect the updated app state
- UI in Flutter is immutable
  - In Flutter you cannot access/update UI elements directly (as done in the imperative approach)
  - The only way to update the UI is by updating the state variable(s) used by the UI elements – this triggers automatic UI update
    - E.g., displayed ***counter text*** can only be changed by updating the ***counter*** state variable

Widget Rebuilding

- When the user interacts with the UI, the widgets raises events such as onChanged
  - Those events should notify the app logic, which can then change the app's state
  - When the state changes it causes the widgets build methods to be automatically called again with the new data => this causes the UI elements to be redrawn
- Flutter intelligently rebuilds only the components that changed

Widget Rebuilding Example



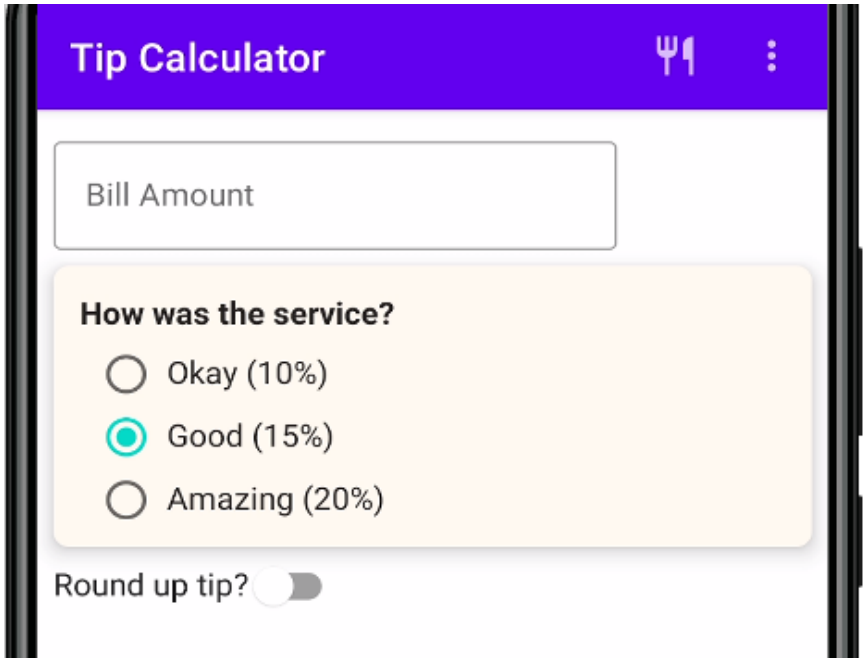
- Every time the button is clicked, the button widget raises ***onPressed*** event to notify the app logic, which increments **clicksCount** state variable
- This causes a **Widget Rebuilding** to take place, i.e., the **ClickCounter** build function is automatically called again to redrawn the widget

```
class ClickCounter extends StatefulWidget {
  const ClickCounter();
  @override
  _ClickCounterState createState()
            => _ClickCounterState();
}
```

```
class _ClickCounterState extends State<ClickCounter> {
  int clicksCount = 0;
  @override
  Widget build(BuildContext context) {
    return Scaffold(
      appBar: AppBar(
        title: const Text('Click Counter'),
        centerTitle: true),
      body: Center(
        child: ElevatedButton(
          onPressed: () {
              setState(() {
                clicksCount += 1;
              });
          },
          child: Text("I've been clicked $clicksCount times"),
        ),
      ));
  }
}
```

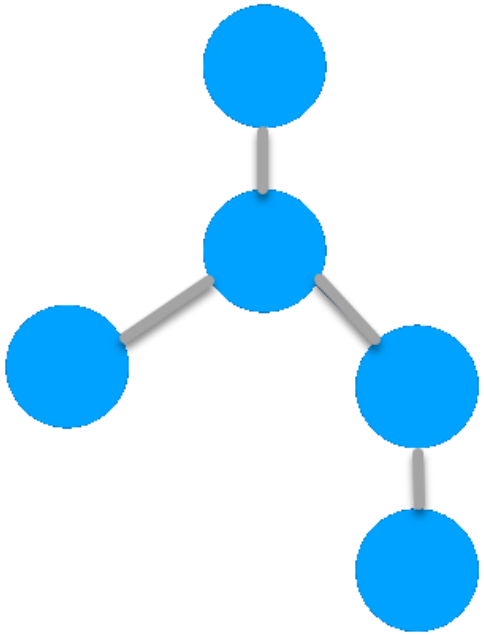
Tip Calculator Example

- In the example below, notice no Compute/OK button, any change of input auto-recomputes and re-displays the tip value
  - Like Excel way: changing a cell value triggers auto-update of formulas and graphs referencing it
- Plus, the code is much more concise and elegant (see posted example)



How recomposition works

1. Creates an abstract tree representation of the UI and renders it
2. When a change occurs, it creates a new tree representation
3. Computes the differences between the two representations
4. Renders the differences [if any]



For more details about Jetpack Compose Runtime, watch this video

Stateful versus Stateless

- **stateful** widgets can hold and manage internal mutable state using the State class
  - You update the state using the **setState()** method, which re-renders the widget when the state changes.
  - Reduced reusability: the state is internal and not exposed, making it hard to reuse the widget in different contexts or with different external state.
  - Harder testing: Testing stateful widgets is more complex because you need to simulate the state transitions to verify behavior.
  - => Where possible, manage state externally and pass it to widgets to improve reusability and testability.
- A stateless composable that doesn't hold any state
  - The caller controls and manages the state
  - State hoisting is a pattern where the state is "hoisted" or moved from a widget into its parent, so the child widgets become stateless
    - The widget that previously managed state now takes the state as an input from the parent

State Hoisting

- To make a widget stateless, **extract** its state and **move it to the parent**
- Then pass the state to the widget as a parameter, along with a callback function that the widget can call to update that state in response to events (e.g., onValueChange, onExpand and onCollapse) e.g.,
  - `name: String` - the current value to display
  - `onNameChange: (String) -> Unit` - a callback that requests the value to change
- Hoisted state variables are owned by the Caller and can passed to other widgets

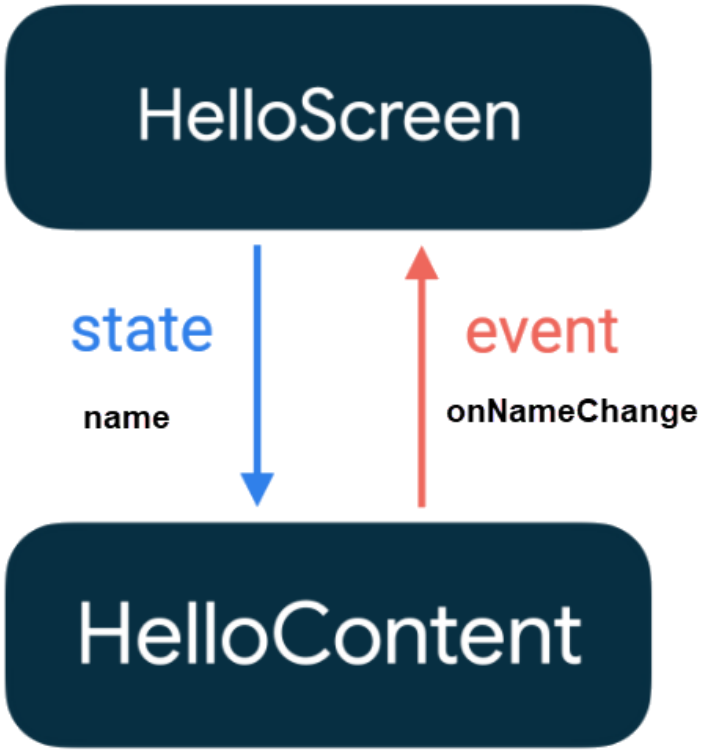
State Hoisting - Example

```
@Composable
fun HelloScreen() {
    var name by remember { mutableStateOf("") }

    HelloContent(name = name, onNameChange = { name = it })
}

@Composable
fun HelloContent(name: String, onNameChange: (String) -> Unit) {
    Column(modifier = Modifier.padding(16.dp)) {
        Text(
            text = "Hello, $name",
            modifier = Modifier.padding(bottom = 8.dp),
            style = MaterialTheme.typography.h5
        )
        OutlinedTextField(
            value = name,
            onValueChange = onNameChange,
            label = { Text("Name") }
        )
    }
}
```

Unidirectional Data Flow

= a design where **state flows down and events flow up**

```
var name by remember { mutableStateOf("") }
HelloContent(name = name, onNameChange = { name = it })
```



State flows down via widget parameter

(e.g., *name*)

(State change) Event flows up via callback function

(e.g., *onNameChange*)

By hoisting the state out of HelloContent, it can be **reused** in different situations, and it is easier to test

Summary

- Declarative UI is the trend for UI development
  - UI is composed of small reusable widgets
  - **Stateless widgets** don't hold state, making them more reusable and test-friendly
  - **Stateful widgets** manage their own state but are harder to reuse and test
  - **State hoisting** shifts state management to the parent, enhancing the flexibility of child widgets
- Layouts are used to size position widgets on the screen
- Widget is **immutable**
  - It only accepts state & exposes events
  - **Unidirectional Data Flow** pattern:
    - State flows down via parameters
    - Events flow up via callbacks
- .. mastering Flutter will take some time and practice   ...

Resources

- Flutter getting started

https://docs.flutter.dev/get-started/

- Flutter architecture

https://docs.flutter.dev/resources/architectural-overview

- Flutter Code Labs

https://docs.flutter.dev/codelabs

- Widgets

https://docs.flutter.dev/ui/widgets

- Layouts

https://docs.flutter.dev/ui/layout