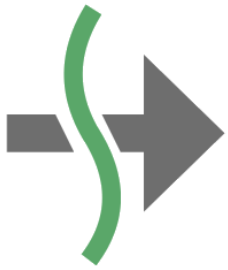
CMPS 312

Asynchronous Programming



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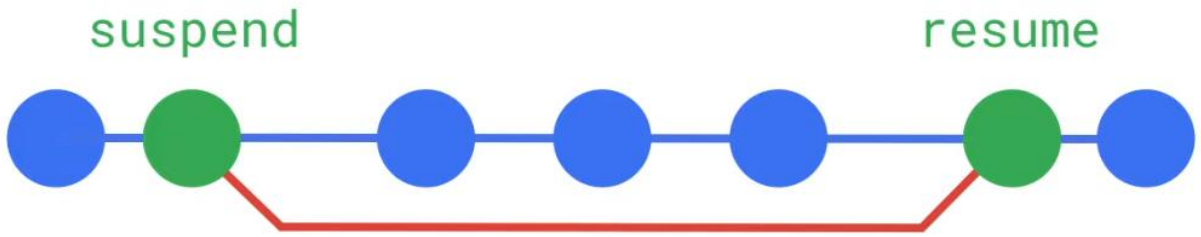
CSE@QU

Outline

1. Asynchronous Programming
   - Future
   - Stream
2. Isolate for Parallel Execution of Tasks

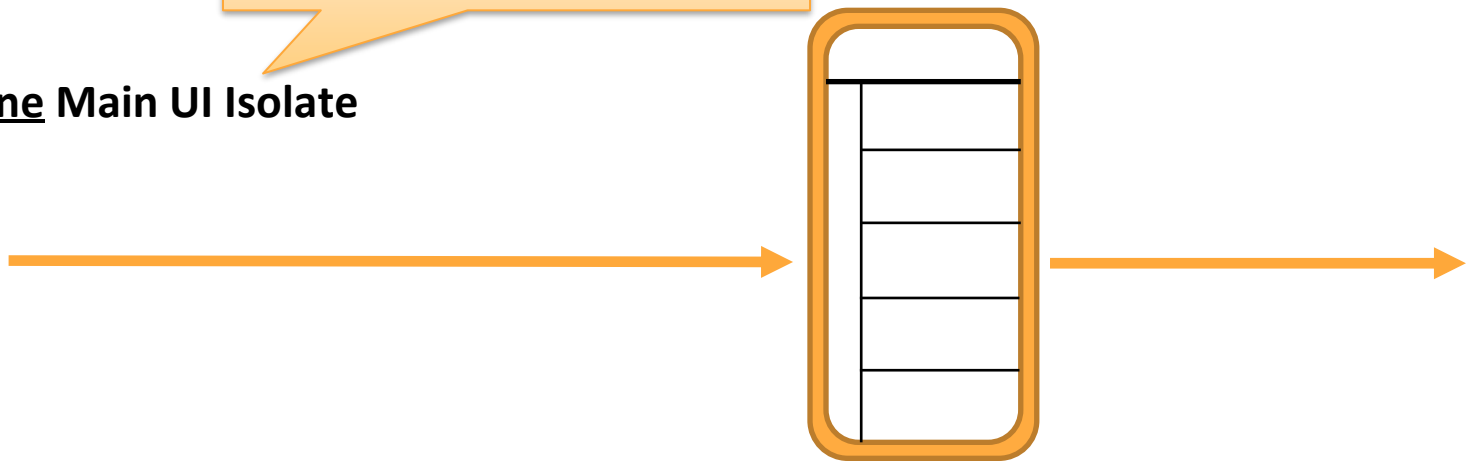
Asynchronous Programming



User Interface Running on the Main Isolate

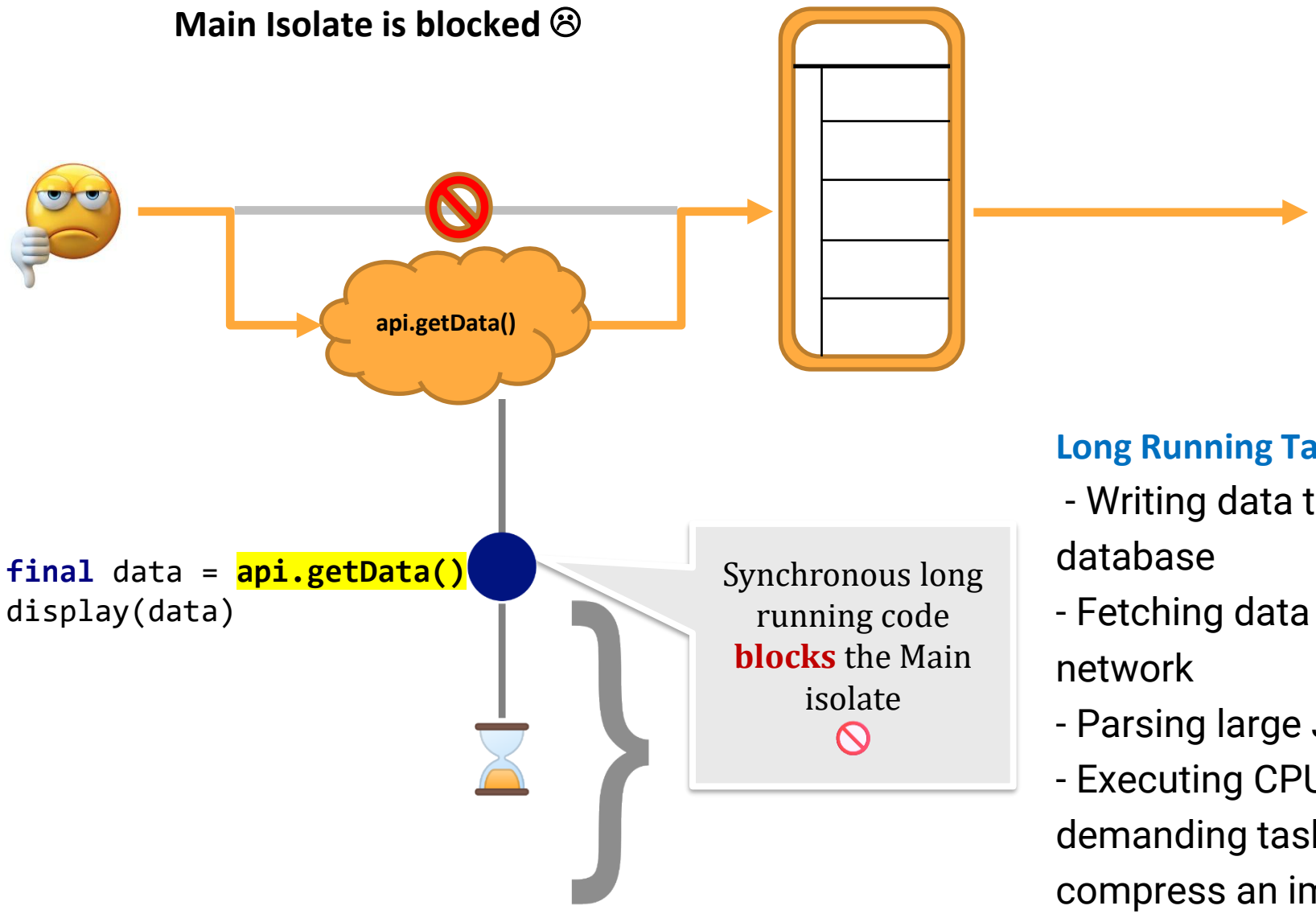
Isolate = an execution unit with its own memory

<u>One</u> Main UI Isolate



To guarantee a great user experience, it's essential to **avoid blocking the main isolate** as it used to handle UI updates and UI events

Long Running Task on the Main Isolate



Long Running Tasks include:

- Writing data to a database
- Fetching data from the network
- Parsing large JSON file
- Executing CPU demanding task (e.g., compress an image)

Concurrency vs Parallelism in Dart

- **Concurrency** use async-await with Future & Stream
  - Handle multiple tasks **over time** without blocking the main isolate
  - Use for Network requests (HTTP calls), File I/O, Database queries
    - Any task that is **I/O-bound** (waiting for external resources)
- **Parallelism** use Isolate
  - Runs tasks a **separate isolate** (like a lightweight thread) with its own memory
  - Use for **CPU-intensive tasks** (e.g., image compression, encryption, large JSON parsing)
  - Keeps Flutter UI **responsive** by offloading heavy tasks

Future

Back

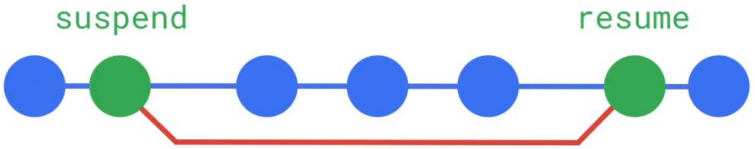
Future

- Future represents a **value** or **error** that will be available later
- Purpose: Used for asynchronous operations
- E.g., `fetchUserOrder` returns a Future

```
final url =
Uri.parse('https://api.example.com/users/$userId/order’);
final response = await http.get(url);
```

- The event loop
  - Starts the HTTP request, keeps the app responsive by processing other tasks,
  - Later delivers the response to your code when it’s ready

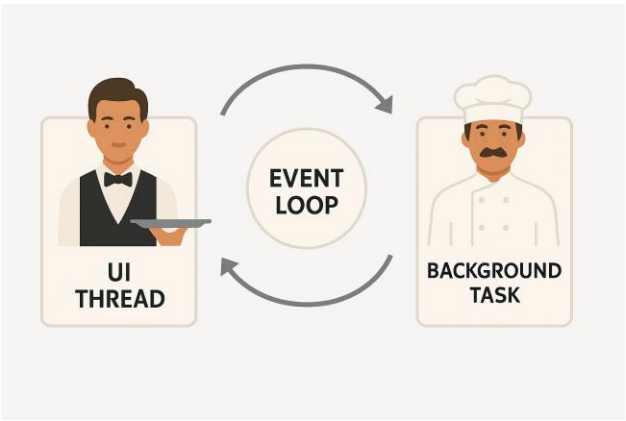
Async function



- An **async function** can pause and resume later
- When it hits **await**, it **does not block** the isolate
- Dart runtime:
  - **Pauses** the function and saves its state
  - **Resumes** when the awaited result is ready
- The **event loop** handles other tasks, so the UI stays responsive while waiting for results

Event Loop: How It Avoids UI Blocking

- **UI thread** (analogy **Waiter**)
  - Takes orders (user actions) and serves customers (updates UI)
  - Never goes to the kitchen → stays responsive to guests
- **Background task** (analogy **Chef**)
  - Prepares meals (long-running tasks: network calls, file I/O)
  - Notifies waiter when ready
- **Event Loop:**
  - **Schedules** tasks and **delivers results** when ready
    - Waiter writes down the order and moves on (doesn't wait in the kitchen)
    - Chef works in the background; notifies the waiter when done
  - This keeps the UI (restaurant) running smoothly without delays



FutureProvider

- Riverpod FutureProvider is used to handle asynchronous operations, like fetching data from an API or database queries
  - **UI rebuilds when the future is completed**: it listens to a Future and triggers a UI rebuild once the operation completes and data is received
  - Handles the **loading**, **error**, and **data** states in a structured manner, e.g.:
    - **loading**: show a spinner until data is available
    - **error**: display error message if something fails
    - **data**: show the received data

FutureProvider Example

```dart
final weatherProvider = FutureProvider<String>((ref) async {
  await Future.delayed(const Duration(seconds: 2)); // Simulate network call
  return "Sunny";  // Data returned from API
});

class WeatherScreen extends ConsumerWidget {
  @override
  Widget build(BuildContext context, WidgetRef ref) {
    final weatherAsync = ref.watch(weatherProvider);

    return Scaffold(
      appBar: AppBar(title: const Text('Weather Forecast')),
      body: weatherAsync.when(
        loading: () => const CircularProgressIndicator(),  // Loading state
        error: (err, stack) => Text('Error: $err'),  // Error state
        data: (weather) => Text('Weather: $weather'), // Success state
      ),
    );
  }
}
```

Stream

Stream

- Stream is used to handle asynchronous data that arrives over time, such as continuous data updates from a remote service
- A Stream allows you to listen and react to events as they arrive, without blocking the main UI
- `Stream.periodic` or `async*` can be used for asynchronous generator functions that produce a stream of values over time

Stream Example 1

```
Stream<int> temperatureStream() {
  return Stream.periodic(Duration(seconds: 1),
      (count) => 25 + count % 5);
}

void main() {
  final tempUpdates = temperatureStream();
  tempUpdates.listen((temp) {
    print("Current temperature: $temp°C");
  });
}
```

Stream Example 2

```
Stream<String> symbolsStream() async* {
  yield "🌊";
  await Future.delayed(Duration(milliseconds: 500));
  yield "⚽";
  await Future.delayed(Duration(milliseconds: 300));
  yield "🎉";
}

void main() async {
  await for (var symbol in symbolsStream()) {
    print("Receiving $symbol");
  }
}
```

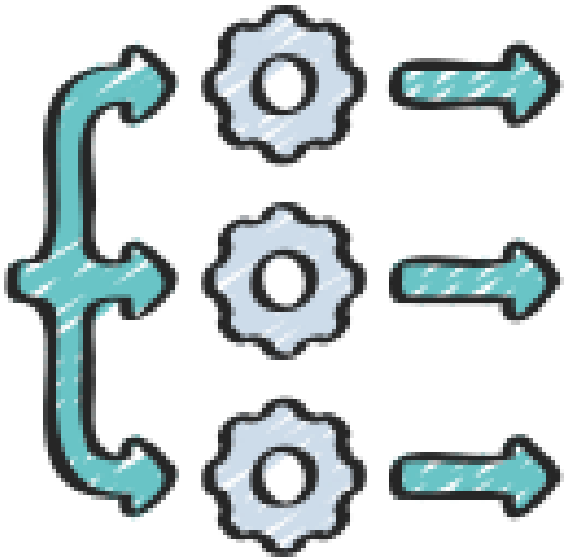
StreamProvider

- Riverpod StreamProvider is used to listen to asynchronous data streams
  - 🌊 It returns a stream of values produced incrementally over time, allowing for live updates (e.g., receiving updates from a database or Web API to refresh the UI)
  - It provides the latest emitted value from the stream to update widgets when new data arrives
  - Ideal for real-time data, such as stock prices, chat messages, or sensor readings
  - Handles the **loading**, **error**, and **data** states in a structured manner

StreamProvider Example

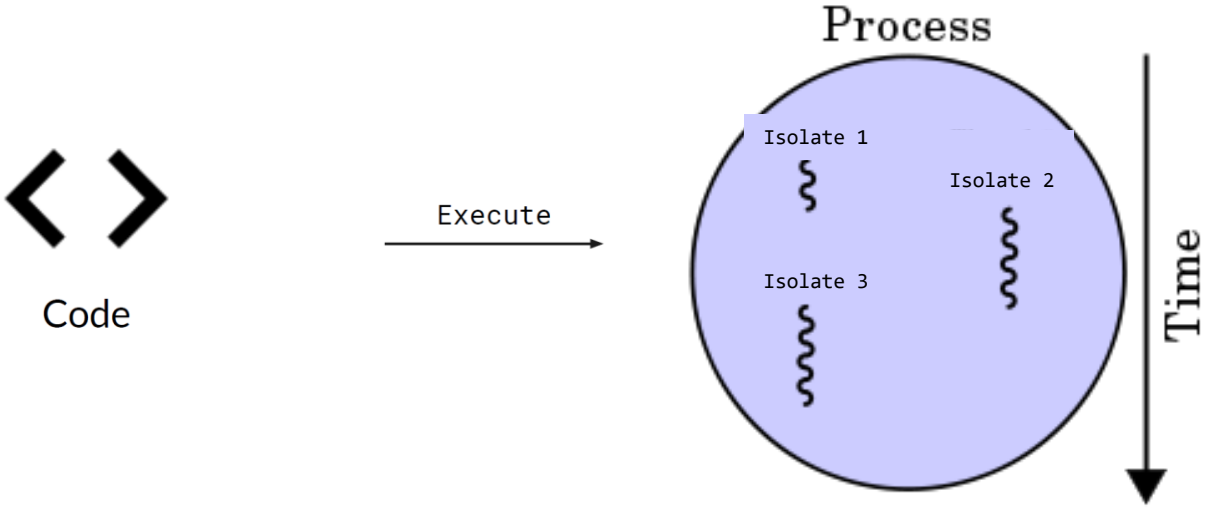
```dart
final stockPriceProvider = StreamProvider<double>((ref) async* {
  // Simulate fetching stock prices from an API.
  await Future.delayed(const Duration(seconds: 1));
  yield 150.0; // Initial price
  await Future.delayed(const Duration(seconds: 2));
  yield 152.5; // New price update
  await Future.delayed(const Duration(seconds: 2));
  yield 151.0; // Another update
});

class StockPriceScreen extends ConsumerWidget {
  @override
  Widget build(BuildContext context, WidgetRef ref) {
    final stockPriceAsync = ref.watch(stockPriceProvider);

    return Center(
        child: stockPriceAsync.when(
          loading: () => const CircularProgressIndicator(),
          error: (err, stack) => Text("Error: $err"),
          data: (price) => Text("Stock Price: \$${price}"),
    );
}}
```

Isolate for Parallel Execution of Tasks

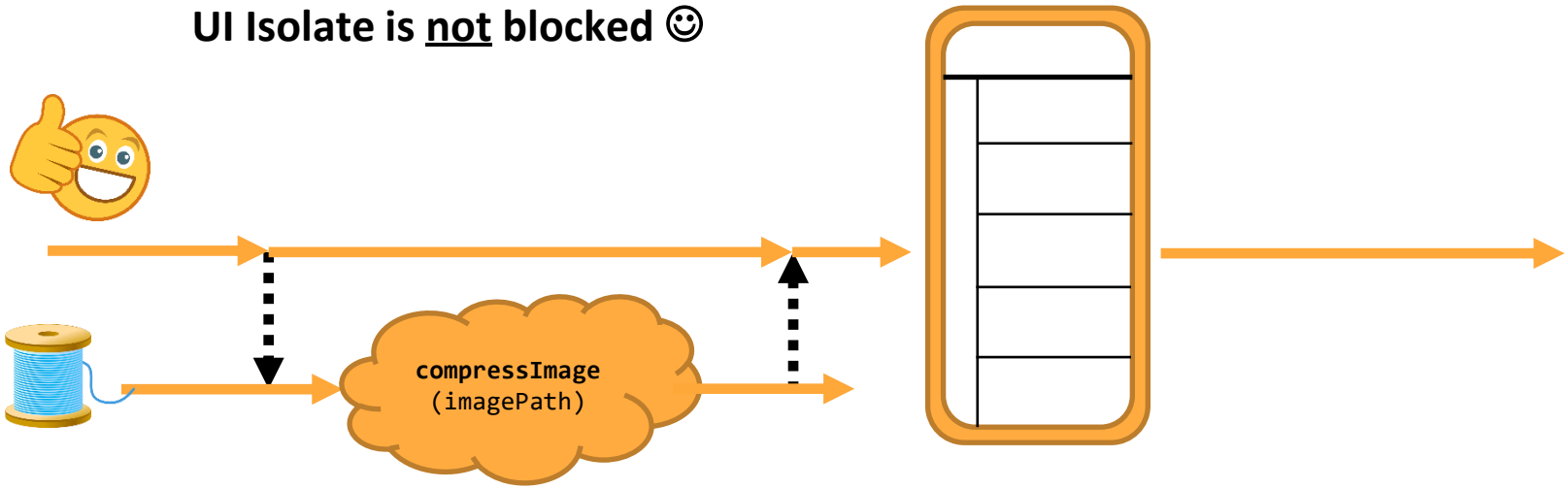


Use Isolate for Parallel Execution of Tasks

- Creates a **separate isolate** to execute a CPU-intensive task without blocking the Main isolate. **Use when:**
  - CPU-intensive tasks (e.g., image compression, encryption, large JSON parsing, heavy computations) that would block the main isolate if run there
  - **Parallel** execution of tasks
- An isolate is the **unit of execution** (like a lightweight thread) within a process
  - Each isolate has its own isolated memory, and its own event loop

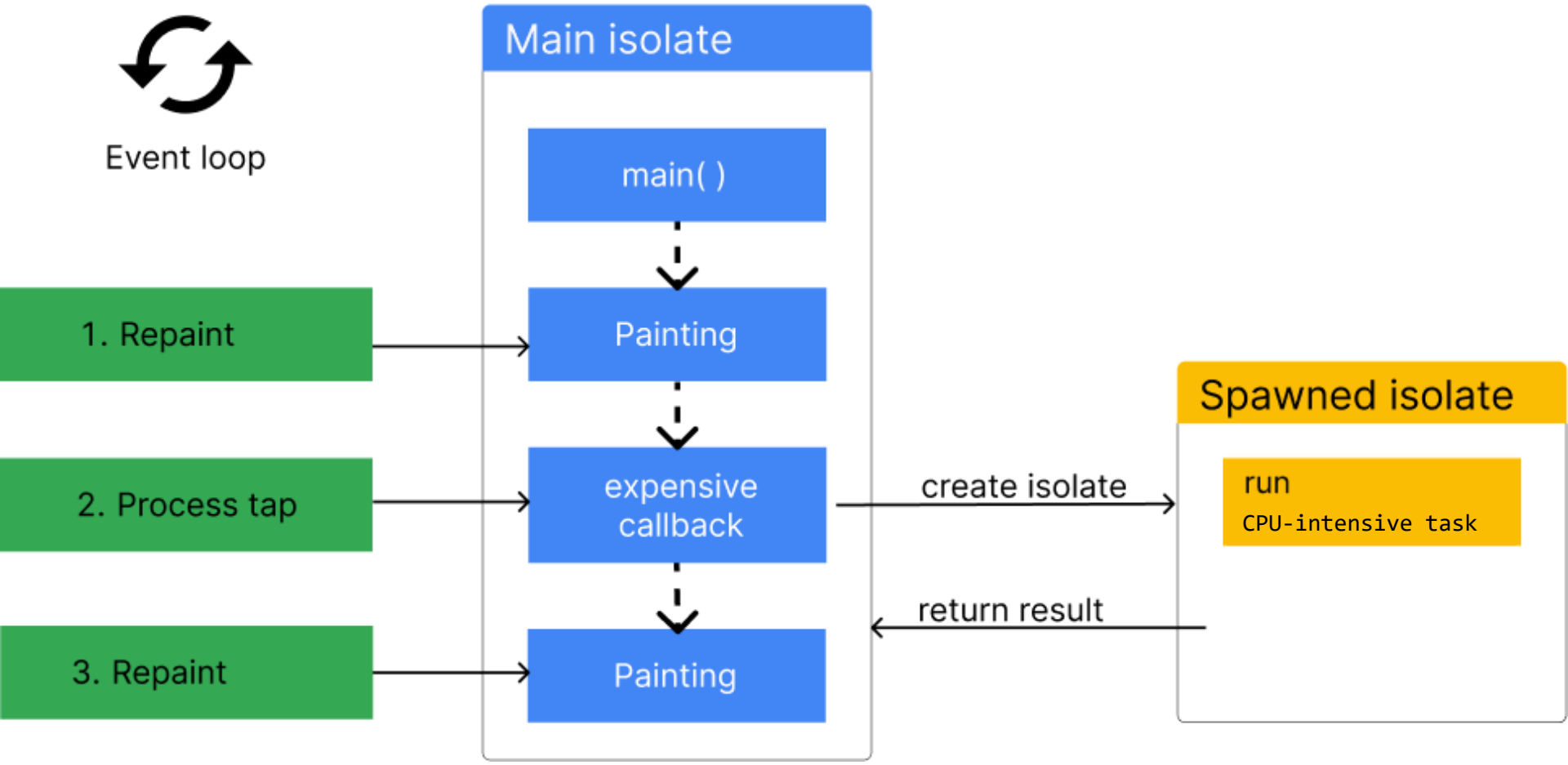


Run Long Running tasks on an isolate




```
// UI remains responsive while compressing the image
var result = await Isolate.run(() => {
      compressImage(imagePath)
})
```

Isolate = Background worker



Async/Await vs Isolate

FEATURE	ASYNC/AWAIT (FUTURE & STREAM)	ISOLATE
Execution Model	Runs on main isolate using the **event loop**	Runs on a separate isolate (parallel lightweight thread)
Memory Sharing	Shares memory with main isolate	Own memory, communicates via messages
Best For	I/O-bound tasks (network, DB, file I/O)	CPU-bound tasks (image compression, heavy computation)
UI Responsiveness	Keeps UI responsive by suspending tasks	Keeps UI responsive by offloading heavy work
Parallelism	No true parallelism, tasks scheduled sequentially	True parallel execution on multiple isolates
Example	`final response = await http.get(url);`	`final result = await Isolate.run(() => compressImage(path));`

Summary

- Use **async/await** for tasks that wait on external resources (network, disk)
  - Manages multiple tasks, one at a time, in a non-blocking way
  - Works with Futures (for single async value) and Streams (for multiple async events over time)
  - Event loop manages tasks sequencing and delivers results when ready
- Use **Isolate** for tasks that heavily use CPU and would block the main thread
  - Allows tasks to execute in parallel on separate threads

Resources

- Concurrency in Dart
  - https://dart.dev/language/concurrency

- Asynchronous programming tutorial: futures, async, await, and streams
  - https://dart.dev/libraries/async/async-await