Exception Handling

Cancellation and Exception Handling

- Cancellation is important for avoiding doing more work than needed which can waste memory and battery life.
- Proper exception handling is key to a great user experience.

Exception Handling

- Exception and error handling is an integral part of asynchronous programming.
- It’s important to know ***how errors and exceptions are propagated*** through the process.

CoroutineScope

- To start & control the **lifecycle** of coroutines, they should be created in `CoroutineScope`.
- A `CoroutineScope` keeps track of any coroutine created using `launch` or `async`.
- Coroutines can be canceled by calling `scope.cancel()` at any time.
- In Android, we have `viewModelScope` and `lifecycleScope`

```
                                        CoroutineContext
                              ┌─────────────────────────────┐
val scope = CoroutineScope(Job() + Dispatchers.Main)
val job = scope.launch {
    // new coroutine
}
```

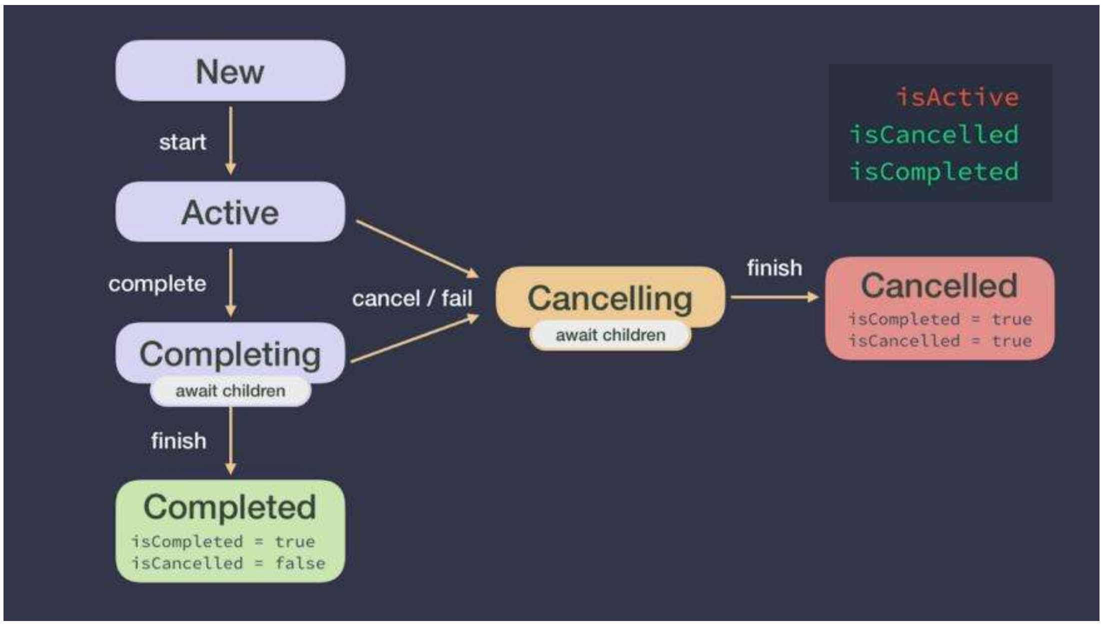
Job

- A `Job` is a ***handle*** to a coroutine.
  - Coroutine builders (`launch` or `async`) returns a `Job` instance that *uniquely identifies* the coroutine and manages its lifecycle.
- You can also pass a `Job` to a `CoroutineScope` to keep a handle on its lifecycle. Otherwise, `default` Job created

```
val scope = CoroutineScope(Job())
```

- Coroutines form a *hierarchy* using *parent-child* relationships among `Job`s.

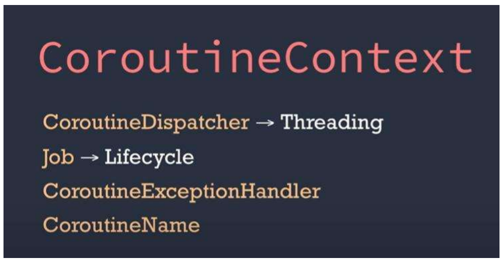
Job lifecycle



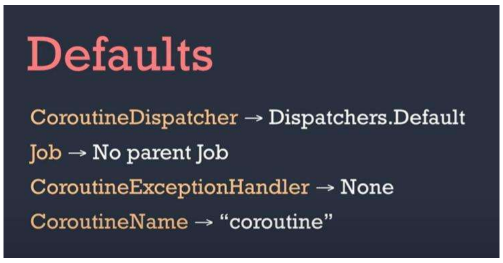
CoroutineContext

The `CoroutineContext` is a set of elements that define the behavior of a coroutine:

- `Job` — controls the lifecycle of the coroutine.
- `CoroutineDispatcher` — dispatches work to the appropriate thread.
- `CoroutineName` — name of the coroutine, useful for debugging.
- `CoroutineExceptionHandler` — handles uncaught exceptions.


CoroutineContext

CoroutineDispatcher → Threading
Job → Lifecycle
CoroutineExceptionHandler
CoroutineName


Defaults

CoroutineDispatcher → Dispatchers.Default
Job → No parent Job
CoroutineExceptionHandler → None
CoroutineName → "coroutine"

What's the CoroutineContext of a new coroutine?

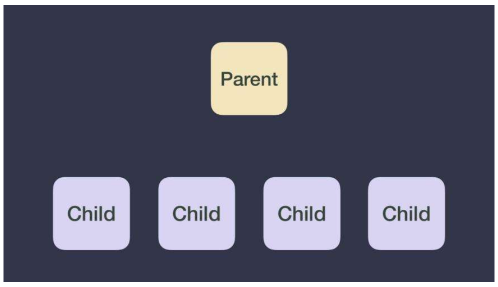
- A ***new instance*** of `Job` will be created, allowing us to control its lifecycle.
- The rest of the elements will be *inherited* from the parent's `CoroutineContext`

Task Hierarchy

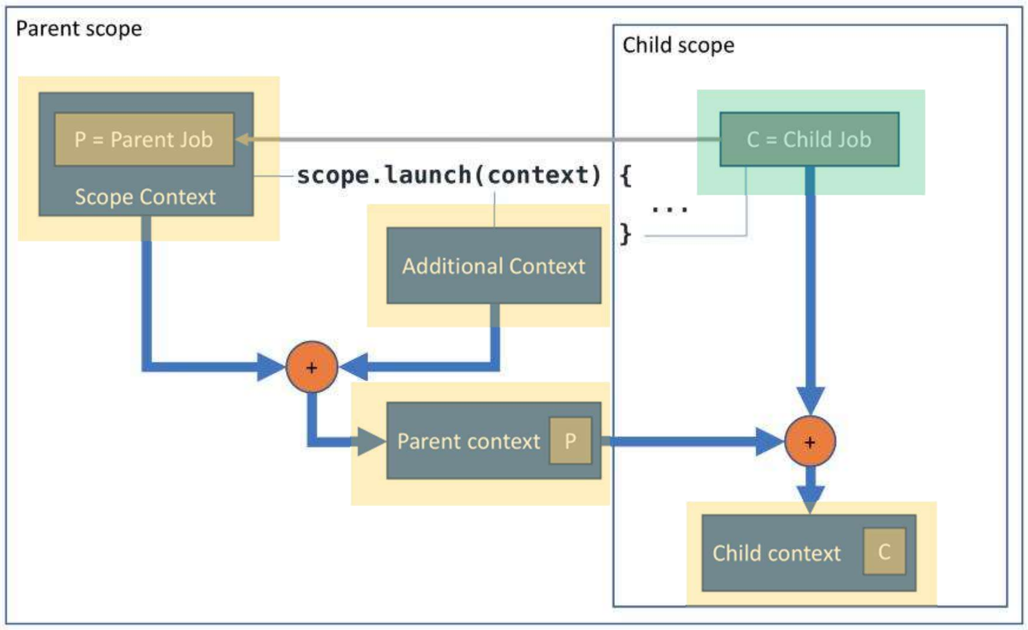
- Since a `CoroutineScope` can create coroutines and you can create more coroutines inside a coroutine, an implicit task hierarchy is created.

```kotlin
val scope = CoroutineScope(Job() + Dispatchers.Main)
val job = scope.launch {
    // New coroutine with CoroutineScope as a parent
    val result = async {
        // New coroutine that has the coroutine
        // started by launch as a parent
    }.await()
}
```

The parent can be either a CoroutineScope or another coroutine.

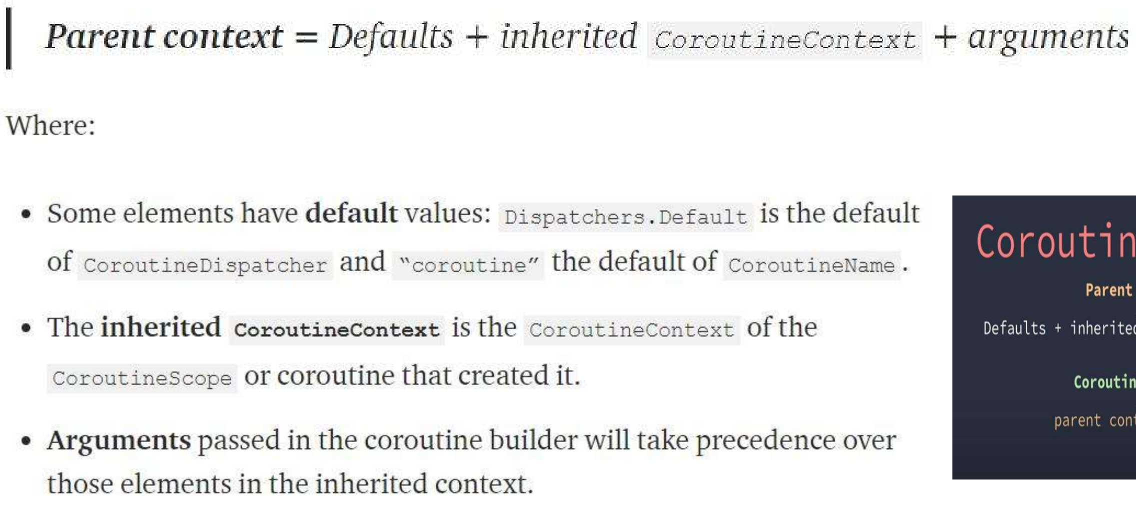


Parent Scope vs Child Scope



Parent CoroutineContext explained

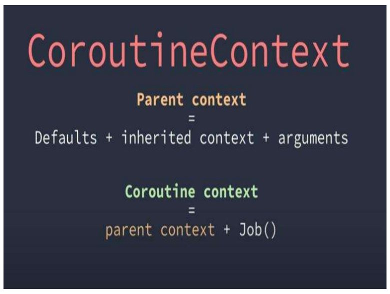
- Child's parent `CoroutineContext` can be different from that of the parent:



> *Parent context* = *Defaults* + *inherited* `CoroutineContext` + *arguments*

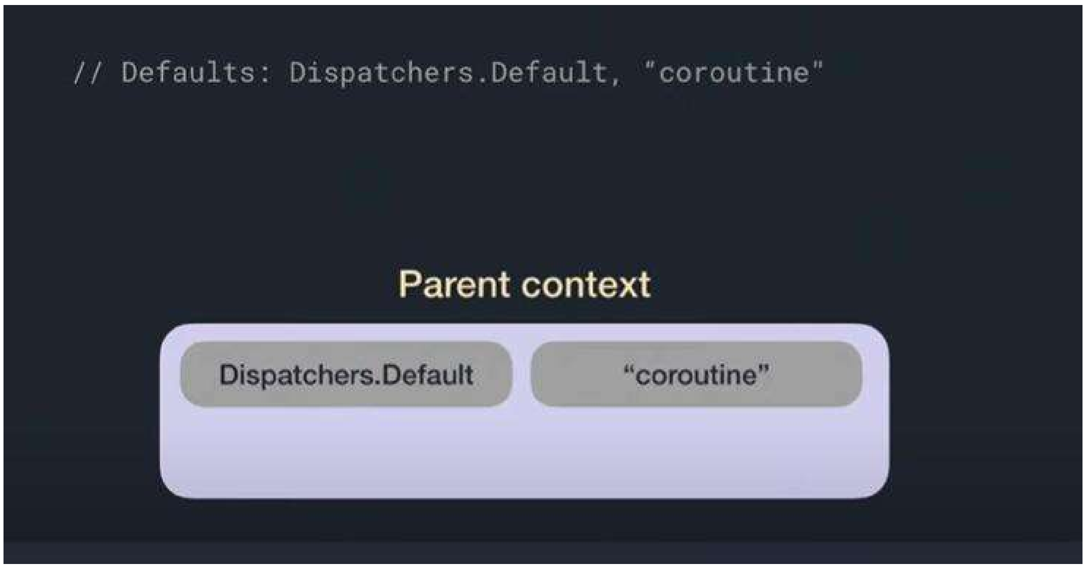
Where:

- Some elements have **default** values: `Dispatchers.Default` is the default of `CoroutineDispatcher` and `"coroutine"` the default of `CoroutineName`.
- The **inherited** `CoroutineContext` is the `CoroutineContext` of the `CoroutineScope` or coroutine that created it.
- **Arguments** passed in the coroutine builder will take precedence over those elements in the inherited context.



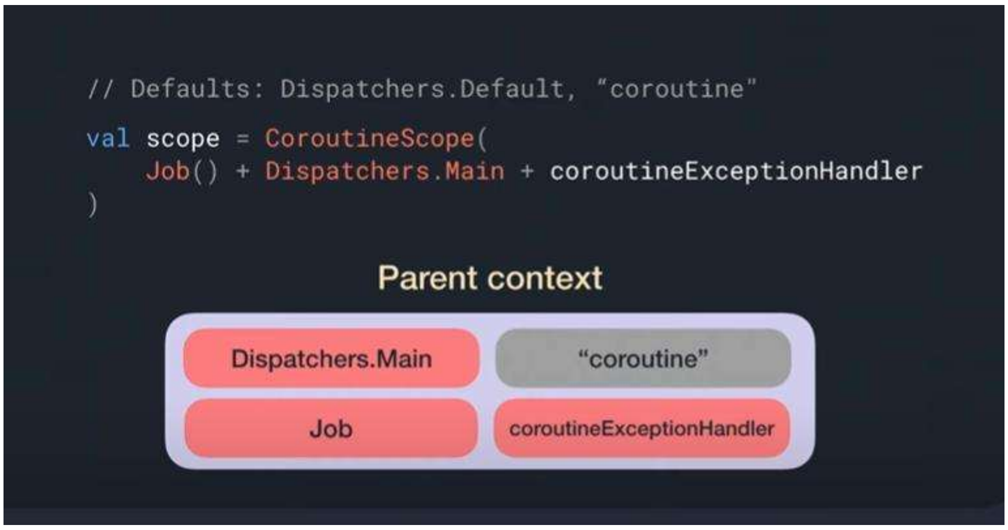
```
CoroutineContext

Parent context
=
Defaults + inherited context + arguments

Coroutine context
=
parent context + Job()
```

CoroutineContext of the Parent



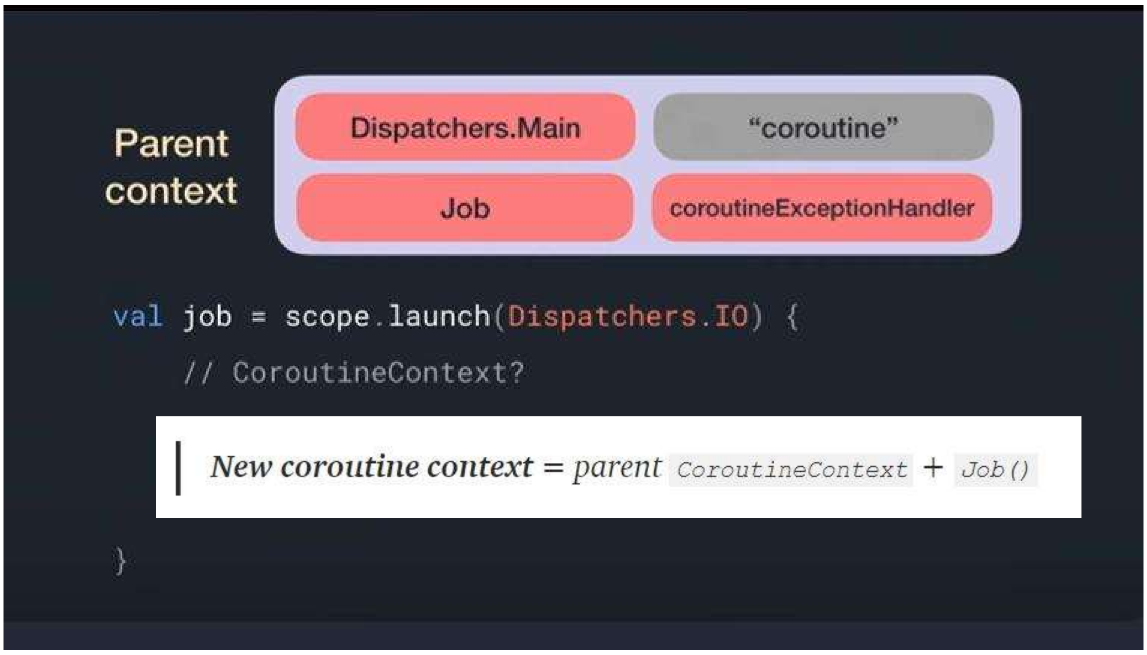
```
// Defaults: Dispatchers.Default, "coroutine"
```

CoroutineContext of the Parent



```
// Defaults: Dispatchers.Default, "coroutine"
val scope = CoroutineScope(
    Job() + Dispatchers.Main + coroutineExceptionHandler
)
```

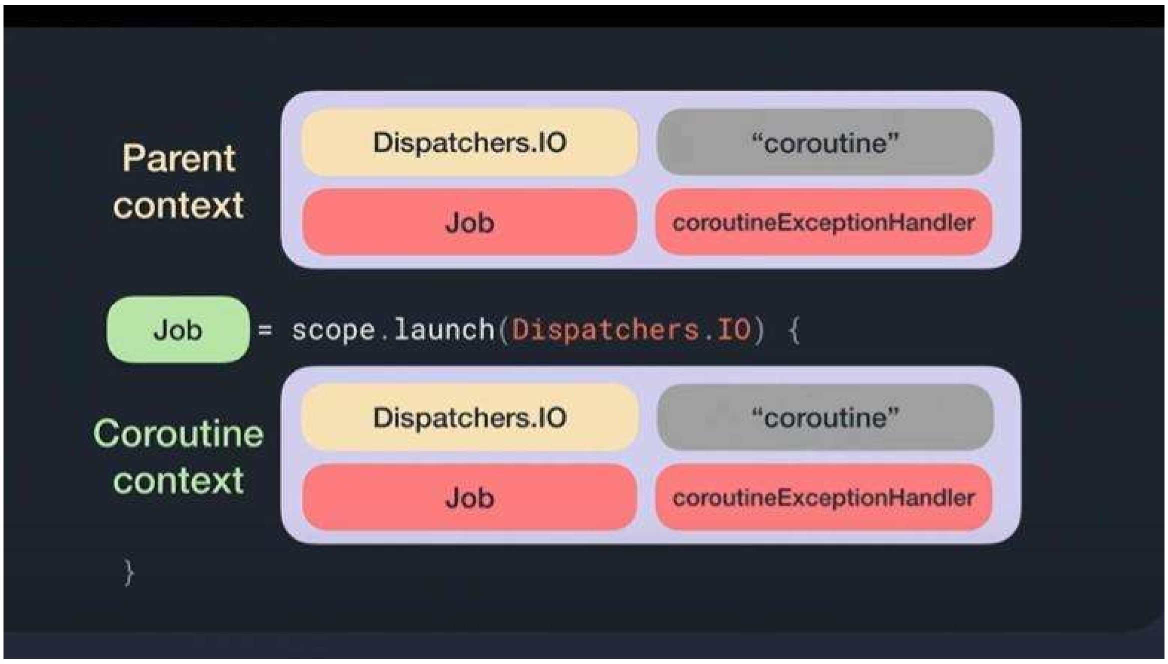
Every coroutine started by this CoroutineScope will have at least those elements in the CoroutineContext. CoroutineName is gray because it comes from the default values.



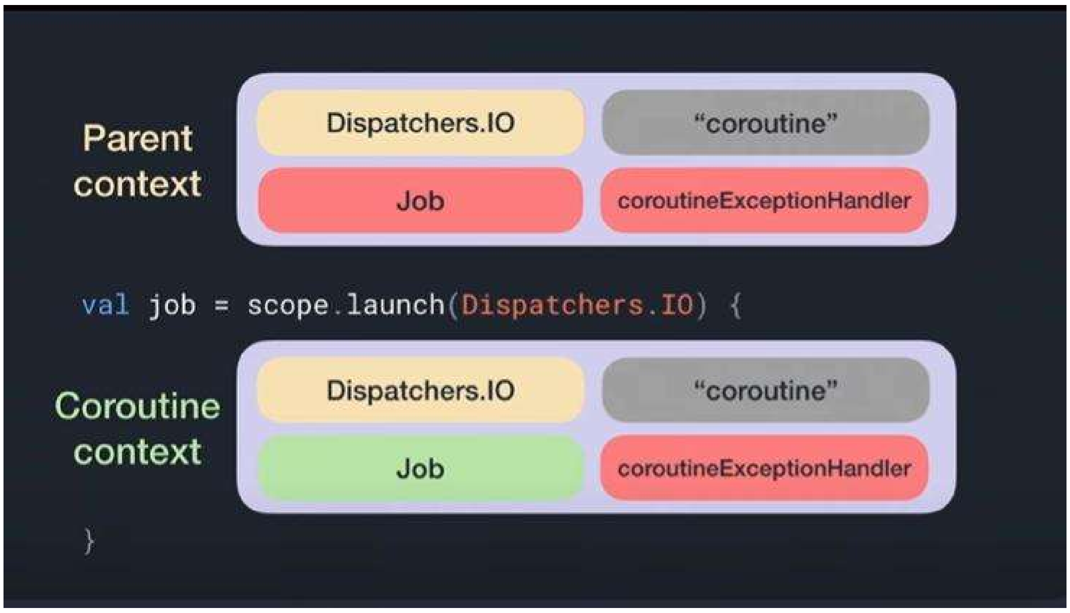
```
val job = scope.launch(Dispatchers.IO) {
    // CoroutineContext?
```

| *New coroutine context* = *parent* `CoroutineContext` + `Job()`

```
}
```



```
Job = scope.launch(Dispatchers.IO) {
}
```



```
val job = scope.launch(Dispatchers.IO) {
}
```

The Job in the CoroutineContext and in the parent context will never be the same instance as a new coroutine always get a new instance of a Job

Exception Propagation

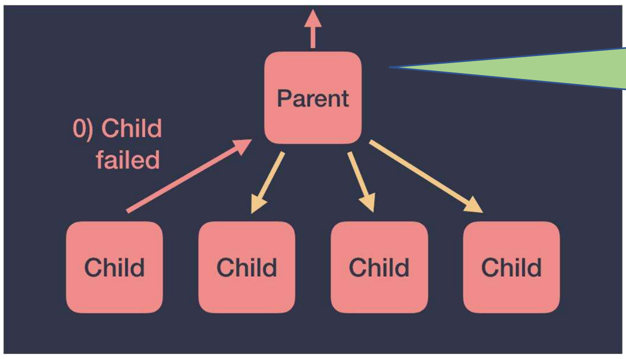
- An **uncaught exception**, instead of being re-thrown, is "**propagated up the job hierarchy**".

WATCH OUT 👀

With a failing child, **uncaught exceptions are propagated** up!

Exception Propagation

- This exception propagation leads to the failure of the parent Job and the cancellation of all the Jobs of its children.
- The exception will reach the root of the hierarchy and all the coroutines that the `CoroutineScope` started will get cancelled too.



Here, the parent is another coroutine.

Step 3) is different if parent is a scope

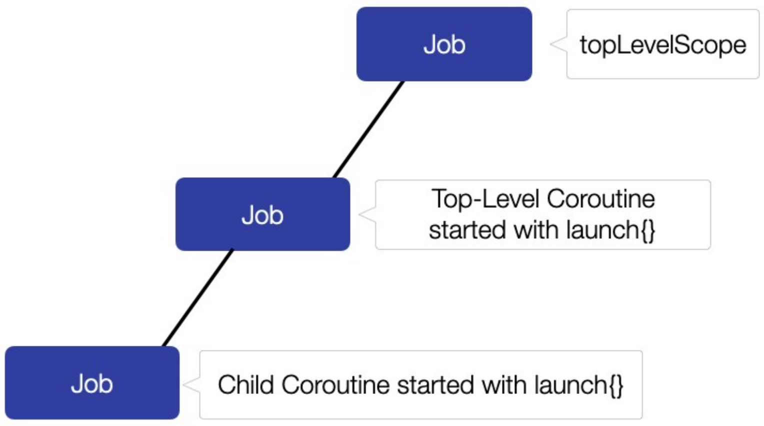
Exception Re-throwing vs. Propagation

- In Kotlin, functions by default **re-throw** all the exceptions that were not caught inside them.
- Therefore, the exception from the `failingMethod` can be caught in the parent `try–catch` block.

```
fun someMethod() {
    try {
        val failingData = failingMethod()
    } catch (e: Exception) {
        // handle exception
    }
}

fun failingMethod() { throw RuntimeException() }
```

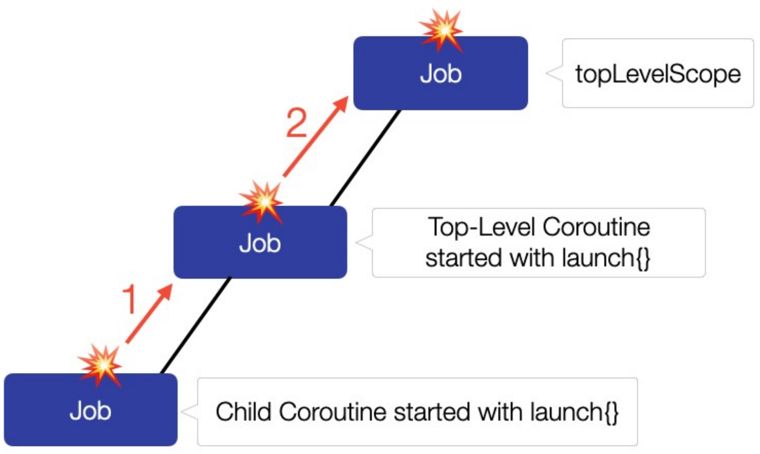
Coroutines Parent-Child Relationship

```
fun main() {
  val scope = CoroutineScope(Job())
  scope.launch {
    try {
      launch {
        throw RuntimeException("…")
      }
    } catch (ex: Exception) {
      // do something …
    }
  }
  Thread.sleep(100)
}
```


Job
topLevelScope
Job
Top-Level Coroutine started with launch{}
Job
Child Coroutine started with launch{}

Exception Propagation up to …

```
fun main() {
  val scope = CoroutineScope(Job())
  scope.launch {
    try {
      launch {
        throw RuntimeException("…")
      }
    } catch (ex: Exception) {
      // do something …
    }
  }
  Thread.sleep(100)
}
```


Job
topLevelScope
2
Job
Top-Level Coroutine started with launch{}
1
Job
Child Coroutine started with launch{}

Exception Re-Thrown vs. Propagation

```
fun main() {
  try {
    failingMethod()
  } catch (ex: Exception) {
    println("Caught: $ex")
  }
}
```

Caught: java.lang.RuntimeException: oops

```
fun main() = runBlocking<Unit> {
  try {
    launch {
      failingMethod()
    }
  } catch (ex: Exception) {
    println("Caught: $ex")
  }                Useless!
}
```

```
Exception in thread "main" java.lang.RuntimeException: oops
  at com.org.androidtestingkt.coroutines. …
```

Exception Propagation: Root is not Scope

```kotlin
@Test(expected = RuntimeException::class)
fun `Uncaught exceptions propagate`() = runBlocking {
    val job = launch {
        println("1. Exception thrown inside launch")
        throw RuntimeException()
    }
    println("2. Wait for child to finish")
    job.join()
    println("3. Joined failed job: Unreachable code")
}
```

```
2. Wait for child to finish
1. Exception thrown inside launch
```

Exception Propagation: Root is Scope

```kotlin
@Test
fun `Uncaught exceptions propagate`() = runBlocking {
    val scope = CoroutineScope(Job())
    val job = scope.launch {
        println("1. Exception thrown inside launch")
        // handled by Thread.defaultUncaughtExceptionHandler
        throw RuntimeException()
    }
    println("2. Wait for child to finish")
    job.join()
    println("3. Joined failed job: Now reachable code")
}
```

```
2. Wait for child to finish
1. Exception thrown inside launch
Exception in thread "DefaultDispatcher-worker-1 …
…
3. Joined failed job: Now reachable code
```

Failures in a Scope

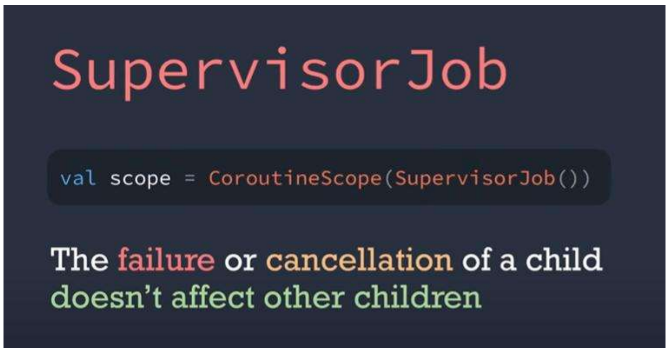
- The failure of a child cancels the parent and other children.

```
val parentJob = launch {
  launch {
    throw RuntimeException("oops")
  }.invokeOnCompletion { ex ->
    println("child1: $ex")
  }
  launch {
    delay(100)
  }.invokeOnCompletion { ex ->
    println("child2: $ex")
  }
}
parentJob.invokeOnCompletion {
  println("isCancelled = ${parentJob.isCancelled}")
}
parentJob.join()
```

```
child1: java.lang.RuntimeException: oops
child2: kotlinx.coroutines.JobCancellationException: ...
isCancelled = true
```

SupervisorJob to the rescue

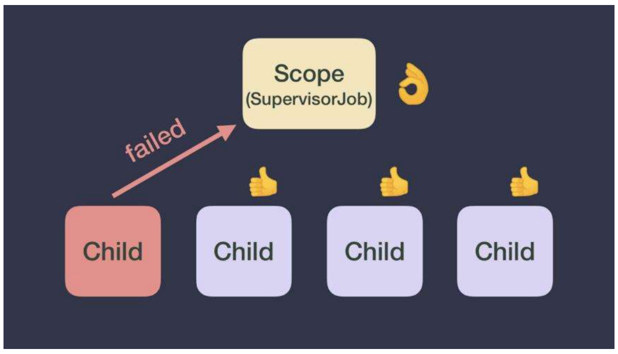
- *A SupervisorJob won't cancel itself or the rest of its children*



SupervisorJob

```
val scope = CoroutineScope(SupervisorJob())
```

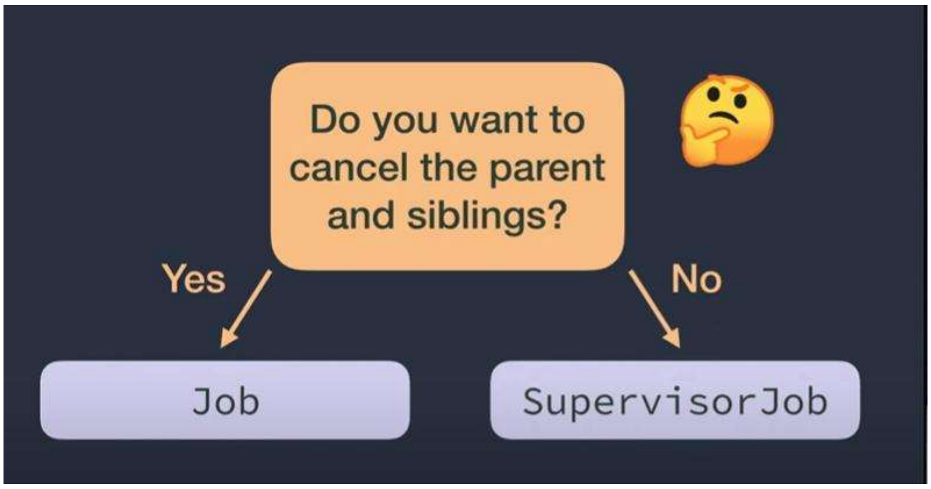
The failure or cancellation of a child doesn't affect other children

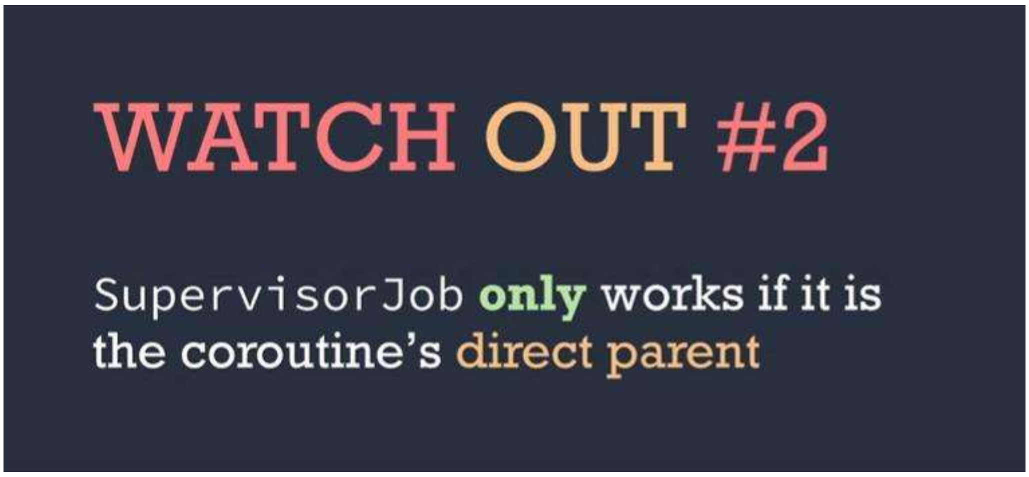


Review of SupervisorJob

- A `CoroutineScope` can have a `SupervisorJob` that changes how the `CoroutineScope` deals with exceptions.
- However, when the **parent of a coroutine is another coroutine**, the parent `Job` will **always** be of type `Job`.

What to choose?





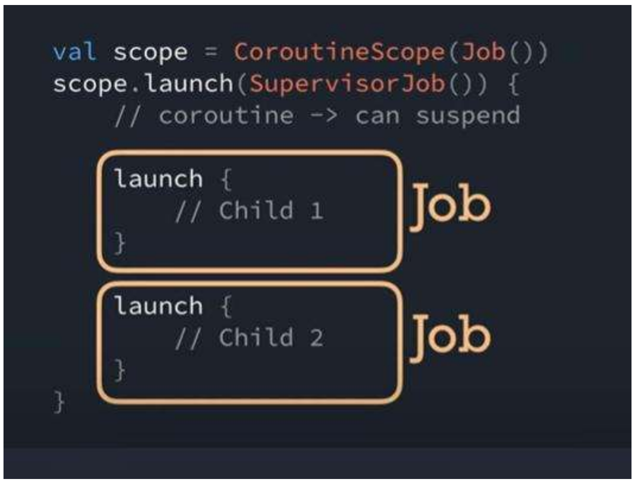
WATCH OUT #2

SupervisorJob **only** works if it is the coroutine's direct parent

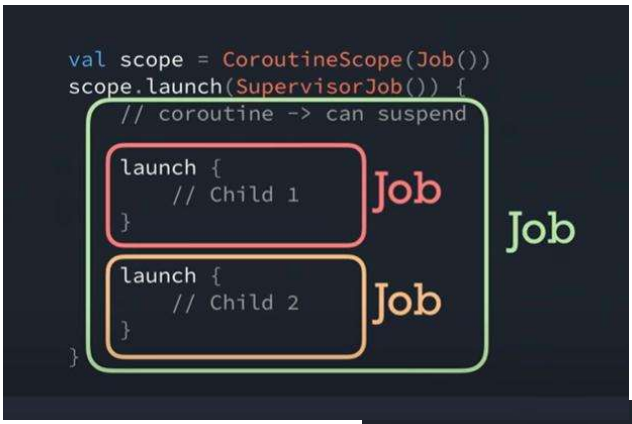
Watch out quiz! Who's my parent? 🎯

- Given the following snippet of code, can you identify what kind of Job "child 1" has as a parent?

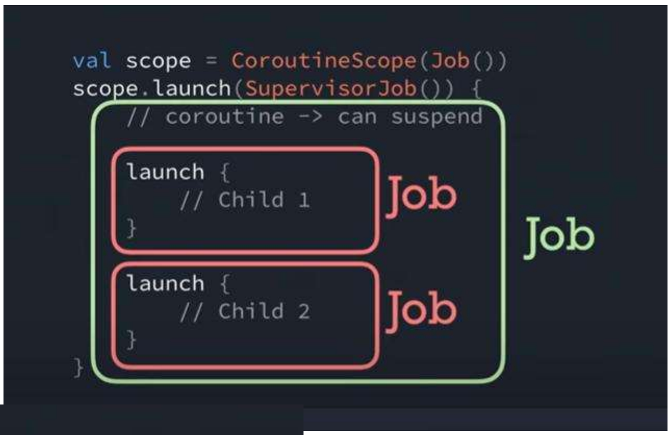
```kotlin
val scope = CoroutineScope(Job())
scope.launch(SupervisorJob()) {
    // new coroutine -> can suspend
    launch {
        // Child 1
    }
    launch {
        // Child 2
    }
}
```



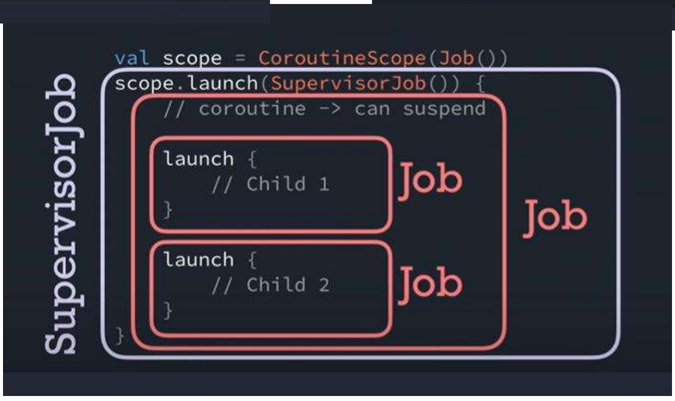
```kotlin
val scope = CoroutineScope(Job())
scope.launch(SupervisorJob()) {
    // coroutine -> can suspend
    launch {
        // Child 1
    }
    launch {
        // Child 2
    }
}
```



```
val scope = CoroutineScope(Job())
scope.launch(SupervisorJob()) {
    // coroutine -> can suspend
    launch {
        // Child 1
    }
    launch {
        // Child 2
    }
}
```



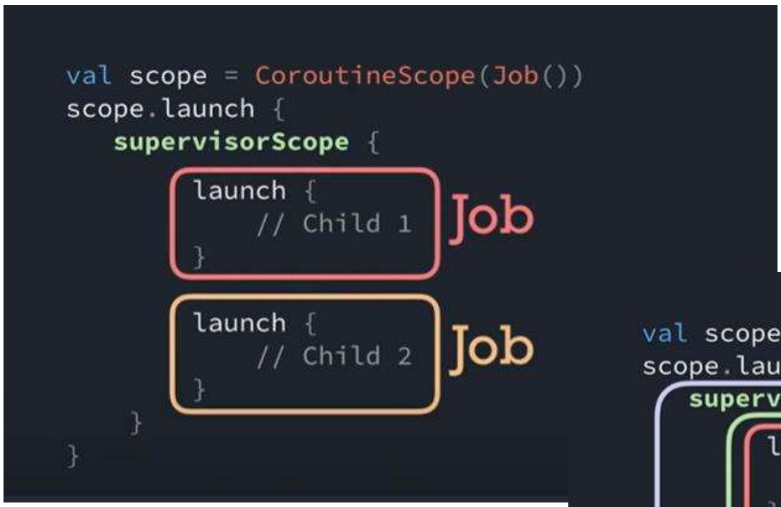
```
val scope = CoroutineScope(Job())
scope.launch(SupervisorJob()) {
    // coroutine -> can suspend
    launch {
        // Child 1
    }
    launch {
        // Child 2
    }
}
```



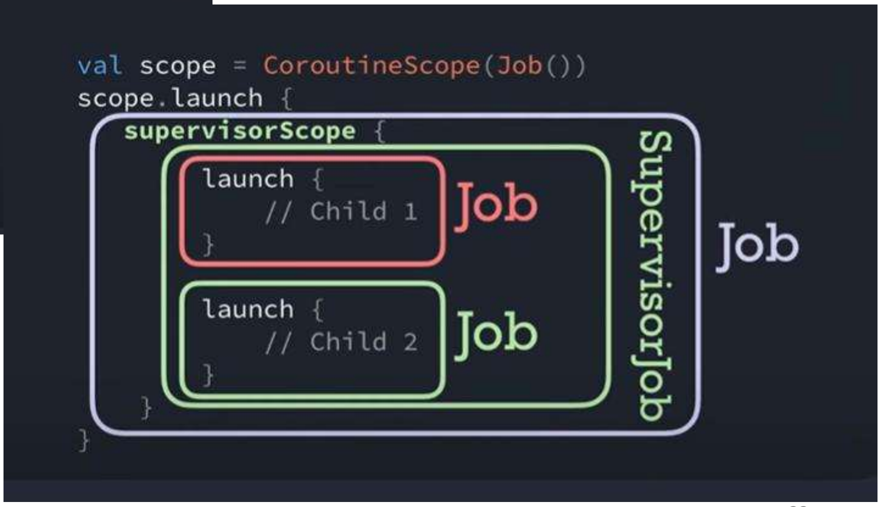
```
val scope = CoroutineScope(Job())
scope.launch(SupervisorJob()) {
    // coroutine -> can suspend
    launch {
        // Child 1
    }
    launch {
        // Child 2
    }
}
```

Remember that a SupervisorJob works if it is coroutine's direct parent

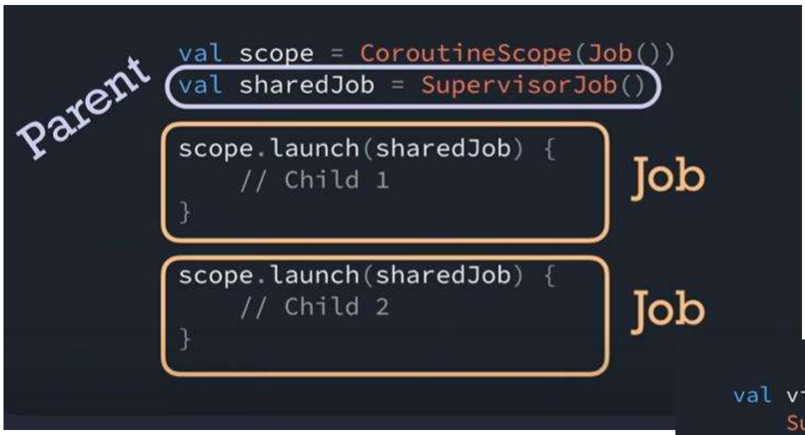
- Either created as a direct child of either `supervisorScope` or `CoroutineScope(SupervisorJob())`.
- Passing a `SupervisorJob` as a parameter of a coroutine builder may **not** have the desired effect.
- If any child throws an exception, that `SupervisorJob` won't either propagate up in the hierarchy or rethrow the exception. Instead, it delegates the exception to `CoroutineExceptionHandler`, if exists, or `Thread.uncaughtExceptionHandler`.



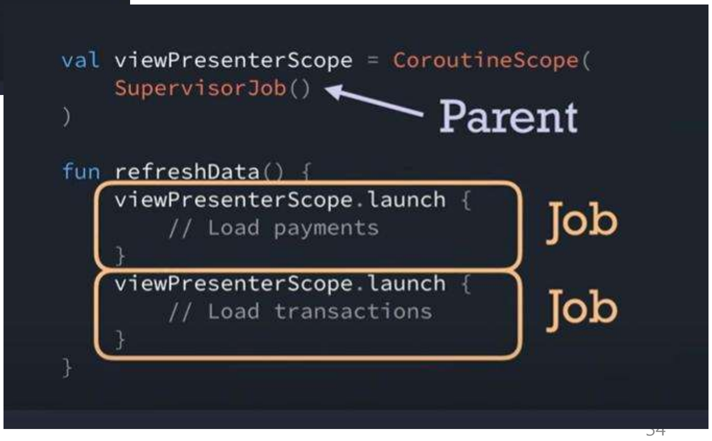
```
val scope = CoroutineScope(Job())
scope.launch {
    supervisorScope {
        launch {
            // Child 1
        }
        launch {
            // Child 2
        }
    }
}
```



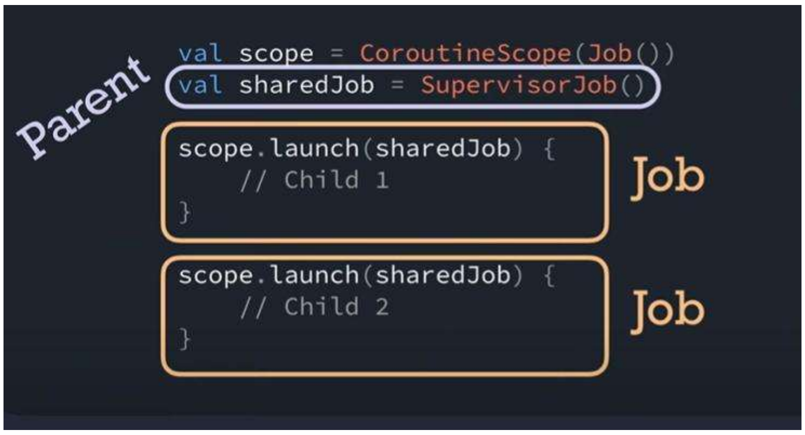
```
val scope = CoroutineScope(Job())
scope.launch {
    supervisorScope {
        launch {
            // Child 1
        }
        launch {
            // Child 2
        }
    }
}
```



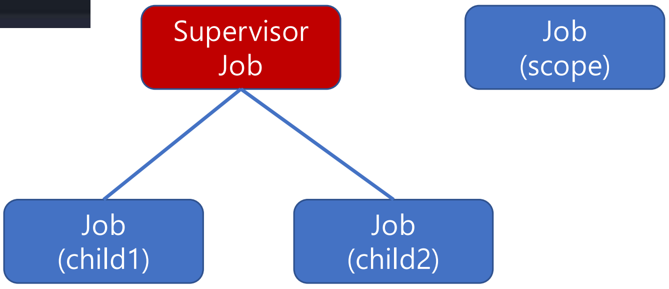
```
val scope = CoroutineScope(Job())
val sharedJob = SupervisorJob()
scope.launch(sharedJob) {
    // Child 1
}
scope.launch(sharedJob) {
    // Child 2
}
```

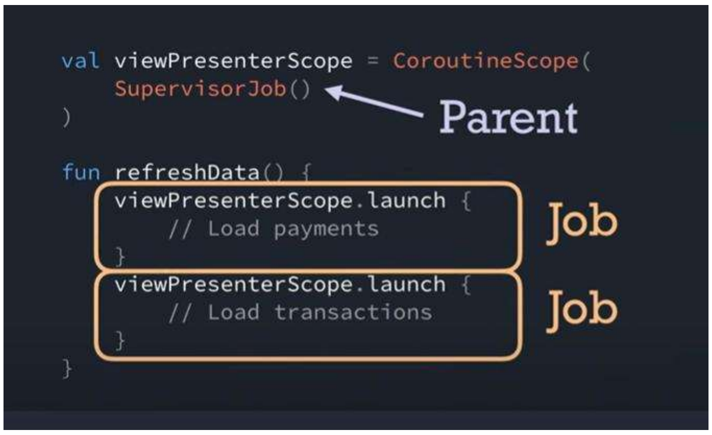


```
val viewPresenterScope = CoroutineScope(
    SupervisorJob()
)

fun refreshData() {
    viewPresenterScope.launch {
        // Load payments
    }
    viewPresenterScope.launch {
        // Load transactions
    }
}
```

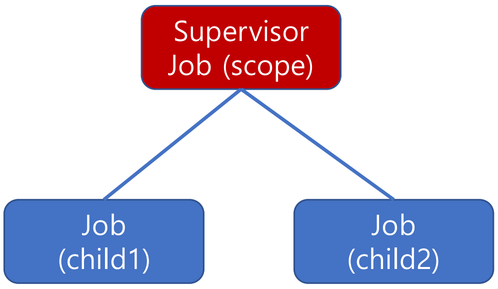


```
val scope = CoroutineScope(Job())
val sharedJob = SupervisorJob()
scope.launch(sharedJob) {
    // Child 1
}
scope.launch(sharedJob) {
    // Child 2
}
```



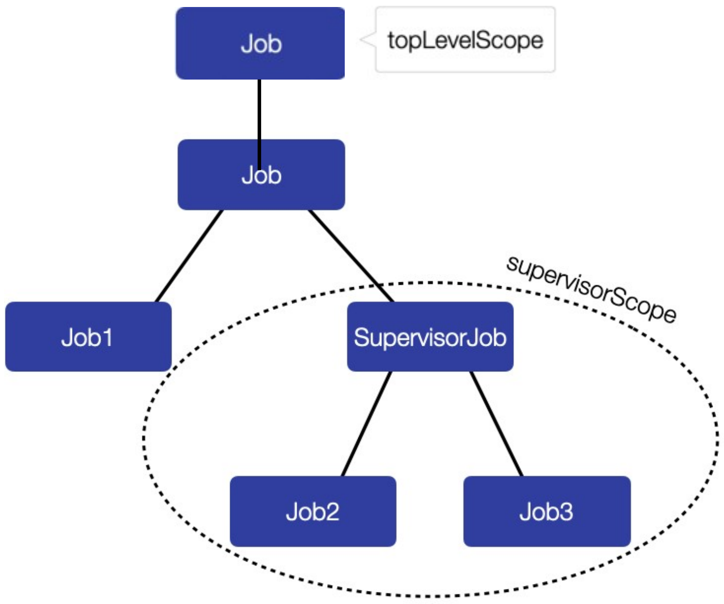


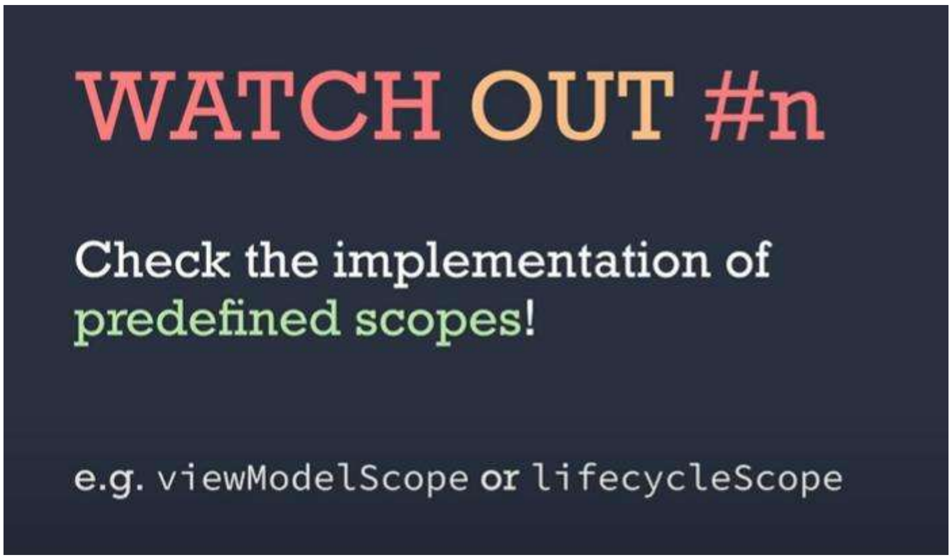
```
val viewPresenterScope = CoroutineScope(
    SupervisorJob()
)

fun refreshData() {
    viewPresenterScope.launch {
        // Load payments
    }
    viewPresenterScope.launch {
        // Load transactions
    }
}
```



Exception Handling properties of supervisorScope{}

```
val scope = CoroutineScope(Job())
scope.launch {
  val job1 = launch {
    println("starting Coroutine 1")
  }
  supervisorScope {
    val job2 = launch(ehandler) {
      println("starting Coroutine 2")
    }
    val job3 = launch {
      println("starting Coroutine 3")
    }
  }
}
```





WATCH OUT #n

Check the implementation of predefined scopes!

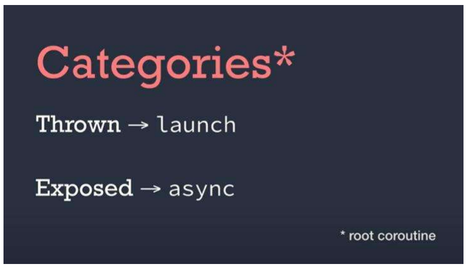
e.g. `viewModelScope` or `lifecycleScope`

Dealing with Exceptions

- try/catch
- runCatching (which uses try/catch internally)
- CoroutineExceptionHandler

Recall that uncaught exceptions will always be thrown.

However, different coroutines builders treat exceptions in different ways.



Categories*

Thrown → launch

Exposed → async

* root coroutine

Coroutine Builder launch Behavior

- With launch, ***exceptions will be thrown as soon as they happen***. Therefore, you can wrap the code that can throw exceptions inside a try/catch, like in this example:

inside launch

```
launch {
    try {
        println("1. Exception thrown inside launch")
        throw RuntimeException()
    } catch (ex: Exception) {
        println("Exception ${ex.javaClass.simpleName} caught ...")
    }
}
```

Coroutine Builder async Behavior

Root coroutines:

Coroutines that are a direct child of a

CoroutineScope or supervisorScope

Coroutine Builder async Behavior

- **Root coroutines**: coroutines that are a direct child of a `CoroutineScope` or `supervisorScope`
- When `async` is used as a root coroutine, **exceptions are not thrown automatically, instead, they're thrown when you call `.await()`**.
- To handle exceptions thrown in `async` whenever it's a root coroutine, you can wrap the `.await()` call inside a `try`/`catch`:

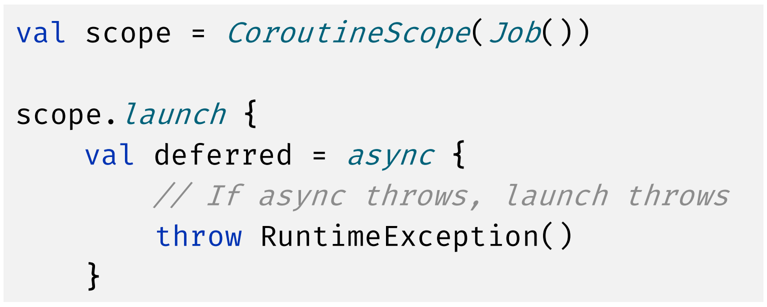
```
supervisorScope {
    val deferred = async {
        throw codeThatMayThrowsException()
    }
    try {
        deferred.await()
    } catch (e: Exception) {
        println("Caught ${e.javaClass.simpleName}")
    }
}
```

Watch out!

- Notice that we're using a `supervisorScope` to call `async` and `await`.
- But, a `coroutineScope` automatically propagate the exception up in the hierarchy so the catch block won't be called:

```
coroutineScope {
  try {
    val deferred = async {
      codeThatCanThrowExceptions()
    }
    deferred.await()
  } catch(e: Exception) {
    // Exception thrown in async WILL NOT be caught here
     // but propagated up to the scope
  }
}
```

Furthermore, exceptions that happen in coroutines created by other coroutines will always be propagated regardless of the coroutine builder.



```
val scope = CoroutineScope(Job())

scope.launch {
    val deferred = async {
        // If async throws, launch throws
        throw RuntimeException()
    }
```

⚠ Exceptions thrown in a coroutineScope builder or in coroutines created by other coroutines won't be caught in a try/catch!

CoroutineExceptionHandler

- The `CoroutineExceptionHandler` is an optional element of a `CoroutineContext` allowing you to handle uncaught exceptions.

```
val handler = CoroutineExceptionHandler {
        context, exception -> println("Caught $exception")
}
```

Exceptions will be caught if these requirements are met:

CEH

When? ⏰

Automatically propagated exceptions

Where? 🌍

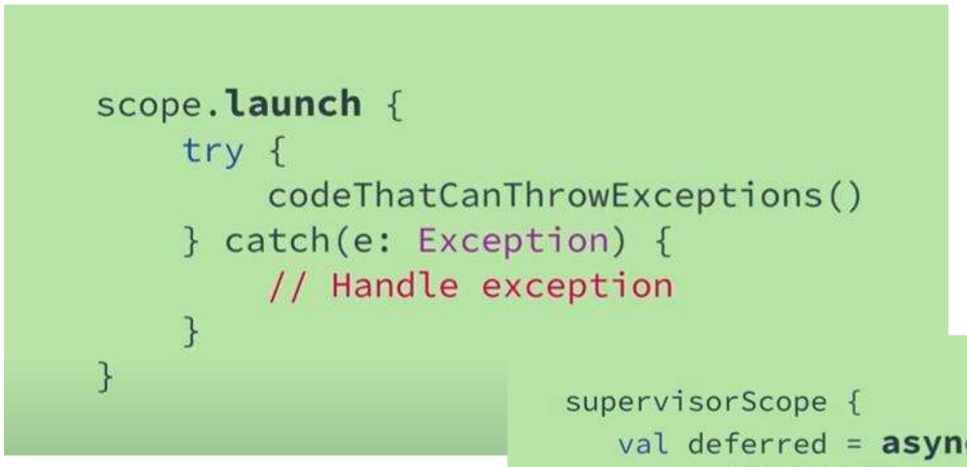
Scope || Root coroutine ||

`supervisorScope` direct child

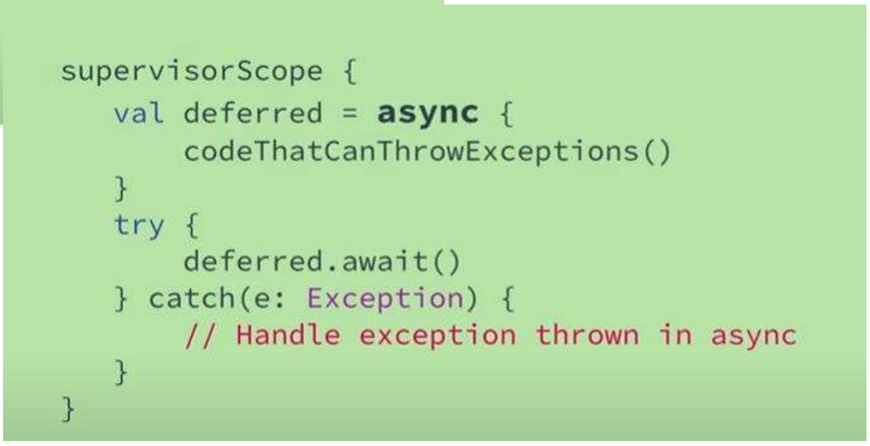
- **When** ⏰: Automatically propagated exceptions
- **Where** 🌍: If it's in the `CoroutineContext` of a `CoroutineScope` or a root coroutine (direct child of `CoroutineScope` or a `supervisorScope`).

```
val
scope=CoroutineScope( Job() + handler)

scope.launch {
    launch {
        throw Exception(“failed”)
    }

}
```

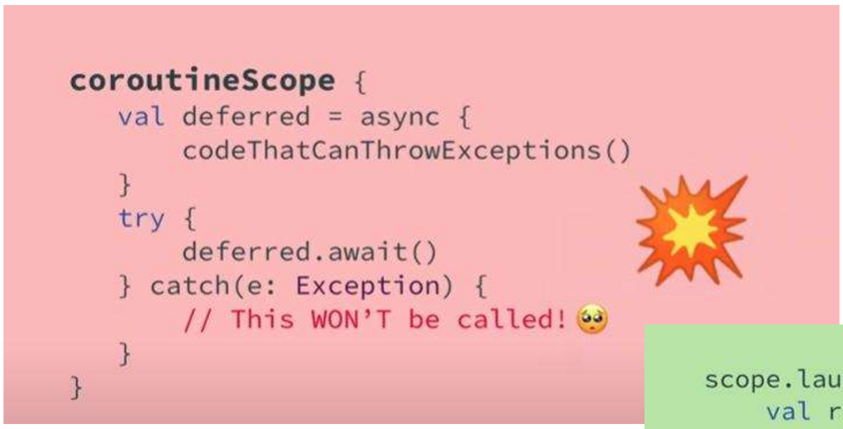
```
val scope = CoroutineScope( Job())

scope.launch(handler) {
    launch {
        throw Exception(“failed”)
    }

}
```



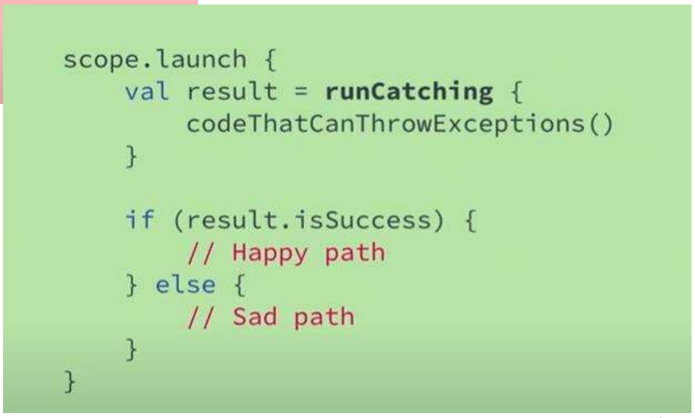
```
scope.launch {
    try {
        codeThatCanThrowExceptions()
    } catch(e: Exception) {
        // Handle exception
    }
}
```



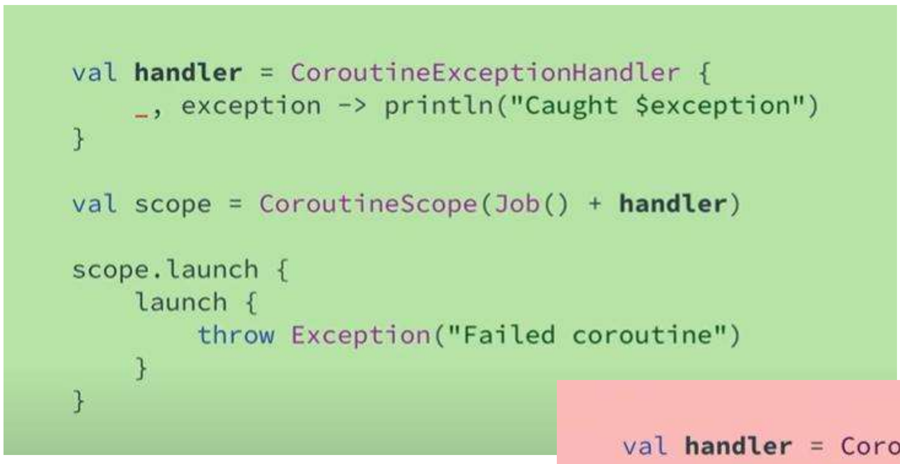
```
supervisorScope {
    val deferred = async {
        codeThatCanThrowExceptions()
    }
    try {
        deferred.await()
    } catch(e: Exception) {
        // Handle exception thrown in async
    }
}
```



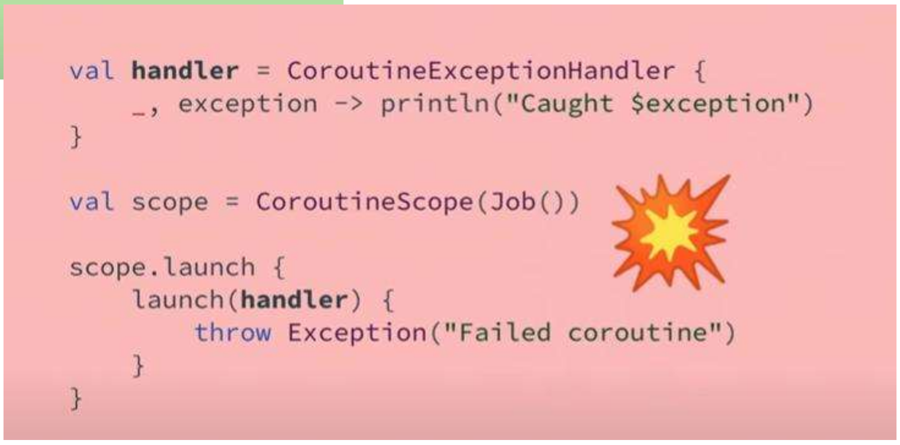
```
coroutineScope {
    val deferred = async {
        codeThatCanThrowExceptions()
    }
    try {
        deferred.await()
    } catch(e: Exception) {
        // This WON'T be called! 🥺
    }
}
```



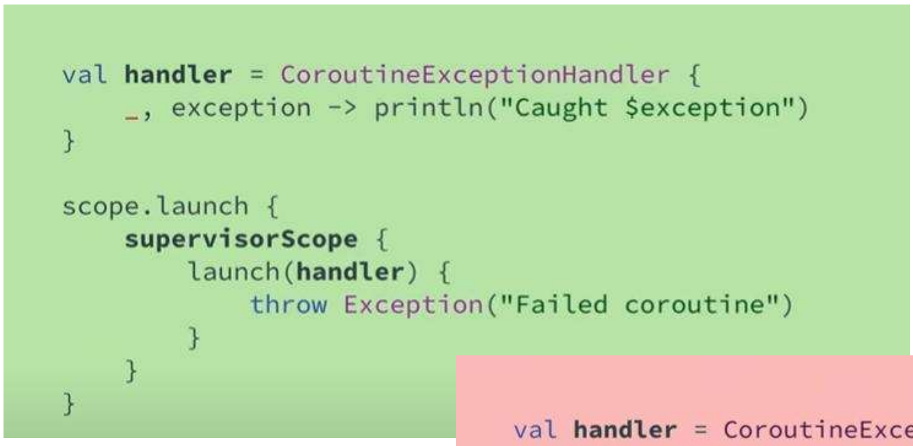
```
scope.launch {
    val result = runCatching {
        codeThatCanThrowExceptions()
    }

    if (result.isSuccess) {
        // Happy path
    } else {
        // Sad path
    }
}
```



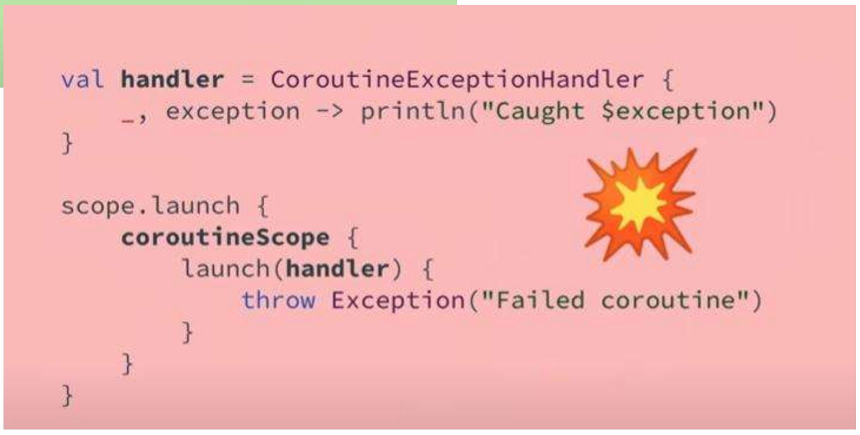
```
val handler = CoroutineExceptionHandler {
    _, exception -> println("Caught $exception")
}

val scope = CoroutineScope(Job() + handler)

scope.launch {
    launch {
        throw Exception("Failed coroutine")
    }
}
```



```
val handler = CoroutineExceptionHandler {
    _, exception -> println("Caught $exception")
}

val scope = CoroutineScope(Job())

scope.launch {
    launch(handler) {
        throw Exception("Failed coroutine")
    }
}
```



```
val handler = CoroutineExceptionHandler {
    _, exception -> println("Caught $exception")
}

scope.launch {
    supervisorScope {
        launch(handler) {
            throw Exception("Failed coroutine")
        }
    }
}
```



```
val handler = CoroutineExceptionHandler {
    _, exception -> println("Caught $exception")
}

scope.launch {
    coroutineScope {
        launch(handler) {
            throw Exception("Failed coroutine")
        }
    }
}
```

Coroutine builders

coroutineScope

- It **inherits the caller's** `CoroutineContext` and supports Structured Concurrency.
- It doesn't propagate exceptions from its children but **re-throws** them instead.
- It **cancels** all other children if one of them fails.

supervisorScope

- It **inherits the caller's** `CoroutineContext` and supports Structured Concurrency.
- It doesn't propagate exceptions from its children. Call CEH if exists. Otherwise call default uncaught exception handler.
- If one of the coroutines inside fails, the others are **not cancelled**.
- Coroutines created inside become **top-level coroutines**.

Summary

- Dealing with exceptions gracefully in your application is important to have a good user experience, even when things don't go as expected.
- Remember to use `SupervisorJob` when you want to avoid propagating cancellation when an exception happens, and `Job` otherwise.
- Uncaught exceptions will be propagated, catch them to provide a great UX!