

# Lecture #5

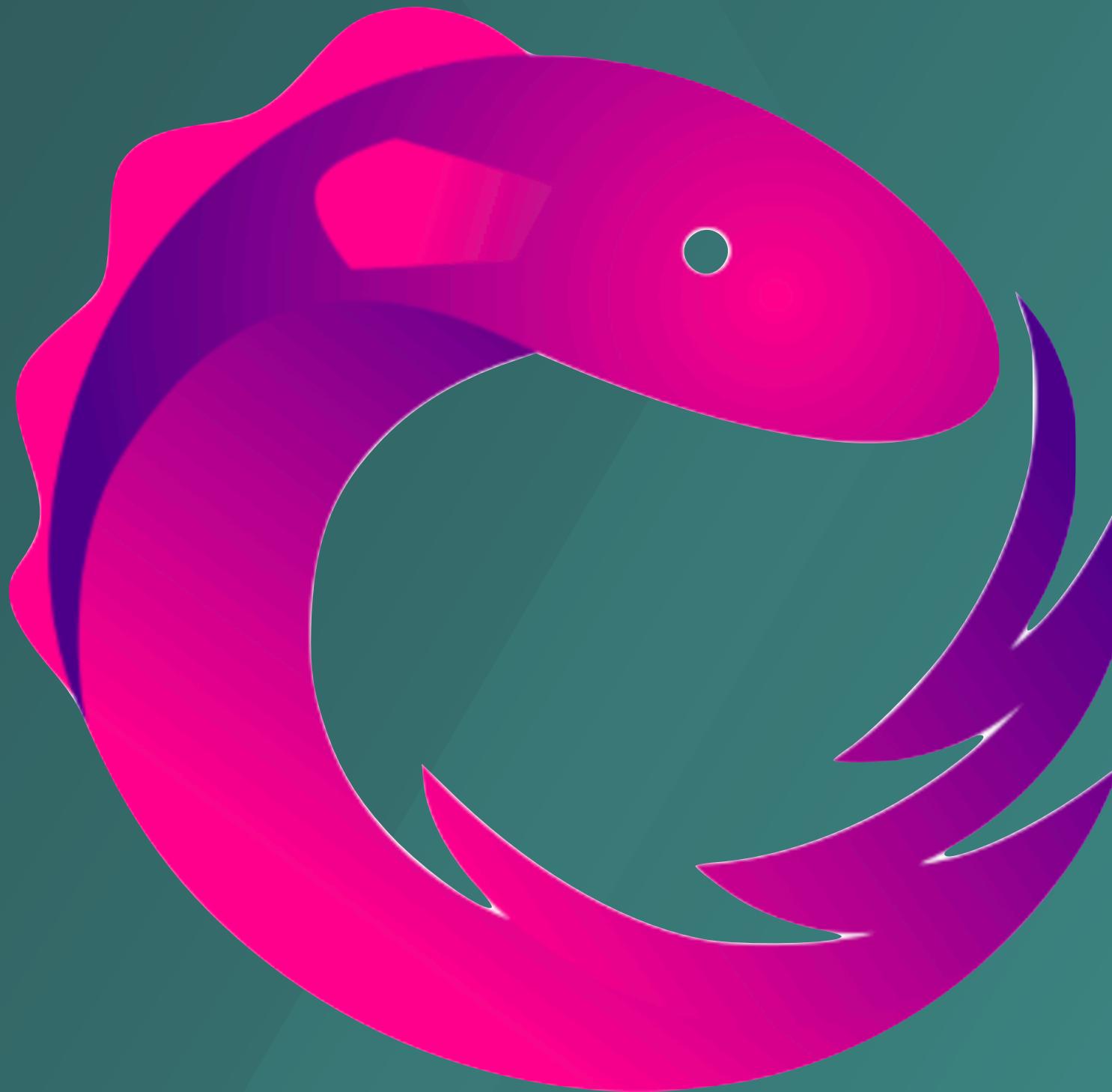
# Coroutines & Reactive

# Programming

Mobile Applications  
Fall 2023

# Why Reactive?

- Unless you can model your entire system synchronously, a single asynchronous source breaks imperative programming. -- Jake Wharton



# Why Reactive?

```
interface UserManager {  
    fun getUser(): User  
} fun setName(name: String)  
    fun setAge(age: Int)  
val um: UserManager = UserManagerImpl()  
logd(um.getUser())  
um.setName("John Doe")  
logd(um.getUser())
```



# Why Reactive?

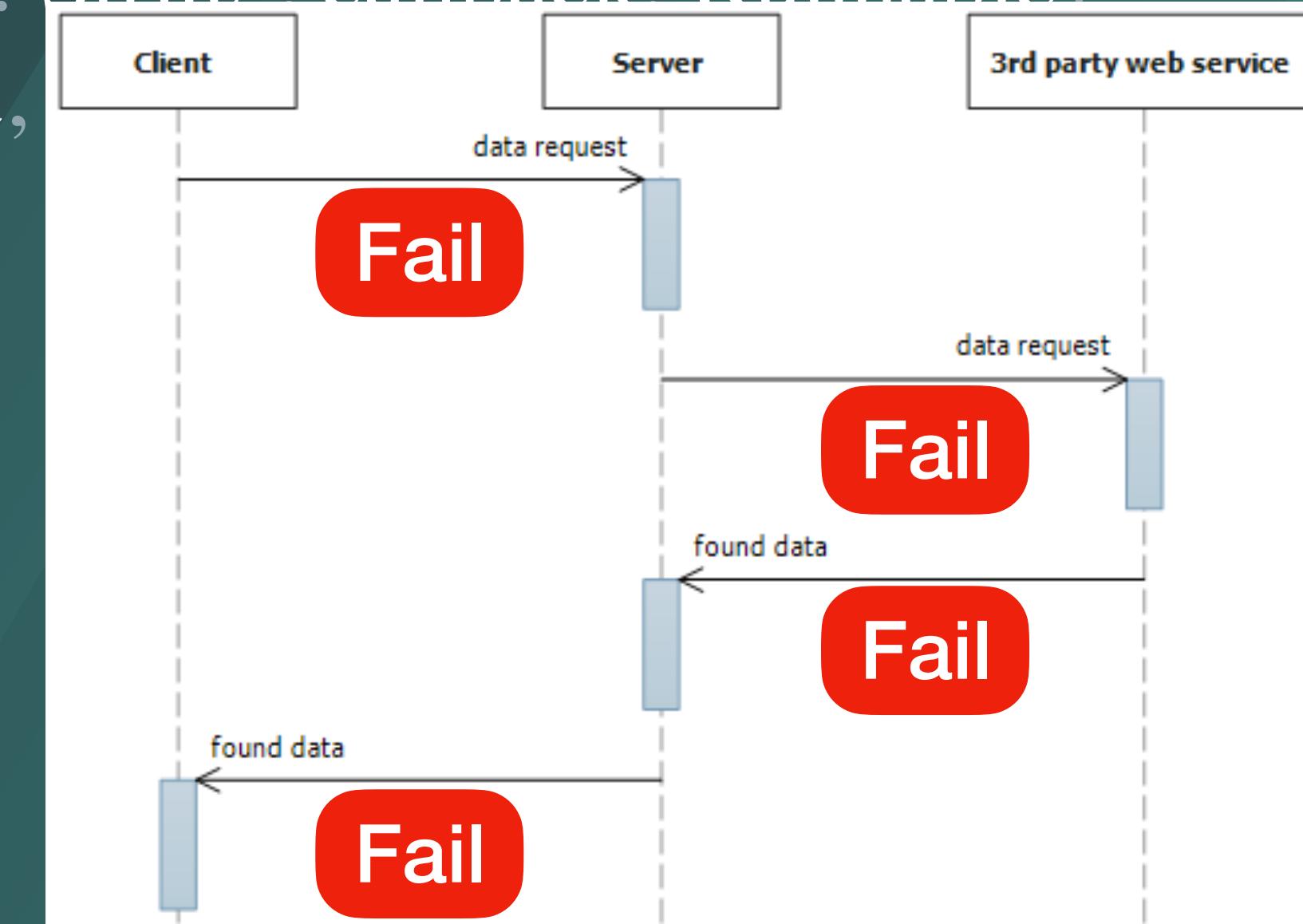
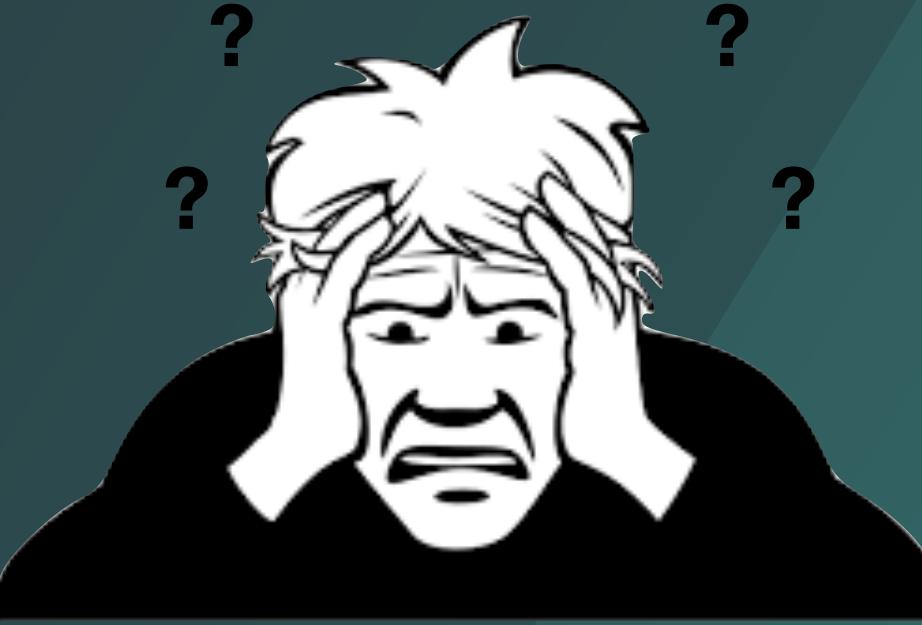
```
interface UserManager {  
    fun getUser(): User  
    fun setName(name: String)  
    fun setAge(age: Int)  
}
```

```
um.setName("John Doe")  
logd(um.getUser())
```



# Why Reactive?

```
interface UserManagerV2 { UserManagerV2Impl()  
    logId(userId: String)  
    fun getName(): String  
    fun getAge(): Int  
    fun setName(name: String, callback: Runnable)  
    fun setAge(age: Int, callback: Runnable)  
}
```



# Why Reactive?

```
interface UserManagerV3 {  
    fun getUser(): User  
    fun setName(name: String, listener: Listener): void  
    fun setAge(age: Int, listener: Listener): void  
  
    interface Listener {  
        fun success(user: User)  
        fun failed(error: UserException)  
    }  
}
```



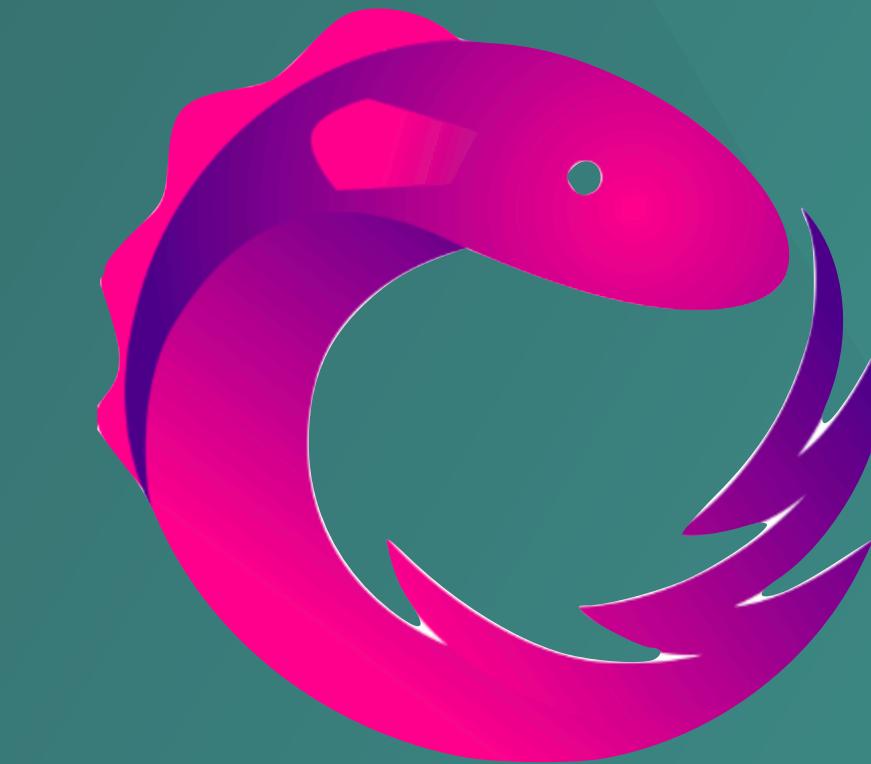
```
interface UserManagerV3 {  
    fun getUser(): User  
    fun setName(name: String, listener: Listener): void  
    fun setAge(age: Int, listener: Listener): void
```

```
interface Listener {  
    fun success(user: User)  
    fun failed(error: UserException)  
}  
}
```

```
val um: UserManagerV3 = UserManagerV3Impl()  
logd(um.getUser())
```

```
um.setName("John Doe", object : UserManagerV3.Listener {  
    override fun success(user: User) {  
        logd(user)  
    }  
})
```

```
override fun failed(error: UserException) {  
    loge("Unable to update the user details", error)  
}  
})
```



```
val um: UserManagerV3 = UserManagerV3Impl()
logd(um.getUser())

um.setName("John Doe", object : UserManagerV3.Listener {
    override fun success(user: User) {
        logd(user)
    }

    override fun failed(error: UserException) {
        loge("Unable to update the user details", error)
    }
})

um.setAge(42, object : UserManagerV3.Listener {
    override fun success(user: User) {
        logd(user)
    }

    override fun failed(error: UserException) {
        loge("Unable to update the user details", error)
    }
})
```

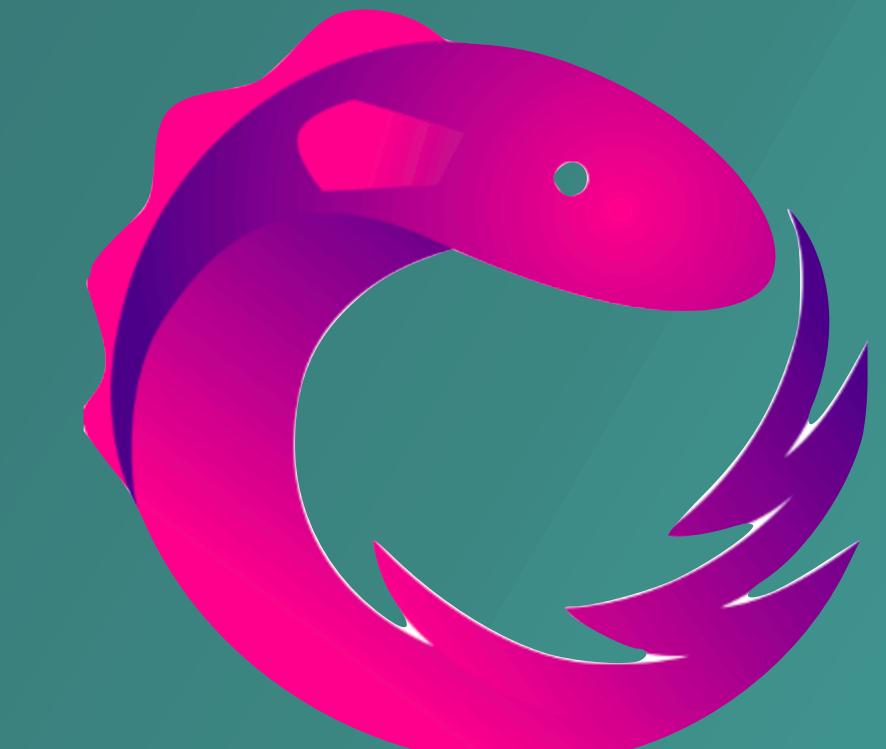


```
um.setAge(42, object : UserManagerV3.Listener {
    override fun success(user: User) {
        logd(user)
    }

    override fun failed(error: UserException) {
        loge("Unable to update the user details", error)
    }
})

um.setName("John Doe", object : UserManagerV3.Listener {
    override fun success(user: User) {
        um.setAge(42, object : UserManagerV3.Listener {
            override fun success(user: User) {
                logd(user)
            }

            override fun failed(error: UserException) {
                loge("Unable to update the user details", error)
            }
        })
    }
})
```



```
um.setName("John Doe", object : UserManagerV3.Listener {  
    override fun success(user: User) {  
        um.setAge(42, object : UserManagerV3.Listener {  
            override fun success(user: User) {  
                logd(user)  
            }  
  
            override fun failed(error: UserException) {  
                loge("Unable to update the user details", error)  
            }  
        })  
    }  
  
    override fun failed(error: UserException) {  
        loge("Unable to update the user details", error)  
    }  
})
```

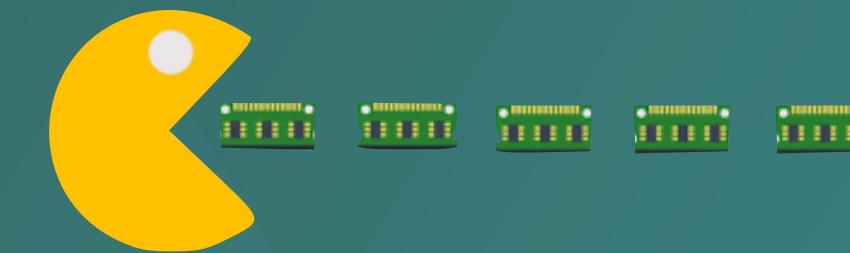




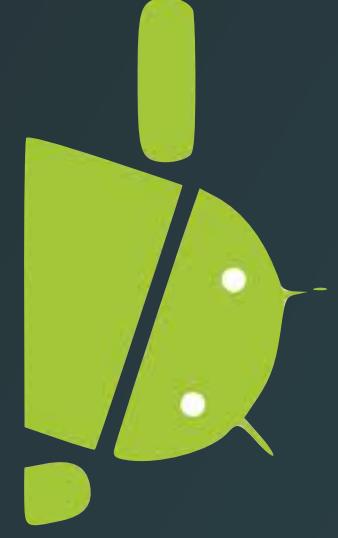
# Why Reactive?



```
class UserActivity : AppCompatActivity() {  
    val um: UserManager = UserManagerImpl()  
    override fun onCreate(savedInstanceState: Bundle?) {  
        override fun onCreate(savedInstanceState: Bundle?) {  
            setContentView(R.layout.activity_user_manager)  
            setContentViewById(activity_UserManager.Listener {  
                um.setName("John Doe", object: UserManager.Listener {  
                    ovum.setAge(42, user: UserManager.Listener {  
                        override fun success(user: User) {  
                            um.setAge(42, object: UserManager.Listener {  
                                override fun success(user: User) {  
                                    override fun success(user: User) {  
                                        textView.setText(user.name)  
                                        logd(user)  
                                        logd(user)  
                                    } logd(user)  
                                } logd(user)  
                            } logd(user)  
                        } logd(user)  
                    } logd(user)  
                } logd(user)  
            } logd(user)  
        } logd(user)  
    } logd(user)  
    override fun failed(error: UserException) {  
        override fun failed(error: UserException) {  
            overloge("fun failed(error:UserException)", error)  
            loge("Unable to update the user details", error)  
        } loge("Unable to update the user details", error)  
    } loge("Unable to update the user details", error)  
}
```



*“A small leak will sink a great ship.”*  
Benjamin Franklin



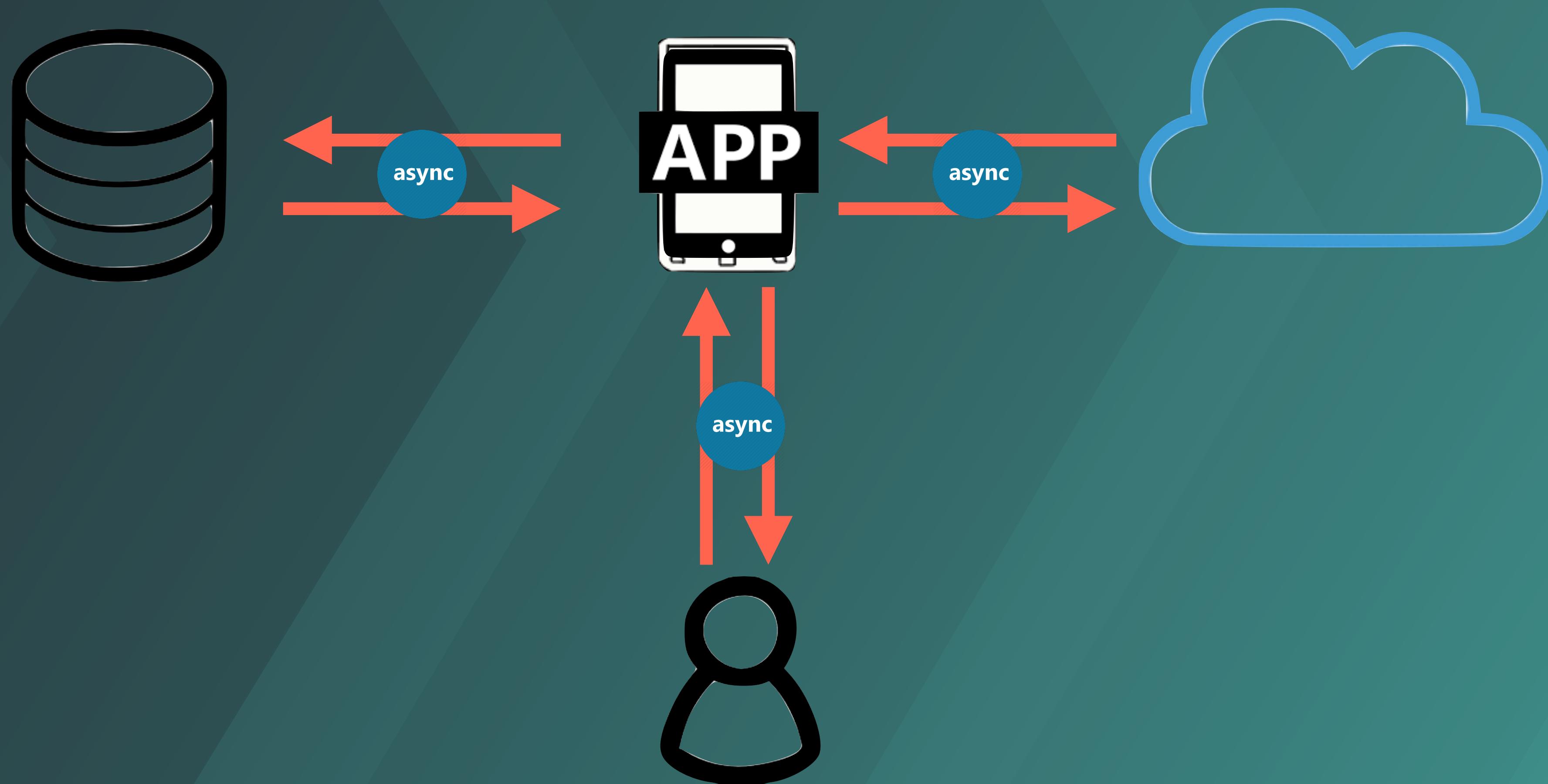
# Why Reactive?



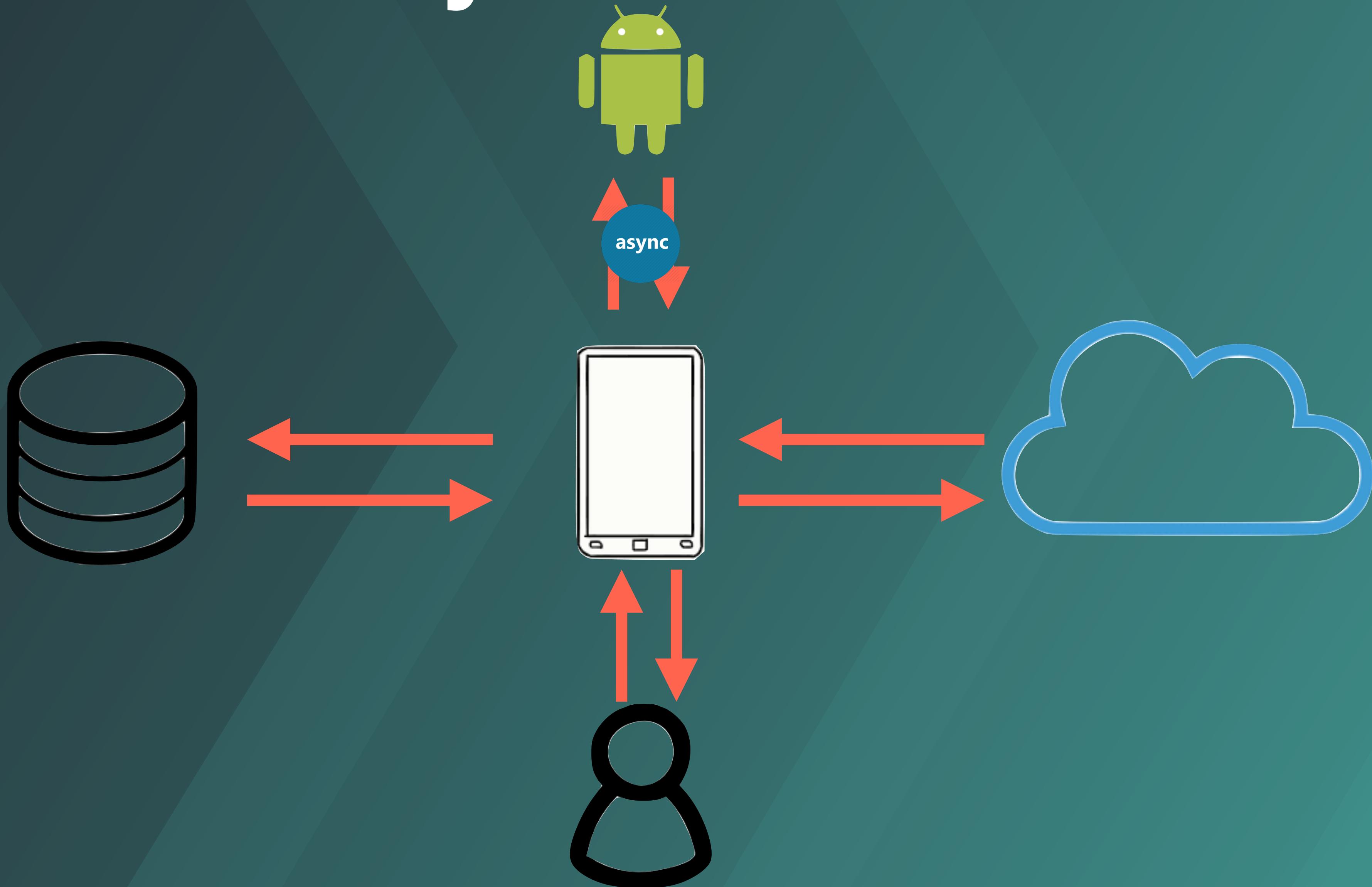
```
class UserActivity : AppCompatActivity() {
    val um: UserManager = UserManagerImpl()
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_user)
        um.setName("John Doe", object : UserManager.Listener {
            override fun success(user: User) {
                um.setAge(42, object : UserManager.Listener {
                    override fun success(user: User) {
                        if(!user.isDestroyed){
                            if(!user.isDestroyed) textView.text = user.name
                            logd(user)
                        }
                    }
                    override fun failed(error: UserException) {
                        loge("User failed", error)
                    }
                })
            }
            override fun failed(error: UserException) {
                //log("Unable to update the user details", error)
            }
        })
    }
}
```



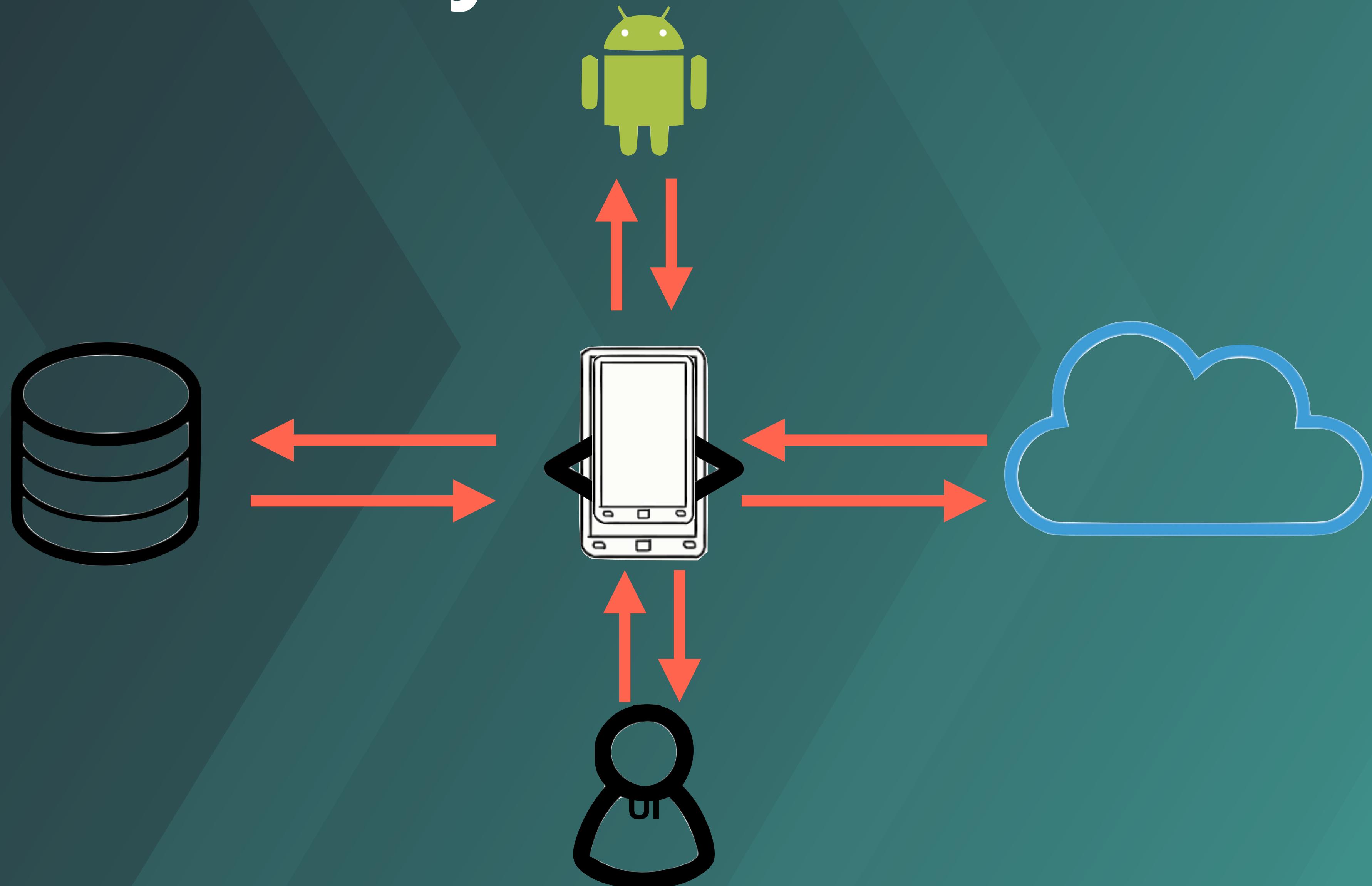
# Why Reactive?



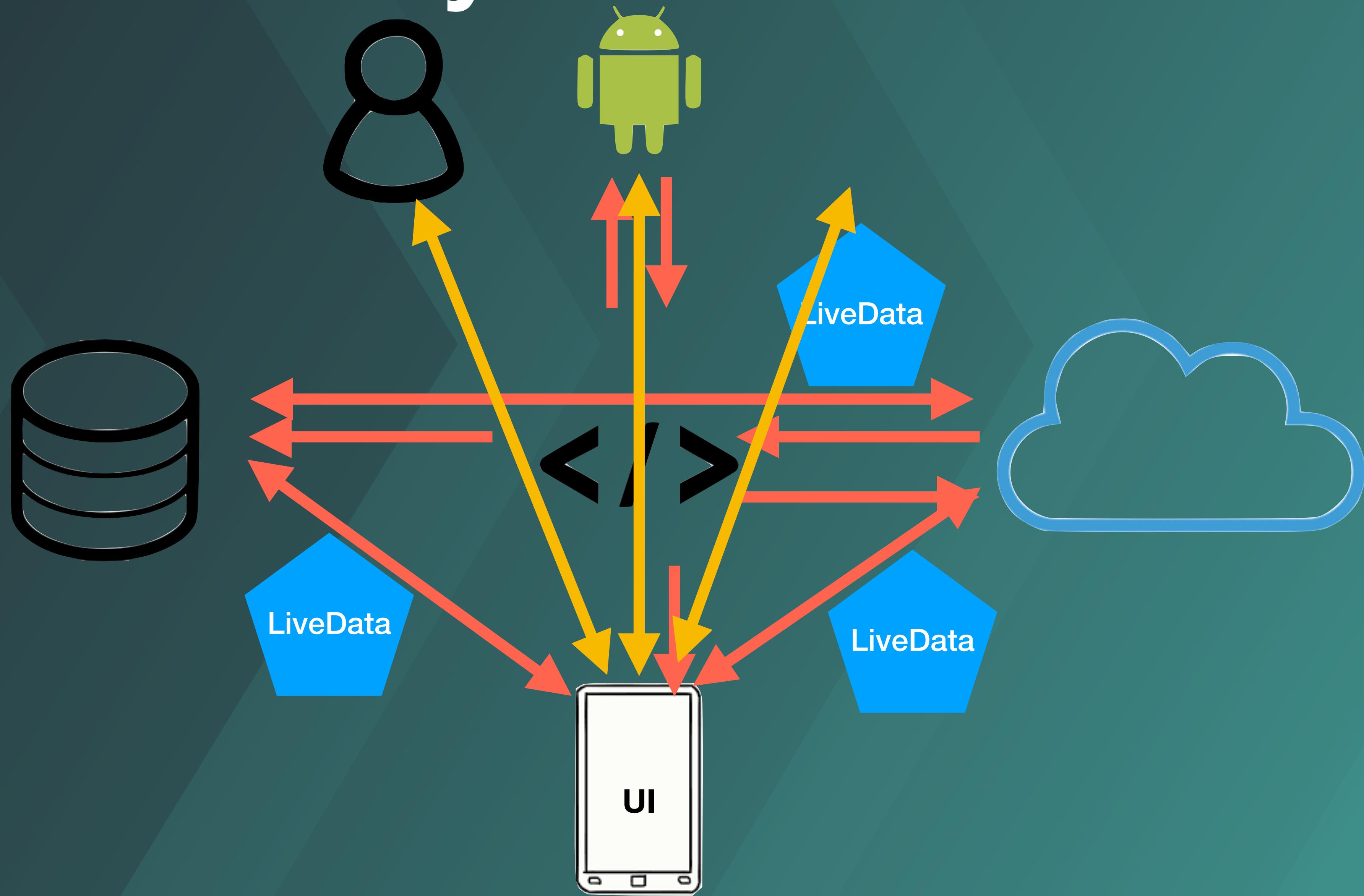
# Why Reactive?



# Why Reactive?



# Why Reactive?



# Rx{Java|Kotlin|Swift|Dart}

- A set of classes for representing sources of data.
- A set of classes for listening to data sources.
- A set of methods for modifying and composing the data.

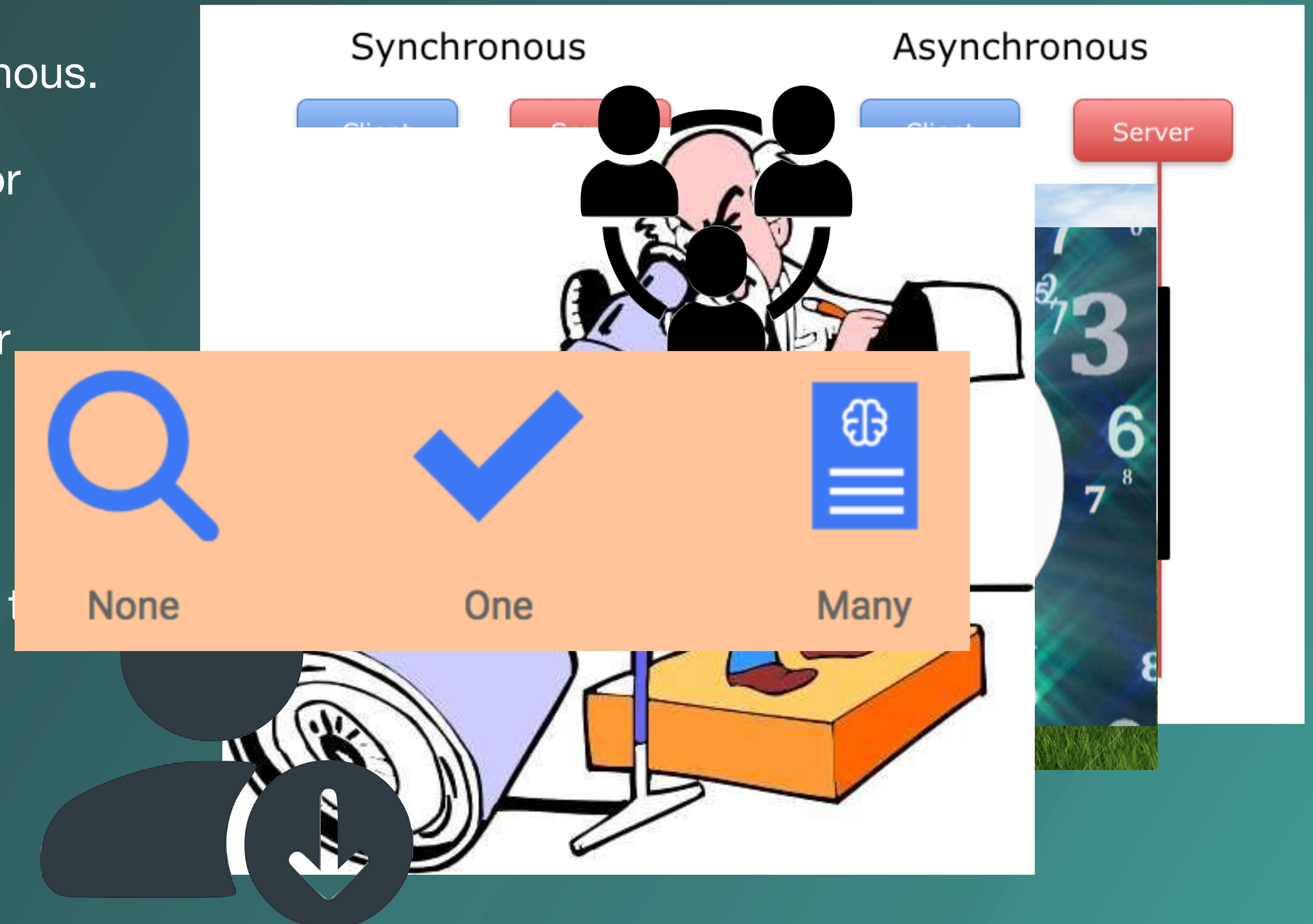


RxSwift



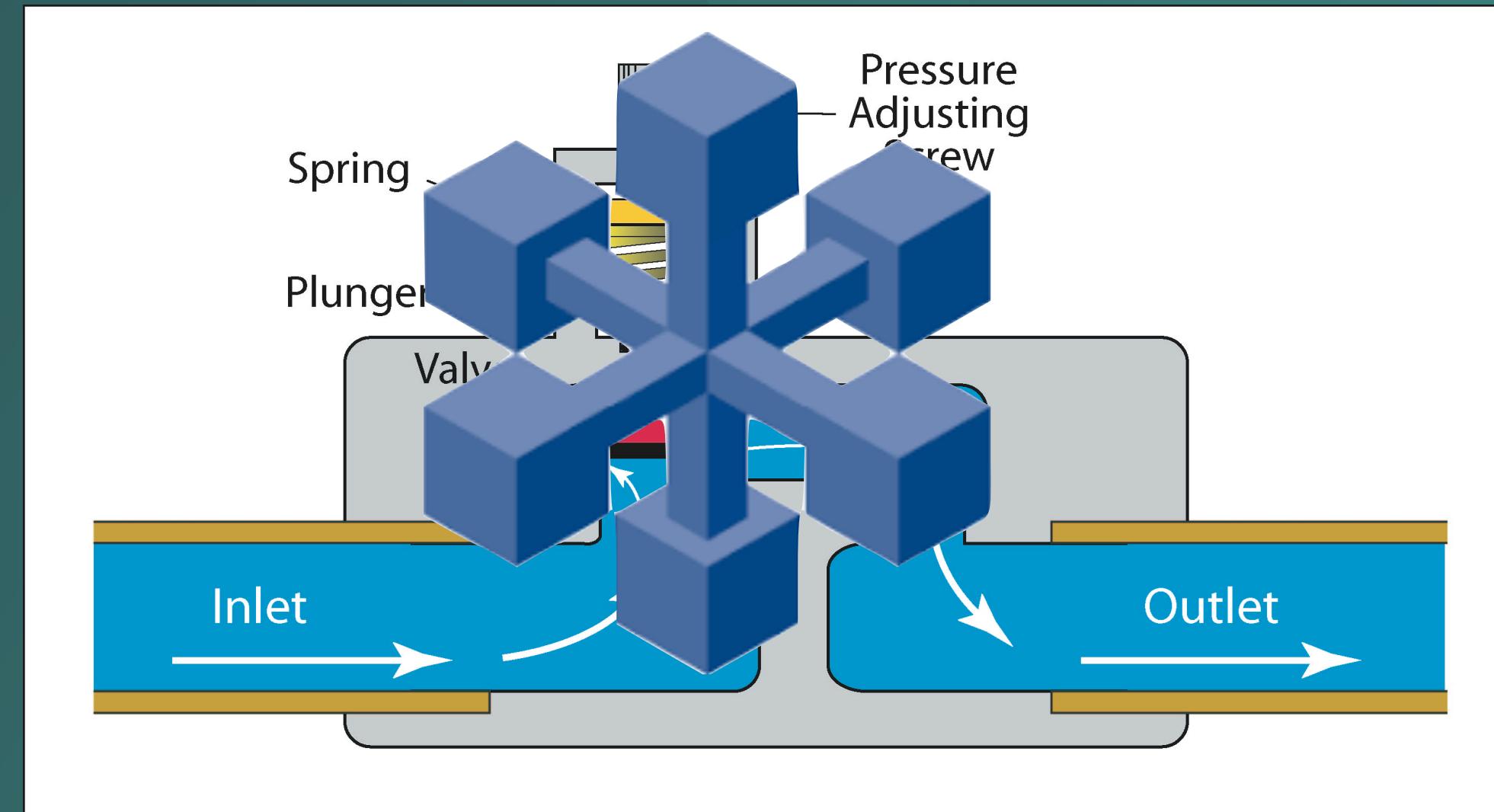
# Sources

- Synchronous or asynchronous.
- Single item, many items, or empty.
- Terminates with an error or succeeds to completion.
- May never terminate!
- Just an implementation of the Observer pattern.



# Sources

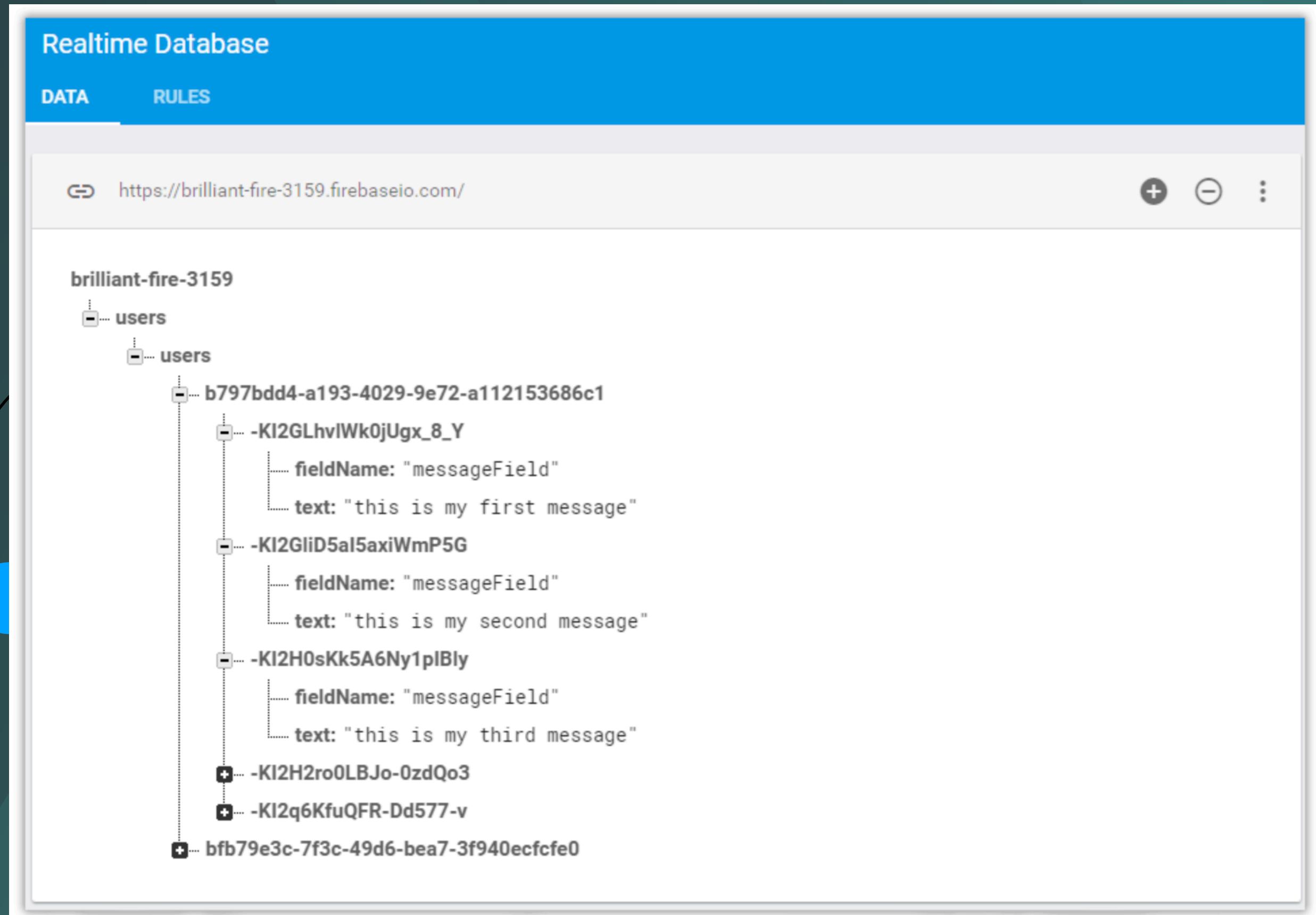
- Observable<T>
- Observable<T>
  - Emits 0 to N items.
  - Emits 0 to N items.
  - Terminates with complete or error.
  - Terminates with complete or error.
  - Does not have backpressure.
- Flowable<T>
- Flowable<T>
  - Emits 0 to N items.
  - Emits 0 to N items.
  - Terminates with complete or error.
  - Terminates with complete or error.
  - Has backpressure.



# Flowable vs. Observable

```
val events: Observable<MotionEvent> = RxView.touches(paintView);
```

```
val users: Observable<User> = db.createQuery("SELECT * FROM .").asObservable();
```



# Flowable vs. Observable

Observable<MotionEvent>

```
interface Observer<T>{
    fun onNext(t: T)
    fun onComplete()
    fun onError(t: Throwable)
    fun onSubscribe(d: Disposable)
}
```

```
interface Disposable{
    fun dispose()
}
```

Flowable<User>

```
interface Subscriber<T>{
    fun onNext(t: T)
    fun onComplete()
    fun onError(t: Throwable)
    fun onSubscribe(s: Subscription)
}
```

```
interface Subscription{
    fun cancel()
    fun request(r: Long)
}
```

# Sources

```
interface UserManager {  
    fun getUser(): Observable<User>  
    fun setName(name: String)  
    fun setAge(age: Int)  
}
```

# Specialized Sources

- Encoding subsets of Observable into the type system:

- Single



- Either succeeds with an item or an error.

- No backpressure support.

- Completable



- Either completes or errors. Has no items!

- No backpressure support.

- Maybe



- Either succeeds with an item, completes with no items, or error.

- No backpressure support.



# Sources

```
interface UserManager {  
    fun getUser(): Observable<User>  
    fun setName(name: String): Completable  
    fun setAge(age: Int): Completable  
}
```

# Creating Sources

```
Flowable.just("Hello")
```

```
Flowable.just("Hello", "World")
```

```
Observable.just("Hello")
```

```
Observable.just("Hello", "World")
```

```
Maybe.just("Hello")
```

```
val array = arrayListOf("Hello", "World")
```

```
val list = array.toList()
```

```
Single.just("Hello")
```

```
Flowable.fromArray(array)
```

```
Flowable.fromIterable(list)
```

```
Observable.fromCallable {
```

```
    Observable.fromArray(array)
```

```
    Observable.fromIterable(list)
```

# Creating Sources

```
val url = "https://example.com"
```

```
val request = Request.Builder().url(url).build()  
val client = OkHttpClient()
```

```
Observable.fromCallable {  
    client.newCall(request).execute()  
}
```

# Create Sources

```
Observable.create<String> {  
    it.onNext("Hello")  
    it.onNext("World")  
} it.onComplete()  
}
```

```
Observable.create(ObservableOnSubscribe<String> {  
    it.onNext("Hello")  
    it.onComplete()  
})
```

```
Observable.create(ObservableOnSubscribe<String>(  
    function = fun(it: ObservableEmitter<String>) {  
        it.onNext("Hello")  
        it.onComplete()  
    }))
```

# Create Sources

```
val request = Request.Builder().url(url).build()
val client = OkHttpClient()

Observable.create<View> {
    Observable.create<String> {
        it.setCancellable { textView.setOnClickListener(null) }
        val call = client.newCall(request)
        textView.setOnClickListener { v -> it.onNext(v) }
    }
    it.setCancellable { call.cancel() }
    call.enqueue(object : Callback {
        override fun onFailure(call: Call, e: IOException) {
            it.onError(e)
        }

        override fun onResponse(call: Call, response: Response) {
            it.onNext(response.body().toString())
            it.onComplete()
        }
    })
}
```

# Observing Sources

## Observable<MotionEvent>

```
interface Observer<T>{
    fun onNext(t: T)
    fun onComplete()
    fun onError(t: Throwable)
    fun onSubscribe(d: Disposable)
}
```

```
interface Disposable{
    fun dispose()
}
```

## Flowable<User>

```
interface Subscriber<T>{
    fun onNext(t: T)
    fun onComplete()
    fun onError(t: Throwable)
    fun onSubscribe(s: Subscription)
}
```

```
interface Subscription{
    fun cancel()
    fun request(r: Long)
}
```

# Observing Sources

```
val observable: Observable<String> = Observable.just("Hello")
val disposable: Disposable = object : DisposableWith<String> & DisposableObserver<String> {
    override fun onComplete() {
        //...
    }
    override fun onNext(t: String) {
        //...
    }
    override fun onError(e: Throwable) {
        //...
    }
})
disposable.dispose()
observer.dispose()  How to we dispose?
```

# Rx{Java|Kotlin|Swift|Dart}

- A set of **classes** for representing sources of data.
- A set of **classes** for listening to data sources.
- A set of **methods** for modifying and composing the data.



RxSwift



# Operators



- Manipulate or combine data in some way.
- Manipulate threading in some way.
- Manipulate emissions in some way.

# Operators

```
val greeting = Observable.just("Hello")
val yelling = greeting.map{it.toUpperCase() }
```

# Operators

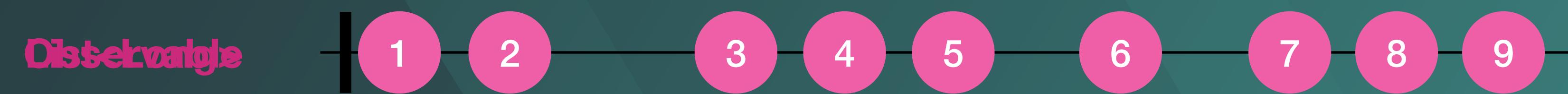
```
class UserActivity : AppCompatActivity() {  
    val um: UserManager = UserManagerImpl()  
    override fun onCreate(savedInstanceState: Bundle?) {  
        super.onCreate(savedInstanceState)  
        setContentView(R.layout.activity_user)  
        um.setName("John Doe", object : UserManager.Listener {  
            override fun success(user: User) {  
                um.setAge(42, object : UserManager.Listener {  
                    override fun success(user: User) {  
                        runOnUiThread {  
                            if (!isDestroyed) {  
                                textView.text = user.name  
                            }  
                        }  
                    }  
                }  
            }  
            override fun failed(error: UserException) {  
                loge("Unable to update the user details", error)  
            }  
        })  
    }  
    //...  
}  
}
```

# Operators

```
val user: Observable<User> = um.getUser()
val mainThreadUser = user.observeOn(AndroidSchedulers.mainThread())
val request = Request.Builder().url(url).build()
val client = OkHttpClient()

val response = Observable.fromCallable { client.newCall(request).execute() }
    .subscribeOn(Schedulers.io()).map { it.body()?.string() }
    .flatMap { Observable.fromArray(it.split(" ")) }
    .observeOn(AndroidSchedulers.mainThread())
```

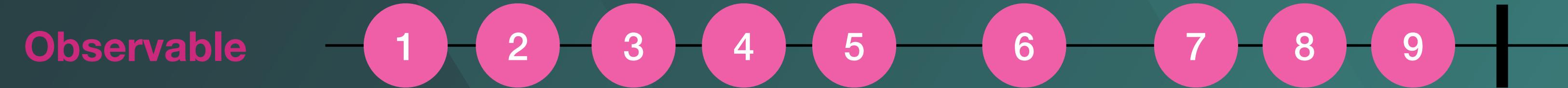
# Operators



`firstElement()`



# Operators



**ignoreElements()**



# Operators

Flowable



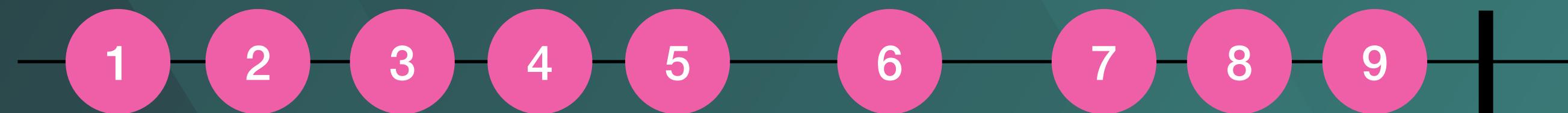
`firstElement()`

Single



# Operators

**Flowable**



**ignoreElements()**

**Completable**



# Being Reactive

```
// onCreate
val disposables = CompositeDisposable()
disposables.add(um.getUser()
    .observeOn(AndroidSchedulers.mainThread())
    .subscribeWith(object: DisposableObserver<User>{
        .subscribeWith(onNext(DisposableObserver<User>(){
            override fun onNext(t: User) {
                textViewName.text = t.name
                textViewName.setTextColor(t.color)
            }
        })
        override fun onError(e: Throwable) {
        }
        override fun onComplete() {
        }
    }))
// onDestroy
disposable.dispose()
```

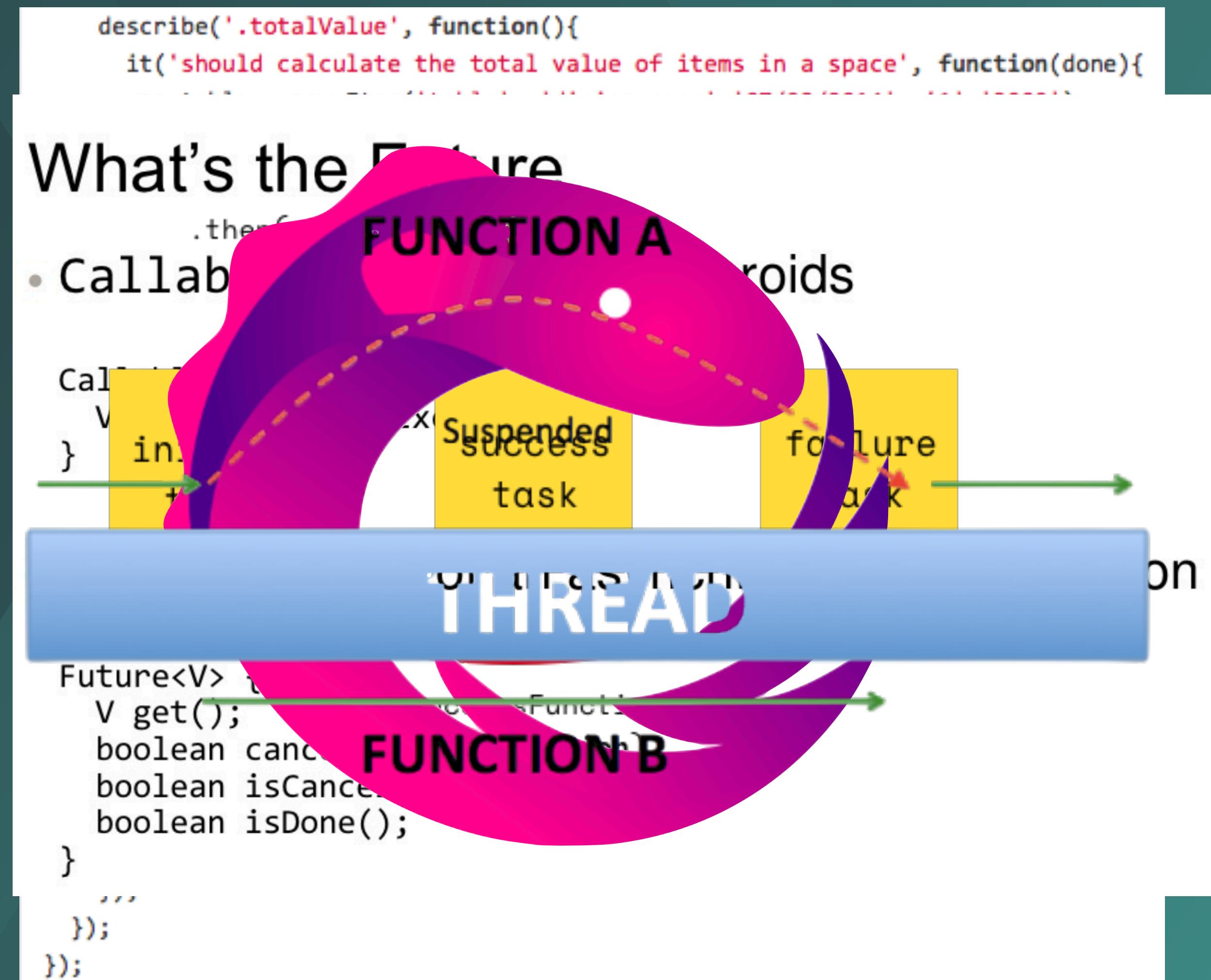
# Dependencies

DEMO

```
allprojects {  
    repositories {  
        maven { url "https://oss.jfrog.org/libs-snapshot" }  
    }  
}  
  
dependencies {  
    implementation 'io.reactivex.rxjava3:rxandroid:3.0.0'  
    // Because RxAndroid releases are few and far between, it is recommended you also  
    // explicitly depend on RxJava's latest version for bug fixes and new features.  
    // (see https://github.com/ReactiveX/RxJava/releases for latest 3.x.x version)  
    implementation 'io.reactivex.rxjava3:rxjava:3.1.5'  
}
```

# Options

- Callbacks
  - Futures
  - Promises
  - Rx
  - Coroutines



# Coroutines



```
fun requestToken(): Token {  
    // make a token request and waits  
    return tokenthread while waiting for result  
}  
} return token  
  
fun createPost(token: Token, item: Item): Post {  
    fun createPost(token$token, item$token): Post {  
        logd("Posting an $item using $token")  
        return post item to the server and waits  
    } return post  
}  
  
fun processPost(post: Post) {  
    fun/ processPost(post$Post) {  
        logd("Processing the $post")  
    } logd("Processing a $post")  
}  
  
fun postItem(item: Item) {  
    fun postItem(item$Item) {  
        val token= createPostToken(), item)  
        processPost(post$Post(token, item)  
    } processPost(post)  
}
```

# Coroutines

```
suspend fun requestToken(): Token {  
    // make a token request and suspends  
    return token  
}
```

```
suspend fun createPost(token: Token, item: Item): Post {  
    logd("Posting an $item using $token")  
    //sends the item to the server and waits  
    return post  
}
```

```
fun processPost(post: Post) {  
    // processing the post  
    logd("Processing a $post")  
}
```

```
suspend fun postItem(item: Item) {  
    val token = requestToken()  
    val post = createPost(token, item)  
    processPost(post)  
}
```



# Bonuses

**Regular loop handling:**

```
try {  
  for ((token, item) in list) {  
    createPost(token, item)  
  } catch (e: BadTokenException) {  
    // ...  
  }  
}
```

**Regular higher-order function:**

```
file.readLines().foreach { line ->  
  createPost(token, line.toItem())  
}
```

Any of: forEach, let, apply, repeat, filter, map, use, etc.

# Builders

```
suspend fun requestToken(): Token {  
    // make a token request and suspends  
    return token  
}
```

```
suspend fun createPost(token: Token, item: Item): Post {  
    logd("Posting an $item using $token")  
    //sends the item to the server and waits  
    return post  
}
```

```
fun processPost(post: Post) {  
    // processing the post  
    logd("Processing a $post")  
}
```

```
fun postItem(item: Item) {  
    GlobalScope.launch(Dispatchers.Main) {  
        val token = requestToken()  
        processPost(post(token, item))  
    }  
}
```

Suspend function 'requestToken()' should be called only from a coroutine or another suspend function



# Builders

```
public fun CoroutineScope.launch(  
    context: CoroutineContext = EmptyCoroutineContext,  
    start: CoroutineStart = CoroutineStart.DEFAULT,  
    block: suspend CoroutineScope.() -> Unit  
): Job {  
    val newContext = newCoroutineContext(context)  
    val coroutine = if (start.isLazy)  
        LazyStandaloneCoroutine(newContext, block) else  
        StandaloneCoroutine(newContext, active = true)  
    coroutine.start(start, coroutine, block)  
    return coroutine  
}
```

# Dependencies

DEMO

```
dependencies {  
    implementation "org.jetbrains.kotlinx:kotlinx-coroutines-android:1.3.9"  
}
```

# Usage

```
class MyViewModel : ViewModel() {  
    private val _result = MutableLiveData<String>()  
    val result: LiveData<String> = _result  
  
    init {  
        viewModelScope.launch {  
            val computationalResult = doComputation()  
            _result.value = computationalResult  
        }  
    }  
}
```

implementation "androidx.lifecycle:lifecycle-viewmodel-ktx:2.6.0-alpha03"

# Usage

```
class MyNewViewModel : ViewModel() {  
    val result = liveData {  
        emit(doComputation())  
    }  
}
```



implementation "androidx.lifecycle:lifecycle-livedata-ktx:2.6.0-alpha03"

# Flow

```
-> suspend fun foo(): List<Int> {  
    delay(1000) // pretend we are doing something asynchronous here  
    return listOf(1, 2, 3)  
}
```

```
-> fun main() = runBlocking<Unit> {  
    foo().forEach { value -> println(value) }  
}
```

Output:

1  
2  
3

# Flow

```
fun foo(): Flow<Int> = flow { // flow builder
    for (i in 1..3) {
        delay(100) // pretend we are doing something useful here
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    // Launch a concurrent coroutine to check if the main thread is blocked
    launch {
        for (k in 1..3) {
            println("I'm not blocked $k")
            delay(100)
        }
    }
    // Collect the flow
    foo().collect { value -> println(value) }
}
```

Output:

```
I'm not blocked 1
1
I'm not blocked 2
2
I'm not blocked 3
3
```

# Flows are cold

```
fun foo(): Flow<Int> = flow {  
    println("Flow started")  
    for (i in 1..3) {  
        delay(100)  
        emit(i)  
    }  
}  
  
fun main() = runBlocking<Unit> {  
    println("Calling foo...")  
    val flow = foo()  
    println("Calling collect...")  
    flow.collect { value -> println(value) }  
    println("Calling collect again...")  
    flow.collect { value -> println(value) }  
}
```

Output:

Calling foo...  
Calling collect...  
Flow started  
1  
3  
Calling collect again...  
Flow started  
1  
3  
Calling collect again...

# Flow Cancellation

```
fun fooCancellation(): Flow<Int> = flow {  
    for (i in 1..3) {  
        delay(100)  
        println("Emitting $i")  
        emit(i)  
    }  
}  
  
fun main() = runBlocking<Unit> {  
    withTimeoutOrNull(250) { // Timeout after 250ms  
        fooCancellation().collect { value -> println(value) }  
    }  
    println("Done")  
}
```

Output:

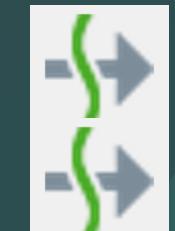
Emitting 1  
1  
Emitting 2  
2  
Done

# Flow Operators



```
suspend fun performRequest(request: Int): String {  
    delay(1000) // imitate long-running asynchronous work  
    return "response $request"  
}
```

Output:



```
fun main() = runBlocking<Unit> {  
    (1..3).asFlow() // a flow of requests  
        .map { request -> performRequest(request) }  
        .collect { response -> println(response) }  
}
```

response 1  
response 2  
response 3

# Transform Operator

```
suspend fun performRequest(request: Int): String {  
    -> delay(1000) // imitate long-running asynchronous work  
    return "response $request"  
}  
(1..3).asFlow() // a flow of requests  
    .transform { request ->  
        -> emit("Making request $request")  
        -> emit(performRequest(request))  
    }  
    .collect { response -> println(response) }  
Output:
```

Making request 1

response 1

Making request 2

response 2

Making request 3

response 3

# Size-limiting Operators

```
fun numbers(): Flow<Int> = flow {  
    try {  
        emit(1)  
        emit(2)  
        println("This line will not execute")  
        emit(3)  
    } finally {  
        println("Finally in numbers")  
    }  
}  
  
@ExperimentalCoroutinesApi  
fun main() = runBlocking<Unit> {  
    numbers()  
        .take(2) // take only the first two  
        .collect { value -> println(value) }  
}
```

Output:

```
1  
2  
Finally in numbers
```

# Terminal Flow Operators

DEMO

```
@ExperimentalCoroutinesApi
fun main() = runBlocking<Unit> {
    val sum = (1..5).asFlow()
        .map { it * it } // squares of numbers from 1 to 5
        .reduce { a, b -> a + b } // sum them (terminal operator)
    println(sum)
}
```



Output: 55

# Lecture outcomes

- Understand the reactive programming (Rx) concepts.
- Use Rx to re-write the application logic.
- Design a real time application logic against a real time backend.
- Understand coroutines and flow.

