Functional Programming: *The Enterprise Edition*

...

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Slides + code: https://git.io/vh4VB

I’m Narek.

Senior Software Engineer

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Scala & FP advocate

My team…
Activities Platform

=> Streaming data, microservices & data lake
=> Millions of customer events per day
=> Spark, Storm, Akka, Kafka, Cassandra
=> **We're hiring...**

Roll call!

Are you writing Scala at work?

Is it purely functional?

Enterprise Functional Programming

Oxymoron?

Realistic Code

- Impure
- Complicated and ugly
- Buggy
- Needs refactoring
- 10-100 normal engineers

Ideal Code

- Pure
- Elegant
- Safe & provable
- Perfect abstraction
- Math geniuses in ivory tower

Thesis:

We'll never be perfect, but functional enterprise code **is possible**.

Functional abstractions are well suited for commercial software.

But we will encounter *a lot* of resistance in implementation.

Bringing up FP concepts at work shouldn't have to feel like this...

image: Twitter

But that's often the case because the imperative mindset is the default...

Why tho?
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Why? Blame FORTRAN.

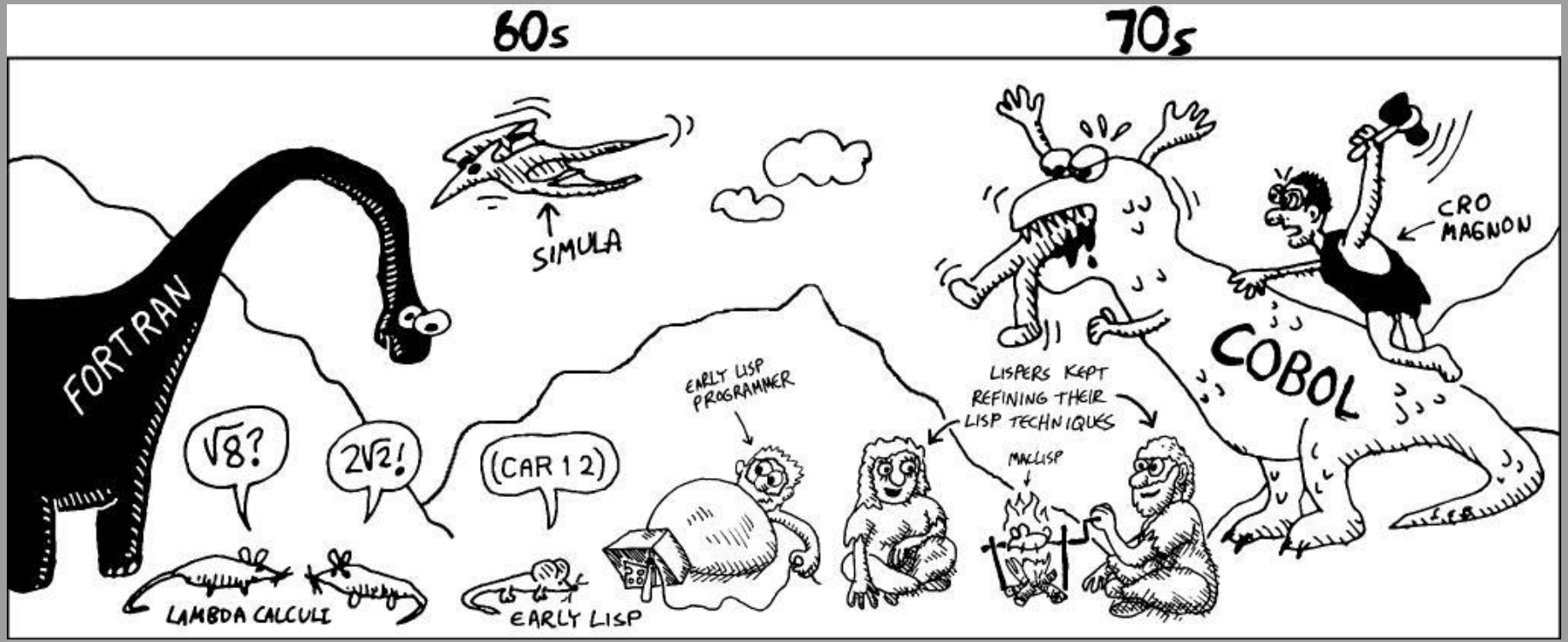


image: “Land of LISP” by Conrad Barski

Why? Blame universities.

- **C**, **Java** and **Python** taught first
- Functional concepts play a minor role (if any)
- FP langs are “too high level” to teach fundamentals with

Why? Blame fear.

- Programmers are afraid
  - “Scary math terms”
  - Imposter syndrome
- Managers are afraid
  - *How will we maintain this alien code when you leave?*
- Some people are also outright *against* FP and fight it...

So what is this talk about?

1. Applied functional abstractions for common and problematic scenarios in enterprise programming

2. 5 strategies for introducing and fostering *functional thinking* in commercial software development

Some Caveats

- Familiarity with Scala is assumed
  - “Java-esque” imperative examples
- This is not a first principles talk
  - Applications first
  - Read FP in Scala for the theory
- Cats typeclass library

Applied FP Abstractions

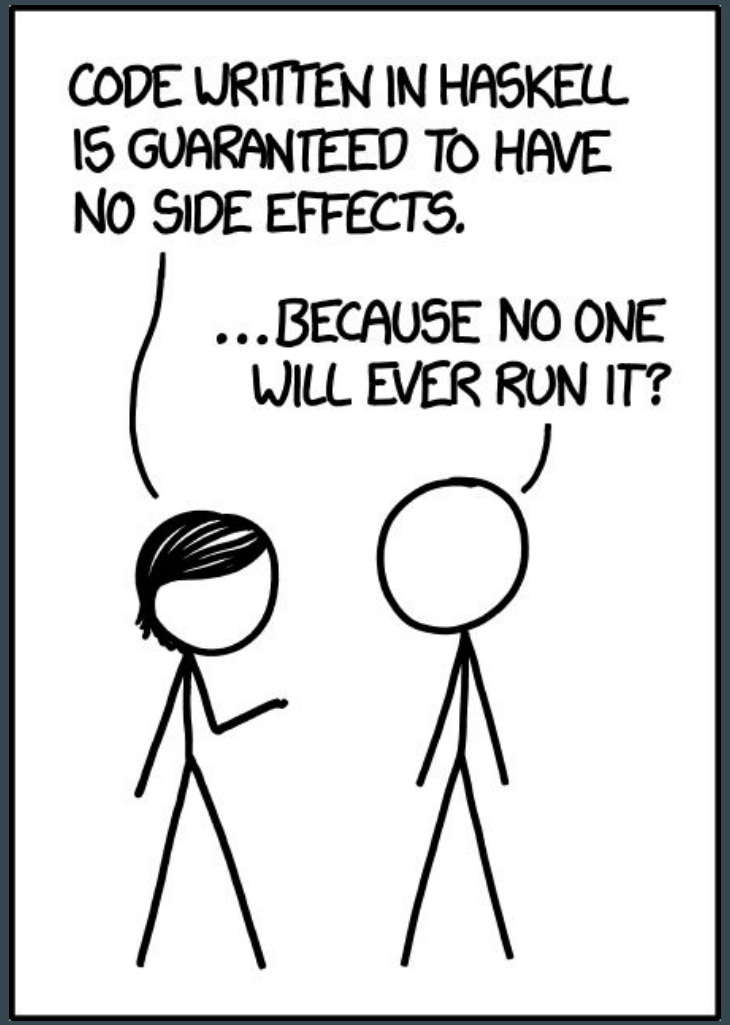


image: xkcd (Creative Commons)

Effects
vs
Side Effects

=> “A change to the world”
=> Accounted for vs unaccounted
=> Typed vs void/Unit

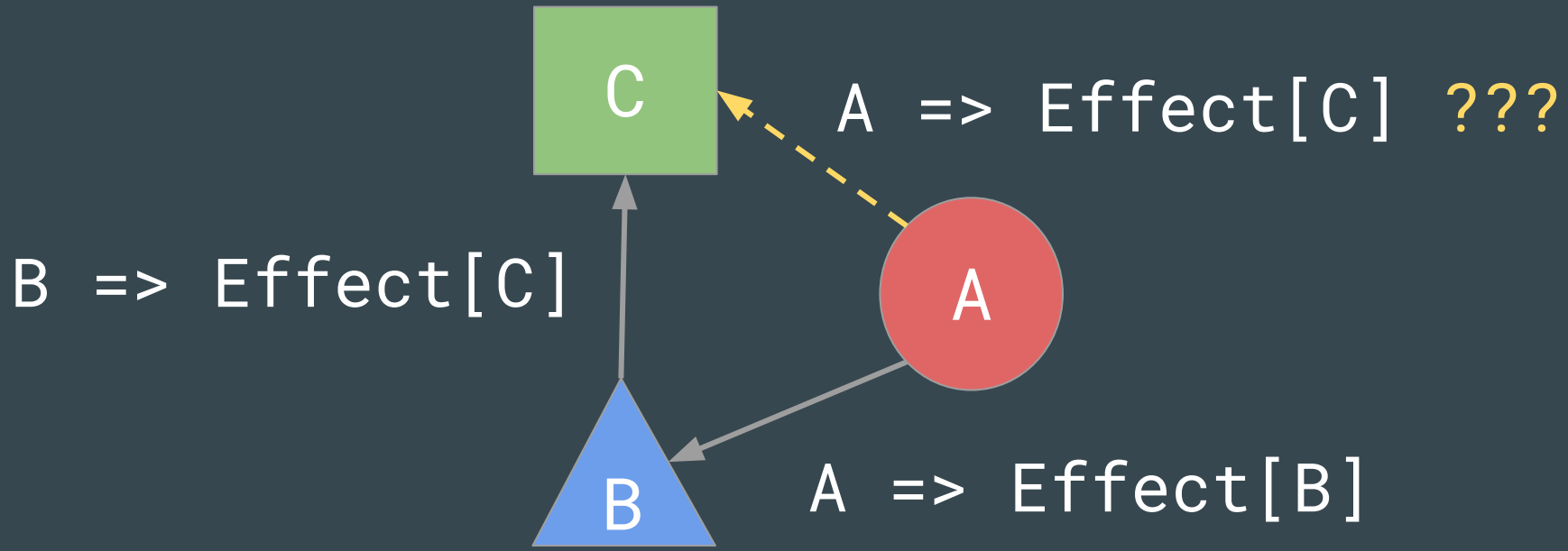
Common Computational Effects

1. **Partiality**
   a. The missing data problem
   b. Option
2. **Failure Handling**
   a. Code fails, what do you do?
   b. Either, Try
3. **IO**
   a. Interacting with the network or disk
   b. Cats IO
   c. Stacking effects

=> Computational effects are central to enterprise programming

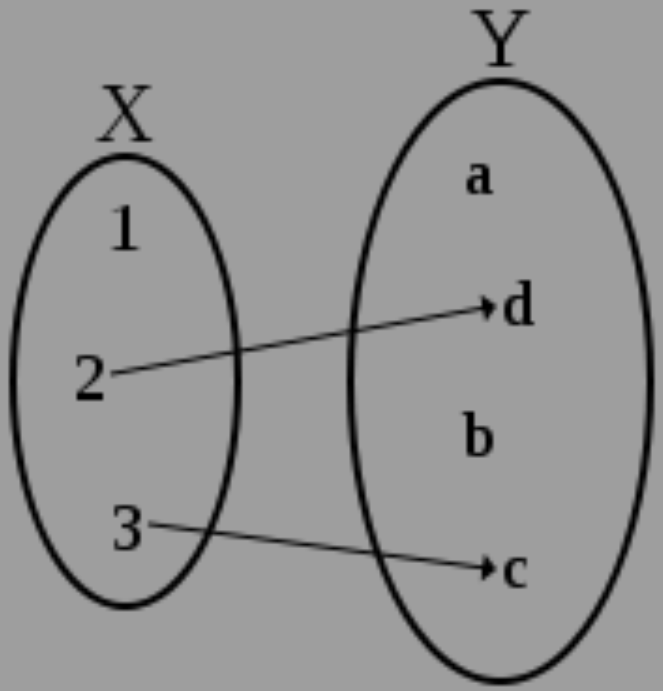
=> Composition is the essence of functional programming

=> But how do we compose effects...?



Partiality

- All values in the domain do not map to values in the codomain
- Happens frequently in enterprise:
  - Empty DB/API queries
  - Function has no result
- Imperative languages use **null** to deal with this situation, *but you know what comes with null...*



NPE (ノ°□°)ノ

image: wikimedia foundation

Option

```
sealed trait Option[+A]
case object None extends Option[Nothing]
case class Some[A](a: A) extends Option[A]
```

=> Algebraic data type or “ADT”
=> Type constructor
=> Introduced to solve the Java **null** problem
=> Simple yet very powerful tool

Great, so we have a type constructor for partiality.

But what are imperative people doing with it?

Using it just like Java null

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Partiality Example

```
// Scala's Map implements get
// def get[K,V](k: K): Option[V]

val personLocation = Map(
  "Jerry Seinfeld"   -> "Manhattan",
  "George Costanza" -> "Manhattan",
  "Frank Costanza"   -> "Queens",
  "Elaine Benes"     -> "Brooklyn"
)
val locationTransit = Map(
  "Manhattan" -> List("J", "Z"),
  "Brooklyn"  -> List("L", "G", "K")
)
```

Partiality Example

```
/*
 * A simple cache lookup
 * 1. Select person from personLocation
 * 2. Select their subway stops from locationTransit
 * 3. Transform stops into a comma-separated string
 */
def listStops(name: String): String = ???
```

Partiality Example (imperative)

```
def listStopsImperative(name: String): String = {
 val location = personLocation.get(name)
 var message: Option[String] = None
 if (location.isDefined) {
   val transit = locationTransit.get(location.get)
   if (transit.isDefined) {
     // Build the output string
     var output = collection.mutable.StringBuilder.newBuilder
     for (s <- transit.get) {
       output.append(s + ",")
     }
     message = Some(output.result())
   }
 }
 if (message.isDefined) message.get
 else "User or stops not found!"
}
```

Partiality Example (functional)

```
def listStopsFunctional(name: String): String =
  personLocation.get(name)
    .flatMap(locationTransit.get)
    .map(_.reduce(_ + ", " + _))
    .getOrElse("User or stops not found!")


def listStopsFunctional2(name: String): String =
  personLocation.get(name)
    .flatMap(locationTransit.get)
    .fold("User or stops not found!")
      (_.reduce(_ + ", " + _))
```

- Why does the imperative style make something so simple **complicated**?

- Lacks effect abstraction
  - Reinventing the same computational patterns every time

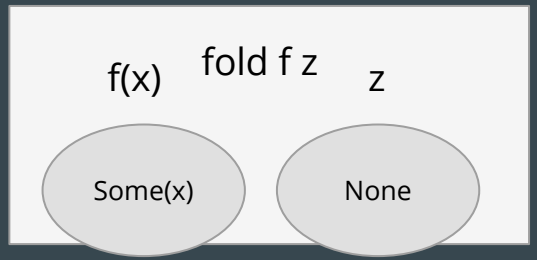
- Functional approach in Scala creates a declarative pipeline

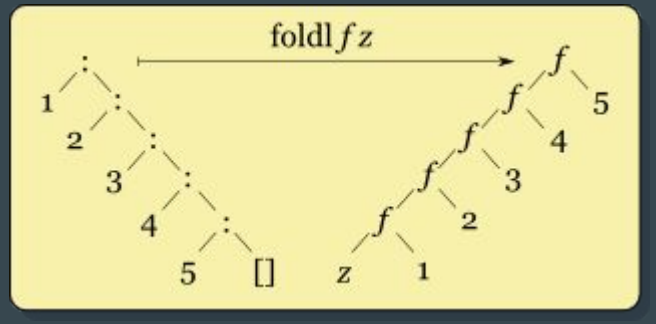
The difference is in using **combinators** as they were intended…

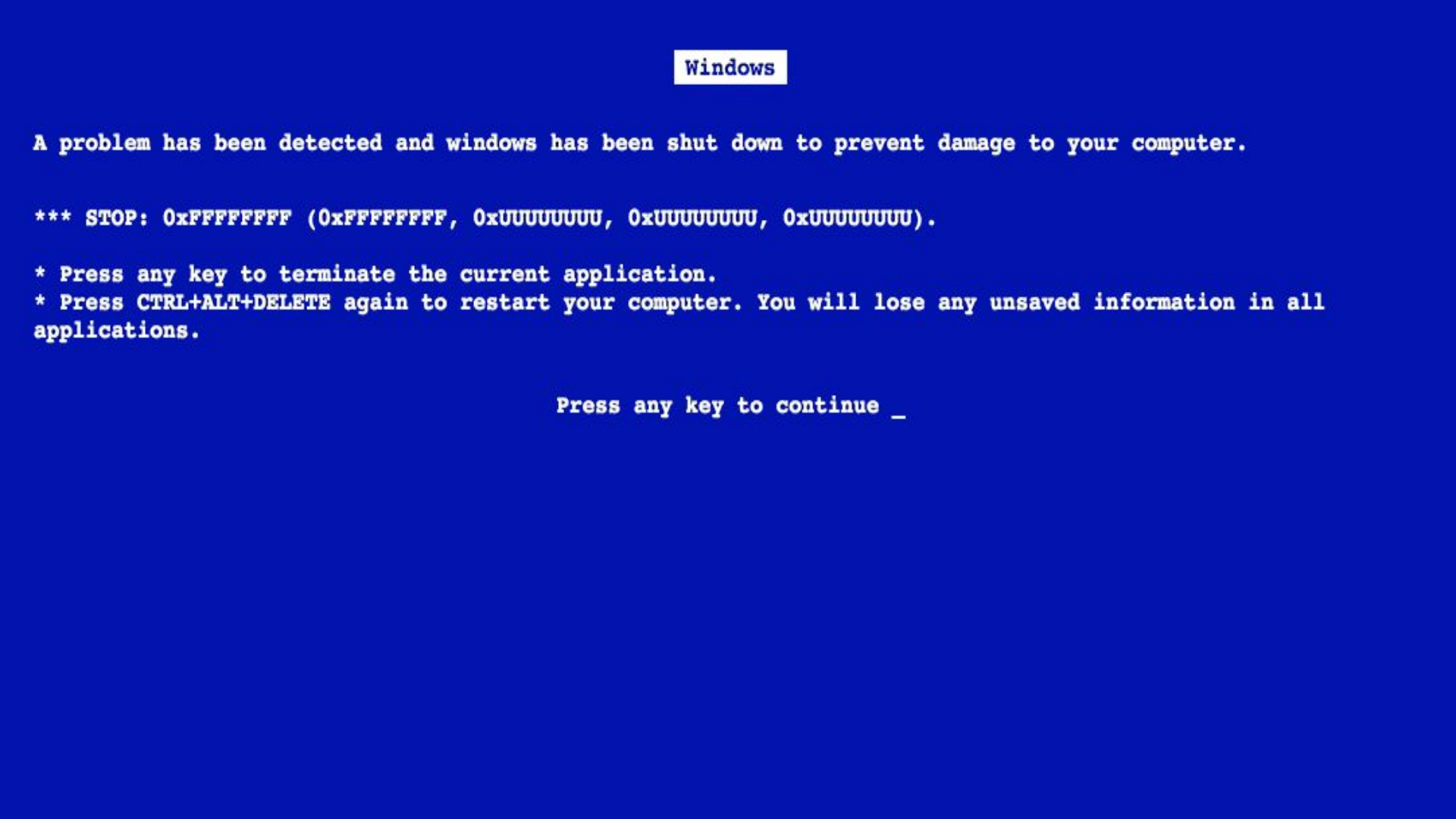
...for *combining* effects!

A quick aside about folds...

- They are everywhere in FP
- *Foldable* is actually a typeclass in Cats and Scalaz
- Lists, sets, maps, trees can fold
- **Non-collection types are foldable too, as we are seeing!**






Windows
A problem has been detected and windows has been shut down to prevent damage to your computer.
*** STOP: 0xFFFFFFFF (0xFFFFFFFF, 0xUUUUUUUU, 0xUUUUUUUU, 0xUUUUUUUU).
* Press any key to terminate the current application.
* Press CTRL+ALT+DELETE again to restart your computer. You will lose any unsaved information in all applications.
Press any key to continue _

Failure

- **Exceptions** naturally exist in programming languages
- Traditionally dealt with using **try-catch-finally**
  - Boilerplate
  - Hard to attribute

image: wikimedia foundation

Failure

- Scala's exceptions are typed values when not thrown

```
// Right biased
sealed trait Either[Throwable, +A]
case class Left[A](t: Throwable) extends Either[Throwable, A]
case class Right[A](a: A) extends Either[Throwable, A]

// Constructor behaves like a try-catch block
sealed trait Try[+A]
case class Failure(t: Throwable) extends Try[Throwable]
case class Success[A](a: A) extends Try[A]
```

Failure Example

```
/*
* Modeling a website signup flow.
*/
def signupFlow(request: AccountRequest): AccountResponse = ???

sealed case class AccountRequest(
  user: String, pw: String, email: String)

sealed trait AccountResponse
case class Denied(msg: String) extends AccountResponse
case class Granted(
  user: String, encryptedPW: String, validEmail: Boolean
  ) extends AccountResponse
```

Failure Example (imperative)

```
/*
 * The "Java" style looks simple here.
 * But can we chain together two functions that throw?
*/
def signupFlowImperative(request: AccountRequest): AccountResponse = {
  try {
    val encrypted = encrypt(request.pw, 10)
    val validEmail = validateEmail(request.email)
    Granted(request.user, encrypted, validEmail)
  } catch {
    case e: Throwable => Denied(e.getMessage)
 }
}
```

Try-Catch makes this simple enough.

But what if we wanted to chain multiple of these operations together?

Imperative version doesn't compose... ಠ∩ಠ

Failure Example (functional)

```
// Example 1: Use Try if we want to use the offending function as-is
def signupFlowFunctional(request: AccountRequest): AccountResponse =
 Try(encrypt(request.pw, 10))
   .flatMap(encrypted =>
     Try(validateEmail(request.email))
       .map(valid => Granted(request.user, encrypted, valid)))
   .fold(t => Denied(t.getMessage), g => g)

def signupFlowFunctional2(request: AccountRequest): AccountResponse = {
 val tryGrant = for {
   encrypted  <- Try(encrypt(request.pw, 10))
   validEmail <- Try(validateEmail(request.email))
 } yield Granted(request.user, encrypted, validEmail)

 tryGrant.fold(t => Denied(t.getMessage), g => g)
}
```

So far we've only dealt with objects in our program…

But there's a whole world of data out there!

IO 

- Communicating with external resources is critical
- Imperative world does not have a principled way to handle IO
  - **try-catch** blocks
  - **async-await** using event loop
  - Even Scala **Future**...

Cats IO

- Referentially transparent
- Composable
  - Allows the separation of actions and execution (as we will see)
- Rich control API
  - *runAsync*
  - *attempt* (returns Either)
  - *cancelable*

IO Example

```scala
// Records in data lake (S3) with key relationships to each other.
sealed trait Record
case class Location(name: String) extends Record
case class Coordinates(lat: Double, lng: Double) extends Record
case class Restaurant(name: String, location: Location) extends Record

val restaurantsDatalake: mutable.Map[String, Restaurant] = mutable.Map(
  "soup" -> Restaurant("Soup Place", Location("Queens")),
  "kabob" -> Restaurant("Babu Bhatt's", Location("Brooklyn")),
  "diner" -> Restaurant("Tom's Diner", Location("Manhattan"))
)

val locationsDatalake: mutable.Map[Location, Coordinates] = mutable.Map(
  Location("Queens") -> Coordinates(40.10, 74.11),
  Location("Brooklyn") -> Coordinates(41.12, 79.00),
  Location("Manhattan") -> Coordinates(44.00, 70.26)
)

val reviewsDatalake: mutable.Map[Restaurant, List[String]] = mutable.Map(
  Restaurant("Soup Place", Location("Queens")) -> List("Guy at counter was really rude."),
  Restaurant("Babu Bhatt's", Location("Brooklyn")) -> List("They changed the entire menu!")
)
```

IO Example

```
/*
 * We'll search a Restaurant by keyword and pair with Coordinates.
 * Simulating IO operations to an S3-like data store.
*/
def searchRestaurants(search: String): (Restaurant, Coordinates)= ???

def fetch[K, V](bucket: mutable.Map[K, V], key: K): Option[V] = {
  Thread.sleep(1000)
  bucket.get(key)
}

def write[K, V](bucket: mutable.Map[K, V], key: K, value: V): Int = {
  Thread.sleep(1000)
  bucket.put(key, value)
  1
}
```

IO Example (imperative)

```
def searchRestaurantsImperative(search: String): (Restaurant, Coordinates) = {
  var restaurant: Option[Restaurant] = null
  var coordinates: Option[Coordinates] = null
  try {
    restaurant = fetch(restaurantsDatalake, search)
    if (restaurant.isDefined) {
      coordinates = fetch(locationsDatalake, restaurant.get.location)
    }
  } catch {
    case e: Exception => println("Fetch failed somewhere... we don't know")
  }
  (restaurant.get, coordinates.get)
}
```

IO Example (functional)

```
/*
 * For convenience and reuse, we wrap the original API.
 * Notice the use of OptionT in `fetch` due to the additional effect.
*/
def ioFetch[K,V](dl: mutable.Map[K, V], key: K): OptionT[IO,V] =
  OptionT[IO,V](IO(fetch(dl, key)))

def ioWrite[K,V](bucket: mutable.Map[K, V], key: K, value: V): IO[Int] =
  IO(write(bucket, key, value))
```

IO Example (functional)

```
// Example 1: Look familiar?
def searchRestaurantsFunctional(search: String):
    Either[Throwable, Option[(Restaurant, Coordinates)]] = {

  val io: OptionT[IO, (Restaurant, Coordinates)] = for {
    restaurant  <- ioFetch(restaurantsDatalake, search)
    coordinates <- ioFetch(locationsDatalake, restaurant.location)
  } yield (restaurant, coordinates)

  io.value.attempt.unsafeRunSync()
}
```

IO Example (functional)

```
// Example 2: Search a restaurant and review it based on distance.
// We can isolate the query from the last example and reuse it. Modularity!
def selectRestaurant(search: String): OptionT[IO, (Restaurant, Coordinates)] =
  for {
    restaurant  <- ioFetch(restaurantsDatalake, search)
    coordinates <- ioFetch(locationsDatalake, restaurant.location)
  } yield (restaurant, coordinates)

// A new insert statement to write a review.
def insertReview(restaurant: Restaurant, review: String): IO[Int] =
  for {
    reviews     <- ioFetch(reviewsDatalake, restaurant).value
    insert       = reviews.fold(List(review))(review :: _)
    numInserted <- ioWrite(reviewsDatalake, restaurant, insert)
  } yield numInserted
```

IO Example (functional)

```
//  Bring it all together to search a restaurant then review it.
def lazyReviewer(restaurant: Restaurant, coordinates: Coordinates): IO[Int] =
  if (coordinates.lat > 40)
    insertReview(restaurant, "Terrible restaurant, too far from me!")
  else 0.pure[IO]

def findAndReview(search: String): Either[Throwable, Option[Int]] = {
  val io: OptionT[IO, Int] = for {
    (restaurant, coordinates) <- selectRestaurant(search)
    reviewsInserted <- OptionT.liftF(lazyReviewer(restaurant, coordinates))
  } yield reviewsInserted

  io.value.attempt.unsafeRunSync()
}
```

Noticing a pattern?

```
trait Functor[F[_]] {
  def map[A, B](fa: F[A])(f: A => B): F[B]
}

trait Monad[F[_]] {
  def pure[A](value: A): F[A]
  def flatMap[A, B](value: F[A])(func: A => F[B]): F[B]
}
```

All the types we used belong to
Functor and Monad typeclasses (+ many more...)

Of course, things can get much more advanced from here…

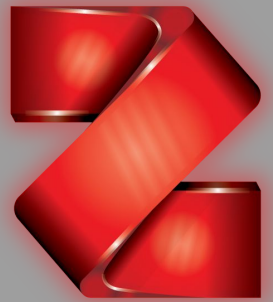
=> But how do we teach this stuff and introduce it at work?

As a functional programmer, you must be a teacher and a salesperson at the same time.

5 Methods for Functional Programming Advocacy

5. Principled Libraries

- Very smart folks have implemented great tools for us - **let's use them**
- **Lead by example**
- In the Scala world…
  - Cats
  - Scalaz
  - Doobie
  - FS2
  - Shapeless



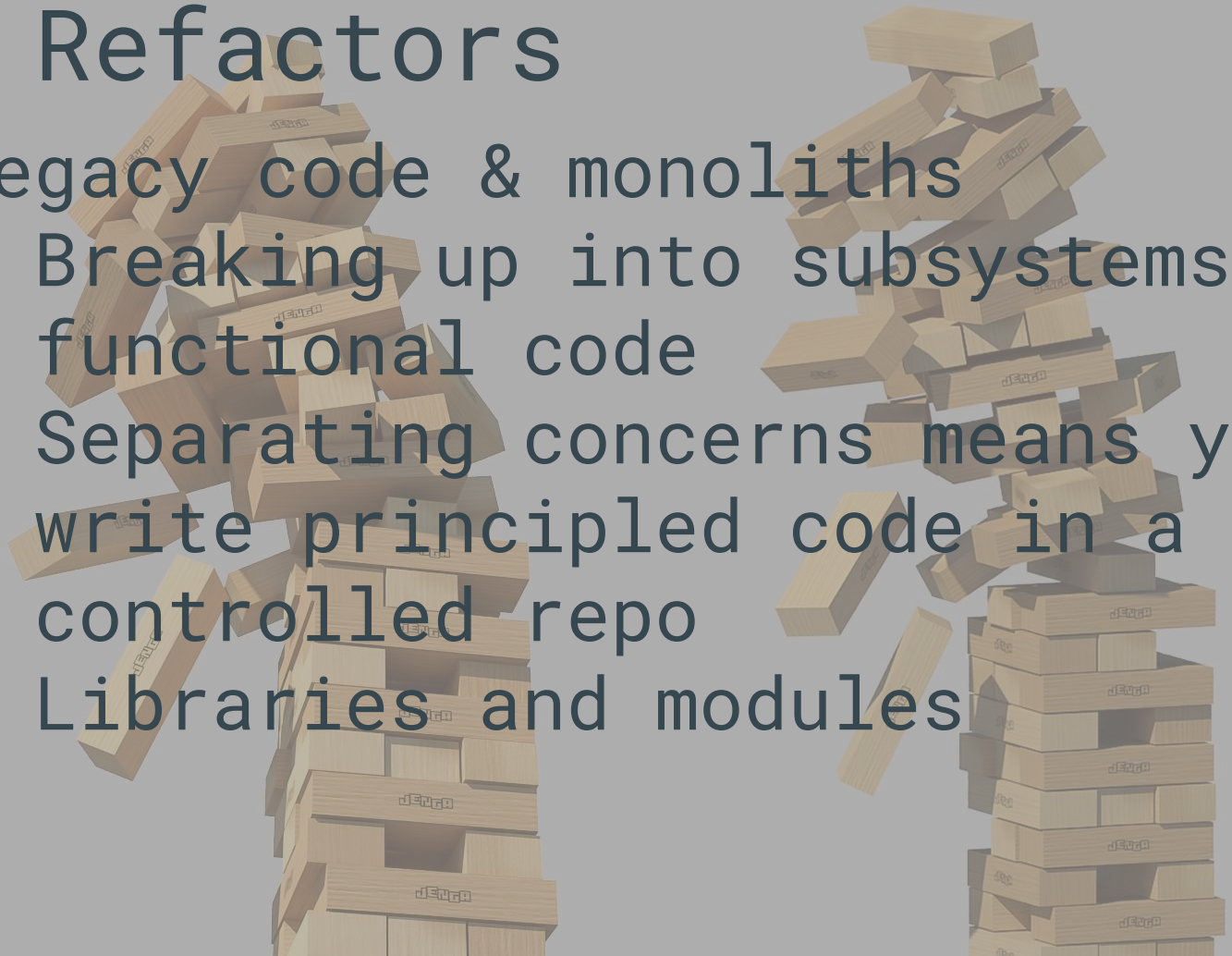
images: open source

4. Organize and Speak

- **Set up an internal meetup or book club**
- **Submit practical talks to conferences!**
- **Write blog posts! Communication works.**

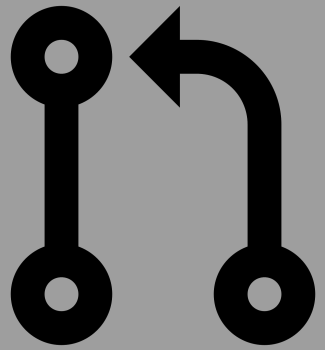
3. Refactors

- Legacy code & monoliths
  - Breaking up into subsystems with functional code
  - Separating concerns means you can write principled code in a controlled repo
  - Libraries and modules



2. Pull Requests

- Highly effective and bite-sized
- Catch impure procedural code before it goes into staging
- Opportunity to teach and mentor other developers w.r.t functional techniques



1. Check ego at the door

- Functional programming already has a bad rap for being inaccessible
  - **Don't make it worse**
- Focus on approachability and application
  - Save the theory for later

If people understand **why**, they will want to know **how**.

Thank you.

Resources...

- Slides and code examples from this talk
  - https://github.com/nasadorian/enterprise-fp/
- Rob Norris, “Functional Programming with Effects”
  - https://www.youtube.com/watch?v=po3wmq4S15A
- Bjarnason & Chiusano, “Functional Programming in Scala”
  - https://www.manning.com/books/functional-programming-in-scala
- Brian Beckman “Don’t Fear the Monad”
  - https://www.youtube.com/watch?v=ZhuHCtR3xq8
- Advanced Scala with Cats
  - https://underscore.io/books/scala-with-cats/
- Try not a Monad
  - https://gist.github.com/ms-tg/6222775