Why I Like Functional Programming

Adelbert Chang
Machine Learning @ Box, Inc.

Let's go back..

http://gauss.cs.ucsb.edu/home/images/UCSB-from-air.jpg

2011

2011

```
void insert(Node* &tree, int value) {
    if (!tree) return;

    Node *trav = tree, *parent;
    while (trav) {
        parent = trav;
        if (value < trav->data) trav = trav->left;
        else if (value > trav->data) trav = trav->right;
        else break;
    }
    if (value < parent->data)
        parent->left = new Node(value);
    else
        parent->right = new Node(value);
}
```

Physics and Math

Physics and Math

- Simplicity and consistency across problems

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  - $v_{avg} = v_0 + \frac{1}{2}a\Delta t$

Physics and Math

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- Example: Deriving laws of motion from first principles
  - $v_f = v_0 + a\,\Delta t$
  - $v_{avg} = v_0 + \frac{1}{2}a\Delta t$
  - $x = x_0 + v_0 t + \frac{1}{2}at^2$

Physics and Math

Deriving $x = x_0 + v_0 t + \frac{1}{2}at^2$

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Physics and Math

Deriving $x = x_0 + v_0t + ½at^2$

$v_{avg} = ½(v_f + v_0)$

$½(v_0 + a\Delta t + v_0)$

$a = \Delta v / \Delta t$

$a = (v_f - v_0) / \Delta t$

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$x_0 + v_0t + \frac{1}{2}at^2$

2012

2012

```
sealed abstract class Tree
case class Branch(data: Int, left: Tree, right: Tree)
  extends Tree
case class Leaf() extends Tree

def insert(tree: Tree, value: Int): Tree =
  tree match {
    case Leaf() => Branch(value, Leaf(), Leaf())
    case b@Branch(d, l, r) =>
      if (value < d) Branch(d, insert(l, value), r)
      else if (value > d) Branch(d, l, insert(r, value))
      else b
  }
```

Hmm.. functional programming seems pretty cool.

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But is it as cool as physics and math?

Functional Programming

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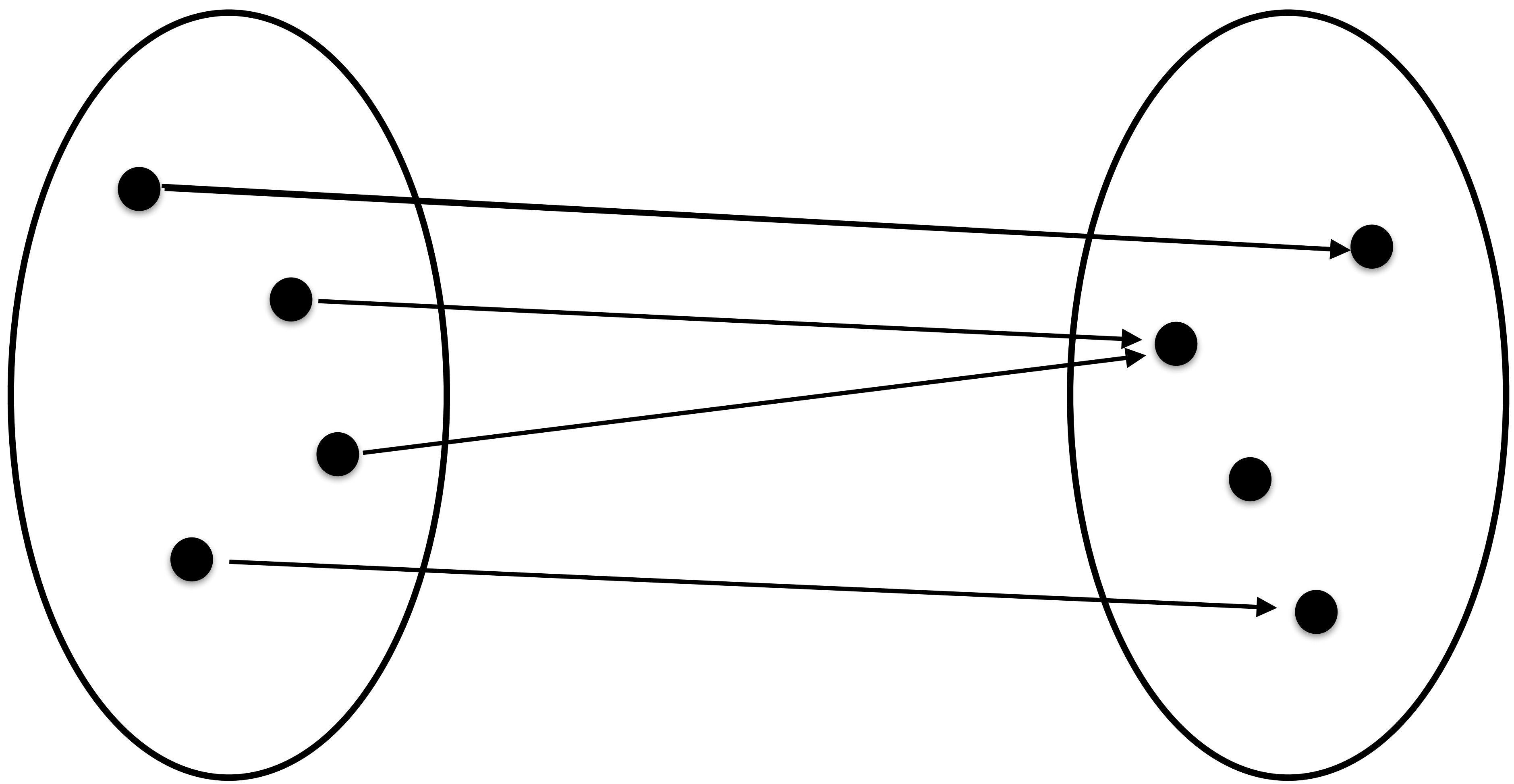
programming with functions

Functional Programming

programming with **pure** functions

Functional Programming

programming with **pure** functions



Functions

Functions

```scala
def parseIntPartial(s: String): Int =
  s.toInt // can throw NumberFormatException
```

Functions

```
def parseIntPartial(s: String): Int =
  s.toInt // can throw NumberFormatException


def parseIntTotal(s: String): Option[Int] =
  try {
    Some(s.toInt)
  } catch {
    case nfe: NumberFormatException => None
  }
```

Functions

Functions

```
class Rng(var seed: Long) {
  def nextInt(): Int = {
    val int = getInt(seed)
    mutate(seed)
    int
  }
}
```

Functions

```
class Rng(var seed: Long) {
  def nextInt(): Int = {
    val int = getInt(seed)
    mutate(seed)
    int
  }
}

case class Rng(seed: Long) {
  def nextInt: (Rng, Int) = {
    val int = getInt(seed)
    val newSeed = f(seed)
    (Rng(newSeed), int)
  }
}
```

Referential Transparency

* Taken from Higher Order blog post "What Purity Is and Isn't" May 29, 2015 http://blog.higher-order.com/blog/2012/09/13/what-purity-is-and-isnt/

Referential Transparency

An expression **e** is referentially transparent if

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Referential Transparency

An expression **e** is referentially transparent if
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every occurrence of **e** in **p**
can be replaced with the result of evaluating **e**

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Referential Transparency

An expression **e** is referentially transparent if
for all programs **p**
every occurrence of **e** in **p**
can be replaced with the result of evaluating **e**
without changing the result of evaluating **p**.*

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Referential Transparency

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$x^4 - 12x^2 + 36 = 0$

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$(-b \pm \sqrt{b^2 - 4ac}) / 2a$

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$a = 1$ $b = -12$ $c = 36$

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$ax^2 + bx + c = 0$

$(-b \pm \sqrt{b^2 - 4ac}) / 2a$

$a = 1 \qquad b = -12 \qquad c = 36$

$(-(-12) \pm \sqrt{(-12)^2 - 4(1)(36)}) / 2(1)$

Referential Transparency

$x^4 - 12x^2 + 36 = 0$

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$12 / 2$

Referential Transparency

$x^4 - 12x^2 + 36 = 0$

$y = x^2$

$y^2 - 12y + 36 = 0$

$y = 6$

$ax^2 + bx + c = 0$

$(-b \pm \sqrt{b^2 - 4ac}) / 2a$

$a = 1$ $b = -12$ $c = 36$

$(-(-12) \pm \sqrt{(-12)^2 - 4(1)(36)}) / 2(1)$

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Referential Transparency

$x^4 - 12x^2 + 36 = 0$

$y = x^2$

$y^2 - 12y + 36 = 0$

$y = 6$

$x^2 = 6$

$ax^2 + bx + c = 0$

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Referential Transparency

$x^4 - 12x^2 + 36 = 0$

$y = x^2$

$y^2 - 12y + 36 = 0$

$y = 6$

$x^2 = 6$

$x = \pm \sqrt{6}$

$ax^2 + bx + c = 0$

$(-b \pm \sqrt{b^2 - 4ac}) / 2a$

$a = 1 \qquad b = -12 \qquad c = 36$

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Referential Transparency

Referential Transparency

```
def userInfo(id: UserId): Future[UserData]

val userId = . . .

val fetchData = userInfo(userId)

fetchData.retry {
  case StatusCode(429) => fetchData
}
```

Referential Transparency

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def userInfo(id: UserId): Future[UserData]

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def userInfo(id: UserId): Future[UserData]

val userId = . . .

val fetchData = userInfo(userId)

fetchData.retry {
  case StatusCode(429) => userInfo(userId)
}
```

???

Referential Transparency

```
def userInfo(id: UserId): Task[UserData]

val userId = . . .

val fetchData = userInfo(userId)

fetchData.retry {
  case StatusCode(429) => fetchData
}
```

Referential Transparency

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def userInfo(id: UserId): Task[UserData]

val userId = . . .

val fetchData = userInfo(userId)

fetchData.retry {
  case StatusCode(429) => fetchData
}
```
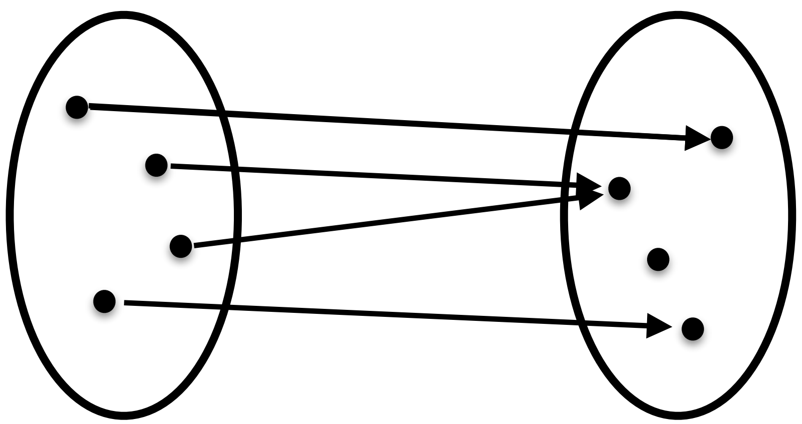

```
trait Task[A] {
  def unsafeRun(): A
}
```

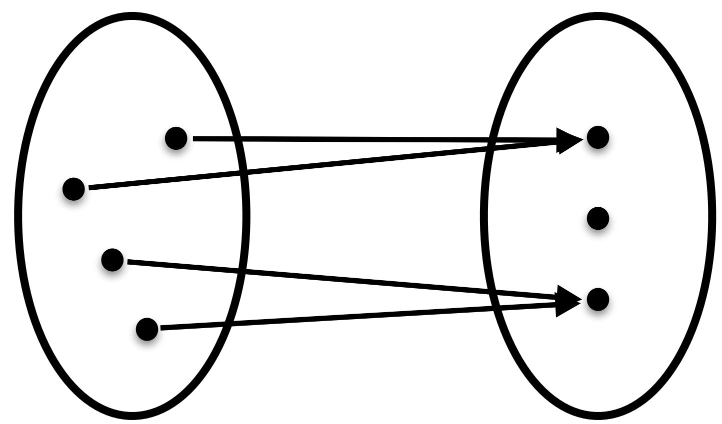
Functions

Functions

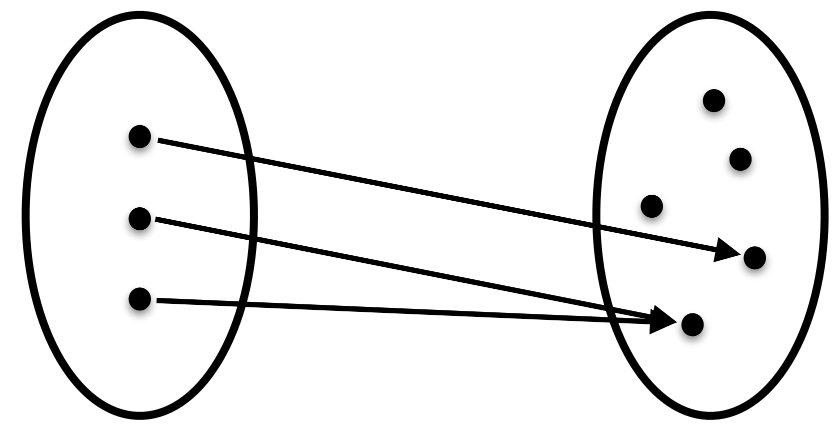
foo: A => B



bar: B => C



baz: C => D



Functions

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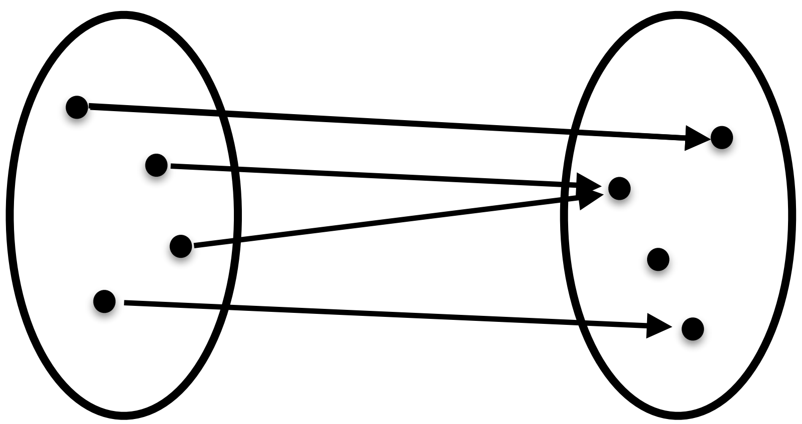

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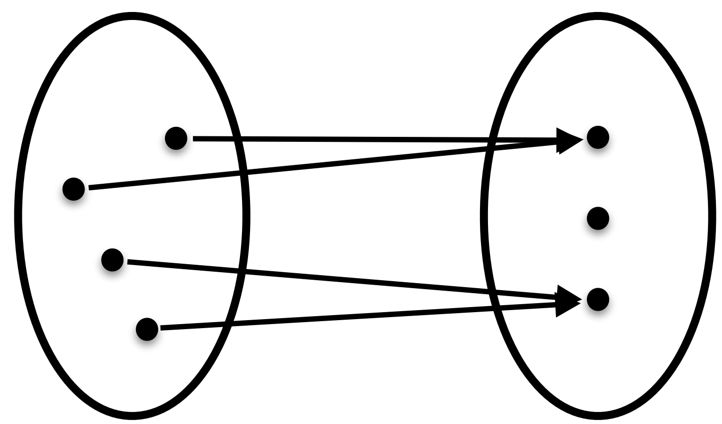

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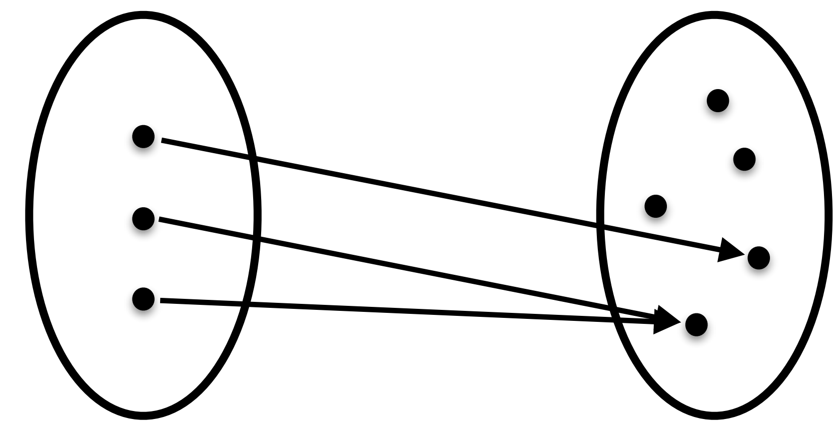
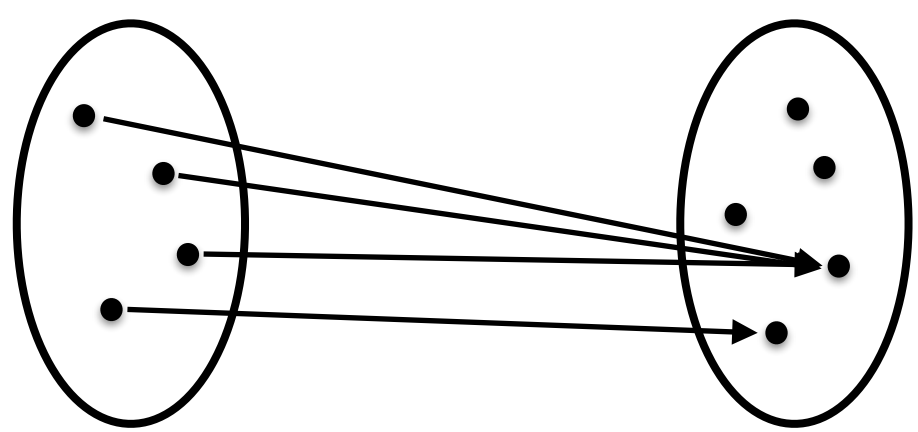


baz.compose(bar).compose(foo): A => D



Tracking Effects

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  - Optional values, error handling, asynchronous computation, input/output
  - Usual means aren’t quite nice

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Solution:

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  - Optional values, error handling, asynchronous computation, input/output
  - Usual means aren't quite nice

Solution:

Reify effects as values.

Missing values

Missing values

```scala
// A value that might exist is either..
sealed abstract class Option[A]

// ..there
final case class Some[A](a: A) extends Option[A]

// .. or not there
final case class None[A]() extends Option[A]
```

Missing values

```
def lookup(map: Map[Foo, Bar], foo: Foo): Option[Bar] =
  if (map.contains(foo)) Some(map(foo))
  else None
```

Errors

```scala
sealed abstract class Either[+E, +A]

final case class Success[+A](a: A) extends Either[Nothing, A]

final case class Failure[+E](e: E) extends Either[E, Nothing]
```

Errors

```
sealed abstract class Error
final case object UserDoesNotExist extends Error
final case object InvalidToken     extends Error

def userInfo(uid: UserId,
             tk: Token): Either[Error, UserInfo] = . . .
```

Manipulating Effects

Manipulating Effects

- The type signature of our functions reflect the effects involved

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```scala
def tokenFor(uid: UserId): Option[EncryptedToken]

def decrypt(token: EncryptedToken): Token

/** Client side */
val encrypted: Option[EncryptedToken] =
  tokenFor(. . .)

// Want EncryptedToken, have Option[EncryptedToken]
val decrypted = decrypt(???)
```

Manipulating Effects

```scala
/** Apply a pure function to an effectful value */
trait Functor[F[_]] {
  def map[A, B](fa: F[A])(f: A => B): F[B]
}
```

Manipulating Effects

```scala
/** Apply a pure function to an effectful value */
trait Functor[F[_]] {
  def map[A, B](fa: F[A])(f: A => B): F[B]
}

new Functor[Option] {
  def map[A, B](fa: Option[A])(f: A => B): Option[B] =
    fa match {
      case Some(a) => Some(f(a))
      case None()  => None()
    }
}
```

Manipulating Effects

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def tokenFor(uid: UserId): Option[EncryptedToken]

def decrypt(token: EncryptedToken): Token

/** Client side */
val encrypted: Option[EncryptedToken] =
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Manipulating Effects

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val encrypted: Option[EncryptedToken] =
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```

- Similar mechanisms for manipulating multiple effects

Lens

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  - Getter: get an **A** field in an object **S**
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- If getters/setters are per-object, cannot compose
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  - Getter: get an **A** field in an object **S**
  - Setter: change an **A** field in an object **S**

```
trait Lens[S, A] {
  def get(s: S): A

  def set(s: S, a: A): S
}
```

Lens

```scala
trait Lens[S, A] { outer =>
  def get(s: S): A

  def set(s: S, a: A): S

  def modify(s: S, f: A => A): S =
    set(s, f(get(s)))

  def compose[B](other: Lens[A, B]): Lens[S, B] =
    new Lens[S, B] {
      def get(s: S): B = other.get(get(s))

      def set(s: S, b: B): S =
        set(s, other.set(outer.get(s), b))
    }
}
```

Lens

```scala
case class Employee(position: Position)

object Employee {
  val position: Lens[Employee, Position] = . . .
}

case class Team(manager: Employee, . . .)

object Team {
  val manager: Lens[Team, Employee] = . . .
}
```

Lens

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case class Employee(position: Position)

object Employee {
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}

case class Team(manager: Employee, . . .)

object Team {
  val manager: Lens[Team, Employee] = . . .
}

/** Client side */
val l: Lens[Team, Position] =
  Team.manager.compose(Employee.position)
l.set(someTeam, somePosition)
```

Lens

Lens

- Effect-ful modifications can be useful
  - Possibly failing: A => Option[A]
  - Many possible values: A => List[A]
  - Async: A => Task[A]

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  - Possibly failing: A => Option[A]
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  - Async: A => Task[A]

```
trait Lens[S, A] {
  def modifyOption(s: S, f: A => Option[A]): Option[S]

  def modifyList(s: S, f: A => List[A]): List[S]

  def modifyTask(s: S, f: A => Task[A]): Task[S]
}
```

Lens

```
trait Lens[S, A] {
  def modifyOption(s: S, f: A => Option[A]): Option[S] =
    f(get(s)).map(a => set(s, a))

  def modifyList(s: S, f: A => List[A]): List[S] =
    f(get(s)).map(a => set(s, a))

  def modifyTask(s: S, f: A => Task[A]): Task[S] =
    f(get(s)).map(a => set(s, a))
}
```

Lens

```
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S] =
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- Example functors:

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  - Option, Either, Future, List, IO
- What if we want to just modify without any effect?
  - We want the F[A] to just be a plain A
    - Type-level identity function

```scala
def identity[A](a: A): A = a
```

Id

```
type Id[A] = A
```

Id

```scala
type Id[A] = A

new Functor[Id] {
  def map[A, B](fa: Id[A])(f: A => B): Id[B] =
}
```

Id

```
type Id[A] = A

new Functor[Id] {
  def map[A, B](fa: Id[A])(f: A => B): Id[B] =
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Id

```
type Id[A] = A

new Functor[Id] {
  def map[A, B](fa: A)(f: A => B): B =
}
```

Id

```scala
type Id[A] = A

new Functor[Id] {
  def map[A, B](fa: A)(f: A => B): B = f(fa)
}
```

Id

```scala
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S] =
    f(get(s)).map(a => set(s, a))

  def modify(s: S, f: A => A): S = modifyF[Id](s, f)
}
```

Setting

```scala
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S] =
    f(get(s)).map(a => set(s, a))

  def modify(s: S, f: A => A): S = modifyF[Id](s, f)

  def set(s: S, a: A): S = modify(s, const(a))
}
```

Setting

```scala
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S] =
    f(get(s)).map(a => set(s, a))

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```

```scala
def const[A, B](a: A)(b: B): A = a
```

Setting

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trait Lens[S, A] {
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  def modify(s: S, f: A => A): S = modifyF[Id](s, f)

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}
```

```
def const[A, B](a: A)(b: B): A = a
```

Setting

```scala
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S]

  def get(s: S): A

  def modify(s: S, f: A => A): S = modifyF[Id](s, f)

  def set(s: S, a: A): S = modify(s, const(a))
}
```

```scala
def const[A, B](a: A)(b: B): A = a
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Getting

```
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S]

  def get(s: S): A
}
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Getting

```scala
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S]

  def get(s: S): A
}
```

- Can we define `get` in terms of `modify`?

Getting

```
trait Lens[S, A] {
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S]

  def get(s: S): A
}
```

- Can we define `get` in terms of `modify`?
    - `modifyF` gives us some F[S].. but we want an A

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    - Type-level constant function

Getting

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}
```

- Can we define `get` in terms of `modify`?
  - `modifyF` gives us some F[S].. but we want an A
  - We need some way of "ignoring" the S parameter and still get an A back
    - Type-level constant function

```scala
def const[A, B](a: A)(b: B): A = a
```

Getting

* Const[Z, ?] syntax is valid due to kind-projector plugin https://github.com/non/kind-projector

Getting

```
type Const[Z, A] = Z
```

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Getting

```scala
type Const[Z, A] = Z

new Functor[Const[Z, ?]] { // *
  def map[A, B](fa: Const[Z, A])(f: A => B): Const[Z, B]
}
```

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Getting

```
type Const[Z, A] = Z

new Functor[Const[Z, ?]] { // *
  def map[A, B](fa: Const[Z, A])(f: A => B): Const[Z, B]
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Getting

```scala
type Const[Z, A] = Z

new Functor[Const[Z, ?]] { // *
  def map[A, B](fa: Z)(f: A => B): Z =
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Getting

```
type Const[Z, A] = Z

new Functor[Const[Z, ?]] { // *
  def map[A, B](fa: Z)(f: A => B): Z = fa
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Getting

```scala
type Const[Z, A] = Z

new Functor[Const[Z, ?]] { // *
  def map[A, B](fa: Z)(f: A => B): Z = fa
}

trait Lens[S, Z] {
  def modifyF[F[_] : Functor](s: S, f: Z => F[Z]): F[S]

  def get(s: S): Z = {
    val const: Const[Z, S] =
      modifyF[Const[Z, ?]](s, z => z) // *
    const
  }
}
```

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Lens

```scala
trait Lens[S, A] {
  /** Abstract */
  def modifyF[F[_] : Functor](s: S, f: A => F[A]): F[S]

  /** Implemented */
  def modify(s: S, f: A => A): S

  def get(s: S): A

  def set(s: S, a: A): S

  def compose[B](other: Lens[A, B]): Lens[S, B]
}
```

Are Id and Const just party tricks?

Traverse

```
trait Traverse[F[_]] {
  def traverse[G[_] : Applicative, A, B]
              (fa: F[A])(f: A => G[B]): G[F[B]]
}
```

Traverse

```
trait Traverse[F[_]] {
  def traverse[G[_] : Applicative, A, B]
              (fa: F[A])(f: A => G[B]): G[F[B]]
}


def validate[A]
    (data: List[A])(f: A => Option[B]): Option[List[B]]
```

Traverse

```scala
trait Traverse[F[_]] {
  def traverse[G[_] : Applicative, A, B]
              (fa: F[A])(f: A => G[B]): G[F[B]]
}

def validate[A]
    (data: List[A])(f: A => Option[B]): Option[List[B]]

def scatterGather[A]
    (data: List[A])(f: A => Task[B]): Task[List[B]]
```

Traverse

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Traverse

```
traverse: F[A] => (A => G[B]) => G[F[B]]
```

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Traverse

```
traverse: F[A] => (A => G[B]) => G[F[B]]
```

```
traverse[Id, A, B]
```

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Traverse

```
traverse: F[A] => (A => G[B]) => G[F[B]]
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    F[A] => (A => Id[B]) => Id[F[B]]
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traverse[Const[Z, ?], A, B] // *, If Z can be "reduced"
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    F[A] => (A => Const[Z, B]) => Const[Z, F[B]]
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    F[A] => (A => Const[Z, B]) => Const[Z, F[B]]
    F[A] => (A => Z)           => Z
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Interested?

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- Functional Programming
    - Cats, Scalaz
    - Argonaut, Atto, Monocle, Shapeless

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- Systems
  - Doobie, HTTP4S, Remotely, Scalaz-stream

EOF