Abstract Data Types in Object Capability Systems

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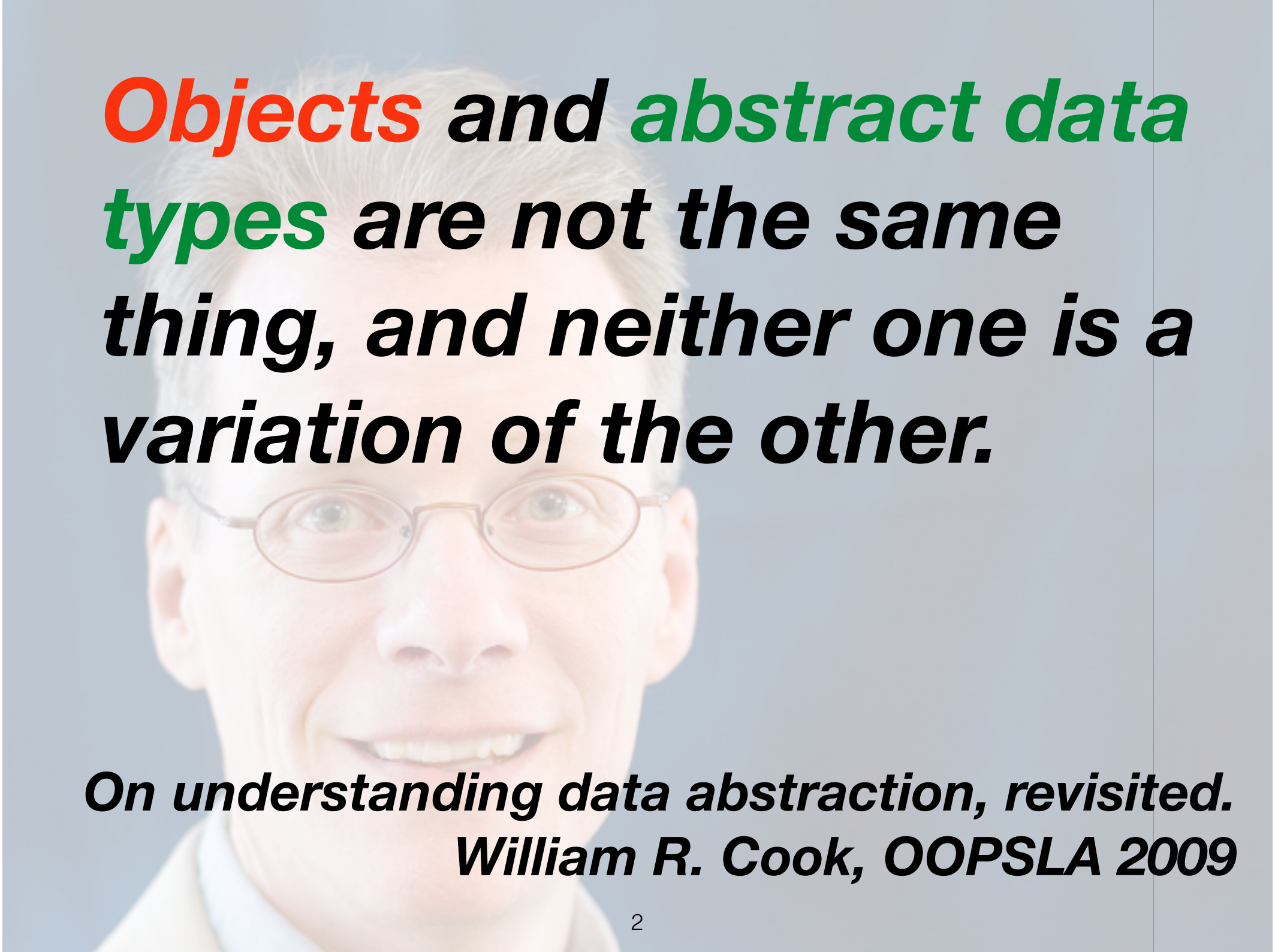
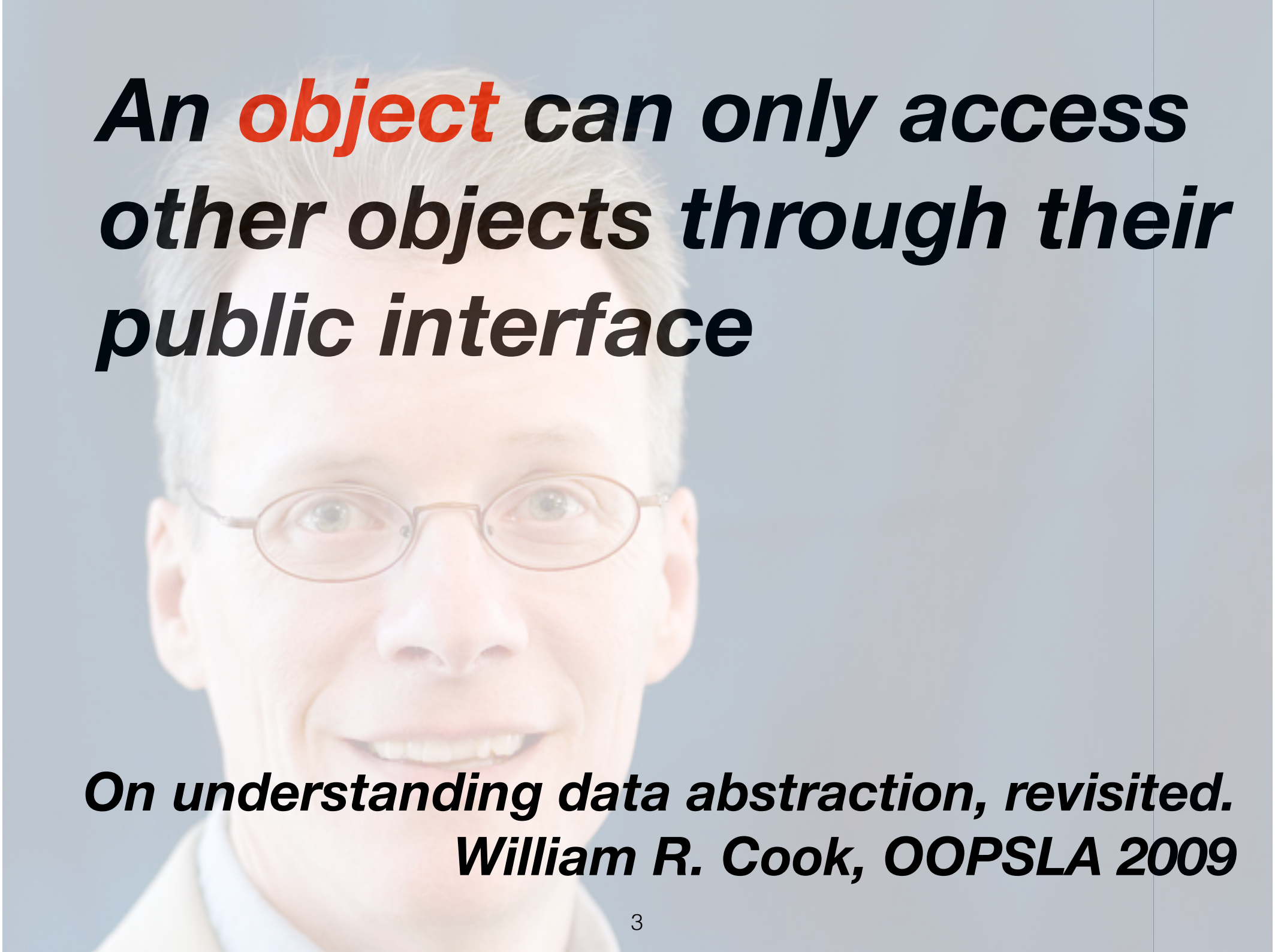


Objects and abstract data types are not the same thing, and neither one is a variation of the other.

On understanding data abstraction, revisited.
William R. Cook, OOPSLA 2009



An object can only access other objects through their public interface

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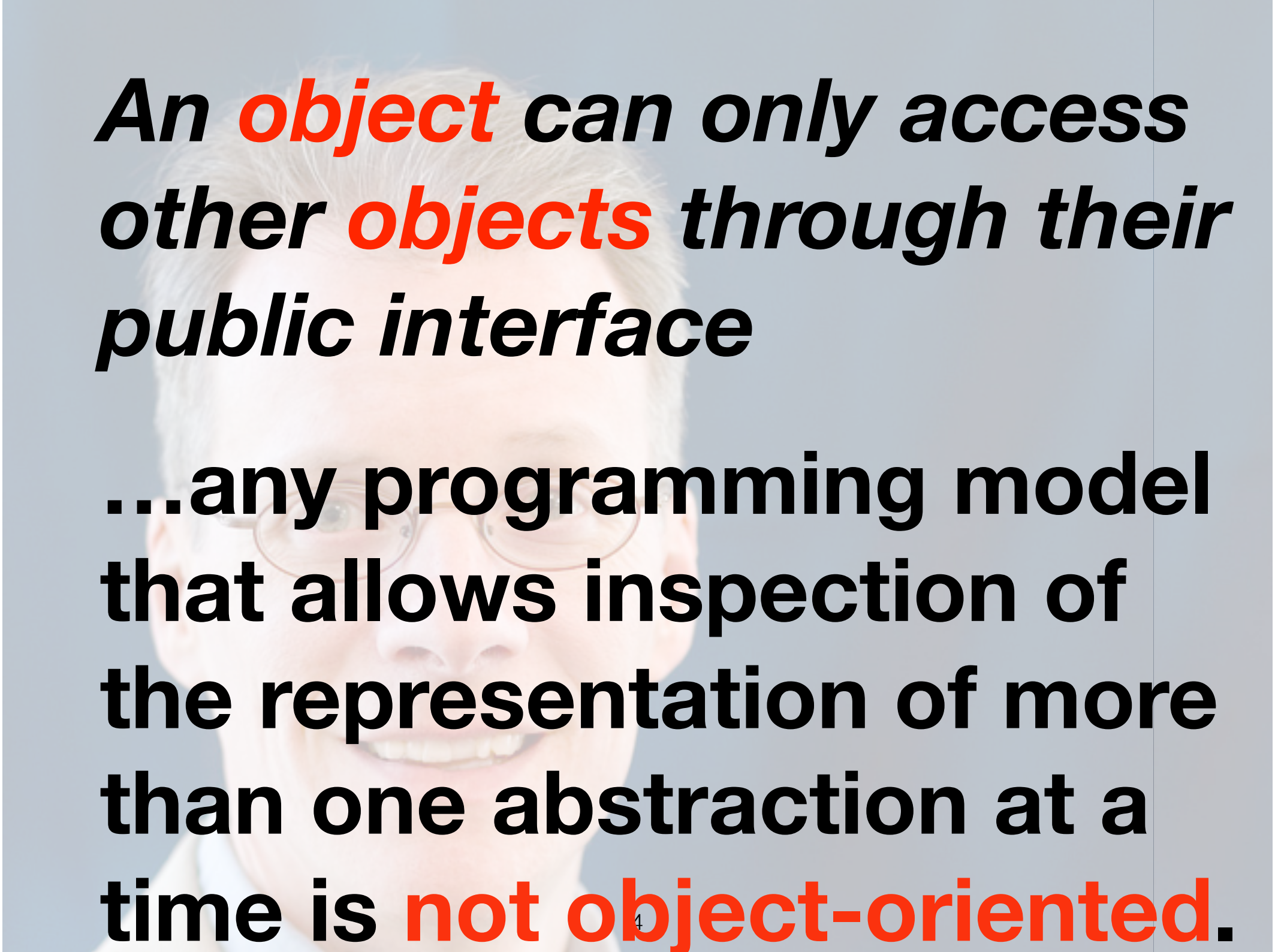


An object can only access other objects through their public interface

…any programming model that allows inspection of the representation of more than one abstraction at a time is not object-oriented.

Object Capabilities

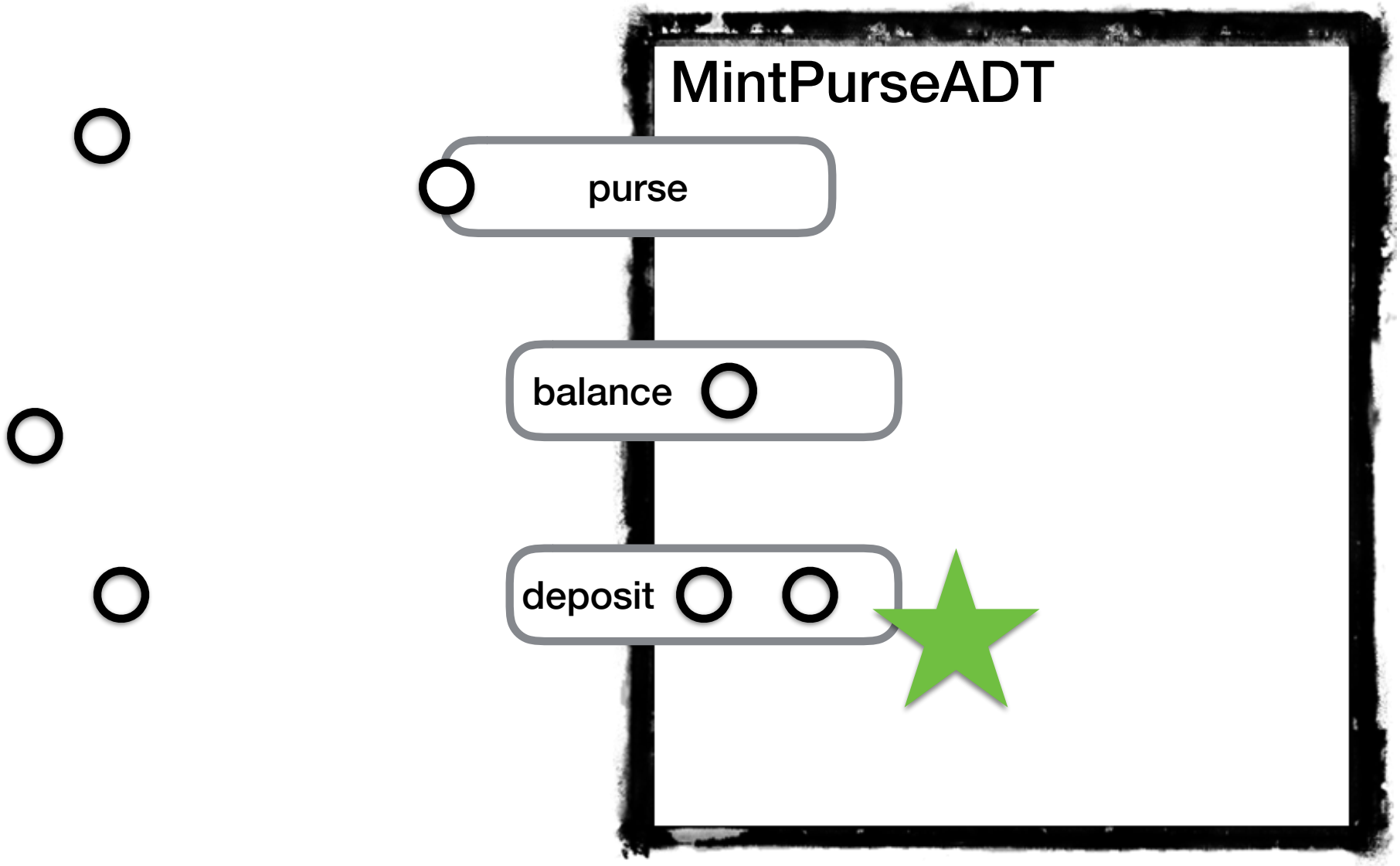
- **Only connectivity begets connectivity**
  - *"No ambient authority"*
- **Access implies permission**
  - *"No access control lists"*
- Dynamic Loading

Capability Based Financial Instruments ***Miller, Morningstar, Frantz.*** **Fin. Cryp. 2000**

Grodula-3

```
type MintPurseADT = interface {
  type T <: Object
  purse(amount : Number) -> T
  balance(of : T) -> Number
  deposit(to : T,
          amount : Number,
          from : T) -> Boolean
  sprout -> T
}
```

Grodula-3



Abstract Data Type

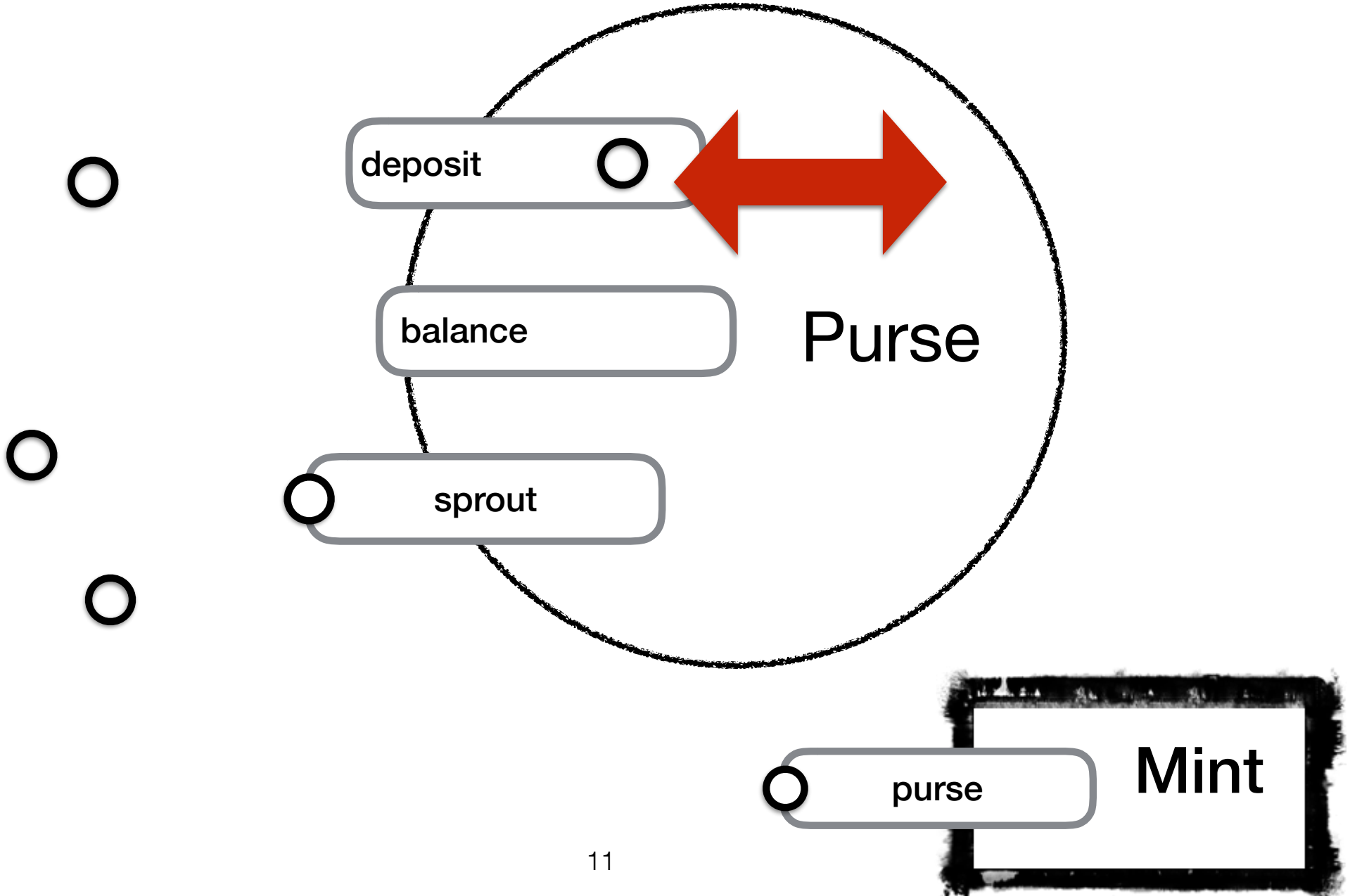
```
module MintPuse {
  reveal T = Purse

  type Purse is private = interface {
    balance -> Number
    balance:= ( n : Number )
  }

  method purse(amount : Number) -> T {
    return object { var balance is public := amount }

  method balance(of : Purse) -> Number { of.balance }
```

```
  method deposit(to : Purse,
                 amount : Number,
                 from : Purse) -> Boolean {
    if ((amount >= 0) && (from.balance >= amount))
      then {
        from.balance := from.balance - amount
        to.balance := to.balance + amount
        return true
      } else {return false}
  }



  method sprout { purse(0) }
}
```

“Classical” “OO” ADT

```
type Mint = interface {
  purse(amount : Number) -> Purse
}

type Purse = interface {
   balance -> Number
   deposit(amount : Number, src : Purse) -> Boolean
   sprout -> Purse
}
```

“Classical” “OO” ADT

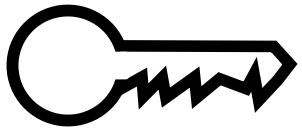


“Classical” “OO” ADT

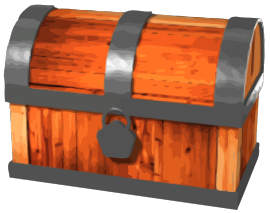
```
class purse(amount : Number) -> Purse {
  var balance is readable, private := amount

   method deposit(amt : Number, src : Purse) -> Boolean
     { if ((amount >= 0) && (src.balance >= amount))
        then {
            src.balance := src.balance - amount
            balance := balance + amount
            return true
         } else {return false}
     }
```

OCaps—Brand Pairs

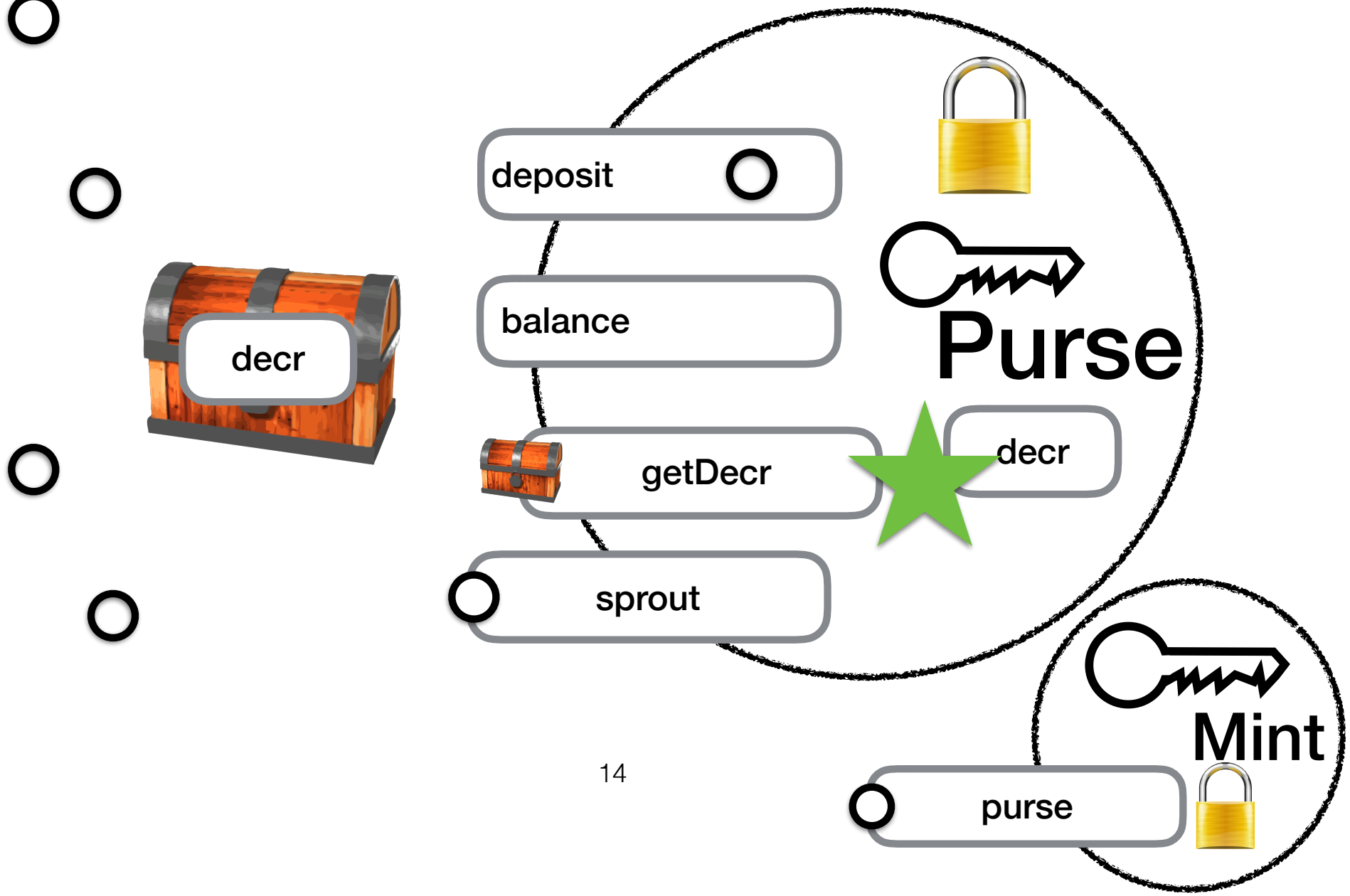
```
type Sealing = interface {
  makeBrandPair -> interface {
    sealer -> Sealer
    unsealer -> Unsealer
  }
}
```



```
type Sealer = interface { seal(o : Object) -> Box }

type Unsealer = interface { unseal(b : Box) -> Object }

type Box = interface { }
```



Brand Pairs

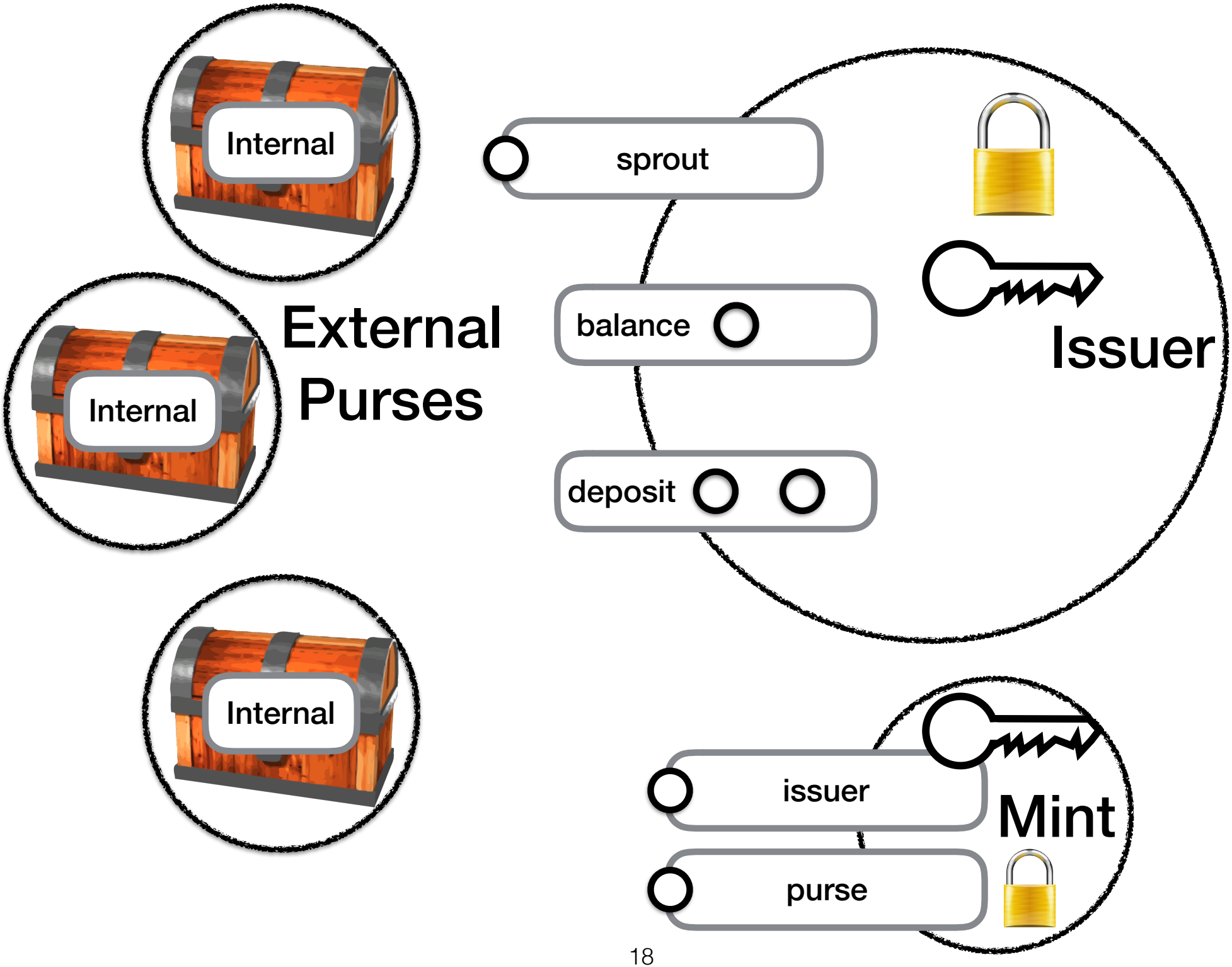


```
class mint -> Mint is public {

  def brandPair = sealing.makeBrandPair

  class purse(amount : Number) -> Purse {

    var balance := amount

    method decr(amt : Number) -> Boolean is confidential {
      if ((amt < 0) || (amt > balance)) then {
          return false }
      balance := balance - amt
      return true }

    method getDecr
      {brandPair.sealer.seal { amt -> decr(amt) } }
```

```
method deposit(amt : Number, src : Purse) -> Boolean {
  if (amt < 0) then { return false }
  var srcDecr
  try { srcDecr := brandPair.unsealer.unseal(src.getDecr) }
    catch { _ -> return false }
  if (srcDecr.apply( amt )) then {
     balance := balance + amt
     return true }
  return false }
```

Generalising the Design

```
type ExternalPurse = interface { }

type InternalPurse = interface {
   balance -> Number
   balance:= ( n : Number )
}

type Issuer = interface {
  balance(of : ExternalPurse) -> Number
  deposit(to : ExternalPurse,
          amount : Number,
          from : ExternalPurse ) -> Boolean
  sprout -> ExternalPurse
}
```


Internal
Internal
Internal
External
Purses
sprout
balance
deposit
Issuer
issuer
purse
Mint

Generalising the Design

```
class mint -> Mint {

  def myBrandPair = sealing.makeBrandPair

  method seal(protectedRep : InternalPurse) -> ExternalPurse
    is confidential { myBrandPair.sealer.seal(protectedRep) }

  method unseal(sealedBox : ExternalPurse) -> InternalPurse
    is confidential { myBrandPair.unsealer.unseal(sealedBox) }

  method purse(amount : Number) -> ExternalPurse {
      seal( object { var balance is public := amount } ) }
```

```
def issuer is public = object {
  method balance(of : ExternalPurse) -> Number {
    return unseal(of).balance}
  method deposit(to : ExternalPurse,
                 amount : Number,
                 from : ExternalPurse) -> Boolean {
    var internalTo
    var internalFrom
    try {
        internalTo := unseal(to)       // throws if fails
        internalFrom := unseal(from)   // throws if fails
    } catch { _ -> return false }
    if ((amount >= 0) && (internalFrom.balance >= amount))
      then {
        internalFrom.balance := internalFrom.balance - amount
        internalTo.balance := internalTo.balance + amount
        return true
      } else {return false}
  }
```

Splitting Mint from Issuer

```
type Mint = interface {
  purse(amount : Number) -> ExternalPurse
  issuer -> Issuer
}
```

External Purse is a pain

```
type ExternalPurse = interface { }
```

Let's be **evil**

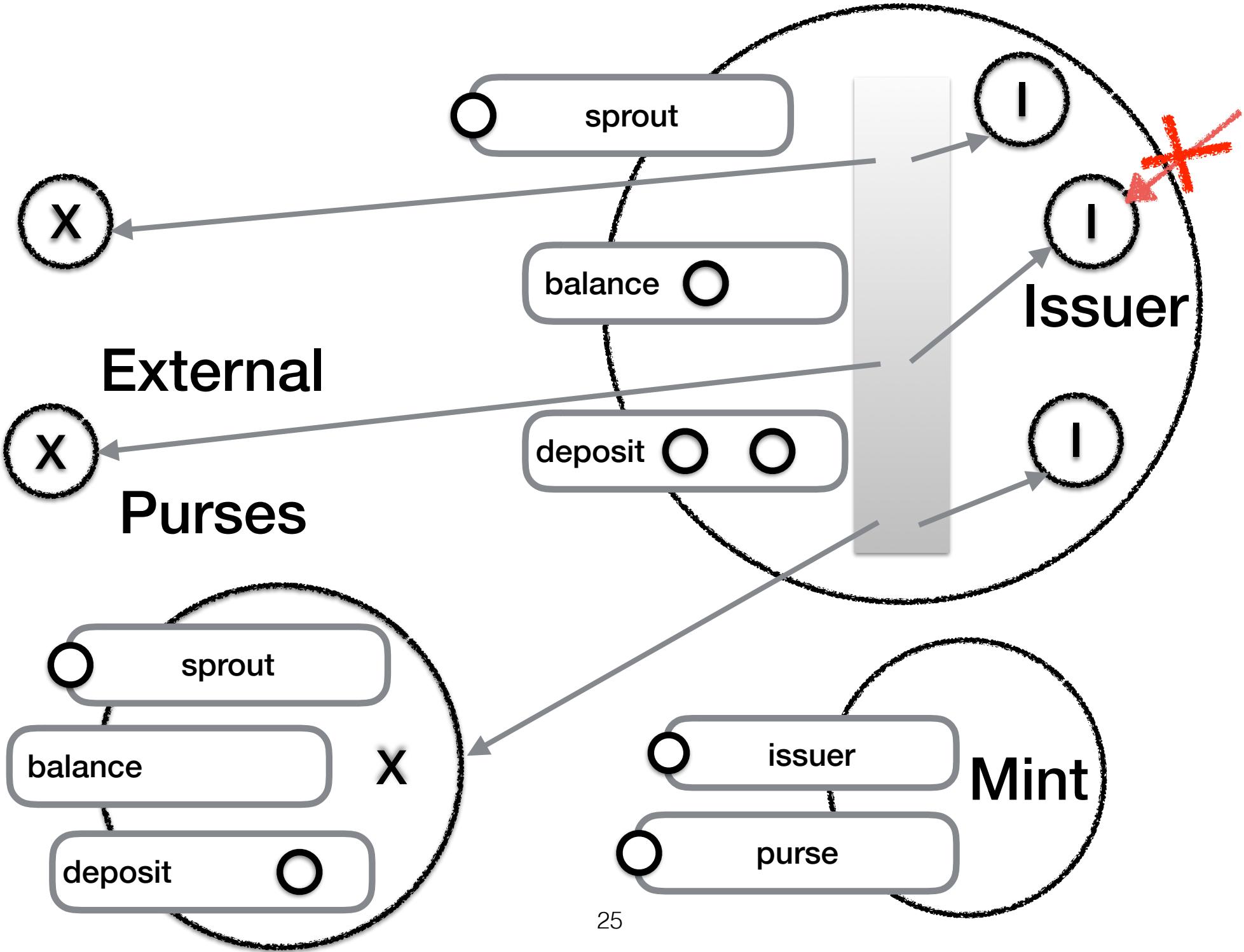
```
type ExternalPurse = interface {
  balance -> Number
  deposit(amount : Number, src : ExternalPurse) -> Boolean
  sprout -> ExternalPurse
}
method seal(protectedRep : InternalPurse) -> ExternalPurse
      is confidential {
     object {
      inherit myBrandPair.sealer.seal(protectedRep)
       method balance { issuer.balance(self) }
       method sprout { issuer.sprout }
       method deposit(amt,src) { issuer.deposit(self,amt,src) }
     }
}
```

```
type ExternalPurse = interface {
  balance -> Number
  deposit(amount : Number, src : ExternalPurse) -> Boolean
  sprout -> ExternalPurse
}
type Mint = interface {
  purse(amount : Number) -> ExternalPurse
  deposit(to : ExternalPurse,
          amount : Number,
          from : ExternalPurse) -> Boolean
  balance(of : ExternalPurse) -> Number
  sprout -> ExternalPurse
}
type InternalPurse = interface {
  balance -> Number
  balance:= (Number) -> Done
  deposit(amount : Number, src : ExternalPurse) -> Boolean
}
```

Hash Table

```
class mint -> Mint {

  def instances = collections.map[[ExternalPurse,InternalPurse]]

  method valid(prs : ExternalPurse) -> Boolean
    { instances.contains(prs) }

  method internal(prs : ExternalPurse) -> InternalPurse
    { instances.get(prs) }

  method purse(amount : Number) -> ExternalPurse {
    def ext = externalPurse(self)
    def int = internalPurse(amount)
    instances.put(ext, int)
    return ext
  }
```

Hash Table


sprout
balance
deposit
I
I
I
Issuer
X
X
External
Purses
sprout
balance
deposit
X
issuer
purse
Mint

Hash Table

```
  method deposit(to : ExternalPurse,
                 amount : Number,
                 from : ExternalPurse) -> Boolean {
    if ((valid(to)) && (valid(from))) then {
        return internal(to).deposit(amount, internal(from))}
    return false
  }
  method balance(prs : ExternalPurse) -> Number
    { internal(prs).balance }

  method sprout -> ExternalPurse {purse(0)}
}
```

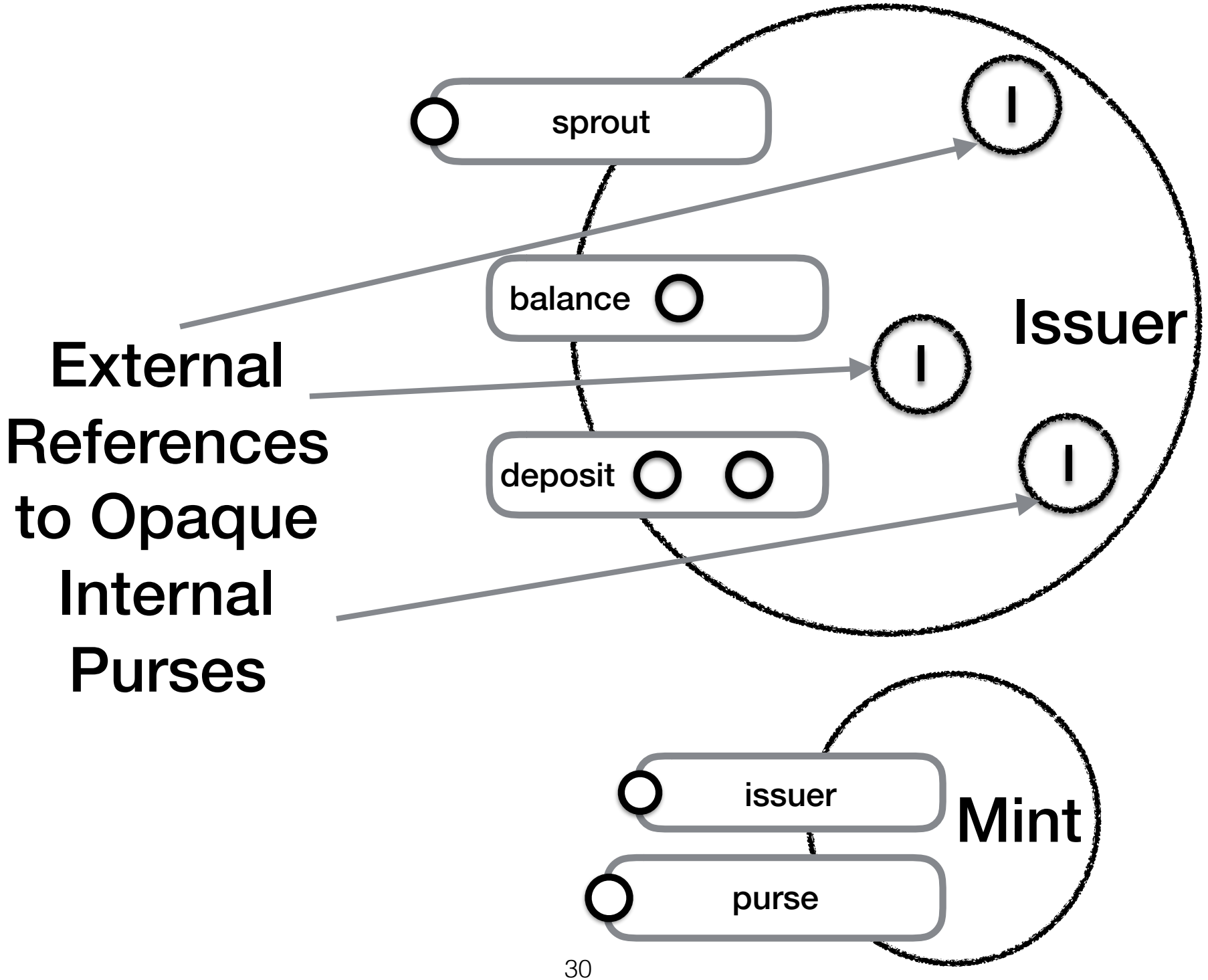
```
class internalPurse(amount : Number) −> InternalPurse {
  var balance is public := amount
  method deposit(amount : Number, src : InternalPurse)
          −> Boolean
    { if ((amount >= 0) && (src.balance >= amount)) then {
        src.balance := src.balance − amount
        balance := balance + amount
        return true }
      return false
    }
}
```

```
class externalPurse(mint' : Mint) −> ExternalPurse {
  def mint = mint'
  method balance {mint.balance(self)}
  method sprout −> ExternalPurse { mint.sprout }
  method deposit(amount : Number, src : ExternalPurse)
          −> Boolean { return mint.deposit(self, amt, src)
  }
}
```

"*you are in a maze of twisty little* ***objects****, all alike*"

```
type Mint = interface {
  purse(amount : Number) −> Purse
  issuer −> Issuer
}

type Issuer = interface {
  balance(of : Purse) −> Number
  deposit(to : Purse,
          amount : Number,
          from : Purse) −> Boolean
  sprout −> Purse
}

type Purse = interface {
   balance −> Number
   balance:= ( n : Number )
}
```

Owners as Readers


External References to Opaque Internal Purses
sprout
balance
deposit
Issuer
issuer
purse
Mint

```
class mint −> Mint {
  class purse(amount : Number) −> Purse is owned {
    var balance is public := amount
  }
  def issuer is public = object {
    method deposit(to : Purse is owned, amount : Number,
           from : Purse is owned) −> Boolean {
      if ((amount >= 0) && (from.balance >= amount))
        then {
          from.balance := from.balance − amount
          to.balance := to.balance + amount
          return true
        } else {return false}
    }
    method balance(of : Purse is owned) −> Number {
      return of.balance}
    method sprout −> Purse { purse(0) }
  }
}
```

```
type Mint = interface {
  purse(amount : Number) −> Purse
  issuer −> Issuer
}

type Issuer = interface {
  balance(of : Purse) −> Number
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          from : Purse) −> Boolean
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}

type Purse = interface {
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   balance:= ( n : Number )
}
```

Owners as Readers ?

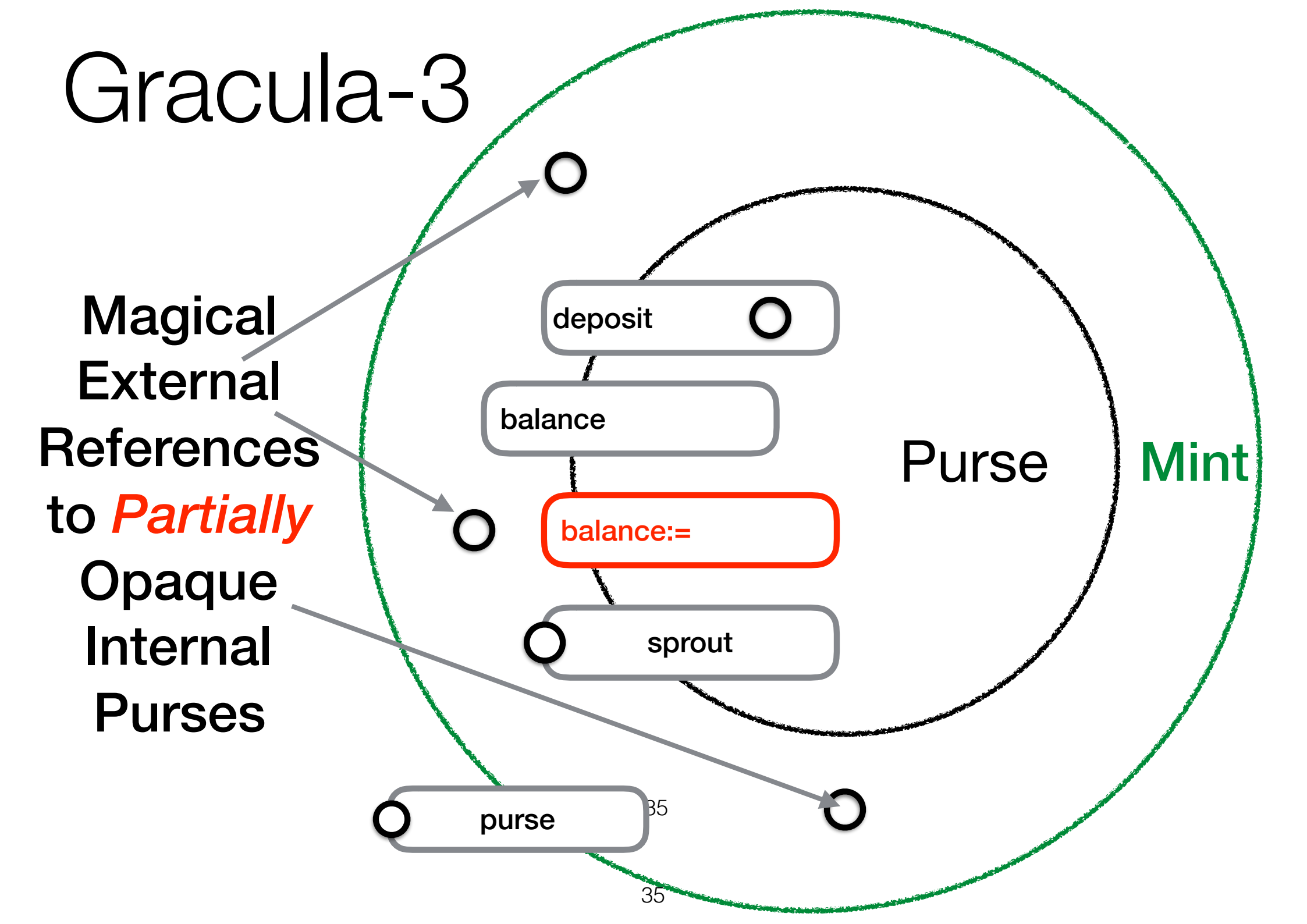
ADTs, Objects, Owners

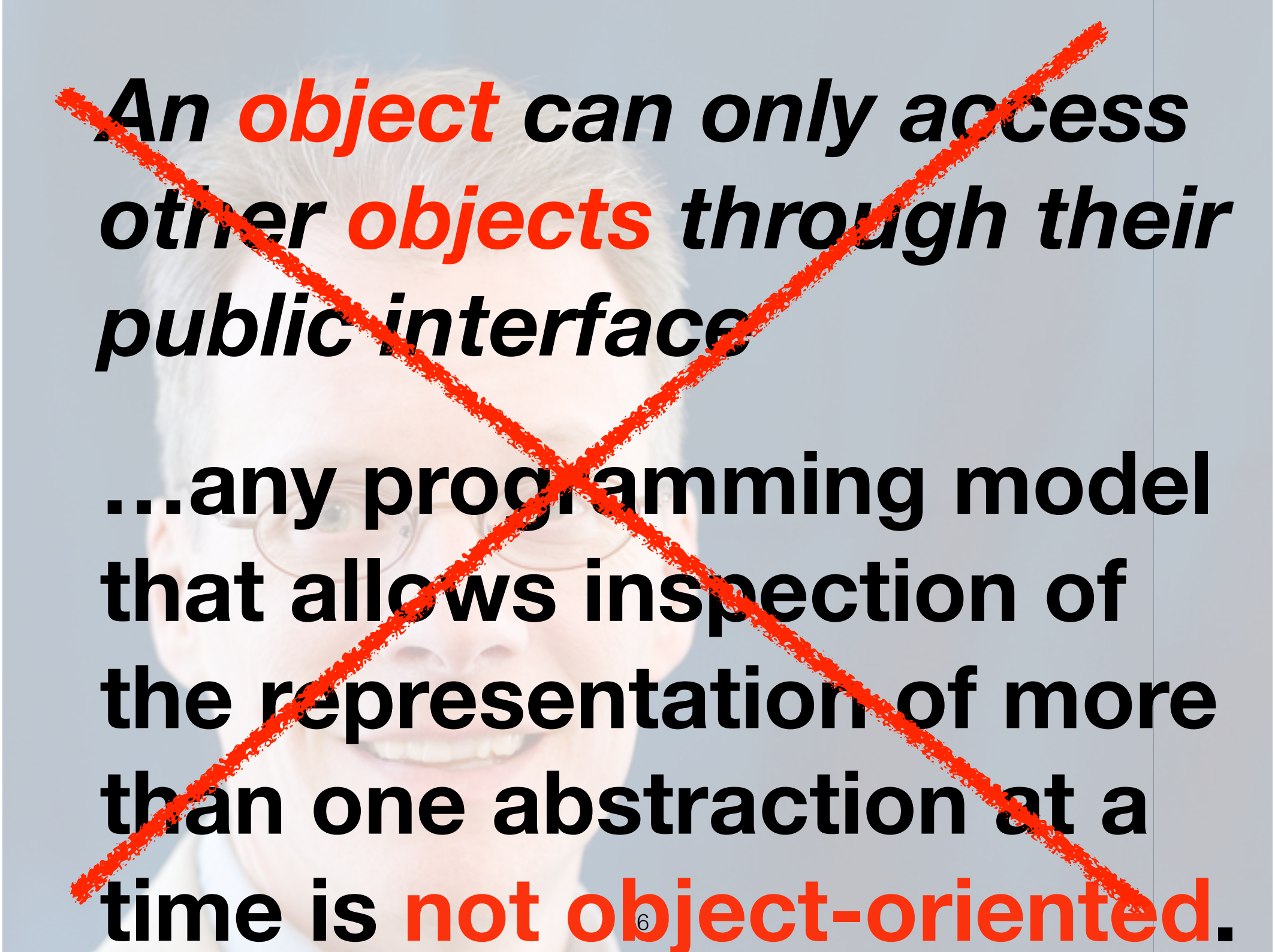
```
type Mint = interface {
  purse(amount : Number) -> Purse
}

type Purse = interface {
   balance -> Number
   deposit(amount : Number, src : Purse) -> Boolean
   sprout -> Purse
}
```

```
class mintADT -> Mint is public {

  class purse(amount : Number) -> Purse is owned {
    var balance is readable, owner := amount

    method deposit(amt : Number,
                   src : Purse is owned) -> Boolean
      { if ((amount >= 0) && (src.balance >= amount))
          then {
              src.balance := src.balance - amount
              balance := balance + amount
              return true
          } else {return false}
      }

    method sprout -> Purse is owned { purse(0) }
  }
}
```

Gracula-3

Gracula-3


Magical
External
References
to *Partially*
Opaque
Internal
Purses
deposit
balance
balance:=
sprout
purse
Purse
Mint



An object can only access other objects through their public interface

…any programming model that allows inspection of the representation of more than one abstraction at a time is not object-oriented.

Object Capabilities

- **Only connectivity begets connectivity**
  - *"No ambient authority"*
- **Access implies permission**
  - *"No access control lists*
- Dynamic Loading

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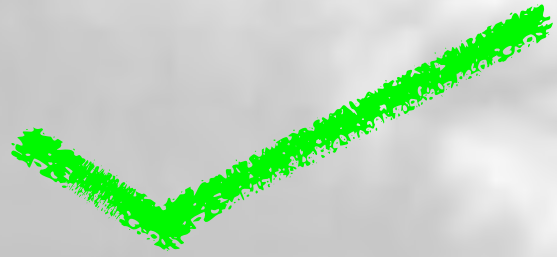

Capability Based Financial Instruments ***Miller, Morningstar, Frantz.*** **Fin. Cryp. 2000**