

NEW!  
Env-lam

$z = (Num\ 1), \emptyset \vdash (Lam\ x\ (Id\ z)) \Downarrow (Clo\ env1\ (Lam\ x\ (Id\ z)))$   
 $z = (Num\ 2), \emptyset \vdash (Let\ f\ (Lam\ x\ (Id\ z))) \Downarrow (Clo\ env1\ (Lam\ x\ (Id\ z)))$   
 $z = (Num\ 1), \emptyset \vdash (Let\ f\ (Lam\ x\ (Id\ z))) \Downarrow (Clo\ env1\ (Lam\ x\ (Id\ z)))$   
 $z = (Num\ 2), \emptyset \vdash (Let\ f\ (Lam\ x\ (Id\ z))) \Downarrow (Clo\ env1\ (Lam\ x\ (Id\ z)))$

$env1 \vdash (Num\ 2) \Downarrow (Num\ 2)$   
 $env1 \vdash (Let\ z\ (Num\ 2)\ \dots)$   
 Env-let

$env1$   
 $(1)$

~~(Id f)~~  
~~(App (Id f) (Num 0))~~  
 $(Let\ z\ (Num\ 2)\ (App\ (Id\ f)\ (Num\ 0))) \Downarrow (Num\ 1)$

$env1\ f = f = (Clo\ env1\ (Lam\ x\ (Id\ z)))\ env1$

$env2 \vdash (Id\ f) \Downarrow (Clo\ env1\ (Lam\ x\ (Id\ z)))$   
 $z = (Num\ 2), env1 \vdash (App\ (Id\ f)\ (Num\ 0)) \Downarrow (Num\ 1)$   
 $z = (Num\ 2), env1 \vdash (App\ (Id\ f)\ (Num\ 0)) \Downarrow (Num\ 1)$   
 $x = (Num\ 0), env1 \vdash (Id\ z)$   
 $\Downarrow (Num\ 1)$

# State

"State is the name of the coldest of all cold monsters." — Nietzsche

UBC CISC 311  
2016W1 2016-11-07 (2)

## Taxonomy

### Mutable state

def. not functional By default, idiomatic: Fortran, Algol-60, Lisp, C, C++, Java, Smalltalk,  
By default, less idiomatic: Racket  
Not by default (mostly): Standard ML, OCaml  
def. functional By simulation: Haskell

Racket: set! on let, define, ..., but "discouraged"

$\langle E \rangle ::=$  ...  
| {Ref  $\langle E \rangle$ } allocate, return pointer  
| {Deref  $\langle E \rangle$ } "dereference" pointer \*  
| {Setref  $\langle E \rangle \langle E \rangle$ } update contents with new value, and return new value

State

(A failed state)

Env: rules  $env \vdash e \Downarrow v$  for pairs

EXAMPLE:  $(Pair (Let x (Num 1) (Id x)) (Let x (Num 2) (Id x)))$

$$\frac{env \vdash e_1 \Downarrow v_1 \quad env \vdash e_2 \Downarrow v_2}{env \vdash (Pair e_1 e_2) \Downarrow (Pair v_1 v_2)}$$

$$\frac{\frac{(Num 1) \Downarrow (Num 1) \quad x = (Num 1), \emptyset \vdash (Id x) \Downarrow (Num 1)}{\emptyset \vdash (Let x (Num 1) (Id x)) \Downarrow (Num 1)} \quad \dots \quad \frac{x = (Num 2), \emptyset \vdash (Id x) \Downarrow (Num 2)}{\emptyset \vdash (Let x (Num 2) (Id x)) \Downarrow (Num 2)}}{\emptyset \vdash (Pair (Let x (Num 1) (Id x)) (Let x (Num 2) (Id x))) \Downarrow (Pair (Num 1) (Num 2))}$$