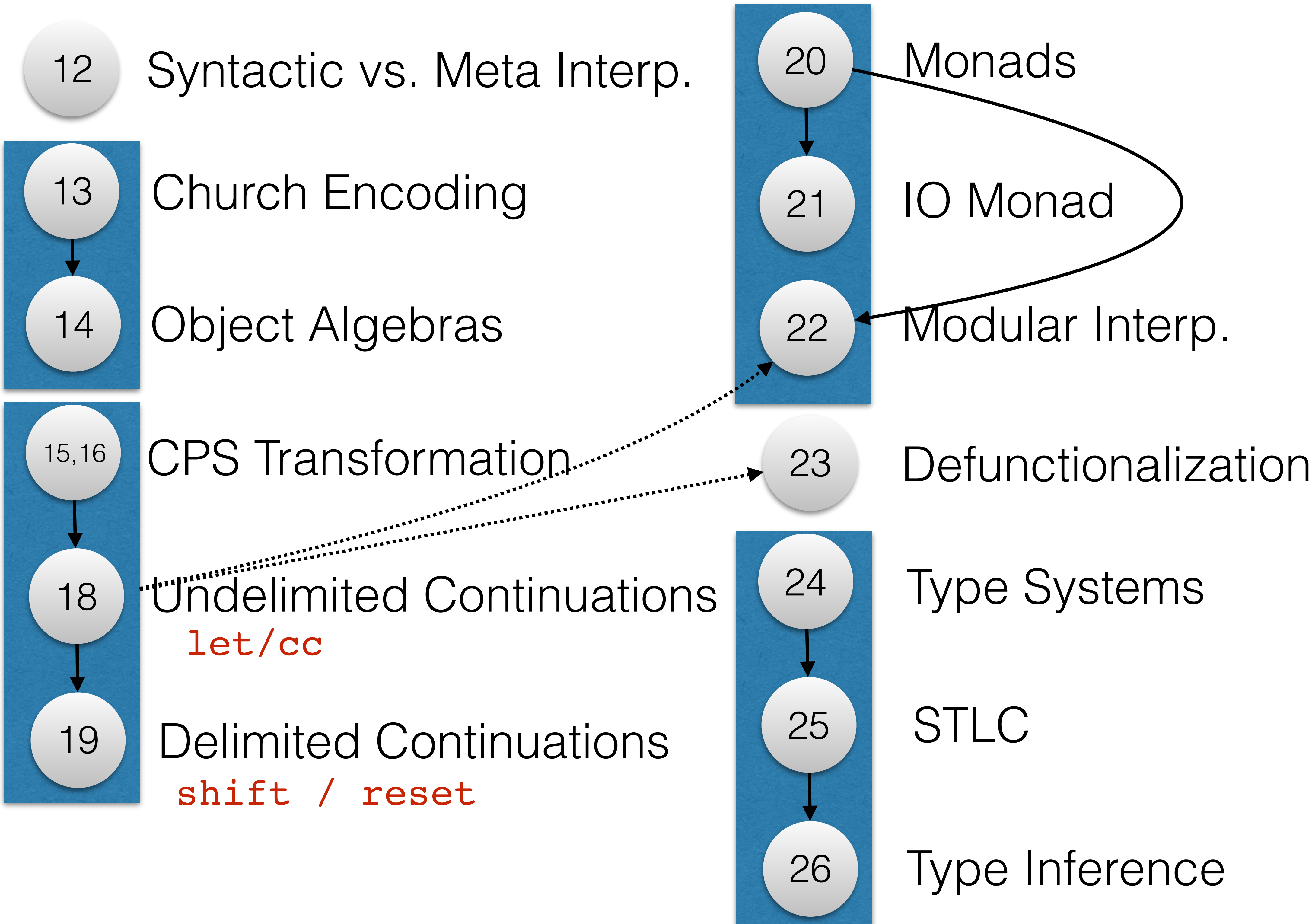
PL1 (SS 2019) — Overview of second part

→ = possible reading order

Lectures



12 Syntactic Vs. Meta Interpretation

- meta vs. syntactic interpretation of a feature:
  uses vs. does not use
  the corresponding host language feature

- e.g. first-class functions:
- meta interpreter returns host language function from values to values as value (compositional)
- syntactic interpreter returns closures

- alternative meta: HOAS -> directly use (embed) host language functions (from expr.s to expr.s)

13 Church Encoding

= ”fold“ over the respective represented object (number, list, …)

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= ”fold“ (catamorphism) over the respective represented object (number, list, …)

know: fold over lists

```
def fold(l)(f,e) = match l with
  []   => e
  h::t => f(h, fold(t)(f,e))
```

13 Church Encoding

```
def fold(l)(f,e) = match l with
  []   => e
  h::t => f(h, fold(t)(f,e))

// Church encoding of [1,2,3]
def ce_123 : (A->B—>B,B)->B =
  fold([1,2,3])
```

13 Church Encoding

```
def fold(l)(f,e) = match l with
  []    => e
  h::t => f(h, fold(t)(f,e))
```

lists can be specialized to Peano nat.s:

```
// Nat = List of Unit
def fold(n)(f,e) = match n with
  []     => e
  ()::t => f((), fold(t)(f,e))
```

13 Church Encoding

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lists can be specialized to Peano nat.s:

```
// Nat = List of Unit
def fold(n)(f,e) = match n with
   []     => e
   ()::t => f((), fold(t)(f,e))
```

always unit, no extra information at each position

13 Church Encoding

```
// Nat = List of Unit
def fold(n)(f,e) = match n with
  []     => e
  ()::t => f((), fold(t)(f,e))
```

compare:

```
def fold(n)(f,e) = match n with
  0     => e
  S(m) => f(fold(m)(f,e))
```

13 Church Encoding

```
def fold(n)(f,e) = match n with
  0     => e
  S(m)  => f(fold(m)(f,e))
```

In other words:
fold over **n** = iterate **n** times the given function f starting with the given number e

```
f(f(…f(e)…))
```

13 Church Encoding

```
f(f(…f(e)…))
```

compare lists:

```
f((),f((),…f((),e)…))
f(1 ,f(2 ,…f(n ,e)…))
```

13 Church Encoding

approach generalizes to other structures:
trees, booleans, …

15,16 CPS Transformation

- every function gets an extra argument to pass the remaining computation = the **continuation**

- CPS transf. makes the evaluation explicit

- after CPS transf.: all function calls are tail calls

15,16 CPS Transformation

Compare:

```
def f(x) = 5 + g(h(x))
```

After CPS transf.:

```
def f(x) = h(x, a => g(a, b => 5 + b))
```

15,16 CPS Transformation

Compare:

```
def f(x) = 5 + g(h(x))
```

first thing to be evaluated

After CPS transf.:

```
def f(x) = h(x, a => g(a, b => 5 + b))
```

first call

15,16 CPS Transformation

Compare:

not a tail call

```
def f(x) = 5 + g(h(x))
```

After CPS transf.:

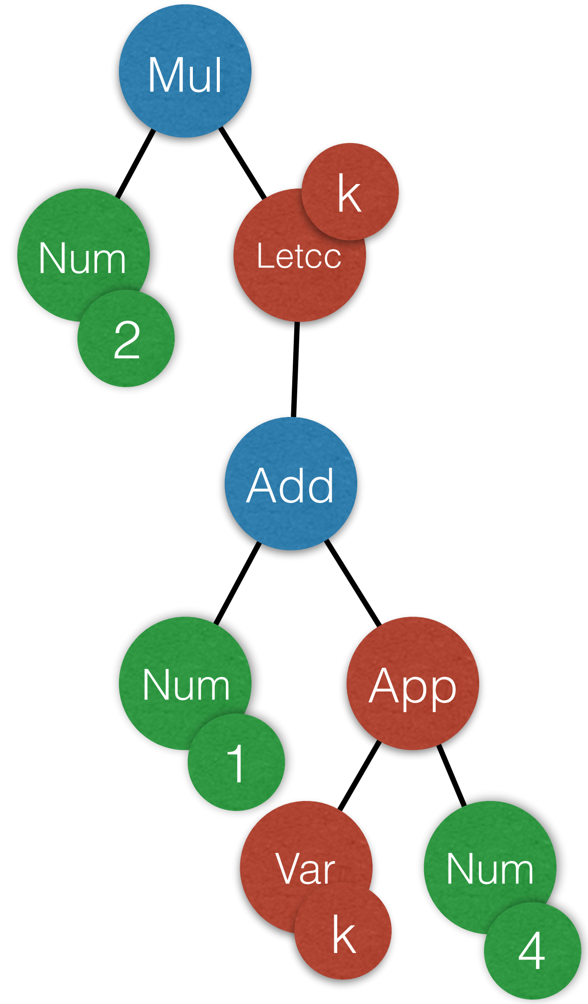
not a tail call

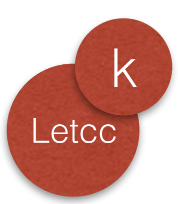
```
def f(x) = h(x, a => g(a, b => 5 + b))
```

tail call

tail call

18 `let/cc`

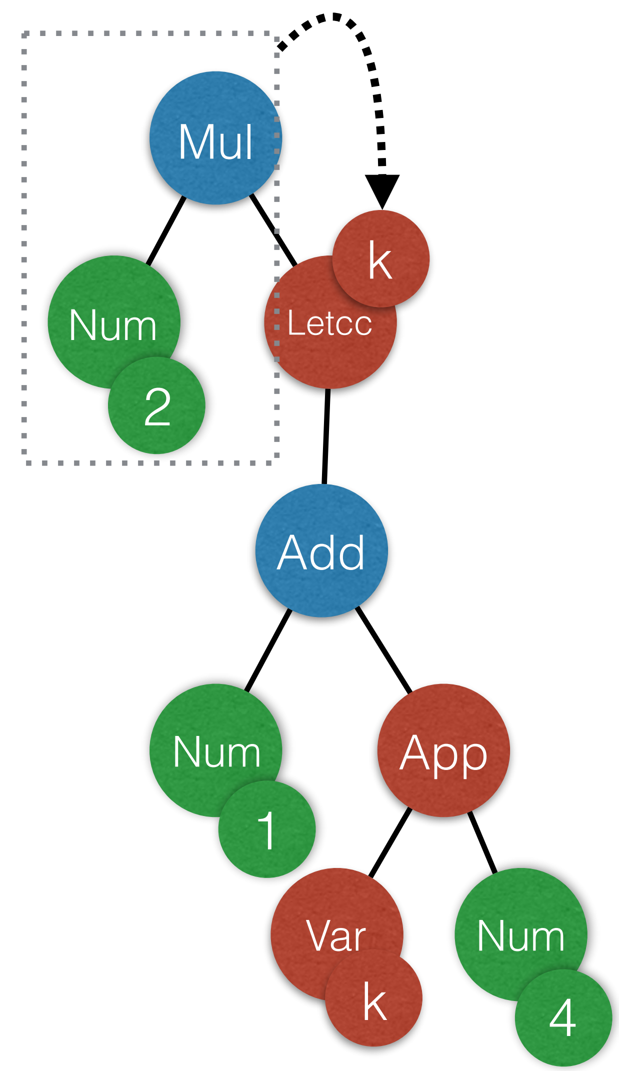




new node type for binding first-class continuations

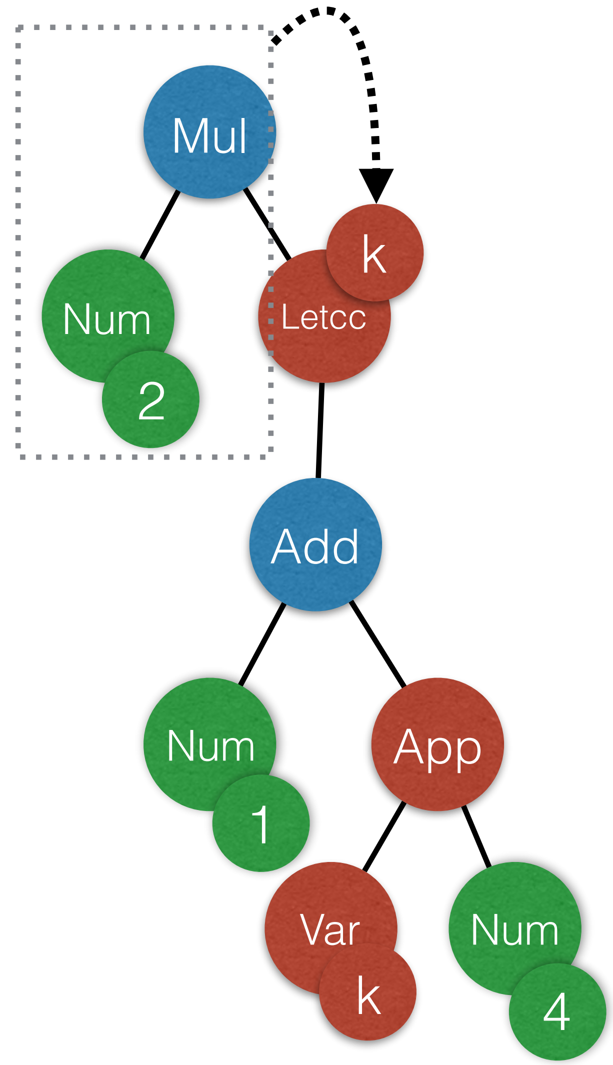
18

let/cc



18

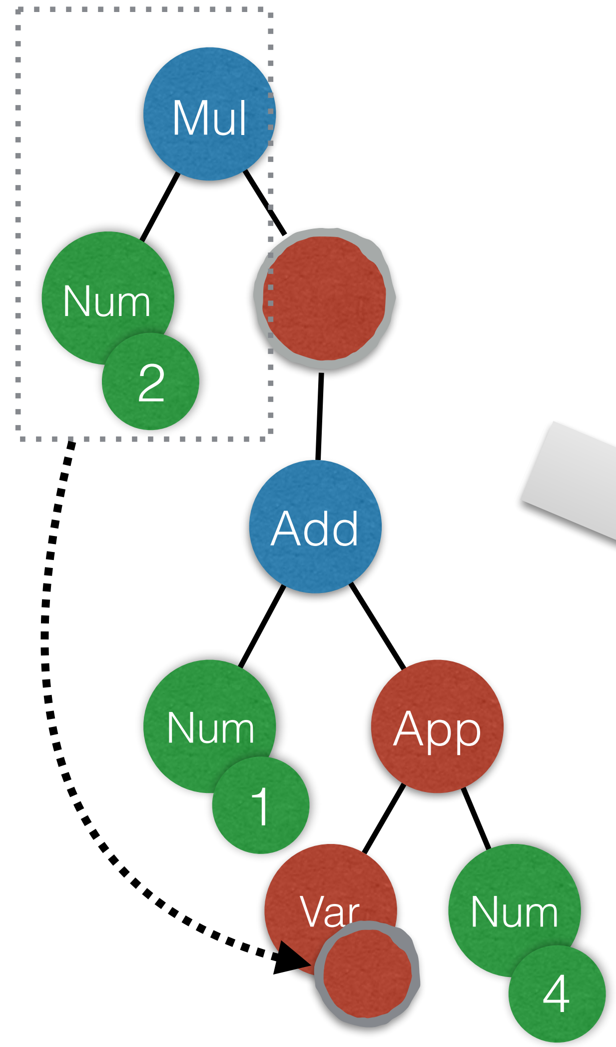
`let/cc`



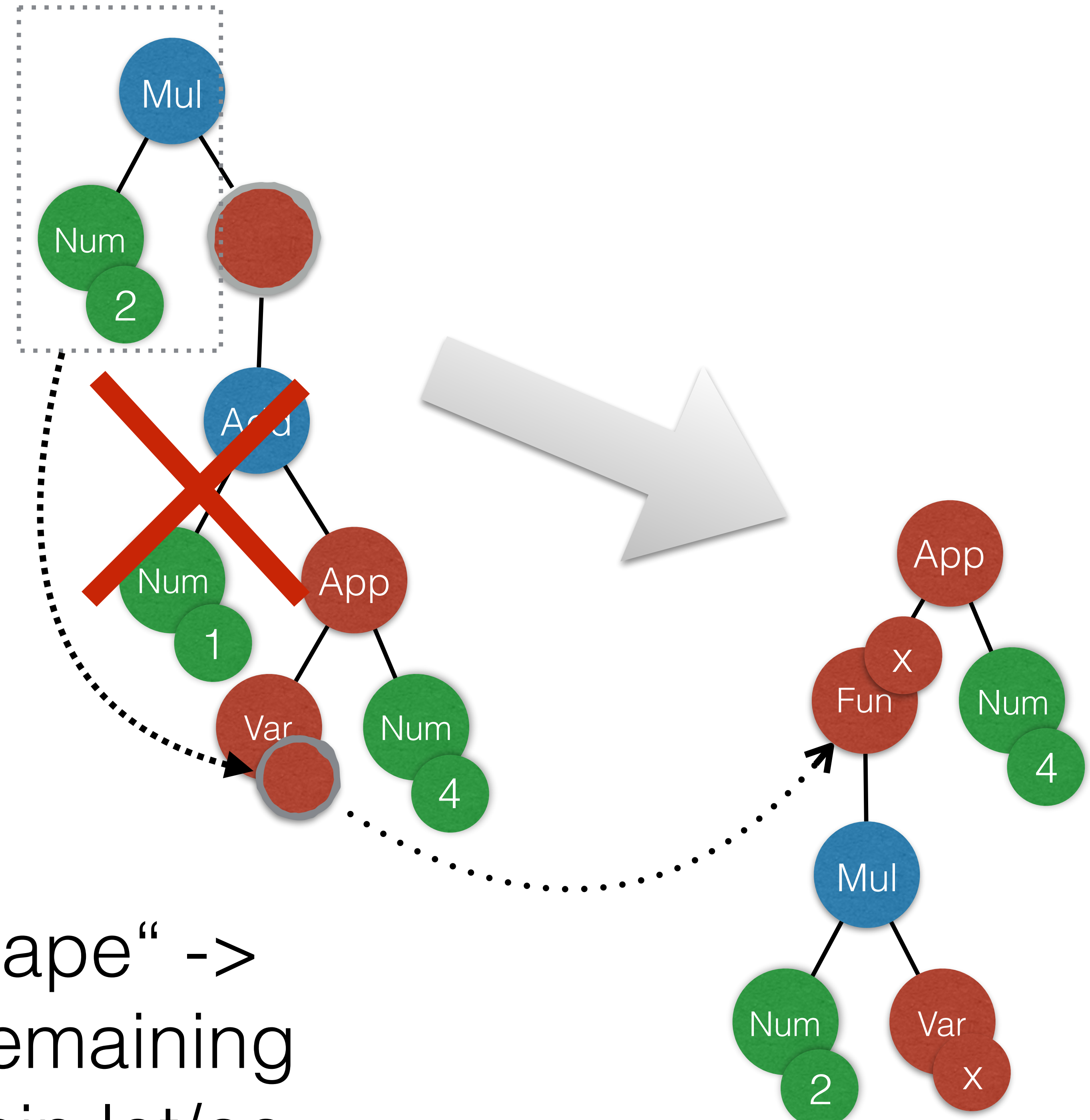
= ”the current continuation (**cc**)“

18

let/cc

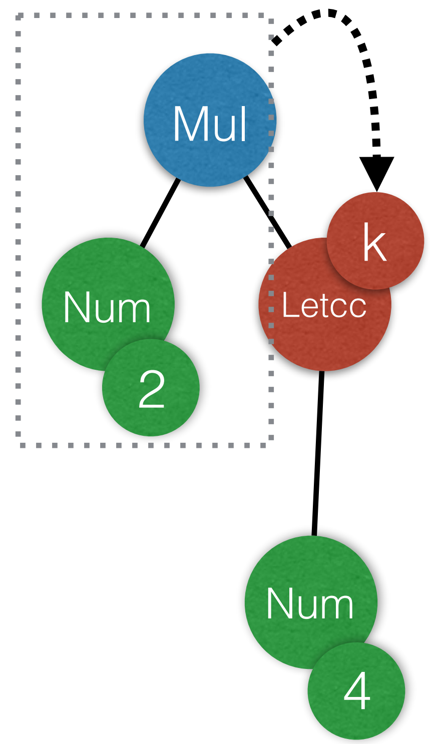


18 let/cc



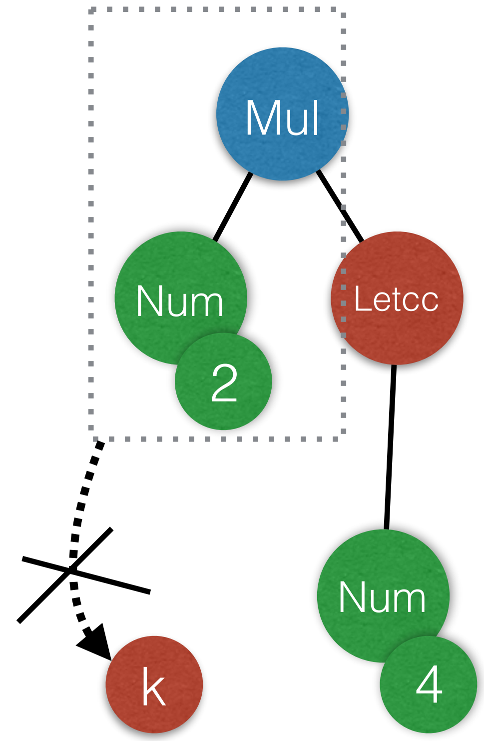
we want to "escape" ->
throw away the remaining
computation within let/cc

18 `let/cc`



example with unused continuation

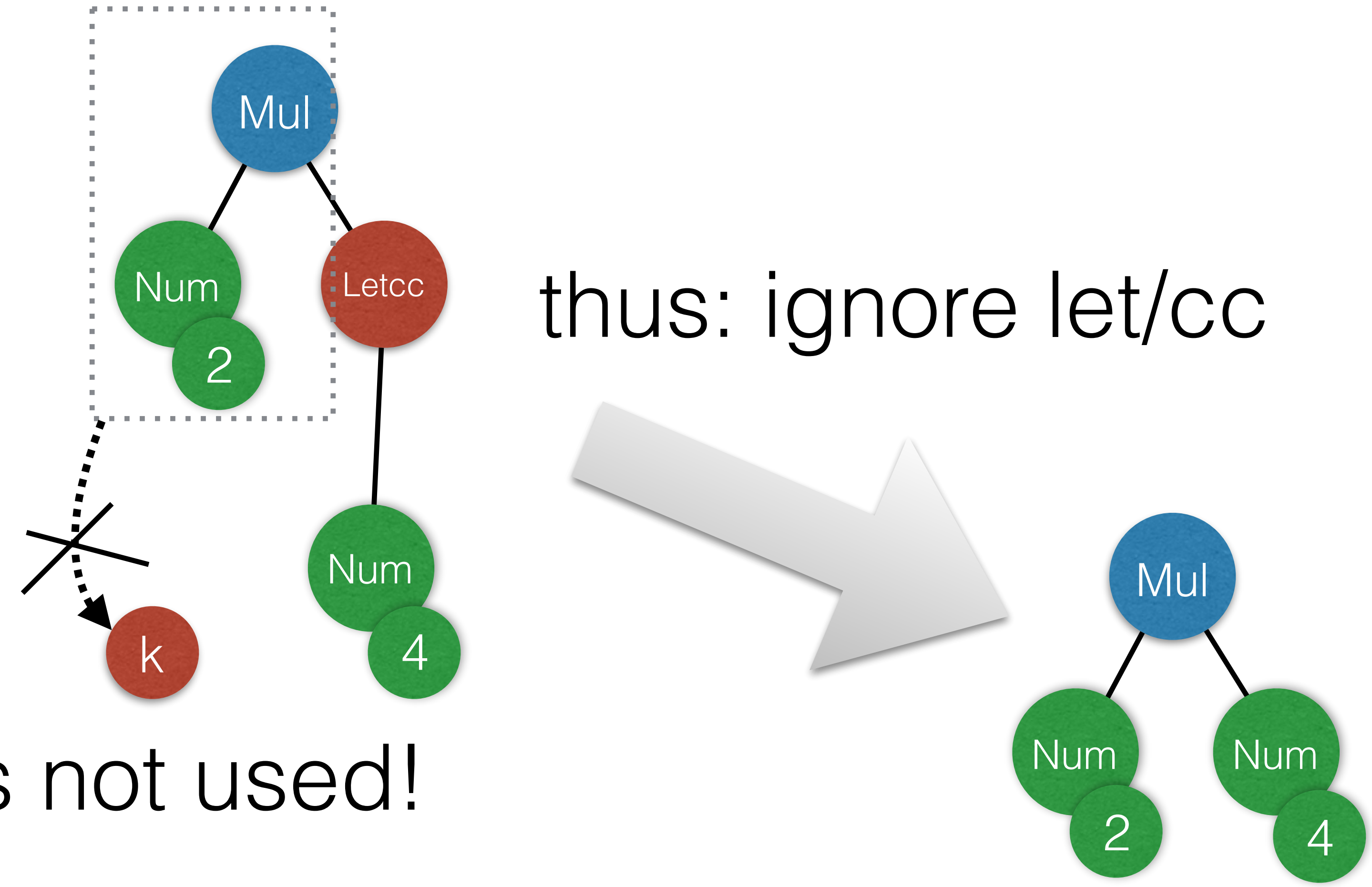
18 let/cc



k is not used!

example with unused continuation

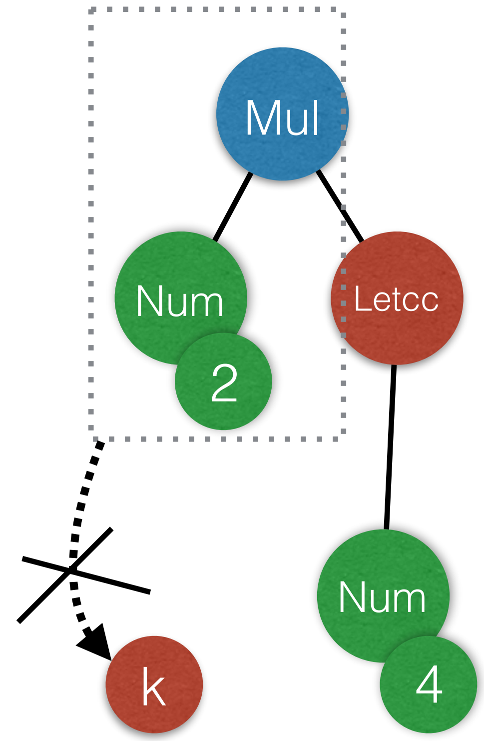
18 let/cc



example with unused continuation

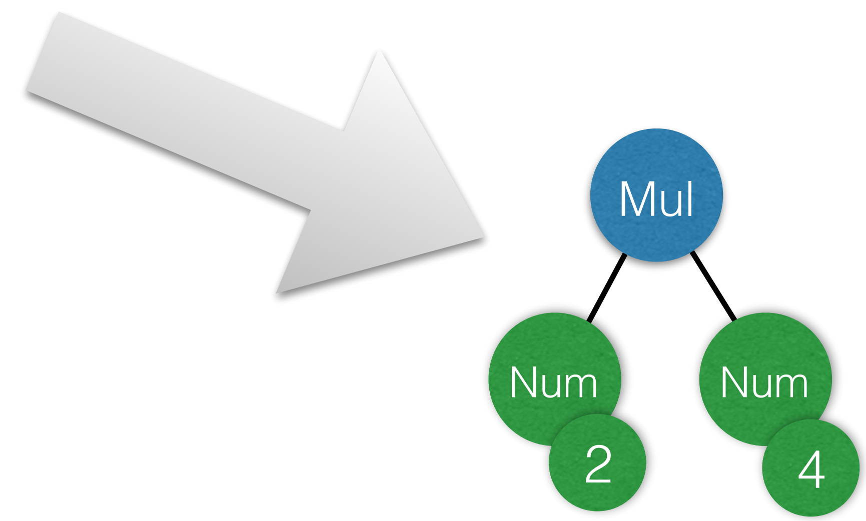
18

let/cc



k is not used!

thus: ignore let/cc

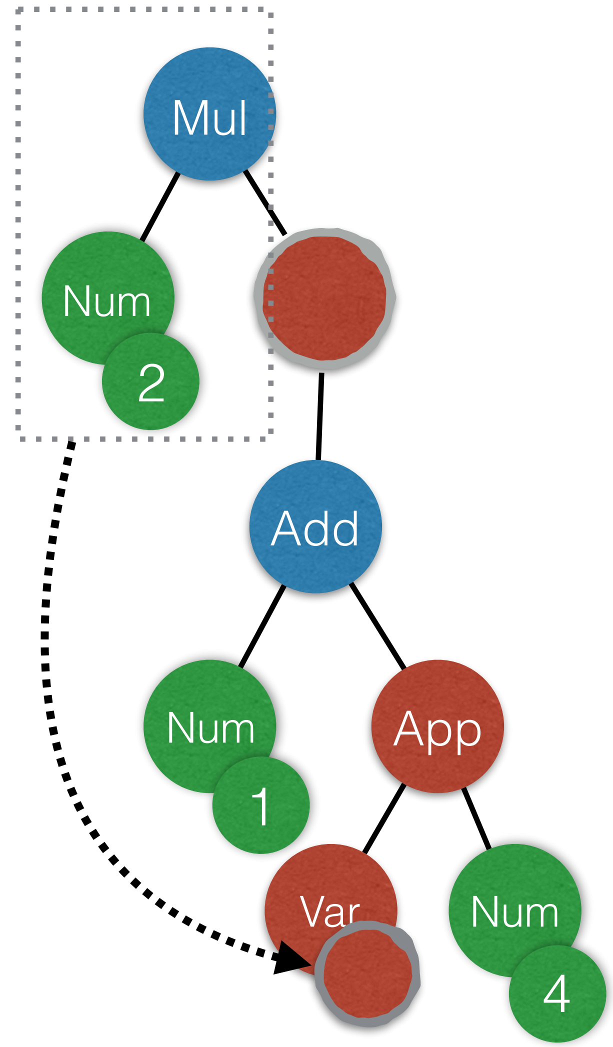


summary: with let/cc …

- we can ”escape“ its body by calling the captured cont. (k)
- **but**: if no ”escape“ happens, computation ignores the let/cc

18

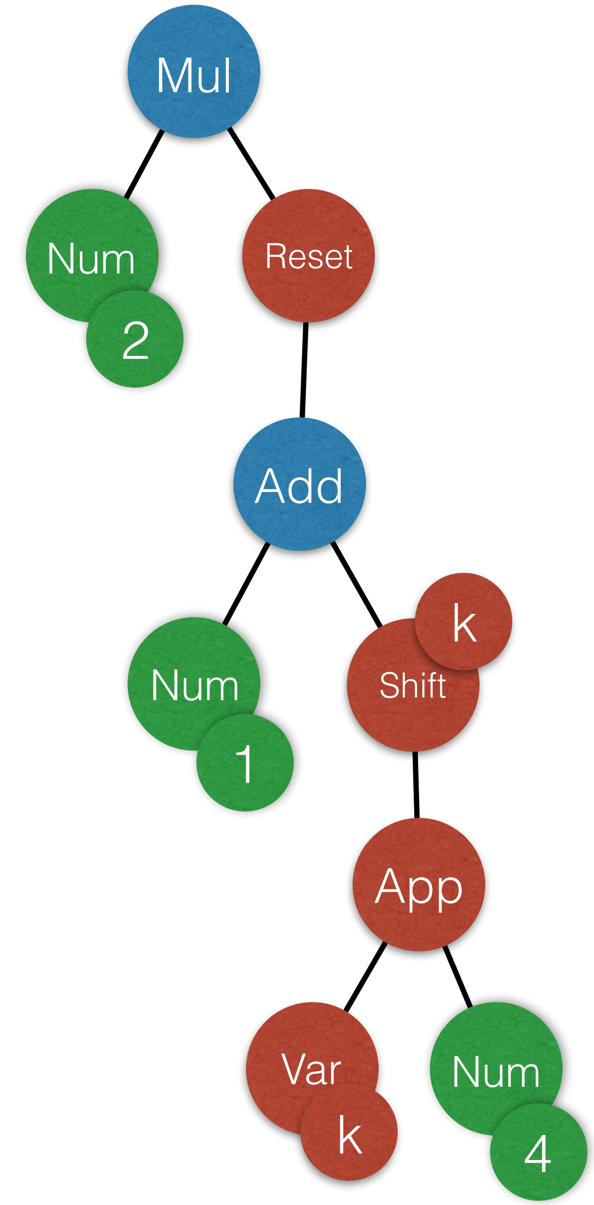
let/cc

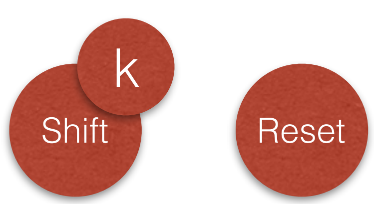


intuitively:
only even consider the ”capturing“ once k is actually applied

19

shift / reset

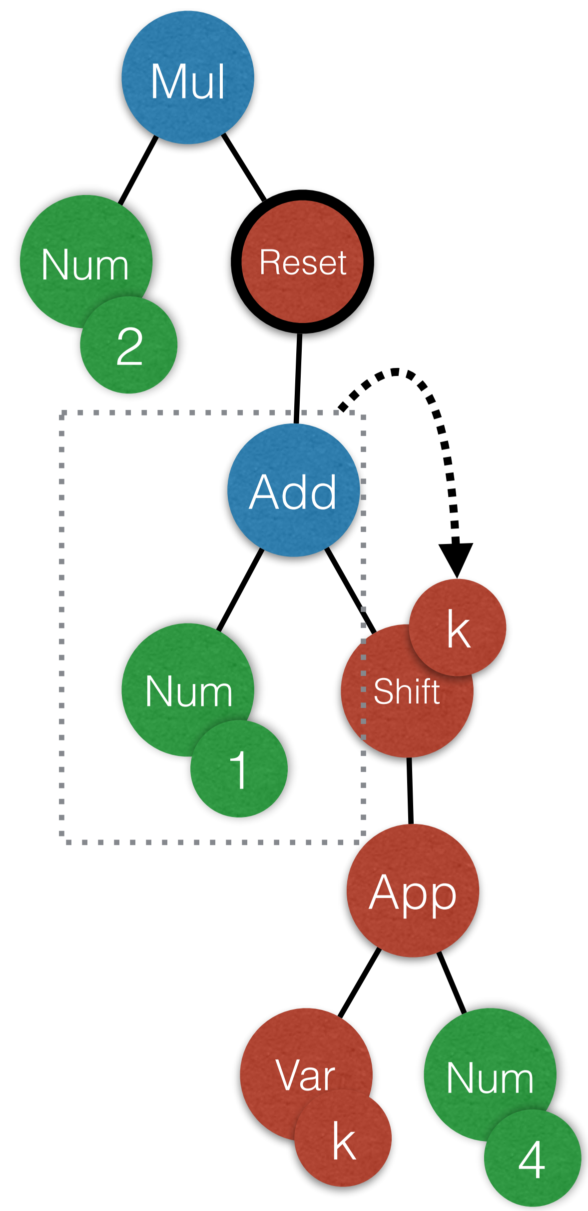




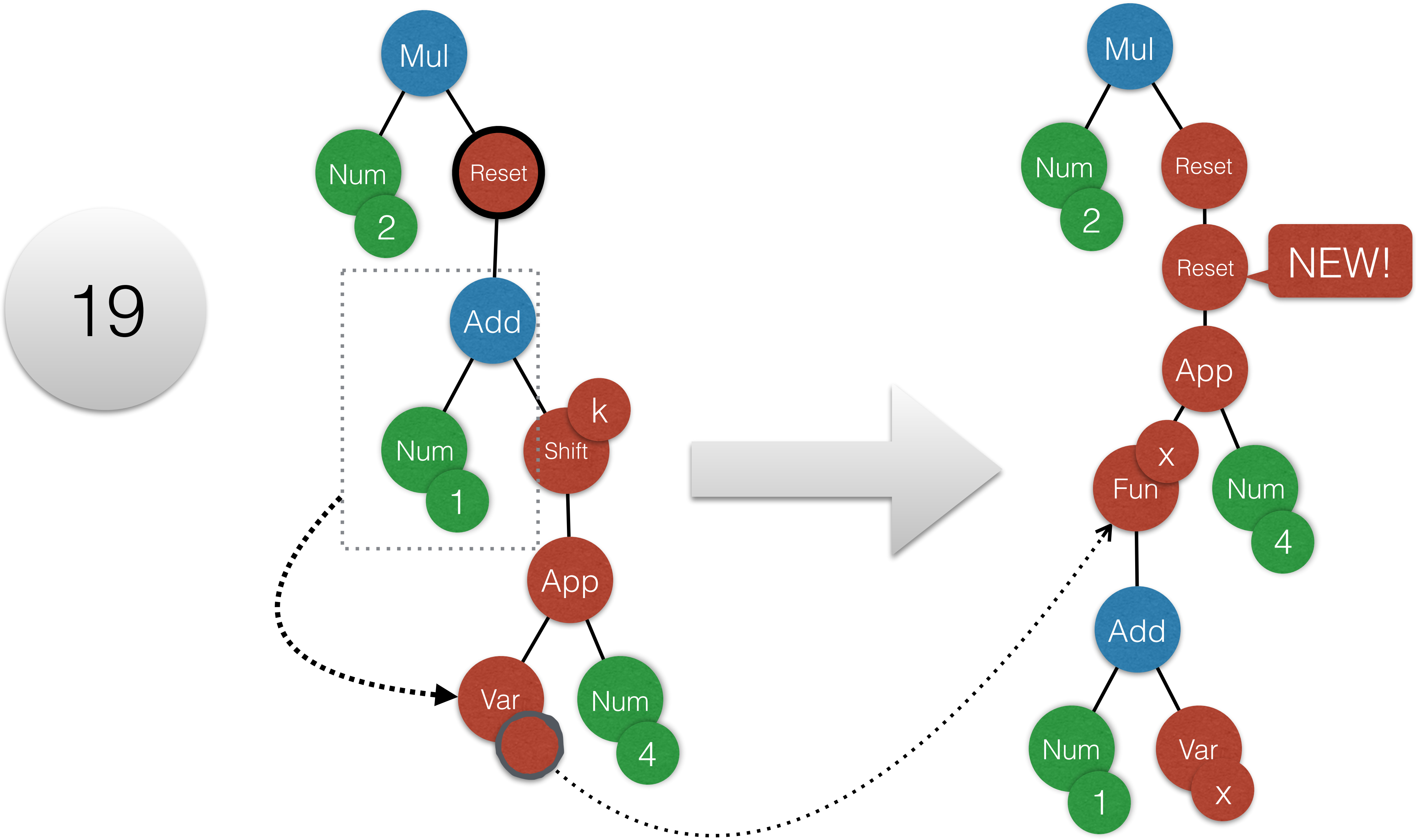
new node types for binding first-class **delimited** continuations

19

shift / reset



= ”the delimited continuation up to the reset“


19
Mul
Num
2
Reset
Add
Num
1
Shift
k
App
Var
Num
4
Mul
Num
2
Reset
Reset
NEW!
App
Fun
x
Num
4
Add
Num
1
Var
x

20 Monads

- a way to structure your code, especially in a (somewhat) modular way
- more specifically, allows to structure computational effects (e.g. the option monad for failure)
- example: **modular interpreter**

22 Modular Interpreter

- uses the technique of **monad transformers**

- with this, we **compose several monads** with which we **structure the effects** of the interpreters we saw so far:
- *Reader* (for the environment)
- *State* (for mutable state/reference cells)
- *Continuation* (for first-class continuations)

23 Defunctionalization

- gets rid of all first-class functions

- to do so, all first-class functions become variants of a datatype (case classes)

- functionality is moved to an `apply` function for that datatype

23 Defunctionalization

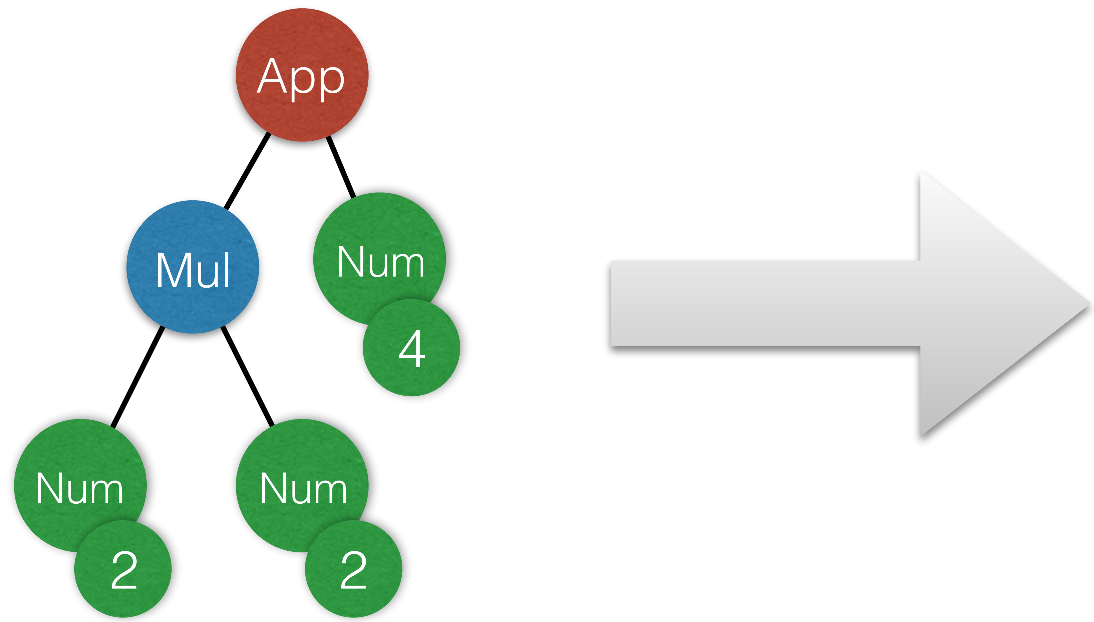
- requires **lambda lifting** as a pre-step

- <u>especially useful after a CPS transformation:</u>
- together, CPS transform and defunc. make the evaluation explicit and get rid of first-class functions

- the resulting program is closer to an abstract machine
  -> useful to **compile** it to efficient low-level code

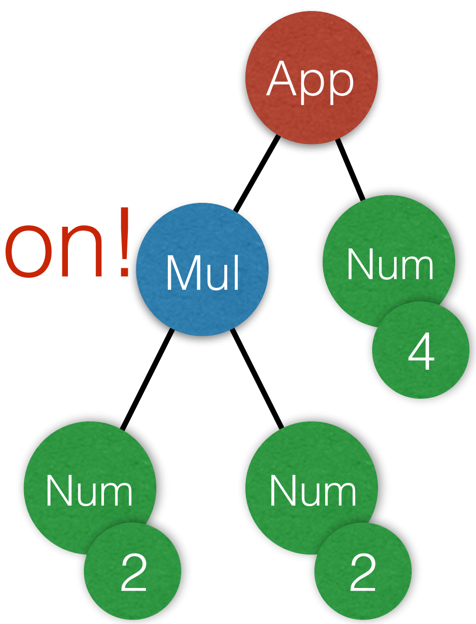
- important drawback:
  defunc. is a **global** program transformation

24 Type Systems



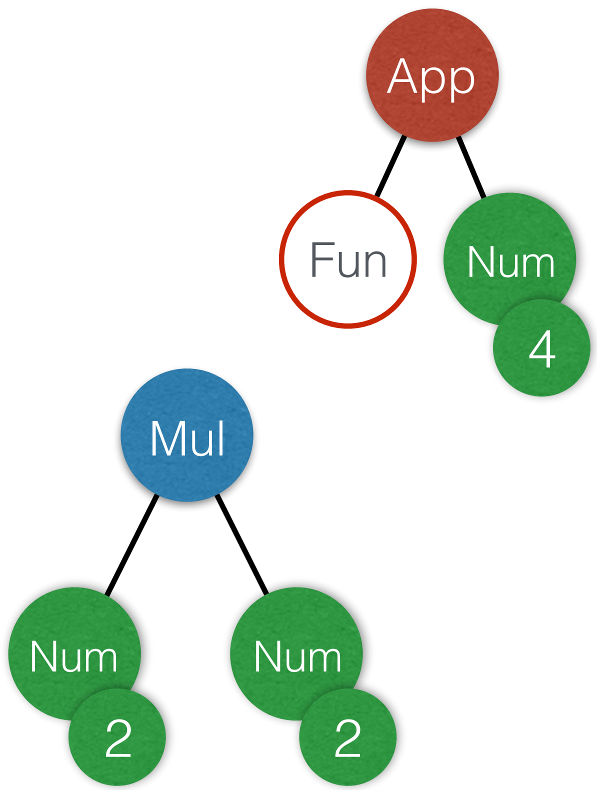
24 Type Systems

not a function!



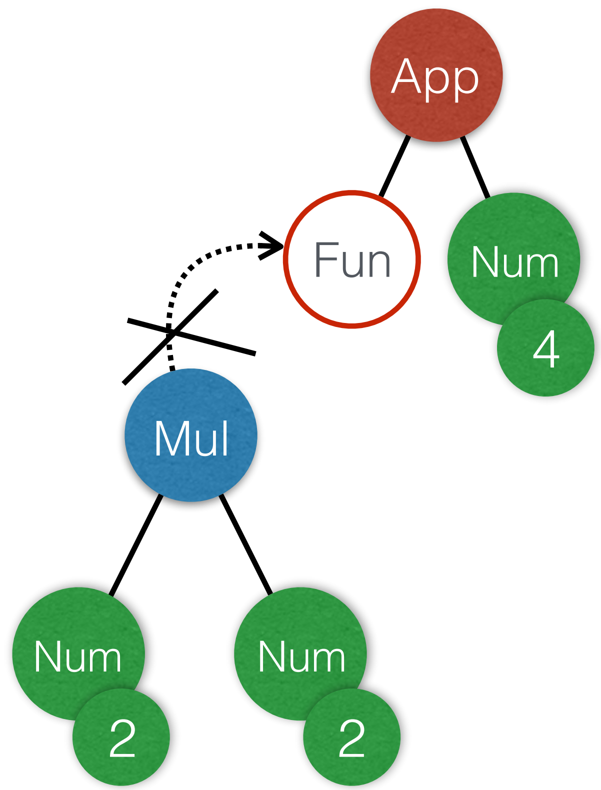
runtime type error!

24 Type Systems



a solution: static type systems

24 Type Systems



a solution: static type systems

typechecking:
separate phase before
the program is run