

TRIVIA: WHAT ARE :

52	2:30
37	3:35
19	11:15
6	7:30

PS#2 DUE 9/22 11:59 PM
QUIZ# ON 9/22 10:10 AM

Q1 BACK MONDAY
9/27 GUEST LECTURE WALKER WHITE
- NO RDZ O.H.

SUBSTITUTION MODEL

PRECISE DESCRIPTION OF OCAML

```
let rec evil (f1, f2, n) =  
  let f(x) = 10 + n in  
  if n = 1 then f(0) + f1(0) + f2(0)  
  else evil (f, f1, n - 1)  
and dummy(x) = 1000  
in  
  evil(dummy, dummy, 3)
```

Model of Evaluation

Type at OCaml: term, or declaration

Evaluate a term to produce a value

Value is a ~~spe~~ subset of terms
needing no further evaluation

Values: constants, tuples of values, functions, etc.

$$\begin{aligned}(1+2) * (3+4) \\ (1+2) * 7 \\ 3 * 7 \\ 21\end{aligned}$$

$$\begin{aligned}((1+2)*3) * (4*5) \\ 3+5 \quad 8\end{aligned}$$

Rewrite expression to another one
continue until value OR [exception, inf loop, etc]

Which reduction does OCaml do?
Leftmost reduction first

Rules:

[IF] if true then e_1 else $e_2 \rightarrow e_1$
if false then e_1 else $e_2 \rightarrow e_2$

if e_0 then e_1 else e_2

if $2=3$ then "hello" else "good" ^ "bye"
false
"good" ^ "bye"

Substitution model

[LET]

let $id = e_1$ in e_2

Go through e_2 and replace id by e_1
substitute

- Evaluate $e_1 \rightarrow v_1$
- "Substitute" v_1 for id in e_2
- Evaluate that

→ let $x = 1+4$ in $x * 3$ →
let $x = 5$ in $x * 3$ →
 $5 * 3$ →
15

Only substitute once we have a value
EAGER OCaml eagerly evaluates
the ~~expression~~ binding for
a variable

→ $(\text{fun } x \rightarrow x * 3) (1+4)$

OCaml is EAGER
Java, C, etc

LAZY, Haskell

Do lazy in OCaml
later on

let $x = v$ in $e \rightarrow e$ with x replaced by v

e expr (arbitrary term)

v value

$v ::= e \mid \lambda(x) \mid (v_1, \dots, v_n) \mid \text{fun } p \rightarrow e$

$\text{Cons}(1, \text{Nil})$ Nil

$\text{Cons}(2+3, \text{Nil})$

$X(v)$ is a value when
 X is a type constructor
 and v a value

$(f(3), 24, 17)$
 $(12, 24, 17)$

$\text{fun } x \rightarrow \text{fun } y \rightarrow \text{fun } z \rightarrow 2+3 \times z$
 ~~$2+3$~~

Values self-evaluate

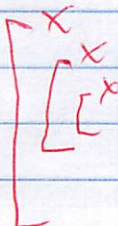
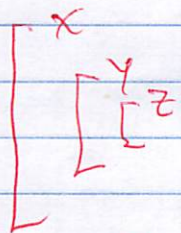
Substitution

let $x = 1+1$ in --- bound occurrence

[let $f(x) = x$ in --- binding

let $y = x+1$ in

fun $(a: \text{string}) \rightarrow$ "x marks the spot"



let $x = v$ in $e \rightarrow e \{v/x\}$

Replace unbound occurrences
 of x by v in e

$e \in \mathcal{E}$

$\lambda x. a$

$x \{2/x\} \rightarrow 2$

$x \{2/y\} \rightarrow x$

$(\text{fun } y \rightarrow x) \{ "hi" / x \} \rightarrow \text{fun } y \rightarrow "hi"$

(let $x := "hi"$
in fun $y \rightarrow x$)
'a' \rightarrow string

$e \{v/id\}$

* Expression e with
unbound occurrences of
the variable id replaced
by the value v

$f(x) \{ \text{fun } y \rightarrow y / f \} \rightarrow (\text{fun } y \rightarrow y)(x)$

Unbound? "Free"

1. let $x = e$ in e_1

x is bound in e_1

2. fun $(z) \rightarrow e$

z is bound in e