# CMSC 330: Organization of Programming Languages

## Lets, Tuples, Records

# Let Expressions

- Enable binding variables in other expressions
  - These are different from the **`let`** *definitions* we've been using at the top-level
- They are expressions, so they have a value

- Syntax
  - **`let`** ***`x`*** **`=`** ***`e1`*** **`in`** ***`e2`***
  - ***`x`*** is a *bound variable*
  - ***`e1`*** is the *binding expression*
  - ***`e2`*** is the *body expression*

# Let Expressions

- Syntax
  - `let` ***x*** `=` ***e1*** `in` ***e2***

- Evaluation
  - Evaluate ***e1*** to ***v1***
  - Substitute ***v1*** for ***x*** in ***e2*** yielding new expression ***e2'***
  - Evaluate ***e2'*** to ***v2***
  - Result of evaluation is ***v2***

Example

```
let x = 3+4 in 3*x
➢let x = 7 in 3*x
➢3*7
➢21
```

# Let Expressions

- Syntax
  - **`let` *`x`* `=` *`e1`* `in` *`e2`***
- Type checking
  - If *`e1`* : *`t1`* and *`e2`* : *`t`* (assuming *`x`* : *`t1`*)
  - Then **`let` *`x`* `=` *`e1`* `in` *`e2`*** : *`t`*
- Example: **`let x = 3+27 in x*3`**
  - **`3+27 : int`**
  - **`x*3 : int`** (assuming **`x:int`**)
  - so **`let x = 3+27 in x*3 : int`**

# Let Definitions vs. Let Expressions

- At the top-level, we write
  - `let x = e;;` (* no `in e2` part *)
  - This is called a let *definition*, not a let *expression*
    - Because it doesn't, itself, evaluate to anything

- Omitting in means "from now on":

```
# let pi = 3.14;;
(* pi is now bound in the rest of the top-level scope *)
```

# Top-level expressions

- We can write any expression at top-level, too
  - `e;;`
  - This says to evaluate `e` and then ignore the result
    - Equivalent to `let _ = e;;`
    - Useful when `e` has an effect, such as reading/writing a file, printing to the screen, etc.

```
let x = 37;;
let y = x + 5;;
print_int y;;
print_string "\n";;
```

    - When run, outputs `42` to the screen

# Let Expressions: Scope

- In **`let x = e1 in e2`**, variable **`x`** is *not* visible outside of **`e2`**

```
let pi = 3.14 in pi *. 3.0 *. 3.0;;
print_float pi;;
```

error: **`pi`** not bound

bind **`pi`** (only) in body of **`let`**
(which is **`pi *. 3.0 *. 3.0`**)

# Binding in other languages

- Compare to similar usage in Java/C

```
let pi = 3.14 in
  pi *. 3.0 *. 3.0;;
pi;; (* pi unbound! *)
```

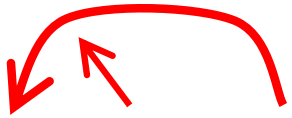
```
{
  float pi = 3.14;

  pi * 3.0 * 3.0;
}
pi; /* pi unbound! */
```

# Examples – Scope of Let bindings

- x;;
  - (* Unbound value x *)

- let x = 1 in x + 1;;
  - (* 2 *)



- let x = x in x + 1;;
  - (* Unbound value x *)

# Examples – Scope of Let bindings

- let x = 1 in( x + 1 + x) ;;
  - (* 3 *)

- (let x = 1 in x + 1) ;; x;;
  - (* Unbound value x *)

- let x = 4 in(let x = x + 1 in x );;
  - (* 5 *)

# Shadowing Names

- Shadowing is rebinding a name in an inner scope to have a different meaning
  - May or may not be allowed by the language

**C**

```
int i;

void f(float i) {

  {
    char *i = NULL;
    ...
  }

}
```

**OCaml**

```
let g = 3;;
let g x = x + 3;;
```

**Java**

```
void h(int i) {
  {
    float i; // not allowed
    ...
  }
}
```

# Let Expressions in Functions

- You can use let inside of functions for local vars

```
let area r =
  let pi = 3.14 in
  pi *. r *. r
```

  - And you can use many lets in sequence

```
let area d =
  let pi = 3.14 in
  let r = d /. 2.0 in
  pi *. r *. r
```

# Nested Let Expressions

- Uses of let can be nested in OCaml
  - Nested bound variables (`pi` and `r`) invisible outside

```
let res =
  (let area =
    (let pi = 3.14 in
    let r = 3.0 in
    pi *. r *. R) in
  area /. 2.0);;
```

- Similar scoping possibilities C and Java

```
float res;
{ float area;
  { float pi = 3.14
    float r = 3.0;
    area = pi * r * r;
  }
  res = area / 2.0;
}
```

# Quiz 1

Which of these is **not** an expression that evaluates to 3?

A. `let x=3`

B. `let x=2 in x+1`

C. `let x=3 in x`

D. `3`

# Quiz 1

Which of these is **not** an expression that evaluates to 3?

A. `let x=3` ---> not an expression

B. `let x=2 in x+1`

C. `let x=3 in x`

D. `3`

# Quiz 2: What does this evaluate to?

```
let x = 2 in
let y = 3 in
x + y
```

A. 2

B. 3

C. 4

D. 5

# Quiz 2: What does this evaluate to?

```
let x = 2 in
let y = 3 in
x + y
```

A. 2

B. 3

C. 4

D. 5

# Quiz 3: What does this evaluate to?

```
let x = 6 in
let y = 4 in
let x = 8 in
x = 10-y
```

A. 6

B. true

C. 12

D. false

# Quiz 3: What does this evaluate to?

```
let x = 6 in
let y = 4 in
let x = 8 in
x = 10-y
```

A. 6

B. true

C. 12

D. false

# Quiz 4: What does this evaluate to?

```
let x = 3 in
let y = x+2 in
let x = 8 in
y
```

A. 5

B. 12

C. 10

D. false

# Quiz 4: What does this evaluate to?

```
let x = 3 in
let y = x+2 in
let x = 8 in
y
```

A. 5

B. 12

C. 10

D. false

# Tuples

- Constructed using **`(e1, ..., en)`**
- Deconstructed using pattern matching
  - Patterns involve parens and commas, e.g., **(p1,p2, …)**
- Tuples are similar to C structs
  - But without field labels
  - Allocated on the heap
- Tuples can be heterogenous
  - Unlike lists, which must be homogenous
  - **`(1, ["string1";"string2"])`** is a valid tuple

# Tuple Types

- Tuple types use `*` to separate components
  - Type joins types of its components
- Examples
  - `(1, 2) :`
  - `(1, "string", 3.5) :`
  - `(1, ["a"; "b"], 'c') :`
  - `[(1,2)] :`
  - `[(1, 2); (3, 4)] :`
  - `[(1,2); (1,2,3)] :`

# Tuple Types

- Tuple types use **`*`** to separate components
  - Type joins types of its components
- Examples
  - `(1, 2)` : **`int * int`**
  - `(1, "string", 3.5)` : **`int * string * float`**
  - `(1, ["a"; "b"], 'c')` : **`int * string list * char`**
  - `[(1,2)]` : **`(int * int) list`**
  - `[(1, 2); (3, 4)]` : **`(int * int) list`**
  - `[(1,2); (1,2,3)]` : ***`error`***

Because the first list element has type int * int, but the second has type int * int * int – list elements must all be of the same type

# Pattern Matching Tuples

```
# let plusThree t =
  match t with
    (x, y, z) -> x + y + z;;
plusThree : int*int*int -> int = <fun>

# let plusThree' (x, y, z) = x + y + z;;
plusThree' : int*int*int -> int = <fun>

# let addOne (x, y, z) = (x+1, y+1, z+1);;
addOne : int*int*int -> int*int*int = <fun>

# plusThree (addOne (3, 4, 5));;
-  : int = 15
```

Remember, **semicolon** for lists, **comma** for tuples

- `[1, 2] = [(1, 2)]` *which is a list of size one*
- `(1; 2)` ***Warning: This expression should have type unit***

# Tuples Are A Fixed Size

- This OCaml definition
  - `# let foo x = match x with`
    `(a, b) -> a + b`
    `| (a, b, c) -> a + b + c;;`
- Would yield this error message
  - This pattern matches values of type 'a * 'b * 'c
    but is here used to match values of type 'd * 'e
- Tuples of different size have different types
  - Thus never more than one match case with tuples

# Records

- Records: identify elements by name
  - Elements of a tuple are identified by position

- Define a record type before defining record values

```
type date = { month: string; day: int; year: int }
```

- Construct a record
  - { *f1*=*e1*; …; *fn*=*en* } : evaluates *e1* to *en*, assigns results to the given fields
    - Fields do not have to be written in order

```
# let today = { day=16; year=2017; month="f"^"eb" };;
today : date = { day=16; year=2017; month="feb" };;
```

# Destructing Records

```
type date = { month: string; day: int; year: int }
let today = { day=16; year=2017; month="feb" };;
```

- Access by field name or pattern matching

```
print_string today.month;; (* prints feb *)
(* patterns *)
let { month=_; day=d } = today in
let { year } = today in
let _ = print_int d in     (* prints 16 *)
print_int year;;           (* prints 2017 *)
```

- Notes:
  - In record patterns, you can skip or reorder fields
  - You can use the field name as the bound variable

# Quiz 5: What does this evaluate to?

```
let get (a,b) y = a+y in
get 1 2
```

A. 3

B. type error

C. 2

D. 1

# Quiz 5: What does this evaluate to?

```
let get (a,b) y = a+y in
get 1 2
```

A. 3

B. type error – get's first argument must be a pair

C. 2

D. 1

# Quiz 6: What does this evaluate to?

```
let get (x,y) =
  match x with
     (a,b) -> a+y
in
get (1,2) 1
```

A. 3

B. type error

C. 2

D. 1

# Quiz 6: What does this evaluate to?

```
let get (x,y) =
  match x with
     (a,b) -> a+y
in
get (1,2) 1
```

A. 3

B. type error – get takes only one argument

C. 2

D. 1

# Quiz 7: What is the type of **shift**?

```
type point = {x:int; y:int}

let shift { x=px; y=py } =
  {x=px+1; y=py+1};;
```

A. point -> bool list

B. int list -> int list

C. point -> point

D. point -> int list

# Quiz 7: What is the type of **`shift`**?

```
type point = {x:int; y:int}

let shift { x=px; y=py } =
  {x=px+1; y=py+1};;
```

A. `point -> bool list`

B. `int list -> int list`

C. `point -> point`

D. `point -> int list`