CSE216
Foundations of Computer Science

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Some slides taken from Prof. YoungMin Kwon. Thanks!

Plan

- Today 1: Revision on Ocaml
- Today 2: Revision for Midterm 1
- Today 3: More clarification on Ocaml

- Thursday: Midterm 1

Midterm 1 (Same as in the announcement)

- - Date & Time: Thursday, Oct 12, from 9:00 AM to 10:30 AM.
- - Location: B203 (our regular Thursday morning lecture room).
- - Coverage: It includes all the topics discussed in the lectures up to next Tuesday.
- - Format: In-person. Unlimited physical notes. All answers must be submitted on BrightSpace. While I recognize this online submission method is cumbersome, it ensures our alignment with the school's ABET accreditation standards

Revision of our last lecture

Revision

- Ocaml program = Definitions + Expressions
- let x = 3 is a definition
- Everything else is an expression, and has a type before runtime
- An expression can be evaluated at runtime following beta-reduction

Exercises on definitions/expressions and types

- **let x = 3 in x+5** is an ____ of type ___

- **if b then 3 else 5** is an ____ of type ___

- **let f x = x+1** is a ___ that associates ___ with an expression of type ___

- **let f x y = x + y** is a ___ that associates ___ with an expression of type ___

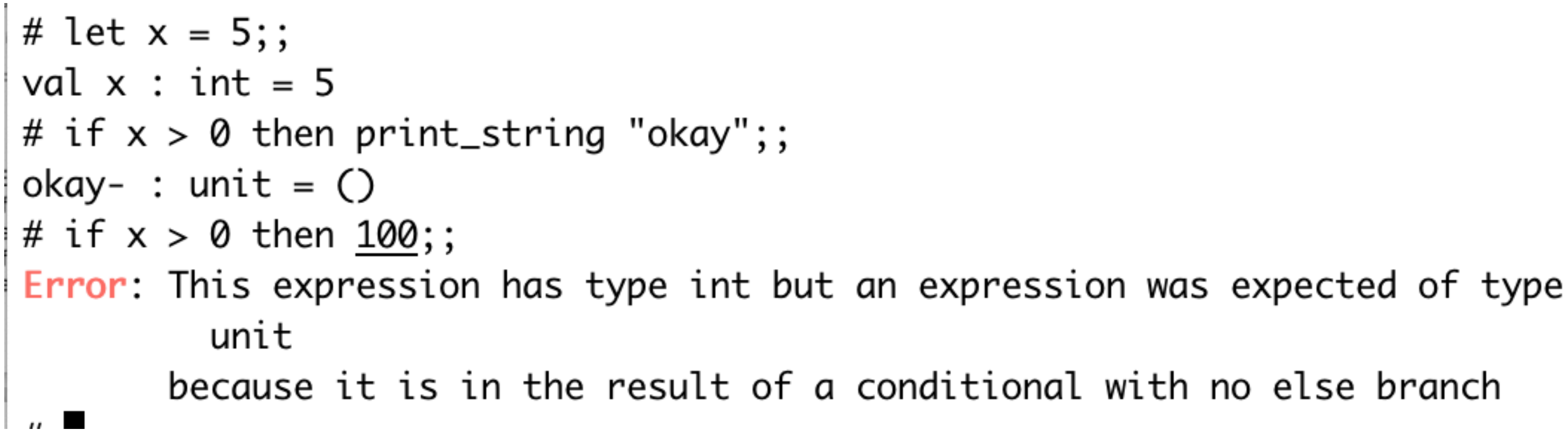
Unit type

Expressions with no meaningful values have type **unit**.

Example: print_string “okay”

The type has a single value, written **()**

it is the type given to the `else` branch when it is omitted



```
# let x = 5;;
val x : int = 5
# if x > 0 then print_string "okay";;
okay- : unit = ()
# if x > 0 then 100;;
Error: This expression has type int but an expression was expected of type
         unit
       because it is in the result of a conditional with no else branch
#
```

Exercises

- **print_endline “hello”** is of type ___
- **print_end** is of type ____

Exercises

- Evaluate let x = 3 in let y = x + 2 in y*y
- Evaluate let x= 3 in (let y= x+1 in y) * (let z = x * x in z)

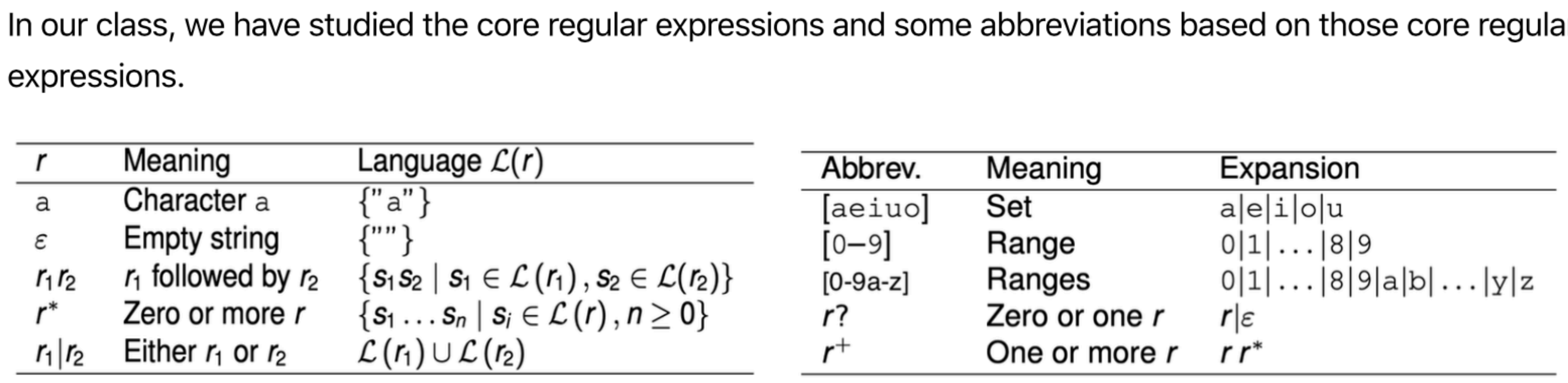
Exercises

- For each of these expressions, what is its value and type. Write the value of a function by “<fun>”:
  - let x = 3 in x * x
  - print_string “hello”
  - print_string
  - let f x y = x + y in f 5 6
  - let x= 5 in (if x > 0 then "pos" else “neg”)
  - let f x y = x + y in f 5

Midterm Revision exercises

- Regular expressions
- Context-free grammar
- lambda calculus
- Ocaml

Regular expression



In our class, we have studied the core regular expressions and some abbreviations based on those core regular expressions.

r	Meaning	Language $\mathcal{L}(r)$
a	Character a	{"a"}
ε	Empty string	{""}
$r_1 r_2$	r_1 followed by r_2	$\{s_1 s_2 \mid s_1 \in \mathcal{L}(r_1), s_2 \in \mathcal{L}(r_2)\}$
r^*	Zero or more r	$\{s_1 \ldots s_n \mid s_i \in \mathcal{L}(r), n \geq 0\}$
$r_1 \mid r_2$	Either r_1 or r_2	$\mathcal{L}(r_1) \cup \mathcal{L}(r_2)$

Abbrev.	Meaning	Expansion
[aeiuo]	Set	a|e|i|o|u
[0–9]	Range	0|1|...|8|9
[0-9a-z]	Ranges	0|1|...|8|9|a|b|...|y|z
$r?$	Zero or one r	$r \mid \varepsilon$
r^+	One or more r	$r\, r^*$

Give a regular expression over {a, b} that has aab as a substring

Regular expression

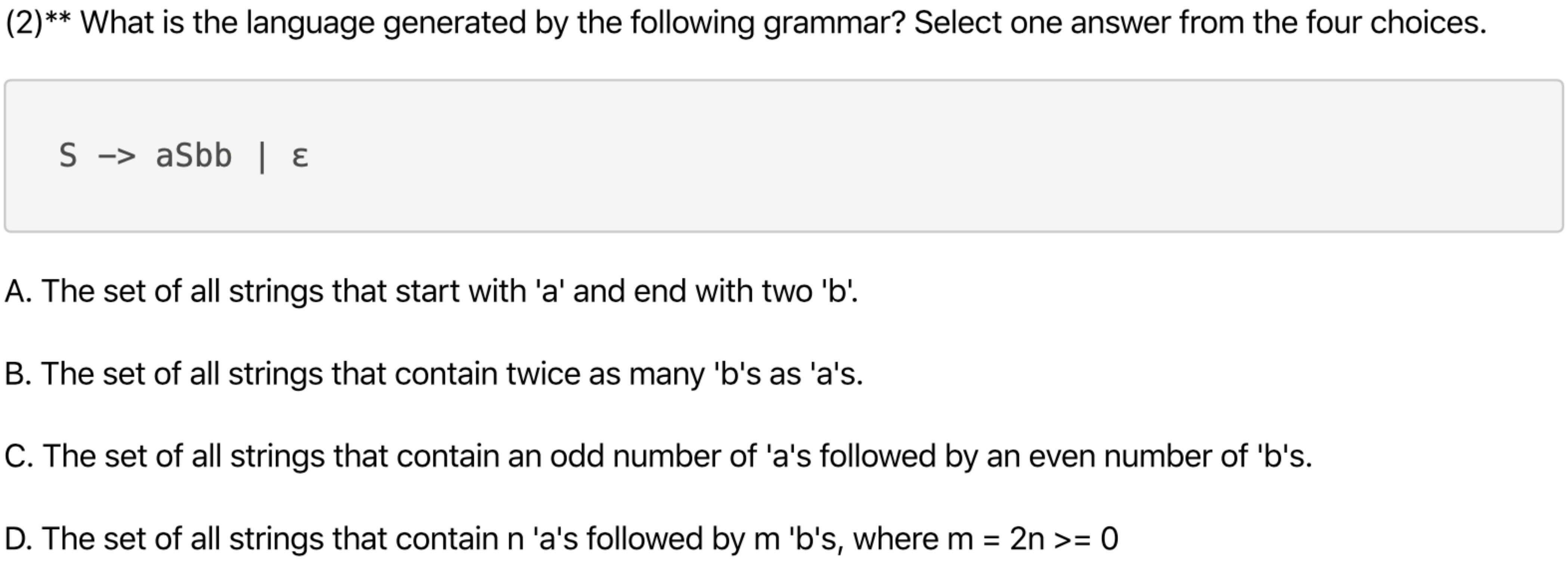
(1) Write a regular expression pattern to match valid music notes according to the criteria below: A music note is represented by a capital letter A to G (inclusive) followed by an optional symbol: sharp (#), flat (b), or natural (n).

```
Example valid inputs: C, D#, Fb, Gn

Example invalid inputs: H, C##, Fm, C#b
```

Note. The sharp symbol ("#") is not a special character in regular expressions. So you do *not* need to escape it with a backslash.

Context-free grammar



(2)** What is the language generated by the following grammar? Select one answer from the four choices.

```
S -> aSbb | ε
```

A. The set of all strings that start with 'a' and end with two 'b'.

B. The set of all strings that contain twice as many 'b's as 'a's.

C. The set of all strings that contain an odd number of 'a's followed by an even number of 'b's.

D. The set of all strings that contain n 'a's followed by m 'b's, where m = 2n >= 0

lambda calculus

- Draw the parse tree of the following lambda terms, and reduce them to the normal form. Write the reduction in details.

    - (λx.(x y))(λz.z)

lambda calculus

- Draw the parse tree of the following lambda terms, and reduce them to the normal form. Write the reduction in details.
  - ((λx.((λy.(x y))x))(λz.w))

Ocaml

- Determine the type of the following Ocaml expression
  - print_endline “hangul”
  - let f x y = x + y in f 3

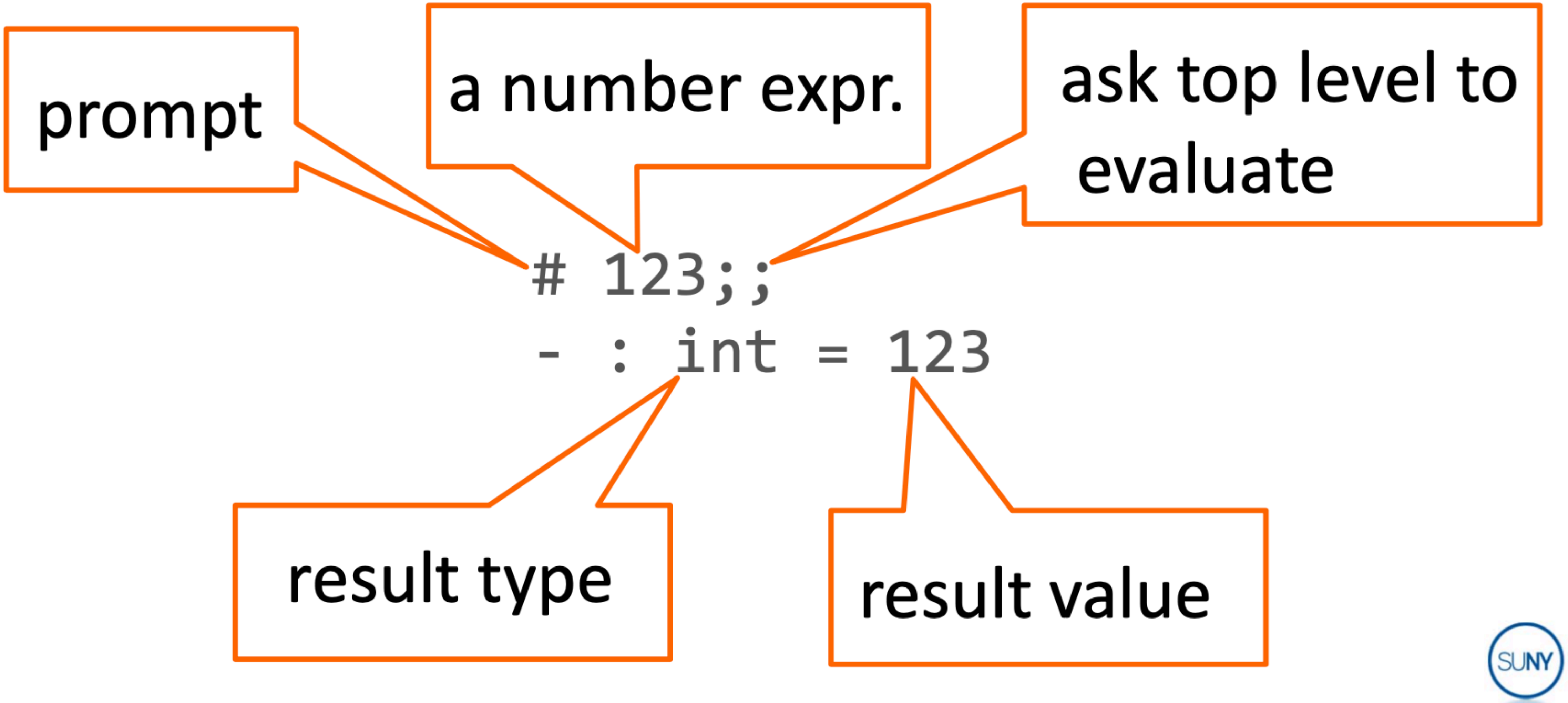
Ocaml

- Determine the type of the following defined Ocaml functions
  - let f x y = x + y
  - let f x = if x then “hello” else “annyeong haseyo"

Ocaml Basics

Numbers

- A primitive expression
- Enter 123;; in the OCaml interactive system (a.k.a. toplevel)



prompt

a number expr.

ask top level to evaluate

```
# 123;;
- : int = 123
```

result type

result value

Arithmetic Operators

- Using arithmetic operators
  - `+ - * / mod    +. -. *. /. **`
- Type 1 + 2 * 3 in the OCaml top level

```
# 1 + 2 * 3;;
- : int = 7
```

- Type 1. +. 2. *. 3.

```
# 1. +. 2. *. 3.;;
- : float = 7.
```

Arithmetic Operators (2)

- For each operator, there is a corresponding function

```
# (+);;
- : int -> int -> int = <fun>
```

- Function application
  - No parenthesis
  - Arguments are separated by spaces

```
# (+) 1 2;;
- : int = 3
```

Arithmetic Operators (3)

- Type coercion is not automatic in OCaml

```
# 1.0 + 2.0;;
Characters 0-3:
  1.0 + 2.0;;
  ^^^
Error: This expression has type float but an expression
         was expected of type int

# 1.0 +. 2.0;;
- : float = 3.
# (+.);;
-  : float -> float -> float = <fun>

# float_of_int 1;;  (* or float 1 *)
- : float = 1.
# int_of_float 1.5;;
- : int = 1
```

Abstraction by Names

- Create a variable to name a value
  - let binding

```
let <variable> = <expr>

# let x = 1 + 2;;
val x : int = 3

# let add = (+);;
val add : int -> int -> int = <fun>
```

Abstraction by Names (2)

- Environment
  - A data structure that keeps track of name-value pairs

```
# x;;
-  : int = 3

# add;;
-  : int -> int -> int = <fun>

# add x 1;;
- : int = 4
```

Evaluating Combinations

- Example

```
# let add = (+);;
val add : int -> int -> int = <fun>

# let mul = ( *);;
val mul : int -> int -> int = <fun>

# let x = 5;;
val x : int = 5

# mul (add 1 (mul 2 3))
      (add 4 x);;
- : int = 63
```

notice the space:
(would start a comment*

Lab exercise

- Try combining x and y using the ^ operator. What error do you see? Choose your own x and y

- Debug and make things right