Introduction to Functional Programming in *OCaml*

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Week 4 - Sequence 1: Functions As First-Class Values

Functions Are Values

- Expressions may denote integers, boolean, . . . , or *functions* :
  `function x -> ...`
- In functional languages, functions are just values of a particular type
- Uniform way of naming a value : `let y = ...`
- Types govern function application: We can apply e_1 to e_2 when
  - e_1 has a type $t_1 \to t_2$
  - t_1 matches the type of e_2

First Class

- This doesn't stop here: Functions may, as any other values
  - be part of a structured data value, like a list,
  - be actual arguments of functions,
  - be the result value of a function application.
- We may say : *Functions are First-Class Values*.

Data Structures Containing Functions I

```
let fl = [(function x -> x+1);(function x -> 2*x)];;
# val fl : (int -> int) list = [<fun>; <fun>]

(List.hd fl) 17;;
# - : int = 18
```

Functions Taking Functions as Argument I

```
let apply_twice f x = f (f x);;
# val apply_twice : ('a -> 'a) -> 'a -> 'a = <fun>

apply_twice (function x -> 2*x) 1;;
# - : int = 4

let rec apply_n_times f n x =
  if n <= 0
  then x
  else apply_n_times f (n-1) (f x);;
# val apply_n_times : ('a -> 'a) -> int -> 'a -> 'a = <fun>

apply_n_times (function x -> 2*x) 10 1;;
# - : int = 1024
```

Functions Returning Functions as Result I

```
let compose f g = (function x -> f(g x));;
# val compose : ('a -> 'b) -> ('c -> 'a) -> 'c -> 'b = <fun>

compose (function x->x+1) (function x->2*x);;
# - : int -> int = <fun>

(compose (function x->x+1) (function x->2*x)) 10;;
# - : int = 21
```

Functions Returning Functions as Result II

```
compose (function x-> x+1) (function x -> x *. 3.14);;
# Characters 43-52:
  compose (function x-> x+1) (function x -> x *. 3.14);;
                                           ^^^^^^^^^^

Error: This expression has type float but an expression was expected
    of type
         int
```

Function Pitfalls

- Functions apply in order from left to right:

```
exp1 exp2 exp3
```

  is equivalent to

```
(exp1 exp2) exp3
```

- We say: *function application associates to the left*

Order of Function Application I

```
let double = function x -> 2*x;;
# val double : int -> int = <fun>

double double 5;;
# Characters 1-7:
  double double 5;;
  ^^^^^^
Error: This function has type int -> int
       It is applied to too many arguments; maybe you forgot a ';'.

double (double 5);;
# - : int = 20
```