

**CS 251** Spring 2020 **Principles of Programming Languages** Ben Wood



# Currying and Partial Application

and other tasty closure recipes

https://cs.wellesley.edu/~cs251/s20/ Currying and Partial Application <sup>1</sup>

# More idioms for closures

- Function composition
- Currying and partial application
- Callbacks (e.g., reactive programming, later)
- Functions as data representation (later)

# Function composition (right-to-left)

fun compose  $(f,g) = fn x \Rightarrow f (g x)$ 

Closure "remembers" f and g

: ('b -> 'c) \* ('a -> 'b) -> ('a -> 'c) REPL prints something equivalent

#### ML standard library provides infix operator o

fun sqrt\_of\_abs i = Math.sqrt(Real.fromInt(abs i))
fun sqrt\_of\_abs i = (Math.sqrt o Real.fromInt o abs) i
val sqrt\_of\_abs = Math.sqrt o Real.fromInt o abs

Right to left.

## Pipelines (left-to-right composition)

#### Common in functional programming.

#### (F#, Microsoft's ML flavor, defines this by default)

# Currying

- Every ML function takes exactly one argument
- Previously encoded *n* arguments via one *n*-tuple
- Another way: Take one argument and return a function that takes another argument and...
  - Called "currying" after logician Haskell Curry

# Example

val sorted3 = fn x => fn y => fn z =>
 z >= y andalso y >= x
val t1 = ((sorted3 7) 9) 11

- 1. Calling (sorted3 7) returns closure #1 with: Code fn y => fn z => z >= y andalso y >= x Environment:  $x \mapsto 7$
- 2. Calling closure #1 on 9 returns closure #2 with: Code fn  $z \Rightarrow z \Rightarrow y$  and also  $y \Rightarrow x$ Environment:  $y \mapsto 9$ ,  $x \mapsto 7$
- 3. Calling closure #2 on 11 returns true

### **Function application is left-associative**

val sorted3 = fn x => fn y => fn z => z >= y andalso y >= x

val t1 = ((sorted3 7) 9) 11

el e2 e3 e4

means

(((e1 e2) e3) e4)

val t1 = sorted3 7 9 11

Callers can just think

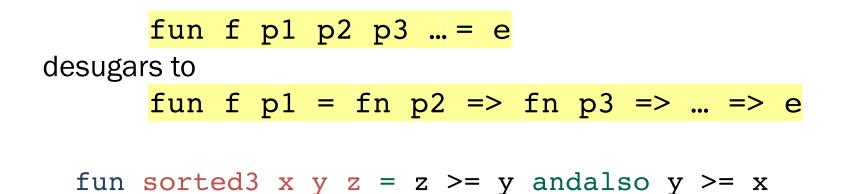
"multi-argument function with spaces instead of a tuple expression"

Does not interchange with tupled version.

## Function definitions are sugar (again)

val sorted3 = fn x => fn y => fn z => z >= y andalso y >= x

val t1 = ((sorted3 7) 9) 11



**Callees** can just think

"multi-argument function with spaces instead of a tuple pattern" Does not interchange with tupled version.

# **Final version**

fun sorted3 x y z = z >= y andalso y >= x val t1 = sorted3 7 9 11

As elegant syntactic sugar (fewer characters than tupling) for:

```
val sorted3 = fn x => fn y => fn z =>
    z >= y andalso y >= x
val t1 = ((sorted3 7) 9) 11
```

Function application is left-associative.

Types are right-associative: sorted3 : int -> int -> int -> bool means sorted3 : int -> (int -> (int -> bool))

# **Curried fold**

fun foldl f acc xs =
 case xs of
 [] => acc
 | x::xs' => foldl f (f(x,acc)) xs'
fun sum xs = foldl (fn (x,y) => x+y) 0 xs

# **Partial Application**

```
fun foldl f acc xs =
   case xs of
   [] => acc
   | x::xs' => foldl f (f(acc,x)) xs'
```

```
fun sum_inferior xs = foldl (fn (x,y) \Rightarrow x+y) 0 xs
```

```
val sum = foldl (fn (x,y) => x+y) 0
```

foldl (fn (x, y) => x+y) 0

evaluates to a closure that, when called with a list xs, evaluates the case-expression with:

f bound to the result of foldl (fn (x,y) => x+y) acc bound to 0

# **Unnecessary function wrapping**

```
fun f x = g x (* bad *)
val f = g (* good *)
(* bad *)
fun sum inferior xs = foldl (fn (x,y) => x+y) 0 xs
(* good *)
val sum = fold (fn (x,y) => x+y) 0
(* best? *)
val sum = fold (op+) 0
               Treat infix operator
               as normal function.
```

# **Iterators and partial application**

```
fun exists predicate xs =
    case xs of
    [] => false
    | x::xs' => predicate x
        orelse exists predicate xs'
    val no = exists (fn x => x=7) [4,11,23]
val hasZero = exists (fn x => x=0)
```

For this reason, ML library functions of this form are usually curried

- List.map, List.filter, List.foldl, ...

# The Value Restriction 🛞

If you use partial application to *create a polymorphic function*, it may not work due to the value restriction

- Warning about "type vars not generalized"
  - And won't let you call the function
- This should surprise you; you did nothing wrong ☺
   but you still must change your code.
- See the code for workarounds
- Can discuss a bit more when discussing type inference

# More combining functions

- What if you want to curry a tupled function or vice-versa?
- What if a function's arguments are in the wrong order for the partial application you want?

Naturally, it is easy to write higher-order wrapper functions

And their types are neat logical formulas

fun other\_curry1 f = fn x => fn y => f y x
fun other\_curry2 f x y = f y x
fun curry f x y = f (x,y)
fun uncurry f (x,y) = f x y