CS 251 Fall 2019
Principles of Programming Languages
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Restricted Mutable State

More idioms

- Pass functions with private data to iterators: Done
- Combine functions (e.g., composition): Done
- Currying (multi-arg functions and partial application): Done
- Callbacks (e.g., in reactive programming)

ML has (restricted) mutation

- Mutable data structures are okay in some situations
  - When "update to state of world" is appropriate model
  - But want most language constructs truly immutable

- ML does this with a separate construct: references

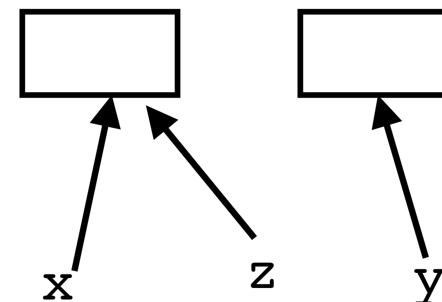
- **Do not use references on your homework.**

References

- New types: `t ref` where `t` is a type
- New expressions:
  - `ref e` to create a reference with initial contents from result of `e`
  - `e1 := e2` to update contents
  - `!e` to retrieve contents (not negation)

References example

```
val x = ref 42
val y = ref 42
val z = x
val _ = x := 43
val w = (!y) + (!z) (* 85 *)
(* x + 1 does not type-check *)
```



- A **variable** bound to a reference (e.g., `x`) is still **immutable**: it will always refer to the same reference
- ***Contents*** of the reference may change via `:=`
- There may be ***aliases*** to the reference, which matter a lot
- References are **first-class** values
- Like a one-field mutable object. `:=` and `!` don't specify field

Callback idiom

Library takes function to apply later, when an *event* occurs.

Library interface:

```
val onKeyEvent : (int -> unit) -> unit
```

Other examples:

- When a key is pressed, mouse moves, data arrives
- When the program enters some state (e.g., turns in a game)

A library may accept multiple callbacks

- Different callbacks need different private data with different types
- Callback function's type does not include the types of bindings in its environment!

Library implementation

Mutable state not absolutely necessary, but is reasonably appropriate.

Create new ref cell with initial contents []

```
val cbs : (int -> unit) list ref = ref []
```

Get contents of ref cell.

```
fun onKeyEvent f =  cbs := f :: (!cbs)
```

Set contents of ref cell.

```
fun onEvent i =
    let
      fun loop fs =
          case fs of
            []      => ()
          | f::fs'  => (f i; loop fs')
    in
      loop (!cbs)
    end
```

Sequencing expression ;
Evaluate left side and throw away result, then evaluate right side and use result.

Clients

Closure's environment captures any necessary context, possibly including mutable state for "remembering" history.

```
val timesPressed = ref 0
val _ = onKeyEvent (fn _ =>
            timesPressed := (!timesPressed) + 1)
fun printIfPressed i =
   onKeyEvent (fn j =>
       if i=j
       then print ("pressed " ^ Int.toString i)
       else ())
fun makeCounterCallback k =
   let count = ref 0 in
     onKeyEvent (fn i => if i=k
                         then count := !count + 1
                         else ());
     count
   end
```