CS109A Notes for Lecture 2/9/96

Curried Functions

In principle, all functions take one argument, but the argument may be a tuple.

However, it is also possible to define a function with more than one parameter and no parentheses called *Curried* form. It makes a subtle difference in the type of the function.

Example:

```
fun add(x,y) = x+y:int;
```
*val add = fn : int * int → int*

```
fun addc x y = x+y:int;
```
val addc = fn : int → int → int

- `add` takes a pair of integers (an `int * int`) and returns their integer sum.
- `addc` takes one integer `x` as argument and returns a function that takes an integer `y` and adds `x` to it.
    - □ Note -> associates from the right, so the type is `int->(int->int)`.

Partial Instantiation

We can name and assign this "intermediate" function.

```
val add3 = addc 3;
```
val add3 = fn : int → int

```
add3(10);
```
val it = 13 : int

Polymorphism

ML restricts types of variables only because it has to.

- A function takes a parameter of a given type.
    - □ e.g., `ord(s)` forces *s* to be a string.

- An overloaded function (e.g., +, <) applies to a variable, which must then be declared.
- A *equality operator*, = or <>, applies to a variable, forcing it to be an *equality type*.
  - Equality types are defined recursively:

Basis: Elementary types (int, etc.) are equality types.

Induction: Tuples or lists of equality types are equality types.

```
fun ins gt (x,nil) = [x]
|   ins gt (x, y::ys) =
    if gt(x,y) then
            y::ins gt (x,ys)
    else x::y::ys;
val ins = fn : ('a * 'a → bool) → 'a * 'a list → 'a list

fun isort gt nil = nil
|   isort gt (x::xs) =
        ins gt (x, (isort gt xs));
val isort = fn : ('a * 'a → bool) → 'a list → 'a list

isort (op >) [3,1,4,1,5,9,2,6];
val it = [1,1,2,3,4,5,6,9] : int list
```

- op converts an infix operator like > into an "ordinary" function that takes a pair of arguments.
  - Conversion is necessary because gt is of that form.

```
fun igt(x:int,y) = x > y;
val igt = fn : int * int → bool

val iisort = isort igt;
val iisort = fn : int list → int list

iisort([5,3,7]);
val it = [3,5,7] : int list
```

Higher-Order Functions

ML makes no restrictions on function types.

- If T_1 and T_2 are any types, then $T_1 \rightarrow T_2$ is also a legal type, representing functions with domain type T_1 and range type T_2.

- Any function whose arguments include one or more function types is a *higher-order function.*

Map

Among the interesting higher-order functions is:

```
fun map F nil = nil
|   map F (x::xs) = F(x)::map F xs;
val map = fn : ('a → 'b) → 'a list → 'b list
```

- Applies function F to each element of a list and returns the resulting list.
- A Curried version of `map` on p. 102, EMLP.

```
fun ++ x = x+1;
val ++ = fn : int → int
```

```
map ++ [1,2,3];
val it = [2,3,4] : int list
```

- Remember that names composed of the usual symbols are legal identifiers in ML.
- We can also use an anonynous function as the first argument of `map`.

```
map (fn x => x+1) [1,2,3]
val it = [2,3,4] : int list
```

- Finally, we can bind the first argument to create a function that applies to lists.

```
val listSq = map(fn x => x*x:int);
val listSq = fn : int list → int list
```

```
listSq([1,2,3,4,5]);
val it = [1,4,9,16,25] ; int list
```

Reduce

- Put a (typically associative) operator between all the elements of a list and evaluate the resulting expression.
  - □ e.g.: `[1,2,3,4]` with `*` as the operator becomes $1 * 2 * 3 * 4 = 24$.
- We'll modify from p. 104, EMLP by also allowing an initial value associated with the empty list, and by Currying partially.

```
fun reduce (F,g) nil = g
|   reduce (F,g) (x::xs) =
    F(x,(reduce (F,g) xs));
val reduce = fn : ('a * 'b → 'b) * 'b → 'a list → 'b

reduce (op *, 1) [2,3,4,5];
val it = 120 :int
```

- The value of this expression is

$$2 * (3 * (4 * (5 * 1)))$$

```
val length =
    reduce (fn(x,y) => y+1, 0);
val length = fn : 'a list → int

length(["a","b","c"]);
val it = 3 : int
```