Agenda

1. SML Docs
   - Standard Basis

2. First-Class Functions
   - Anonymous
   - Style Points
   - Higher-Order

3. Examples

Standard Basis Documentation

Online Documentation

http://www.standardml.org/Basis/index.html

http://www.smlnj.org/doc/smlnj-lib/Manual/toc.html

Helpful Subset

Top-Level	http://www.standardml.org/Basis/top-level-chapter.html
List	http://www.standardml.org/Basis/list.html
ListPair	http://www.standardml.org/Basis/list-pair.html
Real	http://www.standardml.org/Basis/real.html
String	http://www.standardml.org/Basis/string.html

Anonymous Functions

An Anonymous Function

```
fn pattern => expression
```

- An expression that creates a new function with no name.
- Usually used as an argument to a higher-order function.
- Almost equivalent to the following:

```
let fun name pattern = expression in name end
```

- **The difference is that anonymous functions cannot be recursive!!!**

Simple Example

```
fun doSomethingWithFive f = f 5;
val x1 = doSomethingWithFive (fn x => x*2);    (* x1=10 *)
val x2 = (fn x => x+9) 6;                      (* x2=15 *)
val cube = fn x => x*x*x;
val x3 = cube 4;                               (* x3=64 *)
val x4 = doSomethingWithFive cube;             (* x4=125 *)
```

Anonymous Functions

What's the difference between the following two bindings?

```
val name = fn pattern => expression;
fun name pattern = expression;
```

- Once again, the difference is recursion.
- However, excluding recursion, a **`fun`** binding could just be syntactic sugar for a **`val`** binding and an anonymous function.
- This is because there are no recursive **`val`** bindings in SML.

Anonymous Functions (cont.)

Previous Example

```
fun n_times (f,n,x) =  if n=0
                       then x
                       else f (n_times (f, n–1, x));

fun square x = x*x;
fun increment x = x+1;

val x1 = n_times (square, 2, 3);
val x2 = n_times (increment, 4, 7);
val x3 = n_times (tl, 2, [4,8,12,16,20]);
```

With Anonymous Functions

```
val x1 = n_times (fn x => x*x, 2, 3);
val x2 = n_times (fn x => x+1, 4, 7);
val x3 = n_times (fn xs => tl xs, 2, [4,8,12,16,20]);(*Bad Style*)
```

Unnecessary Function Wrapping

What's the difference between the following two expressions?

`(fn xs => tl xs)` vs. `tl`

STYLE POINTS!

- Other than style, these two expressions result in the exact same thing.
- However, one creates an unnecessary function to wrap `tl`.
- This is very similar to this style issue:

`(if ex then true else false)` vs. `ex`

Higher-Order Functions

- A function that returns a function or takes a function as an argument.

Two Canonical Examples

- `map : ('a -> 'b) * 'a list -> 'b list`
  - Applies a function to every element of a list and return a list of the resulting values.
  - Example: `map (fn x => x*3, [1,2,3]) === [3,6,9]`
- `filter : ('a -> bool) * 'a list -> 'a list`
  - Returns the list of elements from the original list that, when a predicate function is applied, result in true.
  - Example: `filter (fn x => x>2, [~5,3,2,5]) === [3,5]`

Note: List.map and List.filter are similarly defined in SML but use currying. We'll cover these later in the course.

Defining map and filter

map

```
fun map (f, lst) =
    case lst of
         [] => []
       | x::xs => f x :: map (f,xs)
```

filter

```
fun filter (f, lst) =
    case lst of
         [] => []
       | x::xs => if f x
             then x:: filter (f, xs)
             else filter (f, xs)
```

Broader Idea

Functions are Awesome!

- SML functions can be passed around like any other value.
- They can be passed as function arguments, returned, and even stored in data structures or variables.
- Functions like `map` are very pervasive in functional languages.
  - A function like `map` can even be written for other data structures such as trees.

Returning a function

```
fun piecewise x = if x < 0.0
                  then fn x => x*x
                  else if x < 10.0
                       then fn x => x / 2.0
                       else fn x => 1.0 / x + x
```

Tree Example

```
(*Generic Binary Tree Type *)
datatype 'a tree = Empty
                 | Node of 'a * 'a tree * 'a tree

(* Apply a function to each element in a tree. *)
val treeMap = fn : ('a -> 'b) * 'a tree -> 'b tree

(* Returns  true iff the given predicate returns
true when applied to each element in a tree. *)
val treeAll = fn : ('a -> bool) * 'a tree -> bool
```