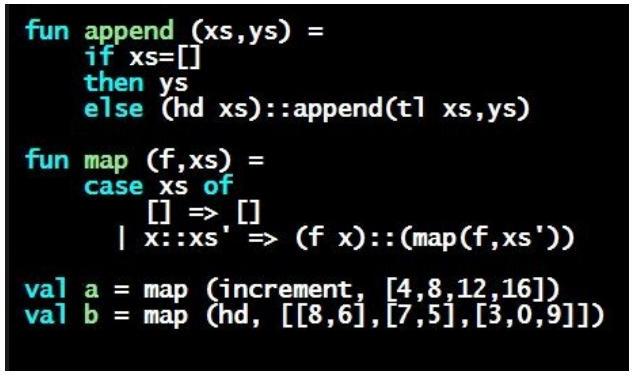

```
fun append (xs,ys) =
    if xs=[]
    then ys
    else (hd xs)::append(tl xs,ys)

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

val a = map (increment, [4,8,12,16])
val b = map (hd, [[8,6],[7,5],[3,0,9]])
```

Programming Languages

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Introducing Lists

Lists

- Despite nested tuples, the type of a variable still "commits" to a particular "amount" of data

In contrast, a list:

- Can have any number of elements
- But all list elements have the same type

Need ways to *build* lists and *access* the pieces…

Building Lists

- The empty list is a value:

```
[]
```

- In general, a list of values is a value; elements separated by commas:

```
[v1,v2,…,vn]
```

- If **`e1`** evaluates to **`v`** and **`e2`** evaluates to a list **`[v1,…,vn]`**, then **`e1::e2`** evaluates to **`[v,…,vn]`**

```
e1::e2 (* pronounced "cons" *)
```

Accessing Lists

Until we learn pattern-matching, we will use three standard-library functions

- `null e` evaluates to `true` if and only if `e` evaluates to `[]`
- If `e` evaluates to `[v1,v2,…,vn]` then `hd e` evaluates to `v1`
  - (raise exception if `e` evaluates to `[]`)
- If `e` evaluates to `[v1,v2,…,vn]` then `tl e` evaluates to `[v2,…,vn]`
  - (raise exception if `e` evaluates to `[]`)
  - Notice result is a list

Type-checking list operations

Lots of new types: For any type `t`, the type `t list` describes lists where all elements have type `t`

- Examples: `int list` `bool list` `int list list`
  `(int * int) list` `(int list * int) list`

- So `[]` can have type `t list` list for *any* type
  - SML uses type `'a list` to indicate this ("quote a" or "alpha")
- For `e1::e2` to type-check, we need a `t` such that `e1` has type `t` and `e2` has type `t list`. Then the result type is `t list`
- `null : 'a list -> bool`
- `hd   : 'a list -> 'a`
- `tl   : 'a list -> 'a list`