Introducing Scheme

A Scheme expression (S-exp) is either an *atom* or a *list*.

An atom can be

- A symbol
- A number
- #t or #f (Boolean values)
- A string (which we will seldom use)

A list is either

- null, which represents the empty list
- or a pair consisting of a head and a tail. The head must be an S-exp (so it could be an atom or a list) and the tail must be a list.

The Scheme interpreter evaluates Scheme expressions.

- The value of an atom: a number, #t, #f, or a string, is the atom itself.
- The value of a symbol is the value bound to it.
- The value of a null list is null.
- The value of a non-null list depends on the head of the list. If the head is one of a specific set of symbols: define, lambda, let, letrec, set!, etc, then the list represents a *special form*. Each special form has its own way of being evaluated.

(More on the next slide)

- If the non-null list is not a special form its values is the result of calling the head of the list as a procedure with the tail of the list as its arguments. For example, the value of

  `(+ 3 4)`

  is 7.
- Note that we can't evaluate the list (1 2 3) because it is not a special form and the head of this list, 1, is not a procedure.

The quote ' is used to prevent evaluation.

'(1 2 3) evaluates to the list (1 2 3)

Basic procedures for working with lists:

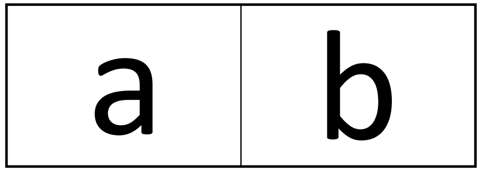
- car (Contents of the Address part of a Register on an old IBM 704) (This is pronounced "car", like an automobile)
- cdr (Contents of the Decrement part of a Register on that 704) (pronounced "could - er"; rhymes with "should stir")
- cons (Construct)

By the way, the IBM 704, introduced in 1954, was the first commercial computer with floating-point hardware. Transistors were just being invented; the 704 was a vacuum tube computer.

Here are the Scheme meanings of the list procedures:

- (cons a b) creates a new pair, where a is the head and b is the tail. If b is a list, this makes a new list.

  (cons a b) creates a *cons-box*

  Note that (1 2) is the same as (list 1 2) and as (cons 1 (cons 2 null))

- (car x) is an error unless x is a pair, in which case (car x) is the head of x. So (car (cons 'a 'b)) is 'a.

- (cdr x) is an error unless x is a cons-box, in which case (cdr x) is the tail of x. So (cdr (cons 'a 'b)) is 'b.

Procedures always evaluate their arguments before performing their actions:

(car (1 2 3)) is an error because the argument (1 2 3)
can't be evaluated.

(car '(1 2 3)) performs the car procedure on the value of
the argument, which is the list (1 2 3).
The head of this list is 1, so
(car '(1 2 3)) => 1.

Examples

- (cons 3 null) => (3)
- (cons 2 (cons 3 null)) => (2 3)
- (cons '(1 2) '(3 4)) => ((1 2) 3 4)
- (car '((1 2) (3 4 5 6)) => (1 2)
- (cdr '(1 2 3)) => (2 3)

cadr is shorthand for "car of the cdr"

```
(cadr '(1 2 3 4)) => (car (cdr '(1 2 3 4)))
                   => (car '(2 3 4))
                  => 2
```

In other words (cadr x) is the second element of list .

Similarly there are procedures caddr, cadddr, etc.

define changes the global environment by binding a value to a symbol.

```
e.g.   (define Beatles '(john paul george ringo))
       (car Beatles)  => 'john
```

The most common things to define are procedures.

Procedures are created with lambda-expressions., following the pattern

```
        (lambda (parameter-list) body)
```

e.g.

```
        (lambda (x) (+ x 5))
as in   ( (lambda (x) (+ x 5)) 6)  => 11
```

or

```
        (lambda () 23)
```

For example

```
(define f (lambda (x y) (+ (* x y) 1)))
(define square (lambda (x) (* x x)))
```

The expression (lambda (parameters) body) evaluates to a *closure*. A closure consists of three parts:

a) the parameter list
b) the body as an un-evaluated expression
c) the environment at the time the lambda expression is evaluated.

Suppose the lambda expression has parameters (x y) and it is called with arguments (a b). This call is evaluated by extending the closure’s environment with a binding of variable x to value a, and a binding of y to value b, and then evaluating the closure’s body in this new environment.

Note that define binds symbols to values, not to expressions.

```
(define f (lambda (x) (+ x 1)))
(define bob (f 0))
(define f (lambda (x) (* x x )))
```

```
bob => 1,  not 0
```

There are two *conditional* expressions:

```
        (if <test>  <test-true exp> <test-false exp>)
```

and

```
        (cond
                [test1 exp1]
                [test2 exp2]
                ... )
```

You can use the symbol *else* for the final test.

Note that the square bracket is just an alternative parenthesis.

E.g.

```
        (if (< 1 2) 3 4) => 3

        (cond [(< 2 1) 3] [(< 5 6) 4] [else 5]) => 4
```

E.g.

```
(if (< 1 2) 3 4) => 3

(cond
    [(< 2 1) 3]
    [(< 5 6) 4]
    [else 5])              => 4
```

We can put all of this together to get our first interesting procedure:

```
(define f (lambda (x)
        (cond
                [(= x 1) 1]
                [else (* x (f (- x 1)))])))
```