Class Information

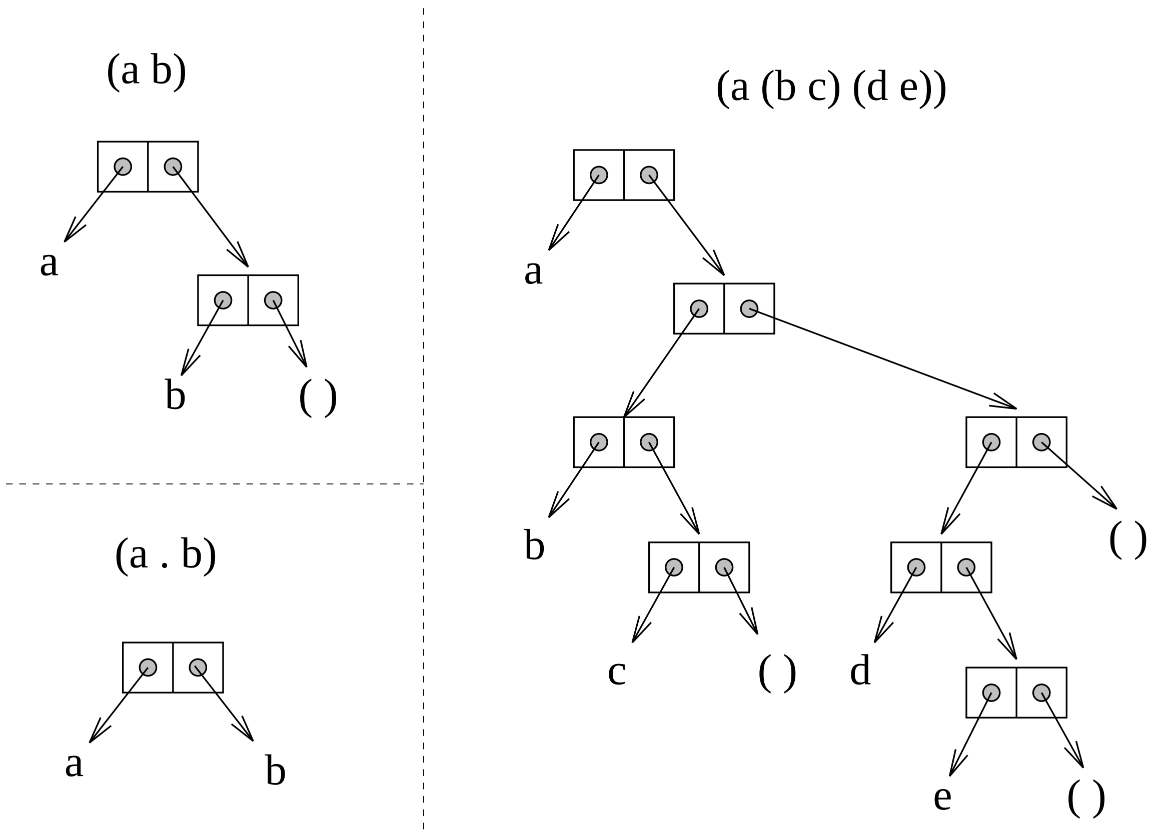
- Homework problem set 6 is due this Friday.
- Midterm exams have been graded, and grades have been posted.

  There were two different exams.

  Average: 180 / 250; range: 65 . . . 249
- Midterm sample solutions are not yet ready. Will post as soon as possible.

Review - Lists in Scheme

The building blocks for lists are pairs or cons-cells. Lists use the empty list ( ) as an "end-of-list" marker.



Note: (a.b) is not a list!

Special (Primitive) Functions

- `eq?`: identity on names (atoms)
- `null?`: is list empty?
- `car`: selects first element of list *(contents of address part of register)*
- `cdr`: selects rest of list *(contents of decrement part of register)*
- `(cons element list)`: constructs lists by adding `element` to front of `list`
- `quote` or `'`: produces constants

Other Functions

- `+ - * /` numeric operators, e.g.,
  `(+ 5 3)` = `8`, `(- 5 3)` = `2`
  `(* 5 3)` = `15`, `(/ 5 3)` = `1.6666666`
- `= < >` comparison operators for numbers
- Explicit type determination and test functions:

  ⇒ All return Boolean values: `#f` and `#t`

  - `(number? 5)` evaluates to `#t`
  - `(zero? 0)` evaluates to `#t`
  - `(symbol? 'sam)` evaluates to `#t`
  - `(list? '(a b))` evaluates to `#t`
  - `(null? '())` evaluates to `#t`

Note: SCHEME is a strongly typed language.

Other Functions

- `(number? 'sam)` evaluates to `#f`
- `(null? '(a))` evaluates to `#f`
- `(zero? (- 3 3))` evaluates to `#t`
- `(zero? '(- 3 3))` $\Rightarrow$ type error
- `(list? (+ 3 4))` evaluates to `#f`
- `(list? '(+ 3 4))` evaluates to `#t`

READ-EVAL-PRINT Loop

The Scheme interpreters on the ilab machines are called mzscheme, racket, and drracket. “drracket” is an interactive environment, the others are command-line based. For example: Type `mzscheme`, and you are in the READ-EVAL-PRINT loop. Use Control D to exit the interpreter.

READ: Read input from user:
  a function application

EVAL: Evaluate input:
  `(f` $\texttt{arg}_1$ $\texttt{arg}_2$ `...`$\texttt{arg}_n$`)`

1. evaluate `f` to obtain a function
2. evaluate each $\texttt{arg}_i$ to obtain a value
3. apply function to argument values

PRINT: Print resulting value:
  the result of the function application

You can write your Scheme program in file <name>.ss and then read it into the Scheme interpreter by saying at the interpreter prompt: `(load "<name>.ss")`

READ-EVAL-PRINT Loop Example

```
> (cons 'a (cons 'b '(c d)))
(a b c d)
```

1. Read the function application
   `(cons 'a (cons 'b '(c d)))`
2. Evaluate `cons` to obtain a function
3. Evaluate `'a` to obtain `a` itself
4. Evaluate `(cons 'b '(c d))`:
   (a) Evaluate `cons` to obtain a function
   (b) Evaluate `'b` to obtain `b` itself
   (c) Evaluate `'(c d)` to obtain `(c d)` itself
   (d) Apply the `cons` function to `b` and `(c d)` to obtain `(b c d)`
5. Apply the `cons` function to `a` and `(b c d)` to obtain `(a b c d)`
6. Print the result of the application:
   `(a b c d)`

Quotes Inhibit Evaluation

```
;;Same as before:
> (cons 'a (cons 'b '(c d)))
(a b c d)

;;Now quote the second argument:
> (cons 'a '(cons 'b '(c d)))
(a cons (quote b) (quote (c d)))

;;Instead, un-quote the first argument:
> (cons a (cons 'b '(c d)))
ERROR: unbound variable:  a
```

Scheme Programming and Emacs

You can invoke the interpreter **mzscheme** Scheme interpreter on the ilab cluster from within `emacs` by executing the commands: ESC-x run-scheme.

Typically, you want to split your emacs window into two parts (CTRL-x 2), and then edit your Scheme file in one window, and execute it in the other. To read a Scheme program into the interpreter, say (load "<name>.ss"). You can switch between windows by saying CTRL-x o.

You can save the "scheme interpreter" window into a file to inspect it later, i.e., to keep a record on what you have done. This may be useful during debugging.

Defining Global Variables

The define constructs extends the current interpreter environment by the new defined (name, value) association.

```
> (define foo '(a b c))
#<unspecified>

> (define bar '(d e f))
#<unspecified>

> (append foo bar)
(a b c d e f)

> (cons foo bar)
((a b c) d e f)

> (cons 'foo bar)
(foo d e f)
```

Defining Scheme Functions

```
(define <fcn-name> (lambda (<fcn-params>)
  <expression>))
```

Example: Given function `pair?` (true for non-empty lists, false o/w) and function `not` (boolean negation):

```
(define atom?
   (lambda (object) (not (pair? object))))
```

Evaluating `(atom? '(a))`:

1. Obtain function value for `atom?`
2. Evaluate `'(a)` obtaining `(a)`
3. Evaluate `(not (pair? object))`
   a) Obtain function value for `not`
   b) Evaluate `(pair? object)`
      i. Obtain function value for `pair?`
      ii. Evaluate `object` obtaining `(a)`
      Evaluates to `#t`
   Evaluates to `#f`

Evaluates to `#f`

Conditional Execution: if

```
(if <condition> <result1> <result2>)
```

1. Evaluate `<condition>`
2. If the result is a “true value” (i.e., anything but `#f`), then evaluate and return `<result1>`
3. Otherwise, evaluate and return `<result2>`

```
(define abs-val
  (lambda (x)
    (if (>= x 0) x (- x))))

(define rest-if-first
  (lambda (e l)
    (if (eq? e (car l)) (cdr l) '())))
```

Conditional Execution: cond

```
(cond (<condition1> <result1>)
      (<condition2> <result2>)
      ...
      (<conditionN> <resultN>)
      (else <else-result>)) ; optional else
                            ; clause
```

1. Evaluate conditions in order until obtaining one that returns a true value
2. Evaluate and return the corresponding result
3. If none of the conditions returns a true value, evaluate and return `<else-result>`

Conditional Execution: cond

```
(define abs-val
  (lambda (x)
     (cond ((>= x 0) x)
           (else (- x)))))

(define rest-if-first
  (lambda (e l)
     (cond ((null? l) '())
           ((eq? e (car l)) (cdr l))
           (else '()))))
```

Recursive Scheme Functions: Abs-List

- `(abs-list '(1 -2 -3 4 0))` ⇒ `(1 2 3 4 0)`
- `(abs-list '())` ⇒ `()`

```
(define abs-list
  (lambda (l)









)
```

Recursive Scheme Functions: Append

(append '(1 2) '(3 4 5)) $\Rightarrow$ (1 2 3 4 5)

(append '(1 2) '(3 (4) 5)) $\Rightarrow$ (1 2 3 (4) 5)

(append '() '(1 4 5)) $\Rightarrow$ (1 4 5)

(append '(1 4 5) '()) $\Rightarrow$ (1 4 5)

(append '() '()) $\Rightarrow$ ()

```
(define append
  (lambda (x y)









)
```

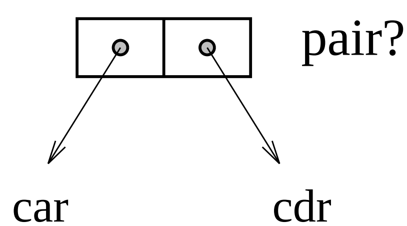
Equality Checking

The `eq?` predicate doesn't work for lists.

Why not?

1. `(cons 'a '())` produces a new list
2. `(cons 'a '())` produces another new list
3. `eq?` checks if its two arguments are *the same*
4. `(eq? (cons 'a '()) (cons 'a '()))` evaluates to `#f`

Lists are stored as pointers to the first element (car) and the rest of the list (cdr). This elementary "data structure", the building block of lists, is called a pair.



Symbols are stored uniquely, so `eq?` works on them.

Equality Checking for Lists

For lists, need a comparison function to check for the same **structure** in two lists

```
(define equal?
  (lambda (x y)
    (or (and (atom? x) (atom? y) (eq? x y))
        (and (not (atom? x)) (not (atom? y))
             (equal? (car x) (car y))
             (equal? (cdr x) (cdr y))))))
```

- `(equal? 'a 'a)` evaluates to `#t`
- `(equal? 'a 'b)` evaluates to `#f`
- `(equal? '(a) '(a))` evaluates to `#t`
- `(equal? '((a)) '(a))` evaluates to `#f`

Next Lecture

Things to do:

- Project 2 (Scheme) will be posted this Saturday; start programming in Scheme!
- Dependence analysis and different notions of parallel execution