Scheme : *variant of LISP*

LISP : John McCarthy (1958)

Scheme : Steele and Sussman (1973)

Those who do not learn from history are doomed to repeat it. - George Santayana

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Scheme (now called Racket)

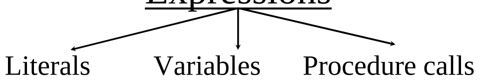
- Scheme = LISP + ALGOL
  - symbolic list manipulation
  - block structure; static scoping
- Symbolic Computation
  - Translators
    - Parsers, Compilers, Interpreters.
  - Reasoners
    - Natural language understanding systems
    - Database querying
  - Data / Text Processors
    - *emacs*

"Striking" Features

- Simple and uniform syntax
- Support for convenient list processing
- (Automatic) Garbage Collection
- Environment for Rapid Prototyping

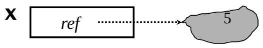
- Intrinsically generic functions
- Dynamic typing (*flexible but inefficient*)
- Compositionality through extensive use of lists. (*minimizing impedance mismatch*)

Expressions



Literals Variables Procedure calls

- Literals
  - numerals(`2`), strings(`"abc"`), boolean(`#t`), etc.
- Variables
  - Identifier *represents* a variable. Variable reference *denotes* the value of its binding.



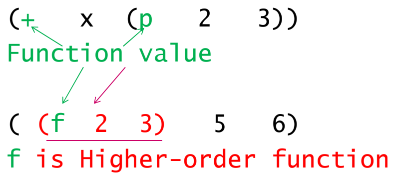
Scheme Identifiers

- *E.g.*, `y`, `x5`, `+`, `two+two`, `zero?`, `list->string`, etc
- *(Illegal)* `5x`, `y)2`, `ab c`, etc
- Identifiers
  - reserved keywords
  - variables
    - pre-defined functions/constants
    - ordinary
- *functions* = *procedures*

Not case sensitive

Procedure Call (application)

- `(operator-expr operand-expr ...)`
  - **prefix** expression (proc/op arg1 arg2 arg3 ...)



```
(+    x  (p   2   3))
Function value

( (f  2  3)   5   6)
f is Higher-order function
```

Simple Scheme Expressions

- `(+ 12 13)`
  `= 25`
- `(/ 12 14)`
  `= 6/7`
- `(+ 2.2+1.1i 2.2+1.1i )`
  `= 4.4+2.2i`
- `(* 2.2+1.1i 0+i )`
  `= (-1.1+2.2i)`
- `(< 2.2 3 4.4 5)`
  `= #t`

- `(positive? 25)`
  `= #t`
- `(negative? (- 1 0))`
  `= #f`
- `(expt 2 10)`
  `= 1024`
- `(sqrt 144)`
  `= 12`
- `(string->number “12” 8)`
  `= 10`
- `(string->number “AB” 16)`
  `= 171`

Scheme Evaluation Rule (REPL)

- *Expression*
  - blank separated, parentheses delimited, nested list structure
- *Evaluation*
  - Evaluate each element of the outerlist **recursively**.
  - Apply the result of the operator expression (*of function type*) to the results of zero or more operand expressions.

Simple Example

```
(+  (* 2 3) (- 4 (/ 6 3) ))
```

```
(+  (* 2 3) (- 4 (/ 6 3) ))

   (+  (* 2 3) (- 4 2) )

          (+ 6 2)
             8
```

Lists

- Ordered sequence of elements of arbitrary type (*Heterogeneous*)
  - – *Empty List* : `()`
  - – *3-element list* : `(a b  3)`
  - – *Nested list* : `(1  (2.3   x)  4)`

- Sets vs lists
  - Duplication matters: `(a)  =/=  (a  a)`
  - Order matters: `(a b) =/=  (b  a)`
  - Nesting-level matters: `( a ) =/= ( (a) )`

Key Point

- Syntax of Scheme programs has been deliberately designed to match syntax of lists -- its most prominent data structure

- Important consequence:

  Supports meta-programming

  - Enables program manipulating programs

Special Forms

- *Definition*

```
(define    <var>    <expr>)
   > (define false  #f)
```

- *Conditional*

```
(if  <test>  <then>  <else>)
    > (if (symbol? 'a)
                (zero?  5)
                (/ 10 0) )
```

Symbols

- Identifiers treated as *primitive values*.
  - – Distinct from identifiers that name variables in program text.
  - – Distinct from strings (sequence of characters).
- Some meta-programming primitives

  `quote`

  `symbol?`

Symbolic Data : `quote` function

“say *your name* aloud”

“say **‘your name’** aloud”

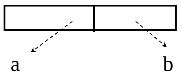
variable *vs* symbolic data (to be taken literally)

- – `(define x 2)`
- – `x` = *2*
- – `(quote x)` = *x*
- – `’x` = *x*
- – `(+ 3 6)` = 9
- – `’(+ 3 6)` -> list value

Pairs

`(cons ’a ’b)`

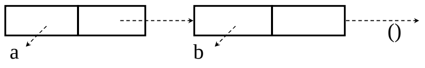
Printed as: `(a . b)`



`(a . (b . ()))`

Printed as: `(a b)`

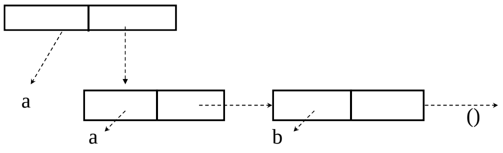
`(cons ’a (cons ’b ’()) )`



(cont’d)

`(cons ’a (cons ’a (cons ’b ’())))`

Printed as: `(a a b)`



List Functions

- *Operations*
  - `car, cdr, cons, null?, ...`
  - `list, append, ...`
  - `cadr, caddr, caaar, ...`
- *Expressions*
  - `( length   (quote (quote a)) )`
  - `( length   '''a )` *= 2*
  - `( length   '''''''quote )`
  - **`(cadar X) = (car (cdr (car X)))`**

`(define xl '(a b c))`

{ *allocate storage for the list and initialize* `xl`}

- `car, first :` list -> element
  - `(car xl)` = *a*
- `cdr :` list -> list
  - `(cdr xl)` = *(b c)*

{ *non-destructive* }

- `cons :` element `x` list -> list
  - `(cons 'a '(b c))` = *(a b c)*

- For all non-empty lists `xl`:

`(cons  (car xl) (cdr xl)) = xl`

- For all `x` and lists `xl`:

`(car (cons x xl)) = x`

`(cdr (cons x xl)) = xl`

- **`car :`** first element of the outermost list.
- **`cdr :`** list that remains after removing `car`.

`(cons '() '())` = ??

`(cons '() '())` = **(())**

- `null? :` list -> boolean
  - `(null? '())` = *#t*
  - `(null? '(a))` = *#f*
  - `(null?  25)` = *#f*
- `list :` elements `x` ... -> list
  - `(list 'a '(a) 'ab)` = *(a (a) ab)*
- `append :` list `x` ...-> list
  - `(append '() (list 'a) '(0))` = *(a 0)*

{ *variable arity functions* }

Role of parentheses

- **Program**
  - Extra call to interpreter

```
(list ’append)
        = (append)

(list (append))
        = (())
```

- **Data**
  - Extra level of nesting

```
(car ’(a))
        =  a

(car ’((a)))
        =  (a)
```

```
(list (append)
      (append))  = ?
        = (()())
```

```
(list append
      append)  = ?
        = (@fn @fn)
```

Equivalence Test

```
(eq? (cons 3 ’()) (cons 3 ’()))      = #f

(define a (cons 3 ’()))
(define b (cons 3 ’()))

(eq? a b)                            = #f

(define c a)

(eq? a c)                            = #t
```

Equivalent Scheme Expressions

```
  (  (car (list append list))
           (cons ’a ’())      ’(1 2 3)  )
= (  append  ’(a)  ’(1 2 3)  )
= ’(a 1 2 3)
```

```
(  (cdr (cons car cdr))
           (cons ’car ’cdr)  )
= (  cdr  ’(car  .  cdr)  )
= ’cdr
```