Scheme

Class outline:

- Scheme expressions
- Special forms
- Quotation

Scheme

A brief history of programming languages

The Lisp programming language was introduced in 1958.

The Scheme dialect of Lisp was introduced in the 1970s, and is still maintained by a standards committee today.

Genealogical tree of programming languages

Scheme itself is not commonly used in production, but has influenced many other languages, and is a good example of a functional programming language.

Scheme expressions

Scheme programs consist of expressions, which can be:

- Primitive expressions: `2` `3.3` `#t` `#f` `+` `quotient`
- Combinations: `(quotient 10 2)` `(not #t)`

Numbers are self-evaluating; symbols are bound to values.

Call expressions include an operator and 0 or more operands in parentheses:

```
> (quotient 10 2)
5
> (quotient (+ 8 7) 5)
3
> (+ (* 3
        (+ (* 2 4)
           (+ 3 5)))
     (+ (- 10 7)
        6))
```

Special forms

Special forms

A combination that is not a call expression is a special form:

- if expression:
  `(if <predicate> <consequent> <alternative>)`
- and/or:
  `(and <e1> ... <en>)`
  `(or <e1> ... <en>)`
- Binding symbols:
  `(define <symbol> <expression>)`
- New procedures:
  `(define (<symbol> <formal parameters>) <body>)`

Scheme spec: special forms

define form

`define <name> <expression>`

Evaluates `<expression>` and binds the value to `<name>` in the current environment. `<name>` must be a valid Scheme symbol.

```
(define x 2)
```

Scheme Spec: define

define procedure

`define (<name> [param] ...) <body>)`

Constructs a new procedure with `param`s as its parameters and the `body` expressions as its body and binds it to `name` in the current environment. `name` must be a valid Scheme symbol. Each `param` must be a unique valid Scheme symbol.

```
(define (double x) (* 2 x) )
```

Scheme Spec: define

If expression

`if <predicate> <consequent> <alternative>`

Evaluates `predicate`. If true, the `consequent` is evaluated and returned. Otherwise, the `alternative`, if it exists, is evaluated and returned (if no `alternative` is present in this case, the return value is undefined).

Example: This code returns the length of non-empty lists and 0 for empty lists:

```
(define nums '(1 2 3))
(if (null? nums) 0 (length nums))
```

Scheme Spec: If

and form

`(and [test] ...)`

Evaluate the `test`s in order, returning the first false value. If no `test` is false, return the last `test`. If no arguments are provided, return `#t`.

Example: This `and` form evaluates to true whenever `x` is both greater than 10 and less than 20.

```
(define x 15)
(and (> x 10) (< x 20))
```

Scheme Spec: And

or form

`(or [test] ...)`

Evaluate the `test`s in order, returning the first true value. If no `test` is true and there are no more `test`s left, return `#f`.

Example: This `or` form evaluates to true when either `x` is less than -10 or greater than 10.

```
(define x -15)
(or (< x -10) (> x 10))
```

Scheme Spec: Or

lambda expressions

Lambda expressions evaluate to anonymous procedures.

`(lambda ([param] ...) <body> ...)`

Two equivalent expressions:

```
(define (plus4 x) (+ x 4))
(define plus4 (lambda (x) (+ x 4)))
```

An operator can be a call expression too:

```
((lambda (x y z) (+ x y (square z))) 1 2 3)
```

Scheme Spec: Lambda

Cond form

The cond special form that behaves similar to if expressions in Python.

```
if x > 10:
    print('big')
elif x > 5:
    print('medium')
else:
    print('small')
```

```
(cond ((> x 10) (print 'big))
    ((> x 5) (print 'medium))
    (else (print 'small)))
```

```
(print (cond ((> x 10) 'big)
    ((> x 5) 'medium)
    (else 'small)))
```

Scheme Spec: Cond

The begin form

```
if x > 10:
    print('big')
    print('pie')
else:
    print('small')
    print('fry')
```

```
(cond ((> x 10) (begin (print 'big) (print 'pie)))
      (else (begin (print 'small) (print 'fry))))
```

Scheme Spec: Begin

The begin form

```
if x > 10:
    print('big')
    print('pie')
else:
    print('small')
    print('fry')
```

```
(cond ((> x 10) (begin (print 'big) (print 'pie)))
       (else (begin (print 'small) (print 'fry))))
```

```
(if (> x 10) (begin
                (print 'big)
                (print 'guy))
              (begin
                (print 'small)
                (print 'fry)))
```

Scheme Spec: Begin

let form

The `let` special form binds symbols to values temporarily; just for one expression

```
a = 3
b = 2 + 2
c = math.sqrt(a * a + b * b)
```

⬆ a and b are still bound down here

```
(define c (let ((a 3)
                (b (+ 2 2)))
               (sqrt (+ (* a a) (* b b)))))
```

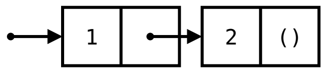
⬆ a and b are **not** bound down here

Scheme Spec: Let

Scheme lists

Constructing a list

Scheme lists are linked lists.



Python (with our `Link` class:)

Constructing a list

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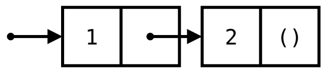

Python (with our `Link` class:)

```
Link(1, Link(2))
```

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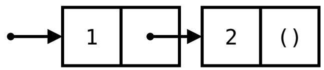


Python (with our `Link` class:)

```
Link(1, Link(2))
```

Scheme (with the `cons` form:)

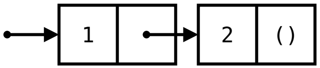
```
(cons 1 (cons 2 nil))
```

`nil` is the empty list.

Lists are written in parentheses with space-separated elements:

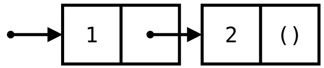
```
(cons 1 (cons 2 (cons 3 (cons 4 nil))))    ; (1 2 3 4)
```

Accessing list elements



Python access:

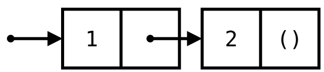
Accessing list elements



Python access:

```
lst = Link(1, Link(2))
lst.first   # 1
lst.rest    # Link(2)
```

Accessing list elements



Python access:

```
lst = Link(1, Link(2))
lst.first   # 1
lst.rest    # Link(2)
```

Scheme access:

```
(define lst (cons 1 (cons 2 nil)))
(car lst)   ; 1
(cdr lst)   ; (2)
```

- `car`: Procedure that returns the first element of a list
- `cdr`: Procedure that returns the rest of the list

Remember: "cdr" = "Cee Da Rest"

The list procedure

The built-in `list` procedure takes in an arbitrary number of arguments and constructs a list with the values of these arguments:

```
(list 1 2 3)                          ; (1 2 3)
(list 1 (list 2 3) 4)
(list (cons 1 (cons 2 nil)) 3 4)
```

Procedure reference: list

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(list 1 (list 2 3) 4)                   ; (1 (2 3) 4)
(list (cons 1 (cons 2 nil)) 3 4)        ; ((1 2) 3 4)
```

Procedure reference: list

Symbolic programming

Referring to symbols

Symbols typically refer to values:

```
(define a 1)
(define b 2)
(list a b)
```

Quotation is used to refer to symbols directly:

```
(list 'a 'b)
(list 'a b)
```

The `'` is shorthand for the `quote` form:

```
(list (quote a) (quote b))
```

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(list (quote a) (quote b))    ; (a b)
```

Quoting lists

Quotation can also be applied to combinations to form lists.

```
'(a b c)          ; (a b c)
(car '(a b c))
(cdr '(a b c))
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```
'(a b c)           ; (a b c)
(car '(a b c))     ; a
(cdr '(a b c))     ; (b c)
```

Scheme tips

- Use the references!
- Auto-format your code!
- Constrain your brain: you're now living in a world of applicative programming. Look, ma, no mutation!