Scheme

Announcements

Scheme

Scheme is a Dialect of Lisp

What is Lisp?

- LISt Processor language – all code consists of either primitives or lists (combinations)
- One of the oldest high-level programming languages
- Dependent on Linked List-like structures
- Functional, not object-oriented programming

Why are we learning Scheme?

- To learn an extremely elegant language
- To see how to learn new programming languages now that you’ve already learned Python
- To lay the foundation for learning about how to write interpreters

What's important in a programming language?

Computation

Variables

Variable assignments

Creating functions

Calling functions

Conditional flow

Scheme Expressions

Scheme programs consist of expressions, which can be:

- Primitive expressions: 2   3.3   true   +   quotient
- Combinations: (quotient 10 2)   (not true)
  - Combinations look like lists! Lists are created with parentheses and delimited with spaces

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))
```

"quotient" names Scheme's built-in integer division procedure (i.e., function)

Combinations can span multiple lines (spacing doesn't matter)

(Demo)

Special Forms

Special Forms

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

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

Evaluation:
(1) Evaluate the predicate expression
(2) Evaluate either the consequent or alternative

```
> (define pi 3.14)
pi
> (* pi 2)
6.28
```

The symbol “pi” is bound to 3.14 in the global frame

```
> (define (abs x)
    (if (< x 0)
        (- x)
        x))
abs
> (abs -3)
3
```

A procedure is created and bound to the symbol “abs”

(Demo)

Booleans in Scheme

False values:

```
    #f
```

True values:

Everything else:

```
    1, 2, #t, -1.2, +

    0, nil - are both true values now! This is different from Python!
```

Defining in Scheme

```
>>> x = 4
```

```
scm> (define x 4)
```

```
>>> def f(x, y):
        return x + y
```

```
scm> (define (f x y)
             (+ x y))
```

```
>>> f(1, 2)
3
```

```
scm> (f 1 2)
3
```

Scheme Interpreters

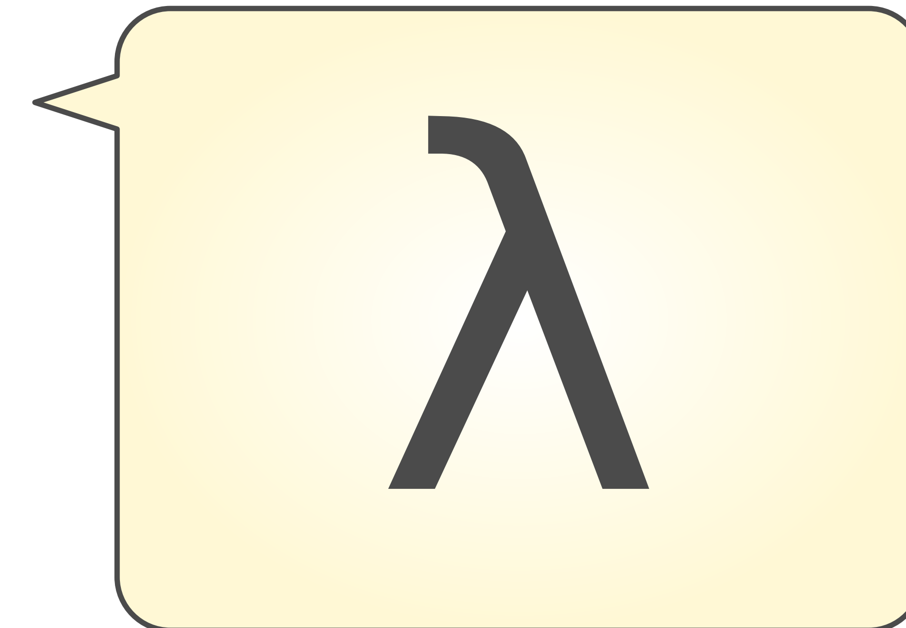
(Demo)

Lambda Expressions

Lambda Expressions

Lambda expressions evaluate to anonymous procedures

```
(lambda (<formal-parameters>) <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)  ▶  12
```

Evaluates to the $x+y+z^2$ procedure

Sierpinski's Triangle

(Demo)

More Special Forms

Cond & Begin

The cond special form that behaves like if-elif-else statements 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)))
```

The begin special form combines multiple expressions into one expression

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

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

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

Let Expressions

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)))))
```

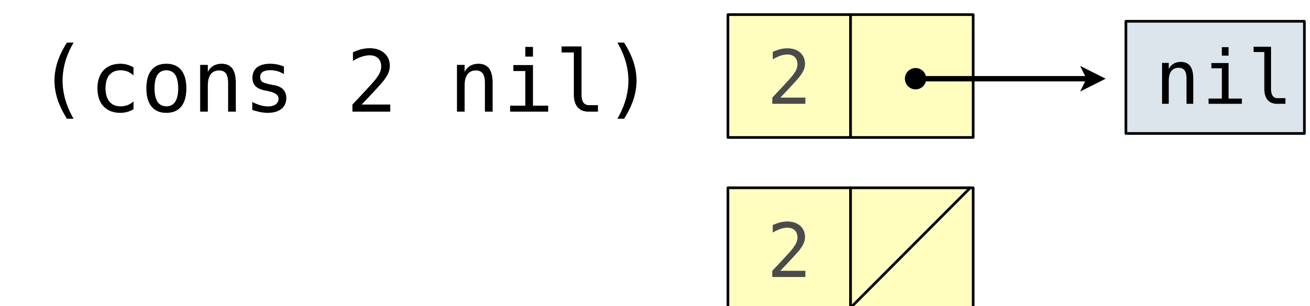
*a and b are **not** bound down here*

Lists

Scheme Lists

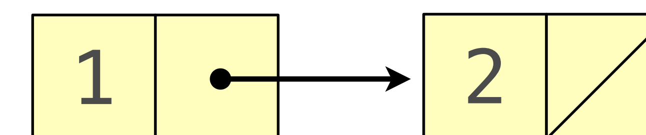
In the late 1950s, computer scientists used confusing names

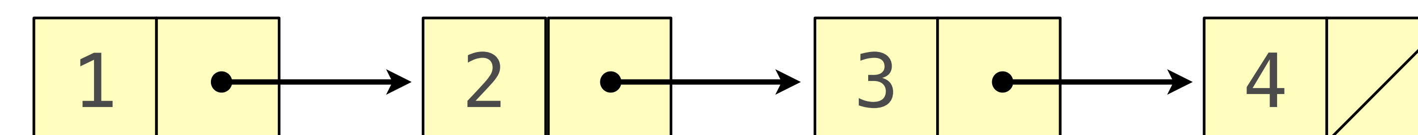
- **cons:** Two-argument procedure that creates a linked list
- **car:** Procedure that returns the first element of a list
- **cdr:** Procedure that returns the rest of a list
- **nil:** The empty list



Important! Scheme lists are written in parentheses with elements separated by spaces

```
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 (cons 2 nil))
> x
(1 2)
> (car x)
1
> (cdr x)
(2)
> (cons 1 (cons 2 (cons 3 (cons 4 nil))))
(1 2 3 4)
```





(Demo)

Scheme Lists vs. Linked Lists

Scheme	Python
`(cons a b)`	`Link(a, b)`
`(car a)`	`a.first`
`(cdr a)`	`a.rest`
`(list a b c)`	`Link(a, Link(b, Link(c)))`

Symbolic Programming

Symbolic Programming

Symbols normally refer to values; how do we refer to symbols?

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

No sign of “a” and “b” in the resulting value

Quotation is used to refer to symbols directly in Lisp.

```
> (list 'a 'b)
(a b)
> (list 'a b)
(a 2)
```

Short for (quote a), (quote b): Special form to indicate that the expression itself is the value.

Quotation can also be applied to combinations to form lists.

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

(Demo)