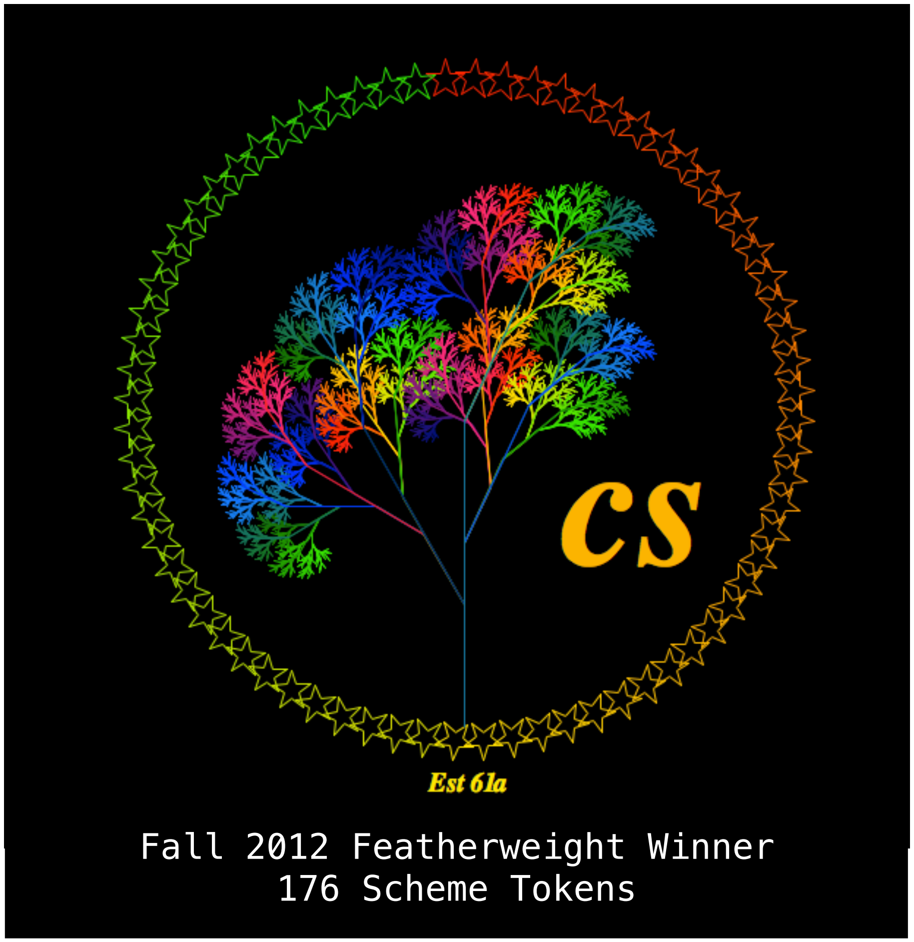
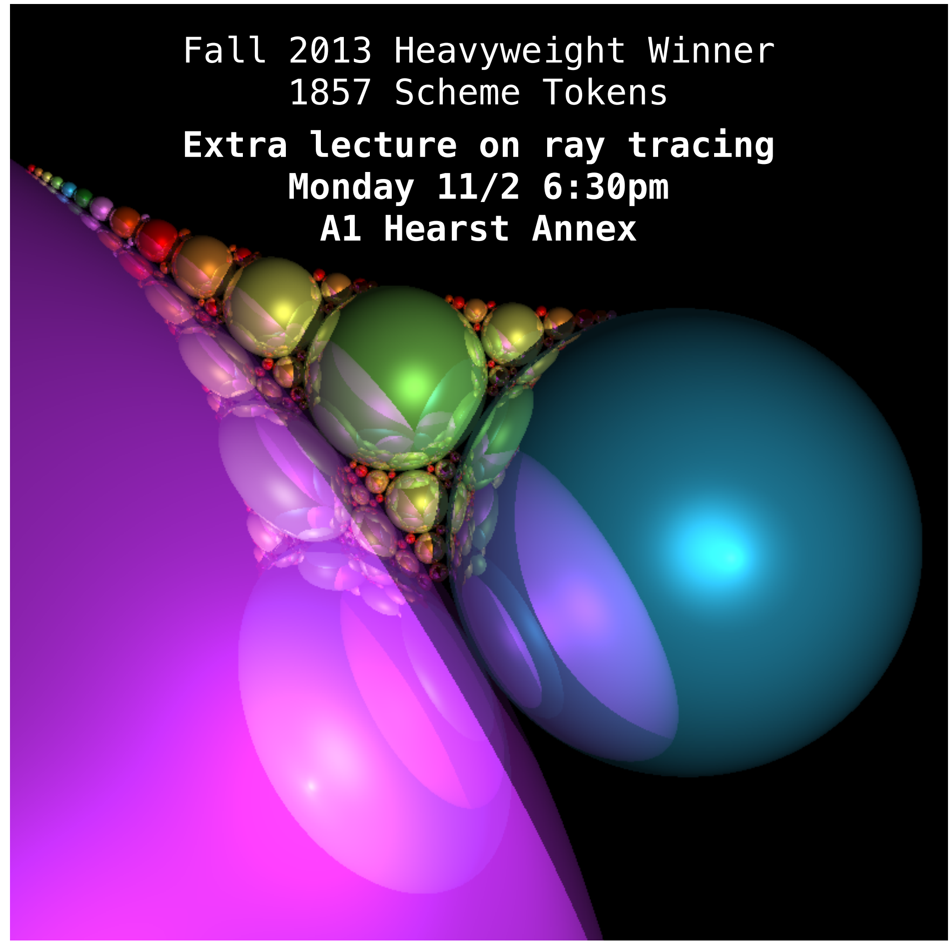
# 61A Lecture 26

# Announcements

# Scheme Recursive Art Contest: Start Early!



# Interpreting Scheme

# The Structure of an Interpreter

***Eval***

Base cases:
- Primitive values (numbers)
- Look up values bound to symbols

Recursive calls:
- Eval(operator, operands) of call expressions
- Apply(procedure, arguments)
- Eval(sub-expressions) of special forms

Requires an environment for symbol lookup

***Apply***

Base cases:
- Built-in primitive procedures

Recursive calls:
- Eval(body) of user-defined procedures

Creates a new environment each time a user-defined procedure is applied

# Special Forms

# Scheme Evaluation

The scheme_eval function choose behavior based on expression form:

- Symbols are looked up in the current environment
- Self-evaluating expressions are returned as values
- All other legal expressions are represented as Scheme lists, called combinations

Special forms are identified by the first list element

```
(if <predicate> <consequent> <alternative>)

(lambda (<formal-parameters>) <body>)

(define <name> <expression>)

(<operator> <operand 0> ... <operand k>)
```

Any combination that is not a known special form is a call expression

```
(define (demo s) (if (null? s) '(3) (cons (car s) (demo (cdr s))) ))

(demo (list 1 2))
```

# Logical Forms

# Logical Special Forms

Logical forms may only evaluate some sub-expressions

- **If** expression: (**if** <predicate> <consequent> <alternative>)
- **And** and **or**: (**and** <e1> **...** <en>), (**or** <e1> **...** <en>)
- **Cond** expression: (**cond** (<p1> <e1>) **...** (<pn> <en>) (else <e>))

The value of an if expression is the value of a sub-expression:

- Evaluate the predicate
- Choose a sub-expression: <consequent> or <alternative>
- Evaluate that sub-expression to get the value of the whole expression

do_if_form

(Demo)

# Quotation

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The quote special form evaluates to the quoted expression, which is not evaluated

(quote <expression>)     (quote (+ 1 2))     evaluates to the three-element Scheme list     (+ 1 2)

The <expression> itself is the value of the whole quote expression

'<expression> is shorthand for (quote <expression>)

(quote (1 2))     is equivalent to     '(1 2)

The scheme_read parser converts shorthand ' to a combination that starts with quote

(Demo)

# Lambda Expressions

# Lambda Expressions

Lambda expressions evaluate to user-defined procedures

```
(lambda (<formal-parameters>) <body>)

(lambda (x) (* x x))
```

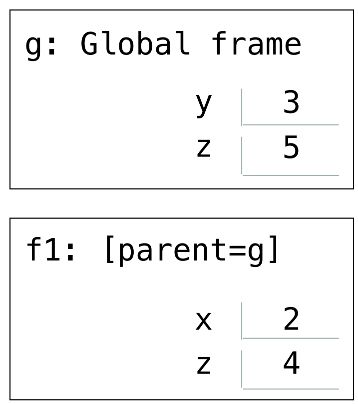
```
class LambdaProcedure:
    def __init__(self, formals, body, env):
        self.formals = formals     A scheme list of symbols
        self.body = body           A scheme list of expressions
        self.env = env             A Frame instance
```

# Frames and Environments

A frame represents an environment by having a parent frame

Frames are Python instances with methods **lookup** and **define**

In Project 4, Frames do not hold return values




(Demo)

# Define Expressions

# Define Expressions

Define binds a symbol to a value in the first frame of the current environment.

```
(define <name> <expression>)
```

1. Evaluate the <expression>
2. Bind <name> to its value in the current frame

```
(define x (+ 1 2))
```

Procedure definition is shorthand of define with a lambda expression

```
(define (<name> <formal parameters>) <body>)

(define <name> (lambda (<formal parameters>) <body>))
```

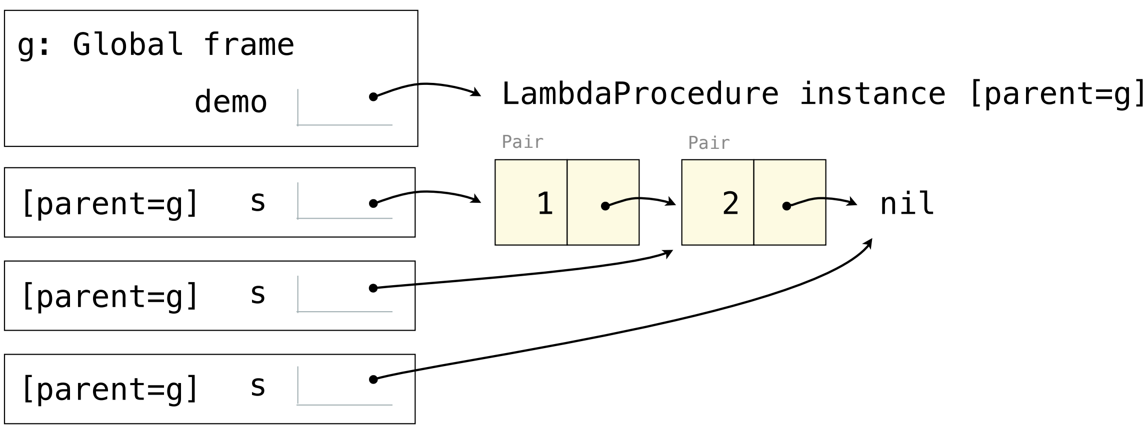
# Applying User-Defined Procedures

To apply a user-defined procedure, create a new frame in which formal parameters are bound to argument values, whose parent is the **env** attribute of the procedure

Evaluate the body of the procedure in the environment that starts with this new frame

```
(define (demo s) (if (null? s) '(3) (cons (car s) (demo (cdr s)))))

(demo (list 1 2))
```



# Eval/Apply in Lisp 1.5

```
apply[fn;x;a] =
      [atom[fn] → [eq[fn;CAR] → caar[x];
                  eq[fn;CDR] → cdar[x];
                  eq[fn;CONS] → cons[car[x];cadr[x]];
                  eq[fn;ATOM] → atom[car[x]];
                  eq[fn;EQ] → eq[car[x];cadr[x]];
                  T → apply[eval[fn;a];x;a]];
      eq[car[fn];LAMBDA] → eval[caddr[fn];pairlis[cadr[fn];x;a]];
      eq[car[fn];LABEL] → apply[caddr[fn];x;cons[cons[cadr[fn];
                                                      caddr[fn]];a]]]
eval[e;a] = [atom[e] → cdr[assoc[e;a]];
       atom[car[e]] →
                [eq[car[e],QUOTE] → cadr[e];
                eq[car[e];COND] → evcon[cdr[e];a];
                T → apply[car[e];evlis[cdr[e];a];a]];
      T → apply[car[e];evlis[cdr[e];a];a]]
```