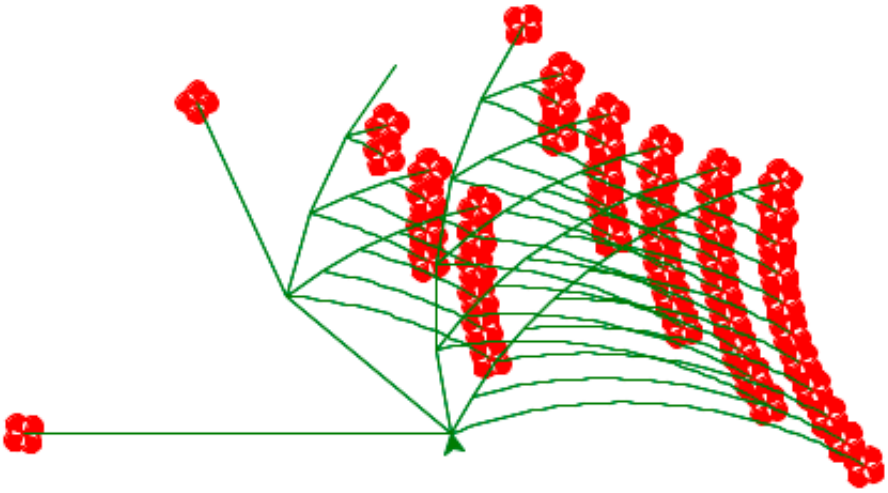
Project 4: A Scheme Interpreter



Eval calls apply,

which just calls eval again!

When does it all end?

Introduction

In this project, you will develop an interpreter for a (slightly modified) subset of the Scheme language. As you proceed, think about the issues that arise in the design of a programming language; many quirks of languages are the byproduct of implementation decisions in interpreters and compilers.

You will also implement some small programs in Scheme, including the `count_change` function that we studied in lecture. Scheme is a simple but powerful functional language. You should find that much of what you have learned about Python transfers cleanly to Scheme as well as to other programming languages. To learn more about Scheme, you can read Brian Harvey and Matthew Wright's *Simply Scheme* textbook online for free.

This project concludes with an open-ended graphics contest that challenges you to produce recursive images in only a few lines of Scheme. As an example of what you might create, the picture above abstractly depicts all the ways of making change for $0.50 using U.S. currency. All flowers appear at the end of a branch with length 50. Small angles in a branch indicate an additional coin, while large angles indicate a new currency denomination. In the contest, you

too will have the chance to unleash your inner recursive artist.

This project includes several files, but all of your changes will be made to the first three: `scheme.py`, `tests.scm`, and `contest.scm`. You can download all of the project code as a zip archive.

`scheme.py`	The Scheme evaluator
`tests.scm`	A set of small test cases and expected outputs for your interpreter
`contest.scm`	A place to write your contest entry
`scheme_tokens.py`	A Tokenizer for scheme
`scheme_primitives.py`	Defines primitive Scheme data structures and primitive functions via the Python Library
`scheme_prelude.scm`	A few more standard functions, defined in Scheme and read during initialization of the interpreter.
`scheme_test.py`	A testing framework for Scheme
`scheme_utils.py`	A few useful utilities.
`ucb.py`	Utility functions for 61A

Logistics

This is a three-part project. As in the previous project, you'll work in a team of two people, person A and person B. In each part, you will do some of the work separately, but most questions can be completed as a pair. Both partners should understand the solutions to all questions.

After completing the first (short) part, you will be able to read and parse Scheme expressions. In the second (long) part, you will develop the interpreter in stages:

1. Calls on primitive functions (those implemented in Python);
2. Symbol evaluation and simple definition;
3. Lambda expressions and complex (function) definitions;

4. Calls on functions created by lambda expressions;
5. Assignment to variables;
6. Conditional expressions;
7. The `let` expression.

Finally, in the third part, you will write Scheme programs.

There are 30 possible points, along with 4 extra credit points. The extra credit problems are a bit involved; we recommend that you complete them all, but only *after* you have the regular stuff working. Finally, participants in the contest can earn up to 3 additional points, along with the glory of victory.

The Scheme Language

Before you begin working on the project, review what you have learned in lecture about the Scheme language. If you would like to experiment with a working Scheme interpreter, look at Stk, which is installed on instructional machines as `stk`.

We've implemented some standard Scheme procedures in Scheme, and you can look at these for examples. They are in the file `scheme_prelude.scm`. (The term *standard prelude* refers to any such collection of definitions that is (at least in effect) executed to establish standard definitions before any program is run.)

Read-Eval-Print. Run interactively, our interpreter reads Scheme expressions from the terminal (the standard input, to be precise), evaluates them, and prints the results. Our interpreter uses `scm>` as the prompt.

```
scm> 2
2
```

The starter code for your Scheme interpreter in `scheme.py` can successfully evaluate this simple expression, since it consists of a single literal numeral. The rest of the examples in this section *will not* work until you complete various portions of the project.

Certain expressions are given no specified value in the Scheme standard. The STk interpreter (annoyingly, in my opinion) prints `okay` for some of these and prints various random things for others (for example, it prints the symbol just defined as the value of the

`define` expression.) Our interpreter, by contrast, returns a special value (called `UNSPEC` in the Python code) that the read-eval-print loop does not print (likewise, our Python interpreter does not print `None`; however `UNSPEC` is not intended to be used in programs, unlike `None`.)

Non-standard Symbols. Our Scheme subset does not have strings. Instead, we use Scheme symbols for this purpose. Officially, symbols in Scheme need only support a limited set of characters. For example, whitespace, parentheses, and apostrophes are not part of this set, for the obvious reason that they have other lexical significance as delimiters in Scheme. However, Scheme dialects are allowed to introduce various extensions that allow extended symbols containing arbitrary characters. In our dialect, you can create non-standard symbols using "|" (vertical bar) as the quotation character. Within such symbols, you can use the standard Python backslash-escapes, with the addition of `\|`, which is how one includes a vertical bar in a non-standard symbol. When printed using the standard Scheme function `display`, the symbols are printed without the quotes and with the escape sequences translated. For example,

```
scm> '(|ALLCAPS| |a string| |two\nlines| |\|x\||)
(|ALLCAPS| |a string| |two\nlines| |\|x\||)
scm> (begin (display '(|ALLCAPS| |a string| |two\nlines| |\|x\||)) (newline))
(ALLCAPS a string two
lines |x|)
```

Non-standard Functions.

Load. Our `load` function differs from standard Scheme in that, since we don't have strings, we use a symbol for the file name. For example

```
scm> (load 'mytests.scm)
scm> (load '|filename with blanks.scm|)
```

Exiting. The functions `bye` or `exit` terminate the interpreter. They allow an extra numeric argument giving the Unix exit code (0 for normal exit, non-zero otherwise).

Words and Sentences. Mostly for the heck of it, we've added a number of functions from the Simply Scheme extensions used in courses at Berkeley. Specifically:

- `(sentence A B ...)` concatenates lists, but also allows symbols and numbers as arguments, treating these as one-element lists.
- `(word A B ...)` concatenates the string representations of the symbols and numbers A, B, etc. into a new symbol or number.
- `(first A)` the first item in (`car` of) A if it a list, or a symbol or number consisting of the first character in A's representation, if A is symbol or number.
- `(last A)` the last item in A if it a list, or a symbol or number consisting of the last character in A's representation, if A is symbol or number.
- `(butfirst A)` if A is a list, its `cdr`, and otherwise if it is a symbol or number, the symbol or number consisting of all but the first character in A's repreentation (abbreviation: `bf`)
- `(butlast A)` if A is a list, the list consisting of all but its last element, and otherwise if it is a symbol or number, the symbol or number consisting of all but the last character in A's repreentation (abbreviation: `bl`).

For example,

```
scm> (sentence 'a 'b '(c d) '() '(e))
(a b c d e)
scm> (first 'abc)
a
scm> (last 'abc)
c
scm> (bf 'abc)
bc
scm> (bl 'abc)
ab
scm> (first '(1 2 3))
1
scm> (bf '(1 2 3))
(2 3)
scm> (last '(1 2 3))
3
scm> (bl '(1 2 3))
(1 2)
```

Turtle Graphics. Finally, to keep up the traditions of recent years, we've added some simple routines for turtle graphics, described later, that simply call functions in the Python

`turtle` package (whose documentation we suggest you see; for one thing, it will let you try out turtle-graphics programs in Python).

Testing

This time, we're letting you come up with tests. As you complete each problem, add tests to the file `tests.scm` of the constructs you have implemented. expressions that you can examine and test to become more familiar with the language. Each line that prints output is followed by the expected result as a comment.

You can run all commands in a file using your Scheme interpreter by passing the file name as an argument to `scheme.py`.

```
# python3 scheme.py tests.scm
```

You can also compare the output of your interpreter to the expected output by passing the file name to `scheme_test.py`.

```
# python3 scheme_test.py tests.scm
```

This is a rather useful script (we used it in developing this project and its solution, for example). As you'll see, `tests.scm` contains Scheme expressions interspersed with comments in the form

```
; expect 3
```

The `scheme_test` script collects these expected outputs and compares them with the actual output from the program, counting and reporting mismatches.

You can even test that your interpreter catches errors. The problem with error tests is that there is no "right" output. Our script, therefore, only requires that error messages start with "`Error`". Any such line will match

```
; expect Error
```

There's an example in the initial `tests.scm` file.

Don't forget to use the `trace` decorator from the `ucb` module to follow the path of execution in your interpreter.

As you develop your Scheme interpreter, you may find that Python raises various uncaught exceptions when evaluating Scheme expressions. As a result, your Scheme interpreter will crash. Some of these may be the results of bugs in your program, and some may be useful indications of errors in user programs. The former should be fixed (of course!) and the latter should be caught and changed into `SchemeError` exceptions, which are caught and printed as error messages by the Scheme read-eval-print loop we've written for you. Python exceptions that "leak out" to the user in raw form are errors in your interpreter (tracebacks are for implementors, not civilians).

Preliminary: Read Some Code

This project is about modifying a modestly complex piece of existing code. In such a situation, it's good to take time at the outset to read what's provided, try to understand what's there, and accumulate questions about parts you don't understand *before* trying to mess around with it. Indeed, a lot of what you take away from this project will simply be what you learn by reading all the code you *don't* have to write. In many cases, you'll be able to experiment with parts of it in isolation, simply by starting up an interactive Python session and using `import` to get access to the parts you'd like to play with.

Take a look over all the files provided with this project (with your partner, of course). Look particularly at `scheme_primitives.py`, which defines the basic data structures that Scheme programs manipulate (subclasses of `SchemeValue`), and at the classes in `scheme.py` that define the Scheme values devoted to functions (subclasses `LambdaFunction` (for functions defined with `lambda` and `define`) and `PrimitiveFunction` (for functions implemented directly in Python). The implementations of primitive functions in `scheme_primitives.py` may be useful to you in understanding how these data structures work.

In the file `scheme.py`, look at `read_eval_print`, which is the top-level function that defines the interpreter's actions. Look also at the class `EnvironFrame`, which represents environment frames (just like those in the text and in lecture). Look at the `run` function and what it calls to see how the interpreter gets initialized and how the global environment comes to be.

You won't have to modify `scheme_tokens.py`, but since you will be modifying the reader

(and since we can ask you anything we want on tests), it might be a good idea to understand the routines it provides and how they are used. At any given time, the "current port" is a `Buffer` (see `scheme_utils.py`), which is used to provide a continuous stream of tokens from a token source. See if you can figure out how to look at the token stream produced for a small Scheme file.

Finally, it would be a good idea to start trying to understand evaluation, which is concentrated in the class `Evaluation` in `scheme.py`.

Part 1: The Reader

The function `scm_read` in `scheme.py` is intended to read Scheme expressions from the "current port" (input source) and return them in their internal form (as various types of `SchemeValue`). At the moment, it only handles numbers, symbols, boolean values, and the end of file.

Problem 1 (2 pt). Your first task, with your partner, is to complete `scm_read` by filling in the portions responsible for reading pairs, lists, and items quoted by the apostrophe (the reader is supposed to treat `'S` as a synonym for `(quote S)`).

The syntax for pairs and lists is a left parenthesis, followed by a "tail", defined as

- A right parenthesis, indicating the null list, or
- A Scheme expression, *H*, followed either by
  - A period, a Scheme expression, *T*, and a right parenthesis.
  - Or (recursively) by a tail, *T*.

  In either case, the indicated value is a pair consisting of *H* and *T*.

The nested function `read_tail` reads the tail, returning its value. For example, the value returned for "`(1 2 . 3)`" consists of the value of the tail "`1 2 . 3)`", which is

- the pair consisting of the Scheme value `1` and the value of the tail "`2 . 3)`", which is
  - the pair consisting of the Scheme value `2` and the Scheme value `3`.

Thus, the value denoted is `Pair(Number(1), Pair(Number(2), Number(3)))`.

As another example, the value returned for "`(1 2)`" is the value of the tail "`1 2)`", which is

- the pair consisting of the Scheme value `1` and the value of the tail "`2)`", which is
  - the pair consisting of the Scheme value `2` and the value of the tail "`)`", which is the empty list.

so that the value denoted is `Pair(Number(1), Pair(Number(2), NULL))`.

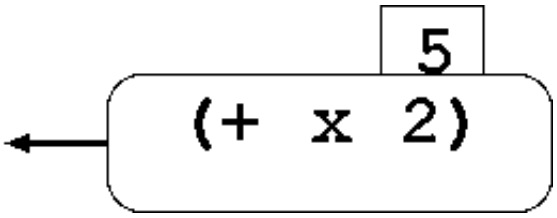
You'll be able to test the resulting reader by easily enough, since the initial project simply prints the Scheme expressions that it reads without evaluating them, so a Unix command like

```
# python3 scheme.py tests.scm
```

will just read `tests.scm` (or any other file full of Scheme expressions), convert them to internal Scheme values, and print out these values.

Part 2: The Evaluator

The heart of the evaluator is the class `Evaluation`, which corresponds roughly to those round-cornered boxes containing expressions and values with links to environment frames:



That is, an `Evaluation` contains an expression being evaluated and the environment in which to evaluate it, or else (if `.evaluated()` is true) a value that requires no further evaluation. Each call to the `.step()` method on an `Evaluation` makes some progress towards a final value: either it finishes the evaluation (so that `.evaluated()` becomes true), or it performs some of the evaluation, and replaces its expression and environment with new ones that, if evaluated, will complete the evaluation.

We do it this way to make tail-recursive programs into iterative ones (Python implementations will eventually run out of space if they pursue a tail-recursive program too far, whereas in Scheme programs, tail recursion is supposed to be the same as iteration). For example, if the expression to be evaluated is a call on a primitive function, then one evaluation step will evaluate the arguments and call the primitive function, completing the

evaluation. However, if the expression is a call on a user-defined function, then an evaluation step will evaluate the arguments of the call, then replace the `Evaluation`'s expression with the body of the user-defined function, and its environment with a new local environment defining the parameters (just as we showed in lecture long ago for Python). Subsequent evaluation steps will evaluate the body. Take a look at the code for the `begin` special form (`do_begin_form`) for a simple example of evaluating a list of expressions, returning the value of the last one.

Problem 2. First, follow the directions in `scm_eval` to make it actually evaluate expressions as intended.

Problem A2 (2 pt). Now we are going to get simple symbol evaluation and definition to work. The first part is to handle the missing symbol case in `Evaluation.step`. Fill this in to properly evaluate `expr` when it consists of a single Scheme symbol. There are a few values you'll be able to look at: the values of primitive functions, such as `+`.

Problem B2 (2 pt). There are two missing parts in the method `do_define_form`, which handles the `(define ...)` construct. Here, we'll do just the first part: handling cases like

```
(define pi 3.1415926)
```

where the defined symbol appears alone. Fill in the missing piece to make this work. When combined with your partner's work on A2, you should now be able to do things like

```
scm> (define x 15)
scm> (define y x)
scm> y
15
```

Now that you can created symbols and give them simple values, it should be easy to come up with tests for A2 and B2 to add to `tests.scm`.

Problem 3 (2 pt). The function `do_call_form` is supposed to evaluate a function call. It does so by evaluating the operands of the call and then using the `apply_step` method, which is supposed to be defined for the first, "operator", operand. At the moment, however, it is incomplete. Instead, the provided implementation just evaluates the operator, and then simply calls the `apply_step` method on it with no arguments.

Also, neither of the `apply_step` bodies—that of `PrimitiveFunction` and that of `LambdaFunction`—are complete. Instead, they simply set the `Evaluation` they are passed so that it immediately evaluates to `#f` (false).

Implement `do_call_form` and `PrimitiveFunction.apply_step` correctly. After you're finished, your evaluator should be able to evaluate calls on primitive functions. For example, you should see the following results:

```
scm> (+ 2 3)
5
```

(By the way: at this point, you can start calling the various turtle graphics functions through your interpreter.)

As always, your implementation should check for errors in the input line! A call such as

```
scm> (quotient 1)
```

should cause your `apply_step` procedure to raise a `SchemeError`, which the `read_eval_print` function will duly report. It turns out to be easy to arrange for this. The `quotient` is implemented as a call to the Python function `scm_quotient`. You might see what Python does when you call a function with the wrong number of arguments and figure out how you can use that to solve the problem of detecting and properly reporting errors.

Be sure you've added tests to `tests.scm` for what you've implemented.

Problem 4. Now we turn to user-defined functions, represented by values of type `LambdaFunction`. When you've finished parts A4 and B4, you should be able to enable the commented-out part of `create_global_environment`, so that initialization of the interpreter will read in the Scheme *prelude*, a set of definitions of standard functions written in Scheme instead of Python.

Problem A4 (2 pt). Before we can call `LambdaFunction`s, we must be able to create them. At the moment, the `do_lambda_form` method, which creates `LambdaFunction` values, is incomplete. Finish it. You can check your work by typing in lambda expressions to the interpreter. You should see something like this:

```
scm> (lambda (x) (set! y x) (+ x y))
```

```
<(lambda (x) (begin (set! y x) (+ x y))), <Global frame at 0x848444c>>
```

For an explanation of why the `begin` is inserted, see the `__init__` function for the `LambdaFunction` class.

Problem B4 (2 pt). The part of `do_define_form` that you didn't do in B2 handles the shorthand form for defining functions, allowing you to write

```
scm> (define f (lambda (x) (* x 2)))
```

as

```
scm> (define (f x) (* x 2))
```

Fill in this missing portion of `do_define_form`.

Problem A5 (3 pt). The `make_call_frame` method of `EnvironFrame` is incomplete. Finish it.

Don't forget the cases where the formal parameter list contains a trailing "varargs" entry, as in

```
(define (format port form . args) ...)
```

One unifying way to handle this case along with the simple lists-of-symbols is to consider the formals list as a kind of *pattern* that is matched against the list of argument values. That is, the formals list *matches* the argument list if you treat each symbol in the formals list as a *pattern variable* or *wildcard* that matches any expression. Thus, the list of values `(1 2 3)` has the internal structure

```
Pair(number, Pair(number, Pair(number, NULL)))
```

while the formals list `(a . b)` has the structure

```
Pair(symbol a, symbol b)
```

These have the same form if we match symbol `a` to the number 1 and symbol `b` to `Pair(number, Pair(number, NULL))` Likewise, the ordinary formals list `(a b c)` has the structure

```
Pair(symbol a, Pair(symbol b, Pair(symbol c, NULL)))
```

so it matches the argument list, too.

Problem B5 (3 pt). Likewise, `check_formals`, the method that checks the formals-list argument to `make_call_frame`, does nothing at the moment. Fix it so that `make_call_frame` can assume that its "formals" argument is correctly formed.

Problem 6 (3 pt). At this point, you should be able to get user-defined functions working by filling in `LambdaFunction.apply_step`. Be sure to add tests for Problems 4–6 to `tests.scm`

Problem 7 (2 pt). Fill in the implementation of `do_set_bang_form`, which handles the `set!` special form. Be sure to include a check that it has the proper form and that symbol being assigned to is defined. And, as usual, be sure to have tests in `tests.scm`

Problem 8. The basic Scheme conditional constructs are `if`, `and`, `or`, and `cond`. In order to handle tail recursion properly, all these methods must be careful how they perform their evaluations. For example, consider the following tail-recursive function

```
(define (contains x L)
        (cond ((null? L) #f)
              ((eqv? x (car L)) #t)
              (else (contains x (cdr L)))))
```

If the `do_cond_form` method were to evaluate the recursive call, then the Python interpreter would have an ever-increasing call depth as it "cdred" down the list, eventually blowing up if the list were long enough. So instead, `do_cond_form` (and the other conditional forms) must use the option of modifying the expression to be evaluated and then returning without actually doing the evaluation.

Problem A8 (3 pt). For the first half of the problem, fill in the implementations of `do_if_form` and `do_and_form` and test them.

Problem B8 (3 pt). For the second half, fill in the implementations of `do_cond_form` and `do_or_form` and test them.

Problem 9 (3 pt). The `let` special form introduces local variables, giving them their initial values. For example,

```
scm> (define x 3) (define y 10)
scm> (let ((x y)
```

```
              (y (+ x 5)))
           (set! x (+ x 1))
           (list x y))
(11 8)
scm> (list x y)
(3 10)
```

In fact, the `let` statement above is equivalent to the call

```
scm> ((lambda (x y) (set! x (+ x 1)) (list x y))
    y (+ x 5))
```

so that the inner `x` and `y` are separate from the outer ones, and the initialization expressions in the `let` construct do *not* reference the local variables `x` and `y`. Implement the `do_let_form` method to have this effect and (need we say it at this point?) test it.

Extra Credit 1. (2 pt). The `let*` construct is like `let`, except that each initialization expression "sees" the definitions that have gone before. Essentially,

```
(define x 3) (define y 10)
(let* ((x y)
       (y (+ x 5)))
   (set! x (+ x 1))
   (list x y))
```

is the same as

```
(define x 3) (define y 10)
(let ((x y))
   (let (y (+ x 5))
      (set! x (+ x 1))
      (list x y)))
```

and therefore has the value `(11 15)`, rather than `(11 8)`, as it would for `let`. Implement this special form (and, yes, test it).

Extra Credit 2 (2 pt). The `case` construct is a fancy conditional similar to the Java and C/C++ `switch` statement. Here are some examples from the Scheme reference manual:

```
scm> (case (* 2 3)
       ((2 3 5 7) 'prime)
       ((1 4 6 8 9) 'composite))
composite
```

```
scm> (case (car '(c d))
       ((a e i o u) 'vowel)
       ((w y) 'semivowel)
       (else 'consonant))
consonant
scm> (define x 3) (define y 10)
scm> (case (car '(+ * /))
       ((+ add) (+ x y))
       ((* mult) (* x y))
       ((/ div) (/ x y)))
13
```

The first operand is evaluated, but the first element of each of the subsequent operands is not evaluated (it's implicitly quoted). As for `cond` the remaining items in the matching operand are evaluated, and the value of the last is the value of the `case`. Implement and test this special form.

We're There!

You should have been adding tests to `tests.scm` as you did each problem. In any case, make sure you have a reasonably complete set, since the readers will be looking at it. Your program should pass all your tests when you (or the autograder) run `# python3 scheme_tests.py tests.scm`

Your Scheme interpreter implementation is now complete.

Part 3: Write Some Scheme

Not only is your Scheme interpreter itself a tree-recursive program, but it is flexible enough to evaluate *other* recursive programs. Implement the following procedures in Scheme at the bottom of `tests.scm`, along with some calls and expected results.

Problem 10. The first problems (one for you and one for your partner) ask you to implement some familiar operations *destructively*. That means that the `cdr`s of the original list may be changed and no new pairs should be created with `cons` or `list`. There's a definition of non-destructive `reverse` in `scheme_prelude.scm` and there are implementations of `filter` on Python rlists in Lecture 9. To see the desired difference between destructive and non-destructive operations, consider:

```
scm> (define L (list 1 2 3 4))
scm> (reverse L)
(4 3 2 1)
scm> L
(1 2 3 4)
scm> (reverse! L)
(4 3 2 1)
scm> L   ; L is now the last element of the reversed list.
(1)
```

Problem A10 (3 pt). Implement the `filter!` procedure, which takes two arguments, a procedure name and a list and destructively returns a list that contains all elements of the input list for which applying the named procedure outputs a true value (i.e., something other than `#f`). Make your program tail recursive. It is easy to do this if you use your partner's `reverse!` function. Try instead to implement it directly.

Problem B10 (3 pt). Implement the `reverse!` procedure, whic takes a list and returns the reverse of that list destructively.

Problem A11 (2 pt). Implement the `count-change` procedure, which counts all of the ways to make change for a `total` amount, using coins with various denominations (`denoms`), but never uses more than `max-coins` in total. Write your implementation in `tests.scm`. The procedure definition line is provided, along with U.S. denominations.

Problem B11 (2 pt) Implement the `count-partitions` procedure, which counts all the ways to partition a positive integer `total` using only pieces less than or equal to another positive integer `max-value`. The number `5` has 5 partitions using pieces up to a `max-value` of `3`:

```
3, 2 (two pieces)
3, 1, 1 (three pieces)
2, 2, 1 (three pieces)
2, 1, 1, 1 (four pieces)
1, 1, 1, 1, 1 (five pieces)
```

Problem 12 (3 pt). Implement the `list-partitions` procedure, which lists all of the ways to partition a positive integer `total` into at most `max-pieces` pieces that are all less

than or equal to a positive integer `max-value`. *Hint*: Define a helper function to construct partitions.

Congratulations! You have finished the final project for 61A! Assuming your tests are good and you've passed them all, consider yourself a proper computer scientist!

Get some sleep.

Contest: Recursive Art

We've added a number of primitive drawing procedures that are collectively called "turtle graphics". The *turtle* represents the state of the drawing module, which has a position, an orientation, a pen state (up or down), and a pen color. The `tcsm_x` functions in `scheme_primitives.py` are the implementations of these procedures, and show their parameters with a brief description of each. The Python documentation of the turtle module contains more detail.

Contest (3 pt). Create a visualization of an iterative or recursive process of your choosing, using turtle graphics. Your implementation must be written entirely in Scheme, using the interpreter you have built (no fair extending the interpreter to do your work in Python, but you can expose other turtle graphics functions from Python if you wish).

Prizes will be awarded for the winning entry in each of the following categories.

- **Featherweight.** At most 128 words of Scheme, not including comments and delimiters.
- **Heavyweight.** At most 1024 words of Scheme, not including comments and delimiters.

Entries (code and results) will be posted online, and winners will be selected by popular vote. The voting instructions will read:

> Please vote for your favorite entry in this semester's 61A Recursion Exposition contest. The winner should exemplify the principles of elegance, beauty, and abstraction that are prized in the Berkeley computer science curriculum. As an academic community, we should strive to recognize and reward merit and

achievement (translation: please don't just vote for your friends).

To improve your chance of success, you are welcome to include a title and descriptive haiku in the comments of your entry, which will be included in the voting. Place your completed entry into the `contest.scm` file.