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Exceptions are raised with a raise statement.

```
raise <expression>
```

<expression> must evaluate to a subclass of BaseException or an instance of one.

Exceptions are constructed like any other object. E.g.,
TypeError('Bad argument!')

```
try:
    <try suite>
except <exception class> as <name>:
    <except suite>
...
```

The <try suite> is executed first.

If, during the course of executing the <try suite>, an exception is raised that is not handled otherwise, and

If the class of the exception inherits from <exception class>, then

The <except suite> is executed, with <name> bound to the exception.

```
>>> try:
        x = 1/0
    except ZeroDivisionError as e:
        print('handling a', type(e))
        x = 0

handling a <class 'ZeroDivisionError'>
>>> x
0
```

```
for <name> in <expression>:
    <suite>
```

1. Evaluate the header <expression>, which yields an iterable object.
2. For each element in that sequence, in order:
   A. Bind <name> to that element in the first frame of the current environment.
   B. Execute the <suite>.

An iterable object has a method __iter__ that returns an iterator.

```
>>> counts = [1, 2, 3]
>>> for item in counts:
        print(item)

1
2
3
```

```
>>> items = counts.__iter__()
>>> try:
        while True:
            item = items.__next__()
            print(item)
    except StopIteration:
        pass
```

```
class FibIter:
    def __init__(self):
        self._next = 0
        self._addend = 1

    def __next__(self):
        result = self._next
        self._addend, self._next = self._next, self._addend + self._next
        return result
```

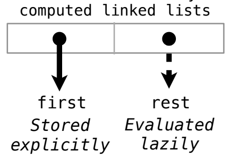
"Please don't reference these directly. They may change."

```
>>> fibs = FibIter()
>>> [next(fibs) for _ in range(10)]
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34]
```

A stream is a linked list, but the rest of the list is computed on demand.

Once created, Streams and Rlists can be used interchangeably using first and rest.

Streams are lazily computed linked lists




```
class Stream:
    """A lazily computed linked list."""
    class empty:
        def __repr__(self):
            return 'Stream.empty'
    empty = empty()

    def __init__(self, first, compute_rest=lambda: Stream.empty):
        assert callable(compute_rest), 'compute_rest must be callable.'
        self.first = first
        self._compute_rest = compute_rest

    @property
    def rest(self):
        """Return the rest of the stream, computing it if necessary."""
        if self._compute_rest is not None:
            self._rest = self._compute_rest()
            self._compute_rest = None
        return self._rest

def integer_stream(first=1):
    def compute_rest():
        return integer_stream(first+1)
    return Stream(first, compute_rest)

def filter_stream(fn, s):
    if s is Stream.empty:
        return s
    def compute_rest():
        return filter_stream(fn, s.rest)
    if fn(s.first):
        return Stream(s.first, compute_rest)
    else:
        return compute_rest()

def map_stream(fn, s):
    if s is Stream.empty:
        return s
    def compute_rest():
        return map_stream(fn, s.rest)
    return Stream(fn(s.first),
                  compute_rest)

def primes(positives):
        def not_divisible(x):
            return x % positives.first != 0
        def compute_rest():
            return primes(filter_stream(not_divisible, positives.rest))
        return Stream(positives.first, compute_rest)
```

The way in which names are looked up in Scheme and Python is called *lexical scope* (or *static scope*).

Lexical scope: The parent of a frame is the environment in which a procedure was *defined*. (lambda ...)

Dynamic scope: The parent of a frame is the environment in which a procedure was *called*. (mu ...)

```
> (define f (mu (x) (+ x y)))
> (define g (lambda (x y) (f (+ x x))))
> (g 3 7)
13
```

```
class LetterIter:
    def __init__(self, start='a', end='e'):
        self.next_letter = start
        self.end = end

    def __next__(self):
        if self.next_letter >= self.end:
            raise StopIteration
        result = self.next_letter
        self.next_letter = chr(ord(result)+1)
        return result

class Letters:
    def __init__(self, start='a', end='e'):
        self.start = start
        self.end = end

    def __iter__(self):
        return LetterIter(self.start, self.end)

def letters_generator(next_letter, end):
    while next_letter < end:
        yield next_letter
        next_letter = chr(ord(next_letter)+1)
```

- A generator is an iterator backed by a generator function.
- Each time a generator function is called, it returns a generator.

```
>>> a_to_c = LetterIter('a', 'c')
>>> next(a_to_c)
'a'
>>> next(a_to_c)
'b'
>>> next(a_to_c)
Traceback (most recent call last):
  ...
StopIteration

>>> b_to_k = Letters('b', 'k')
>>> first_iterator =
b_to_k.__iter__()
>>> next(first_iterator)
'b'
>>> next(first_iterator)
'c'
>>> second_iterator = iter(b_to_k)
>>> second_iterator.__next__()
'b'
>>> first_iterator.__next__()
'd'

>>> for letter in
letters_generator('a', 'e'):
...     print(letter)
a
b
c
d
```

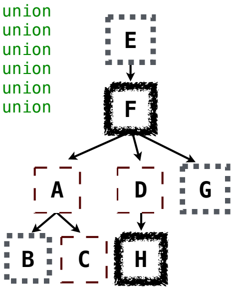
A **table** has columns and rows   A **column** has a name and a type

Latitude	Longitude	Name
38	122	Berkeley
42	71	Cambridge
45	93	Minneapolis

A **row** has a value for each column

```
select [expression] as [name], [expression] as [name], ... ;
select [columns] from [table] where [condition] order by [order];
```

```
create table parents as
  select "abraham" as parent, "barack" as child union
  select "abraham"          , "clinton"         union
  select "delano"           , "herbert"         union
  select "fillmore"         , "abraham"         union
  select "fillmore"         , "delano"          union
  select "fillmore"         , "grover"          union
  select "eisenhower"       , "fillmore";
```




```
create table dogs as
  select "abraham" as name, "long" as fur union
  select "barack"         , "short"       union
  select "clinton"        , "long"        union
  select "delano"         , "long"        union
  select "eisenhower"     , "short"       union
  select "fillmore"       , "curly"       union
  select "grover"         , "short"       union
  select "herbert"        , "curly";
```

```
select a.child as first, b.child as second
  from parents as a, parents as b
  where a.parent = b.parent and a.child < b.child;
```

First	Second
barack	clinton
abraham	delano
abraham	grover
delano	grover

```
with
  ancestors(ancestor, descendent) as (
    select parent, child from parents union
    select ancestor, child
           from ancestors, parents
           where parent = descendent
  )
select ancestor from ancestors where descendent="herbert";
```

ancestor
delano
fillmore
eisenhower

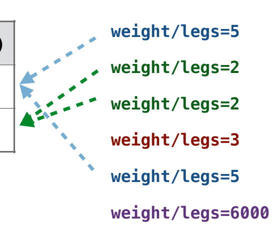
```
create table pythagorean_triples as
  with
    i(n) as (
      select 1 union select n+1 from i where n < 20
    )
  select a.n as a, b.n as b, c.n as c
         from i as a, i as b, i as c
         where a.n < b.n and a.n*a.n + b.n*b.n = c.n*c.n;
```

a	b	c
3	4	5
5	12	13
6	8	10
8	15	17
9	12	15
12	16	20

The number of groups is the number of unique values of an expression
A having clause filters the set of groups that are aggregated

```
select weight/legs, count(*) from animals
                    group by weight/legs
                    having count(*)>1;
```

weight/ legs	count(*)
5	2
2	2



kind	legs	weight
dog	4	20
cat	4	10
ferret	4	10
parrot	2	6
penguin	2	10
t-rex	2	12000

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Scheme programs consist of expressions, which can be:
- Primitive expressions: 2, 3.3, true, +, quotient, ...
- Combinations: (quotient 10 2), (not true), ...

Numbers are self-evaluating; *symbols* are bound to values.
Call expressions have an operator and 0 or more operands.

A combination that is not a call expression is a *special form*:
- **If** expression: (if <predicate> <consequent> <alternative>)
- Binding names: (define <name> <expression>)
- New procedures: (define (<name> <formal parameters>) <body>)

```
> (define pi 3.14)        > (define (abs x)
> (* pi 2)                    (if (< x 0)
6.28                              (- x)
                                  x))
                          > (abs -3)
                          3
```

Lambda expressions evaluate to anonymous procedures.

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

λ

Two equivalent expressions:

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

An operator can be a combination too:

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

In the late 1950s, computer scientists used confusing names.
- **cons**: Two-argument procedure that **creates a pair**
- **car**: Procedure that returns the **first element** of a pair
- **cdr**: Procedure that returns the **second element** of a pair
- **nil**: The empty list

They also used a non-obvious notation for linked lists.
- A (linked) Scheme list is a pair in which the second element is nil or a Scheme list.
- Scheme lists are written as space-separated combinations.
- A dotted list has an arbitrary value for the second element of the last pair. Dotted lists may not be well-formed lists.

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

Not a well-formed list!

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)
```

Symbols are now values

Quotation can also be applied to combinations to form lists.

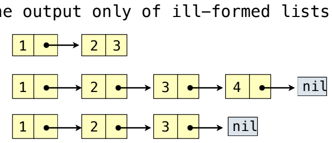
```
> (car '(a b c))
a
> (cdr '(a b c))
(b c)
```

Dots can be used in a quoted list to specify the second element of the final pair.

```
> (cdr (cdr '(1 2 . 3)))
3
```

However, dots appear in the output only of ill-formed lists.

```
> '(1 2 . 3)
(1 2 . 3)
> '(1 2 . (3 4))
(1 2 3 4)
> '(1 2 3 . nil)
(1 2 3)
> (cdr '((1 2) . (3 4 . (5))))
(3 4 5)
```



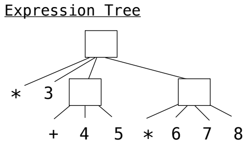

```python
class Pair:
    """A Pair has first and second attributes.

    For a Pair to be a well-formed list,
    second is either a well-formed list or nil.
    """
    def __init__(self, first, second):
        self.first = first
        self.second = second

>>> s = Pair(1, Pair(2, Pair(3, nil)))
>>> print(s)
(1 2 3)
>>> len(s)
3
>>> print(Pair(1, 2))
(1 . 2)
>>> print(Pair(1, Pair(2, 3)))
(1 2 . 3)
```

The Calculator language has primitive expressions and call expressions

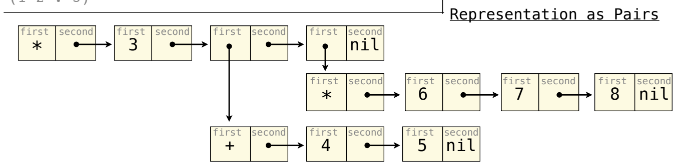
Calculator Expression

```
(* 3
   (+ 4 5)
   (* 6 7 8))
```

Expression Tree



Representation as Pairs



A basic interpreter has two parts: a *parser* and an *evaluator*.

scheme_reader.py		scalc.py	
lines → Parser	expression →	Evaluator	value
'(+ 2 2)'	Pair('+', Pair(2, Pair(2, nil)))		4
'(* (+ 1' / ' (- 23)' / ' (* 4 5.6))' / ' 10)'	Pair('*', Pair(Pair('+', ...))) *printed as* (* (+ 1 (- 23) (* 4 5.6)) 10)		4
Lines forming a Scheme expression	A number or a Pair with an operator as its first element		A number

A Scheme list is written as elements in parentheses:

(<element$_0$> <element$_1$> ... <element$_n$>) — A Scheme list

Each <element> can be a combination or atom (primitive).

(+ (* 3 (+ (* 2 4) (+ 3 5))) (+ (- 10 7) 6))

The task of *parsing* a language involves coercing a string representation of an expression to the expression itself.

Parsers must validate that expressions are well-formed.

A Parser takes a sequence of lines and returns an expression.

Lines → **Lexical analysis** → Tokens → **Syntactic analysis** → Expression

Lines	Tokens	Expression
'(+ 1'	'(', '+', 1	Pair('+', Pair(1, ...))
' (- 23)'	'(', '-', 23, ')'	*printed as*
' (* 4 5.6))'	'(', '*', 4, 5.6, ')', ')'	(+ 1 (- 23) (* 4 5.6))

Lexical analysis:
- Iterative process
- Checks for malformed tokens
- Determines types of tokens
- Processes one line at a time

Syntactic analysis:
- Tree-recursive process
- Balances parentheses
- Returns tree structure
- Processes multiple lines

Syntactic analysis identifies the hierarchical structure of an expression, which may be nested.

Each call to scheme_read consumes the input tokens for exactly one expression.

Base case: symbols and numbers
Recursive call: scheme_read sub-expressions and combine them

The structure of the Scheme 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 name lookup

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

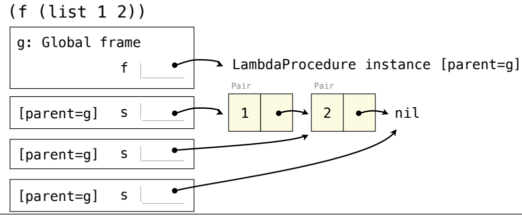
Apply

Base cases:
- Built-in primitive procedures

Recursive calls:
- Eval(body) of 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** of the procedure, then evaluate the body of the procedure in the environment that starts with this new frame.

```
(define (f s) (if (null? s) '(3) (cons (car s) (f (cdr s)))))
(f (list 1 2))
```



A procedure call that has not yet returned is *active*. Some procedure calls are *tail calls*. A Scheme interpreter should support an unbounded number of active tail calls.

A tail call is a call expression in a *tail context*, which are:
- The last body expression in a **lambda** expression
- Expressions 2 & 3 (consequent & alternative) in a tail context **if** expression

```
(define (factorial n k)        (define (length s)
  (if (= n 0) k                  (if (null? s) 0
    (factorial (- n 1)             (+ 1 (length (cdr s)))))
               (* k n))))
                                         Not a tail call
(define (length-tail s)
  (define (length-iter s n)      Recursive call is a tail call
    (if (null? s) n
      (length-iter (cdr s) (+ 1 n)) ) )
  (length-iter s 0) )
```