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Exceptions are raised with a raise statement.

```
raise <expr>
```

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

```
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
```

(append s t): list the elements of s and t; append can be called on more than 2 lists

(map f s): call a procedure f on each element of a list s and list the results

(filter f s): call a procedure f on each element of a list s and list the elements for which a true value is the result

(apply f s): call a procedure f with the elements of a list as its arguments

```
(define size 5) ; =>  size
(* 2 size) ; =>  10
(if (> size 0) size (- size)) ; =>  5
(cond ((> size 0) size) ((= size 0) 0) (else (- size))) ; =>  5
((lambda (x y) (+ x y size)) size (+ 1 2)) ; =>  13
(let ((a size) (b (+ 1 2))) (* 2 a b)) ; =>  30
(map (lambda (x) (+ x size)) (quote (2 3 4))) ; =>  (7 8 9)
(filter odd? (quote (2 3 4))) ; =>  (3)
(list (cons 1 nil) size 'size) ; =>  ((1) 5 size)
(list (equal? 1 2) (null? nil) (= 3 4) (eq? 5 5)) ; => (#f #t #f #t)
(list (or #f #t) (or) (or 1 2)) ; =>  (#t #f 1)
(list (and #f #t) (and) (and 1 2)) ; =>  (#f #t 2)
(list 'a 2) ; =>  (a 2)
(append '(1 2) '(3 4)) ; =>  (1 2 3 4)
(not (> 1 2)) ; =>  #t
(begin (define x (+ size 1)) (* x 2)) ; =>  12
```

```
(define (factorial n)
   (if (= n 0) 1
       (* n (factorial (- n 1)))))

(define (fib n)
   (cond
      ((= n 0) 0)
      ((= n 1) 1)
      (else (+ (fib (- n 2)) (fib (- n 1))))))

(define (nines num)
   (if (= num 0)
      0
      (if (= (modulo num 10) 9 )
          (+ 1 (nines (floor (/ num 10))))
          (nines (floor (/ num 10))))))
```

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
```

There are two ways to quote an expression

```
Quote:      '(a b)   =>   (a b)
Quasiquote: `(a b)   =>   (a b)
```

Parts of a quasiquoted expression can be unquoted with ,

```
            (define b 4)
Quote:      '(a ,(+ b 1))  =>   (a (unquote (+ b 1))
Quasiquote: `(a ,(+ b 1))  =>   (a 5)
```

Quasiquotation is convenient for generating Scheme expressions:

```
            (define (make-add-lambda n) `(lambda (d) (+ d ,n)))
            (make-add-lambda 2)  => (lambda (d) (+ d 2))
```

A **table** has columns and rows

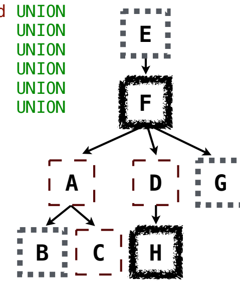
A **column** has a name and a type

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

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

```
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";
```



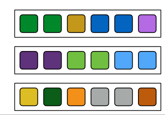

```
CREATE TABLE dogs AS
  SELECT "abraham" AS name, "long" AS fur UNION
  SELECT "barack"         , "short"       UNION
  SELECT "clinton"        , "long"        UNION
  SELECT "delano"         , "long"        UNION
  SELECT "eisenhower"     , "short"       UNION
  SELECT "fillmore"       , "curly"       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

```
create table lift as
  select 101 as chair, 2 as single, 2 as couple union
  select 102         , 0          , 3           union
  select 103         , 4          , 1;

select chair, single + 2 * couple as total from lift;
```



String values can be combined to form longer strings

```
sqlite> SELECT "hello," || " world";
hello, world
```

Basic string manipulation is built into SQL, but differs from Python

```
sqlite> CREATE TABLE phrase AS SELECT "hello, world" AS s;
sqlite> SELECT substr(s, 4, 2) || substr(s, instr(s, " ")+1, 1)
           FROM phrase;
low
```

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

weight/legs=5
weight/legs=2
weight/legs=2
weight/legs=3
weight/legs=5
weight/legs=6000

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

A macro is an operation performed on the source code of a program before evaluation

Macros exist in many languages, but are easiest to define correctly in a language like Lisp

Scheme has a **define-macro** special form that defines a source code transformation

```
(define-macro (twice expr)        > (twice (print 2))  (begin (print 2) (print 2))
  (list 'begin expr expr))        2
                                  2
```

Evaluation procedure of a macro call expression:

- Evaluate the operator sub-expression, which evaluates to a macro
- Call the macro procedure on the operand expressions *without evaluating them first*
- Evaluate the expression returned from the macro procedure

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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)
> (* pi 2)
6.28
```

```
> (define (abs x)
    (if (< x 0)
        (- 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 nil))
> x
(1)
> (car x)
1
> (cdr x)
()
> (cons 1 (cons 2 (cons 3 (cons 4 nil))))
(1 2 3 4)
```

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.

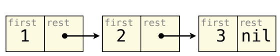
```
> (car '(a b c))
a
> (cdr '(a b c))
(b c)
```

```
(car (cons 1 nil)) -> 1
(cdr (cons 1 nil)) -> ()
(cdr (cons 1 (cons 2 nil))) -> (2)
```

```
class Pair:
    """A pair has two instance attributes:
      first and rest.

      rest must be a Pair or nil.
    """
    def __init__(self, first, rest):
        self.first = first
        self.rest = rest

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

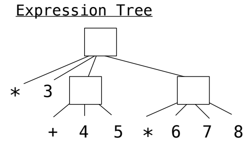


The Calculator language has primitive expressions and call expressions

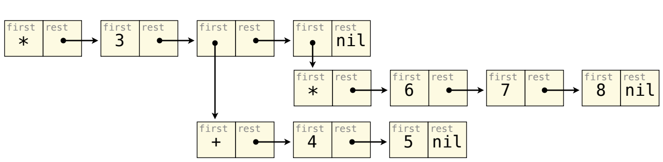
Calculator Expression

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

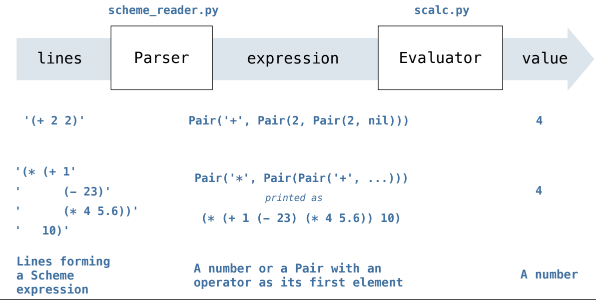
Expression Tree



Representation as Pairs



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



A Scheme list is written as elements in parentheses:

(<element₀> <element₁> ... <elementₙ>) — A Scheme list

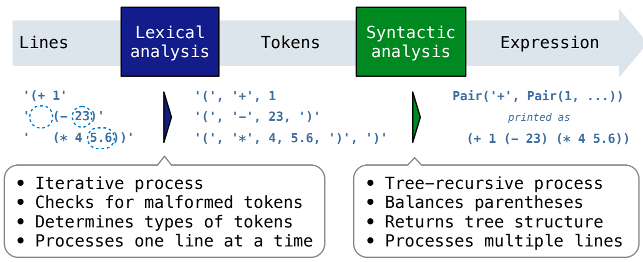
Each <element> can be a combination or atom (primitive).

(+ (* 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.

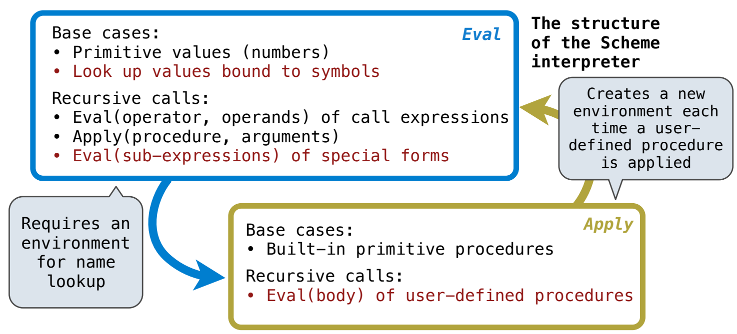
A Parser takes a sequence of lines and returns an expression.



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



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))
```