Scheme

Class outline:

- Scheme expressions
- Call expressions
- Special forms
- Examples

Scheme

A brief history of programming languages

The Lisp programming language was introduced in 1958.

The Scheme dialect of Lisp was introduced in the 1970s, and is still maintained by a standards committee today.

Genealogical tree of programming languages

Scheme itself is not commonly used in production, but has influenced many other languages, and is a good example of a functional programming language.

Scheme expressions

Scheme programs consist of expressions, which can be:

- **Primitive expressions:**
  `2` `3.3` `#t` `#f` `+` `quotient`

Scheme expressions

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- **Primitive expressions:**
  `2` `3.3` `#t` `#f` `+` `quotient`
- **Combinations:**
  `(quotient 10 2)` `(not #t)`
  Combinations are either a call expression or a special form.

Call expressions

Call expressions

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))
```

Built-in arithmetic procedures

Name	**Example**
`+`	`(+ 1 2 3)`
`-`	`(- 12)` `(- 3 2 1)`
`*`	`(*)` `(* 2)` `(* 2 3)`
`/`	`(/ 2)` `(/ 4 2)` `(/ 16 2 2)`
`quotient`	`(quotient 7 3)`
`abs`	`(abs -12)`
`expt`	`(expt 2 10)`
`remainder`	`(remainder 7 3)` `(remainder -7 3)`

Scheme procedure reference: Arithmetic operations

Built-in Boolean procedures (for numbers)

These procedures only work on numbers:

Name	True expressions
`=`	`(= 4 4)` `(= 4 (+ 2 2))`
`<`	`(< 4 5)`
`>`	`(> 5 4)`
`<=`	`(<= 4 5)` `(<= 4 4)`
`>=`	`(>= 5 4)` `(>= 4 4)`
`even?`	`(even? 2)`
`odd?`	`(odd? 3)`
`zero?`	`(zero? 0)` `(zero? 0.0)`

Built-in Boolean procedures

These procedures work on all data types:

Name	True expressions	False expressions
`eq`	`(eq? #t #t)` `(eq? 0 (- 1 1))`	`(eq? #t #f)` `(eq? 0 0.0)`
`not`	`(not #f)`	`(not 0)` `(not #t)`

The only falsey value in Scheme is `#f`.
All other values are truthy.

Scheme procedure reference: Boolean operations

Scheme specification: Booleans

Special forms

Special forms

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

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

Scheme spec: special forms

define form

`define <name> <expression>`

Evaluates `<expression>` and binds the value to `<name>` in the current environment. `<name>` must be a valid Scheme symbol.

```
(define x 2)
```

Scheme Spec: define

define procedure

`define (<name> [param] ...) <body>)`

Constructs a new procedure with `param`s as its parameters and the `body` expressions as its body and binds it to `name` in the current environment. `name` must be a valid Scheme symbol. Each `param` must be a unique valid Scheme symbol.

```
(define (double x) (* 2 x) )
```

Scheme Spec: define

If expression

`if <predicate> <consequent> <alternative>`

Evaluates `predicate`. If true, the `consequent` is evaluated and returned. Otherwise, the `alternative`, if it exists, is evaluated and returned (if no `alternative` is present in this case, the return value is undefined).

Example: This code evaluates to 100/x for non-zero numbers and 0 otherwise:

```
(define x 5)
(if (zero? x)
    0
    (/ 100 x))
```

Scheme Spec: If

and form

`(and [test] ...)`

Evaluate the `test`s in order, returning the first false value. If no `test` is false, return the last `test`. If no arguments are provided, return `#t`.

Example: This `and` form evaluates to true whenever `x` is both greater than 10 and less than 20.

```
(define x 15)
(and (> x 10) (< x 20))
```

Scheme Spec: And

or form

`(or [test] ...)`

Evaluate the `test`s in order, returning the first true value. If no `test` is true and there are no more `test`s left, return `#f`.

Example: This `or` form evaluates to true when either `x` is less than -10 or greater than 10.

```
(define x -15)
(or (< x -10) (> x 10))
```

Scheme Spec: Or

Cond form

The cond special form that behaves similar to if expressions 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)))
```

Scheme Spec: Cond

Why is cond needed?

Without `cond`, we'd have deeply nested `if` forms:

```
(if (> x 10) (print 'big)
    (if (> x 5) (print 'medium)
        (print 'small)
    )
)
```

So much nicer with `cond`!

```
(cond
    ((> x 10) (print 'big))
    ((> x 5)  (print 'medium))
    (else     (print 'small)))
```

The begin form

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

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

Scheme Spec: Begin

The begin form

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

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

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

Scheme Spec: Begin

let form

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

Scheme Spec: Let

lambda expressions

Lambda expressions evaluate to anonymous procedures.

`(lambda ([param] ...) <body> ...)`

Two equivalent expressions:

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

An operator can be a lambda expression too:

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

Scheme Spec: Lambda

Exercises

Exercise: Sum of squares

What's the sum of the squares of even numbers less than 10, starting with some number?

Python version (iterative):

```
def sum_of_squares(num):
    total = 0
    while num < 10:
        total += num ** 2
        num += 2
    return total

sum_of_squares(2)  # 120
```

Exercise: Sum of squares

What's the sum of the squares of even numbers less than 10, starting with some number?

Python version (iterative):

```
def sum_of_squares(num):
    total = 0
    while num < 10:
        total += num ** 2
        num += 2
    return total

sum_of_squares(2)  # 120
```

Python version (recursive):

```
def sum_of_squares(num, total):
    if num >= 10:
        return total
    else:
        return sum_of_squares(num + 2, total + num ** 2)

sum_of_squares(2, 0)  # 120
```

Exercise: Sum of squares (solution)

Scheme version:

```
(define (sum_of_squares num total)
    (if (>= num 10)
        total
        (sum_of_squares (+ num 2) (+ total (* num num)))
    )
)
```

```
(sum_of_squares 2 0)
```

Using helper functions

What if we said the `sum_of_squares` function could only take one argument?

In Python, we could use a helper function:

```
def sum_of_squares(num):
    def with_total(num, total):
        if num >= 10:
            return total
        else:
            return with_total(num + 2, total + num ** 2)
    return with_total(num, 0)
```

Using helper functions (Scheme)

Similarly in Scheme!

```
(define (sum_of_squares num)
    (define (with_total num total)
        (if (>= num 10)
            total
            (with_total (+ num 2) (+ total (* num num)))
        )
    )
    (with_total num 0)
)
```

Scheme tips

- Use the references!
  - Scheme built-in procedure
  - Scheme specification
- Auto-format your code!
- Constrain your brain: you're now living in a world of applicative programming. Look, ma, no mutation!