# CMSC 330: Organization of Programming Languages

## Introduction to Ruby

# Last Lecture

- Many types of programming languages
  - Imperative, functional, logical, OO, scripting
- Many programming language attributes
  - Clear, orthogonal, natural…
- Programming language implementation
  - Compiled, interpreted

# Clickers improve student engagement

Biochem Mol Biol Educ. 2009 Mar;37(2):84-91. doi: 10.1002/bmb.20264.

**Using clickers to improve student engagement and performance class.**

Addison S[1], Wright A, Milner R.

Author information

Abstract

# Students say

**ren**
@rennnn__

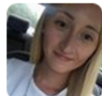
Clickers are the invention of satan I'm convinced.

5:45 PM - 26 Nov 2012 · San Diego, CA, United States

**Rachel Paddock**
@RachelPaddock

Whoever invented clickers.... I despise you.

11:33 AM - 29 Nov 2012



**Cait Corf**
@caitcorf

BUT WHY MUST I BE SO STUPID?! The only reason I stayed is because it this class has I clickers,guess what I forgot to bring to class today?

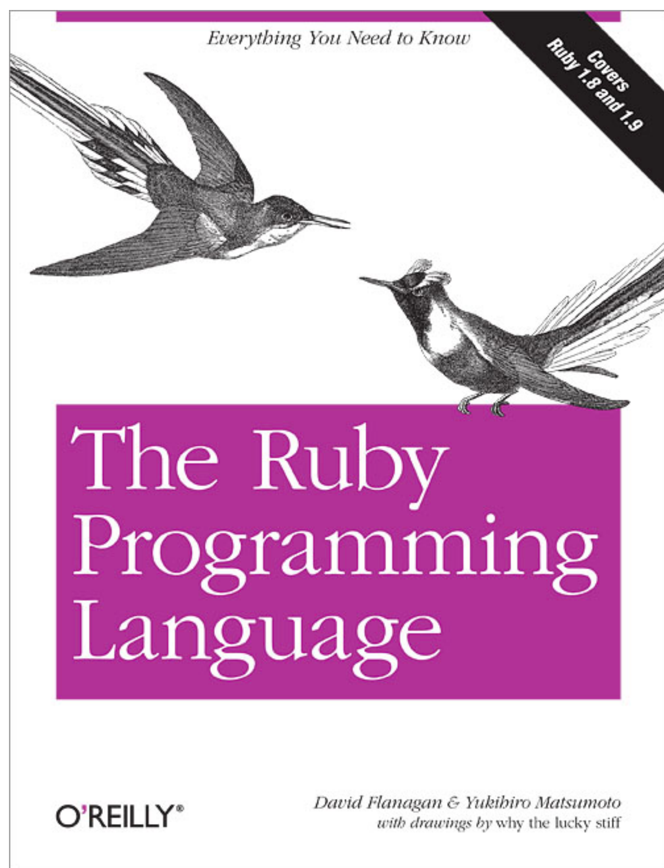
12:18 PM - 15 Mar 2013

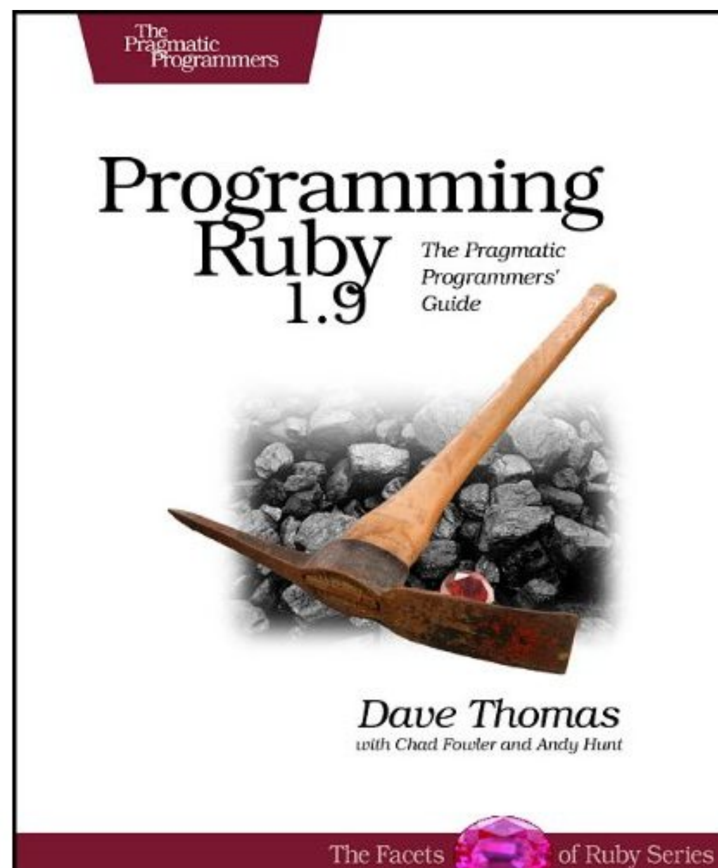
# Introduction

- Ruby is an *object-oriented, imperative scripting language*
  - "I wanted a scripting language that was more powerful than Perl, and more object-oriented than Python. That's why I decided to design my own language."
  - "I believe people want to express themselves when they program. They don't want to fight with the language. Programming languages must feel natural to programmers. I tried to make people enjoy programming and concentrate on the fun and creative part of programming when they use Ruby."

*– Yukihiro Matsumoto ("Matz")*

# Books on Ruby




- Earlier version of Thomas book available on web
  - See course web page

# Applications of Scripting Languages

- Scripting languages have many uses
  - Automating system administration
  - Automating user tasks
  - Quick-and-dirty development

- Major application

Text processing

# Output from Command-Line Tool

```
% wc *
     271     674    5323 AST.c
     100     392    3219 AST.h
     117    1459  238788 AST.o
    1874    5428   47461 AST_defs.c
    1375    6307   53667 AST_defs.h
     371     884    9483 AST_parent.c
     810    2328   24589 AST_print.c
     640    3070   33530 AST_types.h
     285     846    7081 AST_utils.c
      59     274    2154 AST_utils.h
      50     400   28756 AST_utils.o
     866    2757   25873 Makefile
     270     725    5578 Makefile.am
     866    2743   27320 Makefile.in
      38     175    1154 alloca.c
    2035    4516   47721 aloctypes.c
      86     350    3286 aloctypes.h
     104    1051   66848 aloctypes.o

...
```

# Climate Data for IAD in August, 2005

| 1 | 2 | 3 | 4 | 5 | 6A | 6B | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | AVG | MX | 2MIN | | | | | | |
| DY | MAX | MIN | AVG | DEP | HDD | CDD | WTR | SNW | DPTH | SPD | SPD | DIR | MIN | PSBL | S-S | WX | SPD | DR |
| 1 | 87 | 66 | 77 | 1 | 0 | 12 | 0.00 | 0.0 | 0 | 2.5 | 9 | 200 | M | M | 7 | 18 | 12 | 210 |
| 2 | 92 | 67 | 80 | 4 | 0 | 15 | 0.00 | 0.0 | 0 | 3.5 | 10 | 10 | M | M | 3 | 18 | 17 | 320 |
| 3 | 93 | 69 | 81 | 5 | 0 | 16 | 0.00 | 0.0 | 0 | 4.1 | 13 | 360 | M | M | 2 | 18 | 17 | 360 |
| 4 | 95 | 69 | 82 | 6 | 0 | 17 | 0.00 | 0.0 | 0 | 3.6 | 9 | 310 | M | M | 3 | 18 | 12 | 290 |
| 5 | 94 | 73 | 84 | 8 | 0 | 19 | 0.00 | 0.0 | 0 | 5.9 | 18 | 10 | M | M | 3 | 18 | 25 | 360 |
| 6 | 89 | 70 | 80 | 4 | 0 | 15 | 0.02 | 0.0 | 0 | 5.3 | 20 | 200 | M | M | 6 | 138 | 23 | 210 |
| 7 | 89 | 69 | 79 | 3 | 0 | 14 | 0.00 | 0.0 | 0 | 3.6 | 14 | 200 | M | M | 7 | 1 | 16 | 210 |
| 8 | 86 | 70 | 78 | 3 | 0 | 13 | 0.74 | 0.0 | 0 | 4.4 | 17 | 150 | M | M | 10 | 18 | 23 | 150 |
| 9 | 76 | 70 | 73 | -2 | 0 | 8 | 0.19 | 0.0 | 0 | 4.1 | 9 | 90 | M | M | 9 | 18 | 13 | 90 |
| 10 | 87 | 71 | 79 | 4 | 0 | 14 | 0.00 | 0.0 | 0 | 2.3 | 8 | 260 | M | M | 8 | 1 | 10 | 210 |

...

# Raw Census 2000 Data for DC

```
u108_S,DC,000,01,0000001,572059,72264,572059,12.6,572059,572059,572059,0,0,
    0,0,572059,175306,343213,2006,14762,383,21728,14661,572059,527044,15861
    7,340061,1560,14605,291,1638,10272,45015,16689,3152,446,157,92,20090,43
    89,572059,268827,3362,3048,3170,3241,3504,3286,3270,3475,3939,3647,3525
    ,3044,2928,2913,2769,2752,2933,2703,4056,5501,5217,4969,13555,24995,242
    16,23726,20721,18802,16523,12318,4345,5810,3423,4690,7105,5739,3260,234
    7,303232,3329,3057,2935,3429,3326,3456,3257,3754,3192,3523,3336,3276,29
    89,2838,2824,2624,2807,2871,4941,6588,5625,5563,17177,27475,24377,22818
    ,21319,20851,19117,15260,5066,6708,4257,6117,10741,9427,6807,6175,57205
    9,536373,370675,115963,55603,60360,57949,129440,122518,3754,3168,22448,
    9967,4638,14110,16160,165698,61049,47694,13355,71578,60875,10703,33071,
    35686,7573,28113,248590,108569,47694,60875,140021,115963,58050,21654,36
    396,57913,10355,4065,6290,47558,25229,22329,24058,13355,10703,70088,657
    37,37112,21742,12267,9475,9723,2573,2314,760,28625,8207,7469,738,19185,
    18172,1013,1233,4351,3610,741,248590,199456,94221,46274,21443,24831,479
    47,8705,3979,4726,39242,25175,14067,105235,82928,22307,49134,21742,1177
    6,211,11565,9966,1650,86,1564,8316,54,8262,27392,25641,1751,248590,1159
    63,4999,22466,26165,24062,16529,12409,7594,1739,132627,11670,32445,2322
    5,21661,16234,12795,10563,4034,248590,115963,48738,28914,19259,10312,47
    48,3992,132627,108569,19284,2713,1209,509,218,125
...
```

# A Simple Example

- Let's start with a simple Ruby program

ruby1.rb:

```
# This is a ruby program
x = 37
y = x + 5
print(y)
print("\n")
```

```
% ruby -w ruby1.rb
42
%
```

# Language Basics

comments begin with #, go to end of line

variables need not be declared

```
# This is a ruby program
x = 37
y = x + 5
print(y)
print("\n")
```

line break separates expressions (can also use “;” to be safe)

no special main() function or method

# Run Ruby, Run

There are several ways to run a Ruby program

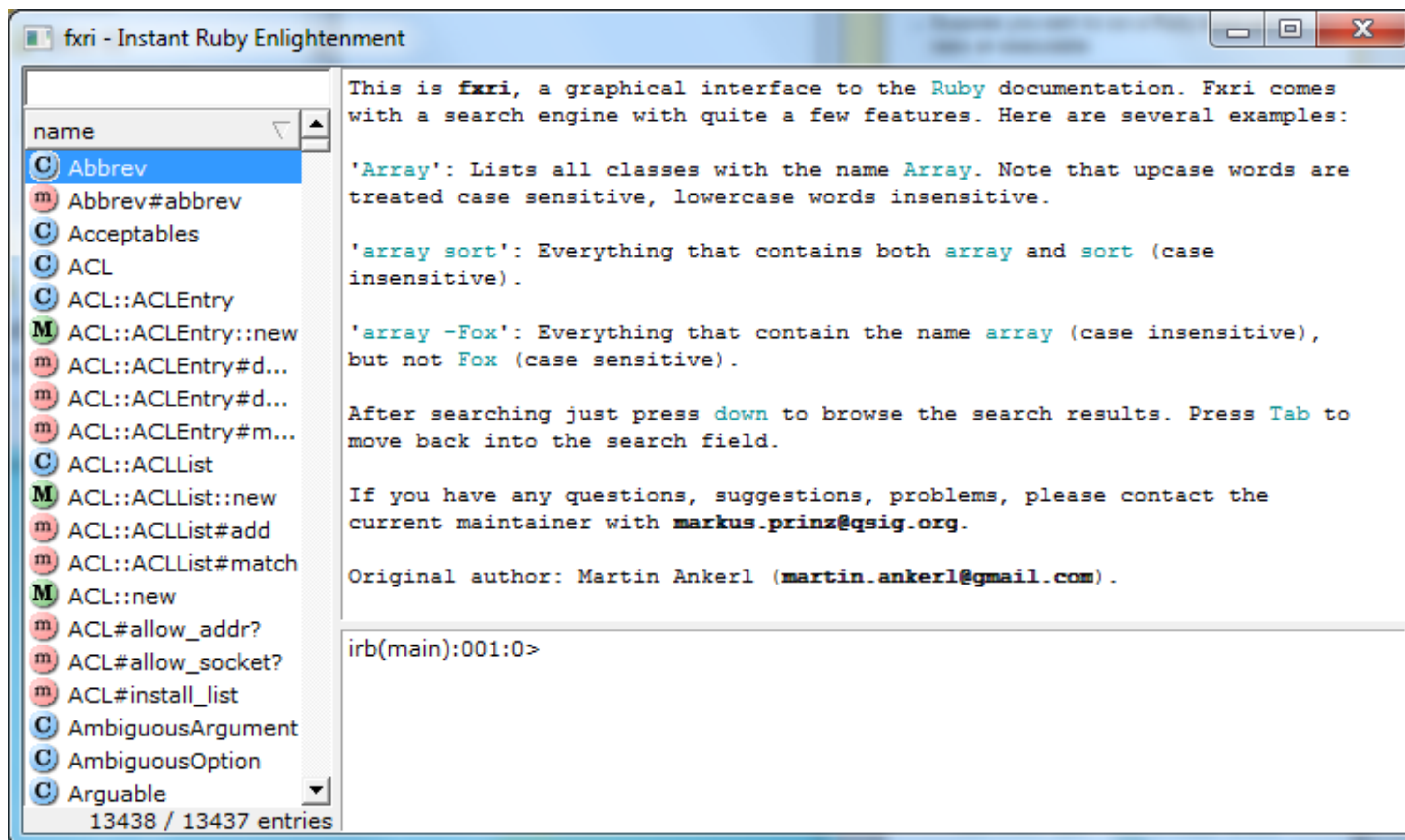
- ruby -w *filename* – execute script in *filename*
  - tip: the -w will cause Ruby to print a bit more if something bad happens
  - Ruby filenames should end with '.rb' extension
- irb – launch interactive Ruby shell
  - Can type in Ruby programs one line at a time, and watch as each line is executed

    irb(main):001:0> 3+4<br>
    ⇒7
  - Can load Ruby programs via load command
    - Form: load *string*
    - String must be name of file containing Ruby program
    - E.g.: load 'foo.rb'

- Ruby 1.9.3 is installed on linuxlab, Grace clusters

# Run Ruby, Run (cont.)

- fxri – launch standalone interactive Ruby shell



# Run Ruby, Run (cont.)

- Suppose you want to run a Ruby script as if it were an executable (e.g. “double-click”, or as a command)
  - Windows
    - Must associate .rb file extension with ruby command
    - If you installed Ruby using the Windows installer, this was done automatically
    - The Ruby web site has information on how to make this association

# Run Ruby, Run (cont.)

- Suppose you want to run a Ruby script as if it were an executable (cont.)
  - *nix (Linux / Unix / etc.)

```
#!/usr/local/bin/ruby -w
print("Hello, world!\n")
```

- The first line ("shebang") tells the system where to find the program to interpret this text file
- Must chmod u+x *filename* first, or chmod a+x *filename* so everyone has exec permission
- Warning: Not very portable: Depends on location of Ruby interpreter
  - /usr/local/bin/ruby vs. /usr/bin/ruby vs. /opt/local/bin/ruby etc.

# Creating Ruby Programs

- As with most programming languages, Ruby programs are text files.
  - Note: there are actually different versions of “plain text”! E.g. ASCII, Unicode, Utf-8, etc.
  - You won’t need to worry about this in this course.
- To create a Ruby program, you can use your favorite text editor, e.g.
  - notepad++ (free, much better than notepad)
  - emacs (free, infinitely configurable)
  - vim
  - Eclipse (see web page for plugin instructions)
  - Many others

# Explicit vs. Implicit Declarations

- Java and C/C++ use explicit variable declarations
  - Variables are named and typed before they are used
    - int x, y; x = 37; y = x + 5;
- In Ruby, variables are implicitly declared
  - First use of a variable declares it and determines type
    - x = 37; y = x + 5;
      - x, y exist, will be integers
  - Ruby allows multi-assignment, too
    - x,y = 37, 5; y += x
      - x,y = 37,x+5 would have failed; x was not yet assigned

# Tradeoffs?

| Explicit Declarations | Implicit Declarations |
| --- | --- |
| More text to type | Less text to type |
| Helps prevent typos | Easy to mistype variable name |
| Forces programmer to document types | Variable not held to a fixed type (could imagine variable declarations without types) |

# Getting started

- All classes examples will be posted on the course schedule webpage.

# Everything is an object

In Ruby:

- All values are references to objects
- Objects communicate via method calls
- Each object has its own (private) state
- Every object is an instance of a class
- An object's class determines the object's behavior
  - How it handles method calls
  - Class contains method definitions

- Java/C#/etc. similar but do not follow (1) (e.g., numbers, `null`) and allow objects to have non-private state

# Everything is an Object

- In Ruby, everything is an object
  - (-4).abs
    - integers are instances of Fixnum
  - 3 + 4
    - infix notation for "invoke the + method of 3 on argument 4"
  - "programming".length
    - strings are instances of String
  - String.new
    - classes are objects with a new method
  - 4.13.class
    - use the class method to get the class for an object
    - floating point numbers are instances of Float

# Classes and Objects

- Class names begin with an uppercase letter
- The "new" method creates an object
  - s = String.new creates a new String and makes s refer to it
- Every class inherits from Object

# Objects and Classes

- Objects are data
- Classes are types (the kind of data which things are)
- But in Ruby, classes themselves are objects!

| Object | Class (aka *type*) |
|---|---|
| 10 | Fixnum |
| -3.30 | Float |
| "CMSC 330" | String |
| String.new | String |
| [‘a’, ‘b’, ‘c’] | Array |
| Fixnum | Class |

- Fixnum, Float, and String are *objects* of type Class
  - So is Class itself!

# Two Cool Things to Do with Classes

- Since classes are objects, you can manipulate them however you like
  - Here, the type of y depends on p
    - Either a String or a Time object

```
if p then
  x = String
else
  x = Time
End
y = x.new
```

- You can get names of all the methods of a class
  - Object.methods
    - => ["send", "name", "class_eval", "object_id", "new", "autoload?", "singleton_methods", ... ]

# The nil Object

- Ruby uses a special object nil
  - All uninitialized fields set to nil (@ prefix used for fields)

    ```
    irb(main):004:0> @x
    => nil
    ```

  - Like NULL or 0 in C/C++ and null in Java
- nil is an object of class NilClass
  - It's a *singleton object* – there is only one instance of it
    - NilClass does not have a **new** method
  - nil has methods like to_s, but not other methods

    ```
    irb(main):006:0> nil + 2
    NoMethodError: undefined method `+' for nil:NilClass
    ```

# Defining Your Own Classes

```
class Point
  def initialize(x, y)
    @x = x
    @y = y
  end

  def add_x(x)
    @x += x
  end

  def to_s
    return "(" + @x.to_s + "," + @y.to_s + ")"
  end
end

p = Point.new(3, 4)
p.add_x(4)
puts(p.to_s)
```

class contains method/ constructor definitions

constructor definition

instance variables prefixed with "@"

method with no arguments

instantiation

invoking no-arg method

# No Access To Internal State

- Instance variables (with @) can be directly accessed only by instance methods
- Outside class, they require accessors:

A typical getter

```
def x
  @x
end
```

A typical setter

```
def x= (value)
  @x = value
end
```

- Very common, so Ruby provides a shortcut

```
class ClassWithXandY
  attr_accessor “x”, “y”
end
```

Says to generate the x= and x and y= and y methods

# No Method Overloading in Ruby

- Thus there can only be one initialize method
  - A typical Java class might have two or more constructors
  - You can code up your own overloading by using a variable number of arguments, and checking at run-time the number/types of arguments
- Ruby does issue an exception or warning if a class defines more than one initialize method
  - But last initialize method defined is the valid one

# Classes and Objects in Ruby (cont.)

- Recall classes begin with an uppercase letter
- inspect converts any instance to a string

```
irb(main):033:0> p.inspect
=> "#<Point:0x54574 @y=4, @x=7>"
```

- The to_s method can be invoked implicitly
  - Could have written puts(p)
    - Like Java's toString() methods

# Inheritance

- Recall that every class inherits from Object

```
class A         ## < Object
  def add(x)
    return x + 1
  end
end

class B < A
  def add(y)
    return (super(y) + 1)
  end
end

b = B.new
puts(b.add(3))
```

extend superclass

invoke add method of parent

```
b.is_a? A
true
b.instance_of? A
false
```

# super( ) in Ruby

- Within the body of a method
  - Call to super( ) acts just like a call to that original method
  - Except that search for method body starts in the superclass of the object that was found to contain the original method

# Methods in Ruby

Methods are declared with def...end

List parameters at definition

May omit parens on call

Invoke method

Like print, but Adds newline

```
def sayN(message, n)
  i = 0
  while i < n
    puts message
    i = i + 1
  end
  return i
end

x = sayN("hello", 3)
puts(x)
```

Methods should begin with lowercase letter and be defined before they are called
Variable names that begin with uppercase letter are *constants* (only assigned once)

# Method Return Values

- Value of the return is the value of the last executed statement in the method
  - These are the same:

```
def add_three(x)
  return x+3
end
```

```
def add_three(x)
  x+3
end
```

- Methods can return multiple results (as a list)

```
def dup(x)
  return x,x
end
```

# Terminology

- Formal parameters
  - Parameters used in the body of the method
  - def sayN(message, n) in our example

- Actual parameters
  - Arguments passed in to the method at a call
  - x = sayN("hello", 3) in our example

# What is a Program?

- In C/C++, a program is...
  - A collection of declarations and definitions
  - With a distinguished function definition
    - int main(int argc, char *argv[]) { ... }
  - When you run a C/C++ program, it's like the OS calls main(...)
- In Java, a program is...
  - A collection of class definitions
  - With some class (say, MyClass) containing a method
    - public static void main(String[] args)
  - When you run java MyClass, the main method of class MyClass is invoked

# A Ruby Program is...

- The class Object
  - When the class is loaded, any expressions not in method bodies are executed

defines a method of Object

invokes self.sayN

invokes self.puts (part of Object)

```
def sayN(message, n)
  i = 0
  while i < n
    puts message
    i = i + 1
  end
  return i
end

x = sayN("hello", 3)
puts(x)
```

# Ruby is Dynamically Typed

- Recall we don't declare types of variables
  - But Ruby does keep track of types at run time

    x = 3; x.foo

    NoMethodError: undefined method 'foo' for 3:Fixnum
- We say that Ruby is dynamically typed
  - Types are determined and checked at run time
- Compare to C, which is statically typed

```
# Ruby
x = 3
x = "foo"   # gives x a
            # new type
```

```
/* C */
int x;
x = 3;
x = "foo"; /* not allowed */
```

# Types in Java and C++

- Are Java and C++ statically or dynamically typed?
  - A little of both
  - Many things are checked statically

    ```
    Object x = new Object();
    x.println("hello");   // No such method error at compile time
    ```

  - But other things are checked dynamically

    ```
    Object o = new Object();
    String s = (String) o;  // No compiler warning, fails at run time
    // (Some Java compilers may be smart enough to warn about
       above cast)
    ```

# Tradeoffs?

| Static types | Dynamic types |
| --- | --- |
| More work when coding | Less work when coding |
| Helps prevent some subtle errors | Can use objects incorrectly and not discover until run time |
| Fewer programs type check | More programs type check |

# Style

- Names of methods that return a boolean should end in ?

- Names of methods that modify an object's state should end in !

- Example: suppose x = [3,1,2] (this is an array)
  - x.member? 3 returns true since 3 is in the array x
  - x.sort returns a new array that is sorted
  - x.sort! modifies x in place

# Control Statements in Ruby

- A control statement is one that affects which instruction is executed next
  - We've seen two so far in Ruby
    - while and method call
- Ruby also has conditionals

```
if grade >= 90 then
  puts "You got an A"
elsif grade >= 80 then
  puts "You got a B"
elsif grade >= 70 then
  puts "You got a C"
else
  puts "You're not doing so well"
end
```

# Ruby Conditionals Must End!

- All Ruby conditional statements must be terminated with the end keyword.
- Examples

```
• if grade >= 90 then
    puts "You got an A"
  end

• if grade >= 90 then
    puts "You got an A"
  else
    puts “No A, sorry"
  end
```

# What is True?

- The guard of a conditional is the expression that determines which branch is taken

Guard

- The true branch is taken if the guard evaluates to anything except
  - false
  - nil
- Warning to C programmers: **0 is not false!**

# Yet More Control Statements in Ruby

- unless cond then stmt-f else stmt-t end
  - Same as "if not cond then stmt-t else stmt-f end"

```
unless grade < 90 then
  puts "You got an A"
else unless grade < 80 then
  puts "You got a B"
end
```

- until cond body end
  - Same as "while not cond body end"

```
until i >= n
  puts message
  i = i + 1
end
```

# Using If and Unless as Modifiers

- Can write if and unless after an expression
  - puts "You got an A" if grade >= 90
  - puts "You got an A" unless grade < 90

- Why so many control statements?
  - Is this a good idea? Why or why not?
    - **Good**: can make program more readable, expressing programs more directly. In natural language, many ways to say the same thing, which supports brevity and adds style.
    - **Bad**: many ways to do the same thing may lead to confusion and hurt maintainability (if future programmers don’t understand all styles)

# Arrays and Hashes

- Ruby data structures are typically constructed from Arrays and Hashes
  - Built-in syntax for both
  - Each has a rich set of standard library methods
  - They are integrated/used by methods of other classes

# Standard Library: Array

- Arrays of objects are instances of class Array
  - Arrays may be heterogeneous

    ```
    a = [1, "foo", 2.14]
    ```
  - C-like syntax for accessing elements, indexed from 0

    ```
    x = a[0]; a[1] = 37
    ```
- Arrays are growable
  - Increase in size automatically as you access elements

    ```
    irb(main):001:0> b = []; b[0] = 0; b[5] = 0; puts b.inspect
    [0, nil, nil, nil, nil, 0]
    ```
  - [ ] is the empty array, same as Array.new

# Standard Library: Arrays (cont.)

- Arrays can also shrink
  - Contents shift left when you delete elements

```
a = [1, 2, 3, 4, 5]
a.delete_at(3)          # delete at position 3; a = [1,2,3,5]
a.delete(2)             # delete element = 2; a = [1,3,5]
```

- Can use arrays to model stacks and queues

```
a = [1, 2, 3]
a.push("a")       # a = [1, 2, 3, "a"]
x = a.pop         # x = "a"
a.unshift("b")    # a = ["b", 1, 2, 3]
y = a.shift       # y = "b"
```

note: `push`, `pop`, `shift`, and `unshift` all permanently modify the array

# Iterating Through Arrays

- It's easy to iterate over an array with while

```
a = [1,2,3,4,5]
i = 0
while i < a.length
  puts a[i]
  i = i + 1
end
```

- Looping through all elements of an array is very common
  - And there's a better way to do it in Ruby

# Iteration and Code Blocks

- The Array class also has an each method
  - Takes a code block as an argument

```
a = [1,2,3,4,5]
a.each { |x| puts x }
```

code block delimited by { }'s or do...end

parameter name

body

- We'll consider code blocks generally a bit later

# Ranges

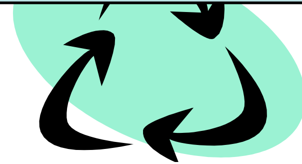
- 1..3 is an object of class Range
  - Integers between 1 and 3 inclusively
- 1…3 also has class Range
  - Integers between 1 and 3 but not including 3 itself.
- Not just for integers
  - ‘a’..’z’ represents the range of letters ‘a’ to ‘z’
  - 1.3…2.7 is the *continuous* range [1.3,2.7)
    - (1.3…2.7).include? 2.0  # => true
- Discrete ranges offer the each method to iterate
  - And can convert to an array via to_a; e.g., (1..2).to_a

# Other Useful Control Statements

```
for elt in [1, "math", 3.4]
  puts elt.to_s
end
```

*generates a string; cf.* to_i

```
for i in (1..3)
  puts i
end
```



```
while i>n
  break
  next
  puts message
  redo
end
```

```
(1..3).each {
  |elt|
  puts elt
}
```

```
IO.foreach(filename)
{ |x|
  puts x
}
```

*code block*

```
case x
when 1, 3..5
when 2, 6..8
end
```

*does not need* break

# More Data-driven Control Statements

Ruby function to print all even numbers from 0 up to (but not including) some given number x

```
def even(x)
  for i in (0…x)
    if i % 2 == 0
      puts i
    end
  end
end
```

```
def even(x)
  x.times { |i|
    if i % 2 == 0
      puts i
    end
  }
end
```

```
def even(x)
  0.upto(x-1) { |i|
    if i % 2 == 0
      puts i
    end
  }
end
```

# Standard Library: Hash

- A hash acts like an associative array
  - Elements can be indexed by any kind of values
  - Every Ruby object can be used as a hash key, because the Object class has a hash method
- Elements are referred to using [ ] like array elements, but Hash.new is the Hash constructor

```
italy["population"] = 58103033
italy["continent"] = "europe"
italy[1861] = "independence"
```

# Hash (cont.)

- Hash methods
  - values returns array of a hash's values (in some order)
  - keys returns an array of a hash's keys (in some order)

- Iterating over a hash

```
italy.keys.each { |k|
    print "key: ", k, " value: ", italy[k]
}

italy.each { |k,v|
    print "key: ", k, " value: ", v
}
```

# Hash (cont.)

Convenient syntax for creating literal hashes

- Use { key => value, ... } to create hash table

```
credits = {
  "cmsc131" => 4,
  "cmsc330" => 3,
}

x = credits["cmsc330"]  # x now 3
credits["cmsc311"] = 3
```

# Mixins

- Another form of code reuse is “mix-in” inclusion
  - `include A` “inlines” A’s methods at that point
    - Referred-to variables/methods captured from context
    - In effect: it adds those methods to the current class

```
class OneDPoint
  attr_accessor “x”
  include Comparable
  def <=>(other)# used by Comparable
    if @x < other.x then return -1
    elsif @x > other.x then return 1
    else return 0
    end
  end
end
```

```
p = OneDPoint.new
p.x = 1
q = OneDPoint.new
q.x = 2
x < y # true
puts [y,x].sort
# prints x, then y
```

# Global Variables in Ruby

- Ruby has two kinds of global variables
  - Class variables beginning with @@ (`static` in Java)
  - Global variables across classes beginning with $

```
class Global
  @@x = 0

  def Global.inc
    @@x = @@x + 1; $x = $x + 1
  end

  def Global.get
    return @@x
  end
end
```

```
$x = 0
Global.inc
$x = $x + 1
Global.inc
puts(Global.get)
puts($x)
```

define a class (“singleton”) method

# Special Global Variables

- Ruby has a special set of global variables that are implicitly set by methods
- The most insidious one: $_
  - Last line of input read by gets or readline
- Example program

```
gets    # implicitly reads input line into $_
print   # implicitly prints out $_
```

- Using $_ leads to shorter programs
  - And confusion
  - We suggest you avoid using it

# Creating Strings in Ruby

- Substitution in double-quoted strings with #{ }
  - course = "330"; msg = "Welcome to #{course}"
  - "It is now #{Time.new}"
  - The contents of #{ } may be an arbitrary expression
  - Can also use single-quote as delimiter
    - No expression substitution, fewer escaping characters
- Here-documents

```
s = <<END
  This is a text message on multiple lines
  and typing \\n is annoying
END
```

# Creating Strings in Ruby (cont.)

- Ruby also has printf and sprintf
  - printf("Hello, %s\n", name);
  - sprintf("%d: %s", count, Time.now)
    - Returns a string

- The to_s method returns a String representation of a class object

# Standard Library: String

- The String class has many useful methods
  - s.length # length of string
  - s1 == s2 # structural equality (string contents)
  - s = "A line\n"; s.chomp # returns "A line"
    - Return new string with s's contents except newline at end of line removed
  - s = "A line\n"; s.chomp!
    - Destructively removes newline from s
    - *Convention:* methods ending in ! modify the object
    - *Another convention:* methods ending in ? observe the object
  - "r1\nr2\n\nr4".each_line { |rec| puts rec }
    - Apply code block to each newline-separated substring

# Standard Library: String (cont.)

- "hello".index("l", 0)
  - Return index of the first occurrence of string in s, starting at n
- "hello".sub("h", "j")
  - Replace first occurrence of "h" by "j" in string
  - Use gsub ("global" sub) to replace all occurrences
- "r1\tr2\t\tr3".split("\t")
  - Return array of substrings delimited by tab

- Consider these three examples again
  - All involve searching in a string for a certain pattern
  - What if we want to find more complicated patterns?
    - Find first occurrence of "a" or "b"
    - Split string at tabs, spaces, and newlines

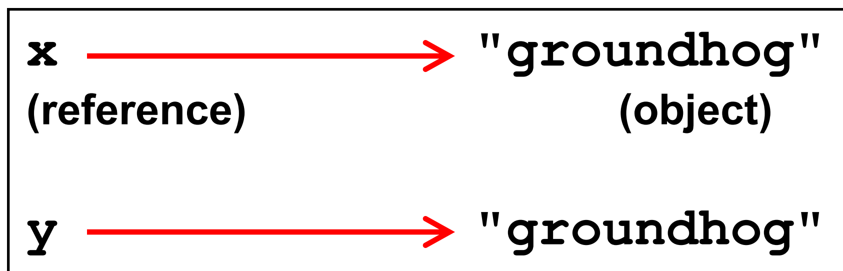
**Regular Expressions!**

# Object Copy vs. Reference Copy

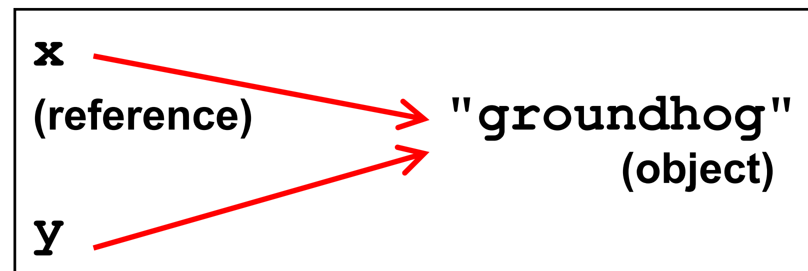
- Consider the following code
  - Assume an object/reference model like Java or Ruby
    - Or even two pointers pointing to the same structure

```
x = "groundhog" ; y = x
```

- Which of these occur?




Object copy




Reference copy

# Object Copy vs. Reference Copy (cont.)

- For

```
x = "groundhog" ; y = x
```

  - Ruby and Java would both do a reference copy

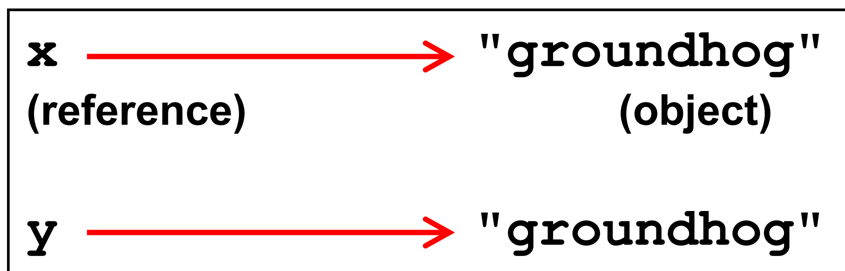
- But for

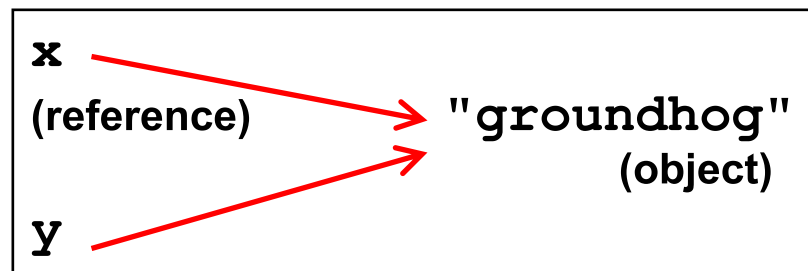
```
x = "groundhog"
y = String.new(x)
```

  - Ruby would cause an object copy
  - Unnecessary in Java since Strings are immutable

# Physical vs. Structural Equality

- Consider these cases again:




- If we compare x and y, what is compared?
  - The references, or the contents of the objects they point to?
- If references are compared (physical equality) the first would return false but the second true
- If objects are compared both would return true

# String Equality

- In Java, x == y is physical equality, always
  - Compares references, not string contents
- In Ruby, x == y for strings uses structural equality
  - Compares contents, not references
  - == is a method that can be overridden in Ruby!
  - To check physical equality, use the equal? method
    - Inherited from the Object class
- It's always important to know whether you're doing a reference or object copy
  - And physical or structural comparison

# Comparing Equality

| Language | Physical equality | Structural equality |
| --- | --- | --- |
| Java | **a == b** | **a.equals(b)** |
| C | **a == b** | ***a == *b** |
| Ruby | **a.equal?(b)** | **a == b** |
| Ocaml | **a == b** | **a = b** |
| Python | **a is b** | **a == b** |
| Scheme | **(eq? a b)** | **(equal? a b)** |
| Visual Basic .NET | **a Is b** | **a = b** |

# Summary

- Scripting languages
- Ruby language
  - Implicit variable declarations
  - Dynamic typing
  - Many control statements
  - Classes & objects
  - Strings