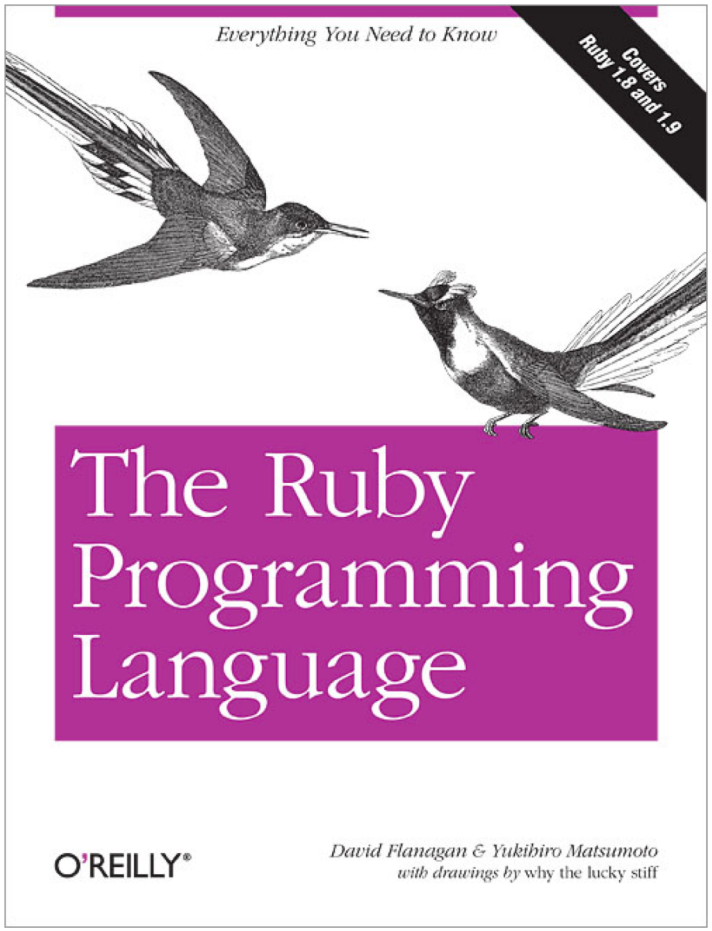
CMSC 330: Organization of Programming Languages

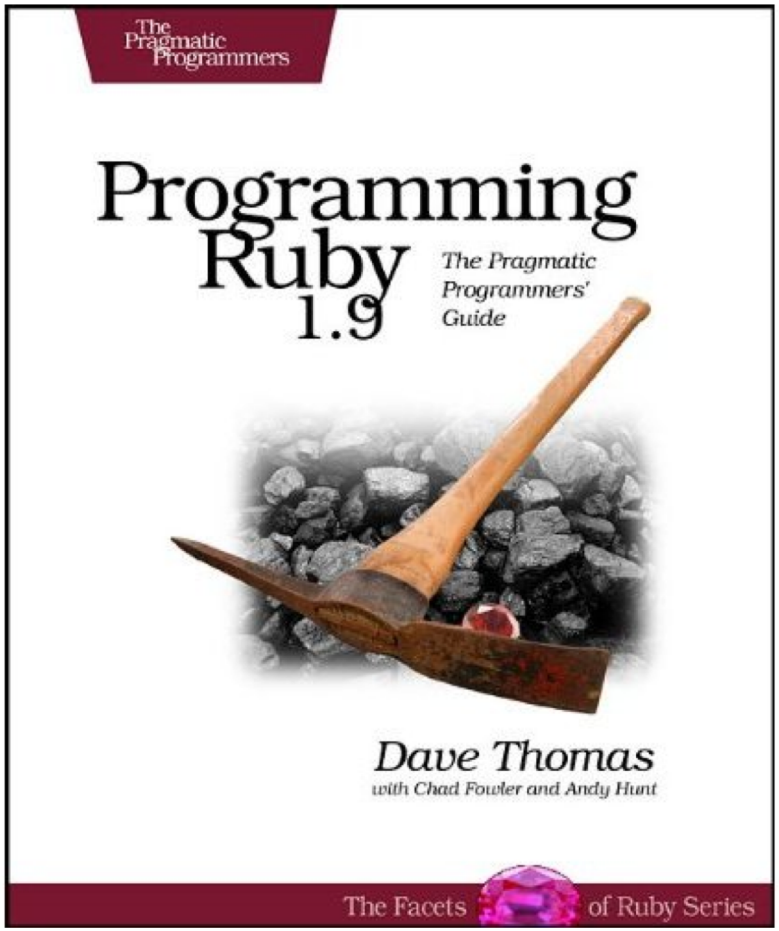
Introduction to Ruby

Ruby

- An *object-oriented, imperative, dynamically typed (scripting) language*
  - Created in 1993 by Yukihiro Matsumoto (Matz)
  - "Ruby is designed to make programmers happy"
  - Core of Ruby on Rails web programming framework (a key to its popularity)
  - Similar in flavor to many other scripting languages
    - Much cleaner than perl
  - Full object-orientation (even primitives are objects!)

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

- Motivating 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 two basic 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

    ⇒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 is installed on Grace cluster

Some Ruby Language Features

- Implicit declarations
  - Java, C have explicit declarations
- Dynamic typing
  - Java, C have (mostly) static typing
- Everything is an object
  - No distinction between objects and primitive data
  - Even “null” is an object (called *nil* in Ruby), as are classes
- No outside access to private object state
  - *Must* use getters, setters
- No method overloading
- Class-based and Mixin inheritance

Implicit vs. Explicit Declarations

- In Ruby, variables are implicitly declared
  - First use of a variable declares it and determines type

```
x = 37;  // no declaration needed – created when assigned to
y = x + 5
```

    - x, y now exist, are integers

- Java and C/C++ use explicit variable declarations
  - Variables are named and typed before they are used

```
int x, y;   // declaration
x = 37;   // use
y = x + 5;  // use
```

Tradeoffs?

Explicit Declarations	Implicit Declarations
More text to type	Less text to type
Helps prevent typos	Easy to mistype variable name

```
var = 37
If (rare-condition)
  y = vsr + 5
```

Typo!

Only caught when this line is actually run.

Bug could be latent for quite a while

Static Type Checking (Static Typing)

- Before program is run
  - Types of all expressions are determined
  - Disallowed operations cause compile-time error
    - Cannot run the program

- Static types are often explicit (*aka* manifest)
  - Specified in text (at variable declaration)
    - C, C++, Java, C#
  - But may also be inferred – compiler determines type based on usage
    - OCaml, C# and Go (limited)

Dynamic Type Checking

- During program execution
  - Can determine type from run-time value
  - Type is checked before use
  - Disallowed operations cause run-time exception
    - Type errors may be latent in code for a long time
- Dynamic types are *not* manifest
  - Variables are just introduced/used without types
  - Examples
    - **Ruby**, Python, Javascript, Lisp

Static and Dynamic Typing

- Ruby is dynamically typed, C is statically typed

```ruby
# Ruby
x = 3
x = "foo"   # gives x a
            # new type
x.foo       # NoMethodError
            # at runtime
```

```c
/* C */
int x;
x = 3;
x = "foo"; /* not allowed */
/* program doesn't compile */
```

- Notes
  - Can always run the Ruby program; may fail when run
  - C variables declared, with types
    - Ruby variables declared *implicitly*
    - Implicit declarations most natural with dynamic typing

Tradeoffs?

- Static type checking
  - More work for programmer (at first)
    - Catches more (and subtle) errors at compile time
  - Precludes some correct programs
    - May require a contorted rewrite
  - More efficient code (fewer run-time checks)
- Dynamic type checking
  - Less work for programmer (at first)
    - Delays some errors to run time
  - Allows more programs
    - Including ones that will fail
  - Less efficient code (more run-time checks)

Java: *Mostly* Static Typing

- In Java, types are mostly checked statically

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

- But sometimes checks occur at run-time

```
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)
```

Quiz 1: Get out your clickers!

- True or false: This program has a type error

```
# Ruby
x = 3
y = "foo"
x = y
```

A. True
B. False

Quiz 1: Get out your clickers!

- True or false: This program has a type error

```
# Ruby
x = 3
y = "foo"
x = y
```

A. True
B. False

- True or false: This program has a type error

```
/* C */
void foo() {
  int x = 3;
  char *y = "foo";
  x = y;
}
```

A. True
B. False

Quiz 1: Get out your clickers!

- True or false: This program has a type error

```
# Ruby
x = 3
y = "foo"
x = y
```

A. True
B. False

- True or false: This program has a type error

```
/* C */
void foo() {
  int x = 3;
  char *y = "foo";
  x = y;
}
```

A. True
B. False

Control Statements in Ruby

- A control statement is one that affects which instruction is executed next
  - While loops
  - Conditionals

```
i = 0
while i < n
  i = i + 1
end
```

```
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
```

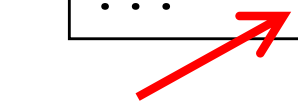
Conditionals and Loops Must End!

- All Ruby conditional and looping 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
    ```
  - ```
    i = 0
    while i < n
      i = i + 1
    end
    ```
    ```

What is True?

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

```
if grade >= 90 then
...
```



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)

Quiz 2: What is the output?

```
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. "true"
B. "== 0"
C. "false"
D. Nothing – there's an error

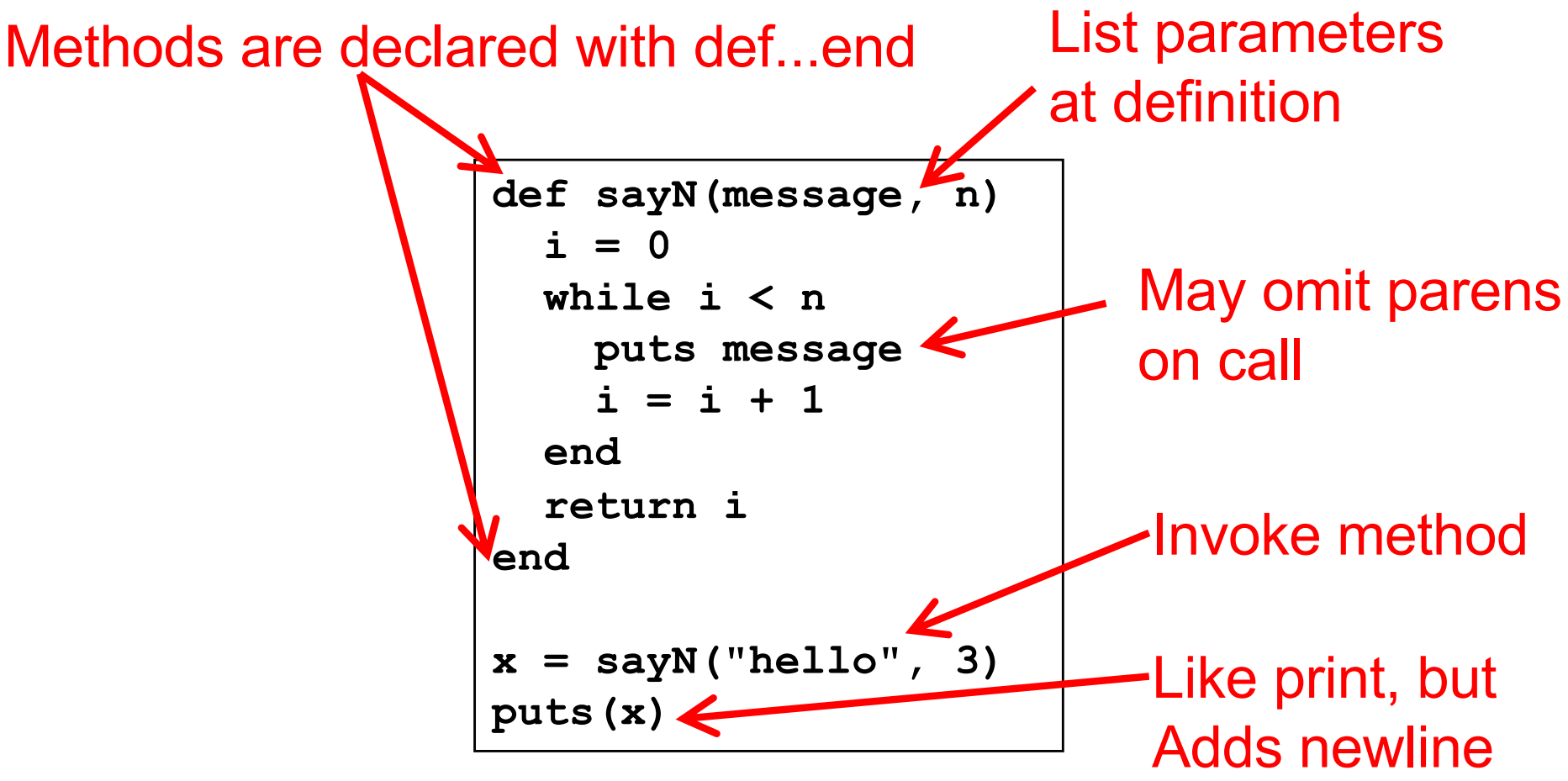
Quiz 2: What is the output?

```
x = 0
if x then
  puts "true"
elsif x == 0 then
  puts "== 0"
else
  puts "false"
end
```

A. "true"
B. "== 0"
C. "false"
D. Nothing – there's an error

x is neither **false** nor **nil** so the first guard is satisfied

Methods in Ruby



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)

Terminology

- Formal parameters
  - Variable parameters used in the method
  - def sayN(message, n) in our example
- Actual arguments
  - Values passed in to the method at a call
  - x = sayN("hello", 3) in our example
- Top-level methods are “global”
  - Not part of a class. sayN is a top-level method.

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 an Array)

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

Everything is an Object

- All values are (references to) objects
  - Java/C/C++ distinguish *primitives* from *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 its behavior:
  - The class contains method and field definitions
    - Both instance fields and per-class ("static") fields

Everything is an Object

- Examples
  - (-4).abs  No-argument instance method of Fixnum
    - integers are instances of class 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

- 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)
- Classes are *also* objects

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

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

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
```

Quiz 3

- What is the type of variable x at the end of the following program?

```
p = nil
x = 3
if p then
  x = nil
else
  x = "hello"
end
```

A. String
B. Integer
C. NilClass
D. *Nothing* – there's a type error

Quiz 3

- What is the type of variable x at the end of the following program?

```
p = nil
x = 3
if p then
  x = nil
else
  x = "hello"
end
```

A. **String**
B. Integer
C. NilClass
D. *Nothing* – there's a type error

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 has printf and sprintf
  - printf("Hello, %s\n", name);
  - sprintf("%d: %s", count, Time.now)
    - Returns a String
- to_s returns a String representation of an object
  - Can be invoked implicitly – write puts(p) instead of puts(p.to_s)
    - Like Java's toString()
- inspect converts any object to a string

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

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

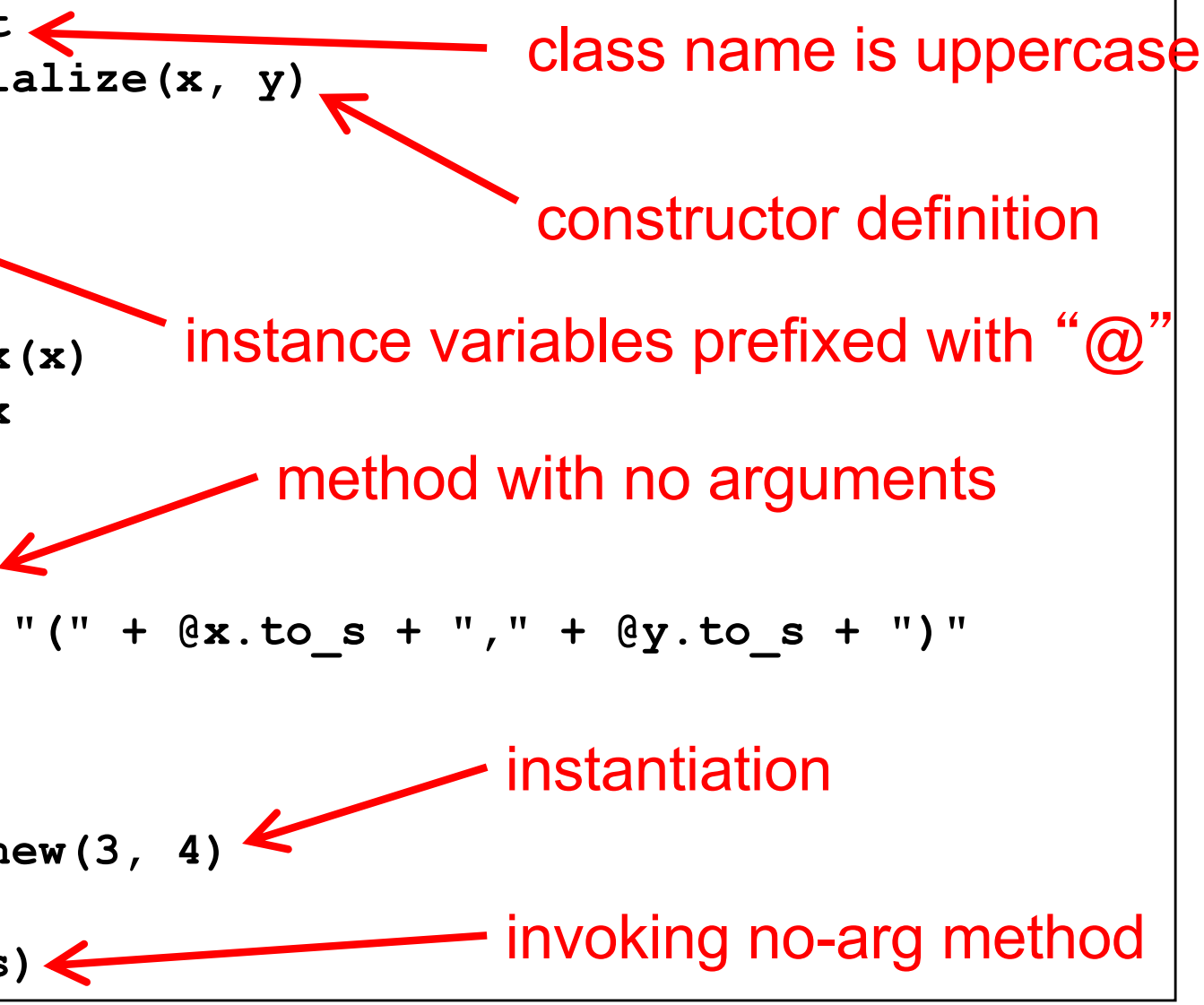
Defining Your Own Classes

```
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)
```



No Outside 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
- No overloading of methods in general
  - 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

Quiz 4: What is the output?

```
class Dog
   def smell(thing)
     "I smelled #{thing}”
   end
   def smell(thing,dur)
     "I smelled #{thing} for #{dur} seconds”
   end
end
fido = Dog.new
puts fido.smell(”Alice”)
```

A. I smelled Alice for nil seconds
B. *Error*
C. I smelled #{thing}
D. I smelled Alice

Quiz 4: What is the output?

```
class Dog
   def smell(thing)
     "I smelled #{thing}”
   end
   def smell(thing,dur)
     "I smelled #{thing} for #{dur} seconds”
   end
end
fido = Dog.new
puts fido.smell(”Alice”)
```

A. I smelled Alice for nil seconds
B. *Error*
C. I smelled #{thing}
D. I smelled Alice

Quiz 5: What is the output?

```
class Dog
   def smell(thing)
     "I smelled #{thing}”
   end
   def smell(thing,dur)
     "I smelled #{thing} for #{dur} seconds”
   end
end
fido = Dog.new
puts fido.smell(”Alice”,3)
```

A. I smelled Alice for seconds
B. *Error*
C. I smelled #{thing} for #{dur} seconds
D. I smelled Alice for 3 seconds

Quiz 5: What is the output?

```
class Dog
   def smell(thing)
     "I smelled #{thing}”
   end
   def smell(thing,dur)
     "I smelled #{thing} for #{dur} seconds”
   end
end
fido = Dog.new
puts fido.smell(”Alice”,3)
```

A. I smelled Alice for seconds
B. *Error*
C. I smelled #{thing} for #{dur} seconds
D. **I smelled Alice for 3 seconds**

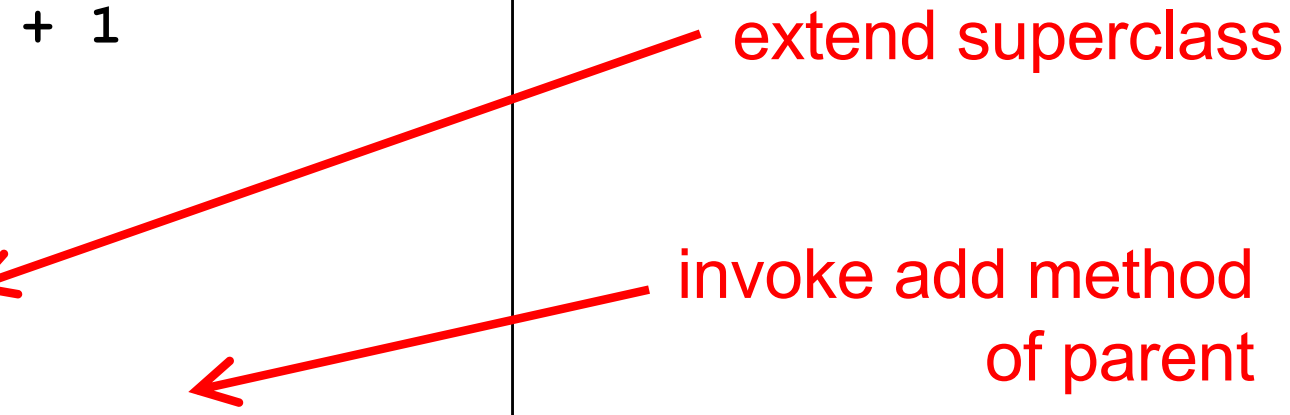
Inheritance

- 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))
```




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

Quiz 6: What is the output?

```
class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end
class Outlaw < Gunslinger
   def full_name
      "Dirty, no good #{super}"
   end
end
d = Outlaw.new("Billy the Kid")
puts d.full_name
```

A. Dirty, no good
B. Dirty, no good Billy the kid
C. Billy the Kid
D. *Error*

Quiz 6: What is the output?

```
class Gunslinger
  def initialize(name)
    @name = name
  end
  def full_name
    "#{@name}"
  end
end
class Outlaw < Gunslinger
   def full_name
      "Dirty, no good #{super}"
   end
end
d = Outlaw.new("Billy the Kid")
puts d.full_name
```

A. Dirty, no good
B. **Dirty, no good Billy the kid**
C. Billy the Kid
D. *Error*

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

Quiz 7: What is the output?

```
class Animal
 def initialize(h, w)
     @@h = h
     @w = w
 end
 def measure()
  return @@h + @w
 end
End
giraffe = Animal.new(1,2)
elephant = Animal.new(3,4)
puts giraffe.measure()
```

A. 0

B. 3

C. 5

D. 7

Quiz 7: What is the output?

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elephant = Animal.new(3,4)
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```

A. 0

B. 3

C. **5**

D. 7

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
(i.e., top-level methods belong to 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)
```