CMSC 330: Organization of Programming Languages

Introduction to Ruby
Clickers improve student engagement


Using clickers to improve student engagement and performance class.

Addison S¹, 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
I have my clicker

A. True
B. False
Introduction

Ruby is an object-oriented, imperative, dynamically typed (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’)
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

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## Raw Census 2000 Data for DC

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A Simple Example

Let’s start with a simple Ruby program

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

`ruby -w ruby1.rb`

```
42
```

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

comments begin with #, go to end of line

variables need not be declared

no special main() function or method

line break separates expressions (can also use ";") to be safe
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 1.9.3 is installed on Grace cluster (upgrading to 2.4)
Run Ruby, Run (cont.)

- **fxri** – launch standalone interactive Ruby shell

```ruby
#!/usr/local/bin/ruby

print("Hello, world!
")
```

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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.)

```ruby
#!/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
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
Implicit vs. Explicit Declarations

- Explicit declarations identify allowed names
  - Variables must be declared before used

```c
void foo(int y) {
    int x;
    x = y + 1;
    return x + y;
}
```

C, Java, C++, etc.
Implicit vs. Explicit Declarations

- Allowed names also declared implicitly
  - Variables do not need to be declared
    - Implicit declaration when first assigned to

Ruby:
```ruby
def foo(y)
    x = y + 1;
    return x + y;
end
```

Also: Perl, Python
Tradeoffs?

Explicit Declarations
More text to type
Helps prevent typos

Implicit Declarations
Less text to type
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* (aka implicit)
  - 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       # NoMethodName # 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
  ```java
  Object x = new Object();
  x.println("hello");  // No such method error at compile time
  ```

- But sometimes checks occur at run-time
  ```java
  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
# Ruby
x = 3
y = “foo”
x = y
```

A. True  
B. False

- **True or false**: This program has a type error

```c
/* 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
# Ruby
x = 3
y = "foo"
x = y
```

- A. True
- B. False

- **True** or **false**: This program has a type error

```c
/* 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

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

```ruby
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)
Other Useful Control Statements

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

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

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

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

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

puts message
redo

end

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

generates a string; cf. to_i

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

does not need break
Methods in Ruby

Methods are declared with `def...end`

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

Invoke method

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

List parameters at definition

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)

Like print, but Adds newline

May omit parens on call

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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:

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

- Methods can return multiple results (as a list)

```ruby
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  
  ➢ 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

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<th>Class (aka type)</th>
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<td>&quot;CMSC 330&quot;</td>
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<td>String.new</td>
<td>String</td>
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<td>Integer</td>
<td>Class</td>
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- Integer, 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

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

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

```plaintext
p = 0
if p then
  x = nil
else
  x = "hello"
end
```

A. String
B. Integer
C. NilClass
D. Nothing – there’s a type error
Quiz 2

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

```ruby
p = 0
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
  
  ```ruby
  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>"`
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
Method naming 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
Defining Your Own Classes

```ruby
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)
```

- **Constructor definition**: `def initialize(x, y) @x = x @y = y end`
- **Instance variables**: Prefixed with `@`.
- **Method with no arguments**: `def add_x(x) @x += x end`
- **Instantiation**: `p = Point.new(3, 4)`
- **Invoking no-arg method**: `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:
  
  ```ruby
  def x
    @x
  end
  def x= (value)
    @x = value
  end
  
  A typical getter
  A typical setter
  
  Very common, so Ruby provides a shortcut
  ```

```ruby
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 3: What is the output?

class Animal
  def eat(food)
    "I ate #{food}"
  end
  def eat(food,amount)
    "I ate #{amount} pounds of #{food}"
  end
end

animal = Animal.new
puts animal.eat("meat")

A. I ate #{food}
B. I ate meat
C. I ate pounds of meat
D. Error
Quiz 3: What is the output?

class Animal
  def eat(food)
    "I ate #{food}"
  end
  def eat(food, amount)
    "I ate #{amount} pounds of #{food}"
  end
end

animal = Animal.new
puts animal.eat("meat")

A. I ate #{food}
B. I ate meat
C. I ate pounds of meat
D. Error
Quiz 4: What is the output?

class Animal
  def eat(food)
    "I ate #{food}"
  end
  def eat(food, amount)
    "I ate #{amount} pounds of #{food}"
  end
End
animal = Animal.new
puts animal.eat("meat", 23)

A. I ate meat
B. I ate 23 pounds of meat
C. Error
D. I ate #{amount} pounds pf #{food}
Quiz 4: What is the output?

class Animal
  def eat(food)
    "I ate #{food}"
  end
  def eat(food,amount)
    "I ate #{amount} pounds of #{food}"
  end
End
animal = Animal.new
puts animal.eat("meat",23)

A. I ate meat
B. I ate 23 pounds of meat
C. Error
D. I ate #{amount} pounds pf #{food}
Inheritance

- Recall that every class inherits from `Object`

```ruby
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
```
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

```ruby
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
```

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

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

```ruby
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

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

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

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

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

defines a method of Object (i.e., top-level methods belong to Object)

invokes `self.sayN`

invokes `self.puts` (part of Object)
class Thing
    @@things = 0
    def initialize(name)
        @name = name
        @@things += 1
    end
    def self.get_things
        return @@things
    end
end
Thing.new("thing20");
Thing.new("thing6")
puts Thing.get_things

Quiz 5: What is the output?
A. 0
B. 1
C. 2
D. 3
Quiz 5: What is the output?

class Thing
  @@things = 0
  def initialize(name)
    @name = name
    @@things += 1
  end
  def self.get_things
    return @@things
  end
end

Thing.new("thing20");
Thing.new("thing6")
puts Thing.get_things

A. 0
B. 1
C. 2
D. 3
Quiz 6: What is the output?

class Dog
  def initialize
    @bark = "ruff ruff"
  end
  def speak
    "I like to #{@bark}"
  end
end

fido = Dog.new
puts fido.speak()
Quiz 6: What is the output?

class Dog
  def initialize
    @bark = "ruff ruff"
  end
  def speak
    "I like to #{@bark}"
  end
end

fido = Dog.new
puts fido.speak()
Quiz 7: What is the output?

class Computer
  def initialize
    @sound = "beep beep"
  end
  def self.about
    "Sometimes I go #{@sound}"
  end
end

print Computer.about

A. Sometimes I go #{@sound}"
B. Sometimes I go
C. Error
D. Sometimes I go nil
Quiz 7: What is the output?

```ruby
class Computer
    def initialize
        @sound = "beep beep"
    end
    def self.about
        "Sometimes I go #{@sound}"
    end
end
print Computer.about
```

A. Sometimes I go #{@sound}"
B. Sometimes I go
C. Error
D. Sometimes I go nil
Quiz 8: What is the output?

class Person
  def initialize(first, last)
    @first = first
    @last = last
  end
  def full_name
    "#{@first} #{@last}"
  end
end

class Doctor < Person
  def full_name
    "Dr. #{super}"
  end
end

d = Doctor.new("Phil", "McGraw")
print d.full_name

A. Dr. #{super}
B. Dr.
C. Dr. Phil McGraw
D. Error
Quiz 8: What is the output?

class Person
  def initialize(first, last)
    @first = first
    @last = last
  end

  def full_name
    "#{@first} #{@last}"
  end
end

class Doctor < Person
  def full_name
    "Dr. #{super}"
  end
end

d = Doctor.new("Phil", "McGraw")
print d.full_name

A. Dr. #{super}
B. Dr.
C. Dr. Phil McGraw
D. Error
Summary

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