CMSC 330: Organization of Programming Languages

Ruby

Reminders and Announcements

- If you're not on the list, you're not in the class (I have the list)
- Project 1 was posted on Sep. 3
  - It is due on Sep. 24
  - Start immediately
- Check glue access
- Use the class forum
- Read complete syllabus online
- Leave 24 hours for email responses

Review

- Why study programming languages?
- What makes a good programming language?
- Compilers vs. Interpreters
- What kind of language is…
  - C
  - Java
  - Ruby
  - OCaml

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")

Applications of Scripting Languages

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

Text processing

Go away or I will replace you with a very small shell script.
ThinkGeek

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

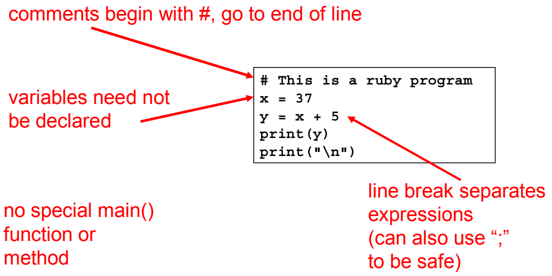
- Let’s start with a simple Ruby program

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")
```

no special main() function or method

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

Run Ruby, Run

- There are three 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
  - 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
irb(main):002:0> print("hello\n")
hello
=> nil
```

Run Ruby, Run (cont’d)

- Suppose you want to run a Ruby script as if it were an executable

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

  - ./filename # run program
  - The first line 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 /usr/local/bin/ruby

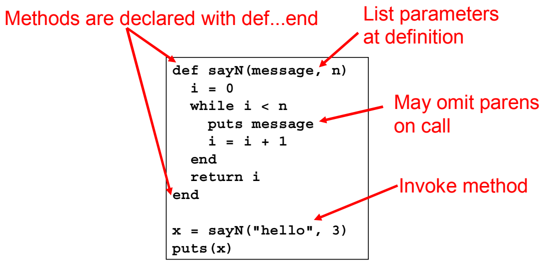
Explicit vs. Implicit Declarations

- 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

Tradeoffs?

Explicit Declarations	Implicit Declarations
Overhead?	Overhead?
Helps prevent typos	Easy to mistype variable name
Forces programmer to document types	Figures out types of variables automatically

Methods in Ruby



Methods are declared with def...end
List parameters at definition
May omit parens on call
Invoke method

```
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 must begin with lowercase letter and be defined before they are called)

Method (and Function) Terminology

- *Formal parameters* – The parameters used in the body of the method
  - message, n in our example
- *Actual parameters* – The arguments passed in to the method at a call
  - "hello", 3 in our example

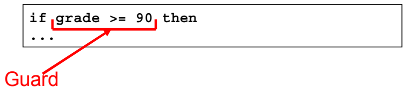
More Control Statements in Ruby

- A *control statement* is one that affects which instruction is executed next
  - We've seen two so far in Ruby
    - while and function 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
```

What is True?

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



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

- 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
end
```

- until *cond body* end
  - Same as “while not *cond body* end”

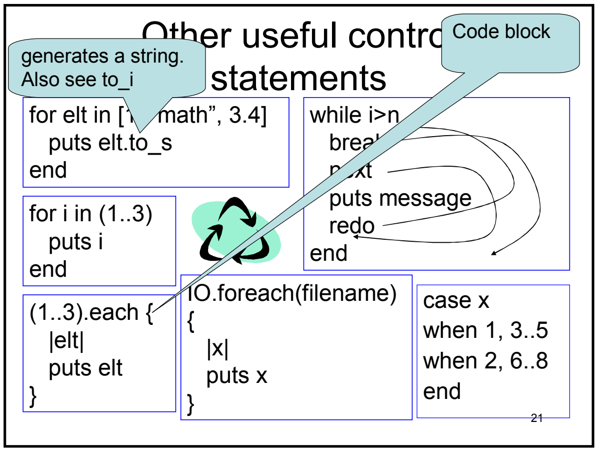
```
until i >= n
  puts message
  i = i + 1
end
```

19

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?
  - Advantages? Disadvantages?

20



Other useful control statements

generates a string. Also see to_i

Code block

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

```
while i>n
  break
  next
  puts message
  redo
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
when 2, 6..8
end
```

21

To try with a neighbor

Write (on paper) a Ruby function to print all even numbers from 1 to some given value x.

```
def even(x)
  for i in (1..x)
    if i % 2 == 0
      puts i
    end
  end
end
```

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

22

Classes and Objects

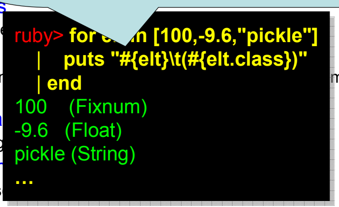
- Class names begin with an uppercase letter
- The “new” method creates an object
  - s = String.new creates a new String and makes s refer to it
- Every class inherits from Object

23

E

Writing **elt** as **#{elt}** makes it clear that it is a variable to be evaluated, not a literal word to be printed. This is a cleaner way to express output; it builds a single string and presents it as a single argument to **puts**.

- In Rub
  - (-4).abs
    - intege
  - 3 + 4
    - infix r ment 4”
  - "progra
    - string
  - String.n
    - class
  - (4.13).class
    - use the class method to get the class for an object
    - floating point numbers are instances of Float



```
ruby> for e  in [100,-9.6,"pickle"]
    |   puts "#{elt}\t(#{elt.class})"
    | end
100    (Fixnum)
-9.6   (Float)
pickle (String)
...
```

24

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
10	Fixnum
-3.30	Float
"CMSC 330"	String
String.new	String
Fixnum	Class
String	Class

- Fixnum, Float, String, etc., (including Class), are objects of type Class

Two Cool Things to Do with Classes

- Since classes are objects, you can manipulate them however you like
  - if p then x = String else x = Time end # Time is
    … # another class
    y = x.new # creates a String or a Time,
    # depending upon p
- 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 (@ refers to a class field)

```
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 that don't make sense

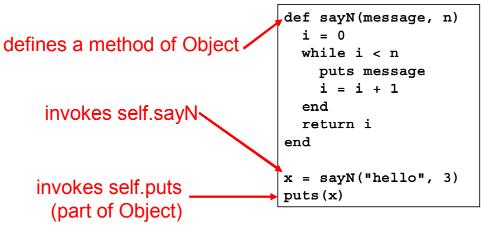
```
irb(main):006:0> @x + 2
NoMethodError: undefined method `+' for nil:NilClass
```

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 a class Cl that contains a method
    - public static void main(String[] args)
  - When you run java Cl, the main method of class Cl is invoked

A Ruby Program is...

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



```
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

invokes self.sayN

invokes self.puts
(part of Object)

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();

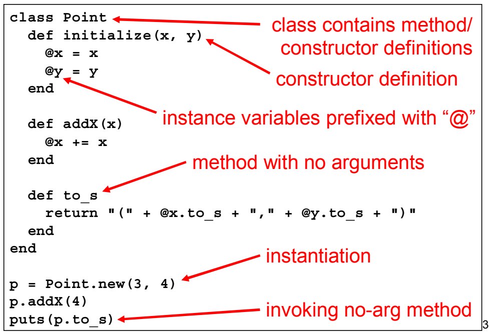
    String s = (String) o; // No compiler warning, fails at run time

    // (Some Java compilers may be smart enough to warn about above cast)

Tradeoffs?

Static types	Dynamic types
More work to do when writing code	Less work when writing code
Helps prevent some subtle errors	Can use objects incorrectly and not realize until execution
Fewer programs type check	More programs type check

Classes and Objects in Ruby



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

  def addX(x)
    @x += x
  end

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

p = Point.new(3, 4)
p.addX(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

Classes and Objects in Ruby (cont’d)

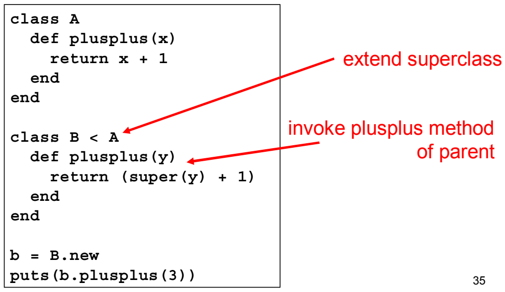
- Recall classes begin with an uppercase letter
- inspect converts *any* instance to a string

  irb(main):033:0> p.inspect

  => "#<Point:0x54574 @y=4, @x=7>"
- Instance variables are prefixed with @
  - Compare to local variables with no prefix
  - *Cannot be accessed outside of class*
- 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



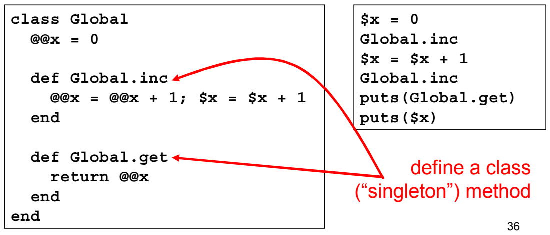
```
class A
  def plusplus(x)
    return x + 1
  end
end

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

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

Global Variables in Ruby

- Ruby has two kinds of global variables
  - Class variables beginning with @@
  - Global variables across classes beginning with $

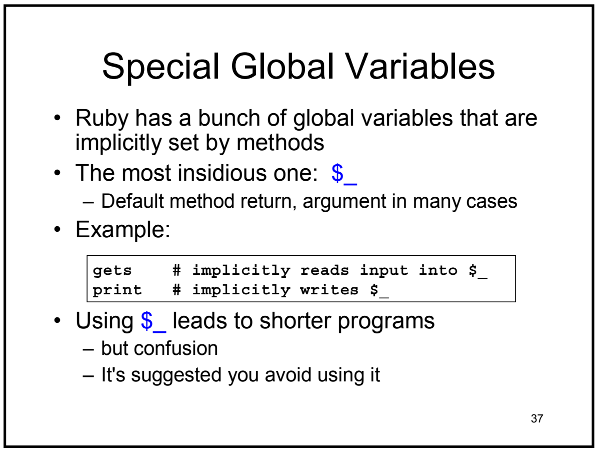


```
class Global
  @@x = 0

  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)
```

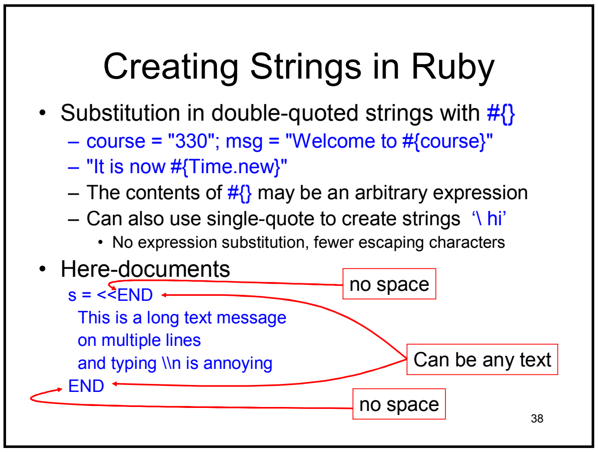


Special Global Variables

- Ruby has a bunch of global variables that are implicitly set by methods
- The most insidious one: $_
  - Default method return, argument in many cases
- Example:

```
gets     # implicitly reads input into $_
print    # implicitly writes $_
```

- Using $_ leads to shorter programs
  - but confusion
  - It's suggested you avoid using it

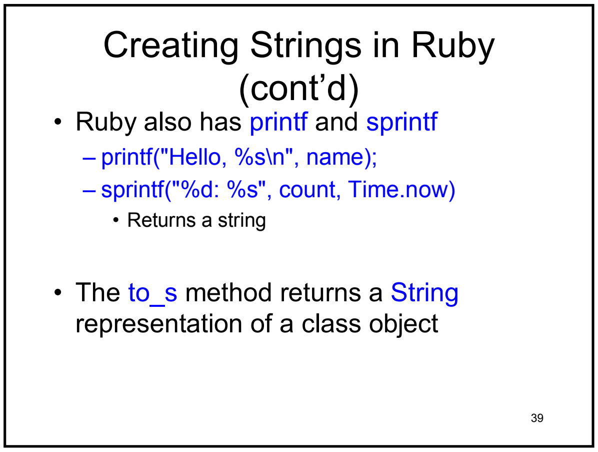


Creating Strings in Ruby

- 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 to create strings '\ hi'
    - No expression substitution, fewer escaping characters
- Here-documents

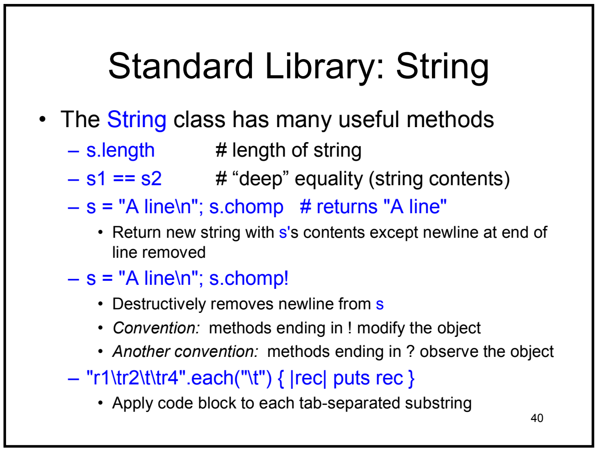
```
s = <<END
  This is a long text message
  on multiple lines
  and typing \\n is annoying
END
```

no space
Can be any text
no space



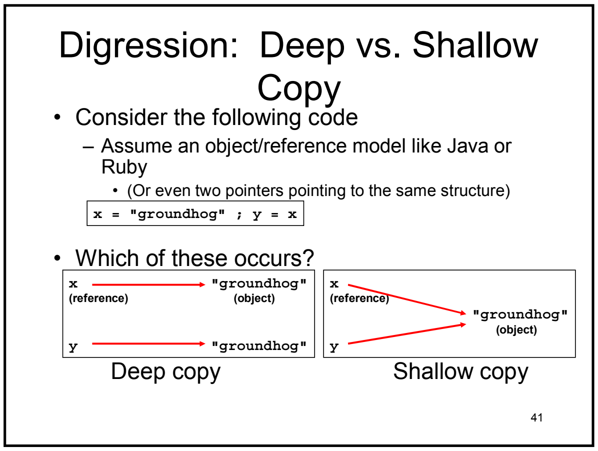
Creating Strings in Ruby (cont'd)

- 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 # "deep" 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\tr2\t\tr4".each("\t") { |rec| puts rec }
    - Apply code block to each tab-separated substring



Digression: Deep vs. Shallow Copy

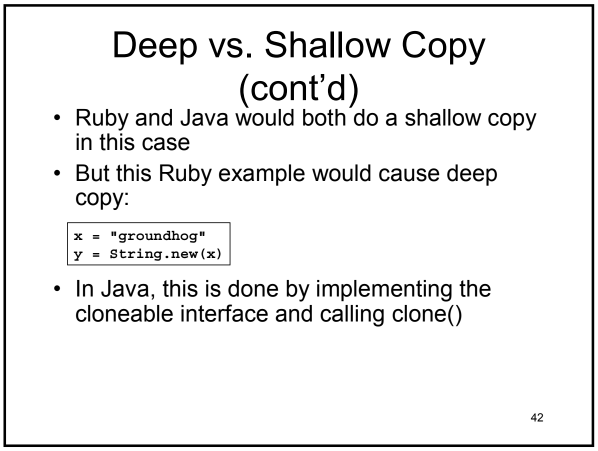
- Consider the following code
  - Assume an object/reference model like Java or Ruby
    - (Or even two pointers pointing to the same structure)

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

- Which of these occurs?

x
(reference)
"groundhog"
(object)
y
"groundhog"
x
(reference)
"groundhog"
(object)
y

Deep copy Shallow copy

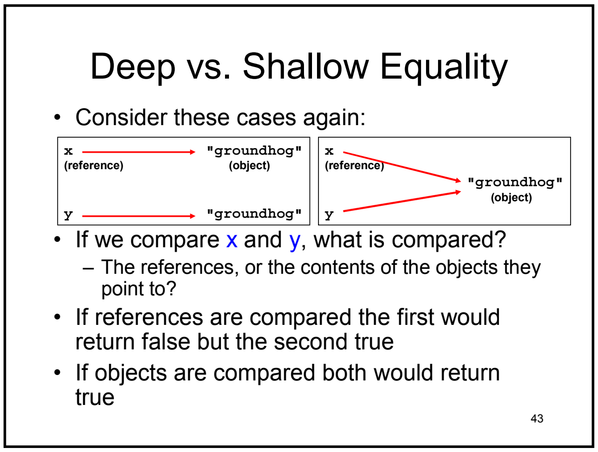


Deep vs. Shallow Copy (cont'd)

- Ruby and Java would both do a shallow copy in this case
- But this Ruby example would cause deep copy:

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

- In Java, this is done by implementing the cloneable interface and calling clone()



Deep vs. Shallow Equality

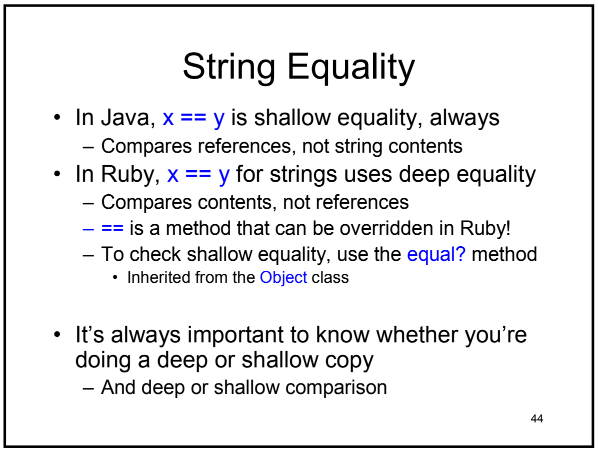
- Consider these cases again:

x (reference) → "groundhog" (object)

y → "groundhog"

x (reference) → "groundhog" (object) ← y

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



String Equality

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