CMSC 330: Organization of Programming Languages

Array, Hashes, Code Blocks, Equality

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

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
  - return nil if no element at given index

```
irb(main):001:0> b = []; b[0] = 0; b[0]
 => 0
irb(main):002:0> b[1]  # no element at this index
 => nil
```

Arrays Grow and Shrink

- Arrays are growable
  - Increase in size automatically as you access elements

```
irb(main):001:0> b = []; b[0] = 0; b[5] = 0; b
 => [0, nil, nil, nil, nil, 0]
```

  - [ ] is the empty array, same as Array.new
- 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]
```

Iterating Through Arrays

- It's easy to iterate over an array with while
  - length method returns array's current length

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

- Looping through elements of an array is common
  - We'll see a better way soon, using code blocks

Arrays as Stacks and Queues

- Arrays can 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 that `push`, `pop`, `shift`, and `unshift` all permanently modify the array

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 like array elements

```
italy = Hash.new
italy["population"] = 58103033
italy["continent"] = "europe"
italy[1861] = "independence"
pop = italy["population"] # pop is 58103033
planet = italy["planet"]  # planet is nil
```

Hash methods

- new(o) returns hash whose default value is o
  - h = Hash.new("fish"); h["go"] # returns "fish"
- values returns array of a hash's values
- keys returns an array of a hash's keys
- delete(k) deletes mapping with key k
- has_key?(k) is true if mapping with key k present
  - has_value?(v) is similar

Hash creation

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
```

- Use { } for the empty hash

Quiz 1: What is the output

```
a = {}
a[“foo”] = 1
print a[“foo”]
print a[“bar”]
```

A. 1
B. 1nil
C. Error
D. foobar

Quiz 1: What is the output

```
a = {}
a[“foo”] = 1
print a[“foo”]
print a[“bar”]
```

A. 1
B. 1nil
C. Error
D. foobar

Quiz 2: What is the output

```
a = {}
a[”Spade”] = [ ]
a[“Spade”][“Club”] = “Heart”
puts a[“Spade”][“Club”]
```

A. Heart
B. [ ]
C. Error
D. { }

Quiz 2: What is the output

```
a = {}
a[”Spade”] = [ ]
a[“Spade”][“Club”] = “Heart”
puts a[“Spade”][“Club”]
```

A. Heart
B. [ ]
C. Error
D. { }

Quiz 3: What is the output

```
a = {}
a[1] = “foo”
print a[0]
```

A. Error
B. nil
C. foo
D. Nothing is printed.

Quiz 3: What is the output

```
a = {}
a[1] = “foo”
print a[0]
```

A. Error
B. nil
C. foo
D. Nothing is printed.

Code Blocks

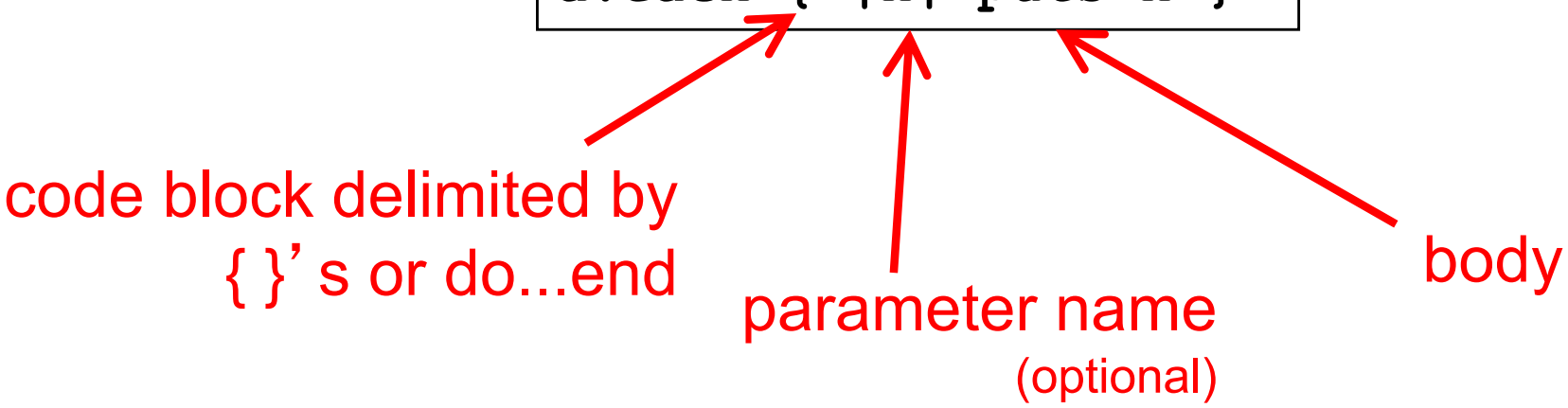
- A code block is a piece of code that is invoked by another piece of code

- Code blocks are useful for encapsulating repetitive computations

Array Iteration with Code Blocks

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

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



More Examples of Code Block Usage

- Sum up the elements of an array

```
a = [1,2,3,4,5]
sum = 0
a.each { |x| sum = sum + x }
printf("sum is %d\n", sum)
```

- Print out each segment of the string as divided up by commas (commas are printed trailing each segment)
  - Can use any delimiter

```
s = "Student,Sally,099112233,A"
s.split(',').each { |x| puts x }
```

("delimiter" = symbol used to denote boundaries)

Yet More Examples of Code Blocks

```
3.times { puts "hello"; puts "goodbye" }
5.upto(10) { |x| puts(x + 1) }
[1,2,3,4,5].find { |y| y % 2 == 0 }
[5,4,3].collect { |x| -x }
```

- n.times runs code block n times
- n.upto(m) runs code block for integers n..m
- a.find returns first element x of array such that the block returns true for x
- a.collect applies block to each element of array and returns new array (a.collect! modifies the original)

Still Another Example of Code Blocks

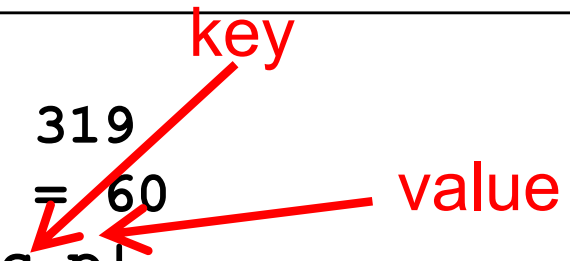
```
File.open("test.txt", "r") do |f|
  f.readlines.each { |line| puts line }
end
```

alternative syntax: do … end instead of { … }

- open method takes code block with file argument
  - File automatically closed after block executed
- readlines reads all lines from a file and returns an array of the lines read
  - Use each to iterate
- Can do something similar on strings directly:
- "r1\nr2\n\nr4".each_line { |rec| puts rec }
  - Apply code block to each newline-separated substring

Code Blocks for Hashes

```
population = {}
population["USA"] = 319
population["Italy"] = 60
population.each { |c,p|
  puts "population of #{c} is #{p} million"
}
```



- Can iterate over keys and values separately

```
population.keys.each { |k|
    print "key: ", k, " value: ", population[k]
  }
popluation.values.each { |v|
    print "value: ", v
  }
```

Using Yield To Call Code Blocks

- Any method can be called with a code block
  - Inside the method, the block is called with yield
- After the code block completes
  - Control returns to the caller after the yield instruction

```
def countx(x)
  for i in (1..x)
     puts i
     yield
  end
end

countx(4) { puts "foo" }
```

```
1
foo
2
foo
3
foo
4
foo
```

So What Are Code Blocks?

- A code block is just a special kind of method
  - { |y| x = y + 1; puts x } is almost the same as
  - def m(y) x = y + 1; puts x end
- The each method takes a code block as a parameter
  - This is called higher-order programming
    - In other words, methods take other methods as arguments
    - We'll see a lot more of this in OCaml
- We'll see other library classes with each methods
  - And other methods that take code blocks as arguments
  - As we saw, your methods can use code blocks too!

Ranges

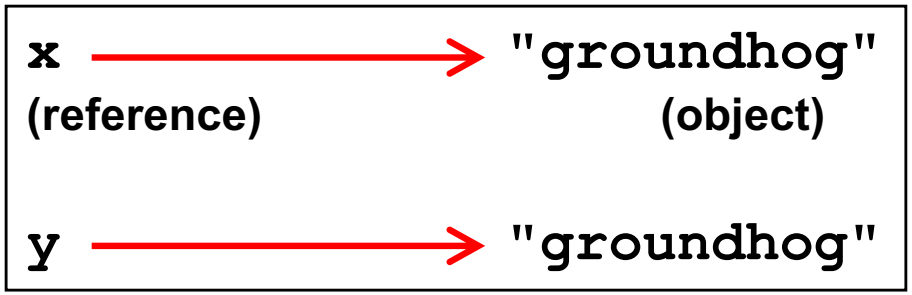
- 1..3 is an object of class Range
  - Integers between 1 and 3 inclusively
- 1…3 also has class Range
  - Integers between 1 and 3 but not including 3 itself.
- Not just for integers
  - 'a'..'z' represents the range of letters 'a' to 'z'
  - 1.3…2.7 is the *continuous* range [1.3,2.7)
    - (1.3…2.7).include? 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

Object Copy vs. Reference Copy

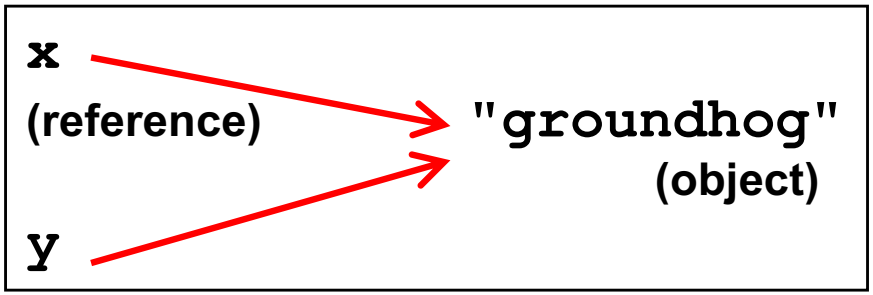
- Consider the following code
  - Assume an object/reference model like Java or Ruby
    - Or even two pointers pointing to the same structure

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

- Which of these occur?



Object copy



Reference copy

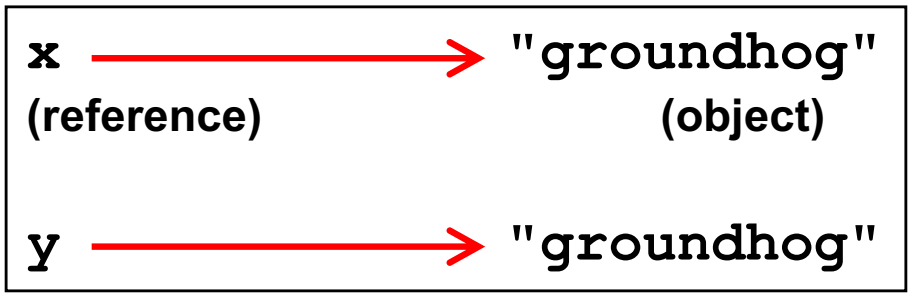
Object Copy vs. Reference Copy (cont.)

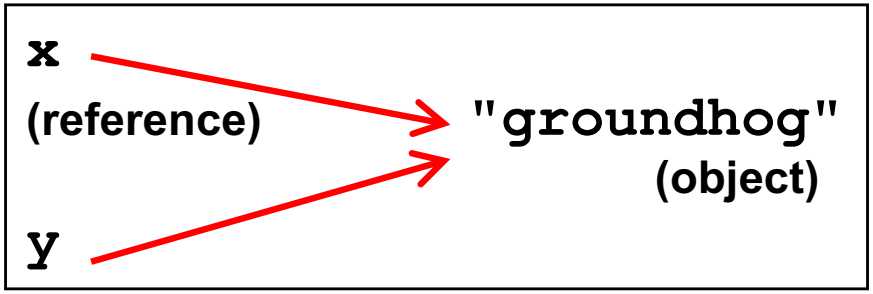
- For
```
x = "groundhog" ; y = x
```
  - Ruby and Java would both do a reference copy

- 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