This lecture

Three mostly separate topics

• Flexible arrays, ranges, and hashes [actually covered in section]

• Ruby’s approach to almost-closures (blocks) and closures (Procs)
  – [partially discussed in section as well]
  – Convenient to use; unusual approach
  – Used throughout large standard library
    • Explicit loops rare
    • Instead of a loop, go find a useful iterator

• Subclasses, inheritance, and overriding
  – The essence of OOP, now in a more dynamic language
Ruby Arrays

• Lots of special syntax and many provided methods for the Array class

• Can hold any number of other objects, indexed by number
  – Get via a[i]
  – Set via a[i] = e

• Compared to arrays in many other languages
  – More flexible and dynamic
  – Fewer operations are errors
  – Less efficient

• “The standard collection” (like lists were in ML and Racket)
Using Arrays

• See many examples, some demonstrated here

• Consult the documentation/tutorials
  – If seems sensible and general, probably a method for it

• Arrays make good tuples, lists, stacks, queues, sets, …

• Iterating over arrays typically done with methods taking blocks
  – Next topic…
Blocks

Blocks are probably Ruby's strangest feature compared to other PLs

But *almost* just closures

- Normal: easy way to pass anonymous functions to methods for all the usual reasons
- Normal: Blocks can take 0 or more arguments
- Normal: Blocks use lexical scope: block body uses environment where block was defined

Examples:

```ruby
3.times { puts "hi" }
[4,6,8].each { puts "hi" }
i = 7
[4,6,8].each { |x| if i > x then puts (x+1) end }
```
Some strange things

- Can pass 0 or 1 block with *any* message
  - Callee might ignore it
  - Callee might give an error if you do not send one
  - Callee might do different things if you do/don’t send one
    - Also number-of-block-arguments can matter

- Just put the block “next to” the “other” arguments (if any)
  - Syntax: `{e}`, `{|x| e}`, `{|x,y| e}`, etc. (plus variations)
    - Can also replace `{` and `}` with `do` and `end`
      - Often preferred for blocks > 1 line
Blocks everywhere

- Rampant use of great block-taking methods in standard library
- Ruby has loops but very rarely used
  - Can write `(0..i).each { |j| e}`, but often better options
- Examples (consult documentation for many more)

```ruby
a = Array.new(5) { |i| 4*(i+1) }
a.each { puts "hi" }
a.each { |x| puts (x * 2) }
a.map { |x| x * 2 } #synonym: collect
a.any? { |x| x > 7 }
a.all? { |x| x > 7 }
a.inject(0) { |acc,elt| acc+elt }
a.select { |x| x > 7 } #non-synonym: filter
```
More strangeness

• Callee does not give a name to the (potential) block argument

• Instead, just calls it with `yield` or `yield(args)`
  – Silly example:

```ruby
def silly a
  (yield a) + (yield 42)
end
```

  – See code for slightly less silly example

• Can ask `block_given?` but often just assume a block is given
  or that a block's presence is implied by other arguments
**Blocks are “second-class”**

All a method can do with a block is **yield** to it

- Cannot return it, store it in an object (e.g., for a callback), ...
- But can also turn blocks into real closures
- Closures are instances of class **Proc**
  - Called with method **call**

This is Ruby, so there are several ways to make **Proc** objects 😊

- One way: method **lambda** of **Object** takes a block and returns the corresponding **Proc**
Example

- Blocks are fine for applying to array elements
  
  ```ruby
  a = [3,5,7,9]
  b = a.map { |x| x+1 }
  i = b.count { |x| x>=6 }
  ```

- But for an array of closures, need `Proc` objects
  - More common use is callbacks
    
    ```ruby
    c = a.map { |x| lambda { |y| x>=y} }
    c[2].call 17
    j = c.count { |x| x.call(5) }
    ```
Moral

• First-class (“can be passed/stored anywhere”) makes closures more powerful than blocks

• But blocks are (a little) more convenient and cover most uses

• This helps us understand what first-class means

• Language design question: When is convenience worth making something less general and powerful?
More collections

- **Hashes** like arrays but:
  - Keys can be *anything*; strings and symbols common
  - No natural ordering like numeric indices
  - Different syntax to make them
    Like a dynamic record with anything for field names
  - Often pass a hash rather than many arguments

- **Ranges** like arrays of contiguous numbers but:
  - More efficiently represented, so large ranges fine

Good style to:
  - Use ranges when you can
  - Use hashes when non-numeric keys better represent data
Similar methods

- Arrays, hashes, and ranges all have some methods other don’t
  - E.g., keys and values

- But also have many of the same methods, particularly iterators
  - Great for duck typing
  - Example

```ruby
def foo a
  a.count {|x| x*x < 50}
end

foo [3, 5, 7, 9]
foo (3..9)
```

Once again separating “how to iterate” from “what to do”
Next major topic

• Subclasses, inheritance, and overriding
  – The essence of OOP
  – Not unlike you have seen in Java, but worth studying from PL perspective and in a more dynamic language
Subclassing

• A class definition has a *superclass* (Object if not specified)

```java
class ColorPoint < Point ...
```

• The superclass affects the class definition:
  – Class *inherits* all method definitions from superclass
  – But class can *override* method definitions as desired

• Unlike Java/C#/C++:
  – No such thing as “inheriting fields” since all objects create instance variables by assigning to them
  – Subclassing has nothing to do with a (non-existent) type system: can still (try to) call any method on any object
class Point
  attr_accessor :x, :y
  def initialize(x, y)
    @x = x
    @y = y
  end
  def distFromOrigin
    # direct field access
    Math.sqrt(@x*@x + @y*@y)
  end
  def distFromOrigin2
    # use getters
    Math.sqrt(x*x + y*y)
  end
end

class ColorPoint < Point
  attr_accessor :color
  def initialize(x, y, c)
    super(x, y)
    @color = c
  end
end
An object has a class

```ruby
p = Point.new(0,0)
cp = ColorPoint.new(0,0,"red")
p.class # Point
p.class.superclass # Object
cp.class # ColorPoint
cp.class.superclass # Point
cp.class.superclass.superclass # Object
cp.is_a? Point # true
cp.instance_of? Point # false
cp.is_a? ColorPoint # true
cp.instance_of? ColorPoint # true
```

- Using these methods is usually non-OOP style
  - Disallows other things that “act like a duck”
  - Nonetheless semantics is that an instance of `ColorPoint` “is a” `Point` but is not an “instance of” `Point`
  - [ Java note: `instanceof` is like Ruby's `is_a?` ]
Example continued

• Consider alternatives to:

```ruby
class ColorPoint < Point
  attr_accessor :color
  def initialize(x,y,c)
    super(x,y)
    @color = c
  end
end
```

• Here subclassing is a good choice, but programmers often overuse subclassing in OOP languages
Why subclass

• Instead of creating `ColorPoint`, could add methods to `Point`
  – That could mess up other users and subclassers of `Point`

```ruby
class Point
  attr_accessor :color
  def initialize(x, y, c="clear")
    @x = x
    @y = y
    @color = c
  end
end
```
Why subclass

• Instead of subclassing `Point`, could copy/paste the methods
  – Means the same thing if you don't use methods like `is_a?` and `superclass`, but of course code reuse is nice

```ruby
class ColorPoint
  attr_accessor :x, :y, :color
  def initialize(x, y, c="clear")
    ...
  end
  def distFromOrigin
    Math.sqrt(@x*@x + @y*@y)
  end
  def distFromOrigin2
    Math.sqrt(x*x + y*y)
  end
end
```
Why subclass

• Instead of subclassing `Point`, could use a `Point` instance variable
  – Define methods to send same message to the `Point`
  – Often OOP programmers overuse subclassing
  – But for `ColorPoint`, subclassing makes sense: less work and can use a `ColorPoint` wherever code expects a `Point`

```ruby
class ColorPoint
  attr_accessor :color
  def initialize(x, y, c="clear")
    @pt = Point.new(x, y)
    @color = c
  end
  def x
    @pt.x
  end
  ... # similar "forwarding" methods
  # for y, x=, y=
end
```
Overriding

• ThreeDPoint is more interesting than ColorPoint because it overrides distFromOrigin and distFromOrigin2
  – Gets code reuse, but *highly disputable* if it is appropriate to say a ThreeDPoint “is a” Point
  – Still just avoiding copy/paste

```ruby
class ThreeDPoint < Point
  ...
  def initialize(x, y, z)
    super(x, y)
    @z = z
  end
  def distFromOrigin  # distFromOrigin2 similar
    d = super
    Math.sqrt(d*d + @z*@z)
  end
  ...
end
```
So far…

• With examples so far, objects are not so different from closures
  – Multiple methods rather than just “call me”
  – Explicit instance variables rather than environment where function is defined
  – Inheritance avoids helper functions or code copying
  – “Simple” overriding just replaces methods

• But there is one big difference:

  Overriding can make a method defined in the superclass call a method in the subclass

  – The essential difference of OOP, studied carefully next lecture
Example: Equivalent except constructor

```ruby
class PolarPoint < Point
  def initialize(r, theta)
    @r = r
    @theta = theta
  end
  def x
    @r * Math.cos(@theta)
  end
  def y
    @r * Math.sin(@theta)
  end
  def distFromOrigin
    @r
  end
  ...
end
```

- Also need to define \( x = \) and \( y = \) (see code file)

- Key punchline:
  ```ruby
def distFromOrigin2
    Math.sqrt(x*x + y*y)
  end
  ```

  - Why: calls to \texttt{self} are resolved in terms of the object's class