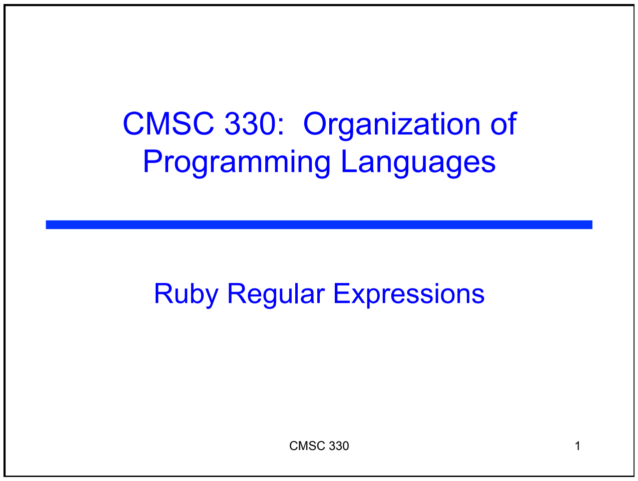
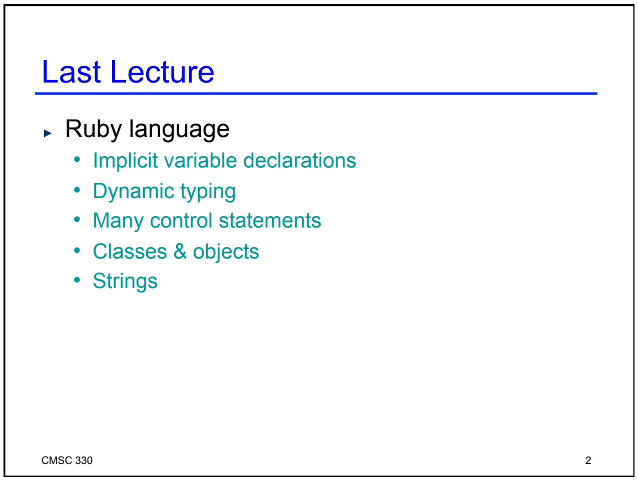


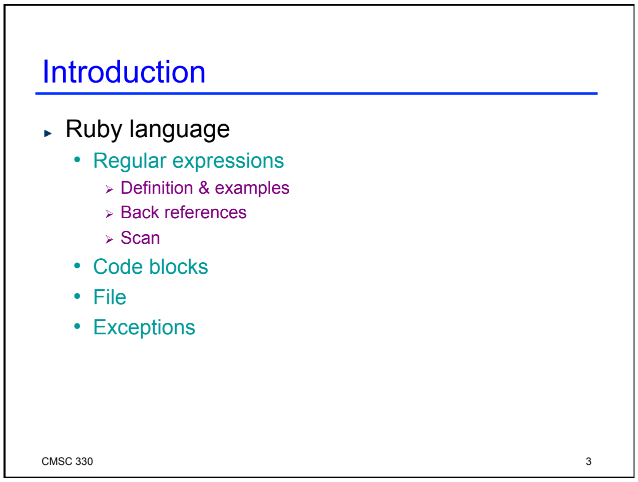
CMSC 330: Organization of Programming Languages

Ruby Regular Expressions



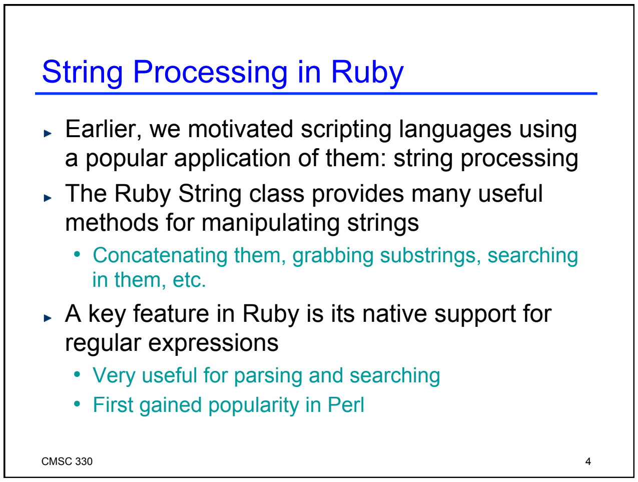
Last Lecture

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



Introduction

- Ruby language
  - Regular expressions
    - Definition & examples
    - Back references
    - Scan
  - Code blocks
  - File
  - Exceptions



String Processing in Ruby

- Earlier, we motivated scripting languages using a popular application of them: string processing
- The Ruby String class provides many useful methods for manipulating strings
  - Concatenating them, grabbing substrings, searching in them, etc.
- A key feature in Ruby is its native support for regular expressions
  - Very useful for parsing and searching
  - First gained popularity in Perl

String Operations in Ruby

- "hello".index("l", 0)
  - Return index of the first occurrence of string in s, starting at n
- "hello".sub("h", "j")
  - Replace first occurrence of "h" by "j" in string
  - Use gsub ("global" sub) to replace all occurrences
- "r1\tr2\t\tr3".split("\t")
  - Return array of substrings delimited by tab
- Consider these three examples again
  - All involve searching in a string for a certain pattern
  - What if we want to find more complicated patterns?
    - Find first occurrence of "a" or "b"
    - Split string at tabs, spaces, and newlines

Regular Expressions

- A way of describing patterns or sets of strings
  - Searching and matching
  - Formally describing strings
    - The symbols (lexemes or tokens) that make up a language
- Common to lots of languages and tools
  - awk, sed, perl, grep, Java, OCaml, C libraries, etc.
- Based on some really elegant theory
  - Future lecture

Example Regular Expressions in Ruby

- /Ruby/
  - Matches exactly the string "Ruby"
  - Regular expressions can be delimited by /'s
  - Use \ to escape /'s in regular expressions
- /(Ruby|OCaml|Java)/
  - Matches either "Ruby", "OCaml", or "Java"
- /(Ruby|Regular)/ or /R(uby|egular)/
  - Matches either "Ruby" or "Regular"
  - Use ( )'s for grouping; use \ to escape ( )'s

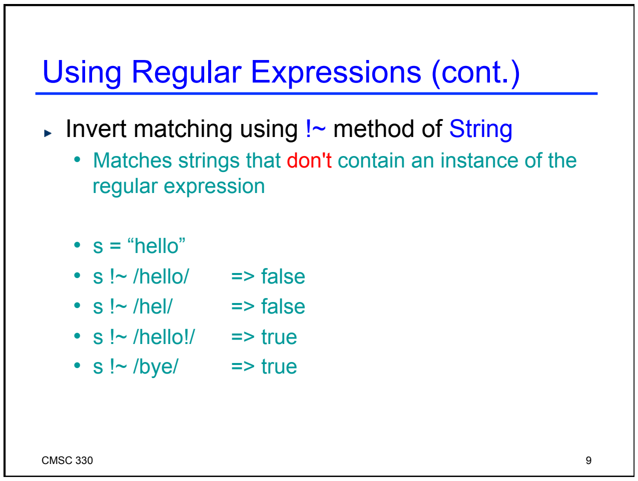
Using Regular Expressions

- Regular expressions are instances of Regexp
  - We'll see use of a Regexp.new later
- Basic matching using =~ method of String

```
line = gets              # read line from standard input
if line =~ /Ruby/ then   # returns nil if not found
  puts "Found Ruby"
end
```

- Can use regular expressions in index, search, etc.

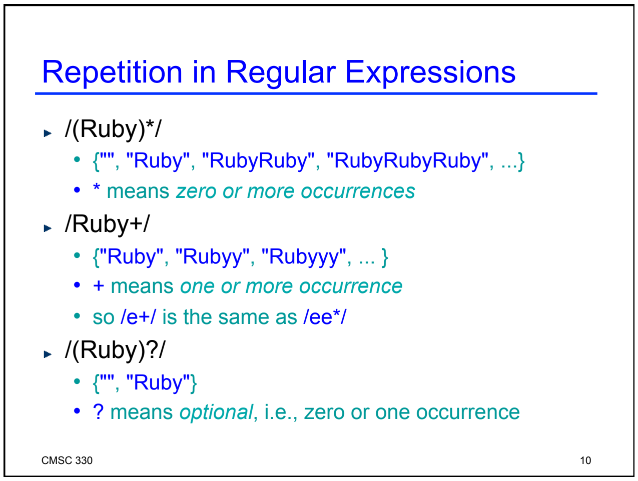
```
offset = line.index(/(MAX|MIN)/)    # search starting from 0
line.sub(/(Perl|Python)/, "Ruby")   # replace
line.split(/(\t|\n| )/)             # split at tab, space,
                                    # newline
```



Using Regular Expressions (cont.)

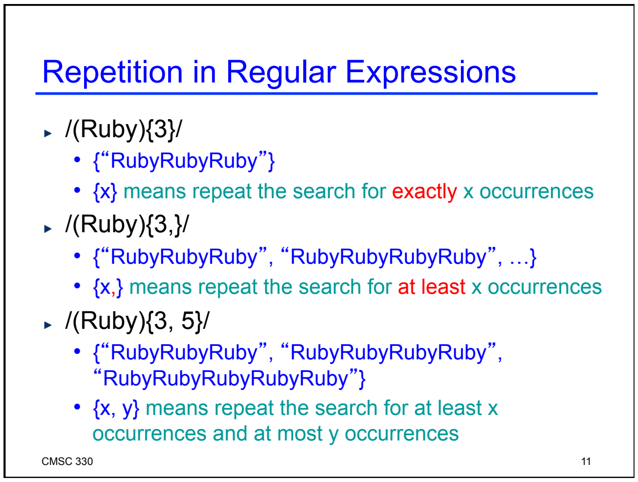
- Invert matching using !~ method of String
  - Matches strings that don't contain an instance of the regular expression

  - s = “hello”
  - s !~ /hello/ => false
  - s !~ /hel/ => false
  - s !~ /hello!/ => true
  - s !~ /bye/ => true



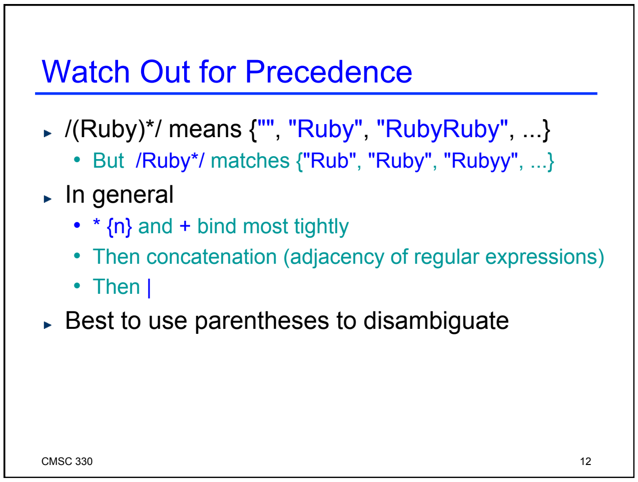
Repetition in Regular Expressions

- /(Ruby)*/
  - {"", "Ruby", "RubyRuby", "RubyRubyRuby", ...}
  - * means *zero or more occurrences*
- /Ruby+/
  - {"Ruby", "Rubyy", "Rubyyy", ... }
  - + means *one or more occurrence*
  - so /e+/ is the same as /ee*/
- /(Ruby)?/
  - {"", "Ruby"}
  - ? means *optional*, i.e., zero or one occurrence



Repetition in Regular Expressions

- /(Ruby){3}/
  - {“RubyRubyRuby”}
  - {x} means repeat the search for exactly x occurrences
- /(Ruby){3,}/
  - {“RubyRubyRuby”, “RubyRubyRubyRuby”, …}
  - {x,} means repeat the search for at least x occurrences
- /(Ruby){3, 5}/
  - {“RubyRubyRuby”, “RubyRubyRubyRuby”, “RubyRubyRubyRubyRuby”}
  - {x, y} means repeat the search for at least x occurrences and at most y occurrences



Watch Out for Precedence

- /(Ruby)*/ means {"", "Ruby", "RubyRuby", ...}
  - But /Ruby*/ matches {"Rub", "Ruby", "Rubyy", ...}
- In general
  - * {n} and + bind most tightly
  - Then concatenation (adjacency of regular expressions)
  - Then |
- Best to use parentheses to disambiguate

Character Classes

- /[abcd]/
  - {"a", "b", "c", "d"} (Can you write this another way?)
- /[a-zA-Z0-9]/
  - Any upper or lower case letter or digit
- /[^0-9]/
  - Any character except 0-9 (the ^ is like not and must come first)
- /[\t\n]/
  - Tab, newline or space
- /[a-zA-Z_\$][a-zA-Z_\$0-9]*/
  - Java identifiers ($ escaped...see next slide)

Special Characters

.	any character
^	beginning of line
$	end of line
\$	just a $
\d	digit, [0-9]
\s	whitespace, [\t\r\n\f\s]
\w	word character, [A-Za-z0-9_]
\D	non-digit, [^0-9]
\S	non-space, [^\t\r\n\f\s]
\W	non-word, [^A-Za-z0-9_]

Using /^pattern$/ ensures entire string/line must match pattern

Potential Character Class Confusions

- ^
  - Inside character classes: not
  - Outside character classes: beginning of line
- [ ]
  - Inside regular expressions: character class
  - Outside regular expressions: array
    - Note: [a-z] does not make a valid array
- ( )
  - Inside character classes: literal characters ( )
    - Note /(0..2)/ does not mean 012
  - Outside character classes: used for grouping
- –
  - Inside character classes: range (e.g., a to z given by [a-z])
  - Outside character classes: subtraction

Summary

- Let *re* represents an arbitrary pattern; then:
  - /*re*/ – matches regexp *re*
  - /(*re*$_1$|*re*$_2$)/ – match either *re*$_1$ or *re*$_2$
  - /(*re*)*/ – match 0 or more occurrences of *re*
  - /(*re*)+/ – match 1 or more occurrences of *re*
  - /(*re*)?/ – match 0 or 1 occurrences of *re*
  - /(*re*){2}/ – match exactly two occurrences of *re*
  - /[a-z]/ – same as (a|b|c|...|z)
  - / [^0-9]/ – match any character that is not 0, 1, etc.
  - ^, $ – match start or end of string

Regular Expression Practice

- Make Ruby regular expressions representing
  - All lines beginning with a or b `/^(a|b)/`
  - All lines containing at least two (only alphabetic) words separated by white-space `/[a-zA-Z]+\s+[a-zA-Z]+/`
  - All lines where a and b alternate and appear at least once `/^((ab)+ a?)|((ba)+ b?)$/`
  - An expression which would match both of these lines (but not radically different ones)
    - CMSC330: Organization of Programming Languages: Fall 2007
    - CMSC351: Algorithms: Fall 2007

Regular Expression Coding Readability

```
> ls -l
drwx------   2 sorelle  sorelle  4096 Feb 18 18:05 bin
-rw-------   1 sorelle  sorelle  674 Jun  1 15:27 calendar
drwx------   3 sorelle  sorelle  4096 May 11 12:19 cmsc311
drwx------   2 sorelle  sorelle  4096 Jun  4 17:31 cmsc330
drwx------   1 sorelle  sorelle  4096 May 30 19:19 cmsc630
drwx------   1 sorelle  sorelle  4096 May 30 19:20 cmsc631
```

What if we want to specify the format of this line exactly?

```
/^(d|-)(r|-)(w|-)(x|-)(r|-)(w|-)(x|-)(r|-)(w|-)(x|-)
(\s+)(\d+)(\s+)(\w+)(\s+)(\w+)(\s+)(\d+)(\s+)(Jan|Feb
|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec)(\s+)(\d\d)
(\s+)(\d\d:\d\d)(\s+)(\S+)$/
```

This is unreadable!

Regular Expression Coding Readability

Instead, we can do each part of the expression separately and then combine them:

```
oneperm_re = '((r|-)(w|-)(x|-))'
permissions_re = '(d|-)' + oneperm_re + '{3}'
month_re = '(Jan|Feb|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec)'
day_re = '\d{1,2}';   time_re = '(\d{2}:\d{2})'
date_re = month_re + '\s+' + day_re + '\s+' + time_re
total_re = '\d+';  user_re = '\w+';   group_re = '\w+'
space_re = '\d+';  filename_re = '\S+'

line_re = Regexp.new('^' + permissions_re + '\s+' + total_re
      + '\s+' + user_re + '\s+' + group_re + '\s+' +
      space_re + '\s+' + date_re + '\s+' + filename_re + '$')

if line =~ line_re
        puts "found it!"
end
```

Extracting Substrings based on R.E.'s Method 1: Back References

Two options to extract substrings based on R.E.'s:

- Use back references
  - Ruby remembers which strings matched the parenthesized parts of r.e.'s
  - These parts can be referred to using special variables called back references (named $1, $2,…)

Back Reference Example

- Extract information from a report

```
gets =~ /^Min: (\d+)  Max: (\d+)$/
min, max = $1, $2
```

```
sets min = $1
 and max = $2
```

- Warning
  - Despite their names, $1 etc are local variables

```
def m(s)
  s =~ /(Foo)/
  puts $1   # prints Foo
end
m("Foo")
puts $1     # prints nil
```

Another Back Reference Example

- Warning 2
  - If another search is performed, all back references are reset to nil

gets =~ /(h)e(ll)o/	hello
puts $1	h
puts $2	ll
gets =~ /h(e)llo/	hello
puts $1	e
puts $2	nil
gets =~ /hello/	hello
puts $1	nil

Method 2: String.scan

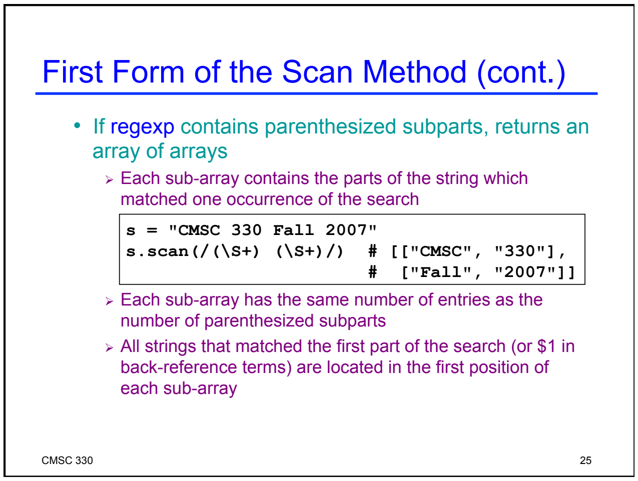
- Also extracts substrings based on regular expressions
- Can optionally use parentheses in regular expression to affect how the extraction is done
- Has two forms which differ in what Ruby does with the matched substrings
  - The first form returns an array
  - The second form uses a code block
    - We' ll see this later

First Form of the Scan Method

- *str*.scan(*regexp*)
  - If regexp doesn't contain any parenthesized subparts, returns an array of matches
    - An array of all the substrings of *str* which matched

```
s = "CMSC 330 Fall 2007"
s.scan(/\S+ \S+/)
# returns array ["CMSC 330", "Fall 2007"]
```

    - Note: these string are chosen sequentially from as yet unmatched portions of the string, so while “330 Fall” *does* match the regular expression above, it is *not* returned since “330” has already been matched by a previous substring.

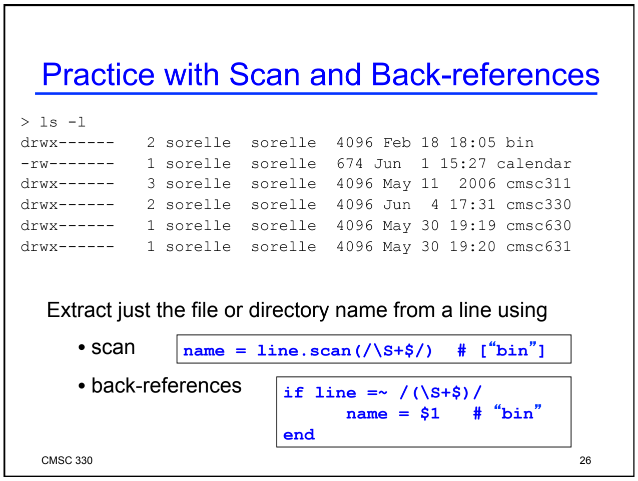


First Form of the Scan Method (cont.)

- If regexp contains parenthesized subparts, returns an array of arrays
  - Each sub-array contains the parts of the string which matched one occurrence of the search

```
s = "CMSC 330 Fall 2007"
s.scan(/(\S+) (\S+)/)   # [["CMSC", "330"],
                        #  ["Fall", "2007"]]
```

  - Each sub-array has the same number of entries as the number of parenthesized subparts
  - All strings that matched the first part of the search (or $1 in back-reference terms) are located in the first position of each sub-array



Practice with Scan and Back-references

```
> ls -l
drwx------   2 sorelle  sorelle  4096 Feb 18 18:05 bin
-rw-------   1 sorelle  sorelle  674 Jun  1 15:27 calendar
drwx------   3 sorelle  sorelle  4096 May 11  2006 cmsc311
drwx------   2 sorelle  sorelle  4096 Jun  4 17:31 cmsc330
drwx------   1 sorelle  sorelle  4096 May 30 19:19 cmsc630
drwx------   1 sorelle  sorelle  4096 May 30 19:20 cmsc631
```

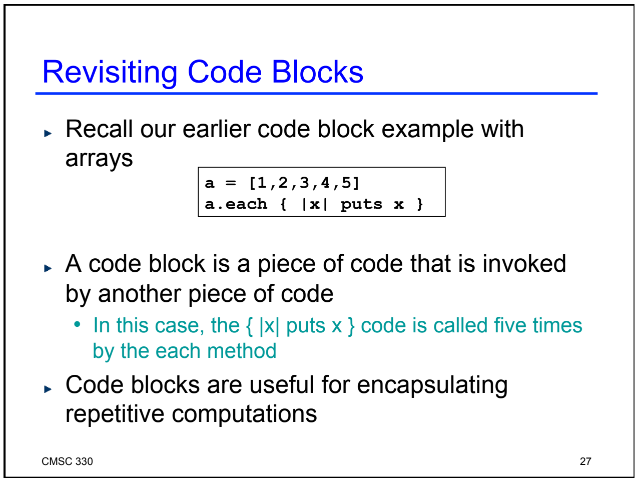
Extract just the file or directory name from a line using

- scan

```
name = line.scan(/\S+$/)   # [“bin”]
```

- back-references

```
if line =~ /(\S+$)/
      name = $1    # “bin”
end
```

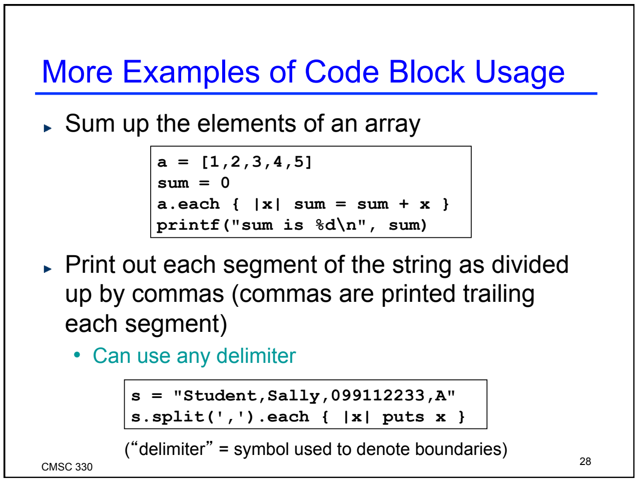


Revisiting Code Blocks

- Recall our earlier code block example with arrays

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

- A code block is a piece of code that is invoked by another piece of code
  - In this case, the { |x| puts x } code is called five times by the each method
- Code blocks are useful for encapsulating repetitive computations



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
```

- 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

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

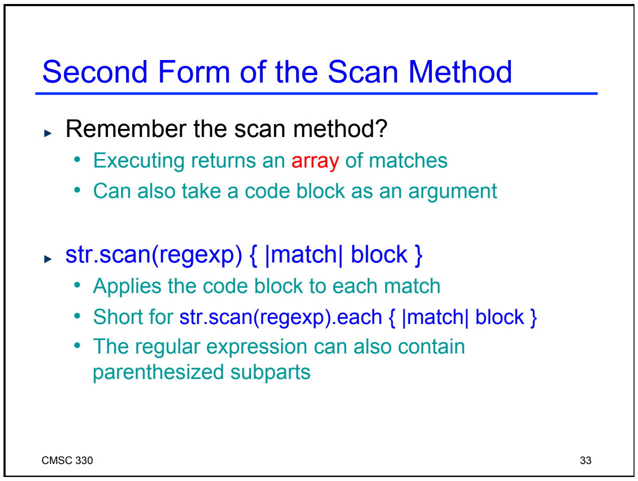
```
def countx(x)
  for i in (1..x)
     puts i
     yield
  end
end

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

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

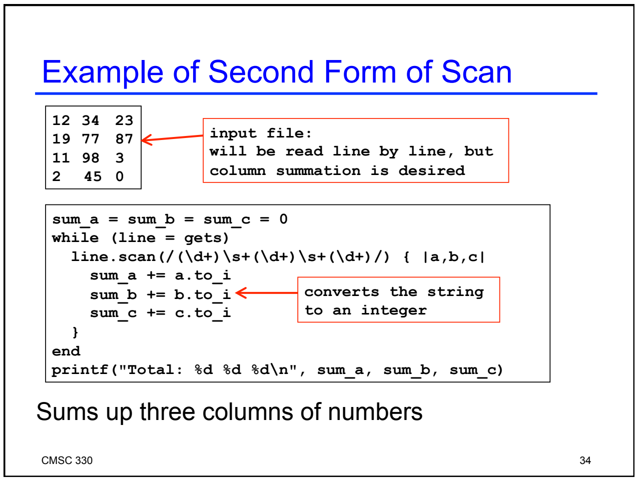
So What Are Code Blocks?

- 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 an argument
  - 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!



Second Form of the Scan Method

- Remember the scan method?
  - Executing returns an array of matches
  - Can also take a code block as an argument
- str.scan(regexp) { |match| block }
  - Applies the code block to each match
  - Short for str.scan(regexp).each { |match| block }
  - The regular expression can also contain parenthesized subparts



Example of Second Form of Scan

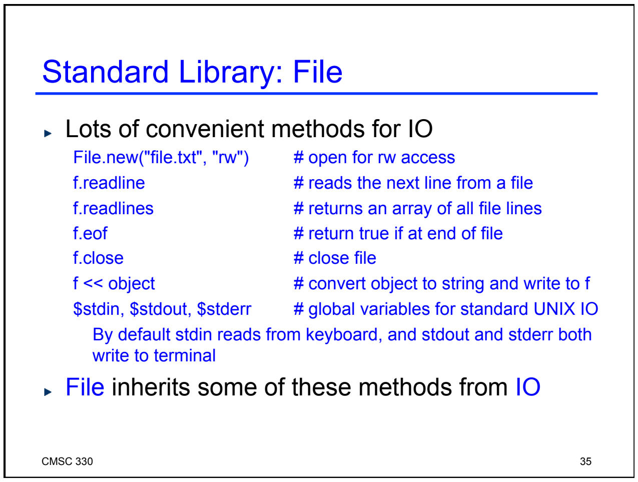
```
12  34  23
19  77  87
11  98  3
2   45  0
```

input file:
will be read line by line, but
column summation is desired

```
sum_a = sum_b = sum_c = 0
while (line = gets)
  line.scan(/(\d+)\s+(\d+)\s+(\d+)/) { |a,b,c|
    sum_a += a.to_i
    sum_b += b.to_i
    sum_c += c.to_i
  }
end
printf("Total: %d %d %d\n", sum_a, sum_b, sum_c)
```

converts the string
to an integer

Sums up three columns of numbers



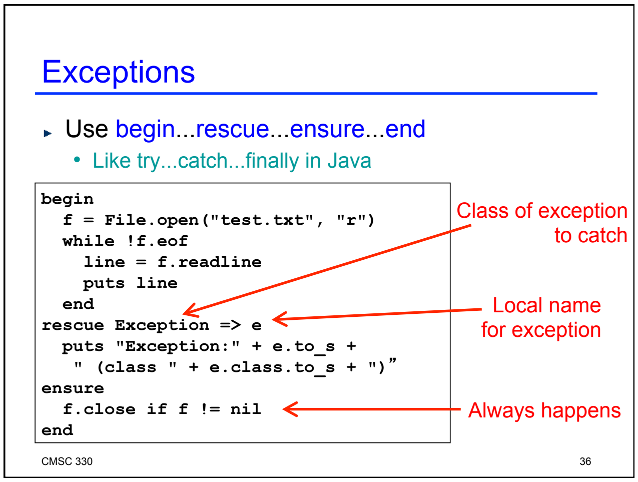
Standard Library: File

- Lots of convenient methods for IO

File.new("file.txt", "rw")	# open for rw access
f.readline	# reads the next line from a file
f.readlines	# returns an array of all file lines
f.eof	# return true if at end of file
f.close	# close file
f << object	# convert object to string and write to f
$stdin, $stdout, $stderr	# global variables for standard UNIX IO

By default stdin reads from keyboard, and stdout and stderr both write to terminal

- File inherits some of these methods from IO



Exceptions

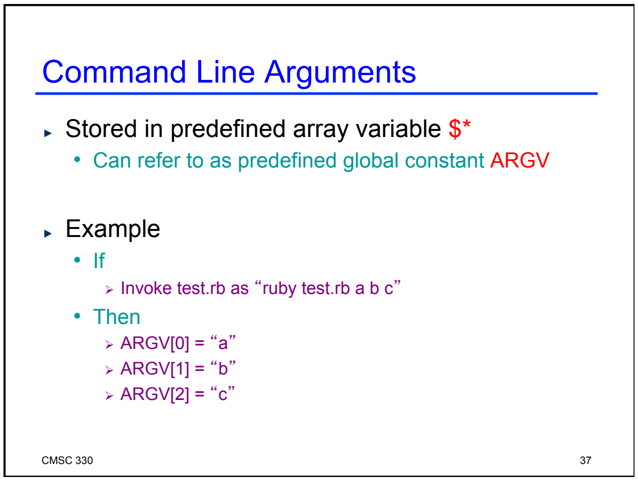
- Use begin...rescue...ensure...end
  - Like try...catch...finally in Java

```
begin
  f = File.open("test.txt", "r")
  while !f.eof
    line = f.readline
    puts line
  end
rescue Exception => e
  puts "Exception:" + e.to_s +
   " (class " + e.class.to_s + ")”
ensure
  f.close if f != nil
end
```

Class of exception
to catch

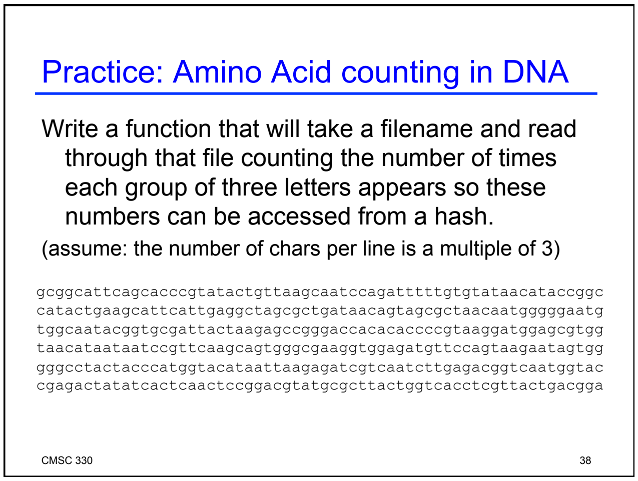
Local name
for exception

Always happens



Command Line Arguments

- Stored in predefined array variable $*
  - Can refer to as predefined global constant ARGV
- Example
  - If
    - Invoke test.rb as “ruby test.rb a b c”
  - Then
    - ARGV[0] = “a”
    - ARGV[1] = “b”
    - ARGV[2] = “c”

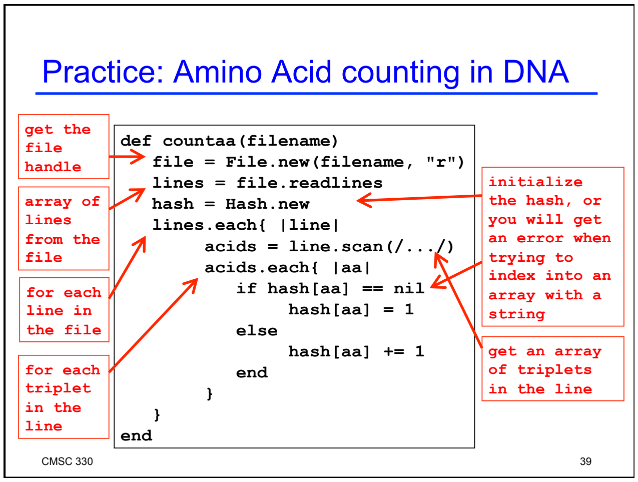


Practice: Amino Acid counting in DNA

Write a function that will take a filename and read through that file counting the number of times each group of three letters appears so these numbers can be accessed from a hash.

(assume: the number of chars per line is a multiple of 3)

```
gcggcattcagcacccgtatactgttaagcaatccagatttttgtgtataacataccggc
catactgaagcattcattgaggctagcgctgataacagtagcgctaacaatgggggaatg
tggcaatacggtgcgattactaagagccgggaccacacaccccgtaaggatggagcgtgg
taacataataatccgttcaagcagtgggcgaaggtggagatgttccagtaagaatagtgg
gggcctactacccatggtacataattaagagatcgtcaatcttgagacggtcaatggtac
cgagactatatcactcaactccggacgtatgcgcttactggtcacctcgttactgacgga
```



Practice: Amino Acid counting in DNA

```
def countaa(filename)
   file = File.new(filename, "r")
   lines = file.readlines
   hash = Hash.new
   lines.each{ |line|
        acids = line.scan(/.../)
        acids.each{ |aa|
           if hash[aa] == nil
                hash[aa] = 1
           else
                hash[aa] += 1
           end
        }
   }
end
```

get the file handle

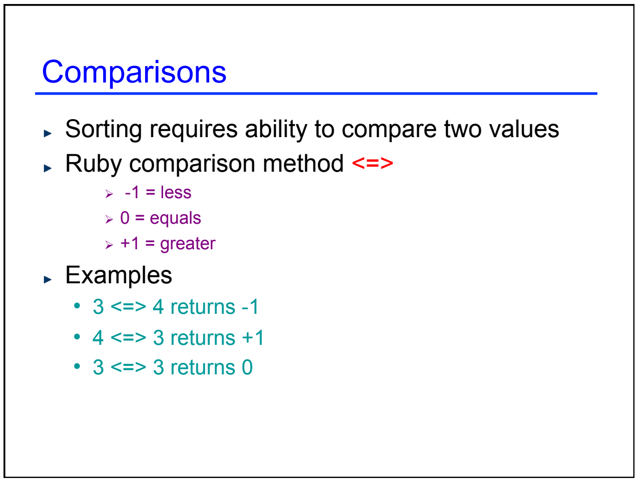
array of lines from the file

for each line in the file

for each triplet in the line

initialize the hash, or you will get an error when trying to index into an array with a string

get an array of triplets in the line



Comparisons

- Sorting requires ability to compare two values
- Ruby comparison method <=>
    - -1 = less
    - 0 = equals
    - +1 = greater
- Examples
  - 3 <=> 4 returns -1
  - 4 <=> 3 returns +1
  - 3 <=> 3 returns 0

Sorting

- Two ways to sort an Array
  - Default sort (puts values in ascending order)
    - [2,5,1,3,4].sort   # returns [1,2,3,4,5]
  - Custom sort (based on value returned by code block}
    - [2,5,1,3,4].sort { |x,y| y <=> x }   # returns [5,4,3,2,1]
    - Where -1 = less, 0 = equals, +1 = greater
    - Code block return value used for comparisons

Ruby Summary

- Interpreted
- Implicit declarations
- Dynamically typed
- Built-in regular expressions
- Easy string manipulation
- Object-oriented
  - Everything (!) is an object
- Code blocks
  - Easy higher-order programming!
  - Get ready for a lot more of this...

Makes it quick to write small programs

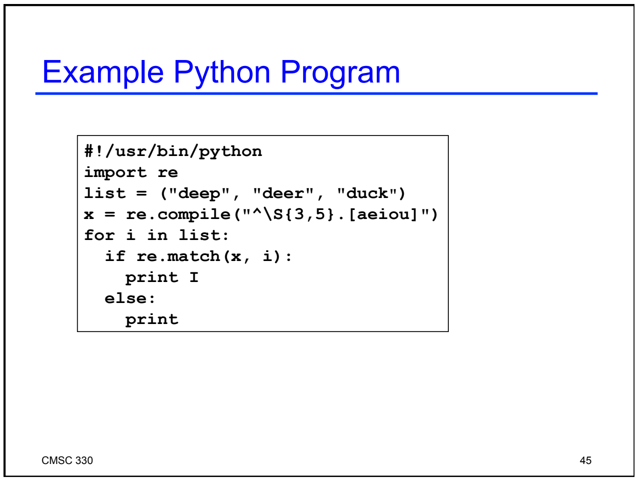
Hallmark of scripting languages

Other Scripting Languages

- Perl and Python are also popular scripting languages
  - Also are interpreted, use implicit declarations and dynamic typing, have easy string manipulation
  - Both include optional “compilation” for speed of loading/execution
- Will look fairly familiar to you after Ruby
  - Lots of the same core ideas
  - All three have their proponents and detractors
  - Use whichever language you personally prefer

Example Perl Program

```
#!/usr/bin/perl
foreach (split(//, $ARGV[0])) {
  if ($G{$_}) {
    $RE .= "\\" . $G{$_};
  } else {
    $RE .= $N ? "(?!\\" .
  join("|\\",values(%G)) . ')(\w)' : '(\w)';
    $G{$_} = ++$N;
}  }
```



Example Python Program

```
#!/usr/bin/python
import re
list = ("deep", "deer", "duck")
x = re.compile("^\S{3,5}.[aeiou]")
for i in list:
  if re.match(x, i):
    print I
  else:
    print
```

CMSC 330

45