

# Lecture 5: Character Strings, Regular Expressions, and Web Scraping.

STAT GR5206 *Statistical Computing & Introduction to Data Science*

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# Character Strings and String Operations

Analyzing textual data is common in machine learning and data science.

## Textual Data Sources

- Classifying and analyzing tweets from Twitter.
- Answering, does this email belong in the spam filter?
- Processing and comparing survey responses.
- Working with character data such as names, birthdays, or addresses.

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## Textual Data Sources

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- Processing and comparing survey responses.
- Working with character data such as names, birthdays, or addresses.

R contains many functions for manipulating character data a few of which we study today.

# Definition

- A **character** is a symbol in a written language - anything you can enter on a keyboard.

Examples: 'Q', '\*', '+', 'd', 'x', ' ', '{' etc.

- A **string** is a sequence of characters.

Examples: 'Columbia University', 'cat, squirrel, hedgehog', etc.

# Definition

- A **character** is a symbol in a written language - anything you can enter on a keyboard.

Examples: 'Q', '\*', '+', 'd', 'x', ' ', '{' etc.

- A **string** is a sequence of characters.

Examples: 'Columbia University', 'cat, squirrel, hedgehog', etc.

- Both are type character in R.

```
> mode("d")
```

```
| [1] "character"
```

```
> mode("cat, squirrel")
```

```
| [1] "character"
```

- Both can go into scalars, vectors, matrices, lists, or dataframes.
- In R strings are denoted by quotation marks.

# Whitespace

As noted above, whitespace ' ' is considered a character and multiple spaces ' ' a string.

```
> mode(" ")
```

```
[1] "character"
```

```
> nchar(" "); nchar("  "); nchar("")
```

```
[1] 1
```

```
[1] 2
```

```
[1] 0
```



# Whitespace

As noted above, whitespace ' ' is considered a character and multiple spaces ' ' a string.

```
> mode(" ")
```

```
[1] "character"
```

```
> nchar(" "); nchar("  "); nchar("")
```

```
[1] 1
```

```
[1] 2
```

```
[1] 0
```

## Special Characters

- Quotes within a string: \"
- Tab: \t
- New Line: \n

# Strings as Elements of a Vector

If strings are elements of an object,

- `length()` reports the number of strings in the object, not the number of characters in the string.
- `nchar()` reports the number of character values in a string.
- `nchar()` is vectorized, like most R functions.

# Strings as Elements of a Vector

```
> length("cat, squirrel, hedgehog")
```

```
| [1] 1
```

```
> length(c("cat", "squirrel", "hedgehog"))
```

```
| [1] 3
```

```
> nchar("cat, squirrel, hedgehog") # Not 25
```

```
| [1] 23
```

```
> nchar(c("cat", "squirrel", "hedgehog"))
```

```
| [1] 3 8 8
```

# Printing Strings

- Can be displayed when their name is typed or using `print()`.
- Often want to use `cat()` to print character strings directly.
- `cat()` coerces its argument to strings, so can be useful when printing warnings.

`\t, \", \n`

# Printing Strings

- Can be displayed when their name is typed or using `print()`.
- Often want to use `cat()` to print character strings directly.
- `cat()` coerces its argument to strings, so can be useful when printing warnings.

```
> print("cat, squirrel")
```

```
[1] "cat, squirrel"
```

```
> cat("cat, squirrel")
```

```
cat, squirrel
```

```
> x <- 6
```

```
> y <- 7
```

```
> cat("I have", x, "cats and", y, "hedgehogs as pets.")
```

```
I have 6 cats and 7 hedgehogs as pets.
```

# Printing Strings

```
> print("cat, \n squirrel")
```

```
[1] "cat, \n squirrel"
```

```
> cat("cat, \nsquirrel")
```

```
cat,  
squirrel
```

```
> print("In R, an \"array\" is a multi-dimension matrix.")
```

```
[1] "In R, an \"array\" is a multi-dimension matrix."
```

```
> cat("A group of hedgehogs is called an \"array\".")
```

```
A group of hedgehogs is called an "array".
```

# Check Yourself

## Task

Use `print()` and `cat()` to print the following in R:

```
"Columbia\tUniversity"
```

How many characters are in the above? Why?

- A **substring** is a smaller string taken from a larger string, but it is itself still a string.
- Note that we can't use regular subsetting options like `[]` or `[]` because a string isn't a vector or list.
- The `substr()` function can extract or change values of parts of strings.



# Substrings

The call `substr(string, start = , stop = )` returns the substring from character position `start` to `stop` in the given string.

# Substrings

The call `substr(string, start = , stop = )` returns the substring from character position `start` to `stop` in the given string.

```
> phrase <- "Christmas Bonus"  
> substr(phrase, start = 8, stop = 12)
```

```
[1] "as Bo"
```

```
> substr(phrase, start = 13, stop = 13) <- "g"  
> phrase
```

```
[1] "Christmas Bogus"
```

# Substrings

## substr() vectorizes

```
> fav_animals <- c("cat", "squirrel", "hedgehog")  
> substr(fav_animals, start = 1, stop = 2)
```

```
[1] "ca" "sq" "he"
```

```
> substr(fav_animals, nchar(fav_animals)-1,  
+        nchar(fav_animals))
```

```
[1] "at" "el" "og"
```

```
> substr(fav_animals, start = 4, stop = 4)
```

```
[1] ""  "i" "g"
```

# Dividing Strings into Vectors

`strsplit(string, split =)` divides its input string at the appearances of the pattern passed to `split`.

```
> todo <- "Lecture, Lab, Homework"  
> strsplit(todo, split = ",")
```

```
[[1]]  
[1] "Lecture"    " Lab"      " Homework"
```

```
> strsplit(todo, split = ", ")
```

```
[[1]]  
[1] "Lecture"  "Lab"      "Homework"
```

# Dividing Strings into Vectors

`strsplit(string, split =)` divides its input string at the appearances of the pattern passed to `split`.

```
> todo <- "Lecture, Lab, Homework"  
> strsplit(todo, split = ",")
```

```
[[1]]  
[1] "Lecture"    " Lab"      " Homework"
```

```
> strsplit(todo, split = ", ")
```

```
[[1]]  
[1] "Lecture"  "Lab"      "Homework"
```

Note that the output of `strsplit()` is a list. Why?

# Dividing Strings into Vectors

```
> todo <- "Lecture, Lab, Homework"  
> strsplit(c(todo, "Midterm, Final"), split = ",")
```

```
[[1]]  
[1] "Lecture"    " Lab"       " Homework"  
  
[[2]]  
[1] "Midterm" " Final"
```

The pattern is recycled over the elements of an input vector.

## Tasks

- Make a vector of three elements which are “Columbia”, “slumber party”, and “sugarplum”. Make a call to `substr()` that returns the “lum” from each element of the vector. The output should be  
"lum" "lum" "lum"
- Use `strsplit()` on the vector you created splitting on “lum”. Output should be a list of length three.

# Building Strings from Multiple Parts

`paste()` combines strings into one long string and is very flexible.

```
> paste("cat", "squirrel", "hedgehog")
```

```
[1] "cat squirrel hedgehog"
```

```
> paste("cat", "squirrel", "hedgehog", sep = ", ")
```

```
[1] "cat, squirrel, hedgehog"
```

```
> paste(c("cat", "squirrel", "hedgehog"), 1:3)
```

```
[1] "cat 1"      "squirrel 2" "hedgehog 3"
```

```
> paste(c("cat", "squirrel", "hedgehog"), 1:2)
```

```
[1] "cat 1"      "squirrel 2" "hedgehog 1"
```



# Building Strings from Multiple Parts

```
> paste(c("cat", "squirrel", "hedgehog"), "(", 1:3, ")")
```

```
[1] "cat ( 1 )"      "squirrel ( 2 )" "hedgehog ( 3 )"
```

```
> paste(c("cat", "squirrel", "hedgehog"), "(", 1:3, ")",  
+       sep = "")
```

```
[1] "cat(1)"      "squirrel(2)" "hedgehog(3)"
```

```
> paste(c("cat", "squirrel", "hedgehog"), " (", 1:3, ")",  
+       sep = "")
```

```
[1] "cat (1)"      "squirrel (2)" "hedgehog (3)"
```

## Exercise

What happens when you pass a vector to the `sep` argument?

# Condensing Multiple Strings

The `paste()` function can also condense multiple strings using the `collapse` argument.

```
> paste(c("cat", "squirrel", "hedgehog"), " (", 1:3, ")",  
+       sep = "", collapse = "; ")
```

```
[1] "cat (1); squirrel (2); hedgehog (3)"
```

# Check Yourself

## Task

Use `paste()` with its first input being `c("Columbia", "slumber party", "sugarplum")` along with the `sep` and `collapse` arguments to create the following string:

```
"Columbia [3-5]; slumber party [2-4]; sugarplum [7-9]"
```

## Honor Code Example

The file "HonorCode.txt" contains Columbia University's Honor Code:

"Students should be aware that academic dishonesty (for example, plagiarism, cheating on an examination, or dishonesty in dealing with a faculty member or other University official) or the threat of violence or harassment are particularly serious offenses and will be dealt with severely under Dean's Discipline..."

Code example.

# Searching Strings

## Honor Code Example

```
> HC <- readLines("HonorCode2.txt")  
> length(HC)
```

```
[1] 43
```

```
> head(HC, 5)
```

```
[1] "Students should be aware that academic dishonesty (for e  
[2] "examination, or dishonesty in dealing with a faculty mem  
[3] "the threat of violence or harassment are particularly se  
[4] "with severely under Dean's Discipline."  
[5] ""
```

HC is a vector with one element per line of text in the Honor Code.

# Searching Strings

The `grep(pattern, x)` function searches for a specified substring given by `pattern` in a vector `x` of strings.

## Honor Code Example

```
> grep("students", HC)
```

```
[1] 6 15 23 30
```

```
> grep("Students", HC)
```

```
[1] 1 19 33
```

```
> head(grepl("students", HC), 15)
```

```
[1] FALSE FALSE FALSE FALSE FALSE TRUE FALSE FALSE FALSE  
[10] FALSE FALSE FALSE FALSE FALSE TRUE
```

## Honor Code Example

```
> grep("students", HC)
```

```
[1] 6 15 23 30
```

```
> HC[grep("students", HC)]
```

```
[1] "Graduate students are expected to exhibit the high level  
[2] "In practical terms, students must not cheat on examinati  
[3] "Graduate students are responsible for proper citation an  
[4] "All incoming doctoral and master's students in the Arts a
```



# Searching Strings

Using functions we've learned today, let's make HC a vector with each element a word of the Honor Code (instead of a line of text). Of course, could do this with `scan()`.

## Honor Code Example

```
> HC <- paste(HC, collapse = " ") # One long string
> HC.words <- strsplit(HC, split = " ")[[1]] # List output
> head(HC.words, 10)
```

```
[1] "Students"      "should"        "be"            "aware"
[5] "that"          "academic"      "dishonesty"    "(for"
[9] "example,"      "plagiarism,"
```

We can count words using `table()`.

## Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

HC.words

and	of	or	the	to	in	from	a	is
23	17	16	13	11	10	8	6	5

# Searching Strings

We can count words using `table()`.

## Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

HC.words

and	of	or	the	to	in	from	a	is
23	17	16	13	11	10	8	6	5

This is much more simple than the strategy we used a few weeks ago to produce the same result!

# Searching Strings

## Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

HC.words

and	of	or	the	to	in	from	a	is
23	17	16	13	11	10	8	6	5

## Some undesirable things are happening here...

- The null string "" is the seventh most common word.
- Punctuation and capitalization are messing up our counts. ("students" vs. "Students" before).

# Searching Strings

## Honor Code Example

```
> head(word_count, 10)
```

```
HC.words
```

and	of	or	the	to	in	from	a	is
23	17	16	13	11	10	8	6	5

## Some undesirable things are happening here...

```
> tail(word_count, 10)
```

```
HC.words
```

vital	which	words	work	work;	works.	world
1	1	1	1	1	1	1
write	Writing	your				
1	1	1				

# Check Yourself

## Task

Use `grep()` to search over `names(word_count)` to find the number of words in the word count vector that have semi-colons in them. Hint: `";"` should be one of your arguments to `grep`. Using your result print the words that `grep()` finds.

## Next

We want to search for text patterns instead of text constants. We can do this with regular expressions.

## Summary

- `nchar()`: Finds the length of a string.
- `substring()`: Extracts substrings and substitutes.
- `strsplit()`: Turns strings into vectors.
- `paste()`: Turns vectors into a string.
- `grep()`: Search for patterns in a string.

# Regular Expressions



# Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog, octopus"
```

# Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog, octopus"
```

```
> strsplit(fav_animals, split = ",")
```

```
[[1]]
```

```
[1] "cat"          "squirrel"    " hedgehog"   " octopus"
```

# Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog, octopus"
```

```
> strsplit(fav_animals, split = ",")
```

```
[[1]]  
[1] "cat"          "squirrel"    " hedgehog"   " octopus"
```

```
> strsplit(fav_animals, split = " ")
```

```
[[1]]  
[1] "cat,squirrel," "hedgehog,"    ""  
[4] ""             "octopus"
```

# Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog, octopus"
```

```
> strsplit(fav_animals, split = ",", " ")
```

```
[[1]]
```

```
[1] "cat,squirrel" "hedgehog"      " octopus"
```

# Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,  octopus"
```

```
> strsplit(fav_animals, split = ",", " ")
```

```
[[1]]
```

```
[1] "cat,squirrel" "hedgehog"      "  octopus"
```

Need to split the entries by a comma and *optionally* some space.

# Why Do We Need Regular Expressions

It's not just annoying we can't do these things, there are a lot of examples where we have to do such manipulations.

- When scraping data from a webpage, will need to get rid of formatting instructions buried in the source of the webpage.
- Names may be preceded by titles such as Mr., Mrs., or Dr. that we aren't interested in using.

# Regular Expressions

- **Regular expressions** are a method of expressing patterns in character strings.
- Used to match sets of strings or patterns of strings in R.
- Can express ideas like match "*this* and then *that*", "*either this or that*", "*this* repeated some number of times".
- **Regular expressions** are rules expressed in a grammar with special symbols.

# Rules for Regular Expressions

1. Every string is a regular expression.

- "cat" matches "categorize" and "dogs and cats".
- "cat" does not match "Dog is man's best friend" and "work doggedly".



# Rules for Regular Expressions

1. Every string is a regular expression.
  - "cat" matches "categorize" and "dogs and cats".
  - "cat" does not match "Dog is man's best friend" and "work doggedly".
2. Can represent OR with a vertical bar |.
  - "cat|dog|Dog" matches all of the above.

# Rules for Regular Expressions

1. Every string is a regular expression.
  - "cat" matches "categorize" and "dogs and cats".
  - "cat" does not match "Dog is man's best friend" and "work doggedly".
2. Can represent OR with a vertical bar |.
  - "cat|dog|Dog" matches all of the above.
3. Precede special characters like | with a backslash \ to match exactly.
  - "A\\|b" matches "P(A|b)".
  - "A|b" matches twice in "Alabama" and twice in "blueberry".

# Rules for Regular Expressions

When I say 'matches', I mean in R:

```
> grep("cat|dog", c("categorize", "work doggedly"))
```

```
[1] 1 2
```

```
> grep("A|b", c("Alabama", "blueberry", "work doggedly"))
```

```
[1] 1 2
```

# Rules for Regular Expressions

1. Indicate sets of characters with brackets `[]`.
  - `"[a-z]"` matches any lower case letters.
  - `"[:punct:]"` matches all punctuation marks.
2. The caret `^` negates a character range when in the leading position.
  - `"[^aeiou]"` matches any characters except lower-case vowels.
3. The period `.` stands for any character and doesn't need brackets.
  - `"c..s"` matches `"cats"`, `"class"`, `"c88s"`, `"c s"`, etc.

# Rules for Regular Expressions

Quantifiers can be used to tell “how often” an expression occurs.

Quantifier	Description (Match if the expression is ...)
+	Repeated one or more times.
*	Repeated zero or more times.
?	Repeated zero or one times.
{n}	Repeated exactly n times.
{n, }	Repeated n or more times.
{n, m}	Repeated between n and m times.

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{n, m}	Repeated between n and m times.

## Notes

- Quantifiers apply to the last character before they appear.
- Any valid expression can be enclosed in parentheses for grouping.

# Rules for Regular Expressions

Quantifiers can be used to tell "how often" an expression occurs.

Quantifier	Description (Match if the expression is ...)
<code>+</code>	Repeated one or more times.
<code>*</code>	Repeated zero or more times.
<code>?</code>	Repeated zero or one times.
<code>{n}</code>	Repeated exactly <code>n</code> times.
<code>{n, }</code>	Repeated <code>n</code> or more times.
<code>{n, m}</code>	Repeated between <code>n</code> and <code>m</code> times.

## Examples

- `"[0-9][0-9][a-zA-Z]+"` matches strings with two digits followed by one or more letters.
- `"(abc){3}"` matches three consecutive occurrences of `"abc"`.
- `"abc{3}"` matches `"abccc"`.

# Rules for Regular Expressions

Quantifiers can be used to tell "how often" an expression occurs.

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*	Repeated zero or more times.
?	Repeated zero or one times.
{n}	Repeated exactly n times.
{n, }	Repeated n or more times.
{n, m}	Repeated between n and m times.

## Examples

- `"M[rs][rs]?\" matches "Mr", "Ms", "Mrs", "Mr.", "Ms.", "Mrs."`
- The above also matches "Mrr", "Msr", "Mss", "Mrr.", "Msr.", "Mss." (and nothing else).



# Rules for Regular Expressions

1. The dollar sign `$` means that a pattern only matches at the end of a line.
  - `"[a-z,]$"` matches strings ending in lower-case letters or a comma.
2. The caret `^` outside of brackets means that a pattern only matches at the beginning of a line.
  - `"^[A-Z]"` matches strings not beginning with capital letters.

- Many R functions we've already seen take regular expressions as their arguments.
  - `strsplit()` can use a regular expression to divide a string into a vector.
  - `grep()` can search for patterns represented by regular expressions in a string.

# Regular Expressions in R

## Honor Code Example

Without regular expressions we get weird results when we try to count words:

```
> head(word_count, 10)
```

```
HC.words
```

and	of	or	the	to	in	from	a	is
23	17	16	13	11	10	8	6	5

```
> tail(word_count, 10)
```

```
HC.words
```

vital	which	words	work	work;	works.	world
1	1	1	1	1	1	1
write	Writing	your				
1	1	1				

# Regular Expressions in R

## Honor Code Example

```
> HC <- readLines("HonorCode2.txt")  
> length(HC)
```

```
[1] 43
```

```
> head(HC, 5)
```

```
[1] "Students should be aware that academic dishonesty (for e  
[2] "examination, or dishonesty in dealing with a faculty mem  
[3] "the threat of violence or harassment are particularly se  
[4] "with severely under Dean's Discipline."  
[5] ""
```

HC is a vector with one element per line of text in the Honor Code.

# Regular Expressions in R

## Honor Code Example

```
> HC <- paste(HC, collapse = " ") # One long string
> HC.words <- strsplit(HC, split=" ")[[1]] # Last Time
> HC.words <- strsplit(HC, split="(\s|[:punct:])+")[[1]]
> head(HC.words, 10)
```

```
[1] "Students"      "should"        "be"            "aware"
[5] "that"          "academic"      "dishonesty"    "for"
[9] "example"       "plagiarism"
```

- Splits at blocks of *only* whitespace and/or punctuation.
- Regular expression is enclosed in quotation marks.
- `"\s"` is a special character like `"\n"` or `"\t"`.

# Regular Expressions in R

## Honor Code Example

In the previous we have the following problem: `university's` splits to `university` and `s`.

## Exercise

Check that `split = "\\s+|([[:punct:]]+[[:space:]]+)"` gives us what we want: *either* any number of white spaces *or* at least one punctuation mark followed by at least one space.

```
help(regexpr)
```

# Earthquakes Example

- Recall that the `grep()` functions search a character string for a specified pattern.
- Now we can use regular expressions to specify that pattern.
- We're going to practice using some data from the web.

# Earthquakes Example

Code Example.



# Earthquakes Example

```
> quakes <- readLines("NCEDC_Search_Results.html",  
+                      warn = FALSE)  
> head(quakes)
```

```
[1] "<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Yo  
[2] "<li>catalog=ANSS"  
[3] "<li>start_time=2002/01/01,00:00:00"  
[4] "<li>end_time=2016/01/01,00:00:00"  
[5] "<li>minimum_magnitude=6.0"  
[6] "<li>maximum_magnitude=10"
```

We suppress a superfluous warning about end-of-line character in the `readLines()` call.

# Earthquakes Example

```
> tail(quakes)
```

```
[1] "2015/12/19 02:10:53.36 -18.3819 169.3857 10.00 6.00  
[2] "2015/12/20 18:47:35.53 3.6384 117.6310 6.93 6.10  
[3] "2015/12/24 19:44:03.13 -55.7550 -123.1158 12.28 6.20  
[4] "2015/12/25 19:14:47.17 36.4872 71.1308 206.00 6.30  
[5] "</PRE>"  
[6] "</BODY></HTML>"
```

Every earthquake of magnitude 6 on the Richter scale from January 1, 2002 until January 1, 2016.

# Earthquakes Example

```
> quakes[8:15]
```

```
[1] "</ul>"
```

```
[2] "<PRE>"
```

```
[3] "Date          Time          Lat          Lon    Depth    Mag Magt  N
```

```
[4] "-----"
```

```
[5] "2002/01/01 10:39:06.82 -55.2140 -129.0000 10.00 6.00 Mw 2
```

```
[6] "2002/01/01 11:29:22.73 6.3030 125.6500 138.10 6.30 Mw 2
```

```
[7] "2002/01/02 14:50:33.49 -17.9830 178.7440 665.80 6.20 Mw 2
```

```
[8] "2002/01/02 17:22:48.76 -17.6000 167.8560 21.00 7.20 Mw 4
```

# Earthquakes Example

```
> quakes[8:15]
```

```
[1] "</ul>"
[2] "<PRE>"
[3] "Date          Time          Lat          Lon    Depth    Mag Magt  N
[4] "-----"
[5] "2002/01/01  10:39:06.82 -55.2140 -129.0000  10.00  6.00  Mw
[6] "2002/01/01  11:29:22.73   6.3030  125.6500 138.10  6.30  Mw  2
[7] "2002/01/02  14:50:33.49 -17.9830  178.7440 665.80  6.20  Mw  2
[8] "2002/01/02  17:22:48.76 -17.6000  167.8560  21.00  7.20  Mw  4
```

## Tasks

- Get rid of the first few lines of HTML formatting code and search parameters.
- Actual data begins on line 12. Headers on line 11.
- Strategy: all data lines begin with a date in format YYYY/MM/DD.

# Earthquakes Example

## Extracting the Data

```
> date_express <- "[0-9]{4}/[0-9]{2}/[0-9]{2}"  
> head(grep(quakes, pattern = date_express))
```

```
[1] 12 13 14 15 16 17
```

# Earthquakes Example

## Extracting the Data

```
> date_express <- "[0-9]{4}/[0-9]{2}/[0-9]{2}"  
> head(grep(quakes, pattern = date_express))
```

```
[1] 12 13 14 15 16 17
```

```
> head(grep(quakes, pattern = date_express, value = TRUE))
```

```
[1] "2002/01/01 10:39:06.82 -55.2140 -129.0000 10.00 6.00  
[2] "2002/01/01 11:29:22.73 6.3030 125.6500 138.10 6.30  
[3] "2002/01/02 14:50:33.49 -17.9830 178.7440 665.80 6.20  
[4] "2002/01/02 17:22:48.76 -17.6000 167.8560 21.00 7.20  
[5] "2002/01/03 07:05:27.67 36.0880 70.6870 129.30 6.20  
[6] "2002/01/03 10:17:36.30 -17.6640 168.0040 10.00 6.60
```

# Earthquakes Example

## What are we leaving behind?

```
> grep(quakes, pattern = date_express,  
+      invert = TRUE, value = TRUE)
```

```
[1] "<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Y  
[2] "<li>catalog=ANSS"  
[3] "<li>start_time=2002/01/01,00:00:00"  
[4] "<li>end_time=2016/01/01,00:00:00"  
[5] "<li>minimum_magnitude=6.0"  
[6] "<li>maximum_magnitude=10"  
[7] "<li>event_type=E"  
[8] "</ul>"  
[9] "<PRE>"  
[10] "Date          Time                Lat          Lon    Depth    Mag Magt  
[11] "-----  
[12] "</PRE>"  
[13] "</BODY></HTML>"
```

## Task

- We just extracted the lines we need by noting that they all begin with a date. The lines we need also seem to all end in an event i.d. which is a 12 digit code. Use this idea with `grep()` to extract the lines of actual data.
- This won't work – we leave behind some data lines. What happened?
- How else could we search for the data using regular expressions?



# More Commands in the `grep()` Family

All return information about where regular expressions are matched *in a string*.

- `grep()` returns a logical indicating a match.
- `regexpr()` returns the location of the first match with attributes like the length of the match.
- `gregexpr()` works similarly to `regexpr()`, but returns *all* matching locations. 'g' for global.
- `regmatches()` takes strings and the output of `regexpr()` or `gregexpr()` and returns the actual matching strings.

# More Commands in the grep() Family

## Examples

```
> # Is there a match?  
> grep("a[a-z]", "Alabama")
```

```
[1] 1
```

```
> # Information about the first match.  
> regexpr("a[a-z]", "Alabama")
```

```
[1] 3  
attr("match.length")  
[1] 2  
attr("useBytes")  
[1] TRUE
```

# More Commands in the grep() Family

## Examples

```
> # Information on all matches.  
> gregexpr("a[a-z]", "Alabama")
```

```
[[1]]  
[1] 3 5  
attr(,"match.length")  
[1] 2 2  
attr(,"useBytes")  
[1] TRUE
```

```
> # What are the matches?  
> regmatches("Alabama", gregexpr("a[a-z]", "Alabama"))
```

```
[[1]]  
[1] "ab" "am"
```

# Earthquakes Example

Let's Extract the (longitude, latitude) Pairs

```
> quakes[11:15]
```

```
[1] "-----"
[2] "2002/01/01 10:39:06.82 -55.2140 -129.0000 10.00 6.00"
[3] "2002/01/01 11:29:22.73 6.3030 125.6500 138.10 6.30"
[4] "2002/01/02 14:50:33.49 -17.9830 178.7440 665.80 6.20"
[5] "2002/01/02 17:22:48.76 -17.6000 167.8560 21.00 7.20"
```

```
> coord_exp <- "-?[0-9]+\\. [0-9]{4}"
```

```
> full_exp <- paste(coord_exp, "\\s+", coord_exp, sep = "")
```

# Earthquakes Example

Let's Extract the (longitude, latitude) Pairs

```
> quakes[11:15]
```

```
[1] "-----"
[2] "2002/01/01 10:39:06.82 -55.2140 -129.0000 10.00 6.00"
[3] "2002/01/01 11:29:22.73 6.3030 125.6500 138.10 6.30"
[4] "2002/01/02 14:50:33.49 -17.9830 178.7440 665.80 6.20"
[5] "2002/01/02 17:22:48.76 -17.6000 167.8560 21.00 7.20"
```

```
> coord_exp <- "-?[0-9]+\\.[0-9]{4}"
> full_exp <- paste(coord_exp, "\\s+", coord_exp, sep = "")
```

A negative sign zero or one times with digits 0 – 9 one or more times followed by a period and four digits.

# Earthquakes Example

```
> head(grepl(quakes, pattern = full_exp), 15)
```

```
[1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  
[10] FALSE FALSE  TRUE  TRUE  TRUE  TRUE
```

```
> coord_log <- grepl(quakes, pattern = full_exp)  
> matches    <- gregexpr(pattern = full_exp,  
+                        text = quakes[coord_log])  
> head(matches, 1)
```

```
[[1]]  
[1] 24  
attr(,"match.length")  
[1] 18  
attr(,"useBytes")  
[1] TRUE
```

# Earthquakes Example

## Let's Extract the (longitude, latitude) Pairs

```
> coords <- regmatches(quakes[coord_log], matches)
> head(coords, 4)
```

```
[[1]]
[1] "-55.2140 -129.0000"
```

```
[[2]]
[1] "6.3030 125.6500"
```

```
[[3]]
[1] "-17.9830 178.7440"
```

```
[[4]]
[1] "-17.6000 167.8560"
```

# Earthquakes Example

Let's get the data out of a list and put it in a two-column matrix.

## Let's Extract the (longitude, latitude) Pairs

```
> coords_split <- sapply(coords, strsplit, split="\\s+")  
> head(coords_split, 3)
```

```
[[1]]  
[1] "-55.2140"  "-129.0000"
```

```
[[2]]  
[1] "6.3030"    "125.6500"
```

```
[[3]]  
[1] "-17.9830"  "178.7440"
```



# Earthquakes Example

Let's get the data out of a list and put it in a two-column matrix.

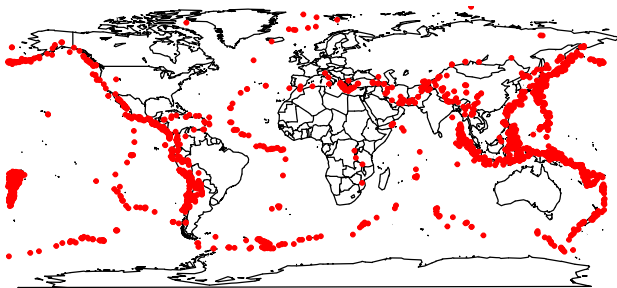
## Let's Extract the (longitude, latitude) Pairs

```
> coords_mat <- matrix(unlist(coords_split), ncol = 2,  
+                        byrow = TRUE)  
> colnames(coords_mat) <- c("Latitude", "Longitude")  
> head(coords_mat)
```

	Latitude	Longitude
[1,]	"-55.2140"	"-129.0000"
[2,]	"6.3030"	"125.6500"
[3,]	"-17.9830"	"178.7440"
[4,]	"-17.6000"	"167.8560"
[5,]	"36.0880"	"70.6870"
[6,]	"-17.6640"	"168.0040"

# Earthquakes Example

```
> library(maps)
> map("world")
> points(coords_mat[, "Longitude"], coords_mat[, "Latitude"],
+         pch = 19, col = "red", cex = .5)
```



# What is Web Scraping?

- We've learned about getting data in and out of R when it's structured: `read.table()`, `read.csv()`, etc.
- Often, like the last example, it's not as structured.
  - Could have metadata.
  - Non-tabular arrangement.
- In general this is true of data on the web.

## Strategy

Read in line-by-line and split into a nicer format (generally requires a lot of regular expressions).

# What is Web Scraping?

- Webpages are generally designed for humans to read.
- Use a computer to extract the information we actually want.
- Iterate the process.

## Strategy

Take in unstructured pages, return rigidly-formatted data.

# What is Web Scraping?

How do we use the computer extract the information we want?

# What is Web Scraping?

How do we use the computer extract the information we want?

- Information is *somewhere* in the page source, usually in the HTML code.
- Often some sort of marker or pointer surrounding the data (again, usually HTML).
- Pick apart the HTML to leave the data using regular expressions.

# What is Web Scraping?

How do we pick apart HTML code with regular expressions?

# What is Web Scraping?

How do we pick apart HTML code with regular expressions?

- What *exactly* do we want from the page?
- How is the page organized? Where is the information we want located?
  - How does it show up on the webpage?
  - How is that represented in the HTML?
- Write a function to automate the information extraction.
- Now iterate over relevant pages.