Motivation and pre-requisites

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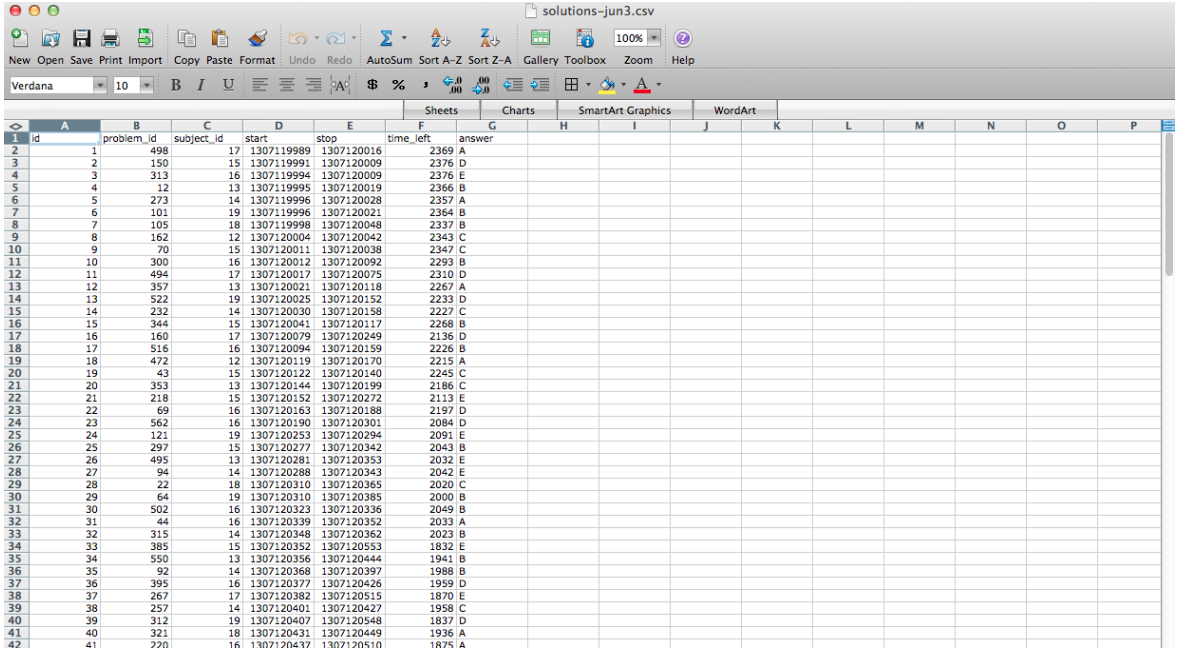
About this course

- This course covers the basic ideas behind getting data ready for analysis
  - Finding and extracting raw data
  - Tidy data principles and how to make data tidy
  - Practical implementation through a range of R packages
- What this course depends on
  - The Data Scientist's Toolbox
  - R Programming
- What would be useful
  - Exploratory analysis
  - Reporting Data and Reproducible Research

What you wish data looked like



	A	B	C	D	E	F	G
1	id	problem_id	subject_id	start	stop	time_left	answer
2	1	498	17	1307119989	1307120016	2369	A
3	2	150	15	1307119991	1307120009	2376	D
4	3	313	16	1307119994	1307120009	2376	E
5	4	12	13	1307119995	1307120019	2366	B
6	5	273	14	1307119996	1307120028	2357	A
7	6	101	19	1307119996	1307120021	2364	B
8	7	105	18	1307119998	1307120048	2337	B
9	8	162	12	1307120004	1307120042	2343	C
10	9	70	15	1307120011	1307120038	2347	C
11	10	300	16	1307120012	1307120092	2293	B
12	11	494	17	1307120017	1307120075	2310	D
13	12	357	13	1307120021	1307120118	2267	A
14	13	522	19	1307120025	1307120152	2233	D
15	14	232	14	1307120030	1307120158	2227	C
16	15	344	15	1307120041	1307120117	2268	B
17	16	160	17	1307120079	1307120249	2136	D
18	17	516	16	1307120094	1307120159	2226	B
19	18	472	12	1307120119	1307120170	2215	A
20	19	43	15	1307120122	1307120140	2245	C
21	20	353	13	1307120144	1307120199	2186	C
22	21	218	15	1307120152	1307120272	2113	E
23	22	69	16	1307120163	1307120188	2197	D
24	23	562	16	1307120190	1307120301	2084	D
25	24	121	19	1307120253	1307120294	2091	E
26	25	297	15	1307120277	1307120342	2043	B
27	26	495	13	1307120281	1307120353	2032	E
28	27	94	14	1307120288	1307120343	2042	E
29	28	22	18	1307120310	1307120365	2020	C
30	29	64	19	1307120310	1307120385	2000	B
31	30	502	16	1307120323	1307120336	2049	B
32	31	44	16	1307120339	1307120352	2033	A
33	32	315	14	1307120348	1307120362	2023	B
34	33	385	15	1307120352	1307120553	1832	E
35	34	550	13	1307120356	1307120444	1941	B
36	35	92	14	1307120368	1307120397	1988	B
37	36	395	16	1307120377	1307120426	1959	D
38	37	267	17	1307120382	1307120515	1870	E
39	38	257	14	1307120401	1307120427	1958	C
40	39	312	19	1307120407	1307120548	1837	D
41	40	321	18	1307120431	1307120449	1936	A
42	41	220	16	1307120437	1307120510	1875	A

What does data really look like?

```
@HWI-EAS121:4:100:1783:550#0/1
CGTTACGAGATCGGAAGAGCGGTTCAGCAGGAATGCCGAGACGGATCTCGTATGCGGTCTGCTGCGTGACAAGACAGGGG
+HWI-EAS121:4:100:1783:550#0/1
aaaaa`b_aa`aa`YaX]aZ`aZM^Z]YRa]YSG[[ZREQLHESDHNDDHNMEEDDMPENITKFLFEEDDDHEJQMEDDD
@HWI-EAS121:4:100:1783:1611#0/1
GGGTGGGCATTTCCACTCGCAGTATGGGTTGCCGCACGACAGGCAGCGGTCAGCCTGCGCTTTGGCCTGGCCTTCGGAAA
+HWI-EAS121:4:100:1783:1611#0/1
a```^\__`_```^a``a`^a_^__]a_]\]`a_______`_^^`]X]_]XTV_\]]NX_XVX]]_TTTTG[VTHPN]VFDZ
@HWI-EAS121:4:100:1783:322#0/1
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+HWI-EAS121:4:100:1783:322#0/1
abaa`^aaaaabbbaabaabbbbbb`bbbb_bbbbbbbb`bbbaV^_a``a``]``aT]a__V\]]_]^a`]a_abbaV__
@HWI-EAS121:4:100:1783:1394#0/1
GGGTCTTTATTGGTCTGGTGATCCCCCATATTCTCCGGTTGTGTGGTTTAACCGATCATCGCGCATTACTTCCCGGCTGC
+HWI-EAS121:4:100:1783:1394#0/1
```[aa\b^^[]aabbb][`a_abbb`a``bbbbbabaabaaaab_VZa_^___bab_X`[a\HV_[_]_[^_X\T_VQQ
@HWI-EAS121:4:100:1783:207#0/1
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+HWI-EAS121:4:100:1783:207#0/1
abba`Xa\^\\`aa]ba__bba[a_O_a`aa`aa`a]^V]X_a^YS\R_\H_[]\ZTDUZZUSOPX]]POP\GS\WSHHD
@HWI-EAS121:4:100:1783:455#0/1
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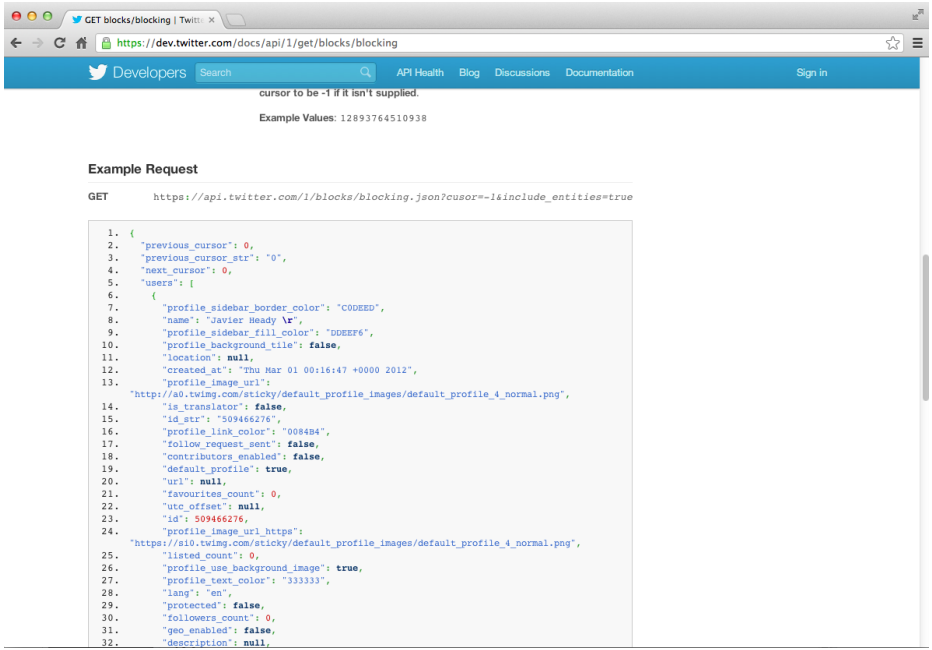
+HWI-EAS121:4:100:1783:455#0/1
abb_babbabaabbbbbbbbbbbbbbbba\`b`\abbbabbbbabbbbbbaabbbbb`bb`ab_O_bab_Q_bbabaa_a
```

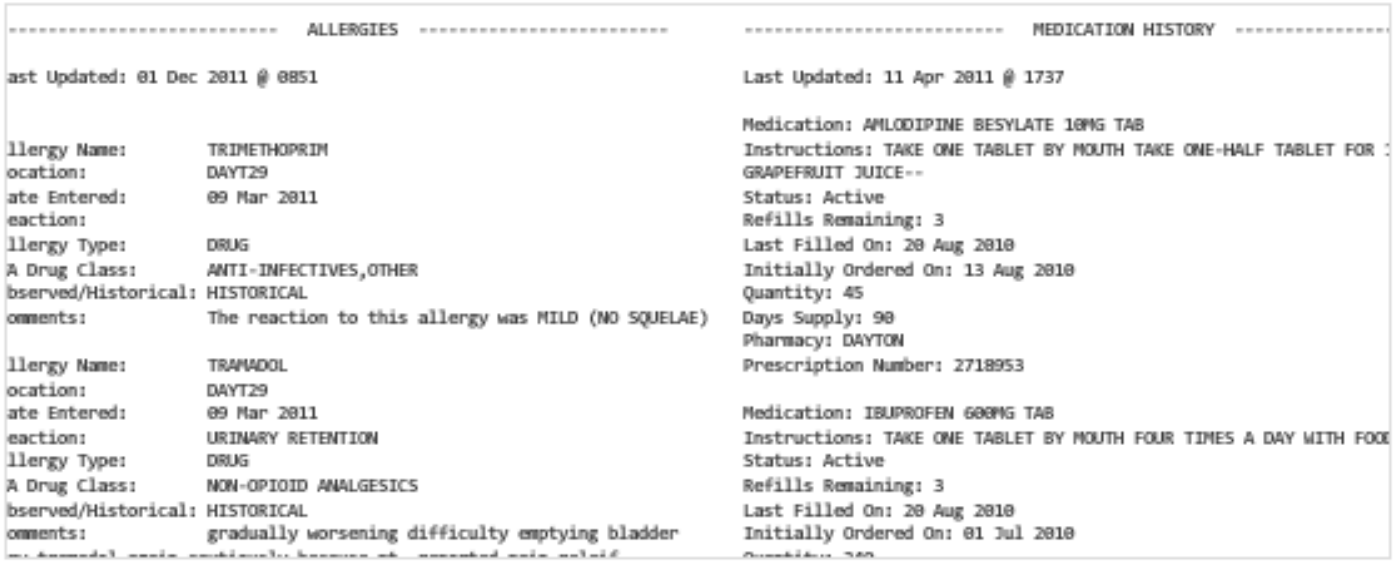
http://brianknaus.com/software/srtoolbox/s_4_1_sequence80.txt
```

What does data really look like?



https://dev.twitter.com/docs/api/1/get/blocks/blocking

What does data really look like?



```
-------------------------  ALLERGIES  -------------------------

ast Updated: 01 Dec 2011 @ 0851


llergy Name:        TRIMETHOPRIM
ocation:            DAYT29
ate Entered:        09 Mar 2011
eaction:
llergy Type:        DRUG
A Drug Class:       ANTI-INFECTIVES,OTHER
bserved/Historical: HISTORICAL
omments:            The reaction to this allergy was MILD (NO SQUELAE)

llergy Name:        TRAMADOL
ocation:            DAYT29
ate Entered:        09 Mar 2011
eaction:            URINARY RETENTION
llergy Type:        DRUG
A Drug Class:       NON-OPIOID ANALGESICS
bserved/Historical: HISTORICAL
omments:            gradually worsening difficulty emptying bladder
```

```
-------------------------  MEDICATION HISTORY  -------------------------

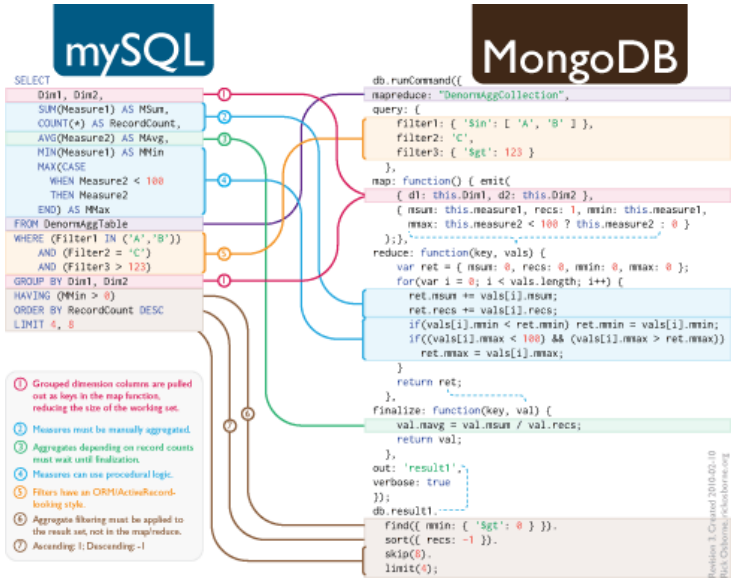
Last Updated: 11 Apr 2011 @ 1737


Medication: AMLODIPINE BESYLATE 10MG TAB
Instructions: TAKE ONE TABLET BY MOUTH TAKE ONE-HALF TABLET FOR
GRAPEFRUIT JUICE--
Status: Active
Refills Remaining: 3
Last Filled On: 20 Aug 2010
Initially Ordered On: 13 Aug 2010
Quantity: 45
Days Supply: 90
Pharmacy: DAYTON
Prescription Number: 2718953

Medication: IBUPROFEN 600MG TAB
Instructions: TAKE ONE TABLET BY MOUTH FOUR TIMES A DAY WITH FOOD
Status: Active
Refills Remaining: 3
Last Filled On: 20 Aug 2010
Initially Ordered On: 01 Jul 2010
```

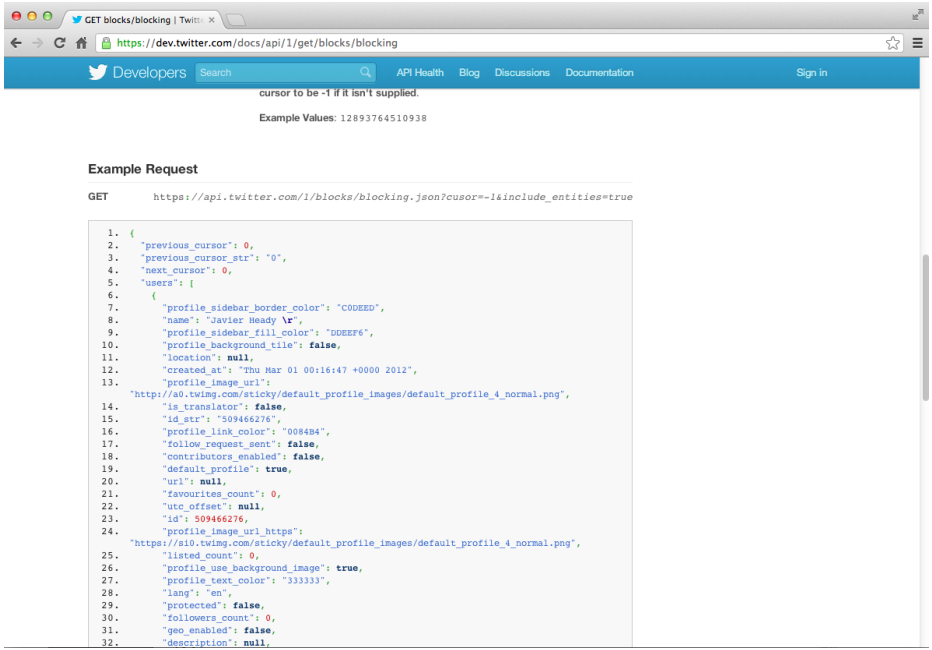
http://blue-button.github.com/challenge/

Where is data?



http://rickosborne.org/blog/2010/02/infographic-migrating-from-sql-to-mapreduce-with-mongodb/

Where is data?



https://dev.twitter.com/docs/api/1/get/blocks/blocking

Where is data?

https://data.baltimorecity.gov/

The goal of this course

Raw data -> Processing script -> tidy data -> data analysis -> data communication

Raw and processed data

Jeffrey Leek, Assistant Professor of Biostatistics
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Definition of data

> “Data are values of qualitative or quantitative variables, belonging to a set of items.”

http://en.wikipedia.org/wiki/Data

Definition of data

> “Data are values of qualitative or quantitative variables, belonging to a set of items.”

http://en.wikipedia.org/wiki/Data

Set of items: Sometimes called the population; the set of objects you are interested in

Definition of data

> “Data are values of qualitative or quantitative variables, belonging to a set of items.”

http://en.wikipedia.org/wiki/Data

Variables: A measurement or characteristic of an item.

Definition of data

> “Data are values of qualitative or quantitative variables, belonging to a set of items.”

http://en.wikipedia.org/wiki/Data

Qualitative: Country of origin, sex, treatment

Quantitative: Height, weight, blood pressure

Raw versus processed data

Raw data

- The original source of the data
- Often hard to use for data analyses
- Data analysis *includes* processing
- Raw data may only need to be processed once

http://en.wikipedia.org/wiki/Raw_data

Processed data

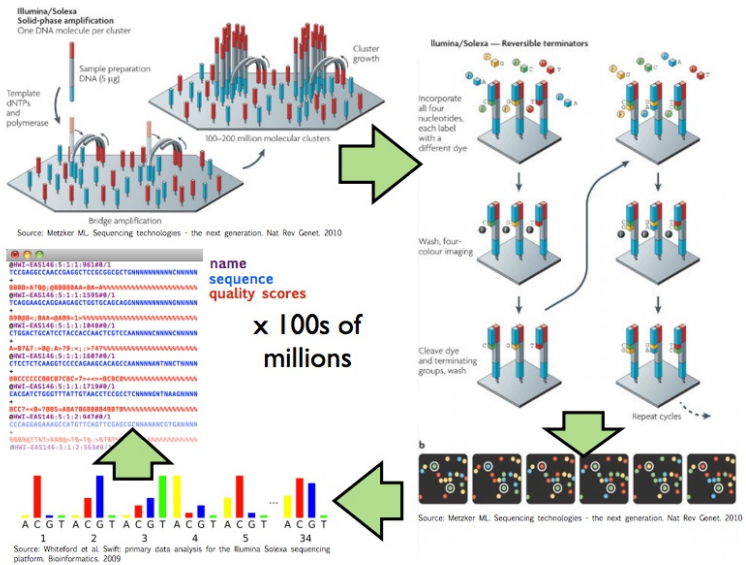
- Data that is ready for analysis
- Processing can include merging, subsetting, transforming, etc.
- There may be standards for processing
- All steps should be recorded

http://en.wikipedia.org/wiki/Computer_data_processing

An example of a processing pipeline

http://www.illumina.com.cn/support/sequencing/sequencing_instruments/hiseq_1000.asp

An example of a processing pipeline



http://www.cbcb.umd.edu/~hcorrada/CMSC858B/lectures/lect22_seqIntro/seqIntro.pdf

The components of tidy data

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The four things you should have

1. The raw data.
2. A tidy data set
3. A code book describing each variable and its values in the tidy data set.
4. An explicit and exact recipe you used to go from 1 -> 2,3.

The raw data

- The strange binary file your measurement machine spits out
- The unformatted Excel file with 10 worksheets the company you contracted with sent you
- The complicated JSON data you got from scraping the Twitter API
- The hand-entered numbers you collected looking through a microscope

You know the raw data is in the right format if you

1. Ran no software on the data
2. Did not manipulate any of the numbers in the data
3. You did not remove any data from the data set
4. You did not summarize the data in any way

https://github.com/jtleek/datasharing

The tidy data

1. Each variable you measure should be in one column
2. Each different observation of that variable should be in a different row
3. There should be one table for each "kind" of variable
4. If you have multiple tables, they should include a column in the table that allows them to be linked

Some other important tips

- Include a row at the top of each file with variable names.
- Make variable names human readable AgeAtDiagnosis instead of AgeDx
- In general data should be saved in one file per table.

https://github.com/jtleek/datasharing

The code book

1. Information about the variables (including units!) in the data set not contained in the tidy data
2. Information about the summary choices you made
3. Information about the experimental study design you used

Some other important tips

- A common format for this document is a Word/text file.
- There should be a section called "Study design" that has a thorough description of how you collected the data.
- There must be a section called "Code book" that describes each variable and its units.

https://github.com/jtleek/datasharing

The instruction list

- Ideally a computer script (in R :-), but I suppose Python is ok too...)
- The input for the script is the raw data
- The output is the processed, tidy data
- There are no parameters to the script

In some cases it will not be possible to script every step. In that case you should provide instructions like:

1. Step 1 - take the raw file, run version 3.1.2 of summarize software with parameters a=1, b=2, c=3
2. Step 2 - run the software separately for each sample
3. Step 3 - take column three of outputfile.out for each sample and that is the corresponding row in the output data set

https://github.com/jtleek/datasharing

Why is the instruction list important?

Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff

Thomas Herndon* Michael Ash Robert Pollin

April 15, 2013

http://www.colbertnation.com/the-colbert-report-videos/425748/april-23-2013/austerity-s-spreadsheet-error

Downloading files

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Get/set your working directory

- A basic component of working with data is knowing your working directory
- The two main commands are `getwd()` and `setwd()`.
- Be aware of relative versus absolute paths
  - **Relative** - `setwd("./data")`, `setwd("../")`
  - **Absolute** - `setwd("/Users/jtleek/data/")`
- Important difference in Windows `setwd("C:\\Users\\Andrew\\Downloads")`

Checking for and creating directories

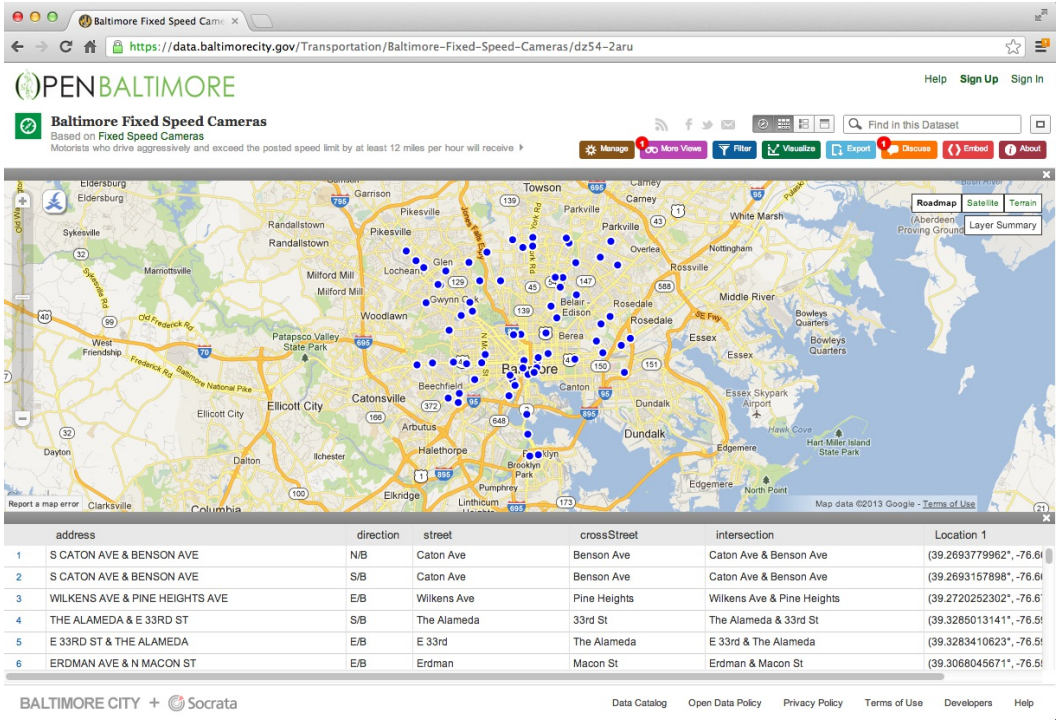
- `file.exists("directoryName")` will check to see if the directory exists
- `dir.create("directoryName")` will create a directory if it doesn't exist
- Here is an example checking for a "data" directory and creating it if it doesn't exist

```
if (!file.exists("data")) {
    dir.create("data")
}
```

Getting data from the internet - download.file()

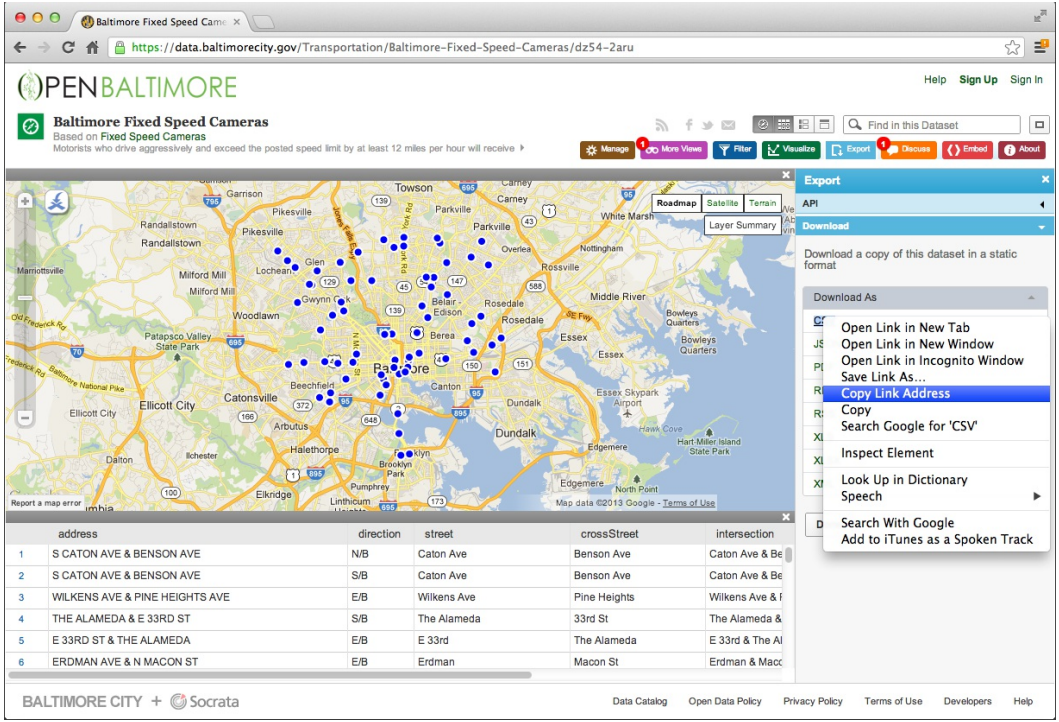
- Downloads a file from the internet
- Even if you could do this by hand, helps with reproducibility
- Important parameters are *url*, *destfile*, *method*
- Useful for downloading tab-delimited, csv, and other files

Example - Baltimore camera data



https://data.baltimorecity.gov/Transportation/Baltimore-Fixed-Speed-Cameras/dz54-2aru

Example - Baltimore camera data



https://data.baltimorecity.gov/Transportation/Baltimore-Fixed-Speed-Cameras/dz54-2aru

Download a file from the web

```
fileUrl <- "https://data.baltimorecity.gov/api/views/dz54-2aru/rows.csv?accessType=DOWNLOAD"
download.file(fileUrl, destfile = "./data/cameras.csv", method = "curl")
list.files("./data")
```

```
## [1] "cameras.csv"
```

```
dateDownloaded <- date()
dateDownloaded
```

```
## [1] "Sun Jan 12 21:37:44 2014"
```

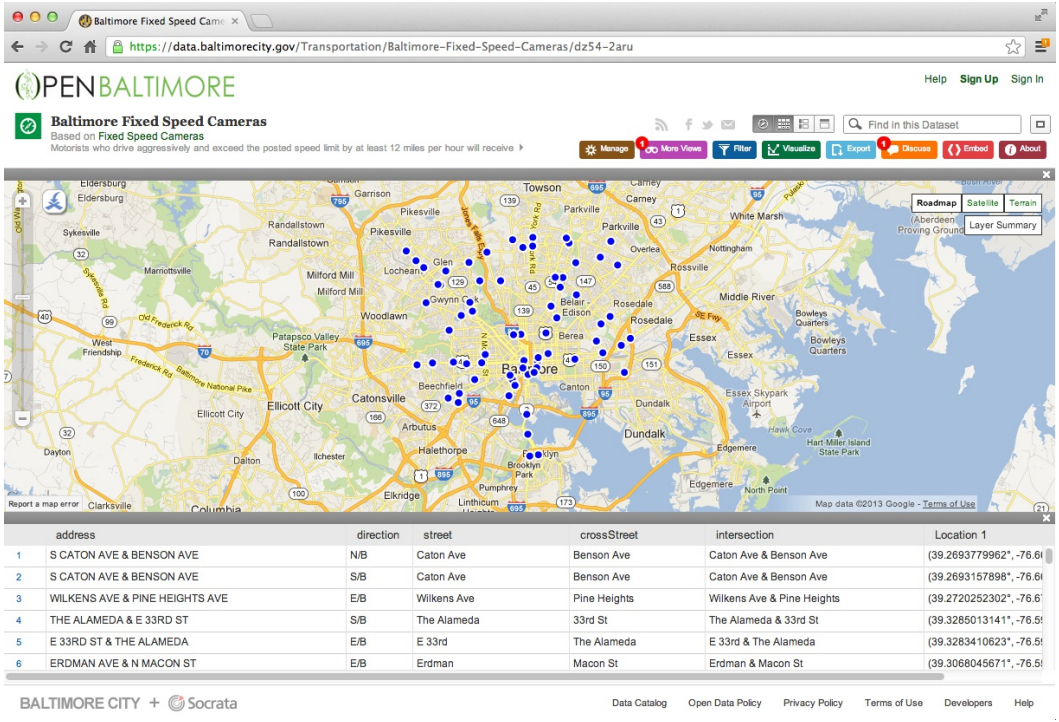
Some notes about download.file()

- If the url starts with *http* you can use download.file()
- If the url starts with *https* on Windows you may be ok
- If the url starts with *https* on Mac you may need to set *method="curl"*
- If the file is big, this might take a while
- Be sure to record when you downloaded.

Reading local flat files

Jeffrey Leek
Johns Hopkins Bloomberg School of Public Health

Example - Baltimore camera data



https://data.baltimorecity.gov/Transportation/Baltimore-Fixed-Speed-Cameras/dz54-2aru

Download the file to load

```
if (!file.exists("data")) {
    dir.create("data")
}
fileUrl <- "https://data.baltimorecity.gov/api/views/dz54-2aru/rows.csv?accessType=DOWNLOAD"
download.file(fileUrl, destfile = "cameras.csv", method = "curl")
dateDownloaded <- date()
```

Loading flat files - read.table()

- This is the main function for reading data into R
- Flexible and robust but requires more parameters
- Reads the data into RAM - big data can cause problems
- Important parameters *file*, *header*, *sep*, *row.names*, *nrows*
- Related: *read.csv()*, *read.csv2()*

Baltimore example

```
cameraData <- read.table("./data/cameras.csv")
```

```
## Error: line 1 did not have 13 elements
```

```
head(cameraData)
```

```
## Error: object 'cameraData' not found
```

Example: Baltimore camera data

```
cameraData <- read.table("./data/cameras.csv", sep = ",", header = TRUE)
head(cameraData)
```

```
##                         address direction      street  crossStreet
## 1       S CATON AVE & BENSON AVE       N/B   Caton Ave   Benson Ave
## 2       S CATON AVE & BENSON AVE       S/B   Caton Ave   Benson Ave
## 3 WILKENS AVE & PINE HEIGHTS AVE       E/B Wilkens Ave Pine Heights
## 4        THE ALAMEDA & E 33RD ST       S/B The Alameda      33rd St
## 5        E 33RD ST & THE ALAMEDA       E/B      E 33rd  The Alameda
## 6        ERDMAN AVE & N MACON ST       E/B      Erdman     Macon St
##                intersection                      Location.1
## 1     Caton Ave & Benson Ave (39.2693779962, -76.6688185297)
## 2     Caton Ave & Benson Ave (39.2693157898, -76.6689698176)
## 3 Wilkens Ave & Pine Heights  (39.2720252302, -76.676960806)
## 4     The Alameda  & 33rd St (39.3285013141, -76.5953545714)
## 5      E 33rd  & The Alameda (39.3283410623, -76.5953594625)
## 6         Erdman  & Macon St (39.3068045671, -76.5593167803)
```

Example: Baltimore camera data

read.csv sets *sep=","* and *header=TRUE*

```
cameraData <- read.csv("./data/cameras.csv")
head(cameraData)
```

```
##                         address direction      street  crossStreet
## 1       S CATON AVE & BENSON AVE       N/B   Caton Ave   Benson Ave
## 2       S CATON AVE & BENSON AVE       S/B   Caton Ave   Benson Ave
## 3 WILKENS AVE & PINE HEIGHTS AVE       E/B Wilkens Ave Pine Heights
## 4        THE ALAMEDA & E 33RD ST       S/B The Alameda      33rd St
## 5        E 33RD ST & THE ALAMEDA       E/B      E 33rd  The Alameda
## 6        ERDMAN AVE & N MACON ST       E/B      Erdman     Macon St
##                intersection                       Location.1
## 1     Caton Ave & Benson Ave (39.2693779962, -76.6688185297)
## 2     Caton Ave & Benson Ave (39.2693157898, -76.6689698176)
## 3 Wilkens Ave & Pine Heights  (39.2720252302, -76.676960806)
## 4     The Alameda  & 33rd St (39.3285013141, -76.5953545714)
## 5      E 33rd  & The Alameda (39.3283410623, -76.5953594625)
## 6         Erdman  & Macon St (39.3068045671, -76.5593167803)
```

Some more important parameters

- *quote* - you can tell R whether there are any quoted values quote="" means no quotes.
- *na.strings* - set the character that represents a missing value.
- *nrows* - how many rows to read of the file (e.g. nrows=10 reads 10 lines).
- *skip* - number of lines to skip before starting to read

In my experience, the biggest trouble with reading flat files are quotation marks ` or " placed in data values, setting quote="" often resolves these.

Reading Excel files

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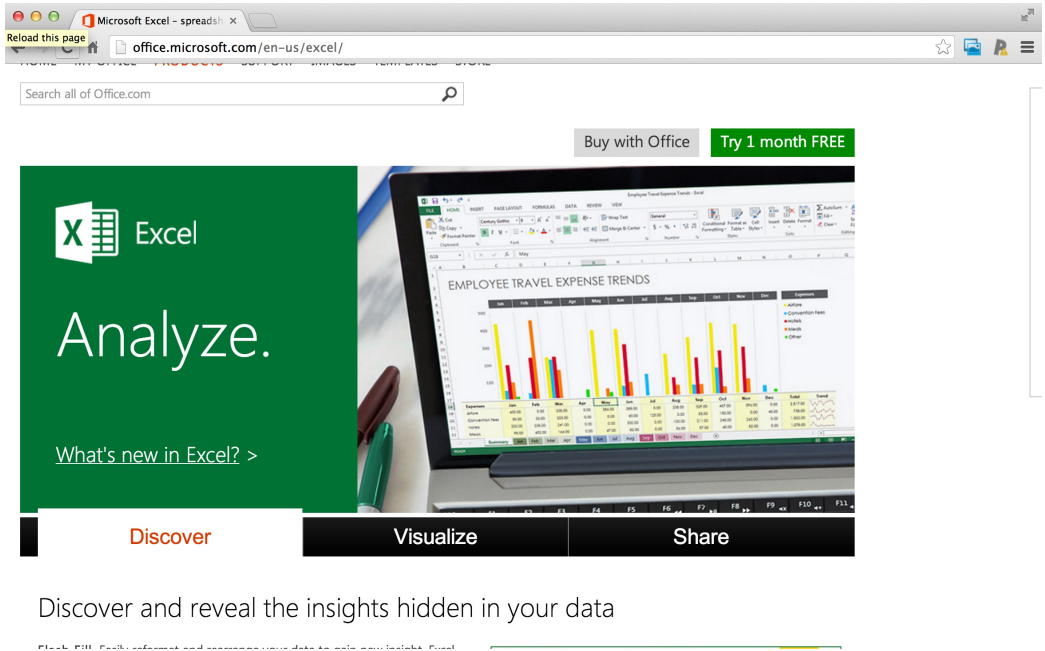
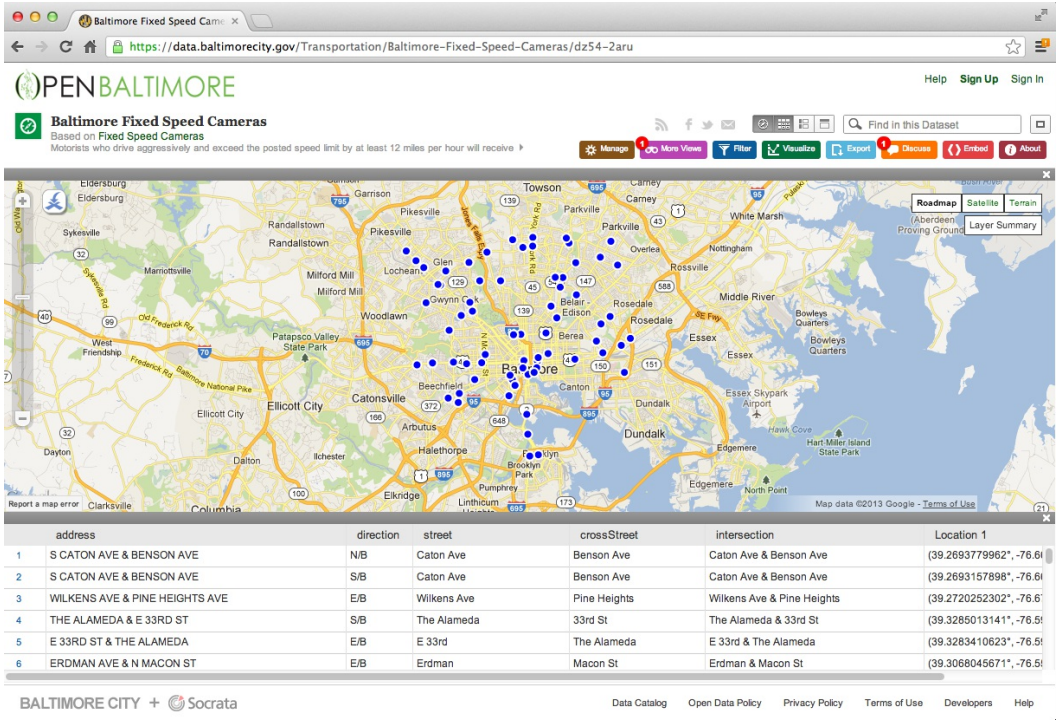
Excel files

Still probably the most widely used format for sharing data



http://office.microsoft.com/en-us/excel/

Example - Baltimore camera data



https://data.baltimorecity.gov/Transportation/Baltimore-Fixed-Speed-Cameras/dz54-2aru

Download the file to load

```
if(!file.exists("data")){dir.create("data")}
fileUrl <- "https://data.baltimorecity.gov/api/views/dz54-2aru/rows.xlsx?accessType=DOWNLOAD"
download.file(fileUrl,destfile="./data/cameras.xlsx",method="curl")
dateDownloaded <- date()
```

read.xlsx(), read.xlsx2() {xlsx package}

```
library(xlsx)
cameraData <- read.xlsx("./data/cameras.xlsx",sheetIndex=1,header=TRUE)
head(cameraData)
```

```
                        address direction      street  crossStreet                intersection
1       S CATON AVE & BENSON AVE       N/B   Caton Ave   Benson Ave     Caton Ave & Benson Ave
2       S CATON AVE & BENSON AVE       S/B   Caton Ave   Benson Ave     Caton Ave & Benson Ave
3 WILKENS AVE & PINE HEIGHTS AVE       E/B Wilkens Ave Pine Heights Wilkens Ave & Pine Heights
4        THE ALAMEDA & E 33RD ST       S/B The Alameda       33rd St     The Alameda  & 33rd St
5        E 33RD ST & THE ALAMEDA       E/B      E 33rd  The Alameda      E 33rd  & The Alameda
6
1 (39.2693779962, -76.6688185297)
2 (39.2693157898, -76.6689698176)
3  (39.2720252302, -76.676960806)
4 (39.3285013141, -76.5953545714)
5 (39.3283410623, -76.5953594625)
6 (39.3068045671, -76.5593167803)
```

Reading specific rows and columns

```
colIndex <- 2:3
rowIndex <- 1:4
cameraDataSubset <- read.xlsx("./data/cameras.xlsx",sheetIndex=1,
                              colIndex=colIndex,rowIndex=rowIndex)
cameraDataSubset
```

```
  direction      street
1       N/B   Caton Ave
2       S/B   Caton Ave
3       E/B Wilkens Ave
```

Further notes

- The *write.xlsx* function will write out an Excel file with similar arguments.
- *read.xlsx2* is much faster than *read.xlsx* but for reading subsets of rows may be slightly unstable.
- The XLConnect package has more options for writing and manipulating Excel files
- The XLConnect vignette is a good place to start for that package
- In general it is advised to store your data in either a database or in comma separated files (.csv) or tab separated files (.tab/.txt) as they are easier to distribute.

Reading XML

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XML

- Extensible markup language
- Frequently used to store structured data
- Particularly widely used in internet applications
- Extracting XML is the basis for most web scraping
- Components
    - Markup - labels that give the text structure
    - Content - the actual text of the document

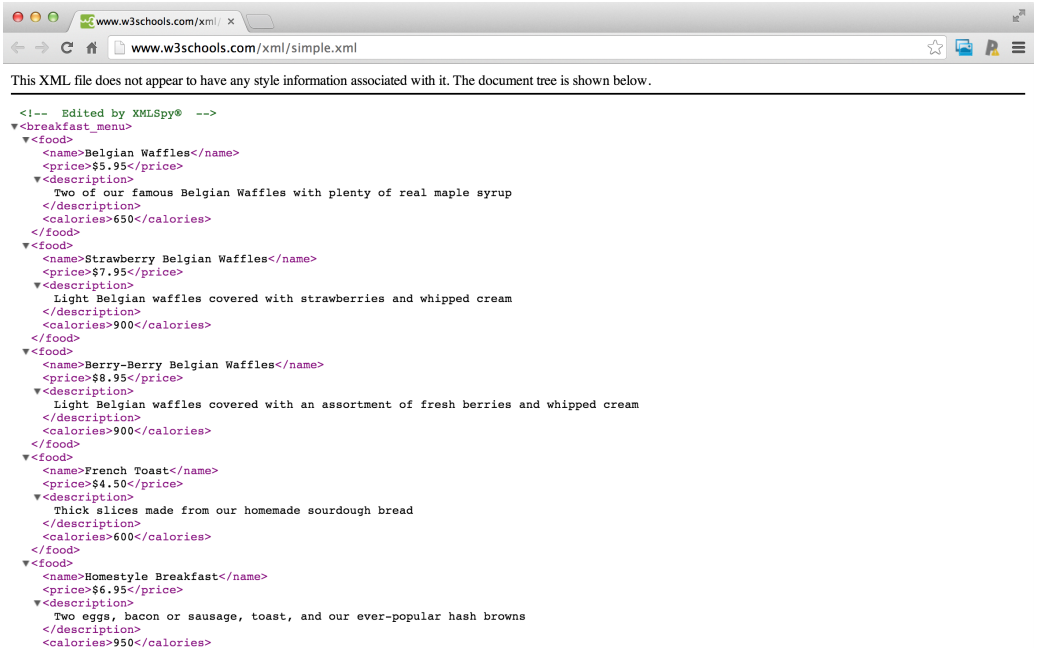
http://en.wikipedia.org/wiki/XML

Tags, elements and attributes

- Tags correspond to general labels
  - Start tags `<section>`
  - End tags `</section>`
  - Empty tags `<line-break />`
- Elements are specific examples of tags
  - `<Greeting> Hello, world </Greeting>`
- Attributes are components of the label
  - `<img src="jeff.jpg" alt="instructor"/>`
  - `<step number="3"> Connect A to B. </step>`

http://en.wikipedia.org/wiki/XML

Example XML file



http://www.w3schools.com/xml/simple.xml

Read the file into R

```
library(XML)
fileUrl <- "http://www.w3schools.com/xml/simple.xml"
doc <- xmlTreeParse(fileUrl,useInternal=TRUE)
rootNode <- xmlRoot(doc)
xmlName(rootNode)
```

```
[1] "breakfast_menu"
```

```
names(rootNode)
```

```
  food   food   food   food   food
"food" "food" "food" "food" "food"
```

Directly access parts of the XML document

```
rootNode[[1]]
```

```
<food>
  <name>Belgian Waffles</name>
  <price>$5.95</price>
  <description>Two of our famous Belgian Waffles with plenty of real maple syrup</description>
  <calories>650</calories>
</food>
```

```
rootNode[[1]][[1]]
```

```
<name>Belgian Waffles</name>
```

Programatically extract parts of the file

```
xmlSApply(rootNode,xmlValue)
```

```
                                "Belgian Waffles$5.95Two of our famous Belgian Waffles with plenty of rea

                          "Strawberry Belgian Waffles$7.95Light Belgian waffles covered with strawberries and

"Berry-Berry Belgian Waffles$8.95Light Belgian waffles covered with an assortment of fresh berries and

                                                    "French Toast$4.50Thick slices made from our homemade so

                          "Homestyle Breakfast$6.95Two eggs, bacon or sausage, toast, and our ever-popula
```

Programatically extract parts of the file

```
xmlSApply(rootNode,xmlValue)
```

```
                                "Belgian Waffles$5.95Two of our famous Belgian Waffles with plenty of rea

                          "Strawberry Belgian Waffles$7.95Light Belgian waffles covered with strawberries and

"Berry-Berry Belgian Waffles$8.95Light Belgian waffles covered with an assortment of fresh berries and

                                                        "French Toast$4.50Thick slices made from our homemade so

                           "Homestyle Breakfast$6.95Two eggs, bacon or sausage, toast, and our ever-popula
```

XPath

- */node* Top level node
- *//node* Node at any level
- *node[@attr-name]* Node with an attribute name
- *node[@attr-name='bob']* Node with attribute name attr-name='bob'

Information from: http://www.stat.berkeley.edu/~statcur/Workshop2/Presentations/XML.pdf

Get the items on the menu and prices

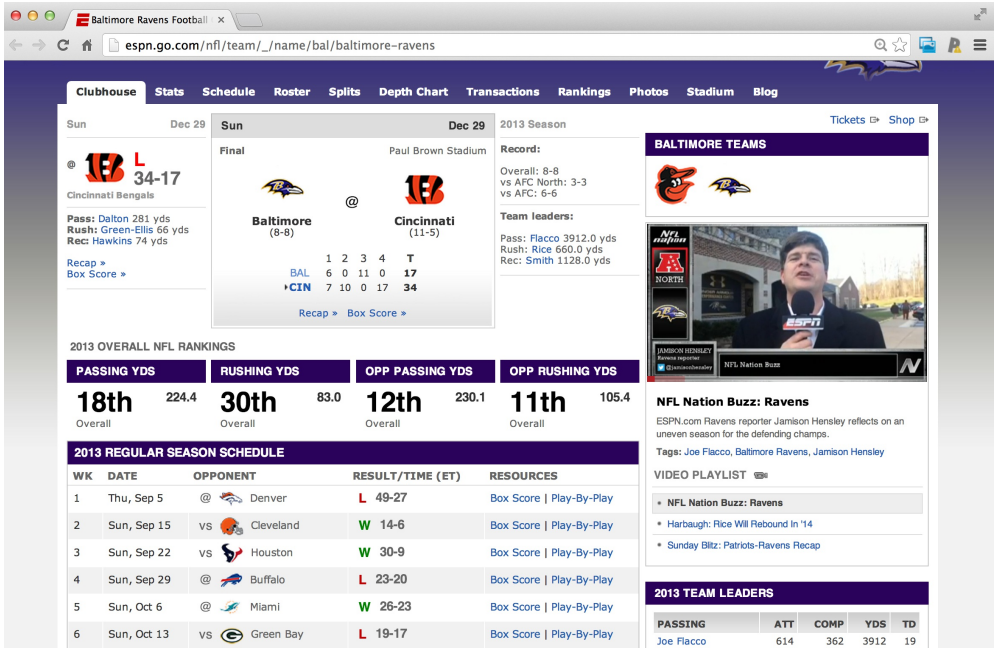
```
xpathSApply(rootNode,"//name",xmlValue)
```

```
[1] "Belgian Waffles"             "Strawberry Belgian Waffles"  "Berry-Berry Belgian Waffles"
[4] "French Toast"                "Homestyle Breakfast"
```

```
xpathSApply(rootNode,"//price",xmlValue)
```

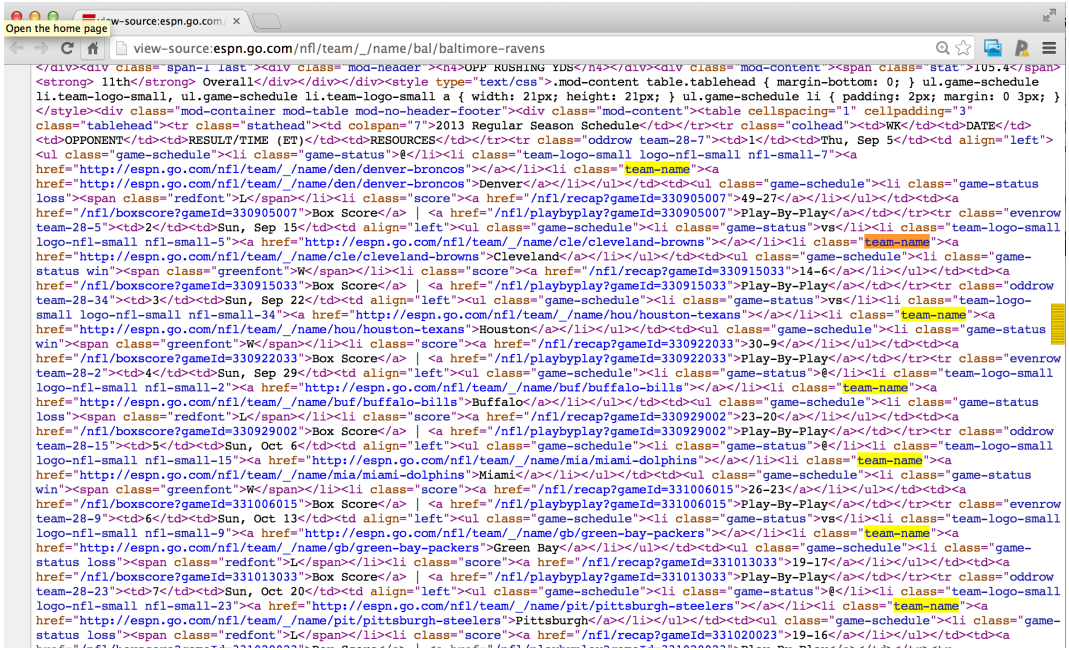
```
[1] "$5.95" "$7.95" "$8.95" "$4.50" "$6.95"
```

Another example



http://espn.go.com/nfl/team/_/name/bal/baltimore-ravens

Viewing the source



http://espn.go.com/nfl/team/_/name/bal/baltimore-ravens

Extract content by attributes

```
fileUrl <- "http://espn.go.com/nfl/team/_/name/bal/baltimore-ravens"
doc <- htmlTreeParse(fileUrl,useInternal=TRUE)
scores <- xpathSApply(doc,"//li[@class='score']",xmlValue)
teams <- xpathSApply(doc,"//li[@class='team-name']",xmlValue)
scores
```

```
 [1] "49-27"    "14-6"     "30-9"     "23-20"    "26-23"    "19-17"    "19-16"    "24-18"
 [9] "20-17 OT" "23-20 OT" "19-3"     "22-20"    "29-26"    "18-16"    "41-7"     "34-17"
```

```
teams
```

```
 [1] "Denver"       "Cleveland"    "Houston"      "Buffalo"      "Miami"        "Green Bay"
 [7] "Pittsburgh"   "Cleveland"    "Cincinnati"   "Chicago"      "New York"     "Pittsburgh"
[13] "Minnesota"    "Detroit"      "New England"  "Cincinnati"
```

Notes and further resources

- Official XML tutorials short, long
- An outstanding guide to the XML package

Reading JSON

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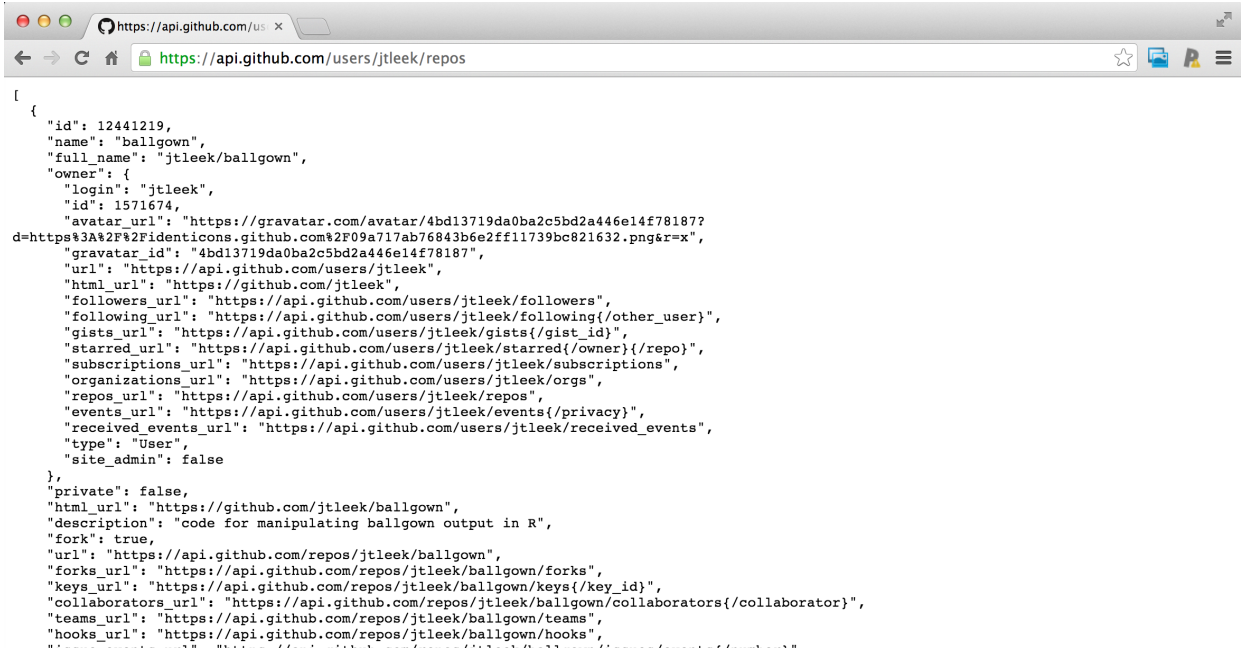
JSON

- Javascript Object Notation
- Lightweight data storage
- Common format for data from application programming interfaces (APIs)
- Similar structure to XML but different syntax/format
- Data stored as
  - Numbers (double)
  - Strings (double quoted)
  - Boolean (*true* or *false*)
  - Array (ordered, comma separated enclosed in square brackets *[]*)
  - Object (unorderd, comma separated collection of key:value pairs in curley brackets *{}*)

http://en.wikipedia.org/wiki/JSON

Example JSON file




```
[
  {
    "id": 12441219,
    "name": "ballgown",
    "full_name": "jtleek/ballgown",
    "owner": {
      "login": "jtleek",
      "id": 1571674,
      "avatar_url": "https://gravatar.com/avatar/4bd13719da0ba2c5bd2a446e14f781877
d=https%3A%2F%2Fidenticons.github.com%2F09a717ab76843b6e2ff11739bc821632.png&r=x",
      "gravatar_id": "4bd13719da0ba2c5bd2a446e14f78187",
      "url": "https://api.github.com/users/jtleek",
      "html_url": "https://github.com/jtleek",
      "followers_url": "https://api.github.com/users/jtleek/followers",
      "following_url": "https://api.github.com/users/jtleek/following{/other_user}",
      "gists_url": "https://api.github.com/users/jtleek/gists{/gist_id}",
      "starred_url": "https://api.github.com/users/jtleek/starred{/owner}{/repo}",
      "subscriptions_url": "https://api.github.com/users/jtleek/subscriptions",
      "organizations_url": "https://api.github.com/users/jtleek/orgs",
      "repos_url": "https://api.github.com/users/jtleek/repos",
      "events_url": "https://api.github.com/users/jtleek/events{/privacy}",
      "received_events_url": "https://api.github.com/users/jtleek/received_events",
      "type": "User",
      "site_admin": false
    },
    "private": false,
    "html_url": "https://github.com/jtleek/ballgown",
    "description": "code for manipulating ballgown output in R",
    "fork": true,
    "url": "https://api.github.com/repos/jtleek/ballgown",
    "forks_url": "https://api.github.com/repos/jtleek/ballgown/forks",
    "keys_url": "https://api.github.com/repos/jtleek/ballgown/keys{/key_id}",
    "collaborators_url": "https://api.github.com/repos/jtleek/ballgown/collaborators{/collaborator}",
    "teams_url": "https://api.github.com/repos/jtleek/ballgown/teams",
    "hooks_url": "https://api.github.com/repos/jtleek/ballgown/hooks",
```

Reading data from JSON {jsonlite package}

```
library(jsonlite)
jsonData <- fromJSON("https://api.github.com/users/jtleek/repos")
names(jsonData)
```

```
 [1] "id"               "name"             "full_name"        "owner"
 [5] "private"          "html_url"         "description"      "fork"
 [9] "url"              "forks_url"        "keys_url"         "collaborators_url"
[13] "teams_url"        "hooks_url"        "issue_events_url" "events_url"
[17] "assignees_url"    "branches_url"     "tags_url"         "blobs_url"
[21] "git_tags_url"     "git_refs_url"     "trees_url"        "statuses_url"
[25] "languages_url"    "stargazers_url"   "contributors_url" "subscribers_url"
[29] "subscription_url" "commits_url"      "git_commits_url"  "comments_url"
[33] "issue_comment_url" "contents_url"    "compare_url"      "merges_url"
[37] "archive_url"      "downloads_url"    "issues_url"       "pulls_url"
[41] "milestones_url"   "notifications_url" "labels_url"     "releases_url"
[45] "created_at"       "updated_at"       "pushed_at"        "git_url"
[49] "ssh_url"          "clone_url"        "svn_url"          "homepage"
[53] "size"             "stargazers_count" "watchers_count"   "language"
```

Nested objects in JSON

```
names(jsonData$owner)
```

```
 [1] "login"             "id"                "avatar_url"          "gravatar_id"
 [5] "url"               "html_url"          "followers_url"       "following_url"
 [9] "gists_url"         "starred_url"       "subscriptions_url"   "organizations_url"
[13] "repos_url"         "events_url"        "received_events_url" "type"
[17] "site_admin"
```

```
jsonData$owner$login
```

```
 [1] "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek"
[11] "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek"
[21] "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek" "jtleek"
```

Writing data frames to JSON

```
myjson <- toJSON(iris, pretty=TRUE)
cat(myjson)
```

```
[
    {
        "Sepal.Length" : 5.1,
        "Sepal.Width" : 3.5,
        "Petal.Length" : 1.4,
        "Petal.Width" : 0.2,
        "Species" : "setosa"
    },
    {
        "Sepal.Length" : 4.9,
        "Sepal.Width" : 3,
        "Petal.Length" : 1.4,
        "Petal.Width" : 0.2,
        "Species" : "setosa"
    },
    {
        "Sepal.Length" : 4.7,
```

Convert back to JSON

```
iris2 <- fromJSON(myjson)
head(iris2)
```

```
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
```

http://www.r-bloggers.com/new-package-jsonlite-a-smarter-json-encoderdecoder/

Further resources

- http://www.json.org/
- A good tutorial on jsonlite - http://www.r-bloggers.com/new-package-jsonlite-a-smarter-json-encoderdecoder/
- jsonlite vignette

Using data.table

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data.table

- Inherets from data.frame
    - All functions that accept data.frame work on data.table
- Written in C so it is much faster
- Much, much faster at subsetting, group, and updating

Create data tables just like data frames

```
library(data.table)
DF = data.frame(x=rnorm(9),y=rep(c("a","b","c"),each=3),z=rnorm(9))
head(DF,3)
```

```
       x y        z
1 0.4159 a -0.05855
2 0.8433 a  0.13732
3 1.0585 a  2.16448
```

```
DT = data.table(x=rnorm(9),y=rep(c("a","b","c"),each=3),z=rnorm(9))
head(DT,3)
```

```
          x y      z
1: -0.27721 a 0.2530
2:  1.00158 a 1.5093
3: -0.03382 a 0.4844
```

See all the data tables in memory

```
tables()
```

```
     NAME NROW MB COLS  KEY
[1,] DT      9 1  x,y,z
Total: 1MB
```

Subsetting rows

```
DT[2,]
```

```
      x y     z
1: 1.002 a 1.509
```

```
DT[DT$y=="a",]
```

```
         x y      z
1: -0.27721 a 0.2530
2:  1.00158 a 1.5093
3: -0.03382 a 0.4844
```

Subsetting rows

```
DT[c(2,3)]
```

```
         x y      z
1:  1.00158 a 1.5093
2: -0.03382 a 0.4844
```

Subsetting columns!?

```
DT[,c(2,3)]
```

```
[1] 2 3
```

Column subsetting in data.table

- The subsetting function is modified for data.table
- The argument you pass after the comma is called an "expression"
- In R an expression is a collection of statements enclosed in curley brackets

```
{
  x = 1
  y = 2
}
k = {print(10); 5}
```

```
[1] 10
```

```
print(k)
```

```
[1] 5
```

Calculating values for variables with expressions

```
DT[,list(mean(x),sum(z))]
```

```
        V1     V2
1: 0.05637 0.5815
```

```
DT[,table(y)]
```

```
y
a b c
3 3 3
```

Adding new columns

```
DT[,w:=z^2]
```

```
          x y        z        w
1: -0.27721 a  0.25300 0.064009
2:  1.00158 a  1.50933 2.278091
3: -0.03382 a  0.48437 0.234619
4: -0.70493 b -1.22755 1.506885
5: -1.36402 b -0.64624 0.417631
6: -0.26224 b -0.51427 0.264475
7: -0.10929 c  1.21445 1.474901
8:  1.40234 c  0.07493 0.005614
9:  0.85494 c -0.56652 0.320948
```

Adding new columns

```
DT2 <- DT
DT[, y:= 2]
```

```
          x y        z        w
1: -0.27721 2  0.25300 0.064009
2:  1.00158 2  1.50933 2.278091
3: -0.03382 2  0.48437 0.234619
4: -0.70493 2 -1.22755 1.506885
5: -1.36402 2 -0.64624 0.417631
6: -0.26224 2 -0.51427 0.264475
7: -0.10929 2  1.21445 1.474901
8:  1.40234 2  0.07493 0.005614
9:  0.85494 2 -0.56652 0.320948
```

Careful

```
head(DT,n=3)
```

```
          x y      z       w
1: -0.27721 2 0.2530 0.06401
2:  1.00158 2 1.5093 2.27809
3: -0.03382 2 0.4844 0.23462
```

```
head(DT2,n=3)
```

```
          x y      z       w
1: -0.27721 2 0.2530 0.06401
2:  1.00158 2 1.5093 2.27809
3: -0.03382 2 0.4844 0.23462
```

Multiple operations

```
DT[,m:= {tmp <- (x+z); log2(tmp+5)}]
```

```
          x y        z        w     m
1: -0.27721 2  0.25300 0.064009 2.315
2:  1.00158 2  1.50933 2.278091 2.909
3: -0.03382 2  0.48437 0.234619 2.446
4: -0.70493 2 -1.22755 1.506885 1.617
5: -1.36402 2 -0.64624 0.417631 1.580
6: -0.26224 2 -0.51427 0.264475 2.078
7: -0.10929 2  1.21445 1.474901 2.610
8:  1.40234 2  0.07493 0.005614 2.695
9:  0.85494 2 -0.56652 0.320948 2.403
```

plyr like operations

```
DT[,a:=x>0]
```

```
          x y        z        w     m     a
1: -0.27721 2  0.25300 0.064009 2.315 FALSE
2:  1.00158 2  1.50933 2.278091 2.909  TRUE
3: -0.03382 2  0.48437 0.234619 2.446 FALSE
4: -0.70493 2 -1.22755 1.506885 1.617 FALSE
5: -1.36402 2 -0.64624 0.417631 1.580 FALSE
6: -0.26224 2 -0.51427 0.264475 2.078 FALSE
7: -0.10929 2  1.21445 1.474901 2.610 FALSE
8:  1.40234 2  0.07493 0.005614 2.695  TRUE
9:  0.85494 2 -0.56652 0.320948 2.403  TRUE
```

plyr like operations

```
DT[,b:= mean(x+w),by=a]
```

```
          x y        z        w     m     a      b
1: -0.27721 2  0.25300 0.064009 2.315 FALSE 0.2018
2:  1.00158 2  1.50933 2.278091 2.909  TRUE 1.9545
3: -0.03382 2  0.48437 0.234619 2.446 FALSE 0.2018
4: -0.70493 2 -1.22755 1.506885 1.617 FALSE 0.2018
5: -1.36402 2 -0.64624 0.417631 1.580 FALSE 0.2018
6: -0.26224 2 -0.51427 0.264475 2.078 FALSE 0.2018
7: -0.10929 2  1.21445 1.474901 2.610 FALSE 0.2018
8:  1.40234 2  0.07493 0.005614 2.695  TRUE 1.9545
9:  0.85494 2 -0.56652 0.320948 2.403  TRUE 1.9545
```

Special variables

`.N` An integer, length 1, containing the numbe r

```
set.seed(123);
DT <- data.table(x=sample(letters[1:3], 1E5, TRUE))
DT[, .N, by=x]
```

```
   x     N
1: a 33387
2: c 33201
3: b 33412
```

Keys

```
DT <- data.table(x=rep(c("a","b","c"),each=100), y=rnorm(300))
setkey(DT, x)
DT['a']
```

```
    x        y
  1: a  0.25959
  2: a  0.91751
  3: a -0.72232
  4: a -0.80828
  5: a -0.14135
  6: a  2.25701
  7: a -2.37955
  8: a -0.45425
  9: a -0.06007
 10: a  0.86090
 11: a -1.78466
 12: a -0.13074
 13: a -0.36984
 14: a -0.18066
 15: a -1.04973
```

Joins

```
DT1 <- data.table(x=c('a', 'a', 'b', 'dt1'), y=1:4)
DT2 <- data.table(x=c('a', 'b', 'dt2'), z=5:7)
setkey(DT1, x); setkey(DT2, x)
merge(DT1, DT2)
```

```
   x y z
1: a 1 5
2: a 2 5
3: b 3 6
```

Fast reading

```
big_df <- data.frame(x=rnorm(1E6), y=rnorm(1E6))
file <- tempfile()
write.table(big_df, file=file, row.names=FALSE, col.names=TRUE, sep="\t", quote=FALSE)
system.time(fread(file))
```

```
   user  system elapsed
  0.312   0.015   0.326
```

```
system.time(read.table(file, header=TRUE, sep="\t"))
```

```
   user  system elapsed
  5.702   0.048   5.755
```

Summary and further reading

- The latest development version contains new functions like `melt` and `dcast` for data.tables
  - https://r-forge.r-project.org/scm/viewvc.php/pkg/NEWS?view=markup&root=datatable
- Here is a list of differences between data.table and data.frame
  - http://stackoverflow.com/questions/13618488/what-you-can-do-with-data-frame-that-you-cant-in-data-table
- Notes based on Raphael Gottardo's notes https://github.com/raphg/Biostat-578/blob/master/Advanced_data_manipulation.Rpres, who got them from Kevin Ushey.