

# Intro to R BootCamp Day 1

## Lecture 1

Steve Pittard [wsp@emory.edu](mailto:wsp@emory.edu)

September 6, 2016

# Why R ?

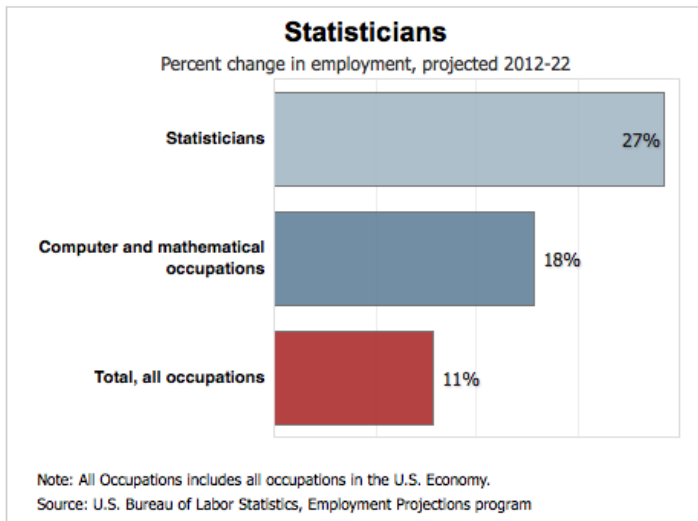
## Occupational Outlook Handbook 2014

Employment of computer and information research scientists is projected to grow 18 percent from 2012 to 2022, faster than the average for all occupations. Employment of statisticians is projected to grow 27 percent from 2012 to 2022, much faster than the average for all occupations.

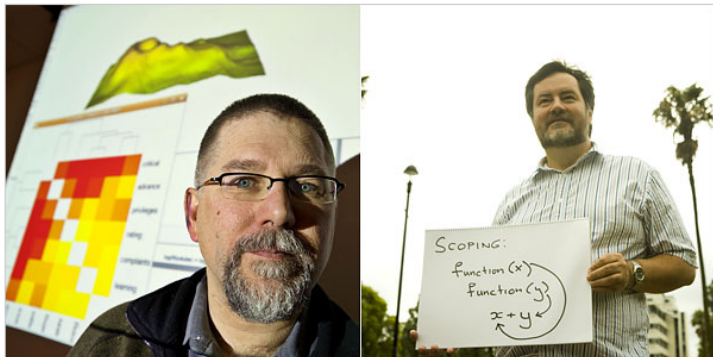
Rapid growth in data collection by businesses may lead to an increased need for data mining services. Information research scientists are likely to enjoy excellent job prospects.

Graduates with a master's degree in statistics and a strong background in a related discipline, such as finance, biology, engineering, or computer science, are projected have the best prospects of finding jobs in their field of study.

# Why R ?



## Data Analysts Captivated by R's Power



Left, Stuart Isett for The New York Times; right, Kieran Scott for The New York Times

R first appeared in 1996, when the statistics professors Robert Gentleman, left, and Ross Ihaka released the code as a free software package.

By **ASHLEE VANCE**

Published: January 6, 2009

<http://tinyurl.com/cxa774n>

# Who Uses R ?

Company	How R is Used
Bank of America	Modeling and visualization
Facebook	User analysis and interaction
FDA	Used in parallel with SAS
Ford Motor Company	Decision support
Google	Calculate ROI on advertising
John Deere	Time series modeling and geospatial analysis
National Weather Service	Visualization for flood forecasting
New York Times Newspaper	Data visualization
Nordstrom	Recommendation systems
Orbitz Travel	Search result optimization
Twitter	User experience analysis
Trulia Real Estate	Housing cost predictions
OK Cupid Online Dating	Trend analysis
Lloyd's of London Insurance	Investment recommendation

<http://www.revolutionanalytics.com/companies-using-r>

# Why R ?

- R is an interactive framework for data and statistical analysis that also happens to have a builtin programming language.
- Compare this to languages such as Python, Perl, and Java that have data analysis addons
- Which language to use ? Use them all if necessary but if data analysis is a large part of the work then R is the “go to” language
- R can reference or call code written in C, C++, Perl, Python, Java, and FORTRAN.
- Most of the effort in using R relates to shaping data for analysis and understanding the available functions and packages.
- To be a good *programmer* in R one must first be a knowledgeable *user* of R.

# Why R ?

## Differences between R and other statistical packages

“When talking about user friendliness of computer software I like to the analogy of cars vs. busses. Using this analogy programs like SPSS are busses, easy to use for the standard things, but very frustrating if you want to do something that is not already preprogrammed.”

“R is a 4-wheel drive SUV with a bike on the back, a kayak on the top, good walking and running shoes in the passenger seat, and a mountain climbing and spelunking gear in the back.”

“R can take you anywhere you want to go if you take the time to learn how to use the equipment, but that is going to take longer than learning where the bus stops are in SPSS.”

Greg Snow, R-help (May 2006)

# Why R ?

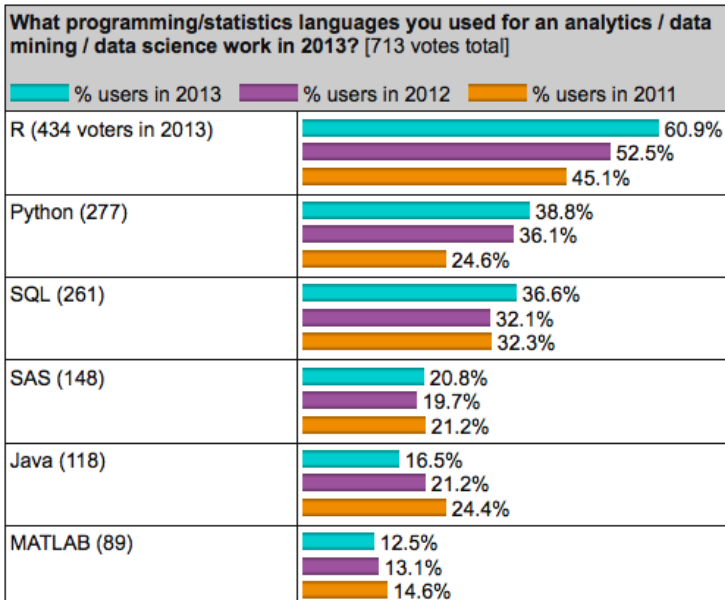
## Cool things about R

- Vast capabilities with a wide range of statistical and graphics techniques
- Written primarily by statisticians
- Free of cost
- Collaborative development with over 6,092 user contributed packages
- Excellent community support with mailing lists, blogs, and tutorials
- Excellent “google” support
- Wildly popular in Academia and increasingly so in the business world

`www.slideshare.net/izahn/rintro`



# R vs Other Languages - kdnuggets.com



# Obtaining R

- Go to <http://cran.revolutionanalytics.com/>
- Click on your platform which will be either Windows or Apple OSX
- You will be redirected to another page which has a download link near the top
- Click it to download and begin installation. Wait till it is finished
- Go to <http://www.rstudio.com/products/rstudio/download/> to download the RStudio GUI
- Double click the installer to initiate the installation of RStudio
- Once finished start up Rstudio

# Base Packages

It is important to note that R comes with a base set of packages as part of every installation.

```
> getOption("defaultPackages")
[1] "datasets" "utils"      "grDevices" "graphics" "stats"      "methods"

> search()
[1] ".GlobalEnv"      "package:stats"    "package:graphics" "package:grDevices"
[5] "package:utils"    "package:datasets" "package:methods"   "Autoloads"
[9] "package:base"

> library(help="stats")
```

# Base Packages

```
> library(help="stats")
```

Description:

```
Package:      stats
Version:      3.1.2
Priority:      base
Title:        The R Stats Package
Author:        R Core Team and contributors worldwide
Maintainer:    R Core Team <R-core@r-project.org>
Description:   R statistical functions
License:       Part of R 3.1.2
Built:         R 3.1.2; x86_64-apple-darwin13.4.0; 2014-10-31 20:19:14 UTC; unix
```

Index:

<code>.checkMFClasses</code>	Functions to Check the Type of Variables passed to Model Frames
<code>AIC</code>	Akaike's An Information Criterion
<code>ARMAacf</code>	Compute Theoretical ACF for an ARMA Process
<code>ARMAtoMA</code>	Convert ARMA Process to Infinite MA Process
<code>Beta</code>	The Beta Distribution
<code>Binomial</code>	The Binomial Distribution
<code>Box.test</code>	Box-Pierce and Ljung-Box Tests
<code>C</code>	Sets Contrasts for a Factor

# Base Packages

Many packages come with example data that is helpful when attempting to understand how various functions work. To see what data sets are available in a given package, do something like:

```
> search()
[1] ".GlobalEnv" "package:lattice" "package:stats" "package:graphics"
[5] "package:grDevices" "package:utils" "package:datasets" "package:methods"
[9] "Autoloads" "package:base"

> data(package="stats") # Find data included in package "stats"
```

Data sets in package "datasets":

AirPassengers	Monthly Airline Passenger Numbers 1949-1960
BJsales	Sales Data with Leading Indicator
BJsales.lead (BJsales)	Sales Data with Leading Indicator
BOD	Biochemical Oxygen Demand
CO2	Carbon Dioxide Uptake in Grass Plants
DNase	Elisa assay of DNase
EuStockMarkets	Daily Closing Prices of Major European
..	

# CRAN Packages

One of the most powerful aspects of R is the ability to install user-contributed add-on packages available in CRAN, (Comprehensive R Archive Network). As of December 2014 there are over 6,000 packages available.

To obtain information on the wide variety of packages then visit the following URL to see some of the areas covered. `cran.cnr.berkeley.edu` Also go to the “Task Views” You can also see packages grouped by domain at <http://cran.r-project.org/web/views/>

# CRAN Packages

Here are some of the areas covered. There are many more of course

## CRAN Task Views

<a href="#">Bayesian</a>	Bayesian Inference
<a href="#">ChemPhys</a>	Chemometrics and Computational Physics
<a href="#">ClinicalTrials</a>	Clinical Trial Design, Monitoring, and Analysis
<a href="#">Cluster</a>	Cluster Analysis & Finite Mixture Models
<a href="#">DifferentialEquations</a>	Differential Equations
<a href="#">Distributions</a>	Probability Distributions
<a href="#">Econometrics</a>	Computational Econometrics
<a href="#">Environmetrics</a>	Analysis of Ecological and Environmental Data
<a href="#">ExperimentalDesign</a>	Design of Experiments (DoE) & Analysis of Experimental Data
<a href="#">Finance</a>	Empirical Finance
<a href="#">Genetics</a>	Statistical Genetics
<a href="#">Graphics</a>	Graphic Displays & Dynamic Graphics & Graphic Devices & Visualization
<a href="#">HighPerformanceComputing</a>	High-Performance and Parallel Computing with R
<a href="#">MachineLearning</a>	Machine Learning & Statistical Learning
<a href="#">MedicalImaging</a>	Medical Image Analysis

# CRAN Packages

If you are using RStudio there are menu items that can simplify the process of identifying and installing packages. However, you can also do this from the command prompt. Let's say you want to install the “actuar” package from CRAN.

```
> install.packages("actuar",dependencies=TRUE)
```

```
trying URL 'http://mirrors.nics.utk.edu/cran/bin/macosx/contrib/2.15/
actuar_1.1-5.tgz'
```

```
Content type 'application/x-gzip' length 1837121 bytes (1.8 Mb)
opened URL
```

```
=====
```

```
downloaded 1.8 Mb
```

```
> library(actuar) # Brings the package into the workspace
```



# CRAN Packages

When we use the **library** command to load the contents of the **actuar** package it will show up when we execute the **search()** function. Check it out.

```
> library(actuar) # Brings the package into the workspace
```

```
> search()
```

```
[1] ".GlobalEnv" "package:actuar" "package:lattice" "package:stats"  
[5] "package:graphics" "package:grDevices" "package:utils"  
[8] "package:datasets" "package:methods" "Autoloads" "package:base"
```

# CRAN Packages

On occasion you will need to install a package from a specific repository such as `omegahat.org` or `R-forge`. RStudio has menu items that can help with this but you can also do it from the command line.

```
> install.packages("GeoIP", repos = "http://www.omegahat.org/R")
```

Sometimes you download packages written by colleagues and you have to install them from your local hard drive. Again, RStudio can help but you could also do something like:

```
$ R CMD INSTALL GeoIP.tar.gz
```

# CRAN Packages

There are lots of free books and tutorials on the web.

```
> install.packages("GeoIP", repos = "http://www.omegahat.org/R")
```

Sometimes you download packages written by colleagues and you have to install them from your local hard drive. Again, RStudio can help but you could also do something like:

```
$ R CMD INSTALL GeoIP.tar.gz
```

# Finding Documentation

There are lots of free books on the web

Resource	URL
The R Inferno	<a href="http://www.burns-stat.com/documents/books/the-r-inferno/">http://www.burns-stat.com/documents/books/the-r-inferno/</a>
R Programming Wiki	<a href="http://en.wikibooks.org/wiki/R_Programming">http://en.wikibooks.org/wiki/R_Programming</a>
Intro to Stats Using R	<a href="http://ipsur.org">http://ipsur.org</a>
Stats with R	<a href="http://zoonek2.free.fr/UNIX/48_R/all.html">http://zoonek2.free.fr/UNIX/48_R/all.html</a>
Lattice Graphics	<a href="http://lmdvr.r-forge.r-project.org">http://lmdvr.r-forge.r-project.org</a>
Contributed R Info	<a href="http://cran.r-project.org/other-docs.html">http://cran.r-project.org/other-docs.html</a>
simpleR Intro Stats	<a href="http://cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf">http://cran.r-project.org/doc/contrib/Verzani-SimpleR.pdf</a>
DIY Intro to R	<a href="http://www.unt.edu/rss/class/Jon/R_SC/">http://www.unt.edu/rss/class/Jon/R_SC/</a>
R Bloggers	<a href="http://www.r-bloggers.com/">http://www.r-bloggers.com/</a>
R Journal	<a href="http://journal.r-project.org/">http://journal.r-project.org/</a>
R Tutorial	<a href="http://www.r-tutor.com/r-introduction">http://www.r-tutor.com/r-introduction</a>
Google Style Guide	<a href="https://github.com/hadley/devtools/wiki/Style">https://github.com/hadley/devtools/wiki/Style</a>
Applied Epi Using R	<a href="http://www.medepi.net/docs/EpidemiologyUsingR.pdf">http://www.medepi.net/docs/EpidemiologyUsingR.pdf</a>

# Finding Documentation

There are some good books you can buy although for this class they aren't required.

Book	Author
R Cookbook	Paul Teetor
R in a Nutshell	Joseph Adler
The Art of Programming	Norman Matloff
Data Manipulation with R	Phil Spector
ggplot2: Elegant Graphics for Data Analyses	Hadley Wickham
Intro to Scientific Programming and Simulation Using R	Jones, Maillardet, Robinson
Introductory Statistics with R	Peter Dalgaard
The R Book	Michael J. Crawley
Discovering Statistics Using R	Andy Field

# Mailing Lists

- Here are some mailing lists that accept questions relative to R and BioConductor.
- Moderators and participants in these lists take questions seriously, sometimes too seriously,
- Please don't ask a question without first searching through the archives to see if your question has already been answered. Chances are it has.

Mailing Lists	URL
R-Help	<a href="http://stat.ethz.ch/mailman/listinfo/r-help">http://stat.ethz.ch/mailman/listinfo/r-help</a>
Cross Validated	<a href="http://stats.stackexchange.com">http://stats.stackexchange.com</a>
Stack Overflow	<a href="http://stackoverflow.com/questions/tagged">http://stackoverflow.com/questions/tagged</a>

# Getting Help

R has a number of ways to get help. Rstudio has a Help menu item. Other ways include the following:

```
> help.start()           # Launches a web browser with search capability

> help(function_name)    # Get help on "function_name"

> ?function_name         # Equivalent to the above

> args(function_name)     # See what arguments the function accepts

> example(function_name) # See an example of the function

> example(mean)
```

```
mean> x <- c(0:10, 50)
mean> xm <- mean(x)
mean> c(xm, mean(x, trim = 0.10))
[1] 8.75 5.50
```

# Getting Help

R has a number of ways to get help. Rstudio has a Help menu item. Other ways include the following:

```
# Find all functions and data having to do with time series
```

```
> help.search("time series")
```

```
> ?? "time series"      # Equivalent to the above
```

Help files with alias or concept or title matching "time series" using fuzzy matching:

<code>boot::tsboot</code>	Bootstrapping of Time Series
<code>datasets::austres</code>	Quarterly Time Series of the Number of Australian Residents
<code>datasets::beavers</code>	Body Temperature Series of Two Beavers
<code>ggplot2::economics</code>	US economic time series.
<code>lattice::xyplot.ts</code>	Time series plotting methods
<code>MASS::beav1</code>	Body Temperature Series of Beaver 1
<code>MASS::beav2</code>	Body Temperature Series of Beaver 2
<code>stats::StructTS</code>	Fit Structural Time Series
<code>stats::ar</code>	Fit Autoregressive Models to Time Series
<code>stats::ar.ols</code>	Fit Autoregressive Models to Time Series by OLS
<code>..</code>	



# Things to Know !

- Everything in R is an object
- The great thing about R is that there are many different ways to do something
- The bad thing about R is that there are many different ways to do something
- Everything that happens in R is a function call
- Supports procedural programming with functions and object oriented programming
- R is based on a “read-eval-print” loop
- Interpreted language

# Walkthrough

```
url <- "http://stevie42.bitbucket.org/YOUTUBE.DIR/table_7_3.csv"
```

```
engine <- read.table(url, sep = ",", header=TRUE)
engine <- engine[,-1]
```

```
head(engine) # 3 engine pollutants
```

```
      hc co nox
1 0.50 5.01 1.28
2 0.65 14.67 0.72
3 0.46 8.60 1.17
4 0.41 4.42 1.31
5 0.41 4.95 1.16
```

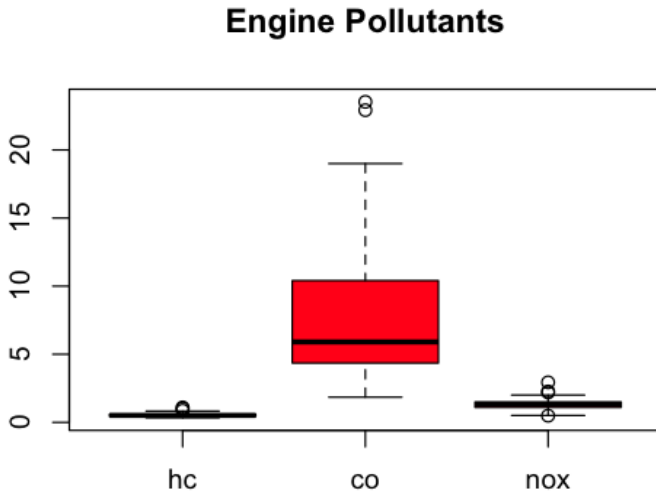
```
summary(engine)
```

```
      en hc co nox
Min.   : 1.00   Min.   :0.3400   Min.   : 1.850   Min.   :0.490
1st Qu.:12.75   1st Qu.:0.4375   1st Qu.: 4.388   1st Qu.:1.110
Median :24.50   Median :0.5100   Median : 5.905   Median :1.315
Mean   :24.00   Mean   :0.5502   Mean   : 7.879   Mean   :1.340
3rd Qu.:35.25   3rd Qu.:0.6025   3rd Qu.:10.015   3rd Qu.:1.495
Max.   :46.00   Max.   :1.1000   Max.   :23.530   Max.   :2.940
```

```
http://www.cyclismo.org/tutorial/R/hwI.html
```

# Walkthrough

```
boxplot(engine,col="red",main="Engine Pollutants")
```



# Walkthrough

```
par(mfrow=c(1,3))
```

```
boxplot(engine$co,main="Carbon Monoxide")
```

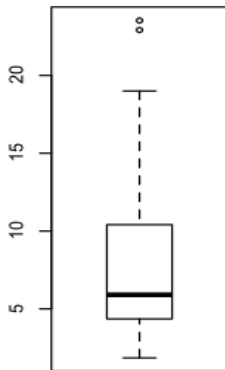
```
hist(engine$co)
```

```
qqnorm(engine$co,main="Carbon Monoxide")
```

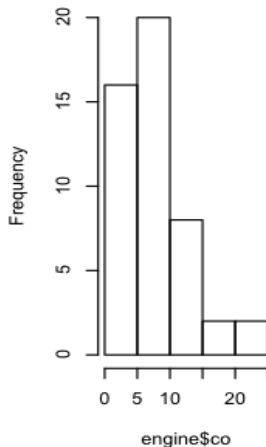
```
qqline(engine$co)
```

# Walkthrough

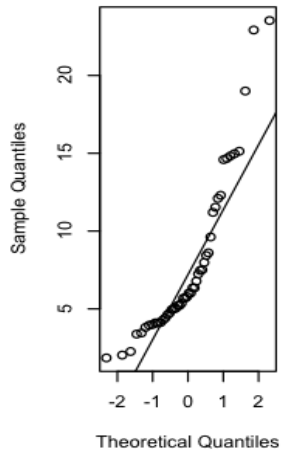
**Carbon Monoxide**



**Histogram of engine\$co**



**Carbon Monoxide**



# Walkthrough

# The null hypothesis is that the data is normal

```
shapiro.test(engine$co)
```

Shapiro-Wilk normality test

```
data: engine$co
```

```
W = 0.8357, p-value = 9.289e-06
```

# Take the log of the CO

```
log.engine <- log(engine$co)
```

```
shapiro.test(log.engine)
```

Shapiro-Wilk normality test

```
data: log.engine
```

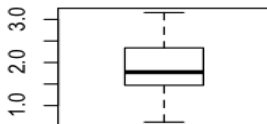
```
W = 0.9693, p-value = 0.2379
```

# Walkthrough

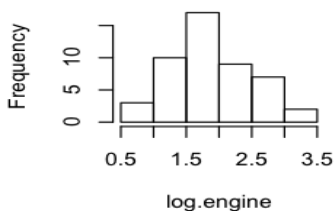
```
par(mfrow=c(2,2))  
  
log.engine <- log(engine$co)  
  
boxplot(log.engine,main="Carbon Monoxide")  
  
hist(log.engine,main="Carbon Monoxide")  
  
qqnorm(log.engine,main="QQ Plot for the Log of the  
Carbon Monoxide")  
  
qqline(log.engine)
```

# Walkthrough

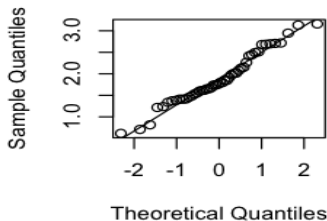
**Carbon Monoxide**



**Carbon Monoxide**



**QQ Plot for the Log of the Carbon Monox**





# Walkthrough

```
# Let's build a confidence interval
```

```
my.mean <- mean(log.engine)
my.sd <- sd(log.engine)
n <- length(log.engine)
```

```
# Get standard error
se <- my.sd/sqrt(n)
```

```
error <- se*qt(0.975,df=n-1)
```

```
left <- my.mean - error
```

```
right <- my.mean + error
```

```
c(left,right)
[1] 1.709925 2.057431
```

```
c(exp(left),exp(right))
[1] 5.528548 7.825840
```

# Walkthrough

```
# Test H0: mu = 5.4
# HA:mu != 5.4

lNull <- log(5.4) - error

rNull <- log(5.4) + error

c(lNull,rNull)
[1] 1.512646 1.860152

my.mean
[1] 1.883678
```

So the mean is outside the range thus we reject the null. There is a low probability that we would have obtained our sample mean if the true mean really was 5.4

# Walkthrough

We could have calculated a p-value by hand

```
p.val <- 2*(1-pt((my.mean-log(5.4))/se,df=n-1))
```

```
p.val  
[1] 0.02692539
```

# But its easier to call a procedure to do it all !!!!

```
t.test(log.engine,mu = log(5.4),alternative = "two.sided")
```

One Sample t-test

data: log.engine

t = 2.2841, df = 47, p-value = 0.02693

alternative hypothesis: true mean is not equal to 1.686399

95 percent confidence interval:

1.709925 2.057431

sample estimates:

mean of x

1.883678

# First R Session

```
?mean                # Get help on the mean function

example(kmeans)      # Run an example of kmeans (if it exists)

pi                    # Some popular quantities are built-in to R
[1] 3.141593

sqrt(2) # Basic arithmetic
[1] 1.414214

print(pi) # Print the comments of the pi variable
[1] 3.141593

X <- 3; Y <- 4 # Semicolon lets you enter 2 commands on the same line

Z <- sqrt(X^2 + Y^2) # Variables contain information

# List all variables in the "environment"

ls()
[1] "X" "Y" "Z"
```

<code>log(10)</code> [1] 2.302585	<code>ceiling(6.8)</code> [1] 7	<code>2+3</code> [1] 5
<code>log10(100)</code> [1] 2	<code>round(6.889,2)</code> [1] 6.89	<code>3/2</code> [1] 1.5
<code>sin(pi/2)</code> [1] 1	<code>3/0</code> [1] Inf	<code>2^3</code> [1] 8
<code>cos(pi/2)</code> [1] 6.123234e-17	<code>0/0</code> [1] NaN	<code>(56-14)/6 - 4*7*10/(5^2-5)</code> [1] -7
<code>1.3e6</code> [1] 1300000	<code>is.finite(3)</code> [1] TRUE	<code>abs(2-4)</code> [1] 2
<code>9 %% 2</code> [1] 1	<code>x &lt;- c(1:8,NA)</code> [1] 1 2 3 4 5 6 7 8 NA	
<code>floor(5.7)</code> [1] 5	<code>mean(x)</code> NA	

# Common Operators

## # RELATIONAL OPERATORS

Equal to	==	if (myvar == "test") {print("EQ")}
	==	if (mynum == 3) {print("EQ")}
Not equal to	!=	if (myvar != "test") {print("NE")}
Less than or equal to	<=	if (number <= 5) {print("LTE")}
Less than	<	if (number < 10) {print("LT")}
Greater than or equal to	>=	if (number >= 10) {print("GTE")}
Greater than	>	if (number > 12) {print("GT")}

## # BOOLEAN OPERATORS

And	&	if ((myvar == "test") & (num <= 10) ) { print("Equal and less than") }
Not	!	if (!complete.cases(myvec)) { print("Non complete cases") }
Or		if ((num > 3)   (num < -3)) { print("Only one of these has to be true") }

# More Examples

Here are some popular math formulas rewritten in R. Note that the variables must first exist in order for the formula to do an actual computation.

```
#  $a^2 + b^2 = c^2$                                 # Pythagorean Theorem
```

```
a <- 2; b <- 4
```

```
c <- sqrt( $a^2 + b^2$ )                                # To solve the PT for c
```

```
a <- 2; b <- 4; c <- 1
```

```
(-b + sqrt( $b^2 - 4*a*c$ )) / (2*a)    # First case quadratic formula solution
```

```
(-b - sqrt( $b^2 - 4*a*c$ )) / (2*a)  # Second case quadratic formula solution  
r <- 4; h <- 6; b <- 3
```

```
circumference <- 2*pi*r                # circumference of a circle
```

```
area <- (b*h)/2 # Area of a triangle
```

# Expressions

We can create functions that contain reusable code for later use

```
my.quad <- function(a,b,c) {  
  r1 <- (-b + sqrt(b^2 - 4*a*c)) / (2*a)  
  r2 <- (-b - sqrt(b^2 - 4*a*c)) / (2*a)  
  my.roots = c(r1,r2)  
  return(my.roots)  
}
```

# Solve for  $ax^2 + bx + c$  where  $a = 1$ ,  $b=6$ , and  $c=8$

```
my.quad(1,6,8)
```



# Startup

- You can use the Preferences menu item in RStudio to specify your default home directory
- When R starts it looks for a file called `.Rprofile` within your home directory
- You can influence the R environment by setting a number of “startup” variables therein
- Use your favorite editor to create/edit this file in your default folder
- You can change many of these variables or options during an R session but if you want them to be permanent then you will need to edit the `.Rprofile` file

# Startup .Rprofile

```
# Things you might want to change

options(editor="notepad")
cd = setwd
pwd = getwd
lss = dir

# R interactive prompt
setwd("/Users/fender/steve.test") # Set's my default directory for me.
options(prompt="> ")
options(continue="+ ")

# General options
options(digits=3)
options(width = 130)
options(graphics.record=TRUE)
.First <- function(){                                # You can load functions
  library(Hmisc)
  cat("\nWelcome at", date(), "\n")
}
.Last <- function(){
  cat("\nGoodbye at ", date(), "\n")
}
```

# Workspace - Being Organized

Being organized helps ! Knowing how to find stuff quickly is essential.  
Create a master folder that will contain your work in this class.

You can create subfolders according to your projects. Note that some people do this on a DropBox folder to insure that all work is backed up.

```
$ ls RProjects
RProjects
  Data_Files
  Genomes
    1000_Genomes
    Centenarians
  HIV
    Replicates
  Hepatitis
    Hep_A
    Hep_B
```

# Workspace - Navigating Directories

There are a number of functions that allow you to “move” around in your folder structure. These are important to know because sometimes you will need to write code that needs to refer to specific folders and files during execution.

```
getwd()  
[1] "/Users/fender/TEST.DIR"
```

```
setwd("/Users/fender")  
getwd()  
[1] "/Users/fender"
```

```
setwd("/Users/fender/TEST.DIR")  
getwd()  
[1] "/Users/fender/TEST.DIR"
```

```
dir()  
[1] "coolpkg" "coolpkg_1.0.tar.gz" "coolpkg.pdf" "coolpkg.Rcheck"  
"g.Rd" "stuff.R"
```

# Workspace - Listing Files

R also has some functions that list files in a folder. You can do this visually within R Studio although sometimes you will need to use these commands to open and read in files as part of a program.

```
myfiles <- list.files()
```

```
str(myfiles)
```

```
chr [1:29] "001.csv" "002.csv" "003.csv" "004.csv" "005.csv" "006.csv" ...
```

```
myfiles[1:5]
```

```
[1] "001.csv" "002.csv" "003.csv" "004.csv" "005.csv"
```

# You could write a for-loop to process each and every file

```
for (ii in 1:length(myfiles)) {  
  file <- myfiles[ii]  
  # Do something  
}
```

# Workspace - ls()

R creates an environment for each session you initiate. This is very useful because it accumulates all your variables and objects while you experiment with data.

Over time your environment will accumulate lots of variables. In general this is good because you don't lose anything. The **ls()** function can show you what objects you currently have in your environment.

```
ls()
[1] "access_log"      "cntr"
[3] "ii"              "init"
[5] "mpg"             "mtcars"
[7] "mymean"          "myrle"
[9] "mystr"           "nhanes1"
[11] "retvec"          "retvectr"
[13] "SacramentocrimeJanuary2006" "Sacramentorealestatetransactions"
[15] "SalesJan2009"
```

# Workspace - rm()

You can remove one or more objects using the **rm()** function

```
ls()
[1] "access_log"          "cntr"
[3] "ii"                  "init"
[5] "mpg"                 "mtcars"
[7] "mymean"              "myrle"
[9] "mystr"               "nhanes1"
[11] "retvec"              "retvectr"
[13] "SacramentocrimeJanuary2006" "Sacramentorealestatetransactions"
[15] "SalesJan2009"
```

```
rm(access_log)    # Removes the object named "access_log"
```

```
access_log        # Now R can't find it
Error: object 'access_log' not found
```

```
rm(mystr,retvec,init)  # Remove more than one object at once
```

## Workspace - .Rdata

When you quit R you will be asked if you wish to save your current environment to disk. If you type “y” then all objects, (and their values), will be written to a file called **.Rdata**

This is useful because when you restart R in the same folder it will read **.Rdata** which contains all previously saved information.

```
> q()
Save workspace image? [y/n/c]: y
Goodbye at Mon Oct 1 14:26:47 2012

fenders-macbook:TEST.DIR fender$ ls .Rdata
.Rdata
```

The **.Rdata** file is a “binary” file, (its contents are unintelligible to the eye), that contains all the R objects and values in between sessions. This file could be shared with others if you wanted.



## Workspace - save()

You can also save one or more objects to a file using the **save()** function. The inverse of the **save()** function is the **load()** function.

```
my.lm <- lm(mpg ~ wt,mtcars)
```

```
ls(my.lm)
```

```
[1] "assign" "call" "coefficients" "df.residual" "effects" "fitted.values"  
[7] "model"   "qr" "rank" "residuals" "terms" "xlevels"
```

```
save(my.lm,file="/Users/myhome/mylmresults")
```

```
# You can come back later and load this file
```

```
mylmstuff <- load("/Users/myhome/mylmresults")
```

# Variables

As in most programming languages, it is customary to store or hold the results of an operation in a variable name.

In R such results are assigned with the symbols "<-" or "=". Variable names are case sensitive.

```
A <- 2.5      # The "<-" is the preferred method of assignment
```

```
A = 2.5       # This is equivalent to the above although using the "=" is  
              # discouraged except in setting function arguments.
```

```
A  
[1] 2.5
```

```
mynewvar <- X + 3
```

```
MYNEWVAR <- X + 3      # Two different variables
```

# Variables

- R has several one-letter reserved words: c, q, s, t, C, D, F, I, T
- Variables cannot begin with the period characters “.”
- Variable names are case sensitive, so “myvar” is different from “Myvar”
- Variable names cannot begin with numbers or symbols (%, \$, \_)
- Variable names cannot contain spaces in the name (“my var”)

# Variables

mean.height	.mean.height
smoker	_myvariable
non.smoker	_Mean.height
temp.var	1variable
patient_id	1_variable
Eye.Color	%some.var
State_Population	some.var
disease.state	"some var"
White_Cell_Count	\$myvar
jobTitle	

# Reading and Writing Files

R has a number of builtin example data frames. One common way to import data is via “.csv” files. Before we consider reading a .csv file let's first create one.

```
head(mtcars)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1

```
write.table(mtcars,file="mtcars.csv",  
            row.names=TRUE,           # Row names get saved  
            col.names=TRUE,          # Header gets saved  
            sep=",")                 # Field separator is ,
```

```
$ head mtcars.csv
```

```
"mpg","cyl","disp","hp","drat","wt","qsec","vs","am","gear","carb"  
"Mazda RX4",21,6,160,110,3.9,2.62,16.46,0,1,4,4  
"Mazda RX4 Wag",21,6,160,110,3.9,2.875,17.02,0,1,4,4
```

# Reading and Writing Files

The first line of `mtcars.csv` describes the column names. Each subsequent row represents an observation with each field being separated by a “,”.  
Let's read it in:

```
mycars <- read.table("mtcars.csv",header=TRUE,sep=",")
```

```
head(mycars)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
Valiant	18.1	6	225	105	2.76	3.460	20.22	1	0	3	1

# Reading Files from an URL

You can read CSV files from the Internet as long as you know the URL.  
Here is a simple case

```
url <- "https://raw.githubusercontent.com/stevie42/bootcamp/master/data/airports.csv"
airports <- read.csv(url)
head(airports)
```

	faa	name	lat	lon	alt	tz	dst
1	04G	Lansdowne Airport	41.13047	-80.61958	1044	-5	A
2	06A	Moton Field Municipal Airport	32.46057	-85.68003	264	-5	A
3	06C	Schaumburg Regional	41.98934	-88.10124	801	-6	A
4	06N	Randall Airport	41.43191	-74.39156	523	-5	A
5	09J	Jekyll Island Airport	31.07447	-81.42778	11	-4	A
6	0A9	Elizabethton Municipal Airport	36.37122	-82.17342	1593	-4	A

# Reading Files - Commas

Sometimes we get numerical data that has delimiters within it. Like with numbers in the thousands. They can contain commas to offset every three zeroes. If you make no effort R will think that they are characters.

```
url <- "https://raw.githubusercontent.com/stevie42/bootcamp/master/data/employees.csv"
employees <- read.csv(url, sep="\t")
```

```
head(employees)
```

```
      name age salary
1 Frank,Smith 34 10,000
2  Jones,Carl 22 12,000
3  Smith,Mary 26 13,000
4 Johnson,Lisa 32 13,500
```

```
str(employees)
```

```
'data.frame': 4 obs. of  3 variables:
 $ name  : Factor w/ 4 levels "Frank,Smith",...: 1 3 4 2
 $ age   : int   34 22 26 32
 $ salary: Factor w/ 4 levels "10,000","12,000",...: 1 2 3 4
```



# Reading Files - Commas

- We can use **coercion** to “persuade” a variable that is character to be a numeric variable
- First we use a function to eliminate the comma since its presence is what makes R think the variable is a character.
- Then we use the **as.numeric()** function to change the variable into a numeric.

```
url <- "https://raw.githubusercontent.com/stevie42/bootcamp/master/data/employees.csv"
employees <- read.csv(url, sep="\t")
```

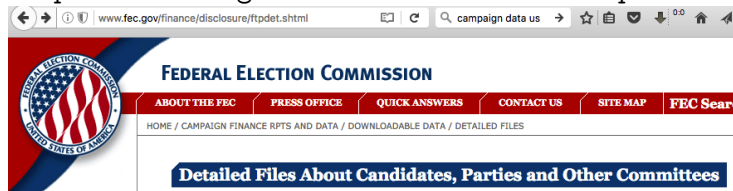
```
employees$salary <- as.numeric(gsub(",", "", employees$salary))
```

```
str(employees)
'data.frame': 4 obs. of 3 variables:
 $ name : Factor w/ 4 levels "Frank,Smith",...: 1 3 4 2
 $ age  : int  34 22 26 32
 $ salary: num  10000 12000 13000 13500
```

# A Real Example

Check out the Federal Election Commission Website for information on Campaign Contributions by Individuals. There are other types of information also but for now we will look at donations from people.

`http://www.fec.gov/finance/disclosure/ftpdet.shtml`



# A Real Example

If you go to the download link and find the file corresponding to individual contributions you will see that the file has 12,395,164 records. There is also a link to the data dictionary link that you can click.

[http://www.fec.gov/finance/disclosure/metadata/indiv\\_header\\_file.csv](http://www.fec.gov/finance/disclosure/metadata/indiv_header_file.csv) The size of the file is about 426 Megabytes. We won't work with that. Instead we will work with a prepared file that has information relating only to Georgia.

[http://www.fec.gov/finance/disclosure/ftpdet.shtml#a2015\\_2016](http://www.fec.gov/finance/disclosure/ftpdet.shtml#a2015_2016)

2015 - 2016 Data Files

Name	Data File	Total Records	Updated	Format Description
Committee Master File	<a href="#">cm16.zip</a>	17175	06-SEP-2016	<a href="#">CM Data Dictionary</a>
Candidate Master File	<a href="#">cn16.zip</a>	7331	06-SEP-2016	<a href="#">CN Data Dictionary</a>
Candidate Committee Linkage File	<a href="#">ccl16.zip</a>	6292	06-SEP-2016	<a href="#">CCL Data Dictionary</a>
Any Transaction from One Committee to Another	<a href="#">oth16.zip</a>	893643	04-SEP-2016	<a href="#">OTH Data Dictionary</a>
Contributions to Candidates (and other expenditures) from Committees	<a href="#">pas216.zip</a>	233391	04-SEP-2016	<a href="#">PAS2 Data Dictionary</a>
Contributions by Individuals	<a href="#">indiv16.zip</a>	12395164	04-SEP-2016	<a href="#">INDIV Data Dictionary</a>
Operating Expenditures	<a href="#">oppexp16.zip</a>	1196454	04-SEP-2016	<a href="#">OPPEXP Data Dictionary</a>

# A Real Example

Let's get to work on this file.

```
url <- "https://raw.githubusercontent.com/stevie42/bootcamp/master/data/georgia_campaign.txt"
```

```
# Rather than read it directly from the Internet we'll first download it
```

```
download.file(url,"georgia_campaign.txt")
```

```
# Let's take a peek at the first three lines
```

```
system("head -3 georgia_campaign.txt")
```

```
C00076182|N|Q1|P|15951125081|15|IND|JAMES, JIM|HOSCHTON|GA|305481390|MAREL STORK POULTRY PROCESSING|VP OF TECHNICAL SERVICES|3242015|300|
C00076182|N|Q1||15951125081|15|IND|JAMES, JIM|HOSCHTON|GA|305481390|MAREL STORK POULTRY PROCESSING|VP OF TECHNICAL SERVICES|3242015|300|
C00186064|N|M4||15970338248|15|IND|NUNNERY, JOHN|COLUMBUS|GA|319062001|PNC BANK NA|SR. VICE PRESIDENT|03312015|03312015|
```

```
# Read it in
```

```
gacamp <- read.csv("georgia_campaign.txt",sep="|",header=FALSE, stringsAsFactors=FALSE)
```

```
head(gacamp,1)
```

```
      V1 V2 V3 V4      V5 V6 V7      V8      V9 V10      V11
1 C00076182 N Q1 P 15951125081 15 IND JAMES, JIM HOSCHTON GA 305481390

      V12      V13      V14 V15 V16
1 MAREL STORK POULTRY PROCESSING VP OF TECHNICAL SERVICES 3242015 300

      V1 V2 V3 V4      V5 V6 V7      V8      V9 V10      V11
1 A0DAECF187E8D4B41ACF 1002289      4.04132e+18
2 A49D962C4ECF047AB97B 1002289      4.04132e+18
```

# A Real Example

Let's get to work on this file.

```
url <- "https://raw.githubusercontent.com/stevie42/bootcamp/master/data/indiv_header_file.csv"
```

```
# Note the "stringsAsFactors" argument
```

```
( colnames <- read.csv(url,sep=",",header=F,stringsAsFactors=FALSE) )
```

```
      V1      V2      V3      V4      V5      V6      V7
1 CMTE_ID AMNDT_IND RPT_TP TRANSACTION_PGI IMAGE_NUM TRANSACTION_TP ENTITY_TP
  V8  V9  V10   V11   V12   V13   V14   V15
1 NAME CITY STATE ZIP_CODE EMPLOYER OCCUPATION TRANSACTION_DT TRANSACTION_AMT
  V16  V17  V18  V19  V20  V21
1 OTHER_ID TRAN_ID FILE_NUM MEMO_CD MEMO_TEXT SUB_ID
```

```
# Let's give each column a more descriptive name
```

```
names(gacamp) <- as.vector(colnames[1,])
```

```
head(gacamp,1)
```

```
      CMTE_ID AMNDT_IND RPT_TP TRANSACTION_PGI IMAGE_NUM TRANSACTION_TP
1 C00076182      N      Q1      P 15951125081      15
  ENTITY_TP      NAME      CITY STATE ZIP_CODE      EMPLOYER
1      IND JAMES, JIM HOSCHTON      GA 305481390 MAREL STORK POULTRY PROCESSING
      OCCUPATION TRANSACTION_DT TRANSACTION_AMT OTHER_ID
1 VP OF TECHNICAL SERVICES      3242015      300
      TRAN_ID FILE_NUM MEMO_CD MEMO_TEXT      SUB_ID
1 A0DAECF187E8D4B41ACF 1002289      4.04132e+18
```

# A Real Example











Let's get to work on this file.

```
str(gacamp)
'data.frame': 267408 obs. of 21 variables:
 $ CMTE_ID      : chr  "C00076182" "C00076182" "C00186064" "C00508804" ...
 $ AMNDT_IND    : chr  "N" "N" "N" "N" ...
 $ RPT_TP       : chr  "Q1" "Q1" "M4" "Q1" ...
 $ TRANSACTION_PGI : chr  "P" "" "" "P" ...
 $ IMAGE_NUM    : num  1.6e+10 1.6e+10 1.6e+10 1.6e+10 1.6e+10 ...
 $ TRANSACTION_TP : chr  "15" "15" "15" "15E" ...
 $ ENTITY_TP    : chr  "IND" "IND" "IND" "IND" ...
 $ NAME         : chr  "JAMES, JIM" "JAMES, JIM" "NUNNERY, JOHN" "DOWNS, BERTIS" ...
 $ CITY         : chr  "HOSCHTON" "HOSCHTON" "COLUMBUS" "ATHENS" ...
 $ STATE        : chr  "GA" "GA" "GA" "GA" ...
 $ ZIP_CODE     : chr  "305481390" "305481390" "319062001" "30606" ...
 $ EMPLOYER     : chr  "MAREL STORK POULTRY PROCESSING" "MAREL STORK POULTRY PROCESSING" "PNC BANK NA" "N/A"
 $ OCCUPATION    : chr  "VP OF TECHNICAL SERVICES" "VP OF TECHNICAL SERVICES" "SR. VICE PRESIDENT" "ATTORNEY"
 $ TRANSACTION_DT : int   3242015 3242015 3312015 3302015 2272015 3312015 3032015 3152015 3312015 3272015 ...
 $ TRANSACTION_AMT : int    300 40 100 500 500 2000 1000 2 50 250 ...
 $ OTHER_ID     : chr  "" "" "" "C00401224" ...
 $ TRAN_ID      : chr  "A0DAECF187E8D4B41ACF" "A49D962C4ECF047AB97B" "PR363907910124" "11AI-000046699" ...
 $ FILE_NUM     : int   1002289 1002289 1002291 1003915 1003915 1003922 1003948 1003950 1003950 1002628 ...
 $ MEMO_CD      : chr  "" "" "" "" ...
 $ MEMO_TEXT    : chr  "" "" "P/R DEDUCTION ($50.00 BI-WEEKLY)" "EARMARKED THROUGH ACTBLUE CONDUIT COMMITTEE
 $ SUB_ID       : num  4.04e+18 4.04e+18 4.04e+18 4.04e+18 4.04e+18 ...
```

>

# Reading Tabular Data

You already know that you can read CSV files directly a URL. But you can also read data directly from a table from a website. Take a look at this example. Let's say we want to get the data from this link on Wikipedia  
[https://en.wikipedia.org/wiki/World\\_population](https://en.wikipedia.org/wiki/World_population). This appears to be the 6th table on the page.

10 most populous countries					
Rank ↕	Country / Territory ↕	Population ↕	Date ↕	Approx. % of world population ↕	Source ↕
1	 China <sup>[note 2]</sup>	1,378,580,000	September 5, 2016	18.8%	[94]
2	 India	1,330,600,000	September 5, 2016	18.1%	[95]
3	 United States	324,405,000	September 5, 2016	4.42%	[96]
4	 Indonesia	257,900,000	March 16, 2016	3.43%	[97]
5	 Brazil	206,610,000	September 5, 2016	2.81%	[98]
6	 Pakistan	194,169,000	September 5, 2016	2.64%	[99]
7	 Nigeria	187,200,000	March 16, 2016	2.36%	[100]
8	 Bangladesh	161,030,000	September 5, 2016	2.19%	[101]
9	 Russia	141,800,000	March 16, 2016	1.99%	[102]
10	 Japan	126,700,000	March 16, 2016	1.73%	[103]

# Reading Tabular Data

```
url <- "https://en.wikipedia.org/wiki/World_population"

# The following will "parse" the underlying HTML for the page

my_html <- read_html(url)

# Next we want to get the "nodes" from the parsed HTML that correspond
# to tables. There are in fact many tables on this page but we are
# trying to target the one that has the ten most populous countries

my_tables <- html_nodes(my_html,"table")[[6]]

populous_table <- html_table(my_tables)
```



# Reading Tabular Data

Rank	Country / Territory	Population	Date
1	1 China[note 2]	1,378,580,000	September 5, 2016
2	2 India	1,330,600,000	September 5, 2016
3	3 United States	324,405,000	September 5, 2016
4	4 Indonesia	257,900,000	March 16, 2016
5	5 Brazil	206,610,000	September 5, 2016
6	6 Pakistan	194,169,000	September 5, 2016
7	7 Nigeria	187,200,000	March 16, 2016
8	8 Bangladesh	161,030,000	September 5, 2016
9	9 Russia	141,800,000	March 16, 2016
10	10 Japan	126,700,000	March 16, 2016

	Approx. % of world\npopulation	Source
1	18.8%	[94]
2	18.1%	[95]
3	4.42%	[96]
4	3.43%	[97]
5	2.81%	[98]
6	2.64%	[99]
7	2.36%	[100]
8	2.19%	[101]
9	1.99%	[102]
10	1.73%	[103]

# Reading Tabular Data

```
# Okay this looks close but there is more work to be done to clean it
# all up. We don't need columns 4 through 6

populous_table <- populous_table[,-4:-6]

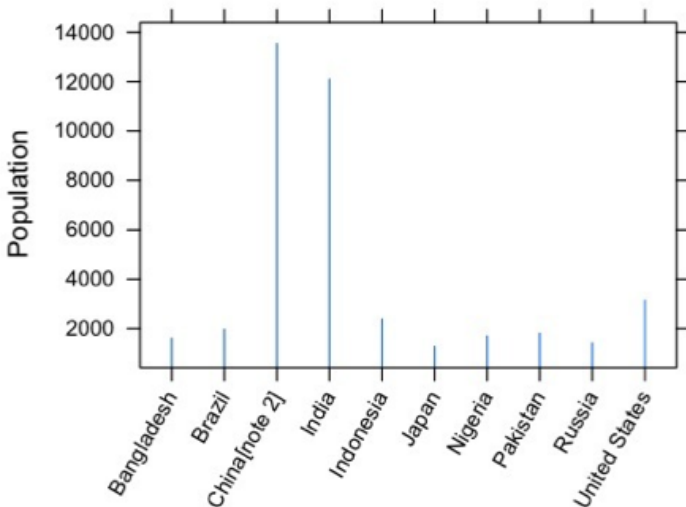
populous_table$Population <- as.numeric(gsub(",", "",
                                              populous_table$Population))/100000

names(populous_table) = c("Rank", "Country", "Population")

library(lattice)
xyplot(Population ~ as.factor(Country), populous_table,
       scales = list(x = c(rot=60)),
       type="h", main="Most Densely Populated Countries")
```

# Reading Tabular Data

## Most Populated Countries



# Reading External Files

Here is a summary of tools to read in various external files, other statistical package formats, and relational databases:

Package/Function	Description
readxl	Reads Excel Worksheets and Workbooks
gdata	Reads Excel Worksheets and Workbooks
XLConnect	Reads Excel Worksheets and Workbooks
RODBC	Reads Excel Worksheets and Workbooks
reader	Read flat/tabular text files from disk
read.table	Read tabular data from disk
read.csv	Read tabular data from disk
fread	Read large data files from disk
haven	Import SAS, STATA, and SPSS files
foreign	Import SAS, STATA, SPSS, Systat, and Weka files
RMySQL	Connect to MySQL Databases
ROracle	Connect to Oracle Databases
RPostgres	Connect to Postgres Databases

# Reading External Files

Here is an example of reading a SAS dataset. Note that this is a proprietary binary format used by SAS although the format can be decoded using functions found in the haven addon package.

```
# SAS datasets can be found at http://www.stats.ox.ac.uk/pub/datasets/csb/
# For a list of cool places to find interesting data look at
# https://catalog.data.gov/dataset?groups=education2168#topic=education\_navigation
# http://www.census.gov/programs-surveys/acs/news/data-releases.html
# https://github.com/caesar0301/awesome-public-datasets

library(haven)

sasdataset <- "http://www.principlesofeconometrics.com/poe4/data/sas/lasvegas.sas7bdat"

las_vegas_loans <- read_sas(sasdataset)

head(las_vegas_loans)
```

	LVR	REF	INSUR	RATE	AMOUNT	CREDIT	TERM	ARM	DELINQUENT
1	80	0	1	6.355	1.5760	532	30	1	0
2	89	1	1	6.875	3.1595	703	30	1	0
3	80	1	1	7.080	1.7600	648	30	1	0
4	80	0	0	12.855	1.9680	599	30	1	1
5	70	1	0	5.760	1.8620	626	30	1	0
6	80	0	1	5.555	2.0800	742	30	1	0

## Reading Excel Files

It is possible to read an Excel spreadsheet although the best thing to do is to first save the spreadsheet into a .csv file and then import it into R using **read.table()** function. However, you can read the spreadsheet directly from a file using the add on **RODBC** package.

```
library(RODBC)
```

```
channel <- odbcConnectExcel("examp.xls")
```

```
## list the spreadsheets
```

```
sqlTables(channel)
```

```
TABLE_CAT TABLE_SCHEM TABLE_NAME TABLE_TYPE REMARKS
1 C:\\bdr NA Sheet1$ SYSTEM TABLE NA
2 C:\\bdr NA Sheet2$ SYSTEM TABLE NA
3 C:\\bdr NA Sheet3$ SYSTEM TABLE NA
4 C:\\bdr NA Sheet1$Print_Area TABLE NA
```

```
## retrieve the contents of sheet 1, by either of
```

```
sh1 <- sqlFetch(channel, "Sheet1")
```

```
sh1 <- sqlQuery(channel, "select * from [Sheet1$]")
```

# Reading Files from Other Packages

R can process XML files which is a format that underlies many websites that distribute interesting data. As an example we can use R and XML to “geocode” cities.

Google Maps API Web Services  191

Introduction

Directions API

Distance Matrix API

Elevation API

**Geocoding API**

Time Zone API

Blog

Forum

FAQ

## The Google Geocoding API

[What is Geocoding?](#)

[Audience](#)

[Usage Limits](#)

[Geocoding Requests](#)

[Geocoding Responses](#)

[JSON Output Formats](#)

[XML Output Formats](#)

[Status Codes](#)

[Results](#)

[Address Component Types](#)

[Reverse Geocoding](#)

[Viewport Biasing](#)

[Region Biasing](#)

[Component Filtering](#)

<https://developers.google.com/maps/documentation/geocoding/>

# Reading XML

```
- <GeocodeResponse>
  <status>OK</status>
  - <result>
    <type>locality</type>
    <type>political</type>
    <formatted_address>Atlanta, GA, USA</formatted_address>
  - <address_component>
    <long_name>Atlanta</long_name>
    <short_name>Atlanta</short_name>
    <type>locality</type>
    <type>political</type>
  </address_component>
  - <address_component>
    <long_name>Fulton</long_name>
    <short_name>Fulton</short_name>
    <type>administrative_area_level_2</type>
    <type>political</type>
  </address_component>
```



# Reading XML

As an example we'll get the latitude and longitude corresponding to the city of Atlanta, Georgia

```
library(RCurl)
library(XML)

my.url <- "http://maps.googleapis.com/maps/api/geocode/xml?
address <- Atlanta,GA&sensor=false"
txt <- getURL(my.url)
hold <- xmlTreeParse(txt,useInternalNodes=TRUE)

hold
<?xml version="1.0" encoding="UTF-8"?>
<GeocodeResponse>
<status>OK</status>
<result>
<type>locality</type>

place <- getNodeSet(hold,"//GeocodeResponse/result[1]/geometry/location[1]/*")
as.numeric(sapply(place,xmlValue))
[1] 33.74900 -84.38798
```

# Sinking Your Work

You can capture the output of your work using the **save()** function. But you can use the **cat**, **write** to print out variable values as your code executes.

But you can also **sink** or dump variable values into a file for later inspection. Let's say we have the following code.

```
set.seed(123)
x <- rnorm(10)
y <- rnorm(10)

print(x)
cat("y =", y, "\n")

t.test(x,y)
plot(x,y)
```

The output from this code is on the next slide

# Sinking Your Work

```
set.seed(123)
x <- rnorm(10)
y <- rnorm(10)

print(x)
[1] -0.56047565 -0.23017749 1.55870831 0.07050839 0.12928774 1.71506499
[7] 0.46091621 -1.26506123 -0.68685285 -0.44566197

cat ("y =", y, "\n")
y = 1.224082 0.3598138 0.4007715 0.1106827 -0.5558411 1.786913 0.4978505
    -1.966617 0.7013559 -0.4727914

t.test(x,y)
      Welch Two Sample t-test
data: x and y
t = -0.3006, df = 17.872, p-value = 0.7672
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-1.0710488 0.8030562
sample estimates:
mean of x mean of y
0.07462564 0.20862196
```

# Sinking Your Work

If desired we could redirect all the output from the `print`, `cat`, `t.test` to a file. When we run the following we don't see any output. To see the output we have to look at the file `my.results.txt`

```
sink("my.results.txt") # All output will now go to "my.results.txt"
```

```
set.seed(123)
```

```
x <- rnorm(10)
```

```
y <- rnorm(10)
```

```
print(x)
```

```
cat ("y =", y, "\n")
```

```
t.test(x,y)
```

```
plot(x,y)
```

```
sink()      # This will deactivate the redirection
```

# Sinking Your Work

Check out the file my.results.txt Note that any graphics files created by the plot command will go into a file called Rplots.pdf

```
$ more my.results.txt
```

```
[1] -0.56047565 -0.23017749 1.55870831 0.07050839 0.12928774 1.71506499  
[7] 0.46091621 -1.26506123 -0.68685285 -0.44566197  
y = 1.224082 0.3598138 0.4007715 0.1106827 -0.5558411 1.786913 0.4978505  
-1.966617 0.7013559 -0.4727914
```

Welch Two Sample t-test

data: x and y

t = -0.3006, df = 17.872, p-value = 0.7672

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

-1.0710488 0.8030562

sample estimates:

mean of x mean of y

0.07462564 0.20862196

# Sinking Your Work

If you want more control of the format of the plot output then you can use one of the functions designed to create plots in a known format (PNG, JPEG, PDF).

```
set.seed(123)
x <- rnorm(10)
y <- rnorm(10)

print(x)
cat ("y =", y, "\n")

t.test(x,y)

pdf("myplots.pdf") # Redirects plots to myplots.pdf

plot(x,y)

dev.off() # Turns off plot redirection
```