Lecture 1

Introduction to R

Andrew Jaffe
Instructor

Welcome to class!

1. Introductions
2. Class overview
3. Getting R up and running
4. File Input/Output

About Me

Postdoctoral Fellow at the Lieber Institute for Brain Development

PhD in Epidemiology, MHS in Bioinformatics

Email: andrewejaffe@gmail.com

TA

John Muschelli

PhD Student in Biostatistics

Email: muschellij2@gmail.com

Introductions

What do you hope to get out of the class?

Why R?

Course Website

http://biostat.jhsph.edu/~ajaffe/rwinter2013.html

Materials will be uploaded the night before class

Learning Objectives

- Reading data into R
- Recoding and manipulating data
- Writing R functions and using add-on packages
- Making exploratory plots
- Performing basic statistical tests
- Understanding basic programming syntax

Course Format

1. 90 minute interactive lectures
    - HTML Slides
    - Pausing to interact with R
2. 5-10 minute break
3. Lab
    - 90 minutes: working on exercises in small groups
    - 10-15 minutes: coming back together to discuss

Grading

1. Attendance/Participation: 20%
2. Nightly "Homework": 3 x 15%
    - Individual: extension of each lab
    - Turn In: Correct Answers + R Code
3. Final "Project": 35%

What is R?

- R is a language and environment for statistical computing and graphics
- R is the open source implementation of the S language, which was developed by Bell laboratories
- R is both open source and open development

(source: http://www.r-project.org/)

Why R?

- Powerful and flexible
- Free (open source)
- Extensive add-on software
- Designed for statistical computing
- High level language

Why not R?

- Fairly steep learning curve
  - "Programming" oriented
  - Minimal interface
- Little centralized support, relies on online community and package developers
- Annoying to update
- Slower, and more memory intensive, than the more traditional programming languages (C, Java, Perl, Python)

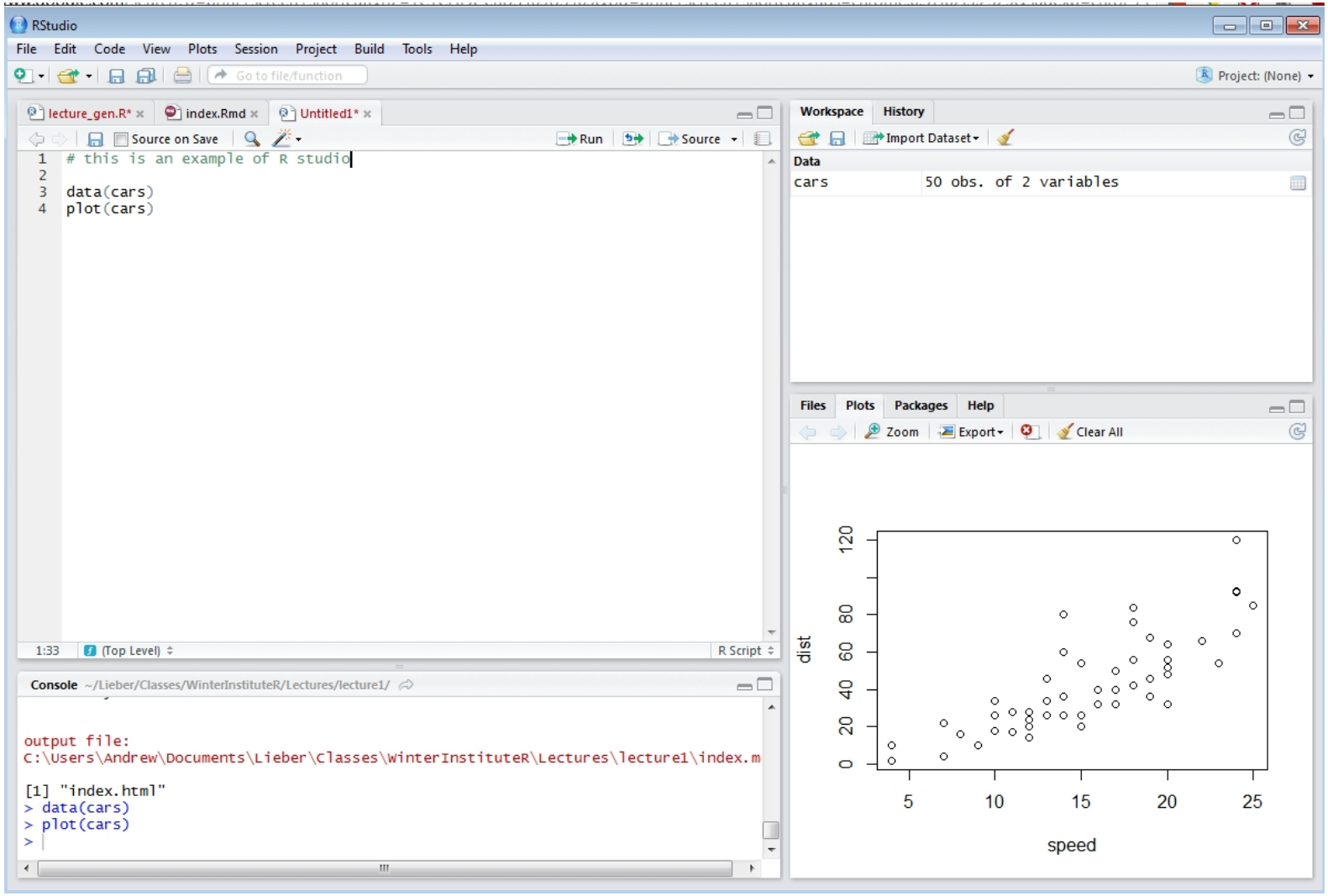
Installing R

Install the latest version from: http://cran.r-project.org/

Note that you must manually update R, often at your own peril...

R Studio

- Integrated Development Environment (IDE) for R
  - Syntax highlighting, code completion, and smart indentation
  - Execute R code directly from the source editor
  - Easily manage multiple working directories using projects
  - Workspace browser and data viewer
  - Plot history, zooming, and flexible image and PDF export
  - Integrated R help and documentation
  - Searchable command history
- http://www.rstudio.com/


RStudio
File Edit Code View Plots Session Project Build Tools Help
Go to file/function
Project: (None)
lecture_gen.R*
index.Rmd
Untitled1*
Source on Save
Run
Source
1 # this is an example of R studio
2
3 data(cars)
4 plot(cars)
1:33
(Top Level)
R Script
Console ~/Lieber/Classes/WinterInstituteR/Lectures/lecture1/
output file:
C:\Users\Andrew\Documents\Lieber\Classes\WinterInstituteR\Lectures\lecture1\index.m
[1] "index.html"
> data(cars)
> plot(cars)
>
Workspace
History
Import Dataset
Data
cars
50 obs. of 2 variables
Files
Plots
Packages
Help
Zoom
Export
Clear All
dist
0
20
40
60
80
120
5
10
15
20
25
speed

Working with R

- The R Console "interprets" whatever you type
  - Calculator
  - Creating variables
  - Applying functions
- "Analysis" Script + Interactive Exploration
  - Static copy of what you did
  - Try things out interactively, then add to your script
- R revolves around 'functions'
  - Commands that take input, performs computations, and returns results
  - Many come with R, but people write external functions you can download and use

Getting Started

- You should have the latest version of R installed (R 2.15.2 as of 12/31/12)!
- Open R Studio
- Files --> New --> R Script
- Save the blank R script as "lecture1.R" in a directory of your choosing
- Add a comment header

Commenting in Scripts

Add a comment header to lecture1.R : '#' is the comment symbol

```
##################
# Title: Demo R Script
# Author: Andrew Jaffe
# Date: 1/7/2013
# Purpose: Demonstrate comments in R
####################

# this is a comment, nothing to the right of it gets read

# this # is still a comment - you can use many #'s as you want

# sometimes you have a really long comment, like explaining what you
#    are doing for a step in analysis. Take it to a second line
```

Useful R Studio Shortcuts

- 'Ctrl+1' takes you to the script page
- 'Ctrl+2' takes you to the console
- 'Ctrl + Enter' ('Cmd + Enter' on OS X) in your script evaluates that line of code

Functions

- R revolves around functions: denoted by "()"
- Every function takes an input, defined by arguments, often provided by the user
- Many functions have default settings for these arguments
- If you know the name of a function, "?[function name]" or 'help([function name])' will pop up the help menu
- 'example([function name])' shows you how it is used

Working Directory

- R looks for files on your computer relative to the "working" directory
- It's always safer to set the working directory at the beginning of your script
- Example of help file

```
> ## get the working directory
> getwd()
```

```
[1] "C:/Users/Andrew/Dropbox/WinterRClass/Lectures/lecture1"
```

```
> ### set the working directory
> ### setwd('F:/Hopkins/Lieber/Classes/WinterInstituteR/Lectures') # desktop
> setwd("..")
> getwd()
```

```
[1] "C:/Users/Andrew/Dropbox/WinterRClass/Lectures"
```

Working Directory

- Setting the directory can sometimes be finicky
  - Windows: Default directory structure involves single backslashes ("\"), but R interprets these as "escape" characters. So you must replace the backslash with forward slashed ("/") or two backslashes ("\")
  - Mac/Linux: Default is forward slashes, so you are okay
- Regular directory structure shortcuts apply
  - ".." goes up one level
  - "./" is the current directory
  - "~" is your home directory

Working Directory

Try some directory navigation:

```
> dir("./")  # shows directory contents
```

```
 [1] "assets"              "index.html"          "index.md"
 [4] "index.Rmd"           "Lecture 1.pdf"       "lecture1_code.R"
 [7] "lecture1_test.html" "libraries"           "Monuments.csv"
[10] "pics"
```

```
> dir("..")
```

```
[1] "extra code"   "extra_code.R" "lecture1"     "lecture2"
[5] "lecture3"     "lecture4"     "lecture5"
```

```
> head(dir("F:/Hopkins/Lieber"))
```

```
[1] "Classes"                "Documents"
[3] "jaffe-website bio.docx" "Jobs"
[5] "Research"
```

Working Directory

- Set your working directory to the same location where you saved the blank R script: "lecture1.R"
- Confirm the directory contains "lecture1.R"

R as a calculator

```
> 2 + 2
```

```
[1] 4
```

```
> 2 * 4
```

```
[1] 8
```

```
> 2^3
```

```
[1] 8
```

R as a calculator

- The R console is a full calculator
- Try to play around with it:
  - +, -, /, * are add, subtract, multiply, and divide
  - ^ or ** is power
  - (and) work with order of operations

R as a calculator

```
> 2 + (2 * 3)^2
```

```
[1] 38
```

```
> (1 + 3)/2 + 45
```

```
[1] 47
```

R variables

- You can create variables from within the R environment and from files on your computer
- R uses "=" or "<-" to assign values to a variable name
- Variable names are case-sensitive, i.e. X and x are different

```
> x = 2
> x
```

```
[1] 2
```

```
> x * 4
```

```
[1] 8
```

```
> x + 2
```

```
[1] 4
```

R variables

- Each variable has a 'class' associated with it

```
> class(x)
```

```
[1] "numeric"
```

```
> y = "hello world!"
> print(y)
```

```
[1] "hello world!"
```

```
> class(y)
```

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

R variables

- You can get more attributes than just class

```
> ## ?str
> str(x)
```

```
 num 2
```

```
> str(y)
```

```
 chr "hello world!"
```

The 'combine' function

The function 'c()' collects/combines/joins single R objects into a vector of R objects. It is mostly used for creating vectors of numbers, character strings, and other data types.

```
> x <- c(1, 4, 6, 8)
> x
```

```
[1] 1 4 6 8
```

```
> str(x)
```

```
 num [1:4] 1 4 6 8
```

R variables

length(): Get or set the length of vectors (including lists) and factors, and of any other R object for which a method has been defined.

```
> length(x)
```

```
[1] 4
```

```
> y
```

```
[1] "hello world!"
```

```
> length(y)
```

```
[1] 1
```

R variables

```
> x + 2
```

```
[1]  3  6  8 10
```

```
> x * 3
```

```
[1]  3 12 18 24
```

```
> x + c(1, 2, 3, 4)
```

```
[1]  2  6  9 12
```

R variables

```
> y = x + c(1, 2, 3, 4)
> y
```

```
[1]  2  6  9 12
```

Note that the R object 'y' is no longer "Hello World!" - It has effectively been overwritten by assigning new data to the variable

Review

- Creating a new script
- Using R as a calculator
- Assigning values to variables
- Performing algebra on numeric variables

Data Input

- 'Reading in' data is the first step of any project/analysis
- R can read almost any file format, especially via add-on packages
- We are going to focus on simple delimited files first
  - tab delimited (e.g. '.txt')
  - comma separated (e.g. '.csv')
  - Microsoft excel (e.g. '.xlsx')
- There are also pre-installed sample datasets in R that we might use in class

Data Input

read.table(): Reads a file in table format and creates a data frame from it, with cases corresponding to lines and variables to fields in the file.

```
# the four ones I've put at the top are the important inputs
read.table( file, # filename
            header = FALSE, # are there column names?
            sep = "", # what separates columns?
            as.is = !stringsAsFactors, # do you want character strings as factors or characters?
            quote = "\"'",  dec = ".", row.names, col.names,
            na.strings = "NA", nrows = -1,
            skip = 0, check.names = TRUE, fill = !blank.lines.skip,
            strip.white = FALSE, blank.lines.skip = TRUE, comment.char = "#",
            stringsAsFactors = default.stringsAsFactors())

# for example: read.table("file.txt", header = TRUE, sep="\t", as.is=TRUE)
```

Data Input

- The filename is the path to your file, in quotes
- The function will look in your working directory if no absolute path is given
- The same back- and forward-slash rules apply as setting the working directory
- Note that the filename can also be a path to a file on a website (e.g. 'www.someurl.com/table1.txt')

Data Aside

- Everything we do in class will be using real publicly available data - there are no 'toy' example datasets or 'simulated' data
- OpenBaltimore and Data.gov will be sources for the first few days

Data Input

Monuments Dataset: "This data set shows the point location of Baltimore City monuments. However, the completness and currentness of these data are uncertain."

- Navigate to: https://data.baltimorecity.gov/Community/Monuments/cpxf-kxp3
- Export --> Download --> Download As: CSV
- Save it (or move it) to the same folder as your lecture1.R script

Data Input

There is a 'wrapper' function for reading CSV files:

```
read.csv
```

```
## function (file, header = TRUE, sep = ",", quote = "\"", dec = ".",
##     fill = TRUE, comment.char = "", ...)
## read.table(file = file, header = header, sep = sep, quote = quote,
##     dec = dec, fill = fill, comment.char = comment.char, ...)
## <bytecode: 0x000000000dbeefd0>
## <environment: namespace:utils>
```

Note: the '...' designates arguments that are passed to read.table()

Head and Tail

- head() shows the first 6 (default) elements of an R object
- tail() shows the last 6 (default) elements of an R object

```
> z = 1:100
> head(z)
```

```
[1] 1 2 3 4 5 6
```

```
> tail(z)
```

```
[1]  95  96  97  98  99 100
```

Data Input

```
mon = read.csv("Monuments.csv", header = TRUE, as.is = TRUE)
head(mon)
```

```
                            name zipCode neighborhood councilDistrict
1           James Cardinal Gibbons   21201     Downtown               11
2              The Battle Monument   21202     Downtown               11
3 Negro Heroes of the U.S Monument   21202     Downtown               11
4              Star Bangled Banner   21202     Downtown               11
5  Flame at the Holocaust Monument   21202     Downtown               11
6                   Calvert Statue   21202     Downtown               11
  policeDistrict                          Location.1
1        CENTRAL  408 CHARLES ST\nBaltimore, MD\n
2        CENTRAL
3        CENTRAL
4        CENTRAL 100 HOLLIDAY ST\nBaltimore, MD\n
5        CENTRAL    50 MARKET PL\nBaltimore, MD\n
6        CENTRAL  100 CALVERT ST\nBaltimore, MD\n
```

Data Input

The read.table() function returns a 'data.frame'

```
> class(mon)
```

```
[1] "data.frame"
```

```
> str(mon)
```

```
'data.frame':   84 obs. of  6 variables:
 $ name           : chr  "James Cardinal Gibbons" "The Battle Monument" "Negro Heroes of the U.S Monumer
 $ zipCode        : int  21201 21202 21202 21202 21202 21202 21202 21211 21213 21211 ...
 $ neighborhood   : chr  "Downtown" "Downtown" "Downtown" "Downtown" ...
 $ councilDistrict: int  11 11 11 11 11 11 11 7 14 14 ...
 $ policeDistrict : chr  "CENTRAL" "CENTRAL" "CENTRAL" "CENTRAL" ...
 $ Location.1     : chr  "408 CHARLES ST\nBaltimore, MD\n" "" "" "100 HOLLIDAY ST\nBaltimore, MD\n" ...
```

Data Classes:

One dimensional classes:

- Character: strings or individual characters, quoted
- Numeric: any real number(s)
- Integer: any integer(s)/whole numbers
- Factor: categorical/qualitative variables that can be ordinal
- Logical: variables composed of TRUE or FALSE

Two dimensional classes:

- Data frame: traditional 'excel' spreadsheets
  - Each column can have a different class, from above
  - There are column names and sometimes row names
- Matrix: two-dimensional data, composed of rows and columns. Unlike data frames, the entire matrix is composed of one R class.

Matrices

```
> n = 1:9  # sequence from first number to second number incrementing by 1
> n
```

```
[1] 1 2 3 4 5 6 7 8 9
```

```
> mat = matrix(n, nr = 3)
> mat
```

```
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9
```

Matrix and Data frame Attributes

- nrow() displays the number of rows of a matrix or data frame
- ncol() displays the number of coloumns
- dim() displays a vector of length 2: # rows, # columns
- colnames() displays the column names (if any) and rownames() displays the row names (if any)

Data Selection

Brackets are used to select and/or subset data in R

```
> x1 = 10:20
> x1
```

```
 [1] 10 11 12 13 14 15 16 17 18 19 20
```

```
> length(x1)
```

```
[1] 11
```

Data Selection

```
> x1[1]  # selecting first element
```

```
[1] 10
```

```
> x1[3:4]  # selecting third and fourth elements
```

```
[1] 12 13
```

```
> x1[c(1, 5, 7)]  # selecting first, fifth, and seventh elements
```

```
[1] 10 14 16
```

Data Selection

Matrices have two "slots": rows and columns

```
> mat[1, 1]  # individual entry: row 1, column 1
```

```
[1] 1
```

```
> mat[1, ]  # first row
```

```
[1] 1 4 7
```

```
> mat[, 1]  # first columns
```

```
[1] 1 2 3
```

Data Selection

Note that the class of the returned object is no longer a matrix

```
> class(mat[1, ])
```

```
[1] "integer"
```

```
> class(mat[, 1])
```

```
[1] "integer"
```

Data Selection

Data frames have special ways to select data, specifically by a "$" and the column name

```
> names(mon)
```

```
[1] "name"           "zipCode"        "neighborhood"   "councilDistrict"
[5] "policeDistrict" "Location.1"
```

```
> head(mon$zipCode)
```

```
[1] 21201 21202 21202 21202 21202 21202
```

```
> head(mon$neighborhood)
```

```
[1] "Downtown" "Downtown" "Downtown" "Downtown" "Downtown" "Downtown"
```

Data Selection

You can also subset data frames like matrices, using row and column indices, but using column names is generally safer and more reproducible.

```
> head(mon[, 2])
```

```
[1] 21201 21202 21202 21202 21202 21202
```

You can also use the bracket notation, but specify the name(s) in quotes if you want more than 1 column. This allows you to subset rows and columns at the same time

```
> mon[1:3, c("name", "zipCode")]
```

```
                              name zipCode
1           James Cardinal Gibbons   21201
2              The Battle Monument   21202
3 Negro Heroes of the U.S Monument   21202
```

Unique entries

unique(): unique returns a vector, data frame or array like x but with duplicate elements/rows removed.

```
> x = c(1, 2, 3, 4, 4, 5, 4, 5)
> unique(x)
```

```
[1] 1 2 3 4 5
```

Note that this does NOT sort entries - it just returns the unique entries in the order it encounters them from first to last:

```
> unique(c(5, 1, 2, 3, 4, 4, 5, 4, 5))
```

```
[1] 5 1 2 3 4
```

Tabulating

table(): table uses the cross-classifying factors to build a contingency table of the counts at each combination of factor levels.

```
> table(mon$zipCode)
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
   11    16     8     4     1     9    14     4     8     1     3     4
21251
    1
```

You can tabulate across as many variables as you like, but anything pass 2 typically gets hard to interpret

Lab 1A: Explore 'Monument' Dataset

Solve using your favorite method (R, Excel, By Eye/Counting Manually, etc):

1. Change the name of the "Location.1" column to "location"
2. How many monuments are in Baltimore (at least this collection...)?
3. What are the (a) zip codes, (b) neighborhoods, (c) council districts, and (d) police districts that contain monuments, and how many monuments are in each?
4. How many zip codes are in the (a) "Downtown" and (b) "Johns Hopkins Homewood" neighborhoods?
5. How many monuments (a) do and (b) do not have an exact location?
6. Which (a) zip code, (b) neighborhood, (c) council district, and (d) police district contains the most number of monuments?

Question 1

Names are just an attribute of the data frame (recall str) that you can change to any valid character name

Valid character names are case-sensitive, contain a-z, 0-9, underscores, and periods (but cannot start with a number).

For data frames, colnames() and names() return the same attribute.

```
> names(mon)
```

```
[1] "name"           "zipCode"        "neighborhood"   "councilDistrict"
[5] "policeDistrict" "Location.1"
```

```
> names(mon)[6] = "location"
> names(mon)
```

```
[1] "name"           "zipCode"        "neighborhood"   "councilDistrict"
[5] "policeDistrict" "location"
```

These naming rules also apply for creating R objects

Question 2

There are several ways to return the number of rows of a data frame or matrix

```
> nrow(mon)
```

```
[1] 84
```

```
> dim(mon)
```

```
[1] 84  6
```

```
> length(mon$name)
```

```
[1] 84
```

Question 3

unique() returns the unique entries in a vector

```
> unique(mon$zipCode)
```

```
 [1] 21201 21202 21211 21213 21217 21218 21224 21230 21231 21214 21223
[12] 21225 21251
```

```
> unique(mon$policeDistrict)
```

```
[1] "CENTRAL"      "NORTHERN"     "NORTHEASTERN" "WESTERN"
[5] "SOUTHEASTERN" "SOUTHERN"     "EASTERN"
```

```
> unique(mon$councilDistrict)
```

```
 [1] 11  7 14 13  1 10  3  2  9 12
```

```
> unique(mon$neighborhood)
```

```
 [1] "Downtown"                      "Remington"
 [3] "Clifton Park"                  "Johns Hopkins Homewood"
 [5] "Mid-Town Belvedere"            "Madison Park"
 [7] "Upton"                         "Reservoir Hill"
 [9] "Harlem Park"                   "Coldstream Homestead Montebello"
[11] "Guilford"                      "McElderry Park"
[13] "Patterson Park"                "Canton"
[15] "Middle Branch/Reedbird Parks"  "Locust Point Industrial Area"
[17] "Federal Hill"                  "Washington Hill"
[19] "Inner Harbor"                  "Herring Run Park"
[21] "Ednor Gardens-Lakeside"        "Fells Point"
[23] "Hopkins Bayview"               "New Southwest/Mount Clare"
[25] "Brooklyn"                      "Stadium Area"
[27] "Mount Vernon"                  "Druid Hill Park"
[29] "Morgan State University"       "Dunbar-Broadway"
[31] "Carrollton Ridge"              "Union Square"
```

```
> length(unique(mon$zipCode))
```

```
[1] 13
```

```
> length(unique(mon$policeDistrict))
```

```
[1] 7
```

```
> length(unique(mon$councilDistrict))
```

```
[1] 10
```

```
> length(unique(mon$neighborhood))
```

```
[1] 32
```

Also note that table() can work, which tabulates a specific variable (or cross-tabulates two variables)

```
> table(mon$zipCode)
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
   11    16     8     4     1     9    14     4     8     1     3     4
21251
    1
```

```
> length(table(mon$zipCode))
```

```
[1] 13
```

Question 4

The "by hand" way is cross-tabulating the zip codes and neighborhoods,

```
> tab = table(mon$zipCode, mon$neighborhood)
> # tab
> tab[, "Downtown"]
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
    2     9     0     0     0     0     0     0     0     0     0     0
21251
    0
```

```
> length(unique(tab[, "Downtown"]))
```

```
[1] 3
```

Logical Statements

But we want non-zero entries. This introduces the logical class, which consists of either TRUE or FALSE

```
> z = c(TRUE, FALSE, TRUE, FALSE)
> class(z)
```

```
[1] "logical"
```

```
> sum(z)
```

```
[1] 2
```

Note that the logical class does NOT use quotes.

```
> z2 = c("TRUE", "FALSE", "TRUE", "FALSE")
> class(z2)
```

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

```
> sum(z2)
```

```
Error: invalid 'type' (character) of argument
```

```
> identical(z, z2)
```

```
[1] FALSE
```

Logical Statements

- This mirrors computer science/programming syntax:
  - '==': equal to
  - '!=': not equal to (it is NOT '~' in R, e.g. SAS)
  - '>': greater than
  - '<': less than
  - '>=': greater than or equal to
  - '<=': less than or equal to

```
> tt = tab[, "Downtown"]
> tt
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
    2     9     0     0     0     0     0     0     0     0     0     0
21251
    0
```

```
> tt == 0  # which entries are equal to 0
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
21251
 TRUE
```

```
> tab[, "Downtown"] != 0
```

```
21201 21202 21211 21213 21214 21217 21218 21223 21224 21225 21230 21231
 TRUE  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
21251
FALSE
```

```
> sum(tab[, "Downtown"] != 0)
```

```
[1] 2
```

```
> sum(tab[, "Johns Hopkins Homewood"] != 0)
```

```
[1] 2
```

We could also subset the data into neighborhoods:

```
> dt = mon[mon$neighborhood == "Downtown", ]
> head(mon$neighborhood == "Downtown", 10)
```

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

```
> dim(dt)
```

```
[1] 11  6
```

```
> length(unique(dt$zipCode))
```

```
[1] 2
```

Question 5

```
> head(mon$location)
```

```
[1] "408 CHARLES ST\nBaltimore, MD\n"  ""
[3] ""                                 "100 HOLLIDAY ST\nBaltimore, MD\n"
[5] "50 MARKET PL\nBaltimore, MD\n"    "100 CALVERT ST\nBaltimore, MD\n"
```

```
> table(mon$location != "")  # FALSE=DO NOT and TRUE=DO
```

```
FALSE  TRUE
   26    58
```

Question 6

```
> tabZ = table(mon$zipCode)
> head(tabZ)
```

```
21201 21202 21211 21213 21214 21217
   11    16     8     4     1     9
```

```
> max(tabZ)
```

```
[1] 16
```

```
> tabZ[tabZ == max(tabZ)]
```

```
21202
   16
```

which.max() returns the FIRST entry/element number that contains the maximum and which.min() returns the FIRST entry that contains the minimum

```
> which.max(tabZ)  # this is the element number
```

```
21202
    2
```

```
> tabZ[which.max(tabZ)]  # this is the actual maximum
```

```
21202
   16
```

```
> tabN = table(mon$neighborhood)
> tabN[which.max(tabN)]
```

```
Johns Hopkins Homewood
                    17
```

```
> tabC = table(mon$councilDistrict)
> tabC[which.max(tabC)]
```

```
11
29
```

```
> tabP = table(mon$policeDistrict)
> tabP[which.max(tabP)]
```

```
CENTRAL
     27
```

Other Useful R Stuff to get you going

which()

?which: Give the TRUE indices of a logical object, allowing for array indices.

```
> mon$location != ""
```

```
 [1]  TRUE FALSE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE
[12] FALSE FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
[23]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE
[34]  TRUE  TRUE  TRUE  TRUE  TRUE FALSE FALSE  TRUE  TRUE  TRUE  TRUE
[45]  TRUE  TRUE  TRUE FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE  TRUE
[56] FALSE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE FALSE
[67] FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE FALSE  TRUE FALSE
[78]  TRUE  TRUE  TRUE  TRUE FALSE FALSE  TRUE
```

```
> which(mon$location != "")
```

```
 [1]  1  4  5  6  7  8  9 11 14 15 17 18 19 20 21 22 23 24 25 26 27 28 29
[24] 31 32 33 34 35 36 37 38 41 42 43 44 45 46 47 50 54 55 57 58 59 60 61
[47] 68 69 70 71 72 73 76 78 79 80 81 84
```

Missing Data

- In R, missing data is represented by the symbol NA (note that it is NOT a character, and therefore not in quotes)
- is.na() is a logical test for which variables are missing
- Many summarization functions do not the calculation you expect (e.g. they return NA) if there is ANY missing data, and these ofen have an argument 'na.rm=FALSE'. Changing this to 'na.rm=TRUE' will ignore the missing values in the calculation (i.e. mean(), sd(), max(), sum())

This will help you with the homework: http://www.statmethods.net/input/missingdata.html

R classes

You can test whether an R object is a specific class. For example:

- is.character(object)
- is.integer(object)
- is.numeric(object)
- is.factor(object)
- is.matrix(object)
- is.data.frame(object)