1.2 — Meet R

ECON 480 • Econometrics • Fall 2020

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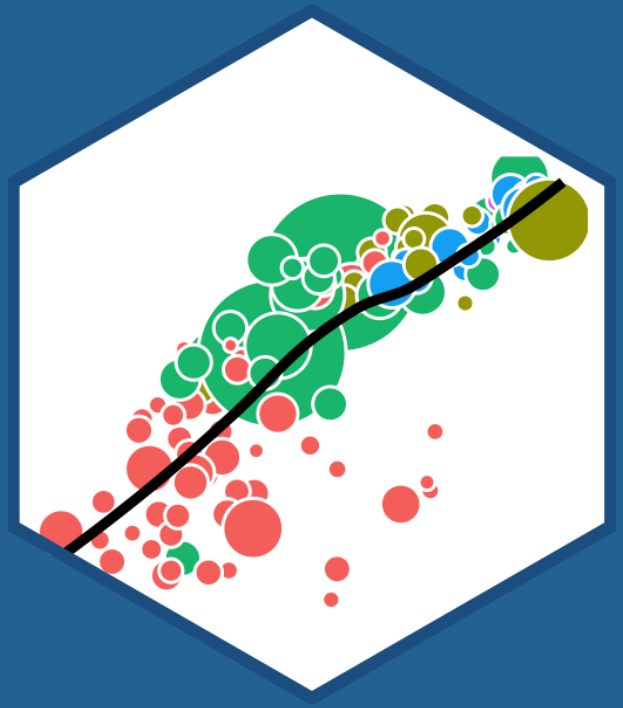
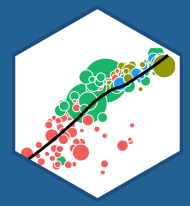
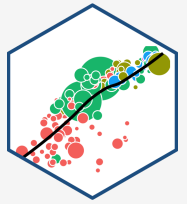


Outline

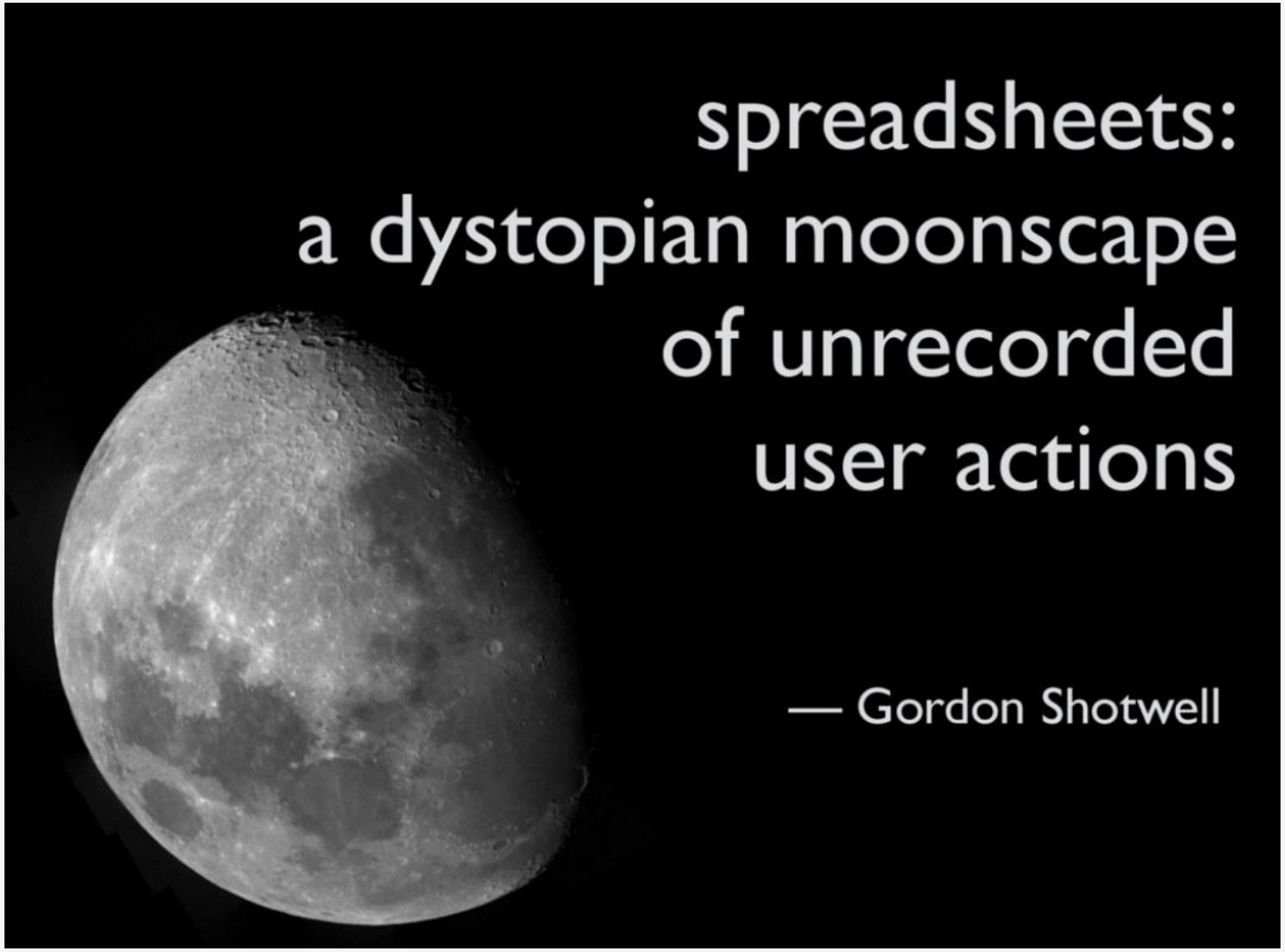


Data Science

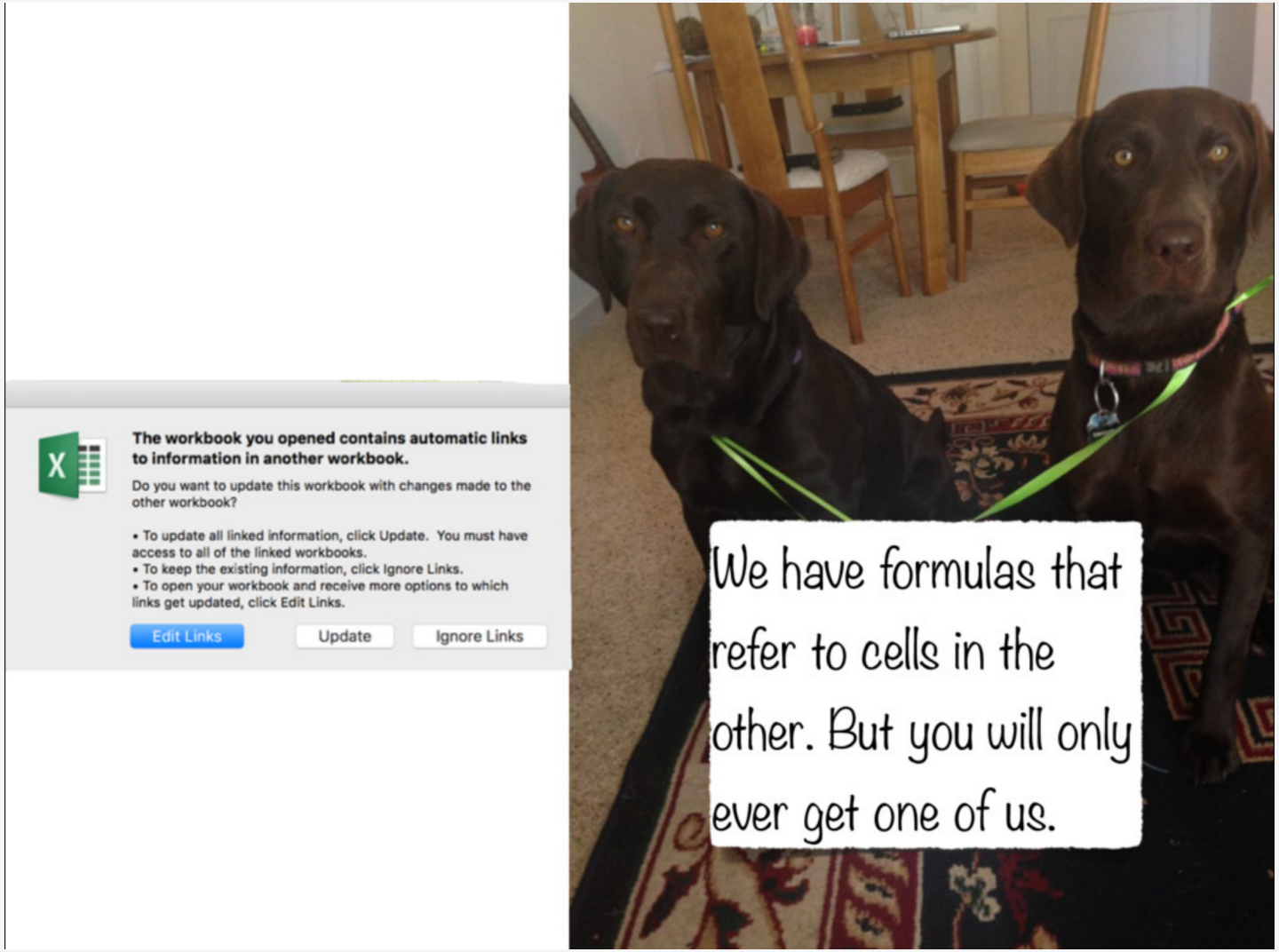


- **You go into data analysis with the tools you know, not the tools you need**
- The next 2-3 weeks are all about giving you the tools you need
    - Admittedly, a bit before you know what you need them *for*
- We will extend them as we learn specific models

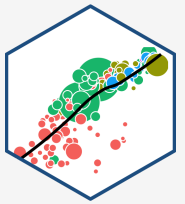
Why Not Excel? I



Why Not Excel? II



Why Use R?

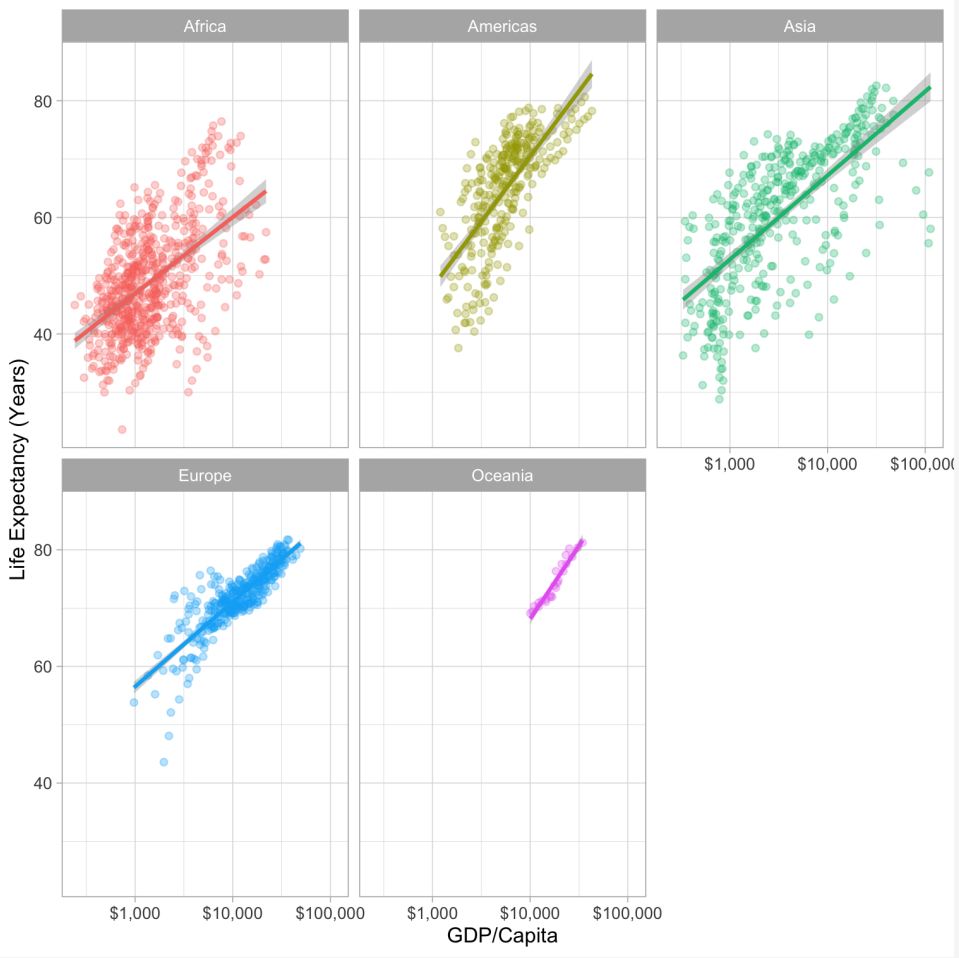


- **Free** and **open source**
- A very large community
  - Written by statisticians for statistics
  - Most packages are written for `R` first
- Can handle virtually any data format
- Makes replication easy
- Can integrate into documents (with `R markdown`)
- R is a *language* so it can do *everything*

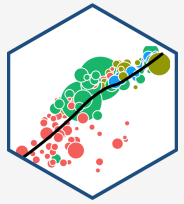
Excel and Stata Can't Do This (In Slides)

```
library("gapminder")

ggplot(data = gapminder,
       aes(x = gdpPercap,
           y = lifeExp,
           color = continent))+
  geom_point(alpha=0.3)+
  geom_smooth(method = "lm")+
    scale_x_log10(breaks=c(1000,10000,
                           label=scales::dollar
    labs(x = "GDP/Capita",
         y = "Life Expectancy (Years)"
  facet_wrap(~continent)+
  guides(color = F)+
  theme_light()
```



Or This: Execute R Code Inside Your Documents



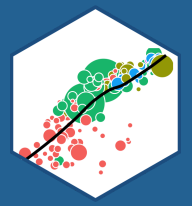
Code

```
library(gapminder)
```

The average GDP per capita is $ `r round(mean(gapminder$gdpPercap),2)` with a standard deviation of $ `r round(sd(gapminder$gdpPercap),2)` .

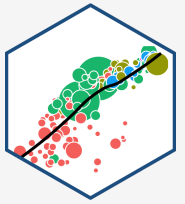
Output

The average GDP per capita is $7215.33 with a standard deviation of $9857.45.



Meet R and R Studio

R and R Studio



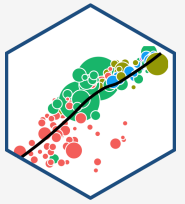
- R is the programming language that executes commands

- R Studio is an integrated development environment (IDE) that makes your coding life a lot easier

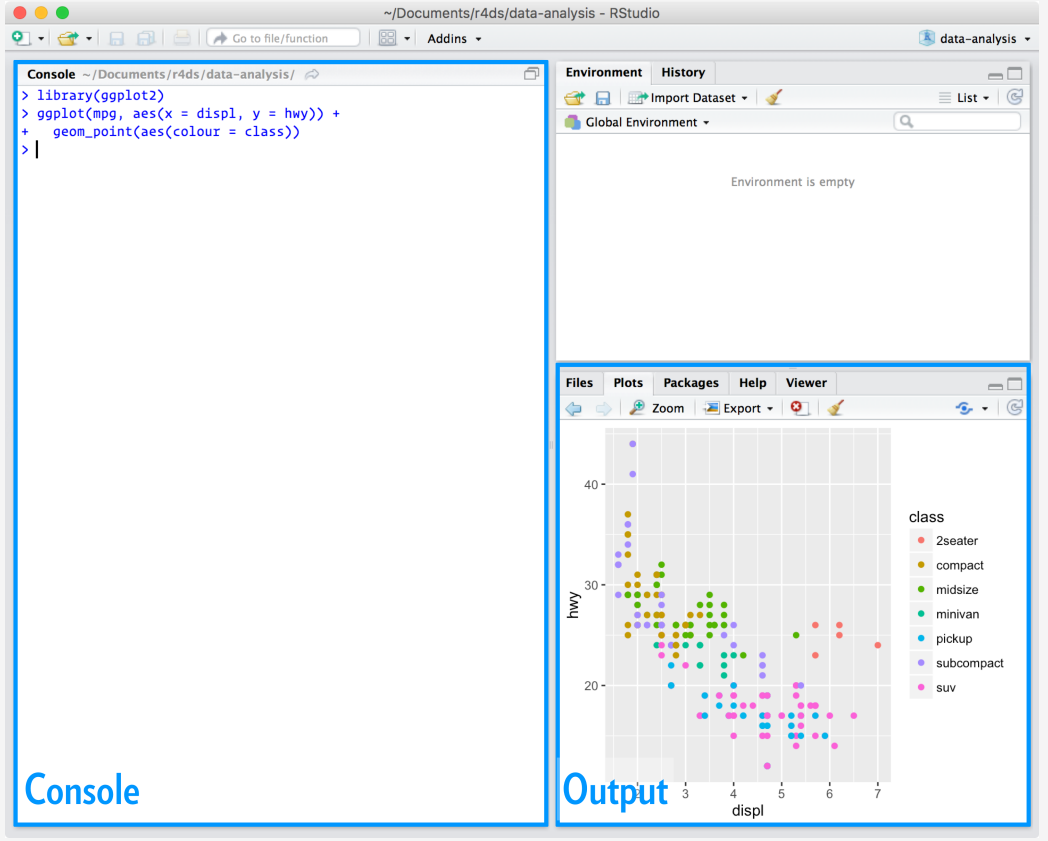
    - Write code in scripts
    - Execute individual commands or entire scripts
    - Auto-complete, highlight syntax
    - View data, objects, and plots
    - Get help and documentation on commands and functions
    - Integrate code into documents with `R Markdown`

R Studio

R and R Studio II

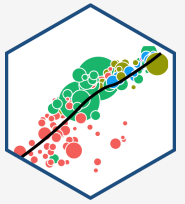


- R is like your car's engine, R Studio is the dashboard
- You will do everything in R Studio
- R itself is just a command language (you could run it in your computer's shell/terminal/command prompt)



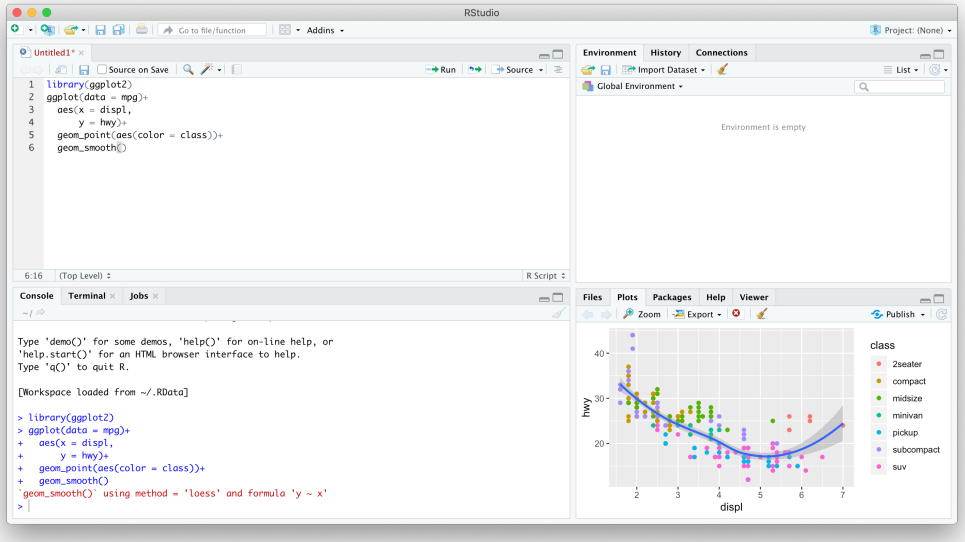
R Studio

R and R Studio III



R Studio has 4 window panes:

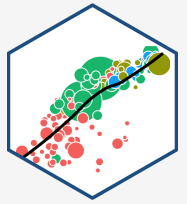
1. **Source**[1]: a text editor for documents, R scripts, etc.
2. **Console**: type in commands to run
3. **Browser**: view files, plots, help, etc
4. **Environment**: view created objects, command history, version control



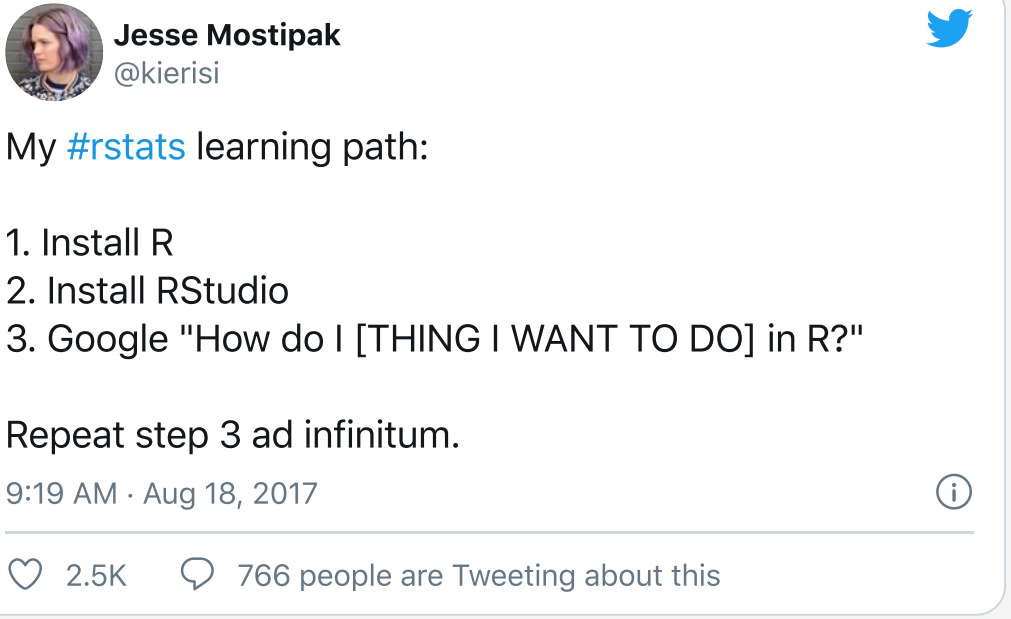
R Studio

[1]May not be immediately visible until you create new files.

Learning...

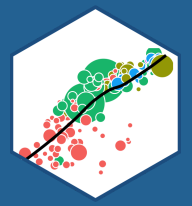


- **You don't "*learn R*", you learn *how to do things in R***
- In order to do learn this, you need to learn *how to search for what you want to do*



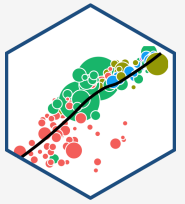
...and Sucking


Dude, sucking at something is the first step
towards being sort of good at something



Ways to Use R

1. Using the Console



- Type individual commands into the console window
- Great for testing individual commands to see what happens
- Not saved! Not reproducible! Not recommended!

```
2+2
```

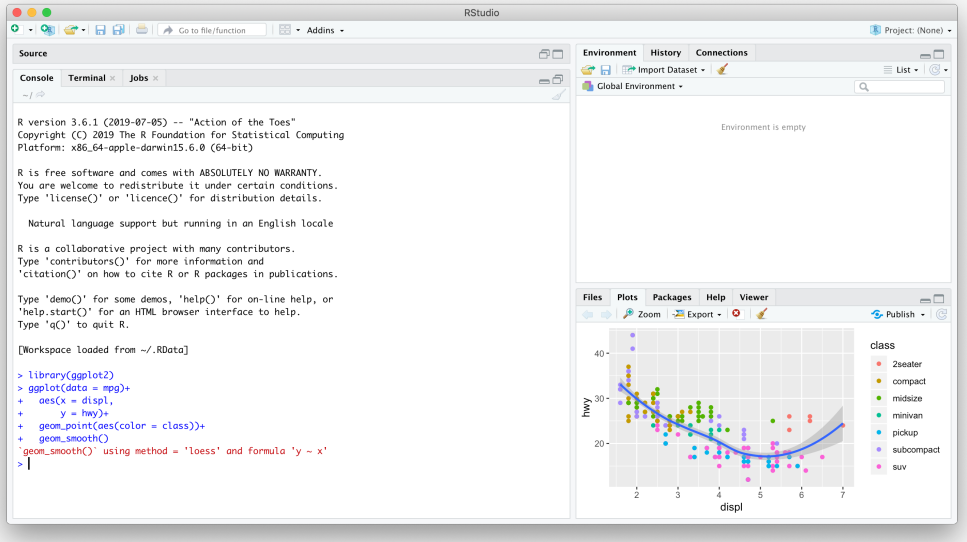
```
## [1] 4
```

```
summary(mpg$hwy)
```

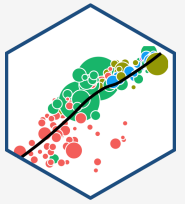
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   12.00   18.00   24.00   23.44   27.00   44.00
```

1. Using the Console

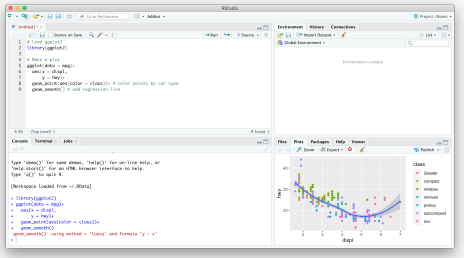
- Type individual commands into the console window
- Great for testing individual commands to see what happens
- Not saved! Not reproducible! Not recommended!



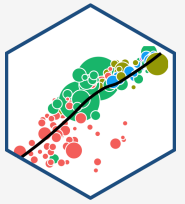
2. Writing an R Script



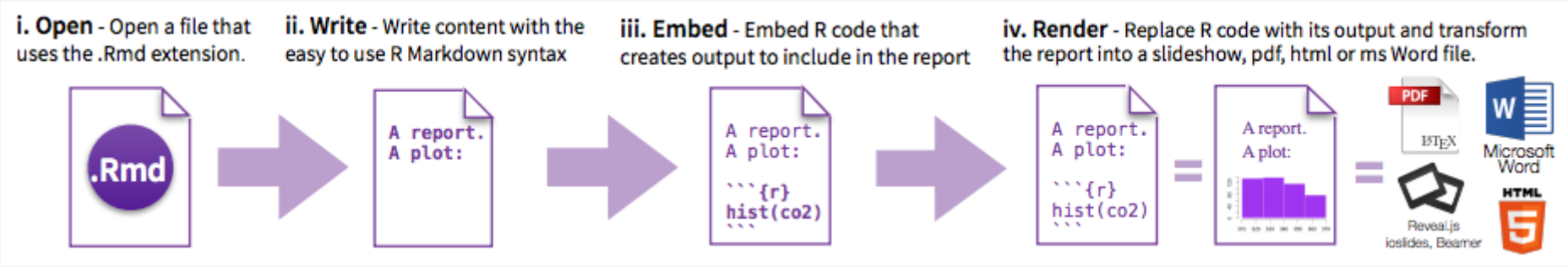
- Source pane is a text-editor
- Make `.R` files: all input commands in a single script
- Comment with `#`
- Can run any or all of script at once
- Can save, reproduce, and send to others!



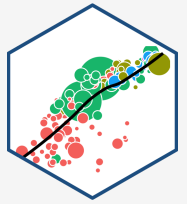
3. Using Markdown



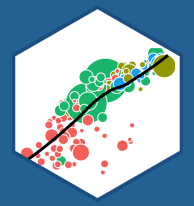
- A later lecture: `R Markdown`, a simple markup language to write documents in
    - **Optional**, but many students have enjoyed it and use it well beyond this class!
- Can integrate text, `R` code, figures, citations & bibliographies in a *single* plain-text file & output into a variety of formats: PDF, webpage, slides, Word doc, etc.



For Today

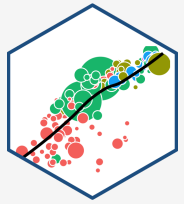


- Practicing typing at the Command line/Console
- Learning different commands and objects relevant for data analysis
- Saving and running `.R` scripts
- Later: `R markdown`, literate programming, workflow management
- **Today may seem a bit overwhelming**
  - You don't need to know or internalize all of this today
  - Use this as a reference to come back to over the semester



Coding Basics

Getting to Know Your Computer



- R assumes a default (often inconvenient) **"working directory"** on your computer
    - The first place it looks to `open` or `save` files
- Find out where R this is with `getwd()`
- Change it with `setwd(path/to/folder)`[1]
- Soon I'll show you better ways where you won't ever have to worry about this

[1] Note the path is OS-specific. For Windows it might be `C:/Documents/`. For Mac it is often your username folder.

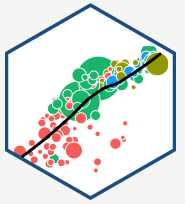
Coding

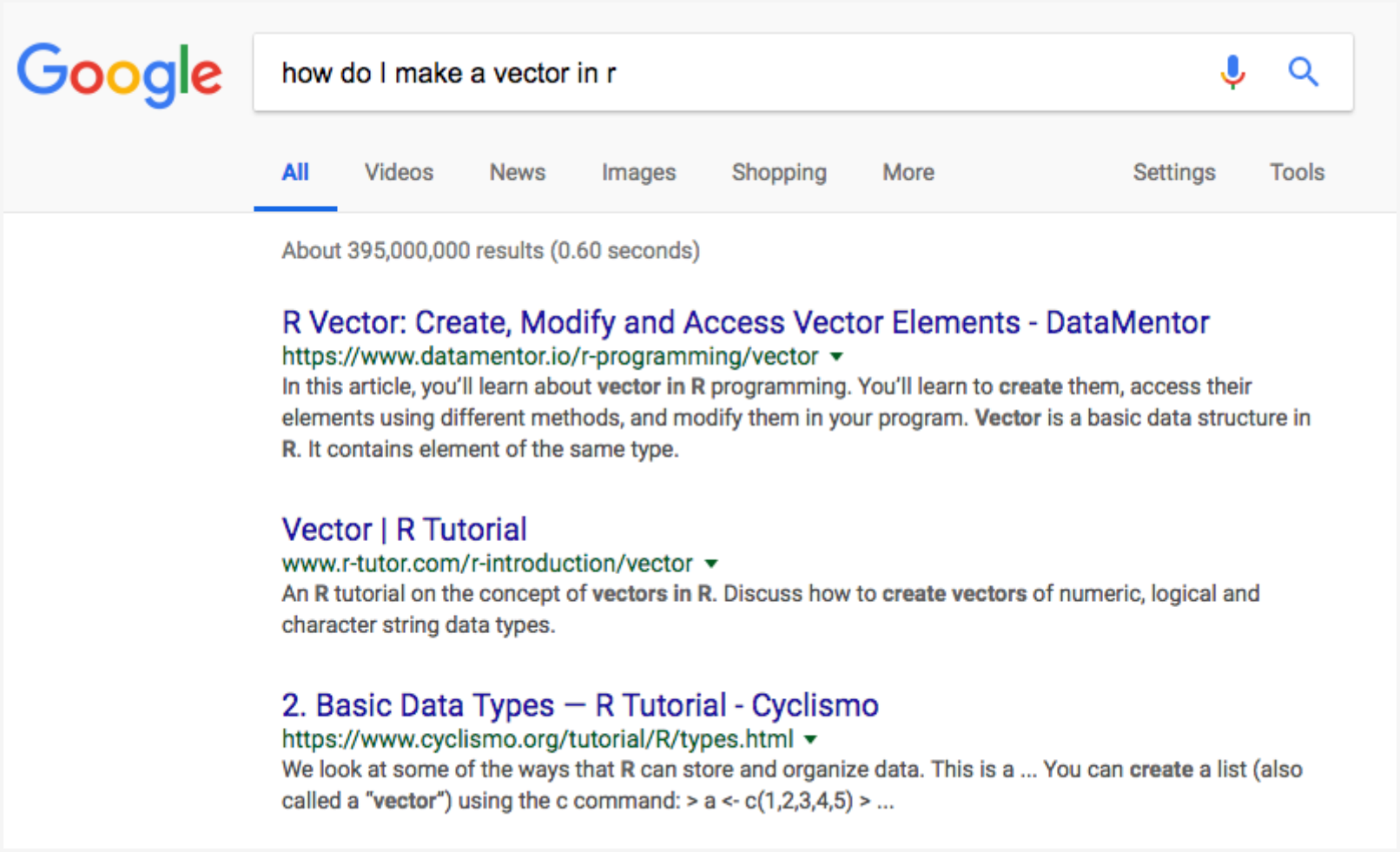
Hadley Wickham

Chief Scientist, R Studio

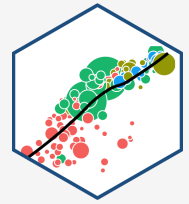
> "There's an implied contract between you and R: it will do the tedious computation for you, but in return, you must be completely precise in your instructions. Typos matter. Case matters." - R for Data Science, Ch. 4

Say Hello to My Little Friend





Say Hello to My Better Friend



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[r] how do I make a vector search

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R is a free, open-source programming language and software environment for statistical computing, bioinformatics, visualization and general computing. Provide minimal, reproducible, representative example(s) with your questions. Use dput() for data and specify all non-base packages with library ...

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2 answers

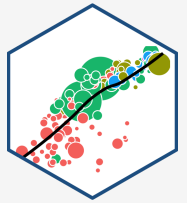
Q: How do I make a specific factor in a vector have a higher level than every other factor?

Given **a vector** for which "b" will always be an element of, **how do I make** "b" have **a** higher level than all the other factors (without reordering the other factors relative to each other)? For example … , but **how do I make** it so levels(df$x) = "c","d","b" In other words, **I** want "b" to always show up last. …

r

asked Dec 26 '13 by Ben

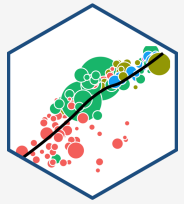
R Is Helpful Too!



- type `help(function_name)` or `?(function_name)` to get documentation on a function

From Kieran Healy's excellent (free online!) book on Data Visualization.

Tips for Writing Code

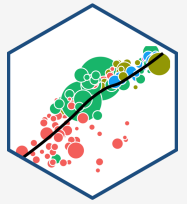


- Comment, comment, comment!
- The hashtag `#` starts a comment, R will ignore everything on the rest of that line

```
# Run regression of y on x, save as reg1
reg1<-lm(y~x, data=data) #runs regression
summary(reg1$coefficients) #prints coefficients
```

- Save often!
  - Write scripts that save the commands that did what you wanted (and comment them!)
  - Better yet, use a version control system like Git (I hope to cover this later)

Style and Naming



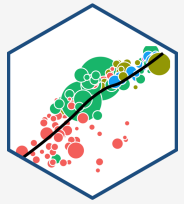
- Once we start writing longer blocks of code, it helps to have a consistent (and human-readable!) style
- I follow this style guide (you are not required to)[1]
- Naming objects and files will become important[2]
    - DO NOT USE SPACES! You've seen seen webpages intended to be called `my webpage in html` turned into `http://my%20webpage%20in%20html.html`

```
i_use_underscores
some.people.use.snake.case
othersUseCamelCase
```

[1] Also described in today's course notes page and the course reference page.

[2] Consider your folders on your computer as well...

Coding Basics



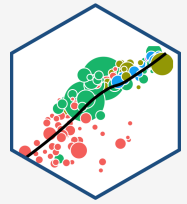
- You'll have to get used to the fact that you are coding in commands to execute
- Start with the easiest: simple math operators and calculations:

```
> 2+2
```

```
## [1] 4
```

- Note that R will ask for **input** with `>` and give you **output** starting with `## [1]`

Coding Basics II



- We can start using more fancy commands

```
2^3
```

```
## [1] 8
```

```
sqrt(25)
```

```
## [1] 5
```

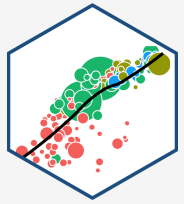
```
log(6)
```

```
## [1] 1.791759
```

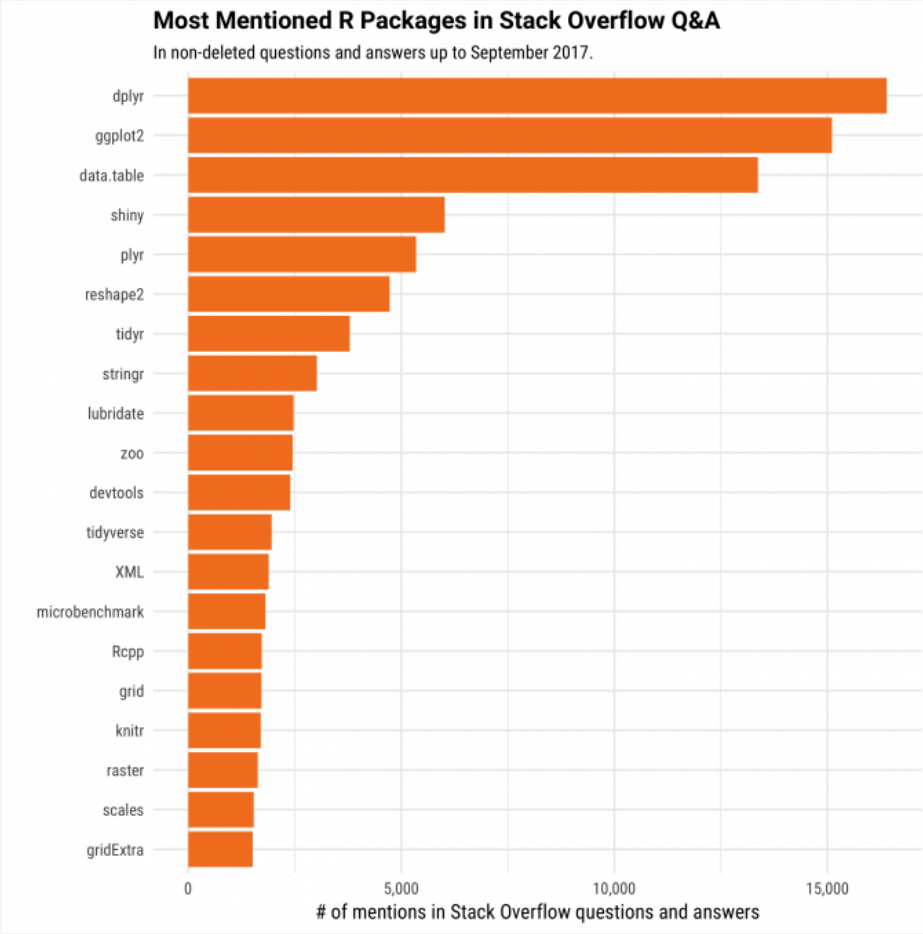
```
pi/2
```

```
## [1] 1.570796
```

Packages

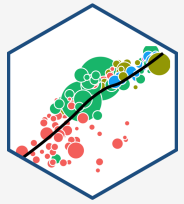


- Since R is open source, users contribute **packages**
  - Really it's just users writing custom functions and saving them for others to use
- Load packages with `library()`
  - e.g. `library("package_name")`
- If you don't have a package, you must first `install.packages()`[1]
  - e.g. `install.packages("package_name")`



[1] Yes, note the plural, even if it's just for one package!

R: Objects and Functions



- R is an **object-oriented** programming language
- 99% of the time, you will be:

1. creating `objects`
    - assign values to an object with `=` (or `<-`)
2. running `functions` on `objects`
    - syntax: `function_name(object_name)`

```
# make an object
my_object = -c(1,2,3,4,5)

# look at it
my_object
```

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

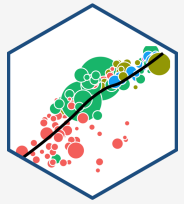
```
# find the sum
sum(my_object)
```

```
## [1] -15
```

```
# find the mean
mean(my_object)
```

```
## [1] -3
```

R: Objects and Functions II



- Functions have "**arguments**," the input(s)
- Some functions may have multiple inputs
- The argument of a function can be another function!

```
# find the sd
sd(my_object)
```

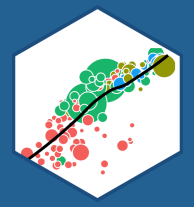
```
## [1] 1.581139
```

```
# round everything in my object to two decimals
round(my_object,2)
```

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

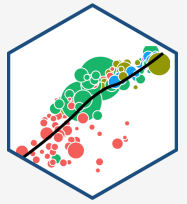
```
# round the sd to two decimals
round(sd(my_object),2)
```

```
## [1] 1.58
```



Types of R Objects

Numeric



- **Numeric** objects are just numbers[1]
- Can be mathematically manipulated

```
x = 2
y = 3
x+y
```

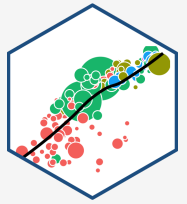
```
## [1] 5
```

```
x*y
```

```
## [1] 6
```

[1] If you want to get technical, R may call these `integer` or `double` if there are decimal values.

Character



- **Character** objects are **"strings"** of text held inside quote marks
- Can contain spaces, so long as contained within quote marks

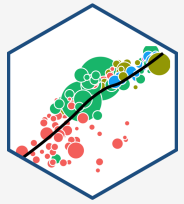
```
name = "Ryan Safner"
address = "Washington D.C."

name
```

```
## [1] "Ryan Safner"
```

```
address
```

```
## [1] "Washington D.C."
```

Logical



- **Logical** objects are **binary** `TRUE` or `FALSE` indicators
- Used a lot to evaluate *conditionals*:
  - `>`, `<`: greater than, less than
  - `>=`, `<=`: greater than or equal to, less than or equal to
  - `==`, `!=`: is equal to, is not equal to[1]
  - `&in&` : Is a member of the set of ($\in$)
  - `&`: "AND"
  - `|`: "OR"

```
z = 10 # set z equal to 10

z==10 # is z equal to 10?
```

```
## [1] TRUE
```

```
"red"=="blue" # is red equal to blue?
```

```
## [1] FALSE
```

```
z > 1 & z < 12 # is z > 1 AND < 12?
```

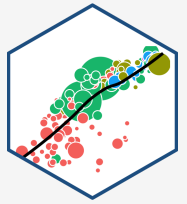
```
## [1] TRUE
```

```
z <= 1 | z==10 # is z >= 1 OR equal to 10?
```

```
## [1] TRUE
```

[1] One `=` *assigns* a value (like `<-`). Two `==` *evaluate* a conditional statement.

Factor

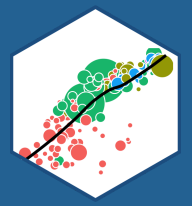


- Factor objects contain **categorical** data - membership in mutually exclusive groups
- Look like strings, behave more like logicals, but with more than two options

```
##  [1] senior    freshman  senior    sophomore sophomore junior    junior
##  [8] freshman  freshman  senior
## Levels: freshman sophomore junior senior
```

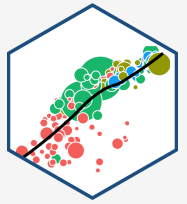
- We'll make much more extensive use of them later

```
##  [1] senior    freshman  senior    sophomore sophomore junior    junior
##  [8] freshman  freshman  senior
## Levels: freshman < sophomore < junior < senior
```



Data Structures

Vectors

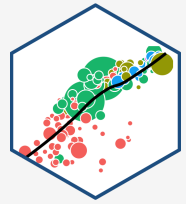


- `Vector`: the simplest type of object, just a collection of objects
- Make a vector using the combine `c()` function

```
# create a vector called vec
vec = c(1,"orange", 83.5, pi)

# look at vec
vec
```

```
## [1] "1"                 "orange"            "83.5"
```

Data Frames I

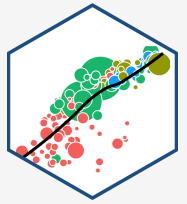


- `Data frame`: what we'll be using almost always
- Think like a "spreadsheet"
- Each *column* is a vector (variable)
- Each *row* is an observation (pair of values for all variables)

```
library("ggplot2")

diamonds
```

```
## # A tibble: 53,940 x 10
##    carat cut       color clarity depth table price
##    <dbl> <ord>     <ord> <ord>   <dbl> <dbl> <int>
##  1 0.23  Ideal     E     SI2      61.5    55   326
##  2 0.21  Premium   E     SI1      59.8    61   326
##  3 0.23  Good      E     VS1      56.9    65   327
##  4 0.290 Premium   I     VS2      62.4    58   334
##  5 0.31  Good      J     SI2      63.3    58   335
##  6 0.24  Very Good J     VVS2     62.8    57   336
##  7 0.24  Very Good I     VVS1     62.3    57   336
##  8 0.26  Very Good H     SI1      61.9    55   337
##  9 0.22  Fair      E     VS2      65.1    61   337
## 10 0.23  Very Good H     VS1      59.4    61   338
## # … with 53,930 more rows
```

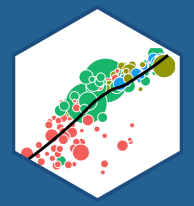
Data Frames II



- Dataframes are really just combinations of (column) vectors
- You can make data frames by combinining named vectors with `data.frame()` or creating each column/vector in each argument

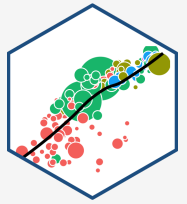
```
# make two vectors
fruits = c("apple","orange","pear","kiwi","pine
numbers = c(3.3,2.0,6.1,7.5,4.2)

# combine into dataframe
df = data.frame(fruits,numbers)

# do it all in one step (note the = instead of
df = data.frame(fruits=c("apple","orange","pear
                numbers=c(3.3,2.0,6.1,7.5,4.2))

# look at it
df
```

```
##       fruits numbers
## 1      apple     3.3
## 2     orange     2.0
## 3       pear     6.1
## 4       kiwi     7.5
## 5 pineapple     4.2
```



Working with Objects

Objects: Storing, Viewing, and Overwriting

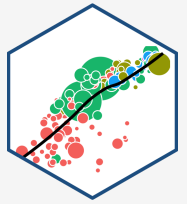


- We want to store things in objects to run functions on them later
- Recall, any object is created with the assignment operator `<-`

```
my_vector = c(1,2,3,4,5)
```

- R will not give any output after an assignment

Objects: Storing, Viewing, and Overwriting



- *View* an object (and list its contents) by typing its name

```
my_vector
```

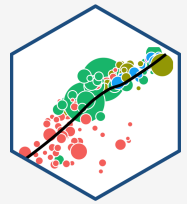
```
## [1] 1 2 3 4 5
```

- objects maintain their values until they are assigned different values that will *overwrite* the object

```
my_vector = c(2,7,9,1,5)
my_vector
```

```
## [1] 2 7 9 1 5
```

Objects: Checking and Changing Classes



- Check what type of object something is with `class()`

```
class("six")
```

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

```
class(6)
```

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

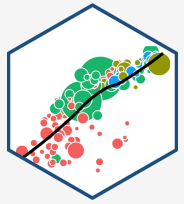
- Can also use logical tests of `is.()`

```
is.numeric("six")
```

```
## [1] FALSE
```

```
is.character("six")
```

Objects: Checking and Changing Classes



- Convert objects from one class to another with `as.object_class()`
  - Pay attention: you can't convert non-numbers to `numeric`, etc!

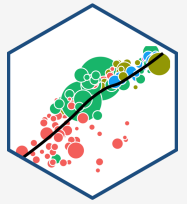
```
as.character(6)
```

```
## [1] "6"
```

```
as.numeric("six")
```

```
## [1] NA
```

Objects: Different Classes and Coercion I



- Different types of objects have different rules about mixing classes
- Vectors can *not* contain different types of data
    - Different types of data will be "**coerced**" into the lowest-common denominator type of object

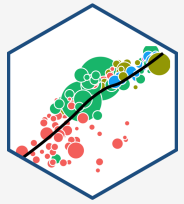
```
mixed_vector = c(pi, 12, "apple", 6.32)
class(mixed_vector)
```

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

```
mixed_vector
```

```
## [1] "3.14159265358979" "12"               "apple"            "6.32"
```

Objects: Different Classes and Coercion II



- Data frames can have columns with different types of data, so long as all the elements in each column are the same class[1]

```
df
```

```
##      fruits numbers
## 1     apple     3.3
## 2    orange     2.0
## 3      pear     6.1
## 4      kiwi     7.5
## 5 pineapple     4.2
```

```
class(df$fruits)
```

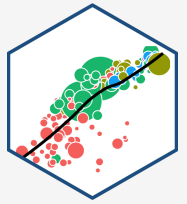
```
## [1] "character"
```

```
class(df$numbers)
```

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

[1]Remember each column in a data frame is a vector!

More on Data Frames I



- Learn more about a data frame with the `str()` command to view its structure

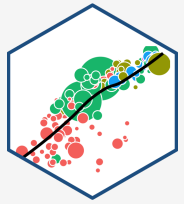
```
class(df)
```

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

```
str(df)
```

```
## 'data.frame':    5 obs. of  2 variables:
##  $ fruits : chr  "apple" "orange" "pear" "kiwi" ...
##  $ numbers: num  3.3 2 6.1 7.5 4.2
```

More on Data Frames II



- Take a look at the first 5 (or `n`) rows with `head()`

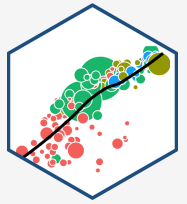
```
head(df)
```

```
##      fruits numbers
## 1     apple     3.3
## 2    orange     2.0
## 3      pear     6.1
## 4      kiwi     7.5
## 5 pineapple     4.2
```

```
head(df, n=2)
```

```
##   fruits numbers
## 1  apple     3.3
## 2 orange     2.0
```

More on Data Frames III



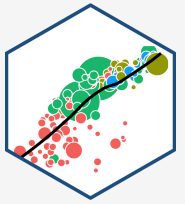
- Get summary statistics[1] by column (variable) with `summary()`

```
summary(df)
```

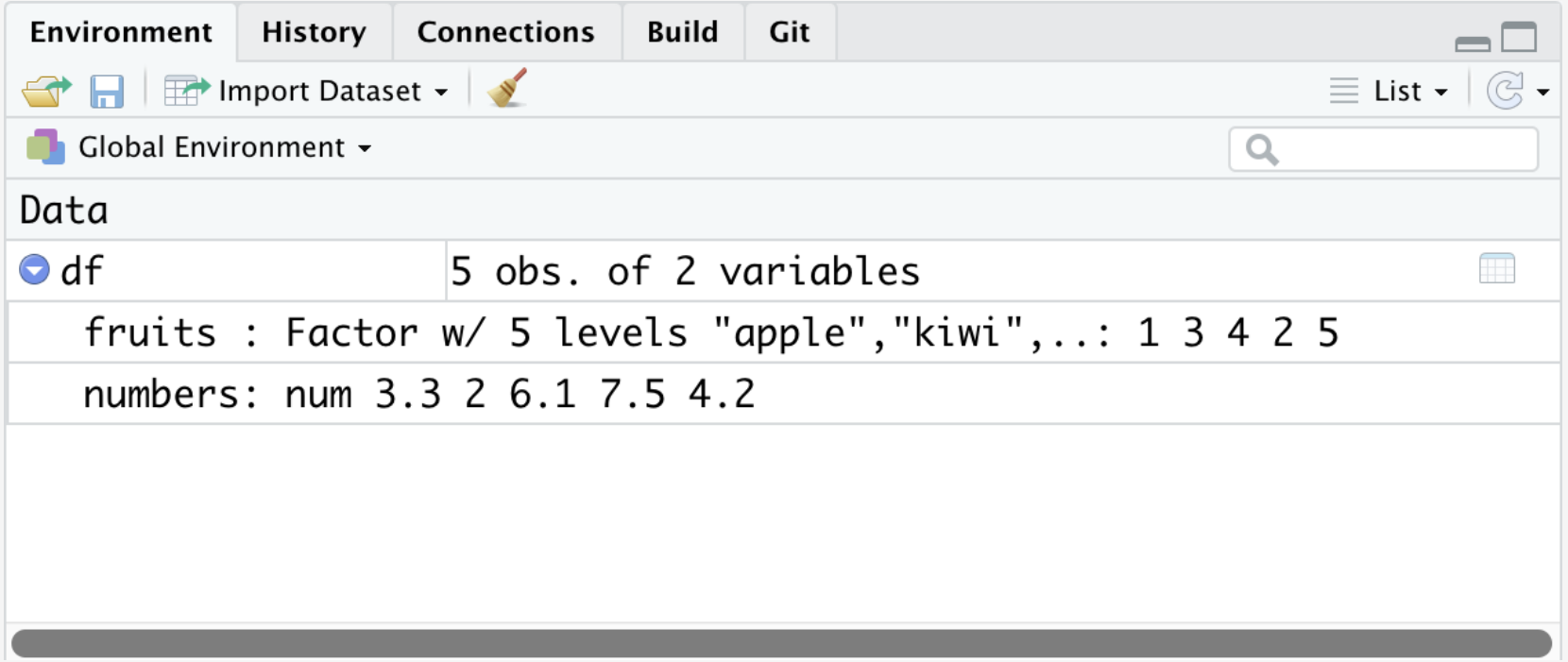
```
##     fruits              numbers
##  Length:5           Min.   :2.00
##  Class :character   1st Qu.:3.30
##  Mode  :character   Median :4.20
##                     Mean   :4.62
##                     3rd Qu.:6.10
##                     Max.   :7.50
```

[1] For `numeric` data only; a frequency table is displayed for `character` or `factor` data

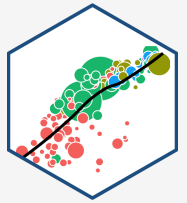
More on Data Frames IV



- Note, once you save an object, it shows up in the **Environment Pane** in the upper right window
- Click the blue arrow button in front of the object for some more information

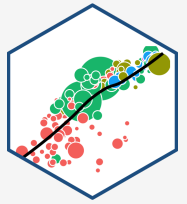


More on Data Frames V



- `data.frame` objects can be viewed in their own panel by clicking on the name of the object
- Note you cannot edit anything in this pane, it is for viewing only

Functions Again I



- Functions in R are vectorized, meaning running a function on a vector applies it to *each* element

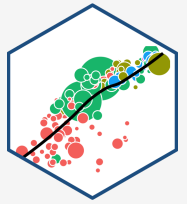
```
my_vector = c(2,4,5,10)
my_vector+4 # add 4 to all elements
```

```
## [1]  6  8  9 14
```

```
my_vector^2 # square all elements
```

```
## [1]   4  16  25 100
```

Functions Again II



- But often we want to run functions on vectors that *aggregate* to a result (e.g. a statistic):

```
length(my_vector) # how many elements
```

```
## [1] 4
```

```
sum(my_vector) # add all elements
```

```
## [1] 21
```

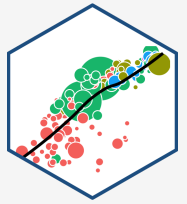
```
max(my_vector) # find largest element
```

```
## [1] 10
```

```
min(my_vector) # find smallest element
```

```
## [1] 2
```

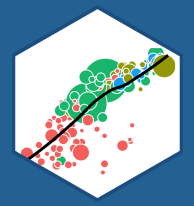
Common Errors



- If you make a coding error (e.g. forget to close a parenthesis), R might show a `+` sign waiting for you to finish the command

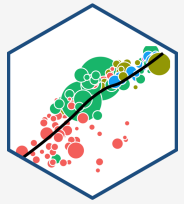
```
> 2+(2*3
+
```

- Either finish the command-- e.g. add `)` --or hit `Esc` to cancel



Working with Data

Indexing and Subsetting I



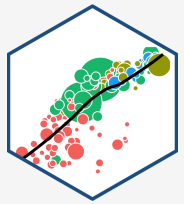
```
mtcars
```

```
##                   mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30
## Merc 280C         17.8   6 167.6 123 3.92 3.440 18.90
## Merc 450SE        16.4   8 275.8 180 3.07 4.070 17.40
```

- Each element in a data frame is indexed by referring to its row and column: `df[r,c]`
- To select elements by row and column ("subset"), type in the row(s) and/or column(s) to select
  - Leaving `r` or `c` blank selects *all* rows or columns
  - Select multiple values with `c()`[1]
  - Select a range of values with `:`
  - Don't forget the comma between `r` and `c`!

[1] You can also "negate" values, selecting everything *except* for values with a `-` in front of them.

Indexing and Subsetting II



```
mtcars
```

```
##                   mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30
## Merc 280C         17.8   6 167.6 123 3.92 3.440 18.90
## Merc 450SE        16.4   8 275.8 180 3.07 4.070 17.40
```

Subset by Row (Observations)

```
mtcars[1,] # first row
```

```
##           mpg cyl disp  hp drat   wt  qsec
## Mazda RX4  21   6  160 110  3.9 2.62 16.46
```

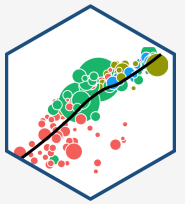
```
mtcars[c(1,3,4),] # first, third, and fourth rows
```

```
##                  mpg cyl disp  hp drat    wt  qsec
## Mazda RX4       21.0   6  160 110 3.90 2.620 16.46
## Datsun 710      22.8   4  108  93 3.85 2.320 18.61
## Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44
```

```
mtcars[1:3,] # first three rows
```

```
##                  mpg cyl disp  hp drat    wt  qsec
## Mazda RX4       21.0   6  160 110 3.90 2.620 16.46
```

Indexing and Subsetting III



```
mtcars
```

```
##                    mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30
## Merc 280C         17.8   6 167.6 123 3.92 3.440 18.90
## Merc 450SE        16.4   8 275.8 180 3.07 4.070 17.40
```

Subset by Column (Variable)

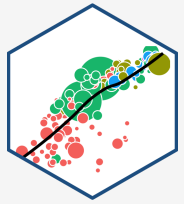
```
mtcars[,6] # select column 6
```

```
##  [1] 2.620 2.875 2.320 3.215 3.440 3.460 3.570 3.190 3
```

```
mtcars[,2:4] # select columns 2 through 4
```

```
##                   cyl  disp  hp
## Mazda RX4           6 160.0 110
## Mazda RX4 Wag       6 160.0 110
## Datsun 710          4 108.0  93
## Hornet 4 Drive      6 258.0 110
## Hornet Sportabout   8 360.0 175
## Valiant             6 225.0 105
## Duster 360          8 360.0 245
## Merc 240D           4 146.7  62
## Merc 230            4 140.8  95
## Merc 280            6 167.6 123
```

Indexing and Subsetting IV



```
mtcars
```

```
##                   mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30
## Merc 280C         17.8   6 167.6 123 3.92 3.440 18.90
## Merc 450SE        16.4   8 275.8 180 3.07 4.070 17.40
```

Subset by Column (Variable)

- Alternatively, double brackets `[[]]` selects a column by position

```
mtcars[[6]] # same thing
```

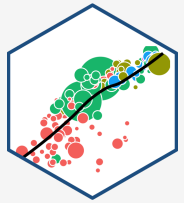
```
##  [1] 2.620 2.875 2.320 3.215 3.440 3.460 3.570 3.190 3
```

- Data frames can select columns by *name* with $

```
mtcars$wt
```

```
##  [1] 2.620 2.875 2.320 3.215 3.440 3.460 3.570 3.190 3
```

Indexing and Subsetting V



```
mtcars
```

```
##                   mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30
## Merc 280C         17.8   6 167.6 123 3.92 3.440 18.90
## Merc 450SE        16.4   8 275.8 180 3.07 4.070 17.40
```

- Select observations (rows) that meet logical criteria

Subset by Condition

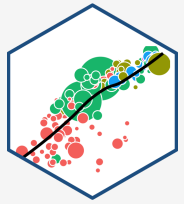
```
mtcars[mtcars$wt>4,] # select obs with wt>4
```

```
##             mpg cyl  disp  hp drat   wt qsec
## Merc 450SE 16.4   8 275.8 180 3.07 4.07 17.4
```

```
mtcars[mtcars$cyl==6,] # select obs with exactly 6
```

```
##                 mpg cyl  disp  hp drat    wt  qsec
## Mazda RX4      21.0   6 160.0 110 3.90 2.620 16.46
## Mazda RX4 Wag  21.0   6 160.0 110 3.90 2.875 17.02
## Hornet 4 Drive 21.4   6 258.0 110 3.08 3.215 19.44
## Valiant        18.1   6 225.0 105 2.76 3.460 20.22
## Merc 280       19.2   6 167.6 123 3.92 3.440 18.30
```

What's To Come



- Next class: data visualization with `ggplot2`
- And then: data wrangling with `tidyverse`
- And then: literate programming and workflow management with `R Markdown`
- Finally: back to econometric theory!