

Introduction to R & RStudio: Day 1

Thursday, September 3, 2020

About Us

Emorie Beck – Post-Doc

- Personality psychology
- Axolotl

Maddy Frumkin – 4th Year

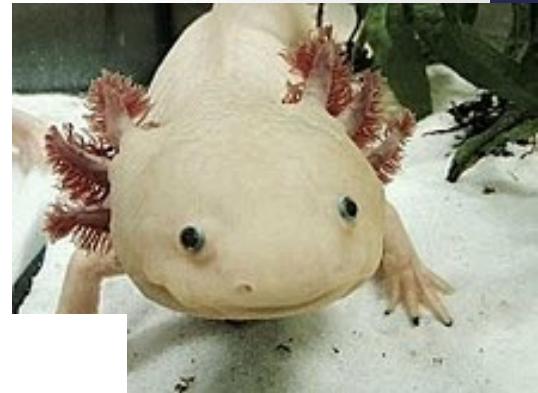
- Clinical psychology
- Bernese mountain dog

Violet Brown – 3rd Year

- Cognitive psychology
- Gorillas

Kendra Smith – 5th Year

- Cognitive psychology
- GumNut



Saturday, July 17, 2010

Koala For Sale



I have a three year old Koala Bear named GumNut that I'm desperately trying to find a new home for. I bought him back in January figuring it would be an awesome pet that would enjoy living in my greenhouse, sadly I was wrong. I paid \$3200 for him back in January and I'm not sure what the used Koala Bear market is like in a good economy or the one we have now; so I'm open to offers. Please use some common sense before contacting me, don't be an idiot, I'm not interested in trading my Koala Bear for your busted up 1980's Camaro, an XBOX, or an offer to paint my garage door.

30/0

This Workshop

2 sessions

- We will send out slides at the end of each class.
- You will have access to all code we write in class – don't worry if you don't get every single thing down.
- End of second session: bring data if you have research questions!

Reactions for exercises in RStudio

- Chat = have a question (can PM leader directly if you prefer)



- = done with exercise

Why R?

FREE!

Open source

Learning R will help you learn other programming languages

- Example: MATLAB, Python, web programming

Flexible

- Can do anything you want it to do

(Did we mention it's free?)

What is R?

R is a programming language

- Statistics & graphing

RStudio is an environment that makes it easy to actually use R

Ask questions

Make mistakes!

When in doubt,
Google



SETTING UP R & RSTUDIO

Installing R & RStudio

1. Install R first

- **Mac users:**
 - 1) Go to: <http://cran.wustl.edu/> → download R for (Mac) OS X
 - 2) Choose the correct version of R to install:
 - **R-latest.pkg** will likely be the case for most of you
- **Windows users:**
 - 1) Go to: <http://cran.wustl.edu/> → download R for Windows
 - 2) Click on the **base** folder --> click on **Download R 4.0.0 for Windows**

2. Then, install RStudio

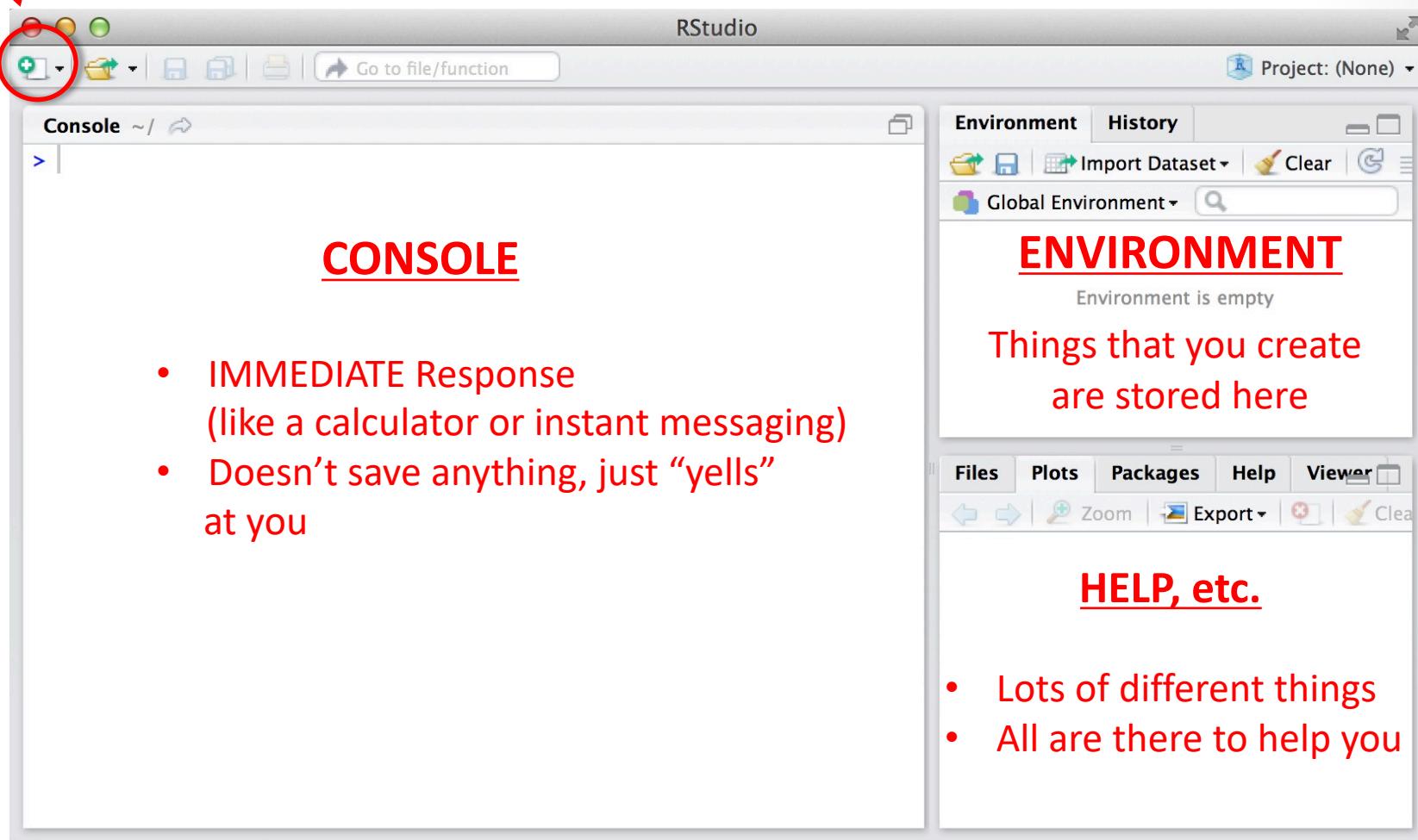
1) Go to <https://www.rstudio.com/products/rstudio/download/>

2) Scroll to the bottom, to "**Installers for Supported Platforms**"

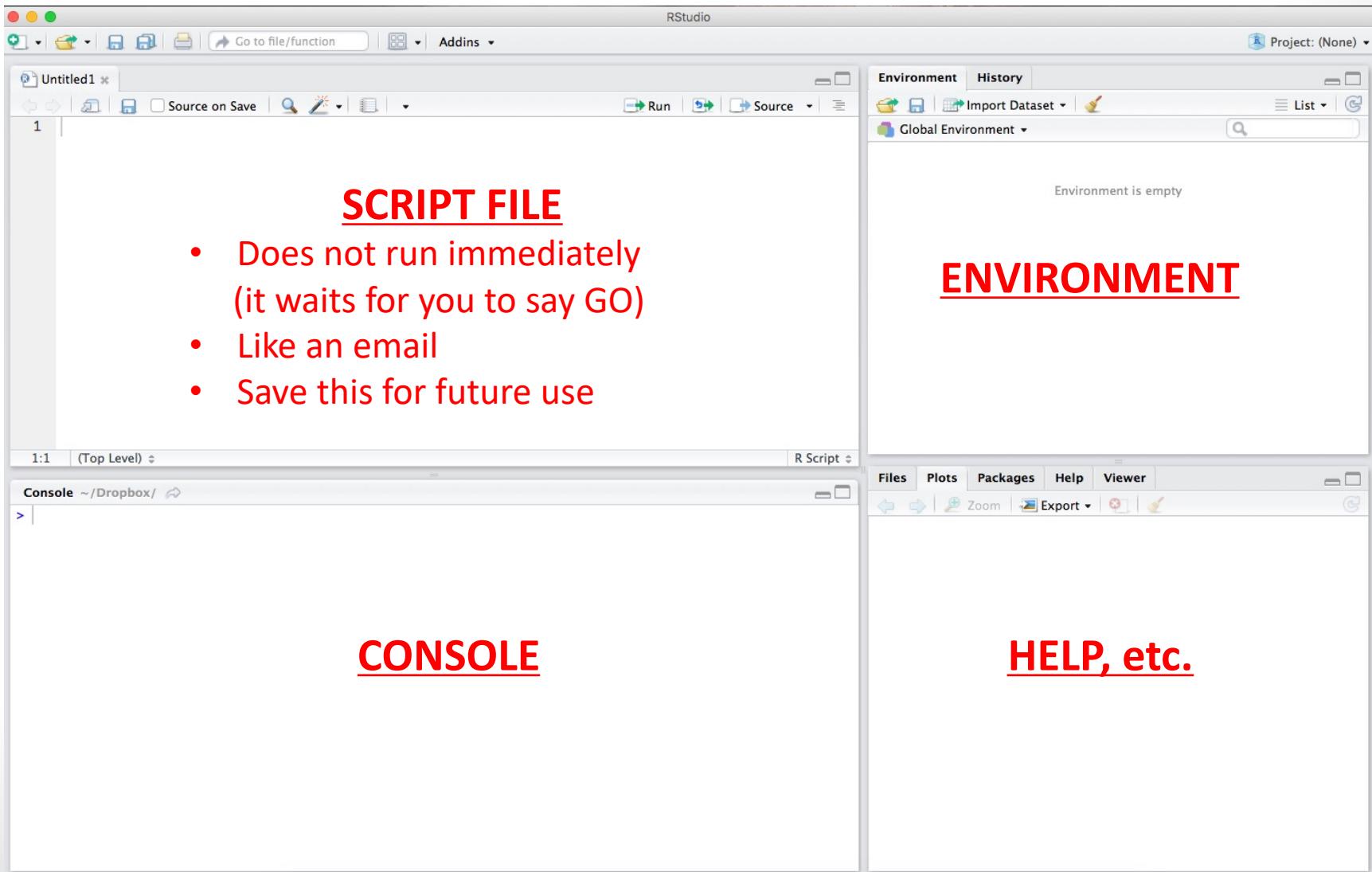
3) Click the first link to download the installer for Windows, OR
click the second link to download the installer for Mac

R Script

Getting Oriented with RStudio



Getting Oriented with RStudio



How to run code from your .R file

Highlight the lines that you want to run, then...

- Click on **Run** button

OR

- Ctrl + Enter (Windows)
- Command + Enter (Mac)



Bachelor Fan Anonymous
@AnonBachFan



#TheBachelor #TheBachelorFinale #TheBachelorABC

This morning I am thankful:

- for sunshine
- for my sweet pup
- for the roof over my head
- that Barb is not my mother in law



6:42 AM · Mar 11, 2020



1.1K 117 people are Tweeting about this

EXAMPLE 1 IN R

DATA FRAMES

How does R make sense of data?

- What “words” does R use?
- We are going to give you a vocabulary so that you can talk to R (and R can understand you)
- ****To be clear, your experiment data is in a separate file that you will put into R****

Data Frames

- Used for storing variables of equal length.
- In Excel, you would call this a “spreadsheet”.
- Many researchers might simply call this “data”.

Data Frames

	name	height	mass	gender	homeworld	species
1	Luke Skywalker	172	77.0	male	Tatooine	Human
2	C-3PO	167	75.0	NA	Tatooine	Droid
3	R2-D2	96	32.0	NA	Naboo	Droid
4	Darth Vader	202	136.0	male	Tatooine	Human
5	Leia Organa	150	49.0	female	Alderaan	Human
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8	Han Solo	180	80.0	male	Corellia	Human
9	Yoda	66	17.0	male	NA	Yoda's species
10	Boba Fett	183	78.2	male	Kamino	Human

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Data Frames

The way to create a data.frame:

- `data.frame()`

Exercise

Create a data.frame named **workshop**.

- Variables:
 - **sub**: “Subject##”
 - **tk**: T/F
 - **cty**: ##
 - **pt**: “dog” vs. “ant”



≡ CLICKHOLE

Are You A Dog Person Or An Ant Person?



OBJECTS

Object

- A basic concept in (statistical) programming is called an **object**.
- An object allows you to store a value or a thing in R.
- You use the object's name to easily access this value or thing.

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9	Yoda	66	17.0	male	NA	Yoda's species
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Object

pi

```
[1] 3.141593
```

Referencing objects

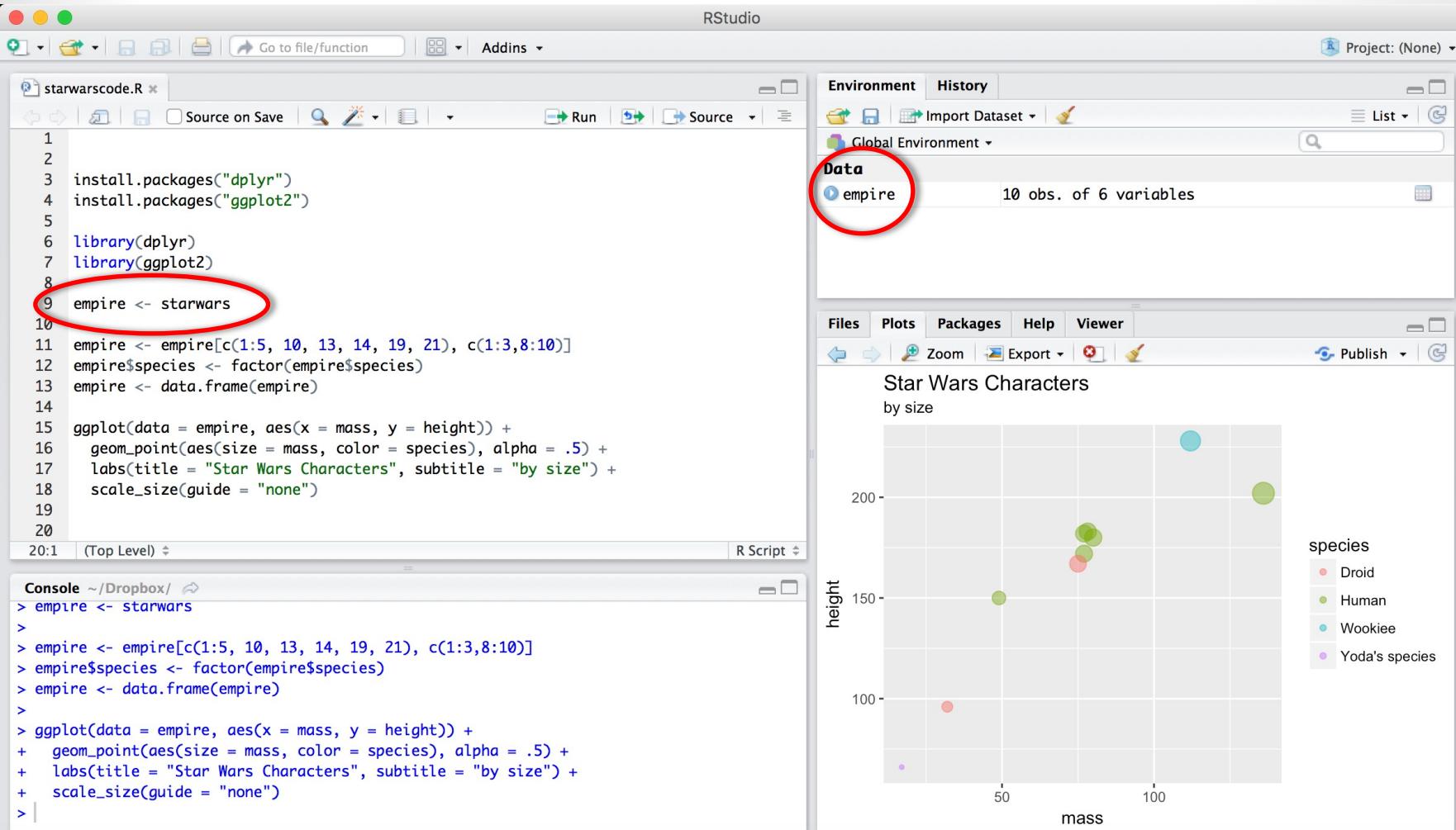
If you want to use an object later on, you have to name it.

```
my_object = thingtoassign
```

```
my_object <- thingtoassign
```

```
Ex) pi <- 3.141593
```

WE RECOMMEND USING THE SECOND WAY!

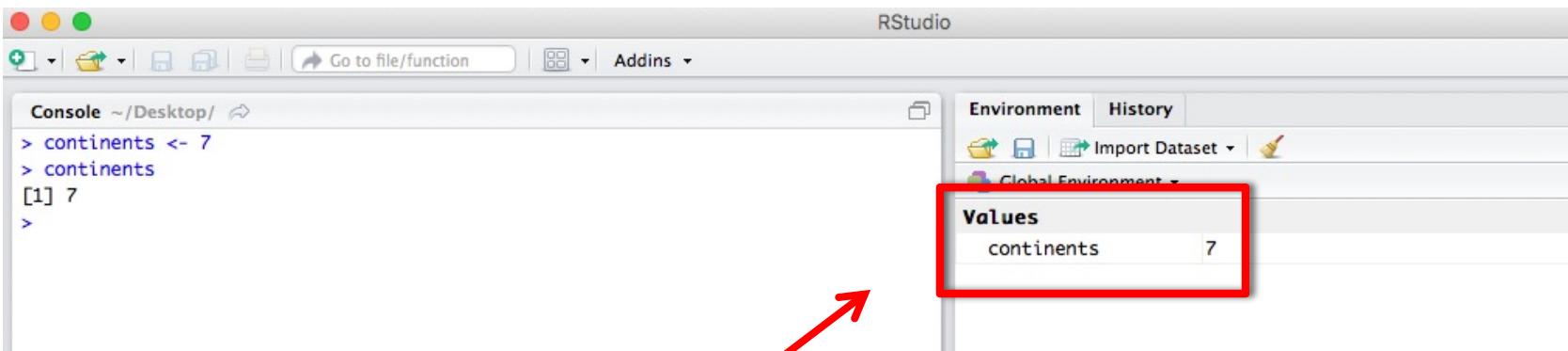


- **Objects** can be used later!
- You can see them in your **Global Environment**.

Exercise

Try creating your own object!

1. In the console, assign the number **7** to **continents**
2. Then type **continents** in the console to print out the assigned value



The screenshot shows the RStudio interface. The console pane on the left contains the following R code and output:

```
> continents <- 7
> continents
[1] 7
```

The environment pane on the right shows a table with one row:

Values	continents	7
--------	------------	---

A red arrow points from the text "Look! Your environment has stored your object!" to the "Values" column of the environment pane.

Look!
Your environment has
stored your object!

BONUS: What is the difference between typing in the console or in a script file?

Exercise

Now, let's try adding together two objects.

In your script:

- Assign the value of **5** to an object called **chickens**.
- Assign the value of **4** to an object called **cows**.
- Give the command **chickens + cows** to find out how many animals you have!
- **BONUS: where is your answer stored?**

Basic Object Classes

Numeric: Decimals (3.141593)

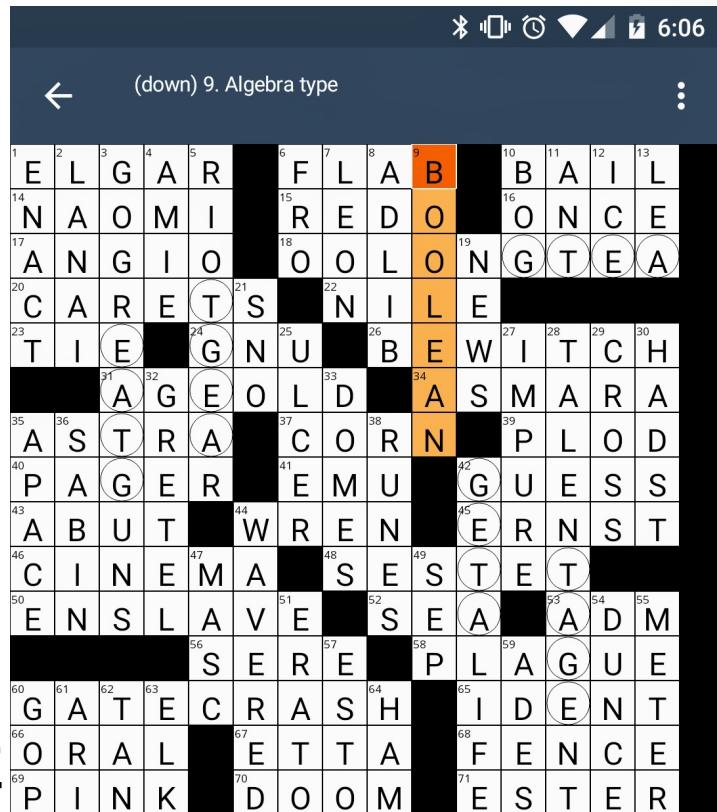
Integer: Natural numbers (0, 1, 2...)

Character: Text or string characters

- Always inside quotations.
- **Factors** (or categories. TBC...)

Logical: Boolean values (True or False)

- No quotations.
- 2 possible values: **TRUE** or **FALSE**



Factors

Character objects

- Compare factors to categorical variables
- Character strings represent distinct groups.
 - Control, Treatment
 - Dog, Ant

Basic Data Class

To check what data class your object is, you can type `class()` into the console.

```
class(cty)
[1] "numeric"
```

Vectors

A group of objects is a **vector**.

Vectors are ONE-DIMENSIONAL.

Vectors

	name	height	mass	gender	homeworld	species
1	Luke Skywalker	172	77.0	male	Tatooine	Human
2	C-3PO	167	75.0	NA	Tatooine	Droid
3	R2-D2	96	32.0	NA	Naboo	Droid
4	Darth Vader	202	136.0	male	Tatooine	Human
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Vectors

	name	height	mass	gender	homeworld	species
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Indexing

Having a group of objects is great, but sometimes you only want one or a few of those objects.

How do we ACCESS our data?

Indexing a vector

To index a vector

- []

For example, how many cities has the **3rd** person been to?

- `cty[3]`

Indexing

You can select multiple objects within a vector

To select objects that are sequential (in a row):

- `cty[3:5]`
- You can think of `:` as “through”
 - `[3:5]` = “three through five”

To select objects that are not in a row:

- `cty[c(1,2,5)]`

Indexing

You can go crazy and combine these!

- `cty[c(1:3, 5)]`

Indexing

Data frames can be indexed just like vectors

EXCEPT: data frames have **2** dimensions

- Rows and columns

Indexing data frames

`data.frame[rows, columns]`

Ex: `empire[1:6, 5]`

`> empire`

		name	height	mass	gender	homeworld	species
1	Luke	Skywalker	172	77.0	male	Tatooine	Human
2		C-3PO	167	75.0	<NA>	Tatooine	Droid
3		R2-D2	96	32.0	<NA>	Naboo	Droid
4		Darth Vader	202	136.0	male	Tatooine	Human
5		Leia Organa	150	49.0	female	Alderaan	Human
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7		Chewbacca	228	112.0	male	Kashyyyk	Wookiee
8		Han Solo	180	80.0	male	Corellia	Human
9		Yoda	66	17.0	male	<NA>	Yoda's species
10	Boba	Fett	183	78.2	male	Kamino	Human

Indexing data frames

empire[1:6,]

**If you want all of something, leave it blank.

```
Console ~/Dropbox/ 
> empire[1:6, ]
      name height mass gender homeworld species
1 Luke Skywalker    172   77 male  Tatooine Human
2        C-3P0     167   75 <NA>  Tatooine Droid
3       R2-D2      96   32 <NA>    Naboo Droid
4   Darth Vader    202  136 male  Tatooine Human
5   Leia Organa    150   49 female Alderaan Human
6 Obi-Wan Kenobi   182   77 male  Stewjon Human
```

Finding Your Data

Most of the time, your data are stored in a `data.frame`...

...BUT you're not doing something with the entire `data.frame`.

In a `data.frame`, our **columns** have names—we can use these names instead of memorizing what the column number is!

You can access just one column at a time by using `$`

Finding Your Data

\$ means you are accessing just one column within your data frame

Console ~/Dropbox/ ⌂

```
> empire
```

		name	height	mass	gender	homeworld	species
1	Luke	Skywalker	172	77.0	male	Tatooine	Human
2		C-3PO	167	75.0	<NA>	Tatooine	Droid
3		R2-D2	96	32.0	<NA>	Naboo	Droid
4	Darth	Vader	202	136.0	male	Tatooine	Human
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7		Chewbacca	228	112.0	male	Kashyyyk	Wookiee
8		Han Solo	180	80.0	male	Corellia	Human
9		Yoda	66	17.0	male	<NA> Yoda's species	species
10	Boba	Fett	183	78.2	male	Kamino	Human

Console ~/Dropbox/ ⌂

```
> empire$height
```

```
[1] 172 167 96 202 150 182 228 180 66 183
```

BONUS: What's an alternative way we could access the entire "height" vector using only numbers?

A NOTE ON ACCESSING DATA

Sometimes (*like now!*), objects can exist in two places in your environment:

- Values
 - You'll see **PT** here, too!
- Data
 - Click on the arrow next to **workshop** → you'll see **personType**

Once your data has a “home”, always use its “address”. We refer to this as “calling” a variable from your data frame.

Ex) If I wanted to use my “dog vs. ant person” variable, I could type:

PT – like yelling **KENDRA** (loudly) in the middle of a busy street to try and get a hold of my friend. Any random person could walk up.

workshop\$personType – like knocking on my friend Kendra’s front door if I want to talk to her.

ACTING ON VARIABLES

Acting on variables

In the previous section, we talked about objects and data sets.

Now let's do something with them!

Actions

- Operators
- Functions

Operators

An **operator** is a simple calculation.

Operators

- + addition
- subtraction
- * multiplication
- / division
- ^ taking powers

Order of Operations

Important note: Order of operations matters!

$$(8-4)/2$$

[1] 2

$$8-(4/2)$$

[1] 6

PEMDAS, anyone?

Logical Operators

`==`

equality

`!=`

inequality

`>`

greater than

`>=`

greater than or equal to

`<`

less than

`<=`

less than or equal to

Logical Operators

- Return a value of **TRUE** or **FALSE**
- `workshop$personType == "ant"`

Example

- Test whether `cities` is greater than 2.

Logical Operators

Has anyone in our data.frame lived in more than 2 cities?

```
workshop$cities > 2
```

Has anyone in our data.frame lived in exactly 2 cities?

```
workshop$cities == 2
```

```
workshop$cities = 2
```

→ **WARNING:** a SINGLE equals sign will change your data!

ACTING ON VARIABLES: FUNCTIONS

Functions

- Sometimes, you want to do more than add or multiply variables.
- To perform more complicated actions, use *functions*.
 - Functions are commands that describe, manipulate or analyze objects.

Functions have three parts

1. Function name

- Ex: *log(10)*

[1] 2.302

Each function has one and only one name.

2. Arguments

- Ex: *log(10)*

[1] 2.302

3. Output

- Ex: *log(10)*

[1] 2.302

Functions have three parts

1. Function name

- Ex: `log(10)`
[1] 2.302

One argument is always specified: the input. This is the object that the function acts on.

2. Arguments

- Ex: `log(10)`
[1] 2.302

Other arguments control **how** the function acts. For example, do you want the natural log? Or log base 10?

3. Output

- Ex: `log(10)`
[1] 2.302

Each function has defaults for its arguments. You should know what those are and how to change them.

Functions have three parts

1. Function name

- Ex: `log(10)`
`[1] 2.302`

Output can be a:

number/integer
a TRUE/FALSE statement
a character value
all of the above

2. Arguments

- Ex: `log(10)`
`[1] 2.302`

Output can be a:

single value
vector
data frame
matrix
list

3. Output

- Ex: `log(10)`
`[1] 2.302`

You can store the output by
assigning it to another object!

Mathematical functions

<code>sqrt()</code>	square root
<code>round()</code>	round a number
<code>log()</code>	logarithm
<code>exp()</code>	exponentiation
<code>abs()</code>	absolute value

Example

1. Find the square root of 85.
2. Take the log of 100.

Example

```
sqrt(85)
```

```
[1] 9.219544
```

```
log(100)
```

```
[1] 4.60517
```

Functions you'll use a lot!

`c()` – combine or concatenate

`class()` – check the class of an object

`factor()` – change a character vector into a factor vector (is there meaning? Ex: Treatment vs. Control, Male vs. Female, Session 1 vs. Session 2)

`table()` – really nice for getting quick counts (Ex: how many males and females are there?)

Exercise

Get the `mean()` of the everyone's # of `cities` visited in our `workshop` data.frame.

What is the name of the function?

What is the input argument?

What is the output?

Multiple arguments

Most functions take more than one argument.

Separate arguments with commas.

```
round (x = 5.86921, digits = 3)  
[1] 5.869
```



Number that
needs to be
rounded.

Multiple arguments

Most functions take more than one argument.

Separate arguments with commas.

```
round (x = 5.86921, digits = 3)  
[1] 5.869
```



Number of digits
to round to.

Arguments have Names

Most arguments in functions have names.

USE THE NAMES!!!

```
round (x = 5.86921, digits = 3)  
[1] 5.869
```

Exercise

1. Use the `seq()` function to list numbers `0` to `100`.

Arguments:

- `from` = starting value of sequence
- `to` = end value of sequence

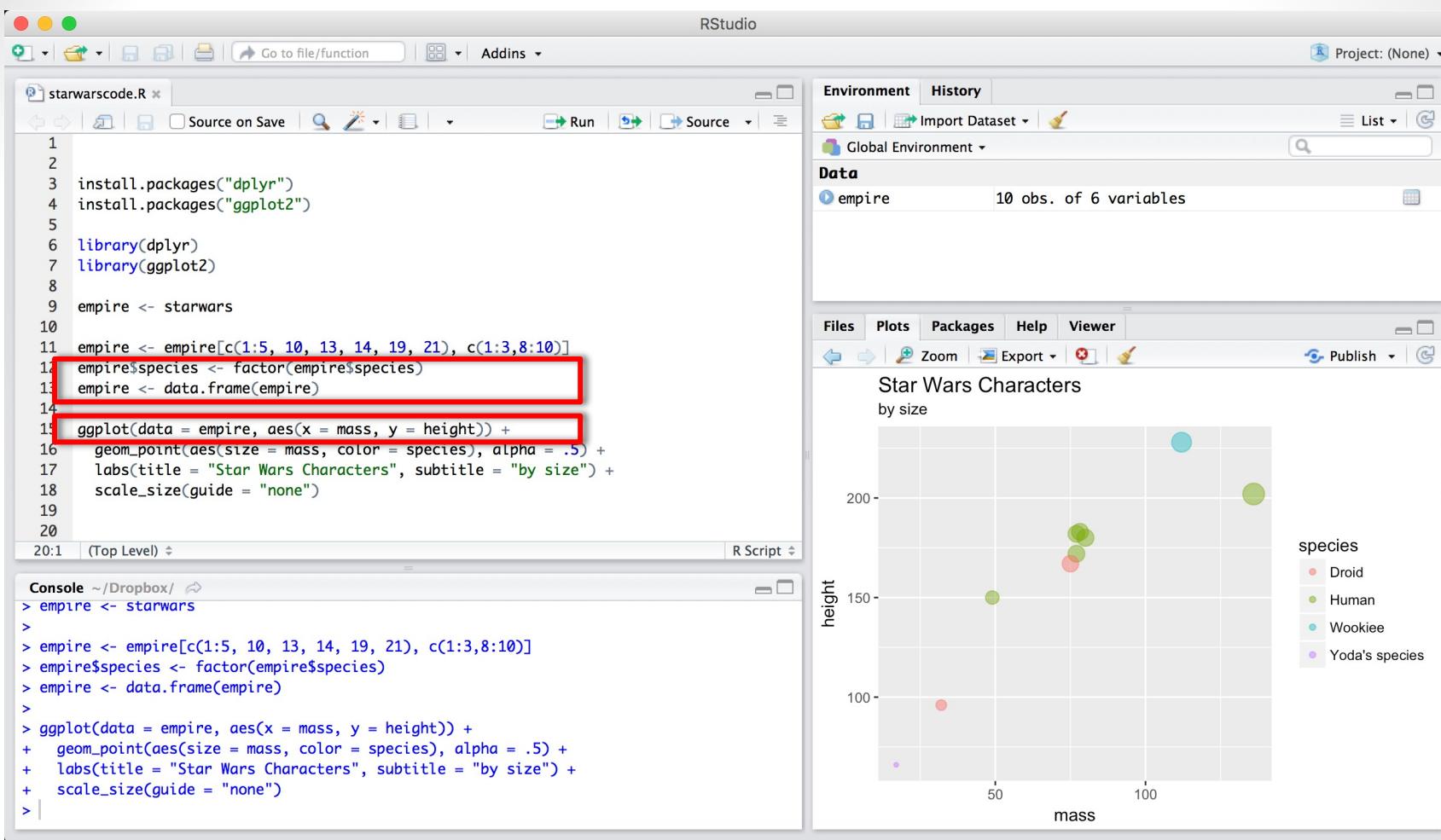
2. Use the `seq()` function to list numbers `0` to `100`, by intervals of `10`.

Arguments:

- `from` = starting value of sequence
- `to` = end value of sequence
- `by` = increment of the sequence

Exercise

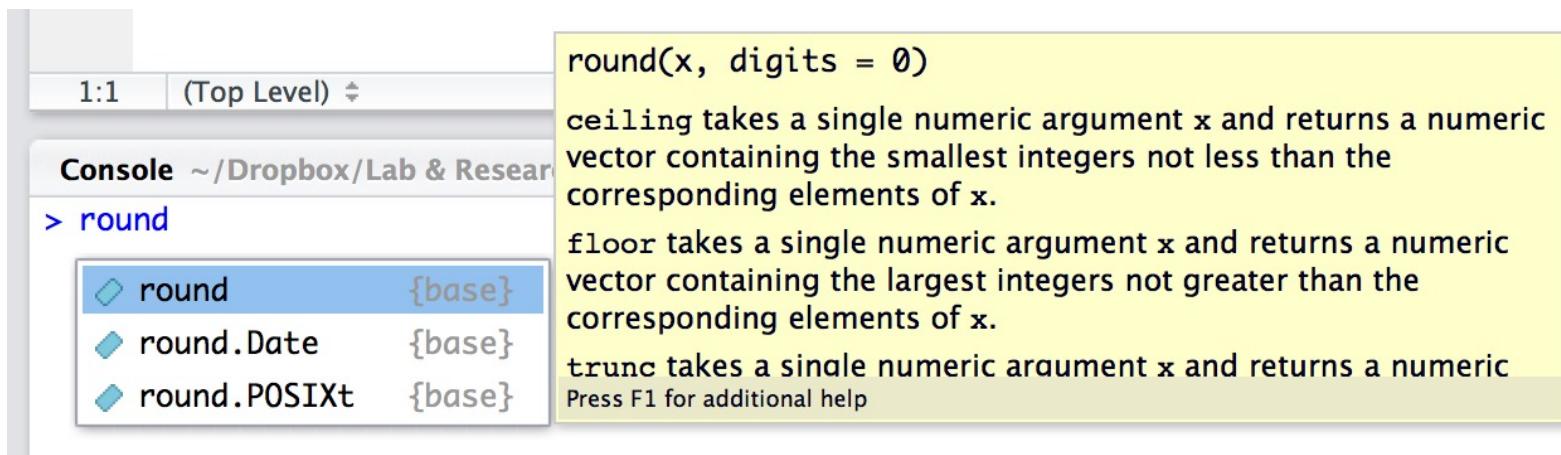
1. Use the `seq()` function to list numbers 0 to 100
 - `seq(from = 0, to = 100)`
2. Use the `seq()` function to list numbers 0 to 100, by intervals of 10
 - `seq(from = 0, to = 100, by = 10)`



Great, but how do I know what the arguments are for a function?

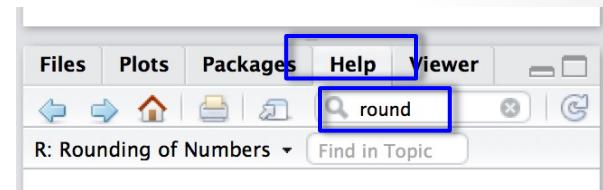
Two ways:

- 1) In RStudio, press the **tab** key to see names of arguments and descriptions.



2) Look in the R documentation!

- Go to Help tab
- Or just type `?round` into the console



The screenshot shows the R Documentation window for the 'Round' function from the 'base' package. The title bar says 'R: Rounding of Numbers'. The main content area is titled 'Rounding of Numbers' and includes sections for 'Description', 'Usage', and 'Details'. The 'Description' section contains several paragraphs explaining the functions ceiling, floor, trunc, round, and signif. The 'Usage' section lists the syntax for each function.

Description

`ceiling` takes a single numeric argument `x` and returns a numeric vector containing the smallest integers not less than the corresponding elements of `x`.

`floor` takes a single numeric argument `x` and returns a numeric vector containing the largest integers not greater than the corresponding elements of `x`.

`trunc` takes a single numeric argument `x` and returns a numeric vector containing the integers formed by truncating the values in `x` toward 0.

`round` rounds the values in its first argument to the specified number of decimal places (default 0).

`signif` rounds the values in its first argument to the specified number of significant digits.

Usage

```
ceiling(x)
floor(x)
trunc(x, ...)
```

You try!

Type code to look up the R documentation for the correlation function, `cor`

`?cor`

R: Correlation, Variance and Covariance (Matrices)

cor {stats}

R Documentation

Correlation, Variance and Covariance (Matrices)

Description

`var`, `cov` and `cor` compute the variance of `x` and the covariance or correlation of `x` and `y` if these are vectors. If `x` and `y` are matrices then the covariances (or correlations) between the columns of `x` and the columns of `y` are computed.

`cov2cor` scales a covariance matrix into the corresponding correlation matrix *efficiently*.

Usage

```
var(x, y = NULL, na.rm = FALSE, use)

cov(x, y = NULL, use = "everything",
     method = c("pearson", "kendall", "spearman"))

cor(x, y = NULL, use = "everything",
     method = c("pearson", "kendall", "spearman"))

cov2cor(V)
```

Arguments

`x` a numeric vector, matrix or data frame.

`y` `NULL` (default) or a vector, matrix or data frame with compatible dimensions to `x`. The default is equivalent to `y = x` (but more efficient).

`na.rm` logical. Should missing values be removed?

`use` an optional character string giving a method for computing covariances in the presence of missing values. This must be (an abbreviation of) one of the strings `"everything"`, `"all.obs"`, `"complete.obs"`, `"na.or.complete"`, or `"pairwise.complete.obs"`.

`method` a character string indicating which correlation coefficient (or covariance) is to be computed. One of `"pearson"` (default), `"kendall"`, or `"spearman"`, can be abbreviated.

`V` symmetric numeric matrix, usually positive definite such as a covariance matrix.

Details

For `cov` and `cor` one must *either* give a matrix or data frame for `x` or give both `x` and `y`.

The inputs must be numeric (as determined by `is.numeric`; logical values are also allowed for historical compatibility): the `"kendall"` and `"spearman"` methods make sense for ordered inputs but `xtfrm` can be used to find a suitable prior transformation to numbers.

`var` is just another interface to `cov`, where `na.rm` is used to determine the default for `use` when that is unspecified. If `na.rm` is TRUE then the complete observations (rows) are used (`use = "na.or.complete"`) to compute the variance. Otherwise, by default `use = "everything"`.

If `use` is `"everything"`, `NA`s will propagate conceptually, i.e., a resulting value will be `NA` whenever one of its contributing observations is `NA`.

```
cor {stats}
```

Correlation, Variance and Covariance (Matrices)

Description

`var`, `cov` and `cor` compute the variance of `x` and the covariance or correlation of `x` and `y` if these are vectors. If `x` and `y` are matrices then the covariances (or correlations) between the columns of `x` and the columns of `y` are computed.

`cov2cor` scales a covariance matrix into the corresponding correlation matrix *efficiently*.

Usage

```
var(x, y = NULL, na.rm = FALSE, use)

cov(x, y = NULL, use = "everything",
     method = c("pearson", "kendall", "spearman"))

cor(x, y = NULL, use = "everything",
     method = c("pearson", "kendall", "spearman"))

cov2cor(V)
```

Arguments

- `x` a numeric vector, matrix or data frame.
- `y` `NULL` (default) or a vector, matrix or data frame with compatible dimensions to `x`. The default is equivalent to `y = x` (but more efficient).
- `na.rm` logical. Should missing values be removed?
- `use` an optional character string giving a method for computing covariances in the presence of missing values. This must be (an abbreviation of) one of the strings `"everything"`, `"all.obs"`, `"complete.obs"`, `"na.or.complete"`, or `"pairwise.complete.obs"`.
- `method` a character string indicating which correlation coefficient (or covariance) is to be computed. One of `"pearson"` (default), `"kendall"`, or `"spearman"`, can be abbreviated.
- `V` symmetric numeric matrix, usually positive definite such as a covariance matrix.

Details

For `cov` and `cor` one must either give a matrix or data frame for `x` or give both `x` and `y`.

The inputs must be numeric (as determined by [is.numeric](#): logical values are also allowed for historical compatibility): the "kendall" and "spearman" methods make sense for ordered inputs but [xtfrm](#) can be used to find a suitable prior transformation to numbers.

Value

For `r <- cor(*, use = "all.obs")`, it is now guaranteed that `all(r <= 1)`.

Examples

```
var(1:10) # 9.166667  
  
var(1:5, 1:5) # 2.5  
  
## Two simple vectors  
cor(1:10, 2:11) # == 1  
  
## Correlation Matrix of Multivariate sample:  
(C1 <- cor(longley))  
## Graphical Correlation Matrix:  
symnum(C1) # highly correlated
```

Exercise

1. Look up documentation for `scale` and `plot`.
2. Using the `height` variable from our `empire` data.frame, make a new variable called `height_z`, using `scale`.
3. Do the same thing for `mass`.
4. Combine `height_z` vector and `mass_z` vector into a new data.frame called `empire_z`.
5. Make a scatter plot of standardized height (*hint: y-axis*) by standardized mass, using the `plot` function.
6. Add a title to your plot.
7. Add labels to the x and y axes.

What happens if you add
`type = "l"`?

What is the default for type?

REMOVE ~~POST-ITS~~ REACTIONS!!



(and save!)

PACKAGES

Packages

R automatically loads some basic functions

- Generally useful!
- But sometimes, maybe you want something better.

Packages

What is a package?

- A collection of functions and datasets.
- Open source (free!)

Packages are the reason R is so powerful.

- And why it will never be out-of-date.

Files Plots **Packages** Help Viewer

Install Update

Name Description Version

User Library

<input type="checkbox"/> abind	Combine multi-dimensional arrays	1.4-0	
Name	Description	Version	
<input type="checkbox"/> Amelia	Amelia II: A Program for Missing Data	1.7.2	
<input type="checkbox"/> arm	Data Analysis Using Regression and Multilevel/Hierarchical Models	1.7-07	
<input type="checkbox"/> assertthat	Easy pre and post assertions.	0.1	
<input type="checkbox"/> BH	Boost C++ header files	1.54.0-4	
<input type="checkbox"/> bitops	Bitwise Operations	1.0-6	
<input type="checkbox"/> car	Companion to Applied Regression	2.0-21	
<input type="checkbox"/> caTools	Tools: moving window statistics, GIF, Base64, ROC AUC, etc.	1.17.1	
<input type="checkbox"/> cluster	Cluster Analysis Extended Rousseeuw et al.	1.15.3	
<input type="checkbox"/> coda	Output analysis and diagnostics for MCMC	0.16-1	
<input type="checkbox"/> colorspace	Color Space Manipulation	1.2-4	
<input type="checkbox"/> DBI	R Database Interface	0.3.1	
<input type="checkbox"/> DEoptimR	Differential Evolution Optimization in pure R	1.0-2	
<input type="checkbox"/> dichromat	Color Schemes for Dichromats	2.0-0	
<input type="checkbox"/> digest	Create cryptographic hash digests of R objects	0.6.4	
<input type="checkbox"/> diptest	Hartigan's dip test statistic for unimodality - corrected code	0.75-5	
<input type="checkbox"/> dplyr	A Grammar of Data Manipulation	0.3.0.2	
<input type="checkbox"/> evaluate	Parsing and evaluation tools that provide more details than the default.	0.5.5	
<input type="checkbox"/> flexmix	Flexible Mixture Modeling	2.3-12	
<input type="checkbox"/> foreach	Foreach looping construct for R	1.4.2	
<input type="checkbox"/> formatR	Format R Code Automatically	1.0	
<input type="checkbox"/> gridExtra	Facilities for "arranging" R <i>grid</i> objects side-by-side or above/below one another.	2.1.0	

Files Plots Packages Help Viewer

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Files Plots Packages Help Viewer

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File Plots Packages Help Viewer

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		2.1.0	

How do I get packages?

Packages can be downloaded from the CRAN
(Comprehensive R Archive Network).

You do this from inside R!

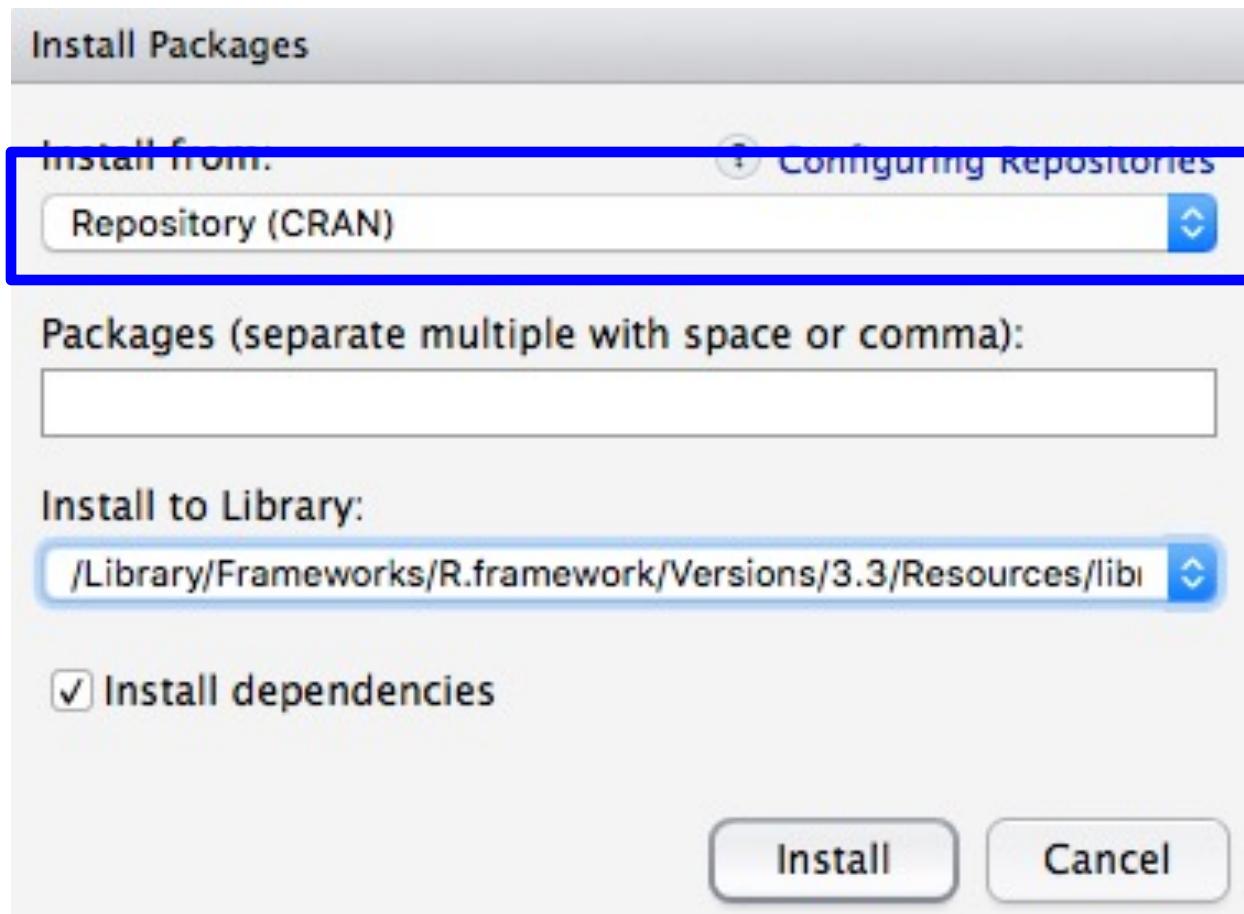
- Need to be connected to the internet

2 ways to install packages

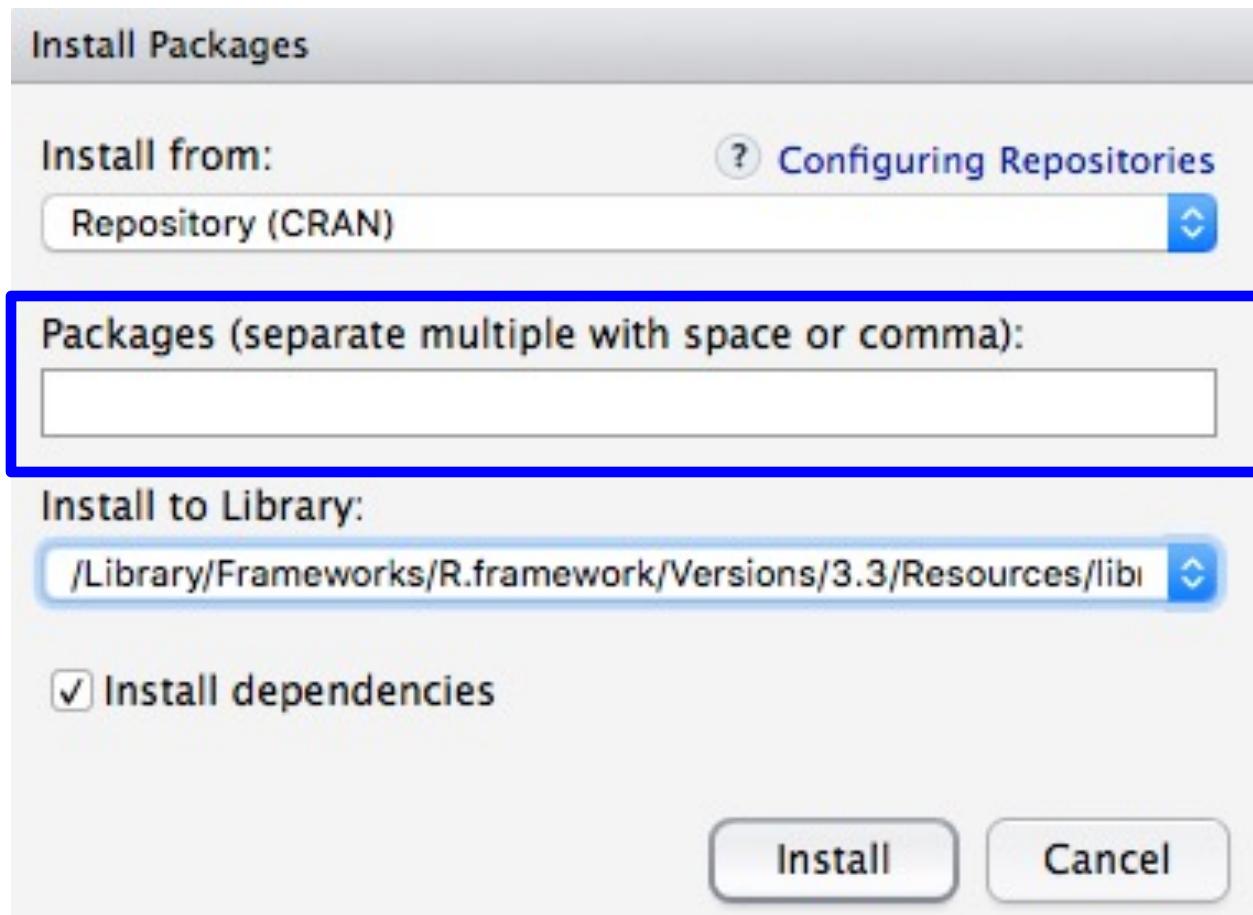
- 1) Install button in the Packages window
- 2) R Code

Either way, you'll need to know the name of the package.

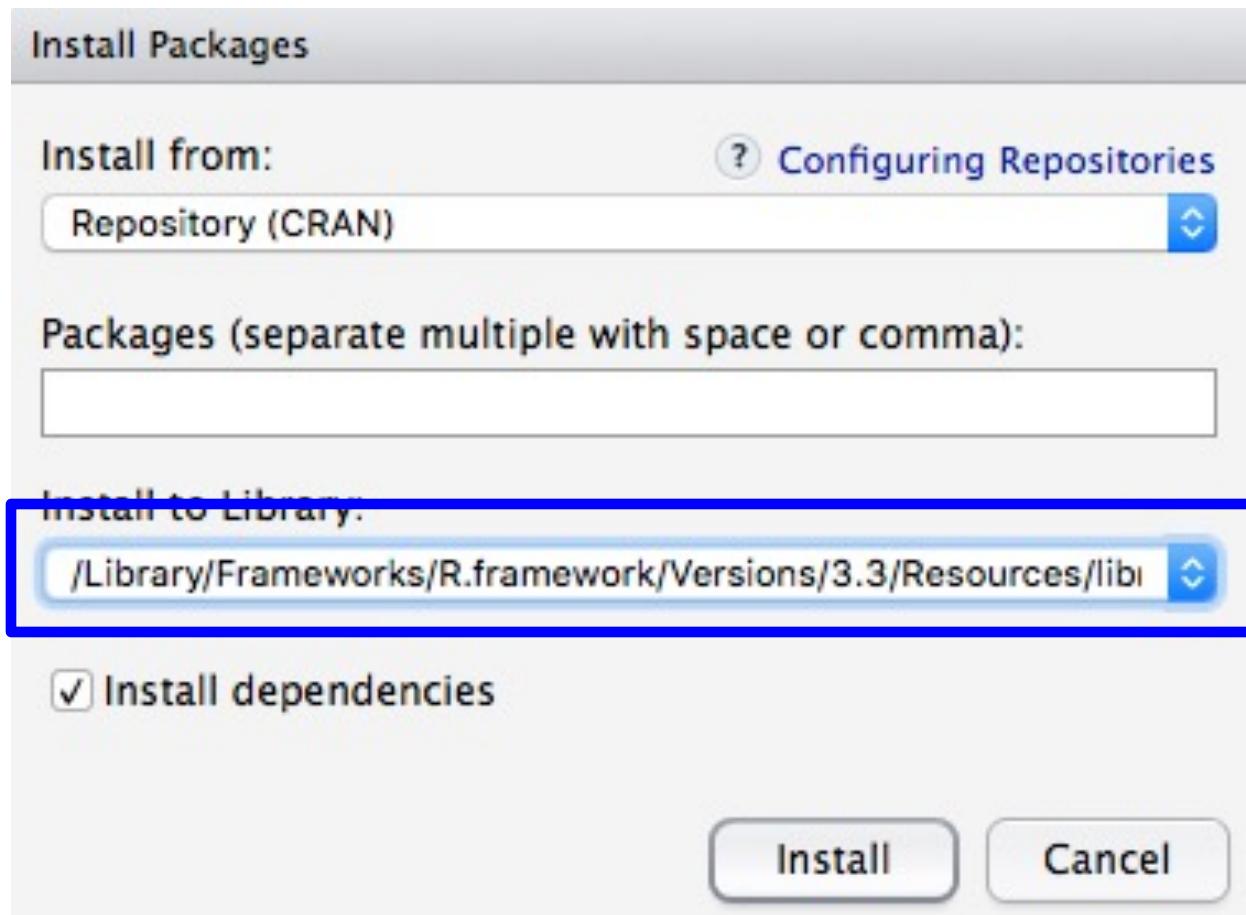
Install Button



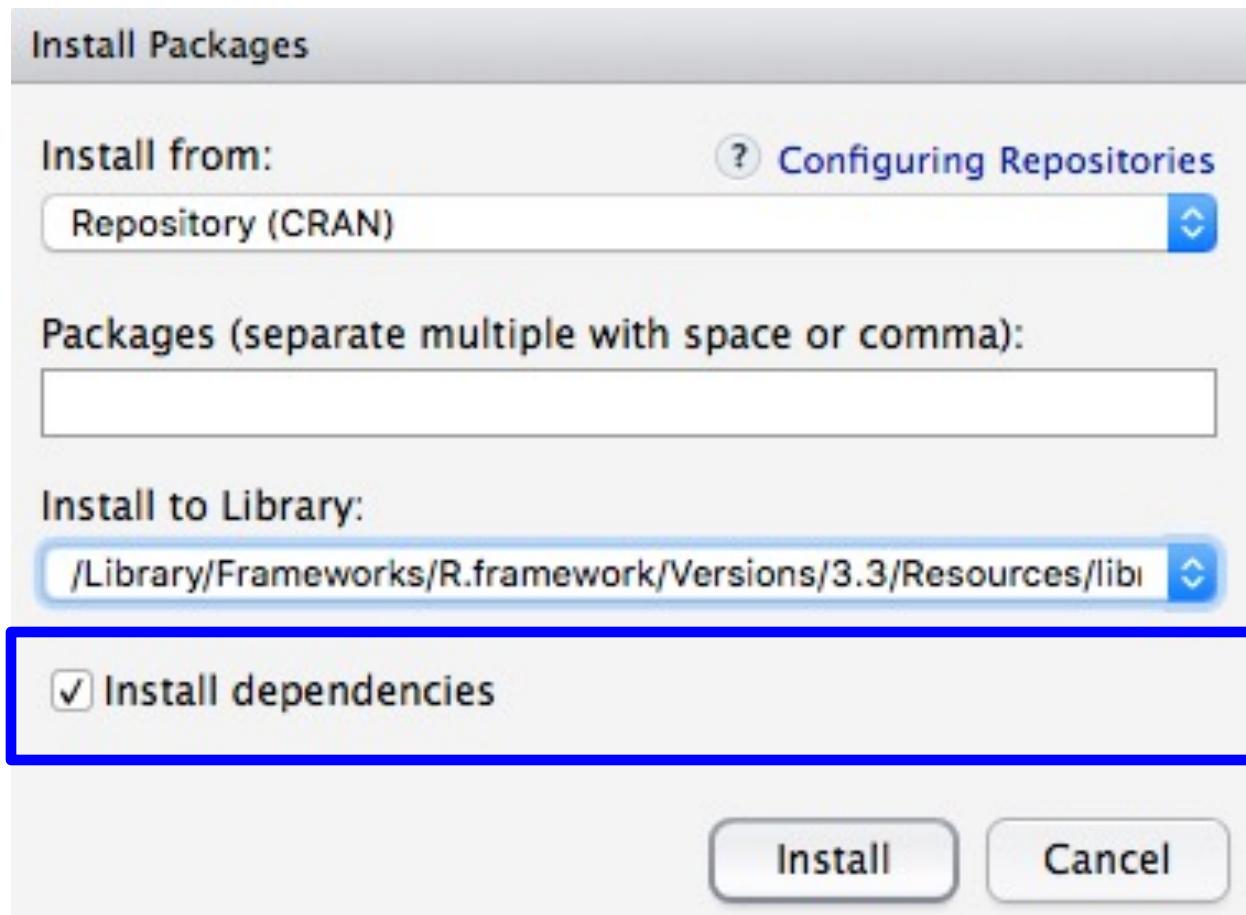
Install Button



Install Button



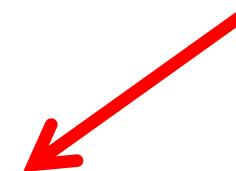
Install Button



R Code to Install Packages

```
install.packages("psych")
```

Note the
quotation
marks!



Packages

INSTALLING

- Downloading the package and saving it to your computer.
- The package is available for use.
- Do this ONCE

LOADING

- Calling the package from your computer and reading its contents.
- R is ready to use the functions in the package.
- Do this EVERY TIME you open an R session

2 ways to load packages

- 1) Checkbox in the Packages window
- 2) R Code

Either way, you'll need to know the name of the package.

Highly recommend option (2)

Files Plots Packages Help Viewer

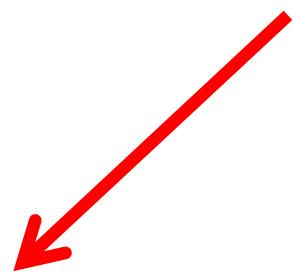
Install Update

Name Description Version

Name	Description	Version
<input type="checkbox"/> mgcv	Mixed GAM Computation Vehicle with GCV/AIC/REML Smoothness Estimation	1.8-14
<input type="checkbox"/> mnormt	The Multivariate Normal and t Distributions	1.5-4
<input type="checkbox"/> multilevel	Multilevel Functions	2.6
<input type="checkbox"/> munsell	Utilities for Using Munsell Colours	0.4.3
<input type="checkbox"/> nlme	Linear and Nonlinear Mixed Effects Models	3.1-128
<input type="checkbox"/> nnet	Feed-Forward Neural Networks and Multinomial Log-Linear Models	7.3-12
<input type="checkbox"/> parallel	Support for Parallel computation in R	3.3.0
<input type="checkbox"/> pbivnorm	Vectorized Bivariate Normal CDF	0.6.0
<input type="checkbox"/> plyr	Tools for Splitting, Applying and Combining Data	1.8.4
<input checked="" type="checkbox"/> psych	Procedures for Psychological, Psychometric, and Personality Research	1.6.6
<input type="checkbox"/> psychometric	Applied Psychometric Theory	2.2
<input type="checkbox"/> quadprog	Functions to solve Quadratic Programming Problems.	1.5-5
<input type="checkbox"/> QuantPsyc	Quantitative Psychology Tools	1.5
<input type="checkbox"/> R6	Classes with Reference Semantics	2.1.3
<input type="checkbox"/> RColorBrewer	ColorBrewer Palettes	1.1-2
<input type="checkbox"/> Rcpp	Seamless R and C++ Integration	0.12.6
<input type="checkbox"/> reshape	Flexibly reshape data.	0.8.5

R Code to Load Packages

Note: NO
quotation
marks!



```
library(psycho)
```

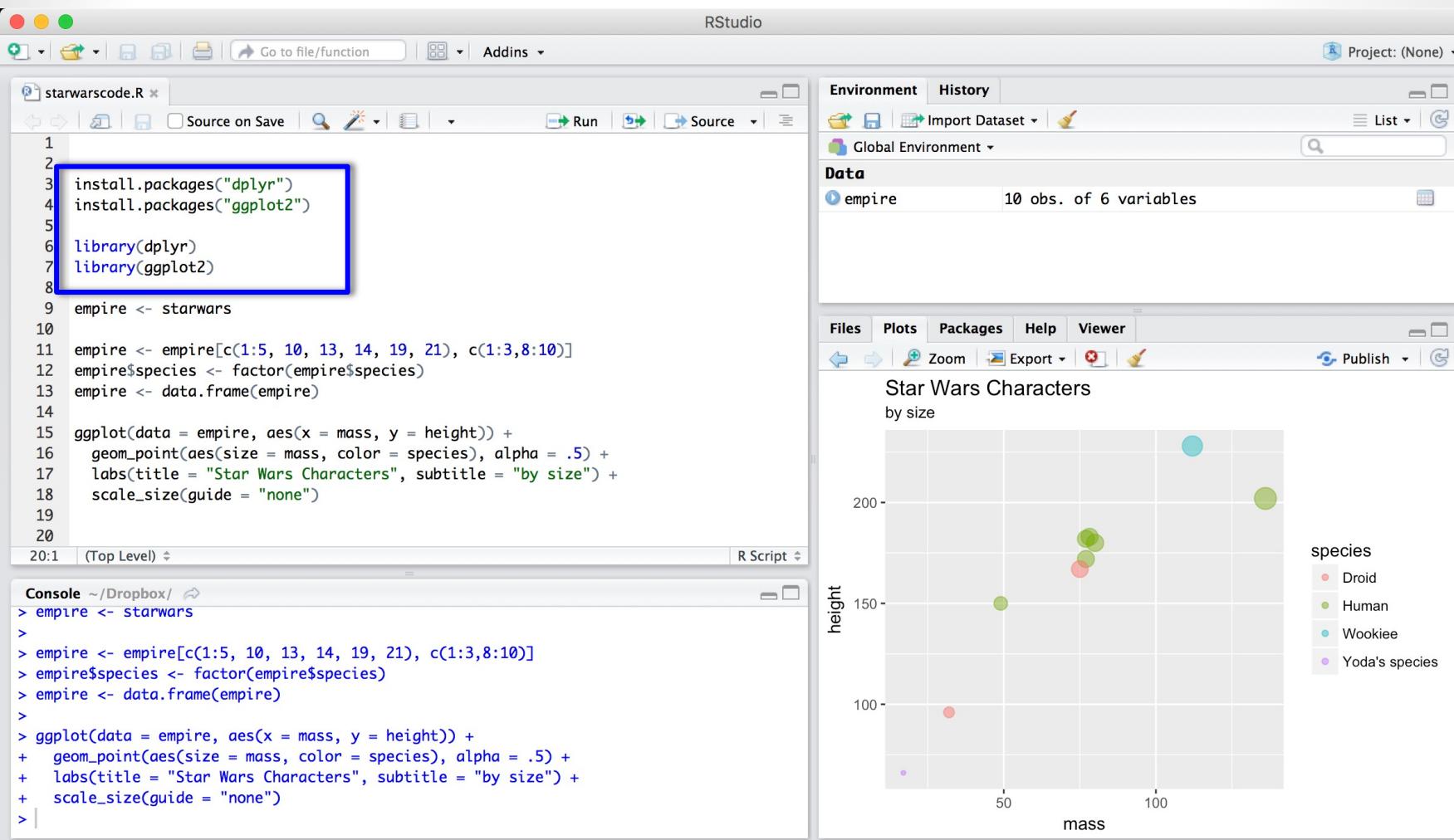
Dependencies

```
> library(lme4)
Loading required package: Matrix
Loading required package: Rcpp
```

Uses functions from another packages.

Installed automatically.

Loaded automatically.



Exercise

1) Check your **Packages** tab to see if the following three packages are listed there:

- psych
- tidyr
- lsr
- If NO, proceed to Step 2! If YES, put up your HAND .

2) INSTALL the above three packages.

3) LOAD the above three packages.

Remember:

- **Need quotes** to install. **No quotes** to load.
- **Install** in console. **Load** in script.
- Spelling and capitalization matter.

```
install.packages("psych")
install.packages("lsr")
install.packages("tidyverse")
```

```
library(psych)
library(lsr)
library(tidyverse)
```

Help! (again)

Ways to find documentation:

`?psych` – opens documentation specific to that package or function

`??psych` – searches for this in all documentation

**Only looks in documentation for packages you have installed and loaded.

To find a package that does what you need: Google ☺

Help! (again)

To find functions available in a package:

In the packages tab, click on the name of the package to see what functions are available!

DIRECTORIES

Directories

Your computer is made up of a series of folders.

The screenshot shows a Mac desktop environment. On the left, there's a sidebar with 'Favorites' (Macintosh HD, Google Drive, Downloads, Recents, AirDrop, Dropbox (Brown), Documents, Applications, Desktop, OneDrive) and 'iCloud' (iCloud Drive). Below that are 'Locations' (Emorie's MacBook Pr..., Macintosh HD, Box, Google Drive, Network) and 'Tags' (report.R34.html, Important). The main area is a file browser with four panes:

- Left pane:** Shows '2019' with 'GitHub' and 'response_...3.19.docx'.
- Second pane:** Shows '2019' with 'age_nets', 'PSC_EMA', and '2018' folder containing 'home', 'net-intervention', 'R-tutorials', 'tmp', and 'Tutorials'.
- Third pane:** Shows 'Today' with 'workshop' and '2019' folder containing 'ALDA', 'anova_regression', 'mlm', 'RA_Files', 'sem', and 'wustl_r_workshops'.
- Right pane:** Shows 'Today' with 'PPT.pptx' selected.

At the bottom of the file browser, it says '1 of 1 selected, 53.79 GB available'. To the right of the file browser is a presentation slide titled 'DIRECTORIES ARE IMPORTANT' by Emorie, Kendra, Maddy, & Violet. The slide features a background of colored dots and text. Below the slide is a file card for 'PPT.pptx':

PPT.pptx
PowerPoint Presentation (.pptx) - 245 KB

Information

Created	Today, 9:04 AM
Modified	Today, 9:04 AM
Last opened	Today, 9:04 AM

At the bottom right are icons for 'cv to intslope' and 'More...'.

Directories

This file path is the directory that contains the file “PPT.pptx”

/Users/emoriebeck/Documents/GitHub/R-tutorials/workshop/PPT.pptx

The screenshot shows a Mac OS X Finder window with four panes. The left pane lists locations like 'Favorites' (Macintosh HD, Google Drive, Downloads, Recents, AirDrop, Dropbox), 'Applications' (Finder, Mail, Safari, etc.), 'Desktop', and 'OneDrive'. The top-right pane shows a folder structure under '2019': 'GitHub' (selected) containing 'Response_...0.10.docx'; 'age_nets', 'PSC_EMA'; and 'R-tutorials' (selected). The bottom-right pane shows a folder structure under 'Today': 'workshop' (selected) containing 'PPT.pptx'; '2019' (ALDA, anova_regression, mlm, RA_Files, sem, wustl_r_workshops); and '2018' (purrr, sampling). The bottom-left pane shows a preview of 'PPT.pptx' with the title 'DIRECTORIES ARE IMPORTANT' and author 'Emorie, Kendra, Maddy, & Violet'. A red box highlights the 'GitHub' folder in the top-right pane, and another red box highlights the 'R-tutorials' folder in the bottom-right pane.

Favorites

- Macintosh HD
- Google Drive
- Downloads
- Recents
- AirDrop
- Dropbox (Brown)
- Documents
- Applications
- Desktop
- OneDrive

iCloud

- iCloud Drive

Locations

- Emorie's MacBook Pr...
- Macintosh HD
- Box
- Google Drive
- Network

Tags

- report.R34.html
- Important

2019

- GitHub
- Response_...0.10.docx
- age_nets
- PSC_EMA

2018

- home
- net-intervention
- R-tutorials
- tmp
- Tutorials

Today

- workshop
- PPT.pptx

2019

- ALDA
- anova_regression
- mlm
- RA_Files
- sem
- wustl_r_workshops

2018

- purrr
- sampling

PPT.pptx
PowerPoint Presentation (.pptx) - 245 KB

Information

Created	Today, 9:04 AM
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cv to intslope More...

Directories

This is the actual file “PPT.pptx”



/Users/emoriebeck/Documents/GitHub/R-tutorials/workshop/PPT.pptx

The screenshot shows a Mac OS X Finder window with three columns. The left column lists locations like 'Macintosh HD', 'Google Drive', 'Downloads', 'Recents', 'AirDrop', 'Dropbox (Brown)', and 'Documents' (which is highlighted with a red box). The middle column shows a folder tree for 'GitHub' (containing 'age_nets', 'PSC_EMA', 'Response_...0.10.docx'), 'R-tutorials' (selected and highlighted with a red box), and 'workshop'. The right column shows files for 'Today' (containing 'workshop' and 'PPT.pptx', with 'PPT.pptx' highlighted with a yellow box) and '2019' (containing 'ALDA', 'anova_regression', 'mlm', 'RA_Files', 'sem', 'wustl_r_workshops', 'purrr', and 'sampling'). On the far right, a preview pane displays a slide from a PowerPoint presentation with the text 'DIRECTORIES ARE IMPORTANT' and 'Emorie, Kendra, Maddy, & Violett'. Below the preview are file details for 'PPT.pptx': 'PowerPoint Presentation (.pptx) - 245 KB', 'Information' section with 'Created', 'Modified', and 'Last opened' all listed as 'Today, 9:04 AM', and a toolbar with icons for 'cv to intslope' and 'More...'.

Favorites

- Macintosh HD
- Google Drive
- Downloads
- Recents
- AirDrop
- Dropbox (Brown)
- Documents**
- Applications
- Desktop
- OneDrive

iCloud

- iCloud Drive

Locations

- Emorie's MacBook Pr...
- Macintosh HD
- Box
- Google Drive
- Network

Tags

- report.R34.html
- Important

2019

GitHub

age_nets

PSC_EMA

Response_...0.10.docx

2018

home

net-intervention

R-tutorials

tmp

Tutorials

Today

workshop

PPT.pptx

2019

ALDA

anova_regression

mlm

RA_Files

sem

wustl_r_workshops

2018

purrr

sampling

DIRECTORIES
ARE
IMPORTANT

Emorie, Kendra, Maddy, & Violett

PPT.pptx

PowerPoint Presentation (.pptx) - 245 KB

Information

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cv to intslope

More...

1 of 1 selected, 53.79 GB available

Setting your working directory

R will only look in one folder to read your files.

Working Directory

- Where R is going to *look for* files
- Where R is going to *save* files

Setting your working directory

`getwd()`

`setwd("/yourpath/goes/here")`

Hint: press tab within the quotes and see what happens

(unimportant bonus info):

In R, `~` points to a very general directory by default. On Macs, this is usually `/Users/YourName`. On PCs, this is `C:/Users/YourName`. If the directory you want is located within this general directory, then you can use the `~` to shorten the file path. Ex:

`setwd("~/goes/here")`

Exercise

1. Create a folder on your desktop for today's R workshop.
2. Set your working directory to that folder
3. Try the `getwd()` function

REMOVE ~~POST~~ ITS REACTIONS!!



(and save!)

TYPES OF FILES

Types of files

.R

Your data

.Rdata

.R files

.R files are text files.

- They contain the code that you've written – the commands that you want R to run.

Equivalent to syntax files in SPSS.

Also called **scripts**.

.R files – why use them?

Keep track of what commands you use.

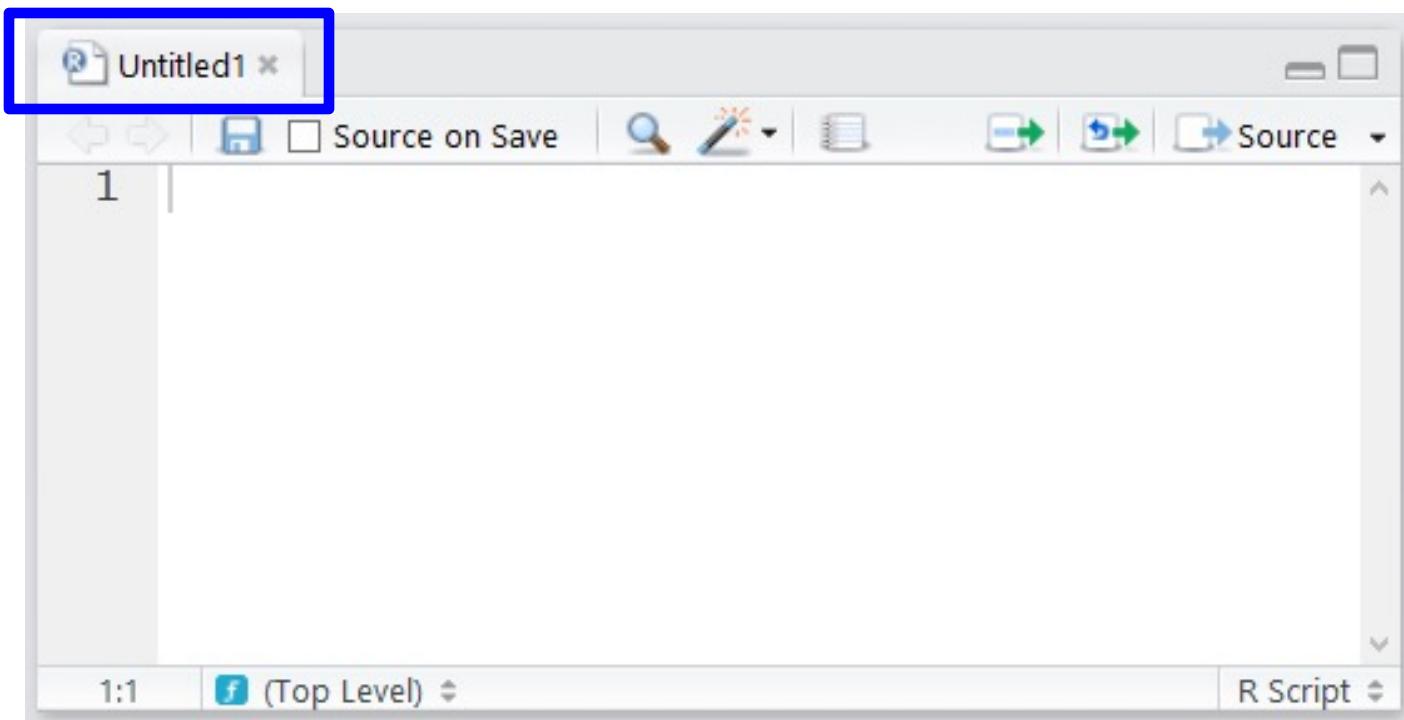
Save only the commands that are useful.

Make notes to yourself!

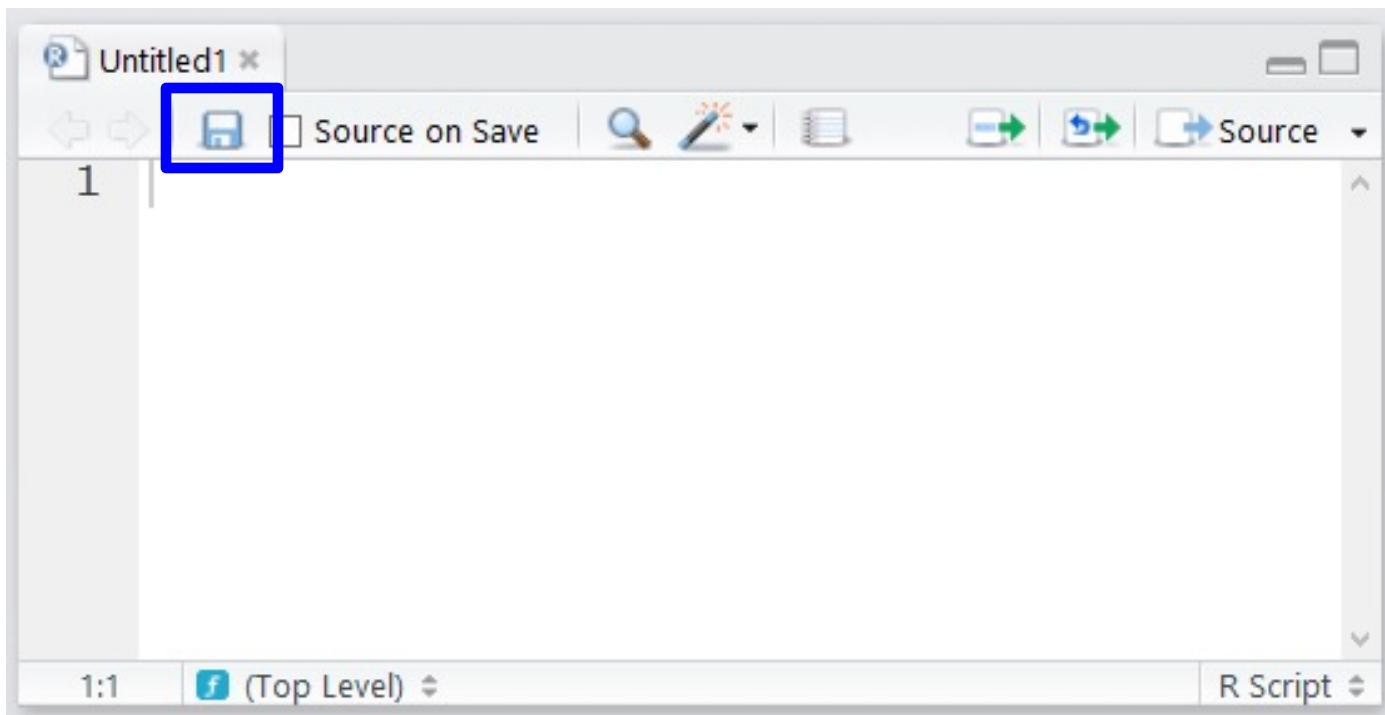
- **#Updated code for R workshop!**
- **#reliability estimates for depression scale**
- **#scatter plot for BMI predicting diabetes diagnosis**

Share your analyses with collaborators and readers.

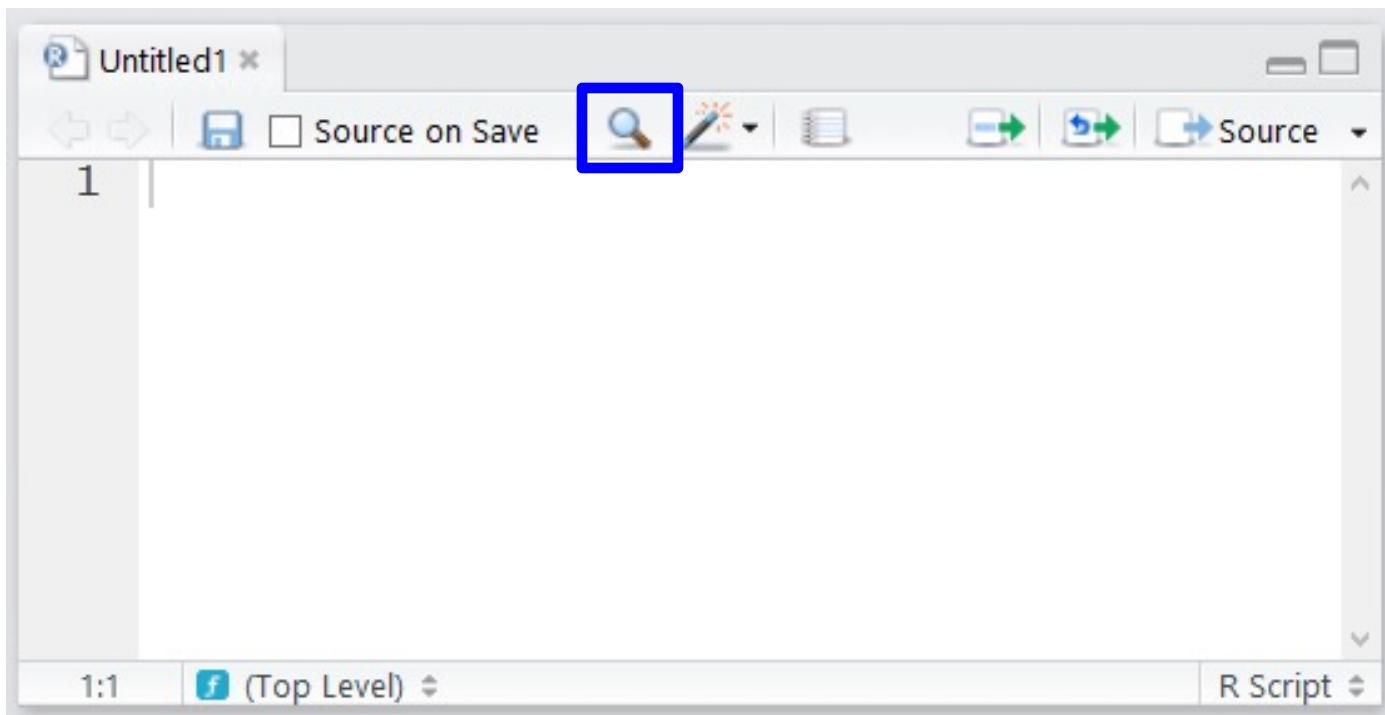
.R files



.R files



.R files



Open your file

Open a file like you would any other document.

How to add things to your .R file

- Type into it!

OR

- Copy over from the History tab.

Environment

History

Presentation *

```
lines(x = c(data[1,c("lb","up")]),y=c(3,3))
lines(x = c(data[2,c("lb","up")]),y=c(2,2))
lines(x = c(data[3,c("lb","up")]),y=c(1,1))
lines(x = c(data[1,c("lb")]), data[1,c("lb")]), y=c(2.9,3.1))
lines(x = c(data[1,c("up")]), data[1,c("up")]), y=c(2.9,3.1))
lines(x = c(data[2,c("lb")]), data[2,c("lb")]), y=c(1.9,2.1))
lines(x = c(data[2,c("up")]), data[2,c("up")]), y=c(1.9,2.1))
lines(x = c(data[3,c("lb")]), data[3,c("lb")]), y=c(0.9,1.1))
lines(x = c(data[3,c("up")]), data[3,c("up")]), y=c(0.9,1.1))
abline(v=0)
axis(1,at = seq(-50,50,10))
text(x = data$x,data$y,c("a","b","c"),pos=3)
a <- c(1,2,3,4,5)
mean(a)
```

Environment

History

Presentation ×



To Console

To Source



```
lines(x = c(data[1,c("lb","up")]),y=c(3,3))
lines(x = c(data[2,c("lb","up")]),y=c(2,2))
lines(x = c(data[3,c("lb","up")]),y=c(1,1))
lines(x = c(data[1,c("lb")]), data[1,c("lb")]), y=c(2.9,3.1))
lines(x = c(data[1,c("up")]), data[1,c("up")]), y=c(2.9,3.1))
lines(x = c(data[2,c("lb")]), data[2,c("lb")]), y=c(1.9,2.1))
lines(x = c(data[2,c("up")]), data[2,c("up")]), y=c(1.9,2.1))
lines(x = c(data[3,c("lb")]), data[3,c("lb")]), y=c(0.9,1.1))
lines(x = c(data[3,c("up")]), data[3,c("up")]), y=c(0.9,1.1))
abline(v=0)
axis(1,at = seq(-50,50,10))
text(x = data$x,data$y,c("a","b","c"),pos=3)
a <- c(1,2,3,4,5)
mean(a)
```

How to run code from your .R file

Highlight the lines that you want to run, then...

- Click on **Run** button

OR

- Ctrl + Enter (Windows)
- Command + Enter (Mac)

Your Data

Original data files

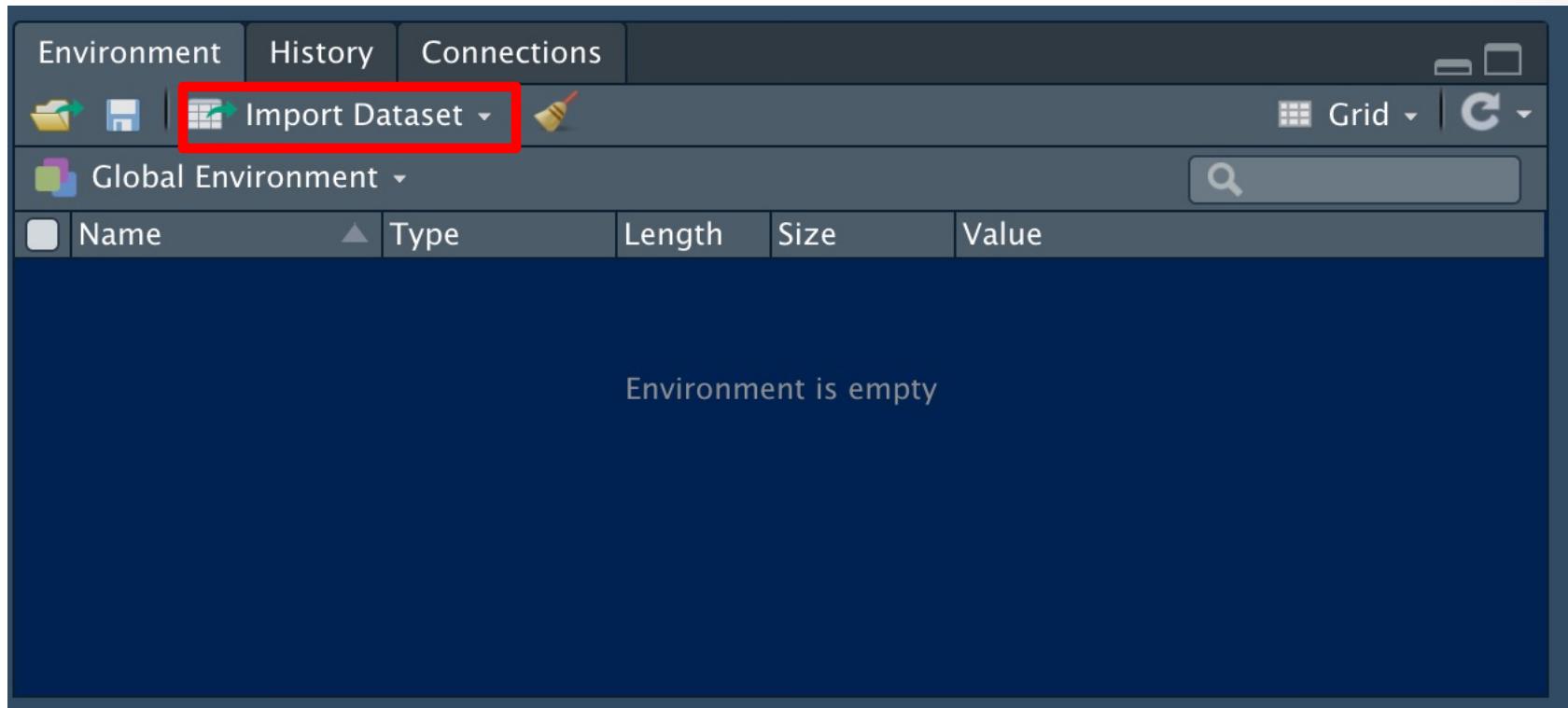
- Most of the time, these are going to be either .csv or .txt, depending on how you collect data.

These are not altered by R!

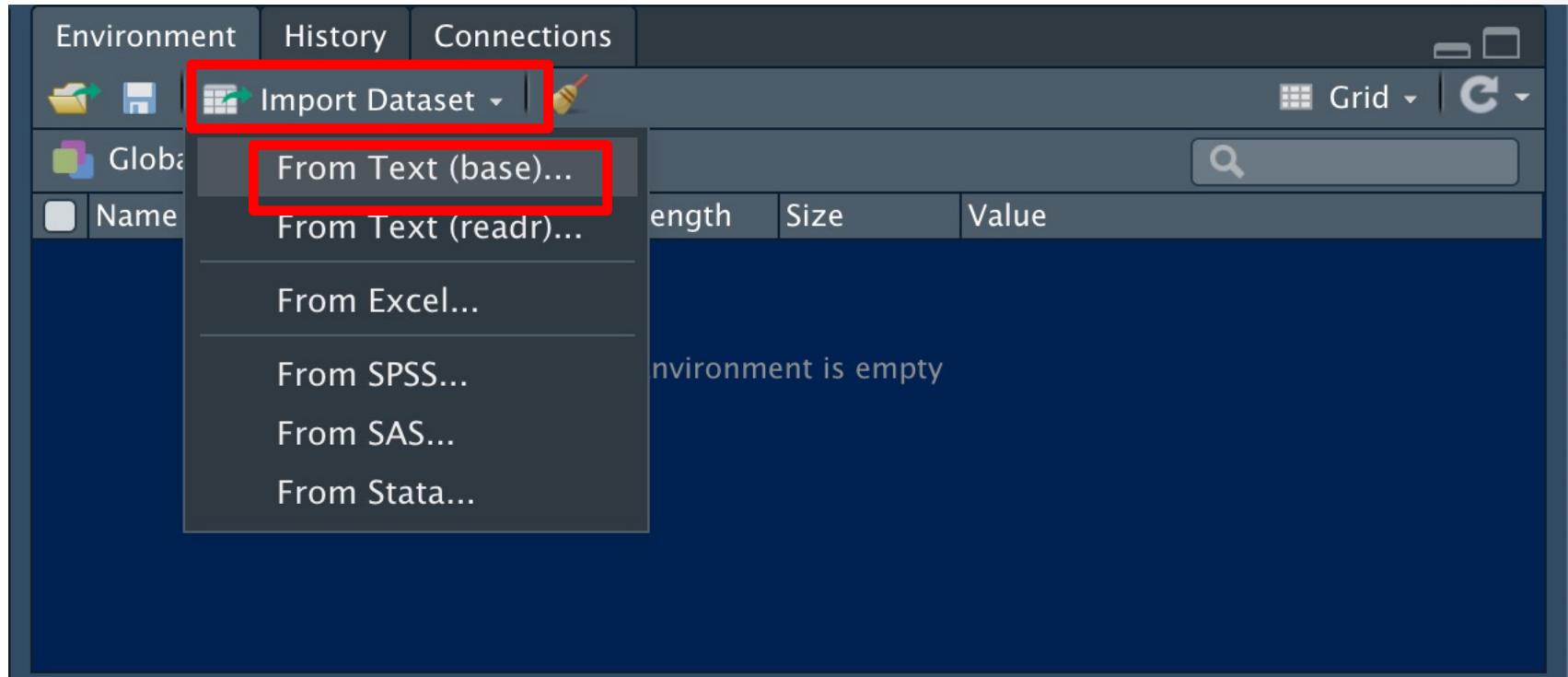
If your data is not a **.csv** or **.txt** file, don't worry! R can do a lot of stuff!

We will work with .csv, just to keep things simple.

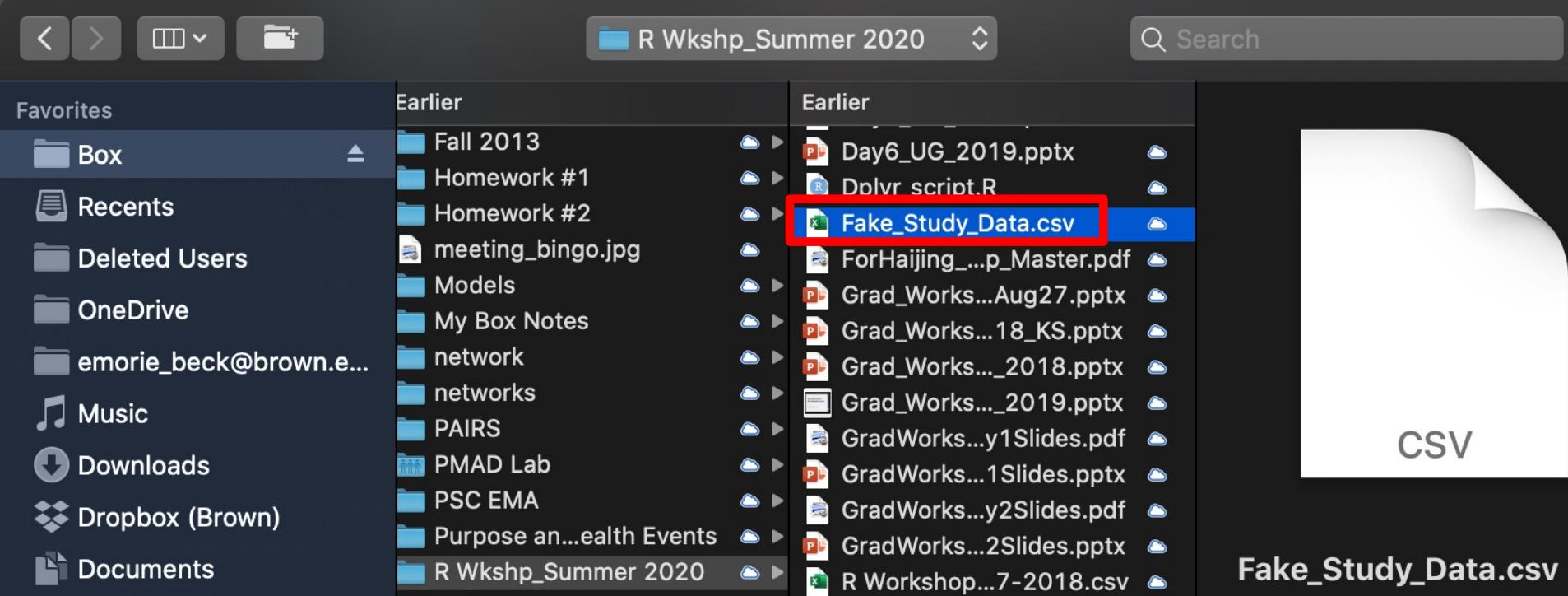
Loading .csv files



Loading .csv files



Loading .csv files



Import Dataset

Name
Fake_Study_Data

Encoding Automatic

Heading Yes

Row names Automatic

Separator Comma

Decimal Period

Quote Double quote ("")

Comment None

na.strings NA

Strings as factors

Input File

Subject_ID, Treatment_Group, Age, SES, Anxiety_SelfReport, Anxiety
ID0001, treatment, 18, 7, 16, 20, 2, 1
ID0002, treatment, 20, 3, 23, 16, 12, 23
ID0003, treatment, 21, 5, 22, 30, 20, 4
ID0004, treatment, 34, 3, 16, 27, 19, 15
ID0005, treatment, 31, 9, 23, 25, 12, 3
ID0006, treatment, 29, 4, 31, 18, 19, 6
ID0007, treatment, 27, 1, 34, 10, 8, 20
ID0008, treatment, 28, 9, 21, 34, 3, 9
ID0009, treatment, 30, 9, 19, 20, 6, 17
ID0010, treatment, 33, 2, 31, 26, 4, 26
ID0011, treatment, 48, 4, 32, 35, 13, 17
ID0012, treatment, 36, 6, 54, 45, 17, 4
ID0013, treatment, 42, 2, 42, 40, 11, 6

Data Frame

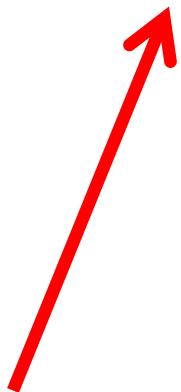
Subject_ID	Treatment_Group	Age	SES	Anxiety_SelfReport
ID0001	treatment	18	7	16
ID0002	treatment	20	3	23
ID0003	treatment	21	5	22
ID0004	treatment	34	3	16
ID0005	treatment	31	9	23
ID0006	treatment	29	4	31
ID0007	treatment	27	1	34
ID0008	treatment	28	9	21
ID0009	treatment	30	9	19
ID0010	treatment	33	2	31
ID0011	treatment	48	4	32
ID0012	treatment	36	6	54
ID0013	treatment	42	2	42

Import

Cancel

Loading .csv files

```
anxiety <- read.csv("~/Box/R wkshp_Summer  
2020/Fake_Study_Data.csv")
```



This will appear
in your console

**We strongly
recommend copying
and pasting this code
into your script file!**

Typical workflow in R

1. Open your data (usually from a .csv file)
2. Run analyses in the console (or in your script file)
3. Save the stuff you want to be able to run again later
 - Save to a .R file
 - Make sure that this includes the code to pull your .csv from your Dropbox/Box/etc.
 - Note: R doesn't change this original file!

Typical Format of .R File

The screenshot shows the RStudio interface with an R script file open. The title bar reads "sample script format.R". The toolbar includes standard icons for file operations, search, and run. The main code editor area contains the following R script:

```
1 #### Summarizing Happiness Survey Data ####
2
3 # get the mean and standard deviation of the age for all subjects that
4 # filled out the survey
5
6 library(psych)
7 library(dplyr)
8 library(readr)
9
10 setwd("~/Box Sync/R-Workshop")
11
12 happiness <- read_csv("~/Box Sync/R-Workshop/happiness.csv")
13
14 meanAge <- mean(happiness$Age)
15
```

The status bar at the bottom shows "1:1" and "Summarizing Happiness Survey Data". The tab bar indicates the file is an "R Script".

Exercise

1. Clear your Global Environment using the broom icon.
2. Open a new .R script file.

**FOR THE FOLLOWING STEPS, TYPE ANY CODE DIRECTLY INTO YOUR
SCRIPT FILE:**

3. Load the following packages:
 - psych
 - dplyr
 - ggplot2
4. **Get** your **working directory**: make sure it's the folder on your Desktop that you made earlier.
5. Drag and drop the Fake_Study_Data.csv file into that same folder.

Exercise, continued:

6. Import data file and rename as **anxiety**.
7. Make sure that the import code ends up in your SCRIPT file.

*Note: If you don't want to use the Import Dataset button every time, you can use a function called `read.csv` so that it looks like this:

```
anxiety <-  
  read.csv("~/Desktop/TestRworkshop/Fake_Study_Data.csv")
```

Exercise, continued:

Now...

Clear your global environment again

Select entire script file and RUN!

Hint: You can also click “Source” in the upper right corner of your script file in order to run the entire script (rather than highlighting everything)

REMOVE ~~POST-ITS~~ REACTIONS!!



(and save!)

Anxiety Data

Clinical trial for a new anxiety treatment

- Participants 18 to 50 years old
- Randomly assigned “treatment” or “placebo” group
- Socioeconomic status (SES)
 - Scale: 0 (low SES) to 10 (high SES)
- Anxiety scores: **Self**-Reported and **Relative**-Reported
 - Scale: 0 (no anxiety) to 100 (severe anxiety)
- Stress
 - Scale: 0 (no stress) to 30 (high stress)
- Drug Use
 - Scale: 0 (no drug use) to 50 (high drug use)

Quick review

What sign would you use if you wanted to access the Stress variable from your anxiety data.frame?

`anxiety$stress`

Indexing...continued!

Indexing a **vector** (1 dimension):

`anxiety$Age[1]`

- The number **1** gives us the **1st** item in the Age vector.

Indexing a **data.frame** (2 dimensions):

`anxiety[1, 2:3]`

- This gives us the **1st** row and the **2nd** thru **3rd** column of this data.frame.

Recap #1

What's the correct way to subset all rows of columns 3, 5, 7 of my anxiety data.frame – *without* changing the data.frame?

- A) `anxiety <- anxiety[,c(3, 5, 7)]`
- B) `anxiety2 <- anxiety[,c(3, 5, 7)]`
- C) `anxiety2 <- anxiety[3, 5, 7,]`
- D) `anxiety <- anxiety[c(3, 5, 7),]`

Recap #1

What's the correct way to subset all rows of columns 3, 5, 7 of my anxiety data.frame – *without* changing the data.frame?

- A) anxiety <- anxiety[,c(3, 5, 7)]
- B) **anxiety2 <- anxiety[,c(3, 5, 7)]**
- C) anxiety2 <- anxiety[3, 5, 7,]
- D) anxiety <- anxiety[c(3, 5, 7),]

Recap #2

How would you read this code?

- `(Age >= 35 | Anxiety == 50)`
 - Age is greater than or equal to 35, OR age equals 50
- `anxiety_score != 99`
 - Anxiety score is not equal to 99
- `data.frame[1:5,]`
 - Calls all columns for rows 1 through 5 of our data frame

Bonus Qs!

- If we ran any of the above output, would we be able to access the result later without re-running that code?
 - No! Need to assign it to something.
- What kind of output would the first 2 pieces of code generate?
 - Logical operators return vectors of `TRUE` / `FALSE` values.

Consider the following piece of code:

```
bestanimal <- "GumNut"
```

- What does this code do?
 - **Creates an object**
 - **Assigns a value to the object**
- What class is the object?
 - **Character**
- How can we verify this?
 - **class(bestanimal)**
- Name two ways that character values look different than other values (i.e., numeric, integer, and boolean values)?
 - **Numeric, integer, and boolean values show up as blue**
 - **Numeric, integer, and boolean values don't need quotation marks**
- What happens if we type in **bestanimal** to our console?
 - **It will print “GumNut”**

Recap #3

Saturday, July 17, 2010

Koala For Sale



I have a three year old Koala Bear named GumNut that I'm desperately trying to find a new home for. I bought him back in January figuring it would be an awesome pet that would enjoy living in my greenhouse, sadly I was wrong. I paid \$3200 for him back in January and I'm not sure what the used Koala Bear market is like in a good economy or the one we have now; so I'm open to offers. Please use some common sense before contacting me, don't be an idiot, I'm not interested in trading my Koala Bear for your busted up 1980's Camaro, an XBOX, or an offer to paint my garage door.

30/0

FUNCTIONS, REVISITED

Functions within Functions

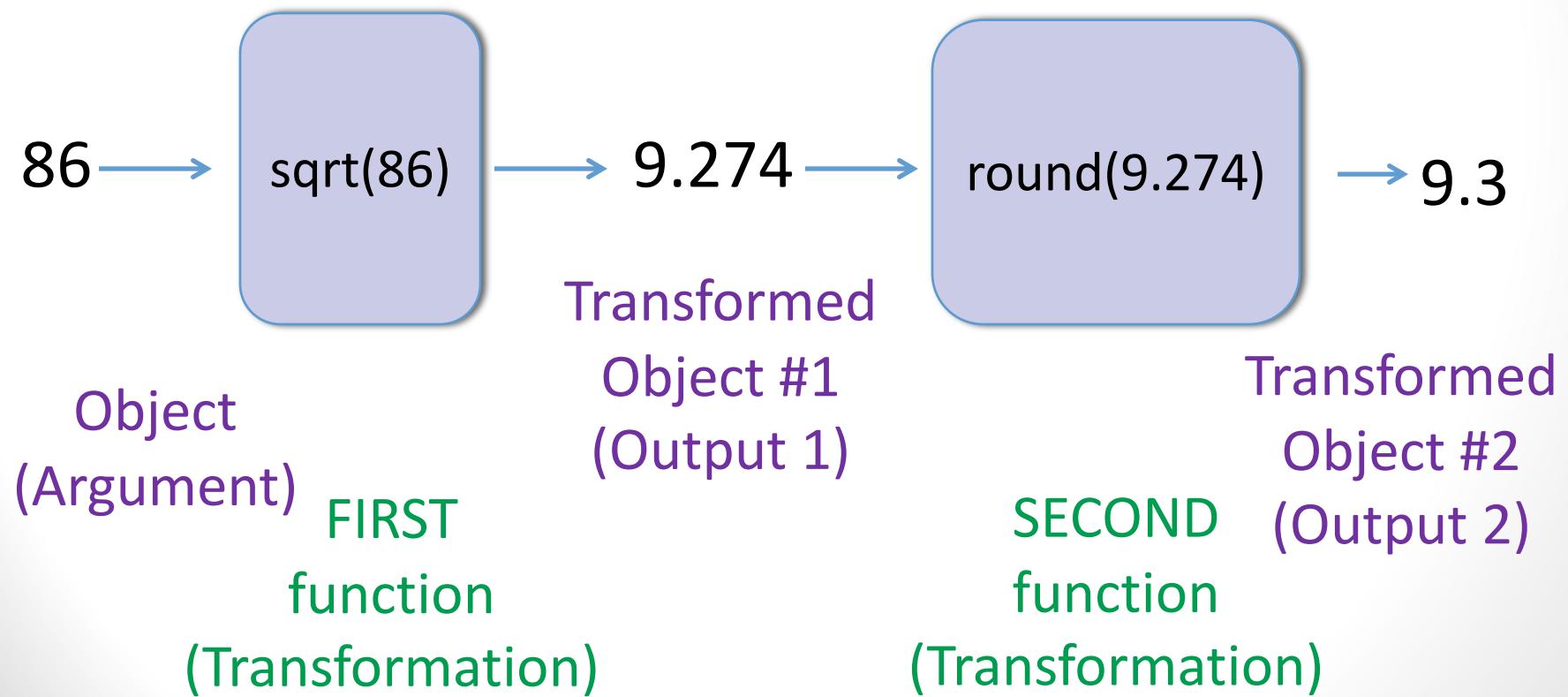
Often, you can wrap functions within functions.

This is called “nesting”.

```
round(x = sqrt(86), digits = 1)  
[1] 9.3
```

Visualizing Nested Functions

```
round(x = sqrt(86), digits = 1)
```



Exercise

Use nested functions to create a subset of the data.frame which `filter`s participants who have `Anxiety_SelfReport` scores above the mean.

Hint: Name this new data.frame!

Adding and Filtering Data

Why would you **add** data?

- New variable
- Collected new subjects
- Etc.

Why would you **filter (e.g. exclude)** data?

- Outliers
- Data file has lots of variables that are not of interest to you
- Etc.

Note: Adding/filtering NEVER changes your original .csv file!

Remember Indexing?

Selecting variables to **ADD** by indexing:

```
data frame to add to  
anxiety[, 9] <- rep(x = "Session1",  
times = 40)  
all the rows           column 9
```

What did R name this column?

Remember Indexing?

data frame to add variable to

```
anxiety[“session”] <- rep(x = “Session1”,  
                           times = 40)
```

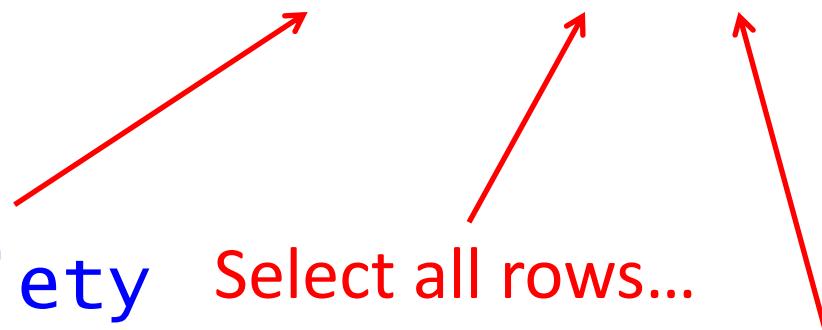
R knows that this is a column

What did R name this column?

Remember Indexing?

Selecting variables to **REMOVE** by indexing:

```
anxiety2 <- anxiety[, 1:8]
```



Take the **anxiety** data.frame Select all rows...
...and columns 1 through 8

Did **anxiety** change at all? Why?

Remember Indexing?

Let's say Subject 10 is an outlier that we'd like to remove...

```
anxiety2 <- anxiety2[-10, ]
```

Take the `anxiety2`
data.frame

Remove row 10...
...for all columns

Did `anxiety2` change at all? Why?

Logical Operator Review

- Returns a value of TRUE or FALSE (Boolean)

<code>==</code>	equality
<code>!=</code>	inequality
<code>></code>	greater than
<code>>=</code>	greater than or equal to
<code><</code>	less than
<code><=</code>	less than or equal to

`A = 3` – “A is an object that stores the number 3.”

`A == 3` – “Is A equal to 3?”

Logical Operators

- Multiple conditions

```
& and  
| or  
! not
```

Is this true? AND Is this true?
 $(10 < 100 \& 24 == 23 + 1)$
TRUE

$(5 > 4 \& 5 > 10)$
FALSE

Is this true? OR Is this true?

$(5 > 4 | 5 > 10)$
TRUE

$(A == B | C != D)$

Subset your data

Sometimes, you will want to perform functions on only some of your data points

You can subset your data to identify subjects in a certain subgroup (e.g., females, persons over 40)

```
filter(.data = empire, (mass > 100))
```

Notes:

- Some functions have a “data” argument, where you name your data.frame. Here, you don’t need to use the dollar \$ign.
- () around **mass > 100** aren’t necessary, but as logical expressions become more complicated they can be helpful...

Exercise

- 1) Make a new data.frame that only includes the treatment group, not the placebos.
Hint: Give a new name to your new data.frame.
- 2) Make a new data.frame that only includes people in the placebo group that are younger than 35.
Hint: Give a new name to your new data.frame.
- 3) In the original **anxiety** data.frame, find the number of people in the placebo group and the number of people in the treatment group. Use **table()**.
- 4) **BONUS:** **Select** all ages from the original **anxiety** data.frame; name the new data.frame **Age_vect**

What if I don't remember the arguments?

Check the R documentation

`?filter`

When in doubt, you can always search the “Help” tab or the Internet.

Remember Subsetting?

Remove one subject:

```
filter(.data = anxiety,  
       Subject_ID != "ID0001")
```

Remember Subsetting?

Subsetting an entire group:

```
filter(.data = anxiety,  
       Treatment_Group == "placebo")
```

```
filter(.data = anxiety,  
       Treatment_Group != "treatment")
```

What are each of these function calls doing?

Cleaning Global Environment

Sometimes your Global Environment can fill up with stuff that you don't need. You can clean this!

One option: Delete EVERYTHING using the broom (we've done this several times)

Another option: Switch to GRID view, check boxes of individual objects you DON'T want, then press the broom button

Exercise

Clean the global environment so that the only thing remaining in the global environment is **anxiety**. Nothing else should be there.

Remove the last 2 columns of the **anxiety** data.frame. (Remove **V9** and **Session**)

*Hint: **V9** is column 9; **Session** is column 10.*

SUMMARIZING DATA

Summarizing Data

Before you start to run any real analyses, most of the time you want to get a feel for what's happening in your data.

Summarizing Data

For really quick viewing of what you have: `describe()`

For count/frequency information: `table()`

Try:

```
describe(anxiety)  
table(anxiety$Treatment_Group)
```

Note: We recommend `dplyr` and `tidyR` (both part of the “tidyverse”).

PLOTTING

Plotting

R can plot without the help of any packages, but they're very ugly.

We will use the `ggplot2` package because it is much more flexible.

Plotting

ggplot2 has the following structure:

```
ggplot(things that impact entire plot) +  
  geom_something (things that  
impact just the something)
```

Plotting

A `geom_` normally means shape. What shapes do you want to use to represent your plot?

- `geom_histogram` (1 variable)
- `geom_density` (1 variable)
- `geom_boxplot` (1 variable)
- `geom_point` (2 variables, scatter plot)
- `geom_col` (2 variables, barplot)

Plotting

`ggplot()` and each `geom_()` can take on different aesthetics as an `aes()` argument.

What do you want your plot to look like? How can you make it pretty?

- Which variables are the `x-axis` and `y-axis`?
- `color` (should you color the plot by some variable?)
- `fill` (very similar to color, should you fill the plot in somehow – used for bar graphs, box plots)
- `shape` (represent groups using different shapes)
- `size` (represent groups using different sizes)

Plotting

- Usually `aes()` contains some information from the data.
- If the information isn't based on the data, it doesn't need to be inside an `aes()`

```
ggplot(data = anxiety, aes(x = Age, y = SES)) +  
  geom_point()
```

```
ggplot(data = anxiety, aes(x = Age, y = SES)) +  
  geom_point(color = "cornflowerblue")
```

```
ggplot(data = anxiety, aes(x = Age, y = SES)) +  
  geom_point(aes(color = Treatment_Group))
```

Reminder: Anxiety Data

Clinical trial for a new anxiety treatment

- Participants 18 to 50 years old
- Randomly assigned “treatment” or “placebo” group.
- Socioeconomic status (SES)
 - Scale: 0 (low SES) to 10 (high SES)
- Anxiety scores: **Self**-Reported and **Relative**-Reported
 - Scale: 0 (no anxiety) to 100 (severe anxiety)
- Stress
 - Scale: 0 (no stress) to 30 (high stress)
- Drug_Use
 - Scale: 0 (no drug use) to 50 (high drug use)

Exercise

Make a scatter plot of `Anxiety_SelfReport` (x-axis) against `Drug_Use` (y-axis).

Make the points of the scatter plot different `shapes` based on `Treatment_Group` (for example, placebo might be circles and treatment might be squares).

Make the `color` of the points different based on `Treatment_Group`.

Set the `size` of all points equal to 3

HINT: one of these...

- `geom_boxplot`
- `geom_point`
- `geom_col`

Exercise

1. Find the mean and standard deviation of self-reported anxiety for the treatment group, then for the placebo group.

Make sure to save each result as a new variable!

****BONUS:** Calculate each variable using a single line of code; so, 4 total lines of code**

2. Make a new data.frame to use for plotting.

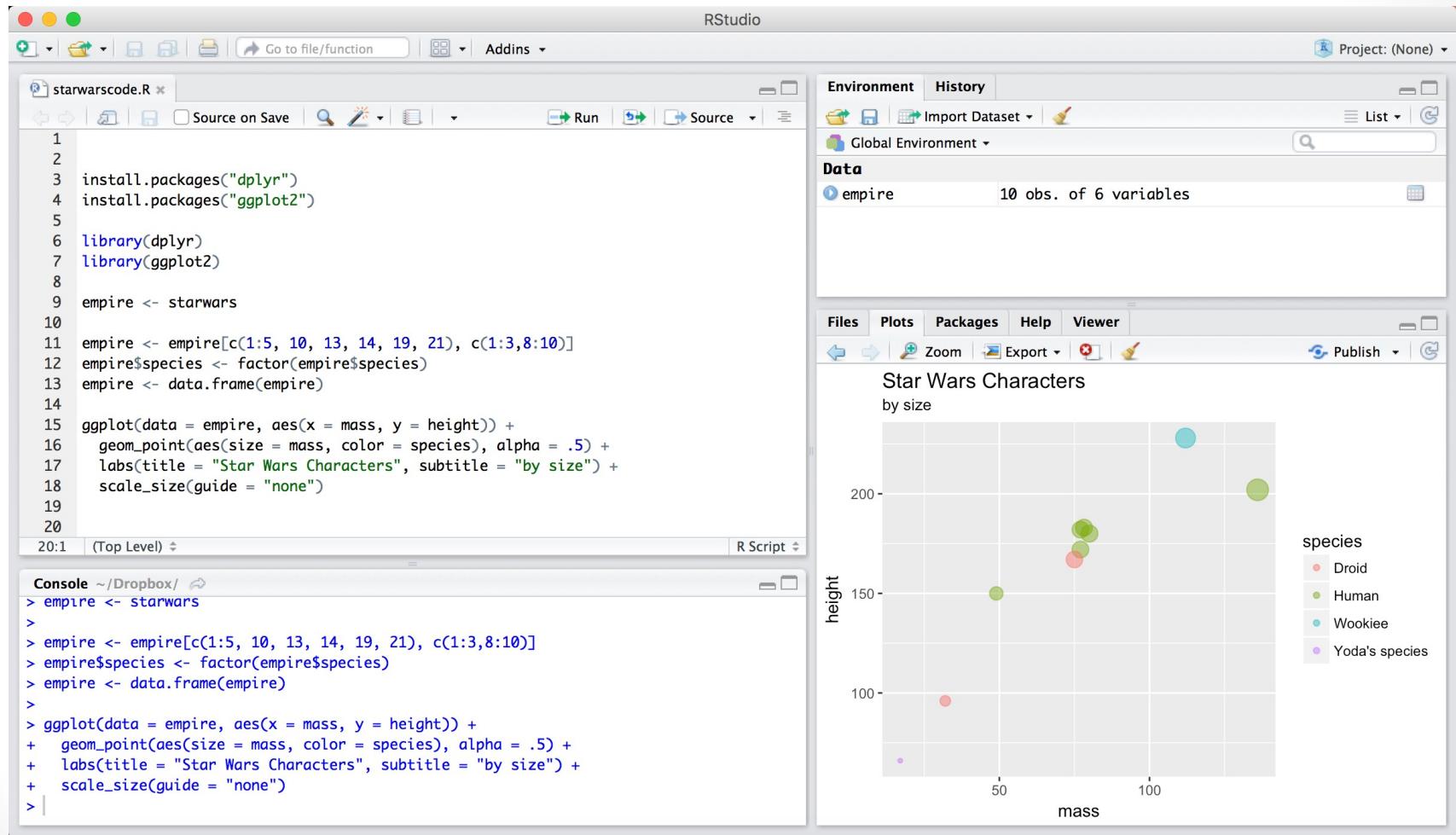
```
newDF <- data.frame(Group = c("Treatment",  
"Placebo"),  
meanAnx = c(_____, _____),  
sdAnx = c(_____, _____))
```

Exercise

- Make a bar plot of mean anxiety by treatment group. Use your new data.frame.
 - Fill in the color of the bars by Group.
 - Include error bars, using the standard deviations.
 - Change the labels to be descriptive.
 - Anxiety is on a scale of 0 to 100. Make sure that the limits of the y-axis include the full range.
 - **BONUS:** center the title and subtitle; change the colors of the bars; remove the gray background

```
ggplot(data = _____, aes(x = _____, y = _____ )) +  
  geom_col(aes(fill = _____ )) +  
  geom_errorbar(aes(ymin = meanAnx - sdAnx,  
                     ymax = _____ + _____ ), width = .25) +  
  labs(x = "Treatment Group", y = _____, title =  
        _____, subtitle = _____ ) +  
  _____ # change y-axis limits here
```

Remember this???



Other things you might need...

Data Transformation:

- Renaming columns
- Save the output

These are all things that you may one day find interesting!

Renaming columns

```
colnames(data.frame)[columnNumber]  
  <- "NewName"
```

```
colnames(anxiety)[5] <- "Session1"  
colnames(anxiety)[6] <- "Session2"
```

Renaming Columns

```
rename(new_name = old_name)
```

```
anxiety <- rename(anxiety,  
  self_anx = Anxiety_SelfReport,  
  rel_anx = Anxiety_RelativeReport)
```

Saving output

It's very easy to export data.frames once you have manipulated them in R. You can use this to your advantage!

```
write.csv(x = R object,  
          file = “newfile.csv”,  
          row.names = FALSE)
```

What if I don't remember how to use a function?

Use the internet!

Any problem you have,
the internet has already
solved it!

Google is your best friend!



R RESOURCES

- **Learning Statistics with R** – free, well-written book available in PDF format; integrates learning R with learning basic stats
 - <https://health.adelaide.edu.au/psychology/ccs/teaching/lsr/>
- **R for Data Science** – free book on the tidyverse: <https://r4ds.had.co.nz>
- **DataCamp** – online tutorials to teach R (also try Coursera and Code School)
 - <https://www.datacamp.com/introduction-to-statistics>
- **Favorite websites for Reference:**
 - Quick-R
 - Cookbook for R
 - Institute for Digital Research and Education (UCLA)
 - Stack Overflow
- **swirl** package inside RStudio: learn R, in R!
- **Email us!**
 - Emorie Beck – emorie_beck@northwestern.edu
 - Maddy Frumkin – mfrumkin@wustl.edu
 - Violet Brown – violet.brown@wustl.edu
 - Kendra Smith – kendrasmith@wustl.edu
- **Google, Google, Google!!!!!**

