

Preliminaries in R

R and RStudio

What is R?

- A statistical programming language
- Free and open-source software
- A core package with many available user-created add-ons (packages)

R is currently popular in a number of fields, including:

- Statistics
- Machine learning
- Data journalism / Data analysis
- Bioinformatics

What is R?

R is a programming language popular for statistical computing.

"The best thing about R is that it was developed by statisticians.

*The worst thing about R is that... it was developed by
statisticians."*

-Bo Cowgill, Google, at the Bay Area R Users Group

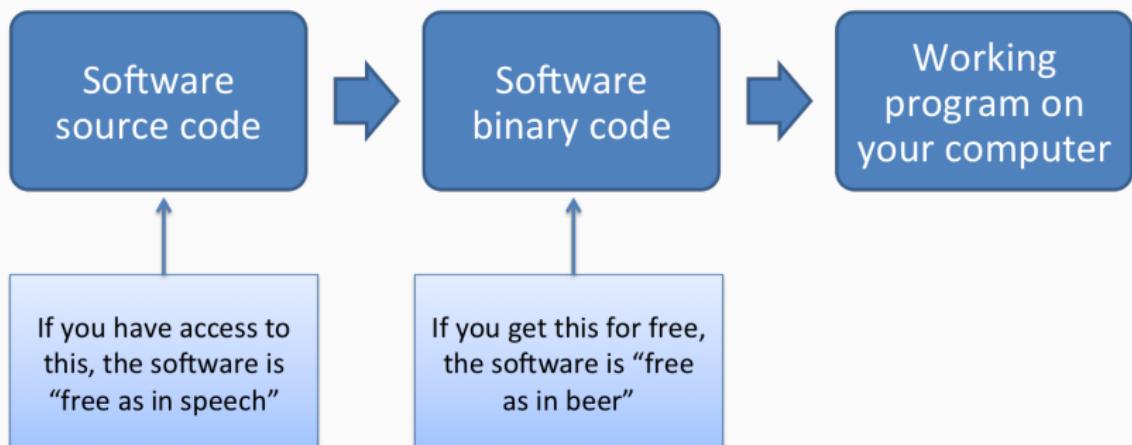
Other programming languages popular for statistical computing include:

- SAS
- SPSS
- Matlab
- Julia
- Python

Free and open-source software

- Gratis: Free as in beer
- Libre: Free as in speech

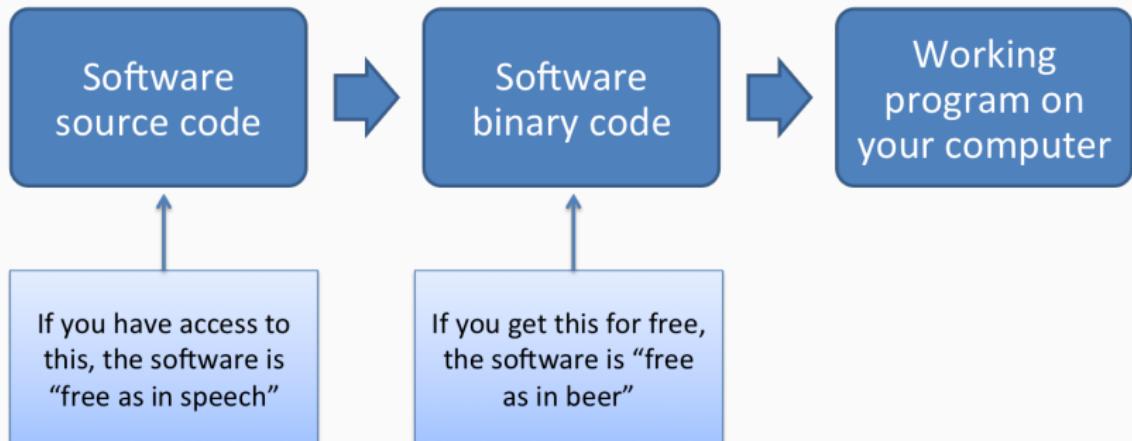
A basic sketch of how software can be “free”:



Open-source software

With open-source software (free as in speech), you can:

- Check out the code to figure out how the software works
- Share the code (and software) with other people
- Make any changes you want to the code



Open-source software

"Despite its name, open-source software is less vulnerable to hacking than the secret, black box systems like those being used in polling places now. That's because anyone can see how open-source systems operate. Bugs can be spotted and remedied, deterring those who would attempt attacks. This makes them much more secure than closed-source models like Microsoft's, which only Microsoft employees can get into to fix."

Woolsey and Fox. *To Protect Voting, Use Open-Source Software*. New York Times. August 3, 2017.

Open-source software

Funding agencies are starting to ask for grant proposals to develop open-source tools. For example, a recent call from the NIH asks for:

“Open-source, generalizable, and scalable bioinformatics tools”

NIH RFA-RM-17-012: “Metabolomics Data Analysis and Interpretation Tools (U01)”

What is RStudio?

RStudio (the software) is an integrated development environment (IDE) for R. You download it separately from R, but it's a “nicer” way to work in R.

This IDE includes:

- An interface with “panes” for key tasks you’ll be doing (e.g., one pane with the R console, one for scripts, one to view graphs)
- Code highlighting
- Version control (git) and interface with GitHub
- Tools for Shiny web app development
- Tools for R package development

What is RStudio?

RStudio (the company) is a leader in the R community. Currently, the company:

- Develops and freely provides the RStudio IDE
- Provides excellent resources for learning and using R (e.g., cheatsheets, free online books)
- Is producing some of the most-used R packages
- Employs some of the top people in R development
- Is a key member of The R Consortium (others include Microsoft, IBM, and Google)

Setting up

If you do not already have them, you will need to download and install both R and RStudio.

- Go to CRAN and download the latest version of R for your system. Install.
- Go to the RStudio download page and download the latest version of RStudio for your system. Install.
- Defaults should be fine for everything.

The “package” system

R packages

Your original download of R is only a starting point:



R packages

To take full advantage of R, you'll want to add on packages:



R packages

You can get packages to add-on to your version of R from:

- CRAN (thousands of available packages)
- Bioconductor (specifically for bioinformatics-related packages)
- GitHub
- Your friends and collaborators
- Make them yourself

The most popular place from which to get packages is currently CRAN.
You can install packages from CRAN using R code.

CRAN

The Comprehensive R Archive Network (CRAN) is the primary source of R packages. Each of the packages available on CRAN has a unique name and has passed some broad checks.



Dirk Eddelbuettel @eddelbuettel · 27 Jan 2017

Big congratulations to @gbwanderson whose new package 'hurricaneexposure' just became package 10,000 on CRAN !!

CRAN Package Updates @CRANberriesFeed

9999 packages on CRAN right now, so imagine dozens of R nerds hanging in suspense waiting for the package to make it 10k ...

2

35

93



Installing from CRAN

The main way you will install new packages will be with the `install.packages` function, which by defaults installs packages available on CRAN.

For example, to get the package “`phonenumbers`”, you could use:

```
install.packages("phonenumbers")
```



Installing from CRAN

Installing a package downloads it (usually from CRAN) to your computer.

You will need to be online to install a package.

Once you install a package, you do not need to install it again. It's on your computer. (At least, until the package maintainer creates a new version.)

Loading an installed package

Once you have a package, you can load it to an R session using the `library()` function.

```
library("phonenumbers")
```

Once it's loaded, you can use all its functions.

```
fedex_number <- "GoFedEx"  
letterToNumber(fedex_number)
```

```
## [1] "4633339"
```

Alternative package::function notation

The library function is the most common way you'll access functions from R packages, but it's not the only way to do this. There is another type of notation that will allow you to use any external function from any package you have installed on your computer: the package::function notation.

You can call functions by specifying the package name, a double colon, and then the function name you want to use from that package. For example:

```
phonenumbers::letterToNumber(fedex_number)
```

```
## [1] "4633339"
```

Alternative package::function notation

The package::function notation is not typically used because it substantially increases how much you have to type in your code.

However, there can be cases where a function name is ambiguous. For example, you might want to use functions from two different packages that have the same name. In this case, using the package::function notation makes it crystal clear which function you mean.

In practice, this problem is most likely to come up when you've loaded both `plyr` and `dplyr`, which share several function names and are both popular packages.

Alternative package::function notation

There is one useful trick that you can do with the package::function notation.

RStudio has tab complemention, which means that once you start typing an object name or function, if you press the Tab key, RStudio will give you suggestions for how you can finish the name.

If you want to scroll through the names of all the external functions in a package, you can do so by typing something like `?phonenumbers::` in the console (don't press Return) and then pressing the Tab key.

Package vignettes

Many packages will come with a “vignette”, or a tutorial on how to use the package. These are very helpful tools for figuring out how to use a package.

To get a list of all the vignettes a package has, use the `vignette` function, specifying a package name with `package`:

```
vignette(package = "phonenumbers")
```

Package vignettes

To open a vignette once you know its name, you can also use the `vignette` function. For example, to open the vignette called "phonenumbers" for the phonenumbers package, run:

```
vignette("phonenumbers", package = "phonenumbers")
```

Many packages only have one vignette, with the same name as the package. In that case, you can open the vignette using a shorter call:

```
vignette("phonenumbers")
```

Function helpfiles

Packages include helpfiles for all the functions they intend for people to use.

You can access the helpfile for a function using ? followed by the function name. For example, to get the helpfile for letterToNumber, you can run:

```
?letterToNumber
```

Some basics of R code

R objects

R lets you save a variety of types of data in things called **objects**, each of which has an **object name** to use to reference the object.

R objects

You can think of an object name as kind of like an acronym.

"Here, we investigate particulate matter with a diameter less than 2.5 micrometers ($PM_{2.5}$). Many large urban centers in developing countries experience multi-day episodes of extremely high $PM_{2.5}$."

By assigning an object a name, you can quickly reference it later, rather than having to re-define (or re-create) the object every time you need to use it.

R's MVP: The *gets arrow*

The *gets arrow*, `<-`, is R's assignment operator. It takes whatever you've created on the right hand side of the `<-` and saves it as an object with the name you put on the left hand side of the `<-` :

```
## Note: Generic code-- this will not work  
[name of object] <- [thing I want to save]
```

R's MVP: The *gets* arrow

For example, if I just type "GoFedEx", R will print it back to me, but won't save it anywhere for me to use later:

```
"GoFedEx"
```

```
## [1] "GoFedEx"
```

R's MVP: The *gets* arrow

However, if I assign it to an object, I can print it out or use it later by referencing that object name:

```
fedex_number <- "GoFedEx"
```

```
fedex_number
```

```
## [1] "GoFedEx"
```

```
letterToNumber(fedex_number)
```

```
## [1] "4633339"
```

<- vs. =

You can make assignments using either <- or =, and you'll see both when you're reading other people's code.

However, R gurus advise using <- in your own code, and as you move to doing more complex things, problems might crop up if you use =.

<- vs. =

For now, though, it will be helpful for you to know that these two calls do the same thing:

```
one_to_ten <- 1:10  
one_to_ten
```

```
## [1] 1 2 3 4 5 6 7 8 9 10
```

```
one_to_ten = 1:10  
one_to_ten
```

```
## [1] 1 2 3 4 5 6 7 8 9 10
```

History of <-



Photo by Marcin Wichary, User:AlanM1 - Derived (cropped) from, CC BY 2.0,
<https://commons.wikimedia.org/w/index.php?curid=20744606>

Naming objects

- Use only letters, numbers, and underscores
- Don't start with anything but a letter

From Hadley Wickham's R style guide

- Use lower case for variable names (`fedex_number`, not `FedExNumber`)
- Use an underscore as a separator (`fedex_number`, not `fedex.number` or `fedexNumber`)
- Avoid using names that are already defined in R (e.g., don't name an object `mean`, because a `mean` function exists)

Listing objects

At any point, you can use the `ls` function to list all the objects in your current R working session:

```
ls()
```

```
## [1] "fedex_number" "one_to_ten"
```

You can also check out the “Environment” pane in RStudio to see some of the R objects defined in your current R session.

R's most basic object types

The two most common types of objects for data in R that we will use in this class are **vectors** (1D) and **dataframes** (2D).

Vectors

- A vector is a string of values.
- All values must be of the same *class* (i.e., all numbers, all characters, all dates)
- You can use `c` to join values together to create a vector
- The *length* of the vector is how many values it has in it

For example:

```
fibonacci <- c(1, 1, 2, 3, 5)
```

```
fibonacci
```

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

```
length(fibonacci)
```

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

Vectors

Vectors can have several different classes, including numeric, character, factor, and date.

Typically, when you use `c`, you'll be creating a numeric or character vector. More complex classes (like factors and dates) require a bit more work to create "from scratch".

- For character vectors, use quotation marks on each element.

```
one_to_five <- c("one", "two", "three", "four", "five")
```

- For numeric, don't use quotation marks, but make sure you're using numbers.

```
fibonacci <- c(1, 1, 2, 3, 5)
```

Vectors

You can use the `class` function to figure out the class of a vector.

```
class(fibonacci)
```

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

```
class(one_to_five)
```

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

```
class(c("1", "2", 5))
```

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

Vectors

If you mix classes, it will default to most generic:

```
mixed_classes <- c(1, 3, "five")
mixed_classes

## [1] "1"     "3"     "five"
```

Vectors

You can pull out certain values by using indexing (`[...]`) to identify the locations you want to get:

```
fibonacci[2] # Get the second value
```

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

```
fibonacci[c(1, 5)] # Get first and fifth values
```

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

```
fibonacci[1:3] # Get the first three values
```

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

Dataframes

A dataframe is one or more vectors of the same length stuck together side-by-side. It is the closest R has to what you'd get with an Excel spreadsheet.

You can create dataframes using the `data_frame` function from the `tibble` package. However, most often you will create a dataframe by reading in data from a file using something like `read_csv` from the `readr` package—most datasets will not be short enough that you want to enter them by hand in R.

Dataframes

The format for using `data_frame` is:

```
## Generic code  
[name of object] <- data_frame([1st column name] =  
                           [1st column content],  
                           [2nd column name] =  
                           [2nd column content])
```

Dataframes

```
library("tibble")
beatles <- data_frame(first_name = c("John", "Paul", "Ringo",
                                      "George"),
                        last_name = c("Lennon", "McCartney",
                                      "Starr", "Harrison"),
                        birth_year = c(1940, 1942, 1940, 1943),
                        alive = c(FALSE, TRUE, TRUE, FALSE))
beatles

## # A tibble: 4 x 4
##   first_name last_name birth_year alive
##   <chr>      <chr>        <dbl> <lgl>
## 1 John       Lennon       1940. FALSE
## 2 Paul       McCartney  1942.  TRUE
## 3 Ringo      Starr        1940.  TRUE
## 4 George     Harrison    1943. FALSE
```

Dataframes

You can also create dataframes by joining together vector objects you previously created, as long as they have the same length and line up:

```
fibonacci_seq <- data_frame(num_in_seq = one_to_five,  
                           fibonacci_num = fibonacci)
```

```
fibonacci_seq
```

```
## # A tibble: 5 x 2  
##   num_in_seq fibonacci_num  
##   <chr>          <dbl>  
## 1 one             1.  
## 2 two             1.  
## 3 three           2.  
## 4 four            3.  
## 5 five            5.
```

Dataframes

You can use indexing (`[..., ...]`) for dataframes, too, but now they'll have two dimensions (rows, then columns). For example:

```
fibonacci_seq[1:2, 2] # First two rows, second column
```

```
## # A tibble: 2 x 1
##   fibonacci_num
##       <dbl>
## 1          1.
## 2          1.
```

Dataframes

If you want all of something, leave the designated spot blank. For example:

```
fibonacci_seq[5, ] # Last row, all columns
```

```
## # A tibble: 1 x 2
##   num_in_seq fibonacci_num
##   <chr>           <dbl>
## 1 five             5.
```

Dataframes

Usually, instead of creating a dataframe from vectors, you'll read one in from data on an outside file, for example using `read_csv` from the `readr` package.

For example, to read in a dataset from a csv file called "daily_show_guests.csv":

```
library("readr")
daily_show <- read_csv("daily_show_guests.csv",
                      skip = 4)
```

Dataframes

This has read data in from the external file into a dataframe object in my R session:

```
daily_show[1:4, 1:4]
```

```
## # A tibble: 4 x 4
##   YEAR GoogleKnowlege_Occupation Show      Group
##   <int> <chr>                  <chr>    <chr>
## 1 1999 actor                  1/11/99  Acting
## 2 1999 Comedian               1/12/99  Comedy
## 3 1999 television actress   1/13/99  Acting
## 4 1999 film actress          1/14/99  Acting
```

Dataframes

You can use the functions `dim`, `nrow`, and `ncol` to figure out the dimensions (number of rows and columns) of a dataframe:

```
dim(daily_show)
```

```
## [1] 2693      5
```

```
nrow(daily_show)
```

```
## [1] 2693
```

```
ncol(daily_show)
```

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

Dataframes

Base R also has some useful functions for quickly exploring dataframes:

- `str`: Show the structure of an R object, including a dataframe
- `summary`: Give summaries of each column of a dataframe.

For example, to get summaries of the first two columns of the Daily Show data, you can run:

```
summary(daily_show[ , c(1, 2)])
```

```
##          YEAR      GoogleKnowlege_Occupation
##  Min.    :1999      Length:2693
##  1st Qu.:2003      Class  :character
##  Median   :2007      Mode   :character
##  Mean     :2007
##  3rd Qu.:2011
##  Max.    :2015
```

In-Course Exercises

Here are a few tips for doing these in-course exercises:

- Sometimes, I will ask you to try out things that we haven't covered yet in class. In this case, I'll give you detailed instructions. You can also use Google, R help files, and any other resources you want to help you figure out how to do something for an in-course exercises. If you're really stumped, I'm happy to help.
- For each section of the exercise, I've included some example R code to show one possible solution. Try to not look at this until you've tried the exercise yourself without it. If you move quickly to this example R code, you will not learn R very quickly.
- Some groups tend to move more quickly than others. I often include "If you have extra time" sections for groups who are moving more quickly.
- Use Google!

In-Course Exercises

The #1 rule for this class:

Don't use spaces in file pathnames!

This includes the names of files and the names of directories. Keep this in mind during today's exercise. (We'll talk more about why not next week.)

In-Course Exercises

We'll take a break now to get started on this week's in-course exercise. You can find all the instructions on the online coursebook (<https://geanders.github.io/RProgrammingForResearch/r-preliminaries.html>).

Get together with your group members and do Sections 1.7.1 through 1.7.4 of the In-Course Exercise for Week #1 ("R Preliminaries").

PROBABLY

As of Wednesday, November 7th, 2012, Nate Silver is probably a witch.

His unusually accurate predictions are, thus far, explained by his use of validated statistical methods. His disregard of momentum, gut feelings, and the interpretations of people paid to promote certain viewpoints is not the result of supernatural assistance.

While we on the Is Nate Silver a Witch editorial board are strict rationalists, Mr Silver's performance has been uncanny enough to raise small but significant doubts as to whether his methodology is entirely of this world. We are following the situation closely.

Brought to you by epistemology and @vruba.



For the first time in our history, the winners of the White House Turkey Pardon were chosen through a highly competitive online vote. And once again, Nate Silver completely nailed it. The guy is amazing.

— Barack Obama —

AZ QUOTES

For the story, see <http://www.politico.com/blogs/media/2012/11/obama-cracks-nate-silver-joke-at-turkey-pardoning-150132>.

Functions

In general, functions in R take the following structure:

```
## Generic code  
function.name(required information, options)
```

The result of the function will be output to your R session, unless you choose to save the output in an object:

```
## Generic code  
new.object <- function.name(required information, options)
```

Functions

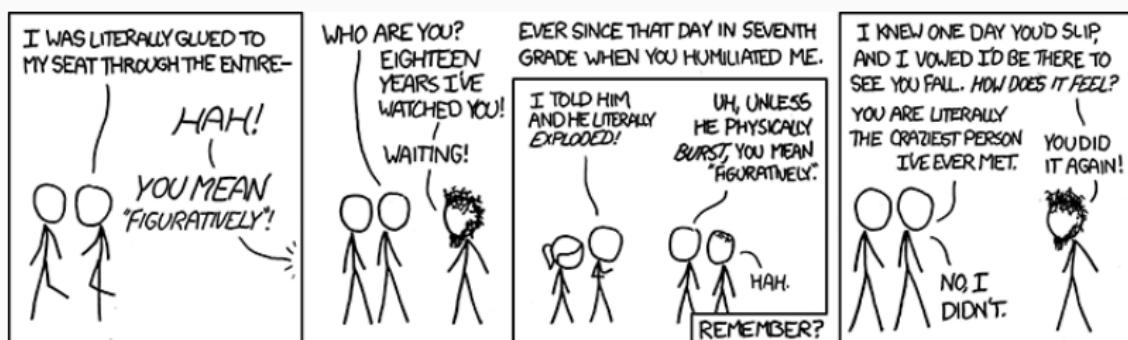
Examples of this structure:

```
head(daily_show)
head(daily_show, n = 3)
daily_show <- read_csv("daily_show_guests.csv",
                      header = TRUE)
```

Find out more about a function by using ? (e.g., ,?head, ?read.csv). This will take you to the help page for the function, where you can find out all the possible arguments for the function, required and optional.

When to use quotations

- Use quotation marks if you **literally** mean that specific character string
- Don't use quotation marks if you want to reference an R object by its name
- Never use quotation marks on the left-hand side of <- or =.



Source: xkcd.com

When to use quotations

- Use quotation marks if you **literally** mean that specific character string

```
c("Alpha", "Bravo")
```

```
## [1] "Alpha" "Bravo"
```

- Never use quotation marks on the left-hand side of <- or =.

```
Alpha <- c("Alan", "Ada")
```

```
Bravo <- c("Bob")
```

- Don't use quotation marks if you want to reference an R object by its name

```
c(Alpha, Bravo)
```

```
## [1] "Alan" "Ada"   "Bob"
```

Working in R Studio

R sessions

An **R session** is an instance of you using R. Once you open R, you will be in a “fresh” R session, unless you restore a saved session (which I strongly recommend against).

This means that, once you open RStudio, you will need to run the code to load any packages, define any objects, and read in any data that you will need for analysis in that session.

Do **not** save the history of your R session when you close RStudio. Instead, get in the habit of writing your R code in reproducible formats (R scripts, RMarkdown documents)

R console versus R scripts

In R studio, you will have one pane called “Console”. The console lets you enter R commands one at a time at the “caret” (>) prompt. Any objects you define at the R console will be available to you for the rest of your R working session.

The console can be great for quick functions to explore the data. However, for most data analysis work you'll want to use a script, so you can save all the code you used for the analysis. This improves the *reproducibility* of your analysis.

R scripts

An **R script** is a file where you can write down and save R code.

When you write, run, and save your R code in a script rather than running it one line at a time in the console, you can easily go back and re-do exactly what you did again later. You can also share the script for someone else to use, or run it on a different computer.

R scripts

RStudio has one pane that shows any R scripts you have open. If you'd like to create new R scripts, you can do that in RStudio with the following steps:

- Open a new script file in RStudio: File -> New File -> R Script.
- I recommend that you make an "R" folder in all of the R projects that you create and save all your script files in that folder.
- Save scripts using the extension .R

R scripts

Running code in R scripts line-by-line:

- To run code from an R script file in RStudio, you can use the Run button (or Command-R).
- This will run whatever's on your cursor line or whatever's highlighted.

Sourcing an R script (i.e., running all the code saved in the script):

- To run the whole script, you can also use the source function with the filename.
- You can also use the “Source” button on the script pane.

R scripts

The screenshot shows the RStudio interface with several tabs at the top: "rcise.Rmd", "InCourseExercises_Week2.Rmd", "Chapter2.Rmd", and "Untitled28*". Below the tabs is a toolbar with icons for "Save", "Run", and "Source". The main area displays R code:

```
1 ## Some example code to show a script file
2
3 one_to_ten <- 1:10
4
5 course_dates <- data.frame(session = c(1, 2, 3),
6                             topic = c("Basic R",
7                                   "Getting and Cleaning Data 1",
8                                   "Exploring Data 1"))
9
10 a <- 1:4 ; b <- rnorm(10)
11 |
```

Annotations with arrows point to specific parts of the code:

- "Save" button: Points to the save icon in the toolbar.
- "Run" button: Points to the run icon in the toolbar.
- "Source" button: Points to the source icon in the toolbar.
- Commented code line: Points to the first line of code starting with "#".
- One command across several lines: Points to the assignment statement on line 10.
- Two commands on one line: Points to the semicolon-separated statements on line 10.

Comment characters

Sometimes, you'll want to include notes in your code. You can do this in all programming languages by using a **comment character** to start the line with your comment.

In R, the comment character is the hash symbol, #. R will skip any line that starts with # in a script.

```
# Don't print this.
```

```
"But print this"
```

```
## [1] "But print this"
```

In-Course Exercises

We'll take a break now to finish this week's in-course exercise. You can find all the instructions on the online coursebook (<https://geanders.github.io/RProgrammingForResearch/r-preliminaries.html>).

Get together with your group members and do Sections 1.7.4 through 1.7.8 of the In-Course Exercise for Week #1 ("R Preliminaries").

Some odds and ends

Missing values

In R, NA is used to represent some types of missing values in a vector. This value can show up in numerical or character vectors (or in vectors of some other classes):

```
c(1, 4, NA)
```

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

```
c("Jane Doe", NA)
```

```
## [1] "Jane Doe" NA
```

The \$ operator

We've talked about how you can combine vectors of the same length to create a dataframe.

To go the other direction (pull a column from a dataframe), you can use the \$ operator.

For example, say you have the following dataset and want to pull the color column as a vector:

```
example_df <- data.frame(color = c("red", "blue"),
                           value = c(1, 2))

example_df
```

```
##   color value
## 1   red     1
## 2 blue     2
```

The \$ operator

You can pull the color column as a vector using the name of the dataframe, the dollar sign, and then the name of the column:

```
example_df$color
```

```
## [1] red blue  
## Levels: blue red
```

```
class(example_df$color)
```

```
## [1] "factor"
```

(Note: You can use tab completion in RStudio after you put in example_df\$.)

Order of evaluation

In R, you can “nest” functions within a single call. Just like with math, the order that the functions are evaluated moves from the inner set of parentheses to the outer one.

For example, to print the structure of the dataframe from the previous example after creating it, you can run:

```
str(data_frame(color = c("red", "blue"), value = c(1, 2)))  
  
## Classes 'tbl_df', 'tbl' and 'data.frame':      2 obs. of  2 vars  
##   $ color: chr  "red" "blue"  
##   $ value: num  1 2
```

paste and paste0

If you want to paste together several character strings to make a length-one character vector, you can use the `paste` function to do that:

```
paste("abra", "ca", "dabra")
```

```
## [1] "abra ca dabra"
```

By default, spaces are used to separate each original character string in the final string.

paste and paste0

If you want to remove these spaces, you can use the `sep` argument in the `paste` function:

```
paste("abra", "ca", "dabra", sep = "")
```

```
## [1] "abracadabra"
```

A short-cut function is `paste0`, which is identical to running `paste` with the argument `sep = ""`:

```
paste0("abra", "ca", "dabra")
```

```
## [1] "abracadabra"
```