Intro to R and Rmarkdown

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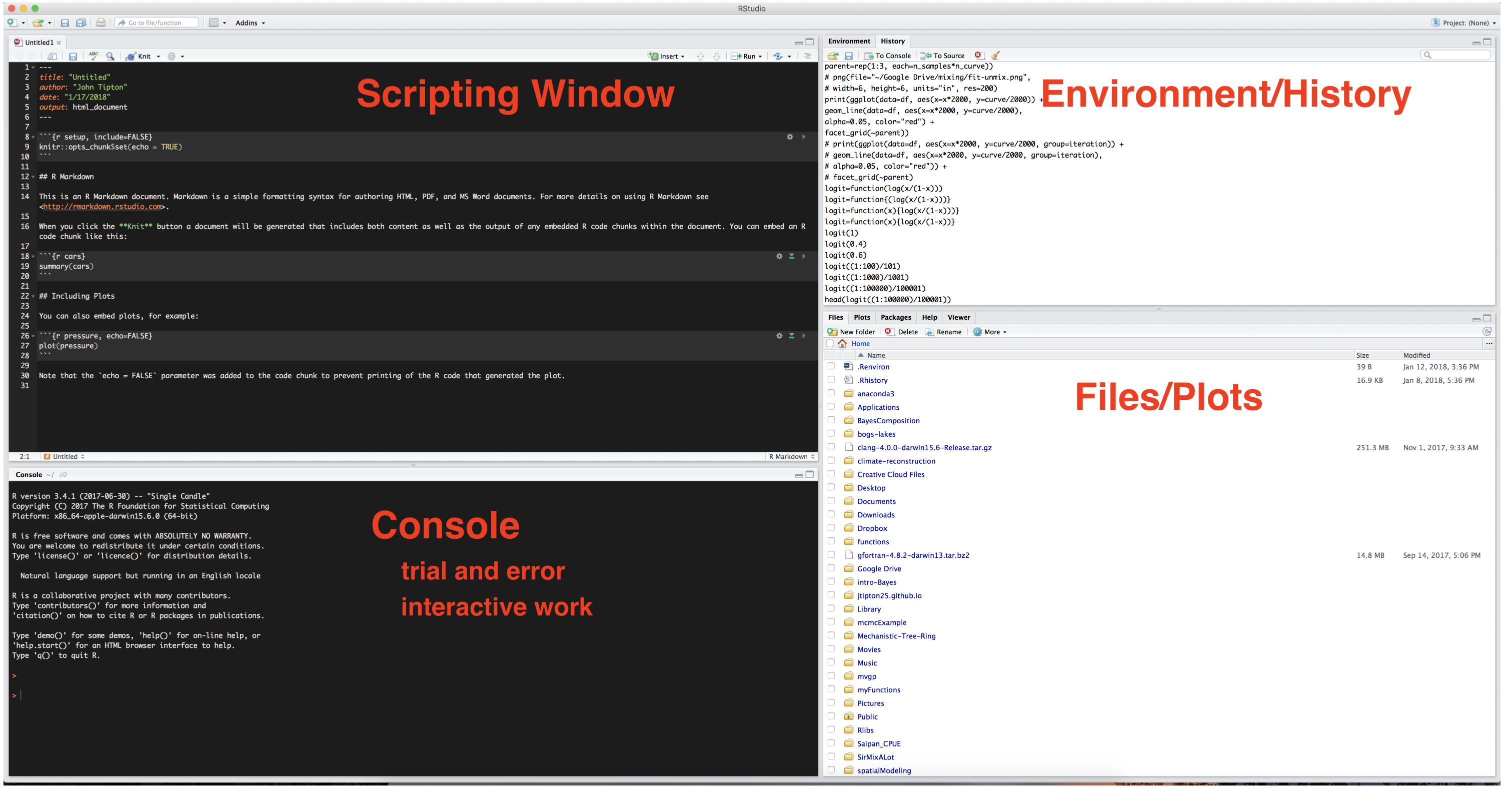
Readings

- R for data science
  - Introduction
  - Chapters 2 (Workflow: basics), 4 (Workflow: scripts), 6 (Workflow: projects), 21 (R Markdown), and 24 (R Markdown workflow)

Introduction to RStudio

- For more examples and information, see Programming with R and R for Reproducible Scientific Analyses.

Locate the different panels within RStudio:



Creating a new RMarkdown file

Let's start by creating a new RMarkdown file:

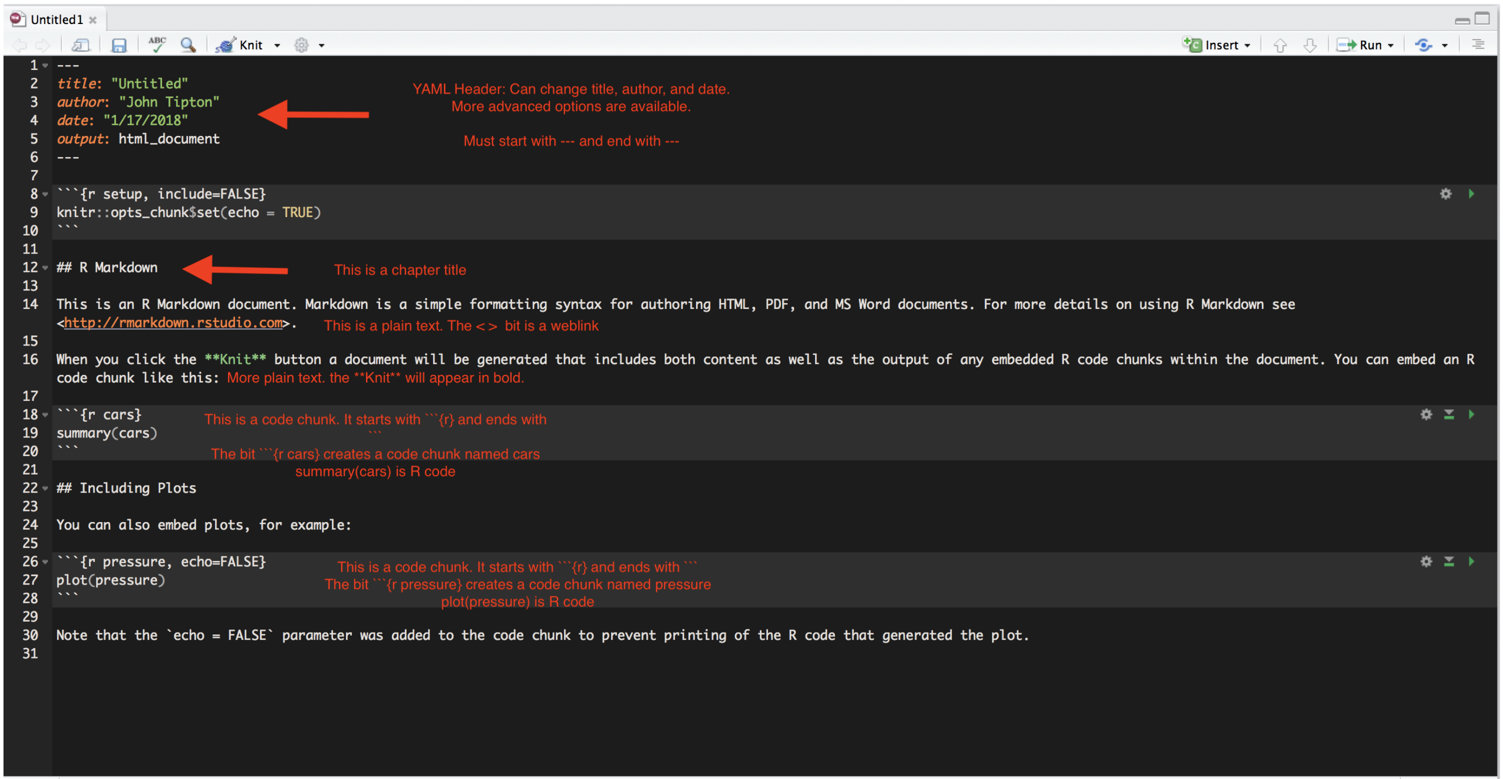
- In the menu bar click **File** $\Rightarrow$ **New File** $\Rightarrow$ **R Markdown**

- Choose the type of file, the output format, the title and the author and click OK.

    - In this class, we will almost always use a **pdf** format
    - **html** formats often look really slick

Creating a new RMarkdown file

The RMarkdown file will be created with some default text. Let's run through it and see what it does.



Working in RMarkdown

We can include plain text in RMarkdown by typing and can add `R` code by using the three tick marks and curly brace notation shown below. Any `R` code in the brackets will be run.

````
```{r}

```
````

Using R code in RMarkdown

For example, we can add two numbers, and the result will be printed below.

```
# add two numbers
4+9
```

```
## [1] 13
```

Notice how the output is preceded by a #. The # represents a comment in R. Everything that is written on the same line as a comment after the comment is not executed. **Use comments everywhere! Your best collaborator/teammate is yourself from 6 months ago!**

Comment your code!

```r
# demonstrate comments
5+7 # +8/9
```

```
## [1] 12
```

- Note: I use two ## for comments (any number of ###s produces a comment until the end of the line)

Variable assignment

We can assign variables to a value using the assign operator `<-`. Below we define the variable `value` as 5 and print the output.

```
## assign values
value <- 5
print(value)
```

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

- Note: The equals symbol also works

```
## assign values
value = 5
print(value)
```

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

- There are **sometimes** cases where there is a difference but most times there is not a difference.

Using R

We can perform calculations on the variable `value`. We multiply `value` by 5 and save the output in the variable `output`.

```
## assign values that are a result of an operation
output <- value * 5
print(output)
```

```
## [1] 25
```

and check that the output is the same as just multiplying by 5

```
print(value*5)
```

```
## [1] 25
```

Try on your own:

- Create a new Rmarkdown document and give it the title "My first Rmarkdown Document"
- Write the line "To be or not to be, that is the question." in plain text in your RMarkdown.
- After this line, create an `R` chunk and assign the variable `b` the value of 7. Then print the value of 2b.
- Add in a comment of your favorite Shakespeare quote (or any quote if you don't like Shakespeare).
- Compile the document and check that your answer looks like mine.

Insert document created in class here

Updating/changing variables

We can also update the variable `value` in the code

```r
value <- 11
print(value)
```

```
## [1] 11
```

```r
value <- value - 8
print(value)
```

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

Functions

We can also use functions. Almost all of the common mathematical functions are available. For example

```
y <- log(10)
print(y)
```

```
## [1] 2.302585
```

```
z <- sin(4 * pi) / cos(sqrt(3 * pi))
print(z)
```

```
## [1] 4.911175e-16
```

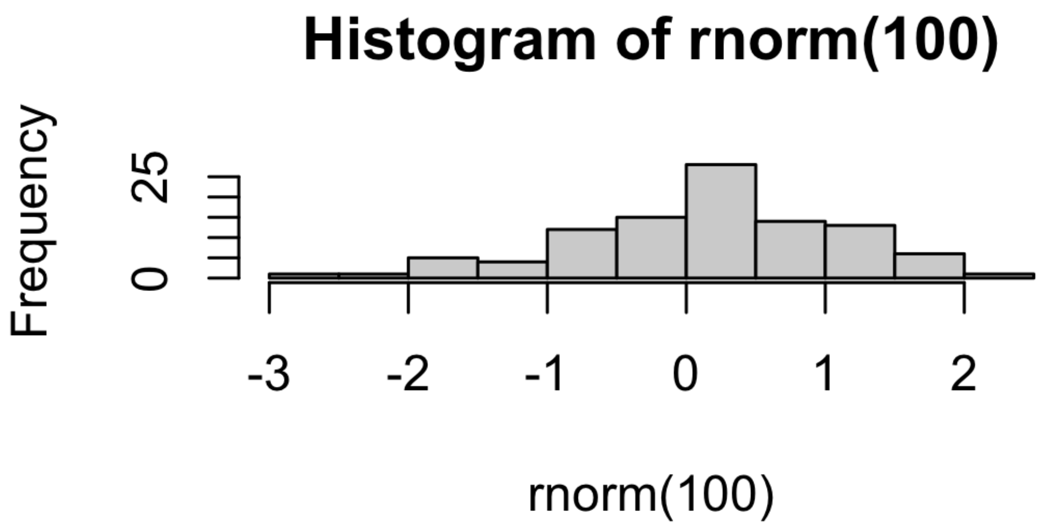
```
print(y+z)
```

```
## [1] 2.302585
```

Functions

We can also use more complex functions and statistical functions. We will make more use of this throughout the course.

```
hist(rnorm(100))
```



Equalities/Inequalities

We can check if two values are equal using `==`

```
7 == 6
```

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

```
(6/3) == 2
```

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

or, a safer way that avoids numerical overflow:

```
2.0000000001 == 2
```

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

```
all.equal(2.0000000001, 2)
```

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

Underflow

What is underflow? Underflow results from the computer using floating point arithmetic that only approximates the math. For example, π has an infinitely long number of digits, but only has about 22 digits in `R`.

```
options(digits=22)
pi
```

```
## [1] 3.141592653589793115998
```

The `all.equal` command asks are these two values equal with respect to the rounding that a computer does.

- Youtube: Subtracting through addition

Testing Inequalities

We can test if a variable is less than some value, greater than some value, or any other inequality.

```r
value <- 6
value < 4
```

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

```r
value > 6
```

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

```r
value >= 6
```

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

Conditional Logic

We can use these tests to write conditional statements (if-else)

```r
value <- 6
if (value < 6) {
  print("less than 6")
} else if (value > 6) {
  print("greater than 6")
} else if (all.equal(value, 6)) {
  print("equals 6")
}
```

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

Conditional Logic

```r
value <- 8
if (value < 6) {
  print("less than 6")
} else if (value > 6) {
  print("greater than 6")
} else if (all.equal(value, 6)) {
  print("equals 6")
}
```

```
## [1] "greater than 6"
```

Tips and tricks

- Order of operations matters. Use parantheses to make things clear

```r
3 + 5 * 6
```

```
## [1] 33
```

```r
(3 + 5) * 6
```

```
## [1] 48
```

```r
3 + (5 * 6)
```

```
## [1] 33
```

Tips and tricks

- If you run a command that takes a long time or was wrong, you can cancel commands with `Esc` or `Ctrl+C`.
- The `ls()` command will list all of the variables and functions in the `R` environment.
- **Packages** use `install.packages("package name here")` to install packages
- If you get an error message "there is no package named tidyverse", you need to install and load the package.
    - You only need to install once per computer.
    - You need to load the library every time you work with the code.

```
install.packages("tidyverse")  ## do this one time
```

In Class Problems

1. What will be the value of each variable after each statement below:

```
mass <- 47.5
age <- 122
mass <- mass * 2.3
age <- age - 20
```

1. After running the code above, does `mass` equal `age`.

2. After running the code above, compare `mass` to `age`. Which is larger?

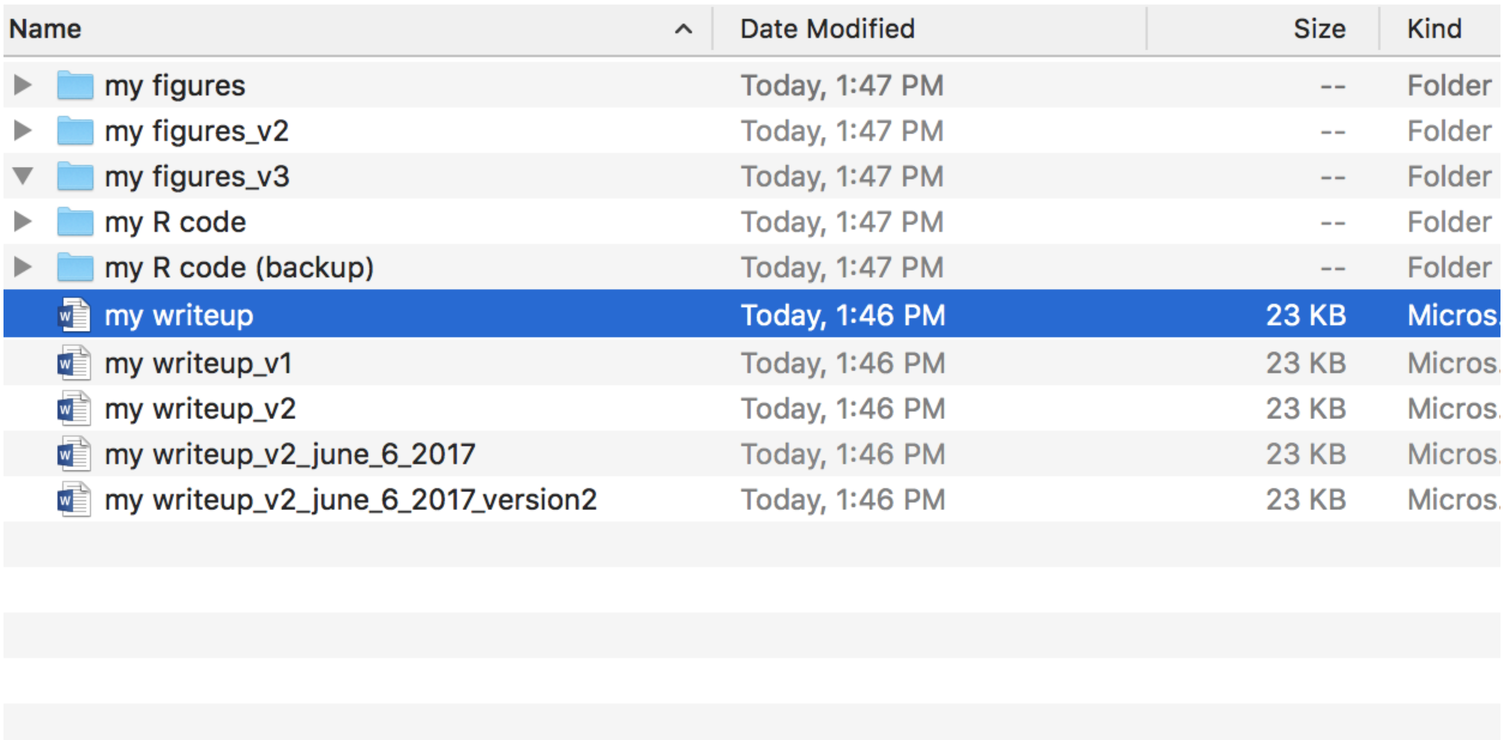
3. Install the following packages using `install.packages()`: `ggplot2` and `dplyr`

Project-based analysis

- Use git.
- Have a consistent file structure and naming convention.
- Focus on reproduciblity and portability.

RStudio Projects

Have you ever had a set of files that looked like this




PEPE SILVIA

RStudio Projects

- It's hard to keep track of what the current version of the file is, what the current data are, what changes you made to the files, etc. It also makes it **really hard to go back to your work weeks, months, or even years later**.

- Instead, we can use **Projects** to organize our analyses.

Why use projects?

- It makes it easier to share your results
    - Example: you need to convince your boss that your results are meaningful
- Reproducing the analysis on new dataset is easier
    - Example: you are a financial trader and want to analyze 10 different stocks
- Resuming the project is easier after a break
    - You can switch back and forth between high-priority projects
    - You can take longer, more relaxing vacations

Creating a new RStudio Project

Let's create a new RMarkdown Project:

- In the menu bar click **File** $\Rightarrow$ **New Project** $\Rightarrow$ **Existing Directory** $\Rightarrow$ **Current folder for class**

- Name your project

- Choose the project location -- add the project to your current gitLab folder
- Click create project

Project organization

Often you want to organize your project into folders. A common set of folders includes

- put your script files in the `R` folder
- put your reports in the `docs` folder
- put your data files in the `data` folder
- put your processed data in the `results` folder

Best practices

- Keep each project in its own folder (i.e. DASC1104)
- **NEVER EVER modify an Excel/data file by hand**
  - load the file into R, modify the data in R, then write an output file in the `results` folder
  - Never have to worry about "which dataset was this"
  - Data is time-consuming and costly to collect.
  - Changing data in Excel leaves no record so you never know which data was the "original" or what changes were made
  - I write a script for processing data usually called `load-data.R` and use the `source` command to run the script.

Best practices

- Treat any code **output** as disposable
    - With an `RMarkdown` document, `R` scripts, and `.py` scripts, you can always re-create the analysis
- Treat the **raw data** as sacred
- If you write the same bit of code more than 3 times, figure out how to write a function
    - If you work on many projects, you might find yourself repeating tasks
    - One function reduces the chance of mistakes from typos or > copy/paste errors
    - Put functions in their own `.R` or `.py` files

Best practices

- Save your data in the `data` directory
- Learn to Google for help and read the help files using the `?` before a function.
    - `?lm` will get you the help page for the `lm` function for linear regression.
    - Google linear regression in R for help on linear regression

Working directories in R

- A `filepath` is the **address** of where a file is located.
  - On a Windows machine this might look like `C:\Documents\DASC1104`
  - On a Mac it might look like `~/Documents/DASC1104`
- The **working directory** is the default filepath in R.
  - To find your working directory use the command `getwd()`.

```
getwd()
```

```
## [1] "/Users/tips/dasc-1104-teaching-2022/lectures"
```

Working Directories and Projects

- If you use a project, the working directory starts in the project folder.
    - On a Windows (Mac) machine with a project in the folder `:\Documents\DASC1104` (`~/Documents/DASC1104`), `getwd()` will return that file path.
    - If we follow the advice above about projects, we can get access to the `R` script at `C:\Documents\DASC1104\R\add-two-numbers.R` (`~/Documents/DASC1104/R/add-two-numbers.R`), by using the command `source(here("R", "add-two-numbers"))`.
- The `here` command from `library(here)` automatically constructs the filepath using the project then finds the file `add-two-numbers.R` in the `/R/` folder.

Working Directories and Projects

Try this in your project now.

```
library(here)
## source tells R to load/run the file
source(here::here("R", "add-two-numbers.R"))

add_two_numbers(5, 7)
```

```
## [1] 12
```

Object types in `R`

data types

- character (string)

```
name <- "Cora"
```

- numeric (like double/float in strongly typed languages)

```
age <- 2
```

- integer

```
fingers <- 10L
```

- complex

```
spectrum <- 2 + 5i
```

- logical

```
success <- TRUE
```

Object types in `R`

data structures

- scalars

```
a <- 4
```

- vectors

```
x <- c(2, 3, 4.5)
```

- matrices

```
y <- matrix(rnorm(6), nrow = 3, ncol = 2)
```

- arrays

```
z <- array(rnorm(60), dim = c(4, 3, 5))
```

Object types in R

data structures

- lists

```
nba_player <- list(
  name = "Lebron James",
  height = 81,
  weight = 250,
  nicknames = c("King James", "LBJ", "Bron-Bron")
)
```

- data.frames

```
dat <- data.frame(x = 1:10, y = rnorm(10), z = rep(c("a", "b"), each = 5))
```

- tibbles

```
library(tidyverse)
dat_tibble <- tibble(dat)
```

Object types in R

data structures

- factors

```
religion <- factor(c("catholicism", "judaism", "islam", "hinduism"))
quality <- factor(c("low", "medium", "high"), levels = c("low", "medium", "high"), order
```

Object types in `R`

object attributes

- names

```r
names(nba_player)
```

```
## [1] "name"      "height"    "weight"    "nicknames"
```

```r
ores <- matrix(
  rnorm(20),
  nrow = 5,
  ncol = 4,
  dimnames = list(
    location = paste("site", 1:5),
    variable = c("lead", "zinc", "copper", "tin")
  )
)
```

Object types in `R`

object attributes

- dimension

```
dim(ores)
```

```
## [1] 5 4
```

```
nrow(ores)
```

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

```
ncol(ores)
```

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

```
length(ores)
```

```
## [1] 20
```

```
length(nba_player)
```

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

Object types in R

object attributes

- class

```
class(ores)
```

```
## [1] "matrix" "array"
```

```
class(nba_player)
```

```
## [1] "list"
```

```
class(dat_tibble)
```

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

- inheritance
    - e.g., animal class
    - a cat is an animal -> the cat class inherits the animal class
    - a lion is a cat and an animal -> the lion class inherits the cat and animal classes

Vector/Matrix operations

R is a very powerful for mathematical functions. One of the great benefits of `R` is the ability to easily apply functions to vectors, matrices, or even larger objects.

$$4\begin{pmatrix}1\\2\\3\end{pmatrix} = \begin{pmatrix}4\\8\\12\end{pmatrix}$$

$$\begin{pmatrix}1\\2\\3\end{pmatrix} + \begin{pmatrix}4\\5\\6\end{pmatrix} = \begin{pmatrix}5\\7\\9\end{pmatrix}$$

Vectors

For instance, we can define a vector using the function `c()` and perform mathematical operations

```
vec <- c(4, 5, 6)
vec / 2
```

```
## [1] 2.0 2.5 3.0
```

```
vec2 <- c(10, 9, 6)
vec + vec2
```

```
## [1] 14 14 12
```

```
vec / vec2
```

```
## [1] 0.4000000000000000222045 0.5555555555555555802272 1.0000000000000000000000
```

Matrices

We can also create matrices

```
A <- matrix(1:4, 2, 2)
A
```

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

```
B <- matrix(6:11, 2, 3)
B
```

```
##      [,1] [,2] [,3]
## [1,]    6    8   10
## [2,]    7    9   11
```

Matrices

And do math with matrices

$$\begin{pmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 1 & 2 & 3 \end{pmatrix} + \begin{pmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \\ 10 & 11 & 12 \end{pmatrix} = \begin{pmatrix} 5 & 7 & 9 \\ 10 & 10 & 10 \\ 11 & 13 & 15 \end{pmatrix}$$

```
A <- matrix(c(1, 3, 1, 2, 2, 2, 3, 1, 3), 3, 3)
B <- matrix(c(4, 7, 10, 5, 8, 11, 6, 9, 12), 3, 3)

A + B
```

```
##      [,1] [,2] [,3]
## [1,]    5    7    9
## [2,]   10   10   10
## [3,]   11   13   15
```

Matrices

We can multiply matrices

$$\begin{pmatrix} 1 & 3 \\ 2 & 4 \end{pmatrix} \times \begin{pmatrix} 6 & 8 & 10 \\ 7 & 9 & 11 \end{pmatrix} = \begin{pmatrix} 27 & 35 & 43 \\ 40 & 52 & 64 \end{pmatrix}$$

```r
A <- matrix(1:4, 2, 2)
B <- matrix(6:11, 2, 3)
## matrix multiplication
A %*% B
```

```
##      [,1] [,2] [,3]
## [1,]   27   35   43
## [2,]   40   52   64
```

Matrices

Or select rows or columns of a matrix (order is rows first, column second)

- First row of

$$\begin{pmatrix} 1 & 3 \\ 2 & 4 \end{pmatrix}$$

is

$$\begin{pmatrix} 1 & 3 \end{pmatrix}$$

```r
## select the first row of A
A[1, ]
```

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

Matrices

- Third column of

$$\begin{pmatrix} 6 & 8 & 10 \\ 7 & 9 & 11 \end{pmatrix}$$

is

$$\begin{pmatrix} 10 \\ 11 \end{pmatrix}$$

```
## select the third column of B
B[, 3]
```

```
## [1] 10 11
```

For loops

- For loops are a powerful programming techniques.
- For loops allow you to repeat the same procedure repeatedly over different values.

For loops

- Let's try a simple example that prints the numbers from 1 to 6

```r
## The a:b function creates a vector of integers starting
## at a and ending at b
1:6
```

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

```r
## loop over the variable i taking the values 1 to 6
for (i in 1:6) {
  print(i)
}
```

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

For loops

We could also print out a set of names one by one

```r
names <- c("John", "Paul", "Ringo", "George")

## loop over the variable i taking the values in names
for (i in names) {
  print(i)
}
```

```
## [1] "John"
## [1] "Paul"
## [1] "Ringo"
## [1] "George"
```

For loops

- We can do mathematical procedures like calculate the cumulative sum of numbers from 1 to 100

```
## define the variable out as a vector of 100 zeros

## rep(a, N) is a function that creates a vector
## of length N where each element is a
out <- rep(0, 100)
# print(out)
```

For loops

```r
out[1] <- 1
## loop over the variable i taking the values 2 to 100
for (i in 2:100) {
  ## take the value of the variable
  ## out at the i-1 position, add i,
  ## and save at the ith position of out
  out[i] <- out[i-1] + i
}
# print(out)
## use the cumsum function
# cumsum(1:100)
all.equal(out, cumsum(1:100))
```

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

Functions

- Functions are an important tool.
- Every time you need to do an operation multiple times, writing a function
  - increases your long term efficiency (your time is the most important)
  - reduces the chance of errors (type the code once, less chance of typos).

Functions

- We can create our version of the function `cumsum` by writing the function `my_cumsum` based on the for loop we wrote above.

```
my_cumsum <- function(x) { ## x is the function argument
  ## N is the length of x
  N <- length(x)
  ## define a vector to store the output
  out <- rep(0, N)
  ## set the first element of out as the first element of x
  out[1] <- x[1]
  ## loop over the remaining N-1 values
  for (i in 2:N) {
    out[i] <- out[i-1] + x[i]
  }
  ## return the value out
  return(out)
}
```

Functions

We can test our function using some examples

```r
a <- 5:13
my_cumsum(a)
```

```
## [1]  5 11 18 26 35 45 56 68 81
```

```r
all.equal(my_cumsum(a), cumsum(a))
```

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

Functions

You can even call a function that calls a function that calls a function…

```
my_cumsum(my_cumsum(my_cumsum(a)))
```

```
## [1]    5   21   55  115  210  350  546  810 1155
```

```
cumsum(cumsum(cumsum(a)))
```

```
## [1]    5   21   55  115  210  350  546  810 1155
```

```
# knitr::include_graphics(here::here("images", "top.gif"))
```