Intro2R

Introduction to R Programming

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Course materials: https://github.com/xp-song/Intro2R
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Before we begin...

1. Navigate to course webpage and read background information
   https://github.com/xp-song/Intro2R

2. Ensure that you have installed **R** on your computer, followed by **R Studio**
   (follow links under 'Instructions' section of webpage)

3. Download workshop materials
   (green button on webpage)

Outline

What is R?

- Programming language and software environment with a command line interface
- RStudio is often used as a software client
- Both R and RStudio are open source software
- Huge library of packages created by the R community

About this crash course

What it IS

- Designed for those with minimal coding experience
- Give you a taste of what R can do

What it is NOT

- A substitute to practicing the fundamentals of the language
- A lesson in statistics

Outline

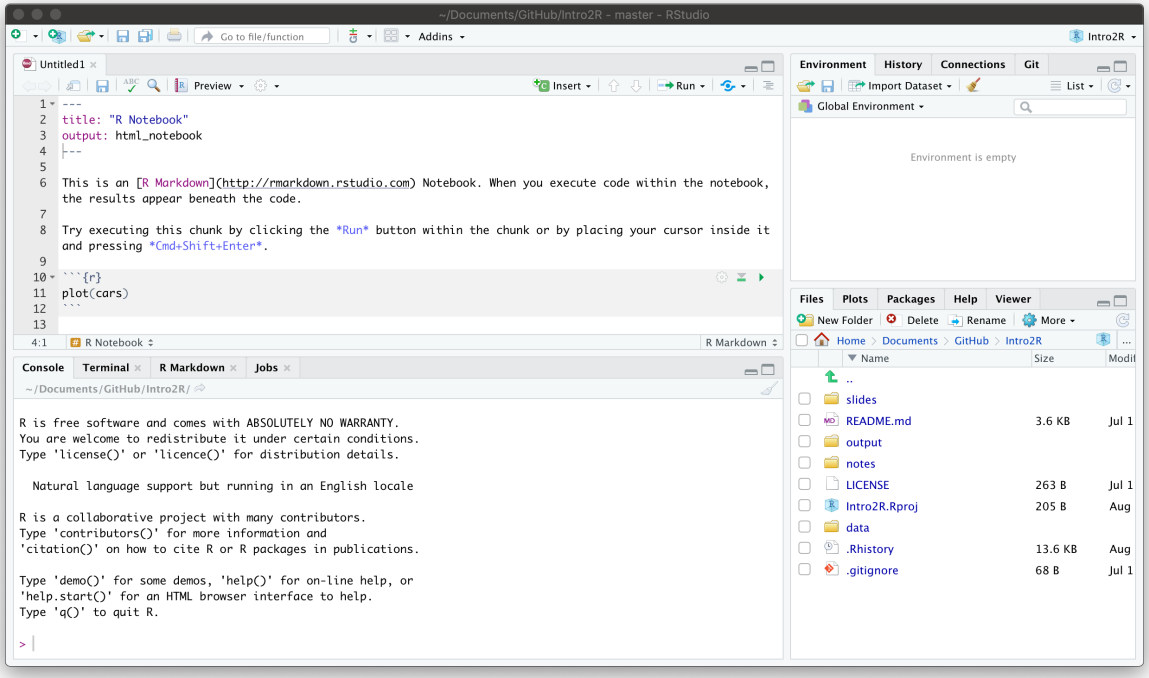
Course materials

On your computer, navigate to downloaded folder

/notes [1]
/data
PDF slide deck
Intro2R.Rproj

[1] View in your web browser by opening the '*.html*' files

R Studio Client



- **Console:** Command line input/output
- **Script editor:** View/edit files that contain code
- **Environment/History**
- **Files/Plots/Packages/Help/Viewer**

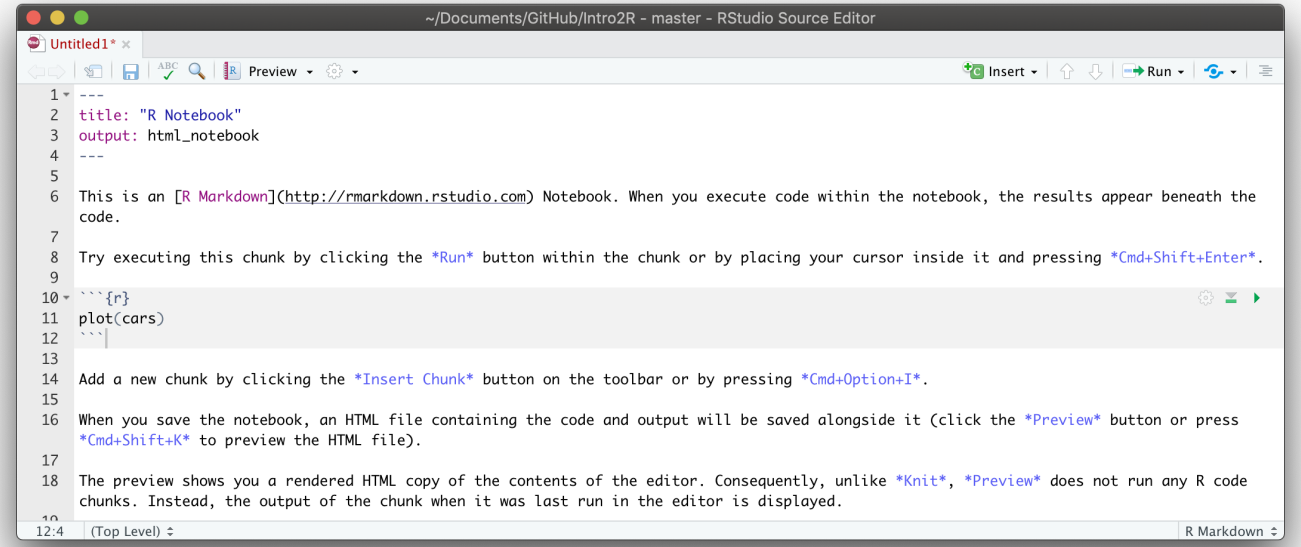
R Notebooks

What are R Notebooks?

- R Notebooks (a.k.a. R Markdown Notebooks) are files ending with '*.Rmd*'.
- Compared to basic '*.R*' scripts, they allows us to:
  - Write normal text alongside code
  - Interact with code within a single document
  - Generate (i.e. '*knit*') different types of files

Try creating a new R Notebook `File > New File > R Notebook`

R Notebooks

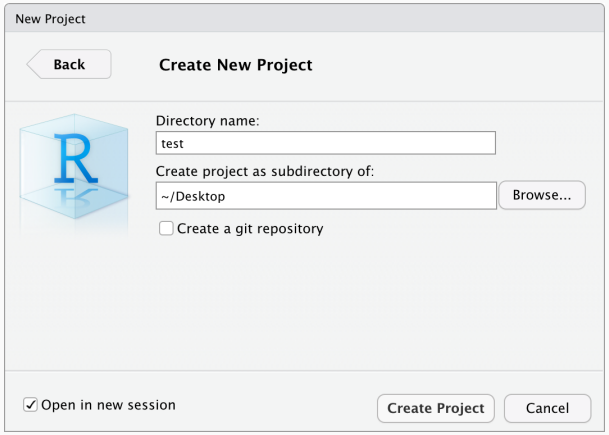


- **Header section:** specify document parameters
- **Normal text**
- **Code chunk:** write code and specify code parameters

Save our new file as '*myanalysis.Rmd*'

RStudio Projects

Try creating a new RStudio Project `File > New Project > New Directory > New Project`



RStudio Projects

What are RStudio Projects?

- RStudio Projects help organise your work into separate 'R sessions'.
- Each project has it's own workspace a.k.a. 'working directory' (separate configuration, history, etc.)
- The location of the '*.RProj*' file defines the 'working directory'
  - **Type `getwd()` in the *console* of our new project**
  - This returns the absolute path to our working directory
    e.g., `/Users/<computer_username>/Desktop/test`

RStudio Projects

🌟 Best Practice

- Use *relative* paths in your script, based on *.RProj* file location
    - **Try reading in data in your R Notebook**

      ```
      read.csv("<path to Intro2R folder>/Intro2R/data/ozone_data.csv")
      ```

      ```
      read.csv("data/ozone_data.csv")
      ```

- Keep all project items in the working directory

Outline

General Syntax

Operators

Arithmetic operators:

E.g., Solve the following equation

$$\frac{(1+2)*(4-5)}{50}$$

```
(1+2)*(4-5)/50
```

```
## [1] -0.06
```

General Syntax

Operators

Logical operators:

E.g., Check if `1e3` is larger or equal to `1*10^3`

```
1e3 >= 1*10^3
```

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

General Syntax

Operators

Variables

Variables are named objects used to store data

- `<-` is used to assign variable names in R (E.g., `x <- 4`)
- Print variables by name (`x` vs. `"x"`)
- Assigning data to an existing variable overwrites it (`x <- 10`)

🌟**Best Practice**

- Clear and consistent names
- Avoid numbers/symbols/whitespace

General Syntax

Operators

Variables

Data types and examples:

- Numeric (`3.142`), Integer (`5L`)
- Character (`"hello"`)
- Logical (`TRUE, FALSE`)
- Complex

Let's assign new variables `name`, `age`, and `weight`

Check the data type for each variable using the function `is.numeric()`, `is.integer()`, `is.character()`

Outline

Data Structures

Vectors

About vectors:

- Linear collection of data
- Must be of the *same* data type

Assign a *vector* of names to the variable `name`
(use the concatenate function `c()`)

```
name <- c("Me", "Tom", "Dick", "Harry", "Susan") # character vector
```

Assign a *vector* of numbers to the variable `age`

```
age <- c(20, 25, 30, 35, 40) # numeric vector
```

Data Structures

Vectors

About vectors:

- Linear collection of data
- Must be of the *same* data type
- *Operations in R are vectorised*

Subtract 5 from the vector `age`

```
age-5
```

```
## [1] 15 20 25 30 35
```

Add together two vectors

```
age+age
```

```
## [1] 40 50 60 70 80
```

Data Structures

Vectors

Lists

About lists:

- Linear collection of data
- Can contain of different *types* and *structure* of data

Create a list with a mix of data types and variables

```
myteam <- list(name, age, "Group 1", 2019)
```

Data Structures

Vectors

Lists

About lists:

- Linear collection of data
- Can contain of different *types* and *structure* of data

```
myteam
```

```
## [[1]]
## [1] "Me"    "Tom"   "Dick"  "Harry" "Susan"
##
## [[2]]
## [1] 20 25 30 35 40
##
## [[3]]
## [1] "Group 1"
##
## [[4]]
## [1] 2019
```

Data Structures

Vectors

Lists

Factors

About factors:

- A special kind of vector that represents categorical data with discrete levels

Let's code the sex of each person in the variable `name`
(use the functions `factor()` and `c()`)

```
sex <- factor(c("M","M","M","M","F"))
sex
```

```
## [1] M M M M F
## Levels: F M
```

Data Structures

Vectors

Lists

Factors

About factors:

- A special kind of vector that represents categorical data with discrete levels

Let's code the performance of each person in `name`

```
perform <- factor(c("High", "Low", "Med", "Med", "High"))
perform
```

```
## [1] High Low  Med  Med  High
## Levels: High Low Med
```

What is wrong with this output?

Data Structures

Vectors

Lists

Factors

About factors:

- A special kind of vector that represents categorical data with discrete levels

Define the order using the `levels=` argument in `factor()`

```
perform <- factor(c("High", "Low", "Med", "Med", "High"),
                  levels = c("Low", "Med", "High"))
perform
```

```
## [1] High Low  Med  Med  High
## Levels: Low Med High
```

Data Structures

Vectors

Lists

Factors

Matrices

About matrices:

- Tabular data (rows & columns)
- Must be of the *same* data type

Create a 4 by 3 matrix of sequential numbers

Use `matrix()` and the `:` operator to create a sequence

```
m <- matrix(1:12, nrow = 4)
m
```

```
##      [,1] [,2] [,3]
## [1,]    1    5    9
## [2,]    2    6   10
## [3,]    3    7   11
## [4,]    4    8   12
```

Data Structures

Vectors

Lists

Factors

Matrices

Dataframes

About dataframes:

- Tabular data (rows & columns)
- Rows represent data entries, columns represent different variables

Import the dataset `ozone_data.csv` into your R Notebook using `read.csv()`

```
ozone <- read.csv("data/ozone_data.csv") # column headers in first row
```

Data Structures

View the first few rows of `ozone`

```
head(ozone) #print first few rows
```

```
##   rad temp wind ozone
## 1 190   67  7.4    41
## 2 118   72  8.0    36
## 3 149   74 12.6    12
## 4 313   62 11.5    18
## 5 299   65  8.6    23
## 6  99   59 13.8    19
```

Check the dimensions of `ozone`

```
dim(ozone)
```

```
## [1] 111   4
```

Data Structures

Check the names of `ozone` using `dimnames()`, `rownames()` and `colnames()`

```
dimnames(ozone)
```

```
## [[1]]
##   [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12
##  [13] "13"  "14"  "15"  "16"  "17"  "18"  "19"  "20"  "21"  "22"  "23"  "24
##  [25] "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36
##  [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48
##  [49] "49"  "50"  "51"  "52"  "53"  "54"  "55"  "56"  "57"  "58"  "59"  "60
##  [61] "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72
##  [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84
##  [85] "85"  "86"  "87"  "88"  "89"  "90"  "91"  "92"  "93"  "94"  "95"  "96
##  [97] "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "10
## [109] "109" "110" "111"
##
## [[2]]
## [1] "rad"   "temp"  "wind"  "ozone"
```

Data Structures

Vectors

Lists

Factors

Matrices

Dataframes

Extract data by colnames using `$`

(output is a vector)

```
ozone$temp
```

```
##   [1] 67 72 74 62 65 59 61 69 66 68 58 64 66 57 68 62 59 73 61 61 67 81 79
##  [26] 90 87 82 77 72 65 73 76 84 85 81 83 83 88 92 92 89 73 81 80 81 82 84
##  [51] 74 86 85 82 86 88 86 83 81 81 81 82 89 90 90 86 82 80 77 79 76 78 78
##  [76] 79 81 86 97 94 96 94 91 92 93 93 87 84 80 78 75 73 81 76 77 71 71 78
## [101] 68 82 64 71 81 69 63 70 75 76 68
```

Data Structures

Vectors

Lists

Factors

Matrices

Dataframes

Create a dataframe with the vectors `name`, `sex`, `age` and `perform`

```
team_details <- data.frame(name, age, sex, perform)
team_details
```

```
##    name age sex perform
## 1    Me  20   M    High
## 2   Tom  25   M     Low
## 3  Dick  30   M     Med
## 4 Harry  35   M     Med
## 5 Susan  40   F    High
```

Back to operators...

Subsetting in R

Extract the 5th element in the vector `name`

```
name[5]
```

```
## [1] "Susan"
```

Extract the 4th element of the column `age` in the dataframe `team_details`

Remember: use `$` to extract columns by their name

```
team_details$age[4]
```

```
## [1] 35
```

Back to operators...

Subsetting in R

Extract the element in the 2nd row and 4th col in `team_details`

```
team_details[2,4]
```

Extract 2nd row and all cols in `team_details`

```
team_details[2,]
```

Extract the 4th col and all rows except the 2nd in `team_details`

```
team_details[-2,4]
```

Back to operators...

Subsetting in R

Extract rows 1 to 3 in `team_details`

```
team_details[1:3,]
```

```
##   name age sex perform
## 1   Me  20   M    High
## 2  Tom  25   M     Low
## 3 Dick  30   M     Med
```

Extract rows 1 and 3 in `team_details`

```
team_details[c(1,3),]
```

```
##   name age sex perform
## 1   Me  20   M    High
## 3 Dick  30   M     Med
```

Back to operators...

Subsetting in R: Quick test!⚡

Load the built-in dataset `data(mtcars)`

Extract data on cars with a fuel efficiency of at least 20 mpg, and that are more than 108 hp

```
##                mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4     21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag 21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## Hornet 4 Drive 21.4  6 258.0 110 3.08 3.215 19.44  1  0    3    1
## Lotus Europa  30.4   4  95.1 113 3.77 1.513 16.90  1  1    5    2
## Volvo 142E    21.4   4 121.0 109 4.11 2.780 18.60  1  1    4    2
```

- **Hint:** `mtcars[ & , ]`
- **Hint:** `mtcars[mtcars$mpg >= 20 & , ]`

Outline

Functions

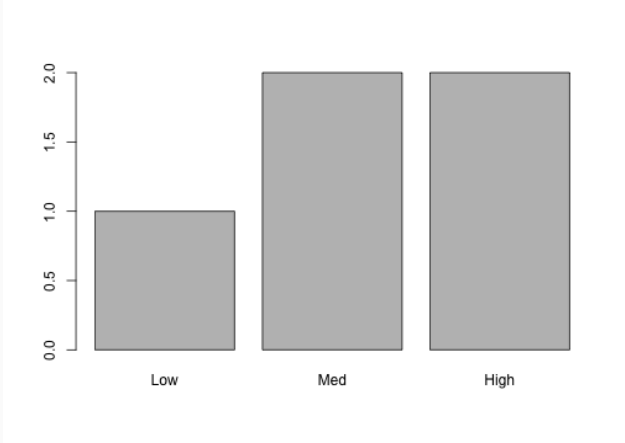
Overview

About functions:

- Functions have inputs and outputs
- Look up details about the function with `?<functionname>`

E.g., Plot the performance distribution in `team_details`

```
plot(team_details$perform)
```



Functions

Overview

E.g., Find the mean age in `team_details`

```
mean(team_details$age)
```

```
## [1] 30
```

E.g., Find the number of people (rows) in `team_details`

```
nrow(team_details)
```

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

Functions

Overview

User-defined

General structure when defining a custom function:

```
functionname <- function(inputs){
  # calculations...
  output
  }
```

Subsequent calls to the function:

```
functionname(inputs)
```

Functions

Overview

User-defined

E.g., Load `data/grades.csv` and assign it the name `grades`

```
##     subject grade grade_point credits
## 1      Math     A         4.5       5
## 2   English     B         3.5       5
## 3 Economics     C         2.0       4
## 4  Mandarin    B+         4.0       5
## 5     Music     F         1.0       0
## 6   History    C+         2.5       5
## 7   Intro2R    A+         5.0       1
```

Functions

Manually calculate the GPA in R using the formula:

$$\frac{\sum_{i=1}^{n} gradepoint_i \times credits_i}{\sum_{i=1}^{n} credits_i}$$

```
sum(grades$grade_point * grades$credits) / sum(grades$credits)
```

```
## [1] 3.42
```

Functions

Overview

User-defined

Create a function named `scorer` that:

- Takes a dataframe as input
- Outputs a calculation based on the colnames `grade_point` and `credits`

```
scorer <- function(x){
  sum(x$grade_point*x$credits) / sum(x$credits)
}
```

```
scorer(grades) #use function
```

```
## [1] 3.42
```

Functions

About loop functions:

- Loop functions repeat code `i` number of times
- Most common type: `for` loop

Functions

Prepare our data inputs to the `for` loop:

Get the grades of other team members within `/data` folder

```
grades_tom <- read.csv("data/grades_tom.csv")
grades_dick <- read.csv("data/grades_dick.csv")
grades_harry <- read.csv("data/grades_harry.csv")
grades_susan <- read.csv("data/grades_susan.csv")
```

Put all these dataframes into a list named `team_grades`

```
team_grades <- list(grades, grades_tom, grades_dick, grades_harry, grades_sus
```

Functions

For every item (person) in the list `team_grades`, use the function `scorer()` and append results to new column "GPA" in `team_details`

```
for(i in 1:length(team_grades)){
  team_details$GPA[i] <- scorer(team_grades[[i]])
  }
#the named object "i" changes in value with iteration of the loop
```

Who has the best grades in the team?

```
##    name age sex perform      GPA
## 1    Me  20   M    High 3.420000
## 2   Tom  25   M     Low 3.710526
## 3  Dick  30   M     Med 4.342105
## 4 Harry  35   M     Med 5.000000
## 5 Susan  40   F    High 4.342105
```

Functions

Examples of Loop functions in base R

`lapply(x, FUN)`: Apply a function on each element of `x`, returns a *list*
`apply(x, MARGIN, FUN)`: Apply a function to tabular data by rows (`1`), cols (`2`), or both `c(1,2)`

E.g., Find the mean value for *each* numeric column in `team_details`

```
apply(team_details[,c(2,5)], 2, mean) #apply mean() function across columns
```

```
##       age       GPA
## 30.000000  4.162947
```

Functions

Quick test!⚡

Calculate the mean for each numeric variable in `data(mtcars)`

```
##                    mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

Answer:

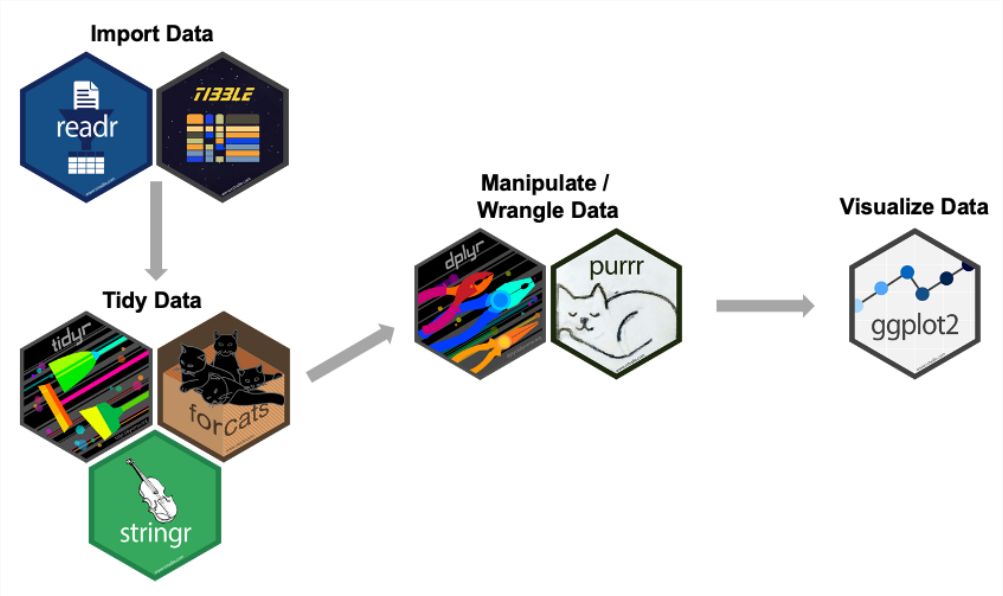
```
apply(mtcars, 2, mean)
```

```
##        mpg        cyl       disp         hp       drat         wt       qse
##  20.090625   6.187500 230.721875 146.687500   3.596563   3.217250  17.84875
...
```

Outline

The *tidyverse*

The *tidyverse* collection of packages are commonly used for data science, and share the same design philosophy, grammar and data structures



Core packages loaded automatically with `library(tidyverse)`

The *tidyverse*

Install the *tidyverse* collection of packages

```
install.packages("tidyverse", dependencies = TRUE) # don't forget the quotes
```

Load these packages into R

```
library(tidyverse) # no need quotes
```

Note:

- If you are asked to restart R, select the Option 'Yes' once
- Enter `n` if you get the following prompt: `Do you want to attempt to install these from sources?`

Tidy syntax

The pipe operator `%>%`

- From the magrittr package
- Frequently used to manipulate data in stages/sequence
- Shortcut: *Ctrl (Cmd) + Shift + M*

For example:

```
round(exp(diff(log(x))), 1) # using nested brackets

x %>% # using the pipe operator
  log() %>%
  diff() %>%
  exp() %>%
  round(1)
```

Note: R 4.1.0 introduced the native pipe operator `|>`. It can be used without installing/loading any packages. However, note that it will not work in earlier versions of R. Differences between the two pipe operators are explained in here

The *tidyverse*

Tidy data

- Tabular data (2D)
- Each variable is a column & each observation is a row
- Can be in long or wide format

country	year	key	value
Afghanistan	1999	infected	135
Afghanistan	1999	population	19839494
Afghanistan	2020	infected	384
Afghanistan	2020	population	21739203
Australia	1999	infected	34
Australia	1999	population	23423534
Australia	2020	infected	45
Australia	2020	population	23346436
Belgium	1999	infected	272
Belgium	1999	population	49273820
Belgium	2020	infected	274
Belgium	2020	population	48928472

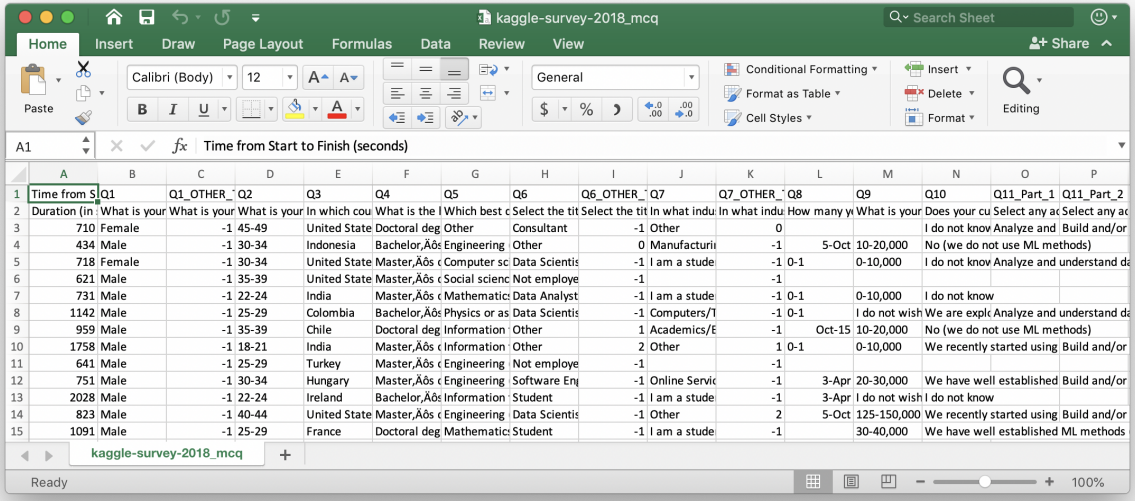
country	year	infected	population
Afghanistan	1999	135	19839494
Afghanistan	2020	384	21739203
Australia	1999	34	23423534
Australia	2020	45	23346436
Belgium	1999	272	49273820
Belgium	1999	274	48928472

Import

Load example survey data as *tibbles*[1] using `readr::read_csv()`

(Source: Kaggle)

```
survey <- read_csv("data/kaggle-survey-2018_mcq.csv", skip = 1)
```



[1] Tibbles are dataframes with stricter rules that avoid hassle/errors often associated with conventional dataframes

The *tidyverse*

Import

Examine the first few rows of `survey`

```
head(survey)
```

```
## # A tibble: 6 × 395
##   `Duration (in seconds)` What is your gender? - Select…¹ What is your genc
##                     <dbl> <chr>
## 1                     710 Female
## 2                     434 Male
## 3                     718 Female
## 4                     621 Male
## 5                     731 Male
## 6                    1142 Male
## # ℹ abbreviated names: ¹`What is your gender? - Selected Choice`,
## #   ²`What is your gender? - Prefer to self-describe - Text`
## # ℹ 392 more variables: `What is your age (# years)?` <chr>,
...
```

The *tidyverse*

Import

Compare `tibble::read_csv()` with `read.csv()` from base R

```
survey2 <- read.csv("data/kaggle-survey-2018_mcq.csv", skip = 1)
head(survey2)
```

```
##   Duration..in.seconds. What.is.your.gender....Selected.Choice
## 1                   710                                 Female
## 2                   434                                   Male
## 3                   718                                 Female
## 4                   621                                   Male
## 5                   731                                   Male
## 6                  1142                                   Male
...
```

Import

Tidy

Column names have unusual characters

```
head(colnames(survey))
```

```
## [1] "Duration (in seconds)"
## [2] "What is your gender? - Selected Choice"
## [3] "What is your gender? - Prefer to self-describe - Text"
## [4] "What is your age (# years)?"
## [5] "In which country do you currently reside?"
## [6] "What is the highest level of formal education that you have attained c
```

Abbreviate the colname `Duration (in seconds)` to `duration` using `dplyr::rename()`

```
survey <- survey %>%
  rename(duration = `Duration (in seconds)`)
```

The *tidyverse*

Import

Tidy

Change the units from seconds to minutes using `dplyr::mutate()`

```
survey <- survey %>%
  mutate(duration = duration/60) # overwrite the colname
```

Print out first few rows of `survey$duration`

```
head(survey$duration)
```

```
## [1] 11.833333  7.233333 11.966667 10.350000 12.183333 19.033333
```

The *tidyverse*

Import

Tidy

Wrangle

Subset rows using `dplyr::filter()` as an alternative to subset operators `[` and `]` in base R

E.g., Subset (filter) the data to respondents who took < 30 minutes to complete the survey

```
survey %>%
  filter(duration < 30)
```

```
## # A tibble: 17,757 × 395
##    duration What is your gender?…¹ What is your gender?…² What is your age
##       <dbl> <chr>                                  <dbl> <chr>
##  1    11.8  Female                                    -1 45-49
##  2     7.23 Male                                      -1 30-34
##  3    12.0  Female                                    -1 30-34
##  4    10.4  Male                                      -1 35-39
##  5    12.2  Male                                      -1 22-24
...
```

The *tidyverse*

Import

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Wrangle

Use `group_by()`, `summarize()` and `arrange()` from the dplyr package to summarise (aggregate) data

```
ctry_breakdown <- survey %>%
  rename(country = `In which country do you currently reside?`) %>% # simplif
  group_by(country) %>%
  summarise(count = n()) %>% # create new col that counts each group size usi
  arrange(-count) # arrange by the colname 'count' in descending order
ctry_breakdown
```

```
## # A tibble: 58 × 2
##    country                                count
##    <chr>                                  <int>
##  1 United States of America                4716
##  2 India                                   4417
##  3 China                                   1644
##  4 Other                                   1036
##  5 Russia                                   879
##  6 Brazil                                   736
##  7 Germany                                  734
...
```

The *tidyverse*

Import

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Plot

Plot a histogram using the `ggplot2::ggplot()` function

Three basic steps:

1. Provide *data*
2. Assign your data *variables* to *aesthetics*
3. Assign the graphical *primitives*

```
survey %>% # data
  ggplot(aes(duration)) + # map variable to aesthetic
  geom_histogram() # graphical primitive
```

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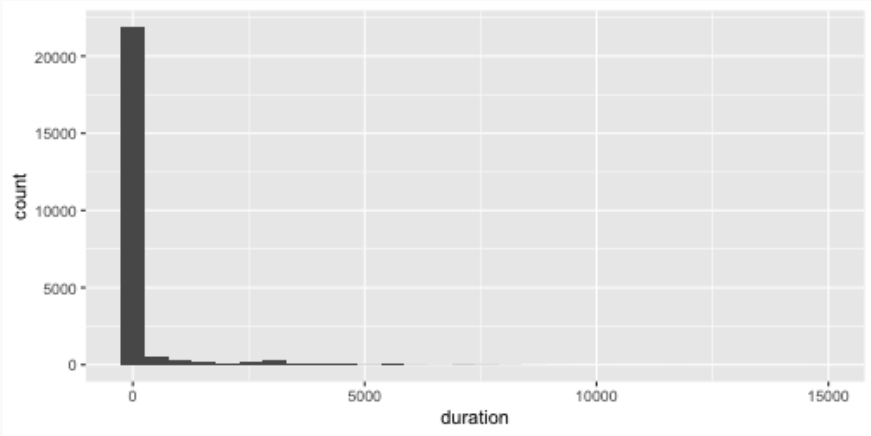
Plot

Plot a histogram using the `ggplot2::ggplot()` function

```
survey %>%
  ggplot(aes(duration)) +
  geom_histogram()
```



The *tidyverse*

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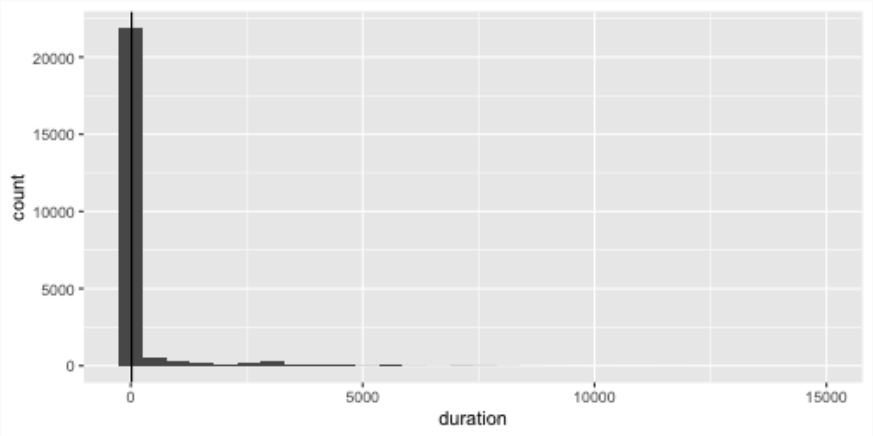
Plot

Plot a histogram using the `ggplot2::ggplot()` function

```
survey %>%
  ggplot(aes(duration)) +
  geom_histogram() +
  geom_vline(xintercept = median(survey$duration)) # add median value
```



The *tidyverse*

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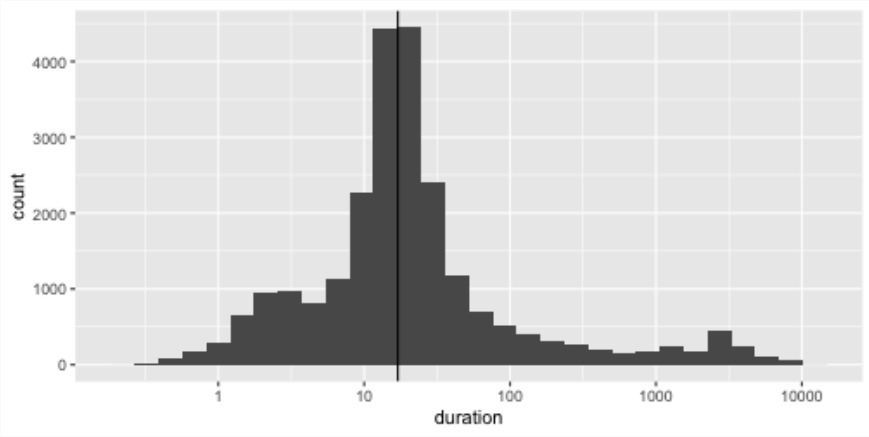
Plot

Plot a histogram using the `ggplot2::ggplot()` function

```
survey %>%
  ggplot(aes(duration)) +
  geom_histogram() +
  geom_vline(xintercept = median(survey$duration)) +
  scale_x_log10() # address extreme x-values
```



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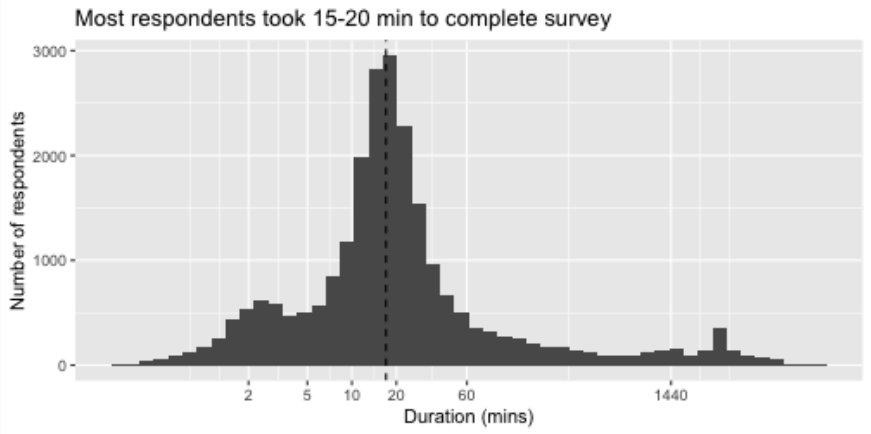
Plot

Plot a histogram using the `ggplot2::ggplot()` function

```
survey %>%
  ggplot(aes(duration)) +
  geom_histogram(bins = 50) +
  geom_vline(xintercept = median(survey$duration), linetype = 2) +

  scale_x_log10(breaks = c(2, 5, 10, 20, 60, 1440)) +

  labs(x = "Duration (mins)", y = "Number of respondents") + #change axis lab
  ggtitle("Most respondents took 15-20 min to complete survey") #add figure t
```



It's your turn!

Explore and visualise `data(diamonds, package = "ggplot2")`

Hint: Use `summary()` *to examine the dataset*

Quick exercise ⚡

Filter diamonds that are less than $3000 with a Premium cut

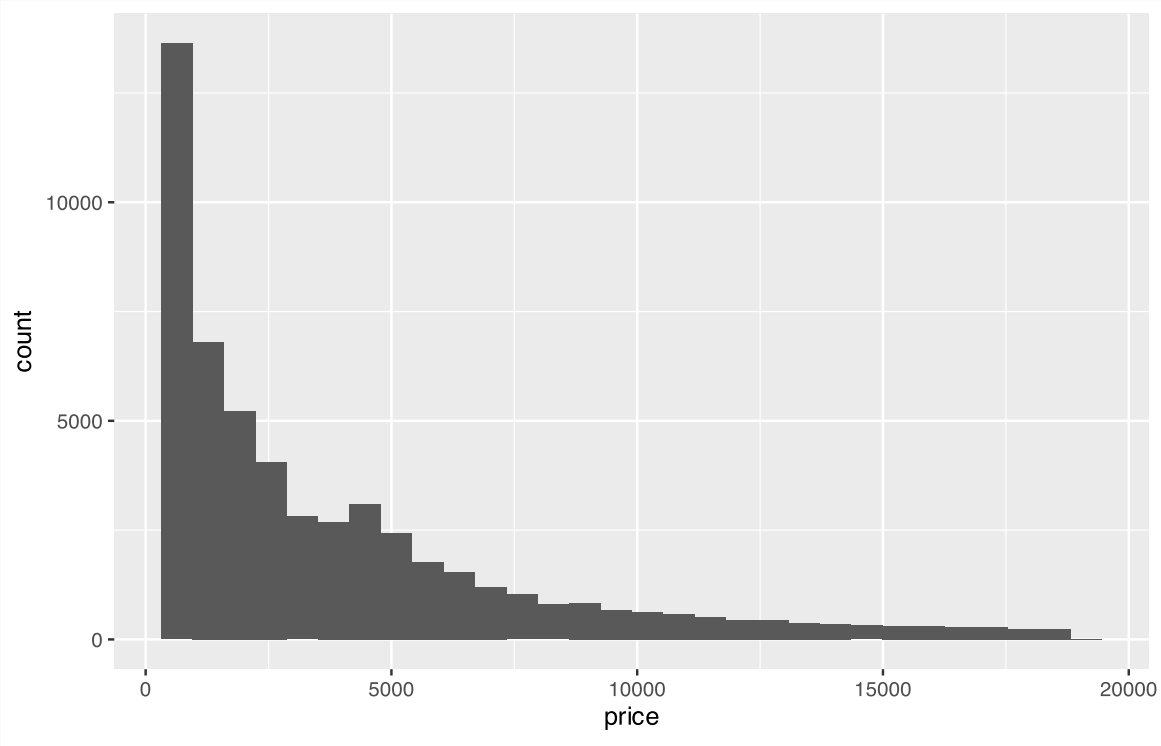
Expected output:

```
## # A tibble: 6,757 × 10
##    carat cut     color clarity depth table price     x     y     z
##    <dbl> <ord>   <ord> <ord>   <dbl> <dbl> <int> <dbl> <dbl> <dbl>
##  1  0.21 Premium E     SI1      59.8    61   326  3.89  3.84  2.31
##  2  0.29 Premium I     VS2      62.4    58   334  4.2   4.23  2.63
##  3  0.22 Premium F     SI1      60.4    61   342  3.88  3.84  2.33
##  4  0.2  Premium E     SI2      60.2    62   345  3.79  3.75  2.27
##  5  0.32 Premium E     I1       60.9    58   345  4.38  4.42  2.68
##  6  0.24 Premium I     VS1      62.5    57   355  3.97  3.94  2.47
##  7  0.29 Premium F     SI1      62.4    58   403  4.24  4.26  2.65
##  8  0.22 Premium E     VS2      61.6    58   404  3.93  3.89  2.41
##  9  0.22 Premium D     VS2      59.3    62   404  3.91  3.88  2.31
## 10  0.3  Premium J     SI2      59.3    61   405  4.43  4.38  2.61
## # ℹ 6,747 more rows
```

Quick exercise ⚡

Plot a histogram of price for all diamonds

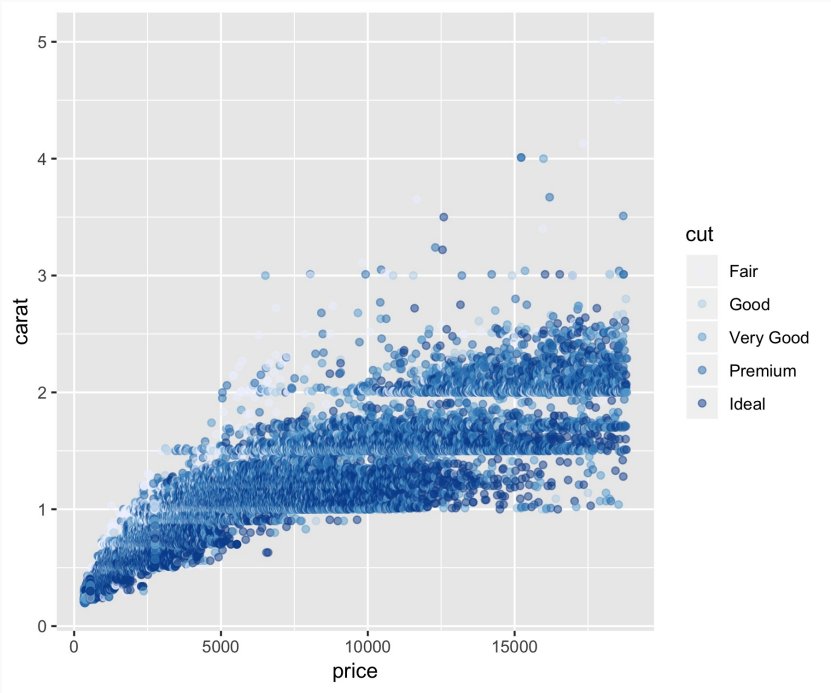
Expected output:



Quick exercise ⚡

Plot a scatter diagram of the price, carat and cut for all diamonds

Expected output:



Questions?

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General Syntax

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Useful Resources

Useful Resources

Online tutorials

- R for Data Science
- Quick R
- Learn the tidyverse
- R markdown cookbook

Online Q&A

- Stack Overflow
- How to ask a good question online
- Remember to check your `sessionInfo()` when troubleshooting!

Others

- Use R/RStudio from an external drive (if you don't have admin rights to install software)