

BADM 372 Applied Analytics

BADM 372

2022-01-06

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Chapter 1

About this course

This website serves as headquarters for **BADM 372 Intro to Applied Analytics**.

Content here will be updated with any changes made during the semester, so if at any point you are told there was a change in the assignment, you can come here to get the updated version.

Also, this book has benefited greatly from lots of free, readily available resources posted on the web and we leverage these extensively. I would encourage you to review these resources in your analytics journey. Some that we specifically use with great frequency are these (and I say loud THANK YOU to the authors!):

- R for Data Science
- An Introduction to Statistical Learning with Applications in R
- Data Science in a Box
- stackoverflow.com, for example

Chapter 2

Syllabus

Instructor: Tobin Turner

Office Hours: mutually convenient time arranged by email e-mail: jttturner@presby.edu

2.1 Course Objectives and Learning Outcomes

This course is designed to introduce to data science. Students will apply statistical knowledge and techniques to both business and non-business contexts.

At the end of this course students should be able to:

By the end of the course, you will be able to... - gain insight from data - gain insight from data, reproducibly - gain insight from data, reproducibly, using modern programming tools and techniques - gain insight from data, reproducibly and collaboratively, using modern programming tools and techniques - gain insight from data, reproducibly (with literate programming and version control) and collaboratively, using modern programming tools and techniques - communicate results effectively

This course will be focused on both understanding and applying key business analytical concepts. Although the text serves as a useful foundation for the concepts covered in the class, simple memorization of the material in the text will not be sufficient. Class participation, discussion, and application are critical.

2.2 Text and Resources

- This course website (primary resource)

- R for Data Science
- An Introduction to Statistical Learning with Applications in R
- Data Science in a Box
- stackoverflow.com, for example
- Other free, publicly available datasets and publications.

2.3 Performance Evaluation (Grading)

- Quizzes and Assignments - 40%
- Exam 1 - 20%
- Exam 2 - 20%
- Final Exam - 20%

2.3.1 Exams

Exams will cover assigned chapters in the textbook, other assigned readings, lectures, class exercises, class discussions, videos, and guest speakers. I will typically allocate time prior to each exam to clearly identify the body of knowledge each test will cover and to answer questions about the format and objectives of the exam.

2.3.2 Quizzes – DON'T MISS CLASS

- The average of all quizzes and assignments will comprise the Quizzes and Assignments - 40% portion of your final grade
- Quizzes and Assignments are designed to prepare you for your exams and to ensure you stay up with the course material
- **Missed Quizzes and Assignments cannot be made up later. Be present.**

Quizzes rule. **LISTEN.** - Missed Quizzes and Assignments cannot be made up later. **Be present.**

2.3.3 Final Average

- Final Average Grade
 - 90-100 A
 - 88-89 B+
 - 82-87 B+
 - 80-81 B-
 - 78-79 C+

- 72-77 C+
- 70-71 C-
- 60-69 D
- 59 and below F

2.4 Class Participation:

I will frequently give readings or assignments for you to complete prior to the next class meeting. I expect you to fully engage the material: answer questions, pose questions, provide insightful observations. Keep in mind that quality is an important component in “participation.” Periodic cold calls will take place. I will also put students in the “hot seat” on occasion. In these class sessions, I may select a random group of students to lead us in the discussion and debate. Because the selection of participants will not be announced until class begins, everyone will be expected to prepare for the discussion. Reading the assigned chapters and articles are the best way to prepare for the discussion. If you have concerns about being called on in class, please see me to discuss. The purpose of the “hot seat” is not to stress or embarrass students, but to encourage students to actively engage the material.

2.5 Phones

Phones are not allowed to be used in class without the instructor’s prior consent. If you have a need of a phone during class please let me know before class. Unauthorized use of electronic devices may result in the lowering of the grade or dismissal from the class. **I mean this.**

2.6 Attendance

You are expected to be regular and punctual in your class attendance. Students are responsible for all the material missed and homework assignments made. If class is missed, notes/homework should be obtained from another student. If I am more than 15 minutes late, class is considered cancelled. No more than 4 absences are allowed during a semester. Exceeding the absence policy may result in receiving an F for the course. The professors roll is the official roll and students not present when roll is taken will be counted as absent. If a student must miss an exam, she or he must work out an agreeable time with the instructor to take the test prior to the exam being given. If a student misses a test due to an emergency, the student must inform the instructor as soon as is possible. In special cases, the instructor may allow the student to take a make-up exam.

2.7 Accommodations

Presbyterian College is committed to providing reasonable accommodations for all students with documented disabilities. If you are seeking academic accommodations under the Americans with Disabilities Act, you must register with the Academic Success Office, located on 5th Avenue (beside Campus Police). To receive these accommodations, please obtain the proper Accommodations Approval Form from that office, and then meet with me at the beginning of the semester to discuss how we may deliver your approved accommodations. I especially encourage you to meet with me well in advance of the actual accommodations being provided, as it may not be feasible to offer immediate accommodations without sufficient advance notice (such as in the case of tests). I can assure you that all discussions will remain confidential. Disability Services information is located at this link <http://bit.ly/PCdisabilityservices>

Additionally, it is the student's responsibility to give the instructor one week's notice prior to each instance where accommodation will be required.

2.8 Honor Code and Plagiarism:

All assignments/exams must be your own work. Any copying or use of unauthorized assistance will be treated as a violation of PC's Honor Code. If you are unsure of what resources are allowed, please ask. Please note that all text longer than 7 words taken from ANY other source must be placed in quotations and cited. Also, summarizing ANY other source must also be cited. Using ANY other source and showing work to be your own is a violation of plagiarism and the honor code.

2.9 First-Generation Version:

I am a Presby First+ Advocate. I am here to support our current first-generation students. At Presbyterian College, first-generation students are those in which neither parent nor legal guardian graduated from a four-year higher education institution with a bachelor's degree. If you are a first-generation college student, please contact me. For more information about support for first-generation college students on our campus visit our Presby First+ webpage.

2.10 Continuing Advocate Version

I am a Presby First+ Advocate. I am committed to supporting first-generation students at Presbyterian College. At Presbyterian College, first-generation students are those in which neither parent nor legal guardian graduated from a

four-year higher education institution with a bachelor's degree. If you are a first-generation college student, please contact me anytime or visit me during my office hours. For more information about support for first-generation college students on our campus visit our Presby First+ webpage.

Chapter 3

The class routine

Monday: Wrap up previous topic and introduce what you've pre-read about. Chat. Play. Work some examples.

Wednesday: Work more examples. Chat as needed. Live our best lives. :).

Friday: Apply what we learned – demonstrate your mastery. Rinse. Repeat.

Chapter 4

Schedule

This is a tentative schedule, and it will change. **BUT** I will do my very best to review this often so that we all stay on the same page and so that you may plan accordingly!

Spring 2022

| Date | Topic |
|------------------------------|---|
| Monday, January 10, 2022 | Intro and A1 review |
| Wednesday, January 12, 2022 | A1 Review & Look ahead to trees & forests |
| Friday, January 14, 2022 | QUIZ 1 |
| Monday, January 17, 2022 | MLK Holiday |
| Wednesday, January 19, 2022 | RMARKDOWN |
| Friday, January 21, 2022 | RMARKDOWN WITH SLIDES ASSIGNMENT |
| Monday, January 24, 2022 | GGPLOT |
| Wednesday, January 26, 2022 | GGPLOT |
| Friday, January 28, 2022 | GG PLOT QUIZ |
| Monday, January 31, 2022 | TIDY SPREAD AND GATHER (R4DS CH 9 DPLYR) |
| Wednesday, February 2, 2022 | RELATIONAL DATA (R4DS CH 10 DPLYR) |
| Friday, February 4, 2022 | QUIZ |
| Monday, February 7, 2022 | STRINGS (R4DS CH 11 stringr) |
| Wednesday, February 9, 2022 | STRINGS (R4DS CH 12 factors) |
| Friday, February 11, 2022 | QUIZ |
| Monday, February 14, 2022 | Dates and Times |
| Wednesday, February 16, 2022 | Dates and Times |
| Friday, February 18, 2022 | QUIZ |
| Monday, February 21, 2022 | Functions |
| Wednesday, February 23, 2022 | Functions |

| Date | Topic |
|---------------------------|---------------------------------|
| Friday, February 25, 2022 | QUIZ |
| Monday, February 28, 2022 | Iteration |
| Wednesday, March 2, 2022 | Iteration |
| Friday, March 4, 2022 | QUIZ |
| Monday, March 7, 2022 | LAUNCH PROJECT |
| Wednesday, March 9, 2022 | INDEPENDENT PROJECT |
| Friday, March 11, 2022 | INDEPENDENT PROJECT |
| Monday, March 14, 2022 | SPRING BREAK |
| Wednesday, March 16, 2022 | SPRING BREAK |
| Friday, March 18, 2022 | SPRING BREAK |
| Monday, March 21, 2022 | INDEPENDENT PROJECT |
| Wednesday, March 23, 2022 | PRESENTATIONS |
| Friday, March 25, 2022 | PRESENTATIONS |
| Monday, March 28, 2022 | Model Building/ADVISING WEEK |
| Wednesday, March 30, 2022 | Model Building/ADVISING WEEK |
| Friday, April 1, 2022 | QUIZ |
| Monday, April 4, 2022 | regression |
| Wednesday, April 6, 2022 | stepwise addition/deletion |
| Friday, April 8, 2022 | QUIZ |
| Monday, April 11, 2022 | logistic regression |
| Wednesday, April 13, 2022 | trees & forests |
| Friday, April 15, 2022 | Easter Holidays |
| Monday, April 18, 2022 | Easter Holidays |
| Wednesday, April 20, 2022 | Model Building |
| Friday, April 22, 2022 | QUIZ |
| Monday, April 25, 2022 | PRESENTATIONS |
| Wednesday, April 27, 2022 | PRESENTATIONS |
| Friday, April 29, 2022 | LAST DAY |
| Monday, May 2, 2022 | Final Exam 8:30 p.m. – F period |

Chapter 5

Applied Analytics Overview

Analytics is the systematic computational analysis of data or statistics.

It is used for the discovery, interpretation, and communication of meaningful patterns in data. It also entails applying data patterns towards effective decision-making.

It can be valuable in areas rich with recorded information; analytics relies on the simultaneous application of statistics, computer programming and operations research to quantify performance.

Organizations may apply analytics to business data to describe, predict, and improve business performance.

Specifically, areas within analytics include predictive analytics, prescriptive analytics, enterprise decision management, descriptive analytics, cognitive analytics, Big Data Analytics, retail analytics, supply chain analytics, store assortment and stock-keeping unit optimization, marketing optimization and marketing mix modeling, web analytics, call analytics, speech analytics, sales force sizing and optimization, price and promotion modeling, predictive science, graph analytics, credit risk analysis, and fraud analytics.

Since analytics can require extensive computation (think: big data), the algorithms and software used for analytics harness the most current methods in computer science, statistics, and mathematics.

5.1 Feel good about Analytics 1?

- R basics
- Data wrangling
- Modeling (lm, glm, etc.)

- lm
- glm
- test & training data
- measures of fit, confusion matrix

5.2 Learning goals

By the end of the course, you will be able to...

Data Science Model

5.3 Toolkit for reproducibility

- Scriptability → R
- Literate programming (code, narrative, output in one place) → R Mark-down
- Version control → Git / GitHub

5.4 Resources We'll Use (R4DS, mostly)

- 1) Explore
- 2) Wrangle
- 3) Program
- 4) Model
- 5) Communicate

5.5 Explore

- 3) Data visualisation
- 4) Workflow: basics
- 5) Data transformation
- 6) Workflow: scripts
- 7) Exploratory Data Analysis
- 8) Workflow: projects

5.6 Wrangle

- 9) Introduction

- 10) Tibbles
- 11) Data import
- 12) Tidy data
- 13) Relational data
- 14) Strings
- 15) Factors
- 16) Dates and times

5.7 Program

- 17) Introduction
- 18) Pipes
- 19) Functions
- 20) Vectors
- 21) Iteration

5.8 Model

- 22) Introduction
- 23) Model basics
- 24) Model building
- 25) Many models

5.9 Communicate

- 26) Introduction
- 27) R Markdown
- 28) Graphics for communication
- 29) R Markdown formats
- 30) R Markdown workflow

5.10 Learning goals

By the end of the course, you will be able to...

- gain insight from data
- gain insight from data, **reproducibly**
- gain insight from data, reproducibly, **using modern programming tools and techniques**

- gain insight from data, reproducibly **and collaboratively**, using modern programming tools and techniques
- gain insight from data, reproducibly (**with literate programming and version control**) and collaboratively, using modern programming tools and techniques

Chapter 6

Data and visualisation

Chapter 7

What is in a dataset?

7.1 Dataset terminology

- Each row is an **observation**
- Each column is a **variable**

```
starwars
#> # A tibble: 87 x 14
#>   name          height mass hair_color skin_color eye_color
#>   <chr>          <int> <dbl> <chr>      <chr>      <chr>
#> 1 Luke Skywa~    172    77 blond      fair        blue
#> 2 C-3PO         167    75 <NA>      gold        yellow
#> 3 R2-D2          96    32 <NA>      white, bl~ red
#> 4 Darth Vader    202   136 none       white       yellow
#> 5 Leia Organa    150    49 brown      light       brown
#> 6 Owen Lars     178   120 brown, grey light       blue
#> 7 Beru White~    165    75 brown      light       blue
#> 8 R5-D4          97    32 <NA>      white, red red
#> 9 Biggs Dark~   183    84 black      light       brown
#> 10 Obi-Wan Ke~   182    77 auburn, wh~ fair        blue-gray
#> # ... with 77 more rows, and 8 more variables:
#> #   birth_year <dbl>, sex <chr>, gender <chr>,
#> #   homeworld <chr>, species <chr>, films <list>,
#> #   vehicles <list>, starships <list>
```

7.2 What's in the Star Wars data?

Take a glimpse at the data:

```
#> Rows: 87
#> Columns: 14
#> $ name      <chr> "Luke Skywalker", "C-3PO", "R2-D2", "Da~
#> $ height    <int> 172, 167, 96, 202, 150, 178, 165, 97, 1~
#> $ mass      <dbl> 77, 75, 32, 136, 49, 120, 75, 32, 84, 7~
#> $ hair_color <chr> "blond", NA, NA, "none", "brown", "brow~
#> $ skin_color <chr> "fair", "gold", "white, blue", "white",~
#> $ eye_color  <chr> "blue", "yellow", "red", "yellow", "bro~
#> $ birth_year <dbl> 19.0, 112.0, 33.0, 41.9, 19.0, 52.0, 47~
#> $ sex        <chr> "male", "none", "none", "male", "female~
#> $ gender     <chr> "masculine", "masculine", "masculine", ~
#> $ homeworld  <chr> "Tatooine", "Tatooine", "Naboo", "Tatoo~
#> $ species    <chr> "Human", "Droid", "Droid", "Human", "Hu~
#> $ films      <list> <"The Empire Strikes Back", "Revenge o~
#> $ vehicles   <list> <"Snowspeeder", "Imperial Speeder Bike~
#> $ starships  <list> <"X-wing", "Imperial shuttle">, <>, <>~
```

7.3 Questions

- How many rows and columns does this dataset have?
- What does each row represent?
- What does each column represent?

7.4 Questions

```
?starwars
```

7.5 How many rows and columns does this dataset have?

```
nrow(starwars) # number of rows
#> [1] 87
ncol(starwars) # number of columns
#> [1] 14
dim(starwars)  # dimensions (row column)
#> [1] 87 14
```

Chapter 8

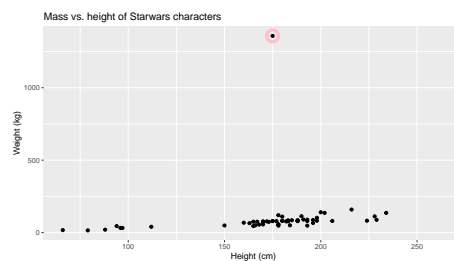
Exploratory data analysis

8.1 What is EDA?

- Exploratory data analysis (EDA) is an approach to analysing data sets to summarize its main characteristics
- Often, this is visual – this is what we'll focus on first
- But we might also calculate summary statistics and perform data wrangling/manipulation/transformation at (or before) this stage of the analysis – this is what we'll focus on next

8.2 Mass vs. height

- How would you describe the relationship between mass and height of Starwars characters?
- What other variables would help us understand data points that don't follow the overall trend?
- Who is the not so tall but really chubby character?



8.3 Jabba!

Chapter 9

Data visualization

9.1 Data visualization

“The simple graph has brought more information to the data analyst’s mind than any other device.” — John Tukey

- Data visualization is the creation and study of the visual representation of data
- Many tools for visualizing data – R is one of them
- Many approaches/systems within R for making data visualizations – **ggplot2** is one of them, and that’s what we’re going to use

9.2 ggplot2 ∈ tidyverse

9.3 ggplot2

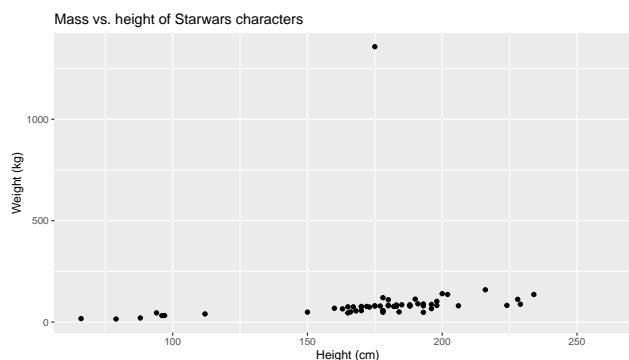
- **ggplot2** is tidyverse’s data visualization package
- **gg** in “ggplot2” stands for Grammar of Graphics
- Inspired by the book **Grammar of Graphics** by Leland Wilkinson

9.4 Grammar of Graphics

A grammar of graphics is a tool that enables us to concisely describe the components of a graphic

9.5 Mass vs. height

```
ggplot(data = starwars, mapping = aes(x = height, y = mass)) +
  geom_point() +
  labs(title = "Mass vs. height of Starwars characters",
       x = "Height (cm)", y = "Weight (kg)")
#> Warning: Removed 28 rows containing missing values
#> (geom_point).
```



9.6 Questions

- What are the functions doing the plotting?
- What is the dataset being plotted?
- Which variables map to which features (aesthetics) of the plot?
- What does the warning mean?+

```
ggplot(data = starwars, mapping = aes(x = height, y = mass)) +
  geom_point() +
  labs(title = "Mass vs. height of Starwars characters",
       x = "Height (cm)", y = "Weight (kg)")
#> Warning: Removed 28 rows containing missing values
#> (geom_point).
```

9.7 Hello ggplot2!

- `ggplot()` is the main function in ggplot2
- Plots are constructed in layers
- Structure of the code for plots can be summarized as


```
ggplot(data = [dataset],  
       mapping = aes(x = [x-variable], y = [y-variable])) +  
  geom_xxx() +  
  other options
```

- The ggplot2 package comes with the tidyverse

```
library(tidyverse)
```

- For help with ggplot2, see ggplot2.tidyverse.org

Chapter 10

Why do we visualize?

10.1 Anscombe's quartet

```
#>      set  x      y
#> 1      I 10  8.04
#> 2      I  8  6.95
#> 3      I 13  7.58
#> 4      I  9  8.81
#> 5      I 11  8.33
#> 6      I 14  9.96
#> 7      I  6  7.24
#> 8      I  4  4.26
#> 9      I 12 10.84
#> 10     I  7  4.82
#> 11     I  5  5.68
#> 12     II 10  9.14
#> 13     II  8  8.14
#> 14     II 13  8.74
#> 15     II  9  8.77
#> 16     II 11  9.26
#> 17     II 14  8.10
#> 18     II  6  6.13
#> 19     II  4  3.10
#> 20     II 12  9.13
#> 21     II  7  7.26
#> 22     II  5  4.74
#> 23    III 10  7.46
#> 24    III  8  6.77
#> 25    III 13 12.74
#> 26    III  9  7.11
```

```
#> 27 III 11 7.81
#> 28 III 14 8.84
#> 29 III 6 6.08
#> 30 III 4 5.39
#> 31 III 12 8.15
#> 32 III 7 6.42
#> 33 III 5 5.73
#> 34 IV 8 6.58
#> 35 IV 8 5.76
#> 36 IV 8 7.71
#> 37 IV 8 8.84
#> 38 IV 8 8.47
#> 39 IV 8 7.04
#> 40 IV 8 5.25
#> 41 IV 19 12.50
#> 42 IV 8 5.56
#> 43 IV 8 7.91
#> 44 IV 8 6.89
```

```
#>      set  x      y
#> 1      I 10  8.04
#> 2      I  8  6.95
#> 3      I 13  7.58
#> 4      I  9  8.81
#> 5      I 11  8.33
#> 6      I 14  9.96
#> 7      I  6  7.24
#> 8      I  4  4.26
#> 9      I 12 10.84
#> 10     I  7  4.82
#> 11     I  5  5.68
#> 12     II 10  9.14
#> 13     II  8  8.14
#> 14     II 13  8.74
#> 15     II  9  8.77
#> 16     II 11  9.26
#> 17     II 14  8.10
#> 18     II  6  6.13
#> 19     II  4  3.10
#> 20     II 12  9.13
#> 21     II  7  7.26
#> 22     II  5  4.74
```

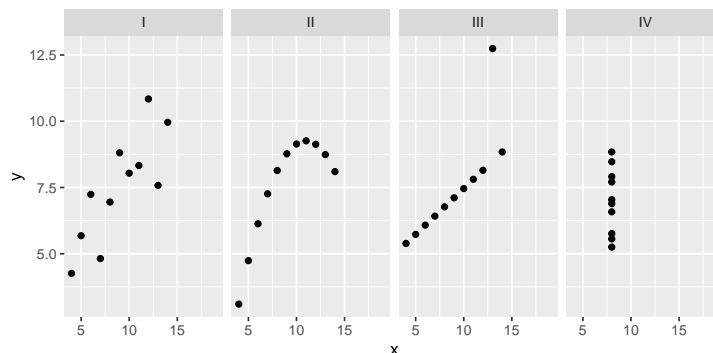
```
#>      set  x      y
#> 23     III 10  7.46
```

```
#> 24 III 8 6.77
#> 25 III 13 12.74
#> 26 III 9 7.11
#> 27 III 11 7.81
#> 28 III 14 8.84
#> 29 III 6 6.08
#> 30 III 4 5.39
#> 31 III 12 8.15
#> 32 III 7 6.42
#> 33 III 5 5.73
#> 34 IV 8 6.58
#> 35 IV 8 5.76
#> 36 IV 8 7.71
#> 37 IV 8 8.84
#> 38 IV 8 8.47
#> 39 IV 8 7.04
#> 40 IV 8 5.25
#> 41 IV 19 12.50
#> 42 IV 8 5.56
#> 43 IV 8 7.91
#> 44 IV 8 6.89
```

10.2 Summarising Anscombe's quartet

```
quartet %>%
  group_by(set) %>%
  summarise(
    mean_x = mean(x),
    mean_y = mean(y),
    sd_x = sd(x),
    sd_y = sd(y),
    r = cor(x, y))
#> # A tibble: 4 x 6
#>   set   mean_x mean_y sd_x sd_y    r
#>   <fct> <dbl> <dbl> <dbl> <dbl> <dbl>
#> 1 I      9  7.50  3.32  2.03 0.816
#> 2 II     9  7.50  3.32  2.03 0.816
#> 3 III    9  7.5  3.32  2.03 0.816
#> 4 IV     9  7.50  3.32  2.03 0.817
```

10.3 Visualizing Anscombe's quartet

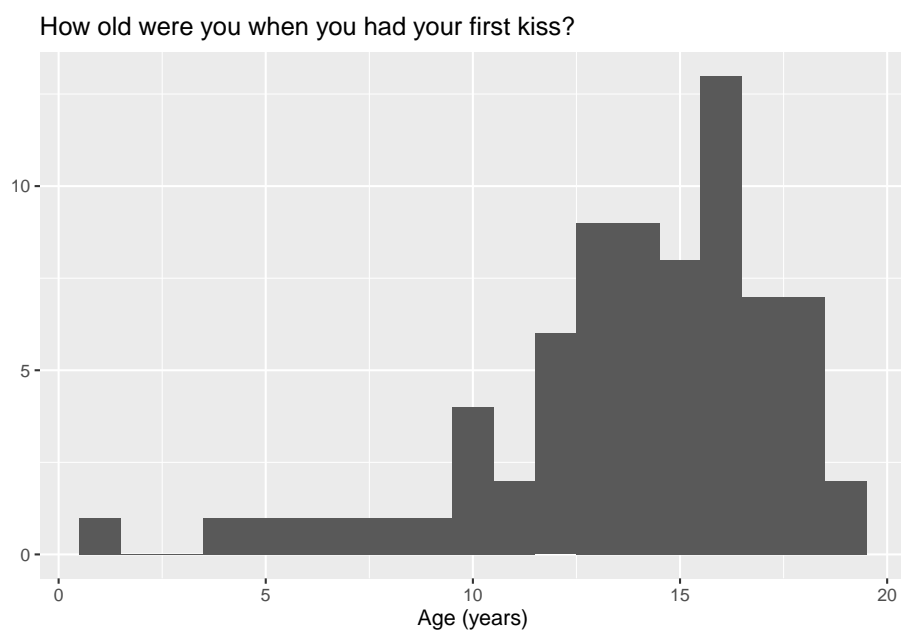


10.4 About Anscombe's quartet

Anscombe's quartet comprises four data sets that have nearly identical simple descriptive statistics, yet have very different distributions and appear very different when graphed. Each dataset consists of eleven (x,y) points. They were constructed in 1973 by the statistician Francis Anscombe to demonstrate both the importance of graphing data before analyzing it and the effect of outliers and other influential observations on statistical properties. He described the article as being intended to counter the impression among statisticians that “numerical calculations are exact, but graphs are *ROUGH*.”

10.5 Age at first kiss

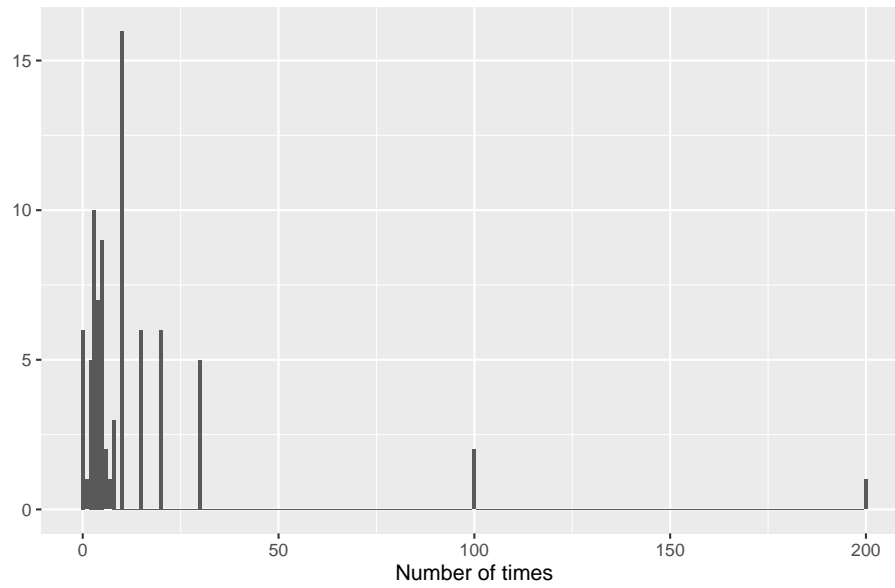
- Do you see anything out of the ordinary?



10.6 Facebook visits

- How are people reporting lower vs. higher values of FB visits?

How many times do you go on Facebook per day?



Chapter 11

Reproducible data analysis

What is reproducible research? Why is it important?

Reproducible research is the idea that data analyses, and more generally, scientific claims, are published with their data and software code so that others may verify the findings and build upon them. The need for reproducibility is increasing dramatically as data analyses become more complex, involving larger datasets and more sophisticated computations. Reproducibility allows for people to focus on the actual content of a data analysis, rather than on superficial details reported in a written summary. In addition, reproducibility makes an analysis more useful to others because the data and code that actually conducted the analysis are available. This course will focus on literate statistical analysis tools which allow one to publish data analyses in a single document that allows others to easily execute the same analysis to obtain the same results.

11.1 Reproducibility checklist

11.1.1 Near-term goals:

- Are the tables and figures reproducible from the code and data?
- Does the code actually do what you think it does?
- In addition to what was done, is it clear *why* it was done?

11.1.2 Long-term goals:

- Can the code be used for other data?

- Can you extend the code to do other things?

Chapter 12

Data and visualisation

Chapter 13

What is in a dataset?

13.1 Dataset terminology

- Each row is an **observation**
- Each column is a **variable**

```
starwars
#> # A tibble: 87 x 14
#>   name          height mass hair_color skin_color eye_color
#>   <chr>          <int> <dbl> <chr>      <chr>      <chr>
#> 1 Luke Skywa~    172    77 blond      fair        blue
#> 2 C-3PO         167    75 <NA>      gold        yellow
#> 3 R2-D2          96    32 <NA>      white, bl~ red
#> 4 Darth Vader    202   136 none       white       yellow
#> 5 Leia Organa    150    49 brown      light       brown
#> 6 Owen Lars     178   120 brown, grey light       blue
#> 7 Beru White~    165    75 brown      light       blue
#> 8 R5-D4          97    32 <NA>      white, red red
#> 9 Biggs Dark~   183    84 black      light       brown
#> 10 Obi-Wan Ke~   182    77 auburn, wh~ fair        blue-gray
#> # ... with 77 more rows, and 8 more variables:
#> #   birth_year <dbl>, sex <chr>, gender <chr>,
#> #   homeworld <chr>, species <chr>, films <list>,
#> #   vehicles <list>, starships <list>
```

13.2 What's in the Star Wars data?

Take a glimpse at the data:

```
#> Rows: 87
#> Columns: 14
#> $ name      <chr> "Luke Skywalker", "C-3PO", "R2-D2", "Da~
#> $ height    <int> 172, 167, 96, 202, 150, 178, 165, 97, 1~
#> $ mass      <dbl> 77, 75, 32, 136, 49, 120, 75, 32, 84, 7~
#> $ hair_color <chr> "blond", NA, NA, "none", "brown", "brow~
#> $ skin_color <chr> "fair", "gold", "white, blue", "white",~
#> $ eye_color  <chr> "blue", "yellow", "red", "yellow", "bro~
#> $ birth_year <dbl> 19.0, 112.0, 33.0, 41.9, 19.0, 52.0, 47~
#> $ sex        <chr> "male", "none", "none", "male", "female~
#> $ gender     <chr> "masculine", "masculine", "masculine", ~
#> $ homeworld  <chr> "Tatooine", "Tatooine", "Naboo", "Tatoo~
#> $ species    <chr> "Human", "Droid", "Droid", "Human", "Hu~
#> $ films      <list> <"The Empire Strikes Back", "Revenge o~
#> $ vehicles   <list> <"Snowspeeder", "Imperial Speeder Bike~
#> $ starships  <list> <"X-wing", "Imperial shuttle">, <>, <>~
```

13.3 Questions

- How many rows and columns does this dataset have?
- What does each row represent?
- What does each column represent?

13.4 Questions

```
?starwars
```

13.5 How many rows and columns does this dataset have?

```
nrow(starwars) # number of rows
#> [1] 87
ncol(starwars) # number of columns
#> [1] 14
dim(starwars)  # dimensions (row column)
#> [1] 87 14
```

Chapter 14

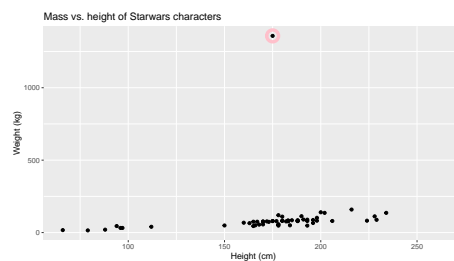
Exploratory data analysis

14.1 What is EDA?

- Exploratory data analysis (EDA) is an approach to analysing data sets to summarize its main characteristics
- Often, this is visual – this is what we'll focus on first
- But we might also calculate summary statistics and perform data wrangling/manipulation/transformation at (or before) this stage of the analysis – this is what we'll focus on next

14.2 Mass vs. height

- How would you describe the relationship between mass and height of Starwars characters?
- What other variables would help us understand data points that don't follow the overall trend?
- Who is the not so tall but really chubby character?



14.3 Jabba!

Chapter 15

Data visualization

15.1 Data visualization

“The simple graph has brought more information to the data analyst’s mind than any other device.” — John Tukey

- Data visualization is the creation and study of the visual representation of data
- Many tools for visualizing data – R is one of them
- Many approaches/systems within R for making data visualizations – **ggplot2** is one of them, and that’s what we’re going to use

15.2 `ggplot2` ∈ tidyverse

15.3 `ggplot2`

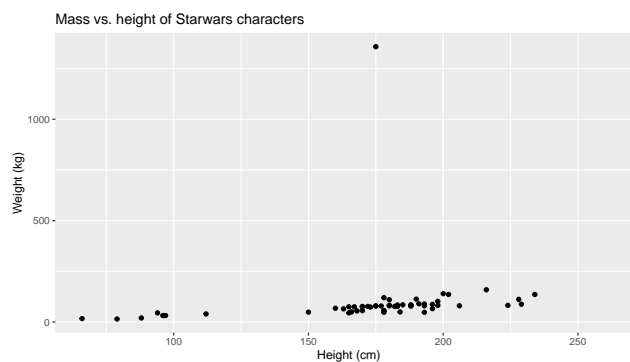
- **ggplot2** is tidyverse’s data visualization package
- **gg** in “`ggplot2`” stands for Grammar of Graphics
- Inspired by the book **Grammar of Graphics** by Leland Wilkinson

15.4 Grammar of Graphics

A grammar of graphics is a tool that enables us to concisely describe the components of a graphic

15.5 Mass vs. height

```
ggplot(data = starwars, mapping = aes(x = height, y = mass)) +
  geom_point() +
  labs(title = "Mass vs. height of Starwars characters",
       x = "Height (cm)", y = "Weight (kg)")
#> Warning: Removed 28 rows containing missing values
#> (geom_point).
```



15.6 Questions

- What are the functions doing the plotting?
- What is the dataset being plotted?
- Which variables map to which features (aesthetics) of the plot?
- What does the warning mean?+

```
ggplot(data = starwars, mapping = aes(x = height, y = mass)) +
  geom_point() +
  labs(title = "Mass vs. height of Starwars characters",
       x = "Height (cm)", y = "Weight (kg)")
#> Warning: Removed 28 rows containing missing values
#> (geom_point).
```

15.7 Hello ggplot2!

- `ggplot()` is the main function in `ggplot2`
- Plots are constructed in layers
- Structure of the code for plots can be summarized as

```
ggplot(data = [dataset],  
       mapping = aes(x = [x-variable], y = [y-variable])) +  
  geom_xxx() +  
  other options
```

- The ggplot2 package comes with the tidyverse

```
library(tidyverse)
```

- For help with ggplot2, see ggplot2.tidyverse.org

Chapter 16

Why do we visualize?

16.1 Anscombe's quartet

```
#>      set  x      y
#> 1      I 10  8.04
#> 2      I  8  6.95
#> 3      I 13  7.58
#> 4      I  9  8.81
#> 5      I 11  8.33
#> 6      I 14  9.96
#> 7      I  6  7.24
#> 8      I  4  4.26
#> 9      I 12 10.84
#> 10     I  7  4.82
#> 11     I  5  5.68
#> 12     II 10  9.14
#> 13     II  8  8.14
#> 14     II 13  8.74
#> 15     II  9  8.77
#> 16     II 11  9.26
#> 17     II 14  8.10
#> 18     II  6  6.13
#> 19     II  4  3.10
#> 20     II 12  9.13
#> 21     II  7  7.26
#> 22     II  5  4.74
#> 23    III 10  7.46
#> 24    III  8  6.77
#> 25    III 13 12.74
#> 26    III  9  7.11
```

```
#> 27 III 11 7.81
#> 28 III 14 8.84
#> 29 III 6 6.08
#> 30 III 4 5.39
#> 31 III 12 8.15
#> 32 III 7 6.42
#> 33 III 5 5.73
#> 34 IV 8 6.58
#> 35 IV 8 5.76
#> 36 IV 8 7.71
#> 37 IV 8 8.84
#> 38 IV 8 8.47
#> 39 IV 8 7.04
#> 40 IV 8 5.25
#> 41 IV 19 12.50
#> 42 IV 8 5.56
#> 43 IV 8 7.91
#> 44 IV 8 6.89
```

```
#>      set  x    y
#> 1      I 10 8.04
#> 2      I  8 6.95
#> 3      I 13 7.58
#> 4      I  9 8.81
#> 5      I 11 8.33
#> 6      I 14 9.96
#> 7      I  6 7.24
#> 8      I  4 4.26
#> 9      I 12 10.84
#> 10     I  7 4.82
#> 11     I  5 5.68
#> 12     II 10 9.14
#> 13     II  8 8.14
#> 14     II 13 8.74
#> 15     II  9 8.77
#> 16     II 11 9.26
#> 17     II 14 8.10
#> 18     II  6 6.13
#> 19     II  4 3.10
#> 20     II 12 9.13
#> 21     II  7 7.26
#> 22     II  5 4.74
```

```
#>      set  x    y
#> 23     III 10 7.46
```

```

#> 24 III 8 6.77
#> 25 III 13 12.74
#> 26 III 9 7.11
#> 27 III 11 7.81
#> 28 III 14 8.84
#> 29 III 6 6.08
#> 30 III 4 5.39
#> 31 III 12 8.15
#> 32 III 7 6.42
#> 33 III 5 5.73
#> 34 IV 8 6.58
#> 35 IV 8 5.76
#> 36 IV 8 7.71
#> 37 IV 8 8.84
#> 38 IV 8 8.47
#> 39 IV 8 7.04
#> 40 IV 8 5.25
#> 41 IV 19 12.50
#> 42 IV 8 5.56
#> 43 IV 8 7.91
#> 44 IV 8 6.89

```

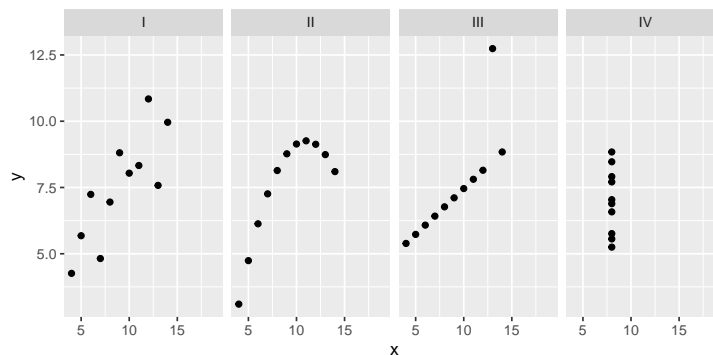
16.2 Summarising Anscombe's quartet

```

quartet %>%
  group_by(set) %>%
  summarise(
    mean_x = mean(x),
    mean_y = mean(y),
    sd_x = sd(x),
    sd_y = sd(y),
    r = cor(x, y))
#> # A tibble: 4 x 6
#>   set   mean_x mean_y sd_x sd_y    r
#>   <fct>   <dbl>   <dbl> <dbl> <dbl> <dbl>
#> 1 I         9   7.50  3.32  2.03 0.816
#> 2 II        9   7.50  3.32  2.03 0.816
#> 3 III       9   7.5   3.32  2.03 0.816
#> 4 IV        9   7.50  3.32  2.03 0.817

```

16.3 Visualizing Anscombe's quartet

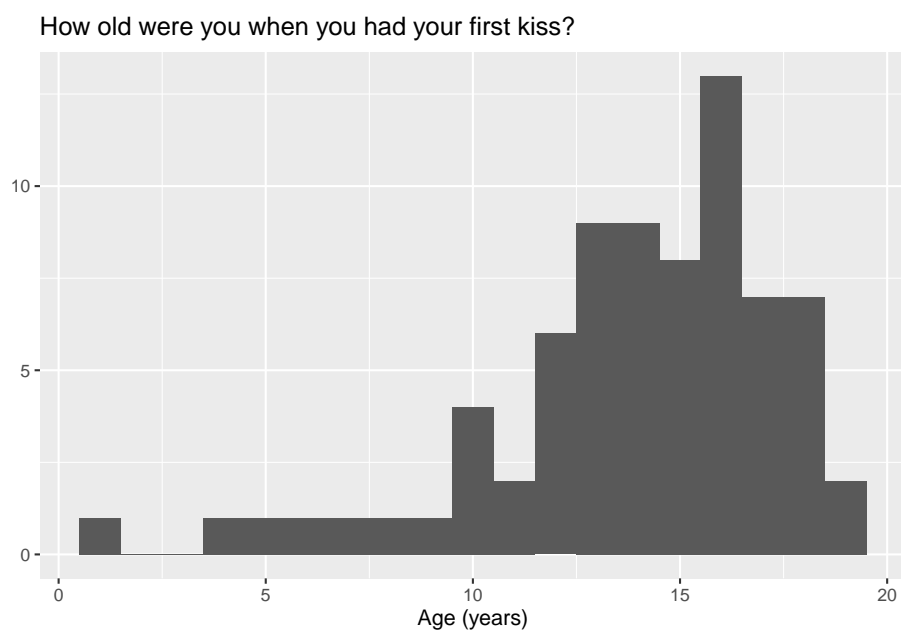


16.4 About Anscombe's quartet

Anscombe's quartet comprises four data sets that have nearly identical simple descriptive statistics, yet have very different distributions and appear very different when graphed. Each dataset consists of eleven (x,y) points. They were constructed in 1973 by the statistician Francis Anscombe to demonstrate both the importance of graphing data before analyzing it and the effect of outliers and other influential observations on statistical properties. He described the article as being intended to counter the impression among statisticians that “numerical calculations are exact, but graphs are *ROUGH*.”

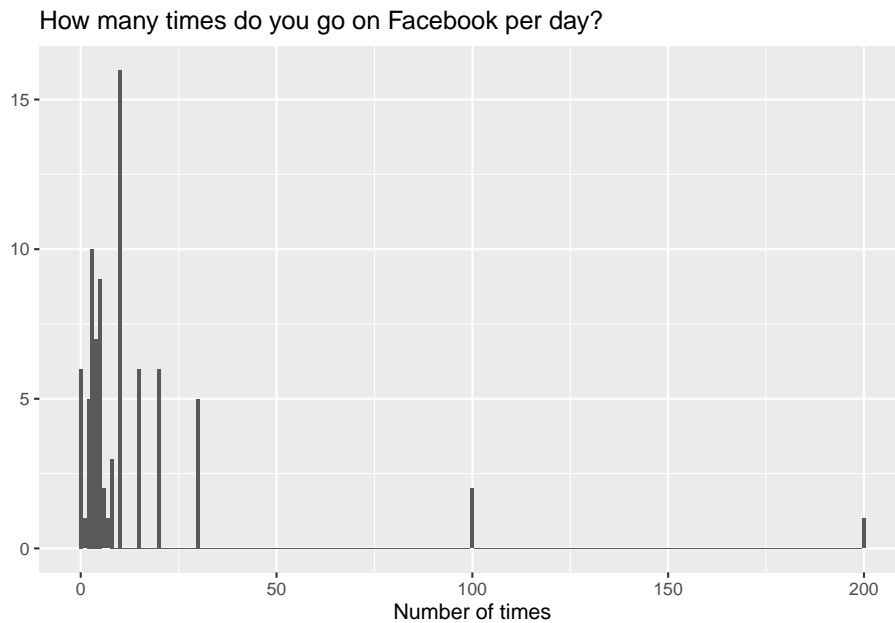
16.5 Age at first kiss

- Do you see anything out of the ordinary?



16.6 Facebook visits

- How are people reporting lower vs. higher values of FB visits?



16.7 ggplot

16.8 For next class

- Flip (or tab!) through R4DS and be able to answer (I **WILL** call on you next class) broadly-speaking what each chapter of the book covers
- Pay particular attention to the visualization chapter and be able to answer (I **WILL** call on you next class) what these terms refer to:
 - mapping
 - data
 - geom
 - stat
 - position

16.9 ggplot2 components

16.10 Quiz Next Class

- Quiz: explain:

- mapping
- data
- geom
- stat
- position

link

16.11 mapping

A set of aesthetic mappings, specified using the `aes()` function and combined with the plot defaults as described in aesthetic mappings. If `NULL`, uses the default mapping set in `ggplot()`.

16.12 data

A dataset which overrides the default plot dataset. It is usually omitted (set to `NULL`), in which case the layer will use the default data specified in `ggplot()`. The requirements for data are explained in more detail in data.

16.13 Geoms

The name of the geometric object to use to draw each observation. Geoms are discussed in more detail in `geom`, and the toolbox explores their use in more depth.

16.14 Geoms

can have additional arguments. All geoms take aesthetics as parameters. If you supply an aesthetic (e.g. `colour`) as a parameter, it will not be scaled, allowing you to control the appearance of the plot, as described in `setting vs. mapping`. You can pass params in `...` (in which case `stat` and `geom` parameters are automatically teased apart), or in a list passed to `geom_params`.

16.15 stat

The name of the statistical transformation to use. A statistical transformation performs some useful statistical summary is key to histograms and smoothes.

To keep the data as is, use the “identity” stat. Learn more in statistical transformations.

You only need to set one of stat and geom: every geom has a default stat, and every stat a default geom.

Most stats take additional parameters to specify the details of statistical transformation. You can supply params either in ... (in which case stat and geom parameters are automatically teased apart), or in a list called `stat_params`.

16.16 position

The method used to adjusting overlapping objects, like jittering, stacking or dodging. More details in `position`.

Chapter 17

About

Originally from the default index.

This is a *sample* book written in **Markdown**. You can use anything that Pandoc’s Markdown supports; for example, a math equation $a^2 + b^2 = c^2$.

17.1 Usage

Each **bookdown** chapter is an .Rmd file, and each .Rmd file can contain one (and only one) chapter. A chapter *must* start with a first-level heading: **# A good chapter**, and can contain one (and only one) first-level heading.

Use second-level and higher headings within chapters like: **## A short section** or **### An even shorter section**.

The `index.Rmd` file is required, and is also your first book chapter. It will be the homepage when you render the book.

17.2 Render book

You can render the HTML version of this example book without changing anything:

1. Find the **Build** pane in the RStudio IDE, and
2. Click on **Build Book**, then select your output format, or select “All formats” if you’d like to use multiple formats from the same book source files.

Or build the book from the R console:

```
bookdown::render_book()
```

To render this example to PDF as a `bookdown::pdf_book`, you'll need to install XeLaTeX. You are recommended to install TinyTeX (which includes XeLaTeX): <https://yihui.org/tinytex/>.

17.3 Preview book

As you work, you may start a local server to live preview this HTML book. This preview will update as you edit the book when you save individual .Rmd files. You can start the server in a work session by using the RStudio add-in “Preview book”, or from the R console:

```
bookdown::serve_book()
```

Chapter 18

Hello bookdown

All chapters start with a first-level heading followed by your chapter title, like the line above. There should be only one first-level heading (#) per .Rmd file.

18.1 A section

All chapter sections start with a second-level (##) or higher heading followed by your section title, like the sections above and below here. You can have as many as you want within a chapter.

An unnumbered section

Chapters and sections are numbered by default. To un-number a heading, add a {.unnumbered} or the shorter {-} at the end of the heading, like in this section.

Chapter 19

Cross-references

Cross-references make it easier for your readers to find and link to elements in your book.

19.1 Chapters and sub-chapters

There are two steps to cross-reference any heading:

1. Label the heading: `# Hello world {#nice-label}`.
 - Leave the label off if you like the automated heading generated based on your heading title: for example, `# Hello world = # Hello world {#hello-world}`.
 - To label an un-numbered heading, use: `# Hello world {-#nice-label}` or `{# Hello world .unnumbered}`.
2. Next, reference the labeled heading anywhere in the text using `\@ref(nice-label)`; for example, please see Chapter 19.
 - If you prefer text as the link instead of a numbered reference use: any text you want can go here.

19.2 Captioned figures and tables

Figures and tables *with captions* can also be cross-referenced from elsewhere in your book using `\@ref(fig:chunk-label)` and `\@ref(tab:chunk-label)`, respectively.

See Figure 19.1.

```
par(mar = c(4, 4, .1, .1))  
plot(pressure, type = 'b', pch = 19)
```



Figure 19.1: Here is a nice figure!

Don't miss Table 19.1.

```
knitr::kable(  
  head(pressure, 10), caption = 'Here is a nice table!',  
  booktabs = TRUE  
)
```

Table 19.1: Here is a nice table!

| temperature | pressure |
|-------------|----------|
| 0 | 0.0002 |
| 20 | 0.0012 |
| 40 | 0.0060 |
| 60 | 0.0300 |
| 80 | 0.0900 |
| 100 | 0.2700 |
| 120 | 0.7500 |
| 140 | 1.8500 |
| 160 | 4.2000 |
| 180 | 8.8000 |

Chapter 20

Parts

You can add parts to organize one or more book chapters together. Parts can be inserted at the top of an .Rmd file, before the first-level chapter heading in that same file.

Add a numbered part: `# (PART) Act one {-}` (followed by `# A chapter`)

Add an unnumbered part: `# (PART*) Act one {-}` (followed by `# A chapter`)

Add an appendix as a special kind of un-numbered part: `# (APPENDIX) Other stuff {-}` (followed by `# A chapter`). Chapters in an appendix are prepended with letters instead of numbers.

Chapter 21

Footnotes and citations

21.1 Footnotes

Footnotes are put inside the square brackets after a caret `^[]`. Like this one ¹.

21.2 Citations

Reference items in your bibliography file(s) using `@key`.

For example, we are using the **bookdown** package (Xie, 2021) (check out the last code chunk in `index.Rmd` to see how this citation key was added) in this sample book, which was built on top of R Markdown and **knitr** (Xie, 2015) (this citation was added manually in an external file `book.bib`). Note that the `.bib` files need to be listed in the `index.Rmd` with the YAML `bibliography` key.

The `bs4_book` theme makes footnotes appear inline when you click on them. In this example book, we added `cs1: chicago-fullnote-bibliography.cs1` to the `index.Rmd` YAML, and include the `.cs1` file. To download a new style, we recommend: <https://www.zotero.org/styles/>

The RStudio Visual Markdown Editor can also make it easier to insert citations: <https://rstudio.github.io/visual-markdown-editing/#/citations>

¹This is a footnote.

Chapter 22

Blocks

22.1 Equations

Here is an equation.

$$f(k) = \binom{n}{k} p^k (1-p)^{n-k} \quad (22.1)$$

You may refer to using `\@ref{eq:binom}`, like see Equation (22.1).

22.2 Theorems and proofs

Labeled theorems can be referenced in text using `\@ref{thm:tri}`, for example, check out this smart theorem 22.1.

Theorem 22.1. *For a right triangle, if c denotes the length of the hypotenuse and a and b denote the lengths of the **other** two sides, we have*

$$a^2 + b^2 = c^2$$

Read more here <https://bookdown.org/yihui/bookdown/markdown-extensions-by-bookdown.html>.

22.3 Callout blocks

The `bs4_book` theme also includes special callout blocks, like this `.rmdnote`.

You can use **markdown** inside a block.

```
head(beaver1, n = 5)
#>   day time  temp activ
#> 1 346  840 36.33     0
#> 2 346  850 36.34     0
#> 3 346  900 36.35     0
#> 4 346  910 36.42     0
#> 5 346  920 36.55     0
```

It is up to the user to define the appearance of these blocks for LaTeX output.

You may also use: `.rmdcaution`, `.rmdimportant`, `.rmdtip`, or `.rmdwarning` as the block name.

The R Markdown Cookbook provides more help on how to use custom blocks to design your own callouts: <https://bookdown.org/yihui/rmarkdown-cookbook/custom-blocks.html>

Chapter 23

Sharing your book

23.1 Publishing

HTML books can be published online, see: <https://bookdown.org/yihui/bookdown/publishing.html>

23.2 404 pages

By default, users will be directed to a 404 page if they try to access a webpage that cannot be found. If you'd like to customize your 404 page instead of using the default, you may add either a `_404.Rmd` or `_404.md` file to your project root and use code and/or Markdown syntax.

23.3 Metadata for sharing

Bookdown HTML books will provide HTML metadata for social sharing on platforms like Twitter, Facebook, and LinkedIn, using information you provide in the `index.Rmd` YAML. To setup, set the `url` for your book and the path to your `cover-image` file. Your book's `title` and `description` are also used.

This `bs4_book` provides enhanced metadata for social sharing, so that each chapter shared will have a unique description, auto-generated based on the content.

Specify your book's source repository on GitHub as the `repo` in the `_output.yml` file, which allows users to view each chapter's source file or suggest an edit. Read more about the features of this output format here:

https://pkgs.rstudio.com/bookdown/reference/bs4_book.html

Or use:

```
?bookdown::bs4_book
```

Bibliography

Xie, Y. (2015). *Dynamic Documents with R and knitr*. Chapman and Hall/CRC, Boca Raton, Florida, 2nd edition. ISBN 978-1498716963.

Xie, Y. (2021). *bookdown: Authoring Books and Technical Documents with R Markdown*. R package version 0.24.