Rotman

# INTRO TO R

## R Workshop

November 5, 2019 Prepared by Jay Cao / TDMDAL

Website: https://tdmdal.github.io/r-workshop-students/

Rotman School of Management
UNIVERSITY OF TORONTO

# What's R?

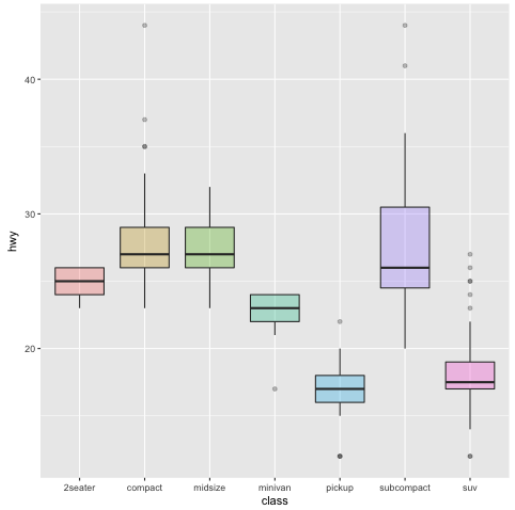
- A programming language
  - Free and open source
  - Extensible with many high-quality user-contributed libraries/packages

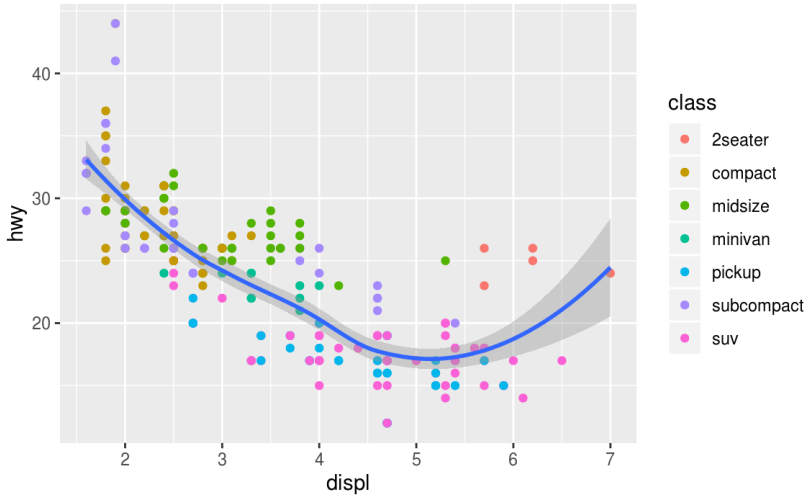
- Great for statistical analysis, graphics and many other things (ex?)

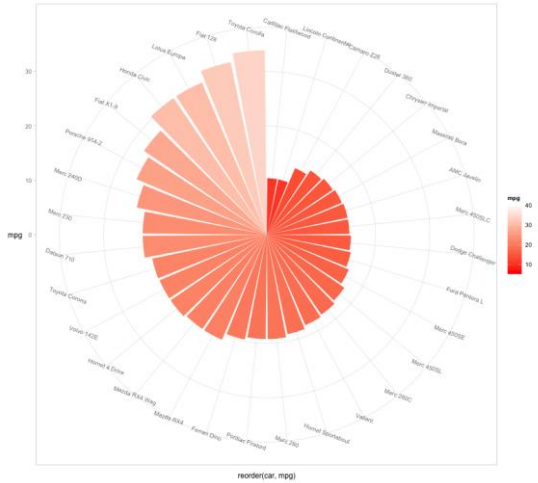
# What can R do – Statistics & related

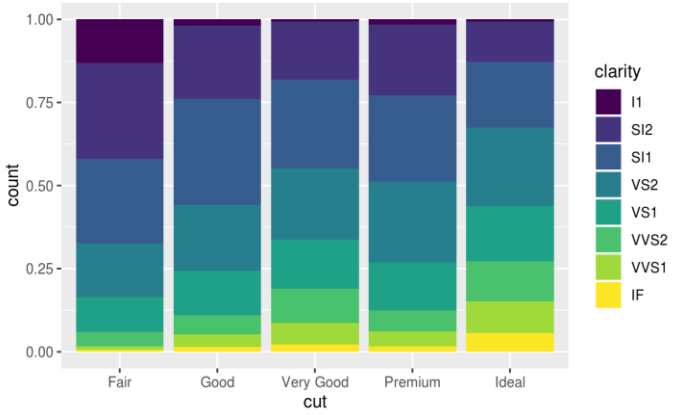
- Statistics & Econometrics
  - Regressions
  - Time series analysis
  - Bayesian inference
  - Survival analysis
  - …
- Numerical Mathematics
  - Optimization
  - Solver
  - Differential equations
  - …
- Finance
  - Portfolio management
  - Risk management
  - Option pricing
  - …
- …

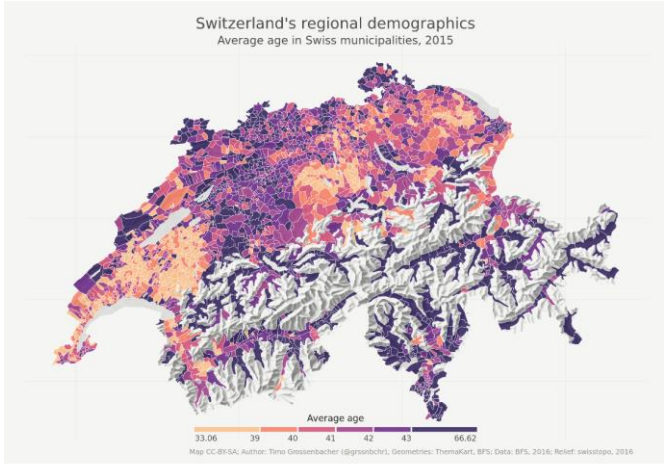
# What can R do – Graphics (static ones)

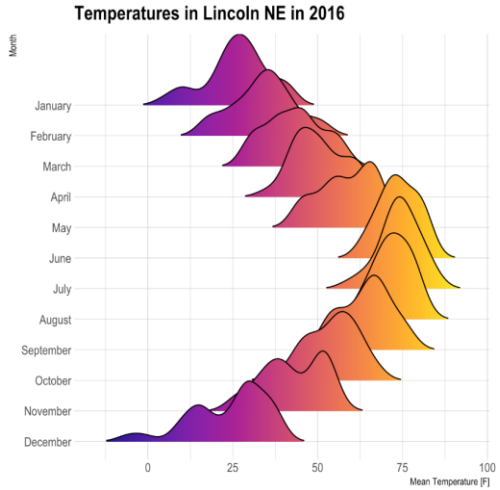


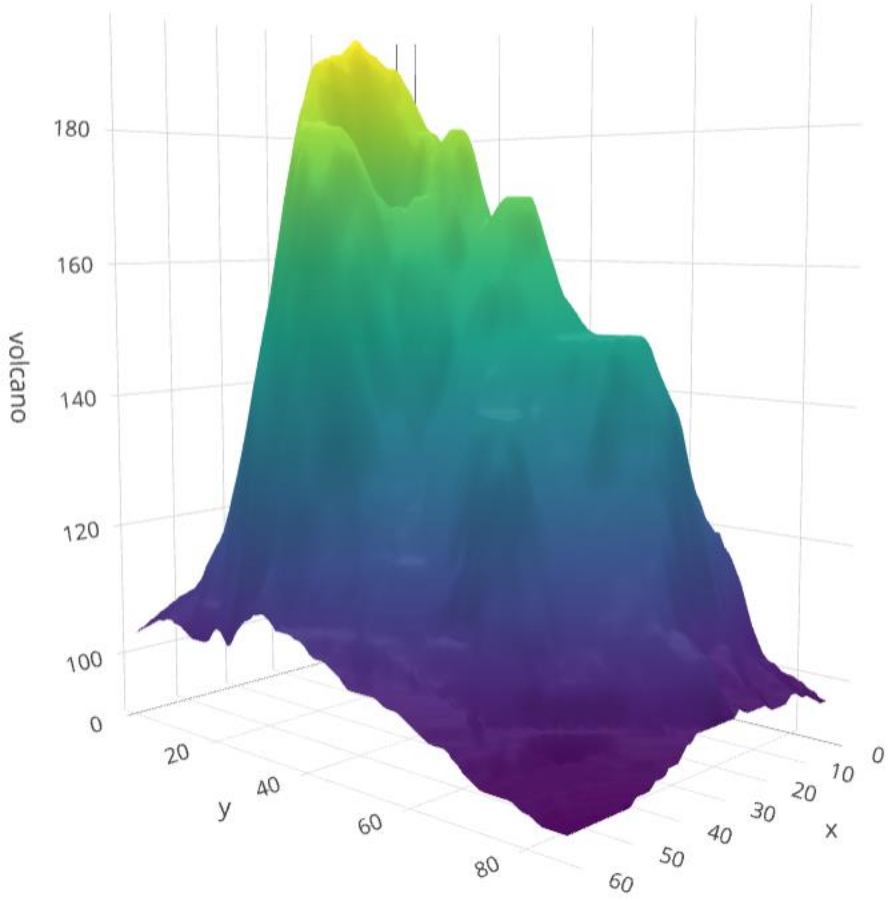



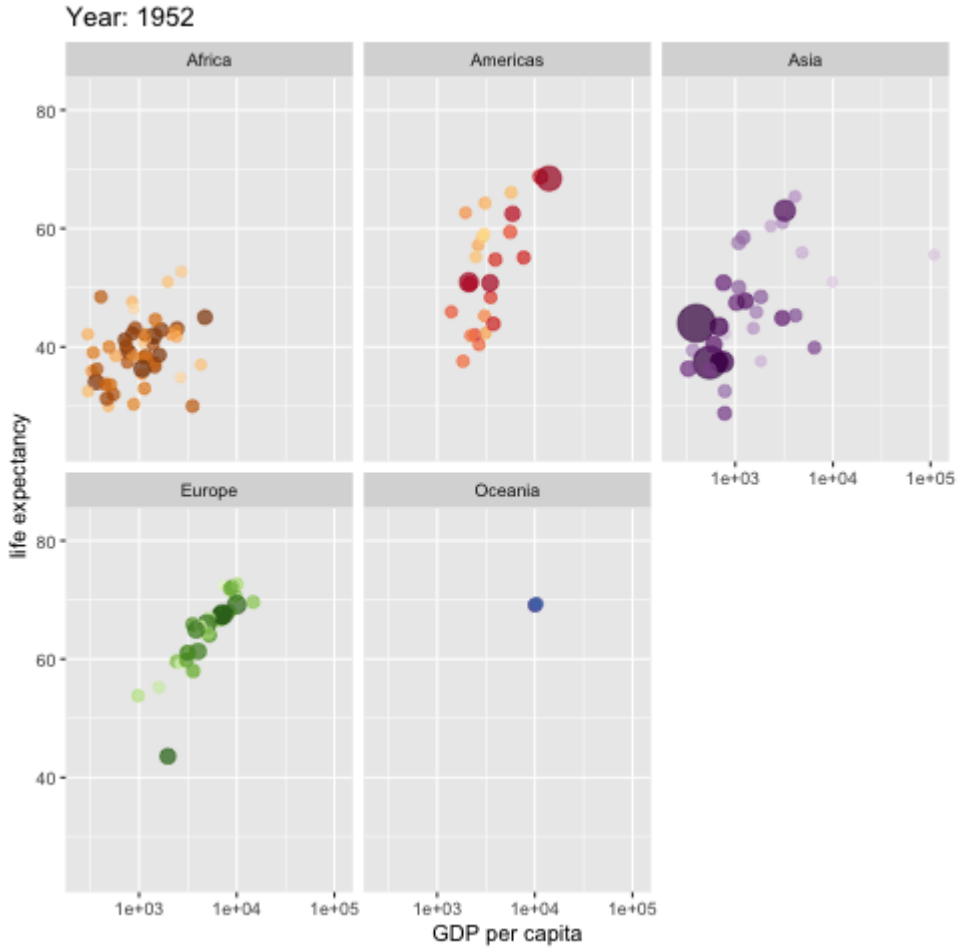




...

https://www.r-graph-gallery.com/
https://timogrossenbacher.ch/2016/12/beautiful-thematic-maps-with-ggplot2-only/;

# What can R do – Graphics (dynamic ones)




https://plot.ly/r/3d-surface-plots/;

https://github.com/thomasp85/gganimate;

# What can R do – Others

- Machine learning (ex. R interface to Keras: keras)
- Natural language processing (ex. tidytext, topicmodels)
- Web technology
  - Web scraping (ex. rvest)
  - API wrapper (ex. Twitter: rtweet; bigquery: bigrquery; Quandl: Quandl)
  - Shiny web app (https://shiny.rstudio.com/)
- Reporting
  - R Markdown (write reports, slides, blogs, books, etc. See a gallery here.)
- … (see R Task View for more)

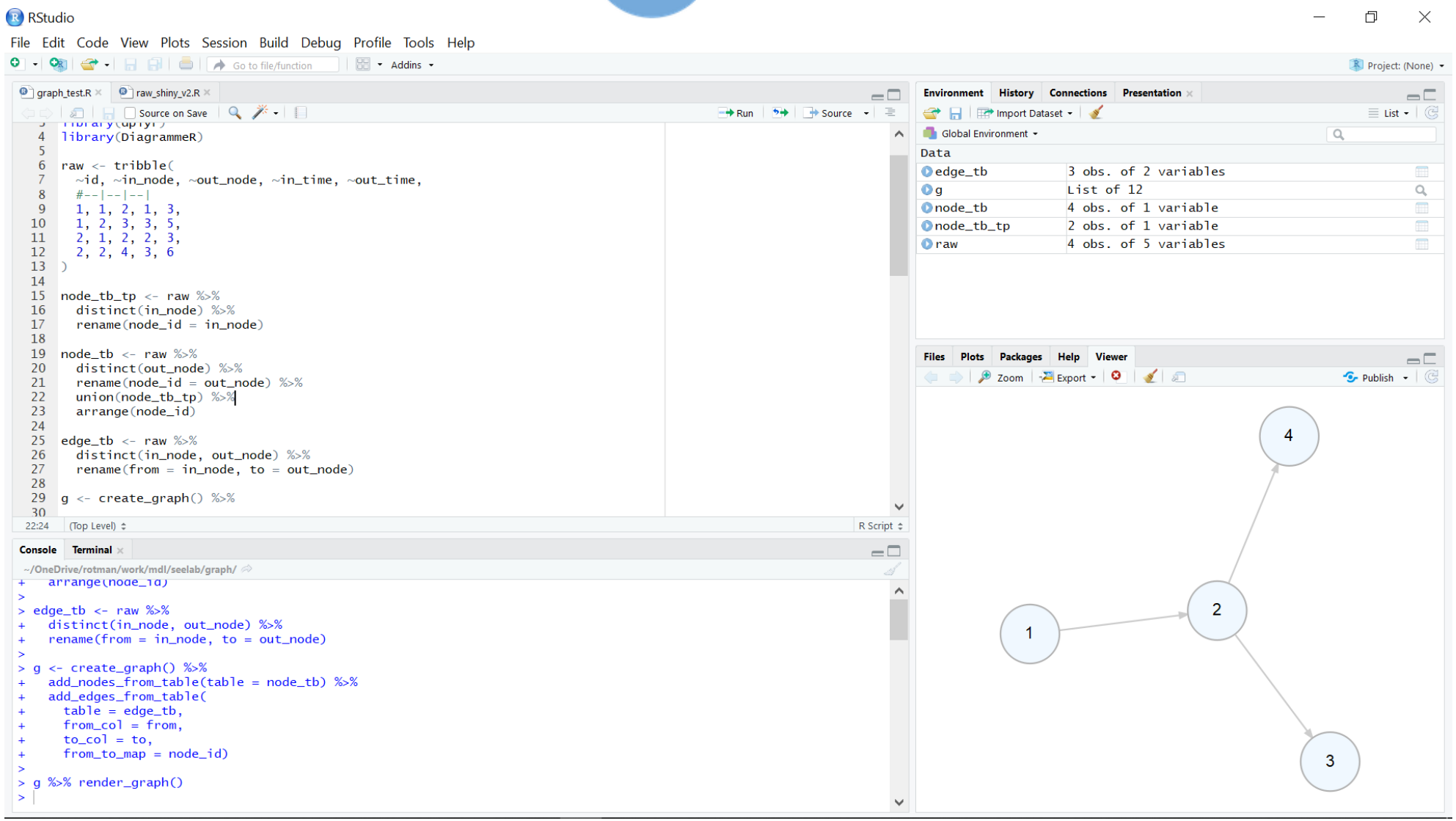
# What can R do, **for you**?

- Beyond Excel
- Automate boring tasks
- Prototype ideas
- …

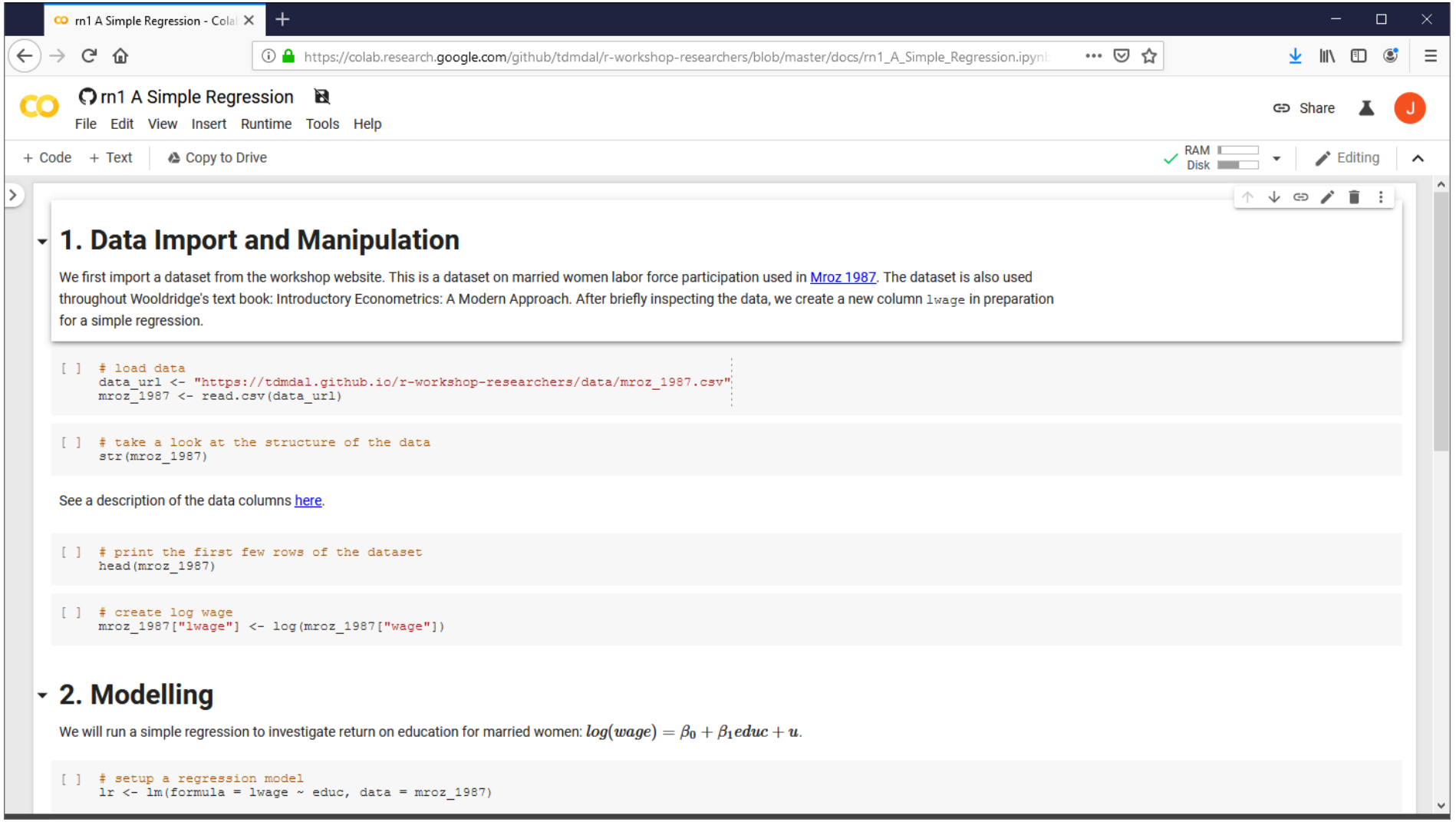
# Plan for Today (~2 hrs)

- Motivation: two examples
  - A simple regression (housing price and pollution)
  - Twitter API
- Basics of R (quick overview)
  - Data structure
  - Programming structure
- A typical analysis workflow: extending the regression example
  - Import and manipulate data
  - Build models
  - Report and graph results

# What's RStudio?

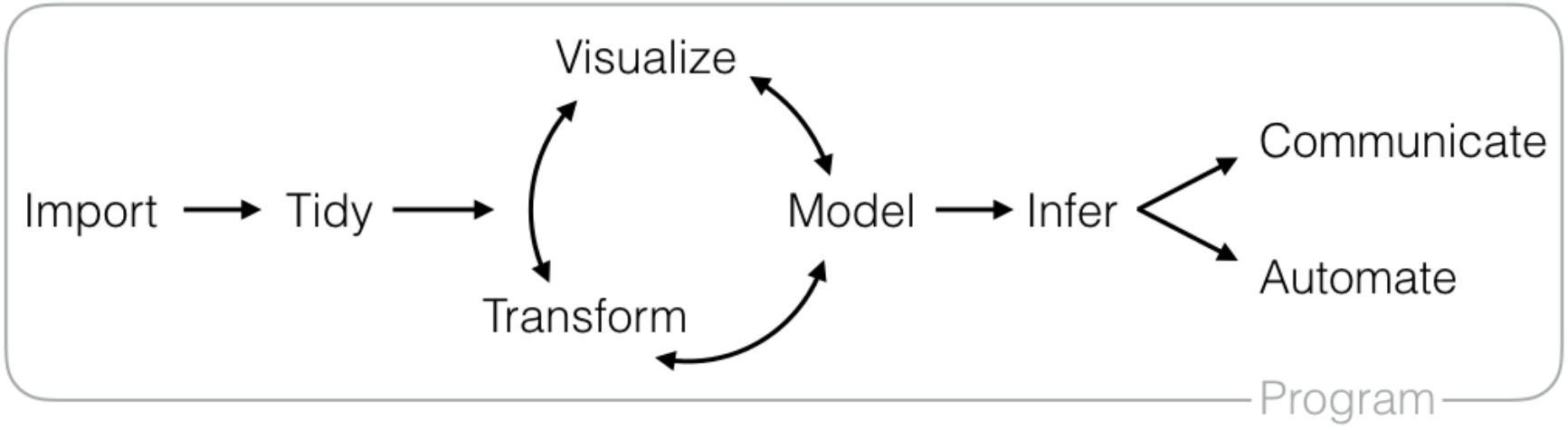


# Google Colab



# Motivation: two examples

- A simple regression
- Twitter API




https://github.com/rstudio/RStartHere

# R Basics

- Data structures
- Programming structures

# R Data Structure - Overview

| | Homogeneous | Heterogeneous |
|---|---|---|
| 1-d | **Atomic vector** | **List** |
| 2-d | Matrix | **Data frame** |
| n-d | Array | |

http://adv-r.had.co.nz/Data-structures.html

# R Data Structure - Overview

| | Homogeneous | Heterogeneous |
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# Atomic Vectors

```
# create R vectors
vec_character <- c("Hello,", "World!")

vec_integer <- c(1L, 2L, 3L)

vec_double <- c(1.1, 2.2, 3.3)

vec_logical <- c(TRUE, TRUE, FALSE)
```

| Hello, | World! |
|---|---|

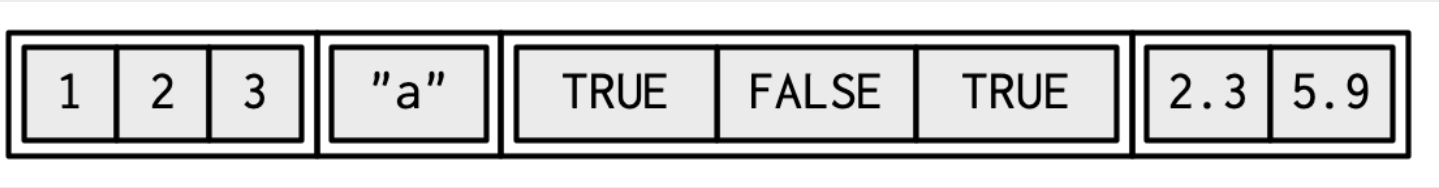
| 1 | 2 | 3 |
|---|---|---|

| 1.1 | 2.2 | 3.3 |
|---|---|---|

| TRUE | TRUE | FALSE |
|---|---|---|

# List

```
# create an R list
l1 <- list(
  1:3,
  "a",
  c(TRUE, FALSE, TRUE),
  c(2.3, 5.9)
)
```




ref. https://adv-r.hadley.nz/vectors-chap.html#list-creating

# Data Frame

```
# create a data frame
df1 <- data.frame(
  x = 1:3,
  y = letters[1:3],
  z = c(1.1, 2.2, 3.3)
)
```

| x | y | z |
|---|---|---|
| 1 | "a" | 1.1 |
| 2 | "b" | 2.2 |
| 3 | "c" | 3.3 |

# Data Frame

```
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# Data Frame

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```

| x | y | z |
|---|---|---|
| 1 | "a" | 1.1 |
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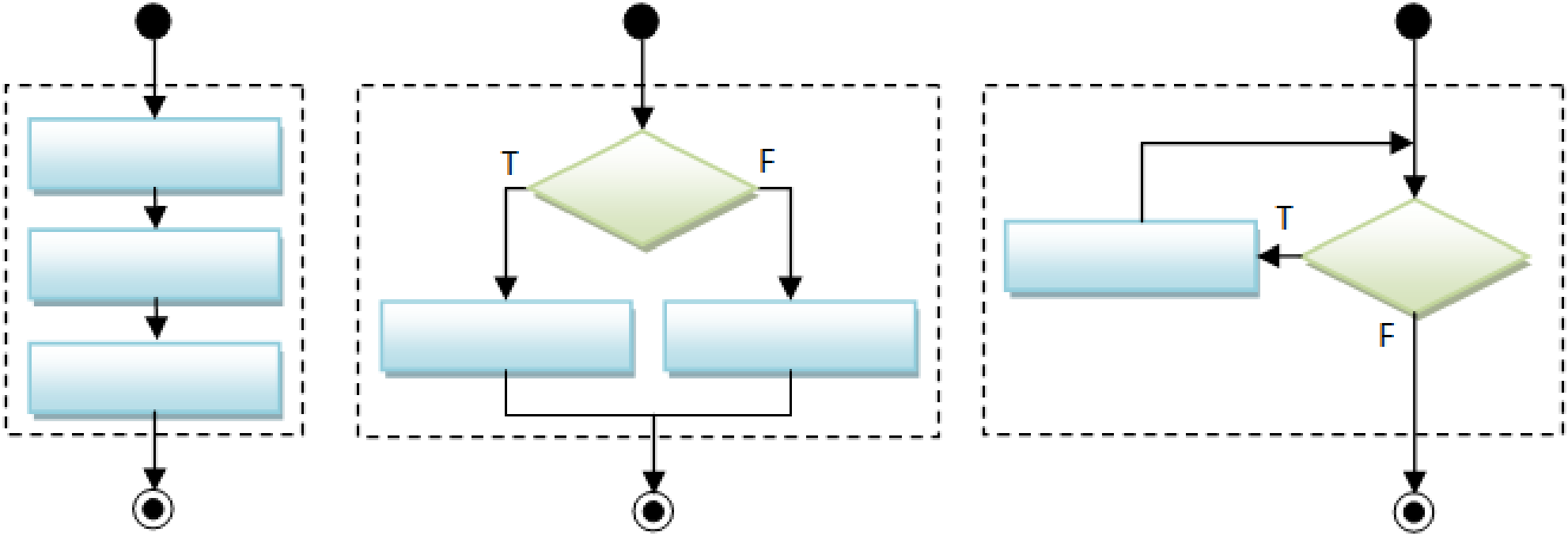
| 3 | "c" | 3.3 |

# Programming Structure: Control Flows



# Sequential

- Example: Sum of Squares

$$\sum_{t=1}^{3} t^2$$

```
# sum of squares
t <- 1:3
y <- sum(t^2)
print(y)
```

# Conditional (if…else…)

```
if (cond) {
  # run here if cond is TRUE
} else {
  # run here if cond is FALSE
}
```

```
# y greater than 10?
if (y > 10) {
  print("greater than 10")
} else {
  print("less or equal to 10")
}
```

# Conditional (if…else if…else…)

```
if (cond1) {
  # run here if cond1 is TRUE
} else if (cond2) {
  # run here if cond1 is FALSE but cond2 is TRUE
} else {
  # run here if neither cond1 nor cond2 is TRUE
}
```

# Iteration

```
for (var in seq) {
  do something
}

while (cond) {
  do something if cond is TRUE
}
```

```
# sum of squares
t <- 1:3
y <- 0

for (x in t) {
  y <- y + x^2
}

print(y)
```

# Programming Structure: Functions

- What's a function
  - a logical block of code
  - input -> output
- Why write functions
  - Reusability
  - Abstraction
  - Maintainability
- Example: $\sum_{t=1}^{n} t^2$

```
# sum of squares from 1 to n
ss <- function(n) {
  t <- 1:n
  sum(t^2)
}

# calling the ss() function
print(ss(2))
print(ss(3))
```

# Extending the regression example

- Manipulate data
  - Load data
  - Create new columns
  - Filter columns and rows
- Build models
  - Multiple regression
  - IV regression
- Report and graph
  - Build a publication-ready table for regression results

# Using R libraries

- Install and load an R library

```
install.packages("library_name")
```

```
library(library_name)
```

- CRAN (The Comprehensive R Archive Network)
  - CRAN Task Views

# Many choices, which one to use

- Often time, many choices of functions/libraries to do one task
  - R is open and extensible!

- Example: load a csv file to a data frame
  - Use `read.csv()` function from the `utils` library
  - Use `read_csv()` function from the `readr` library
  - Use `fread()` function from the `data.table` library
  - Use `vroom()` from the `vroom` library

# Many choices, which one to use

- Start with the one most people use
- Choose one that is well maintained
  - check document, github, etc. for last update
- Choose one that suits your task

# Our Choice: extending the regression example

- Manipulate data (`tidyverse` eco-system)
  - Load data (`read_csv()` from the `readr`)
  - Create new columns (`mutate()` from `dplyr`)
  - Filter columns and rows (`select()` and `filter()` from `dplyr`)
- Build models
  - Multiple regression (`lm()` from `stats` library in R base)
- Report and graph
  - Build a publication-ready table (`stargazer()` from `stargazer` library)

# Load a CSV file

- `read_csv()` from the `readr`

```
read_csv(file)
```

- More about `read_csv()`

- More about `readr`

# Load Data – Many other libraries

- readxl for Excel sheets
- haven for SPSS, Stata and SAS data
- jsonlite for JSON
- xml2 for XML
- httr for web APIs
- rvest for web scraping
- DBI for connecting to DataBase engine
- …

# Data Manipulation: `dplyr` basics

- Filter observations: **`filter()`**
- Select variables: **`select()`**
- Reorder rows: **`arrange()`**
- Create new variables: **`mutate()`**
- Collapse column values to a single summary: **`summarise()`**

- Group by: **`group_by()`**

# Data Manipulation: **filter()**

```
filter(my_dataframe, condition1, …)
```

# Data Manipulation: **mutate()**

```
mutate(my_dataframe, new_var1 = expression1, …)
```

# Data Manipulation: **select()**

```
select(my_dataframe, var1, …)
```

# Data Manipulation: Data Pipe (%>%)

```
iris_cleaned <- filter(iris, Species == "setosa")
iris_cleaned <- select(iris_cleaned, Sepal.Length)
```

# Data Manipulation: Data Pipe (%>%)

```
iris_cleaned <- filter(iris, Species == "setosa")
iris_cleaned <- select(iris_cleaned, Sepal.Length)

iris_cleaned <- iris %>%
  filter(., Species == "setosa") %>%
  select(., Sepal.Length)
```

# Data Manipulation: Data Pipe (%>%)

```
iris_cleaned <- filter(iris, Species == "setosa")
iris_cleaned <- select(iris_cleaned, Sepal.Length)

iris_cleaned <- iris %>%
  filter(Species == "setosa") %>%
  select(Sepal.Length)
```

# Data Manipulation: Others

- Join two data frames
  - `_join()` family in `dplyr`

- Reshape data frames
  - `pivot_longer()` and `pivot_wider()` in `tidyr`

# Regression

- Multiple regressions: `lm()` from `stats` library in base R

```
my_model <- lm(y ~ x1 + x2, data)
```

- Multiple regressions with interactive terms

```
my_model <- lm(y ~ x1 + x2 + I(x1 * x2), data)
```

- Regression result summary: `summary()`

Ref. https://faculty.chicagobooth.edu/richard.hahn/teaching/FormulaNotation.pdf

# Report

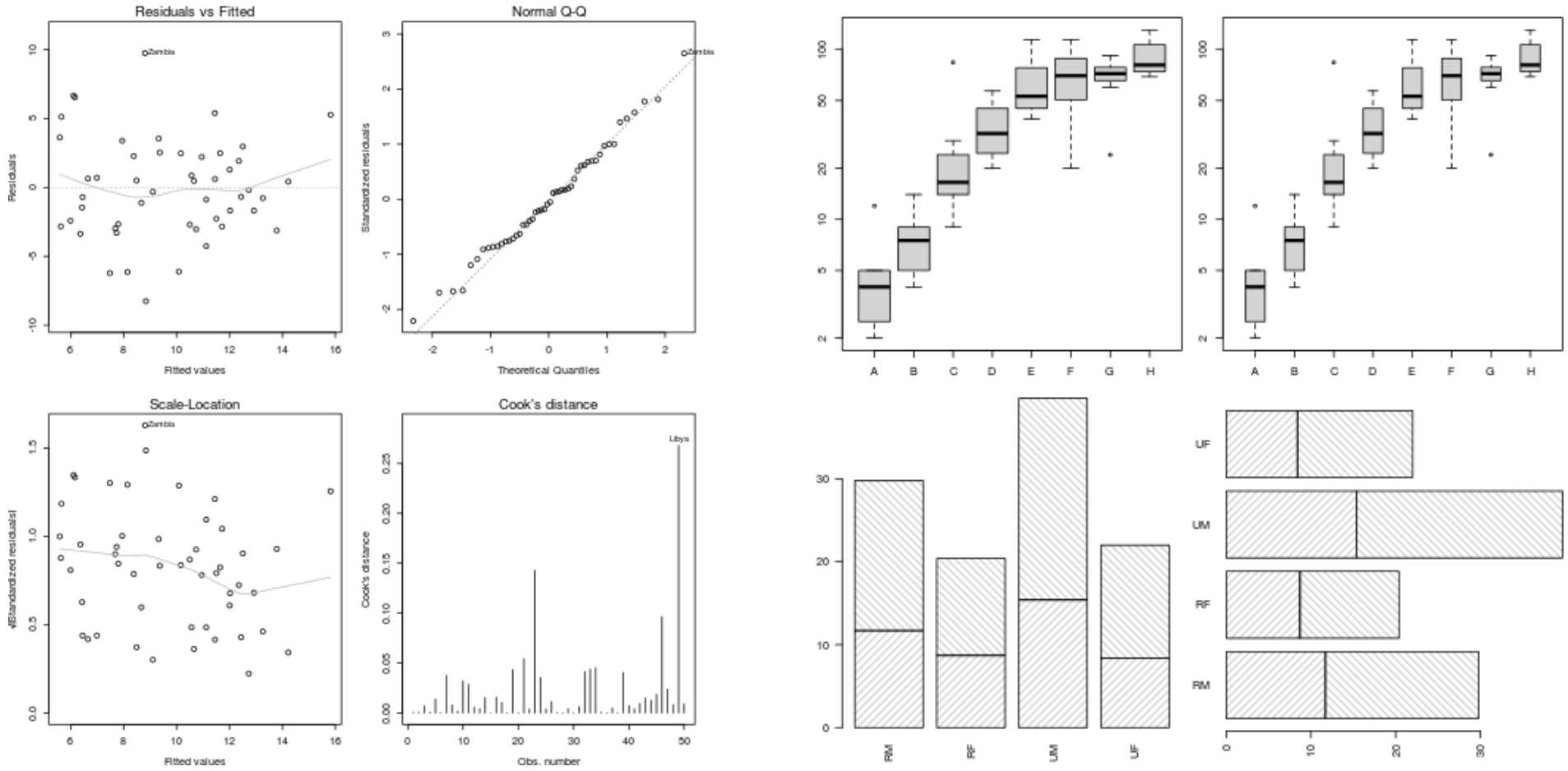
- Summary table
  - Summary for lm(): `summary(my_model)`

- publication-ready table: `stargazer()` from `stargazer` library

```
stargazer(my_model1, my_model2, …)
```

Ref. https://cran.r-project.org/web/packages/stargazer/vignettes/stargazer.pdf

# R Graphics – Base plots (examples)

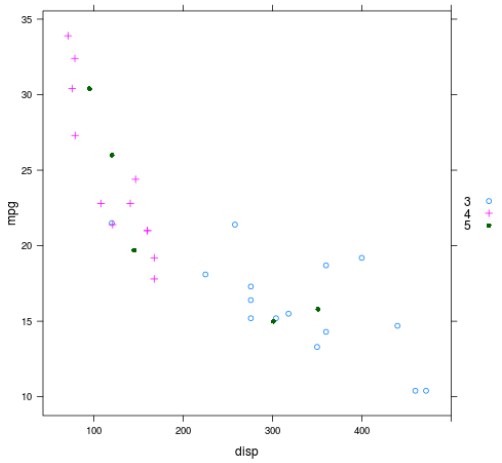



https://www.stat.auckland.ac.nz/~paul/RG3e/chapter2.html

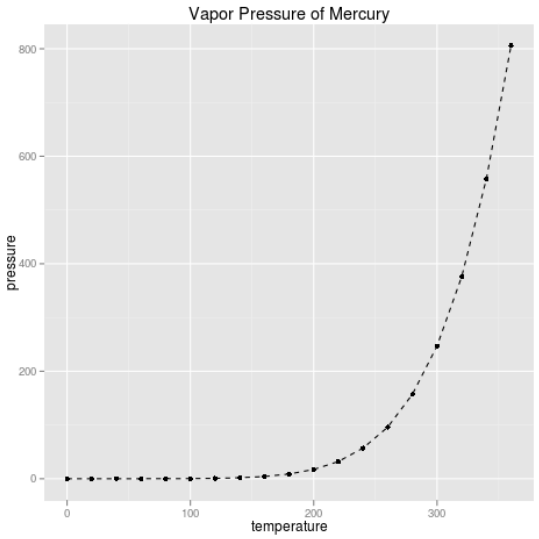
# R Graphics – Two Main Plotting Systems

- System?

- R package: lattice
  - implements Trellis system by William Cleveland:



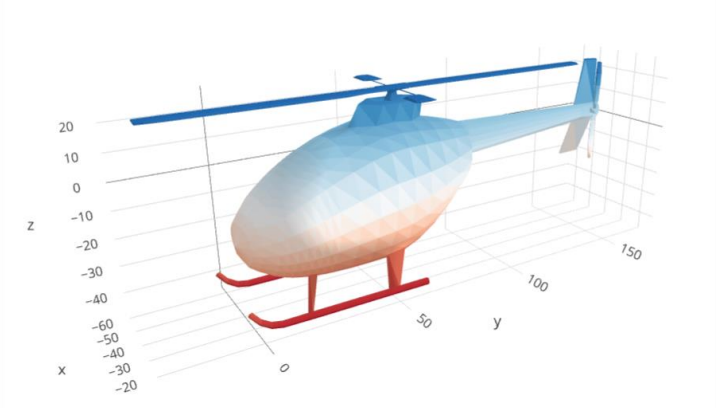

- R package: ggplot2
  - implements "A Grammar of Graphics" by Leland Wilkinson
  - **Recommended**



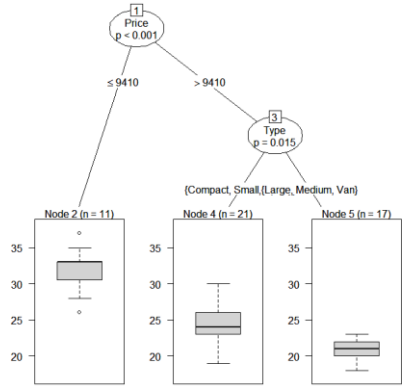

https://www.stat.auckland.ac.nz/~paul/RG3e/chapter4.html
https://www.stat.auckland.ac.nz/~paul/RG3e/chapter5.html

# Other Specialized Plots

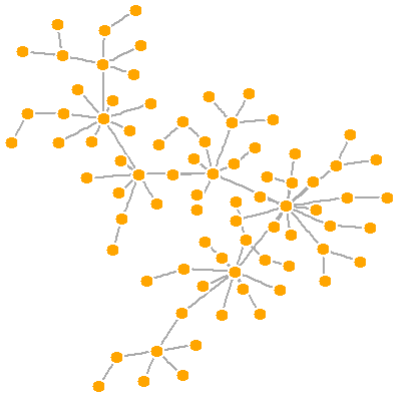
- Graphic functions provided by specialized packages
  - Based on R primitive graphical engines like grid (eg. plot() in party, igraph)
  - Following a plotting system (eg. ggmap, tmap, gganimate, plotly, etc.)
  - Wrapper of plotting tools in another languages (ex. leaflet, grViz() in DiagrammeR)




3D tri-surface interactive plot using the plotly package https://plot.ly/r/trisurf/




Decision tree plot using party package https://www.statmethods.net/advstats/cart.html



Network plot using igraph package http://kateto.net/networks-r-igraph

# ggplot2

- Based on the Grammar of Graphics

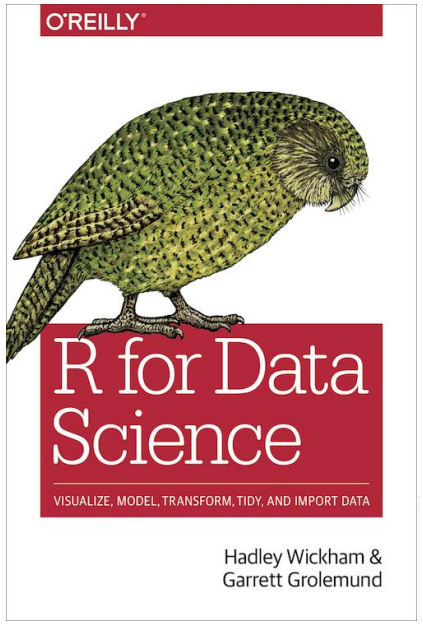
- Basic idea: you can build any graph from the same components
  - Data
  - Coordinate system
  - Geoms – visual marks that represent data points

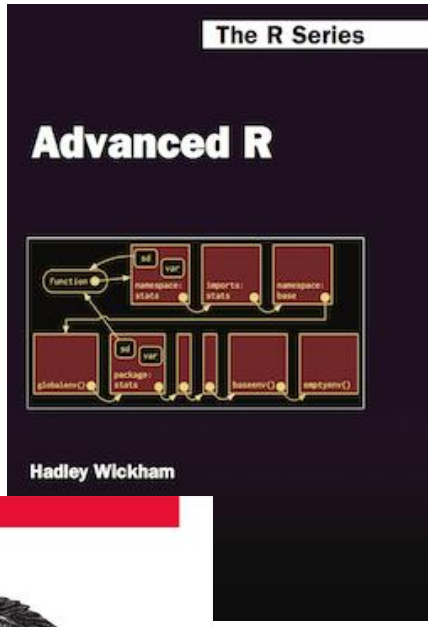
- A layer-by-layer approach

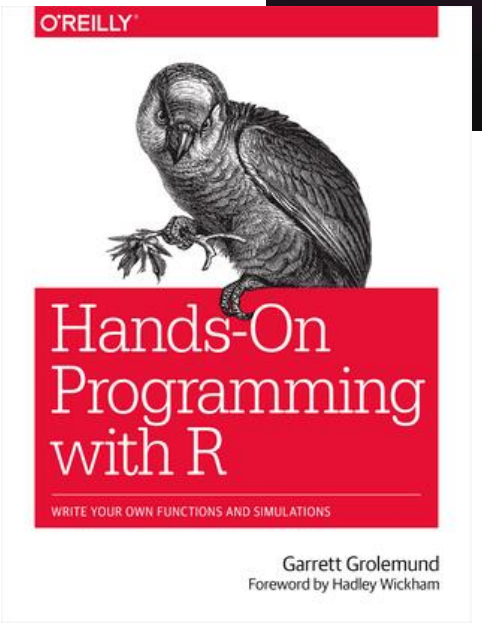
Free ggplot2 book: https://ggplot2-book.org/
Paper: A layered grammar of graphics

# Free Learning Resources - Books

- R for Data Science
- Advanced R
- Hands-On Programming with R
- Check bookdown.org often



# Free Learning Resources – Video Courses

- RStudio Resources Site

- LinkedIn Learning (used to be lynda.com)
  - free for UofT students and Toronto Public Library users
  - Search R and learn

# Free Learning Resources – Others

- CRAN Task View
- Sample notebooks / reports at http://rpubs.com/
- Twitter (a few seeds: #rstat, @hadleywickham, @WeAreRLadies)