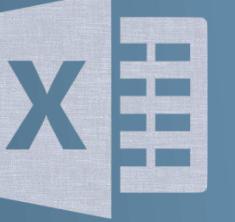


FROM  EXCEL TO 



# WHO ARE WE?

Center for Health Data Science (**HeaDS**):

- Data Science Research Groups
- HDS Sandbox (Infrastructure Project)
- **SUND Data Lab**

<https://heads.ku.dk/>



Thilde Terkelsen



Helene Wegener



Chelsea Lennox



Tugce Karaderi

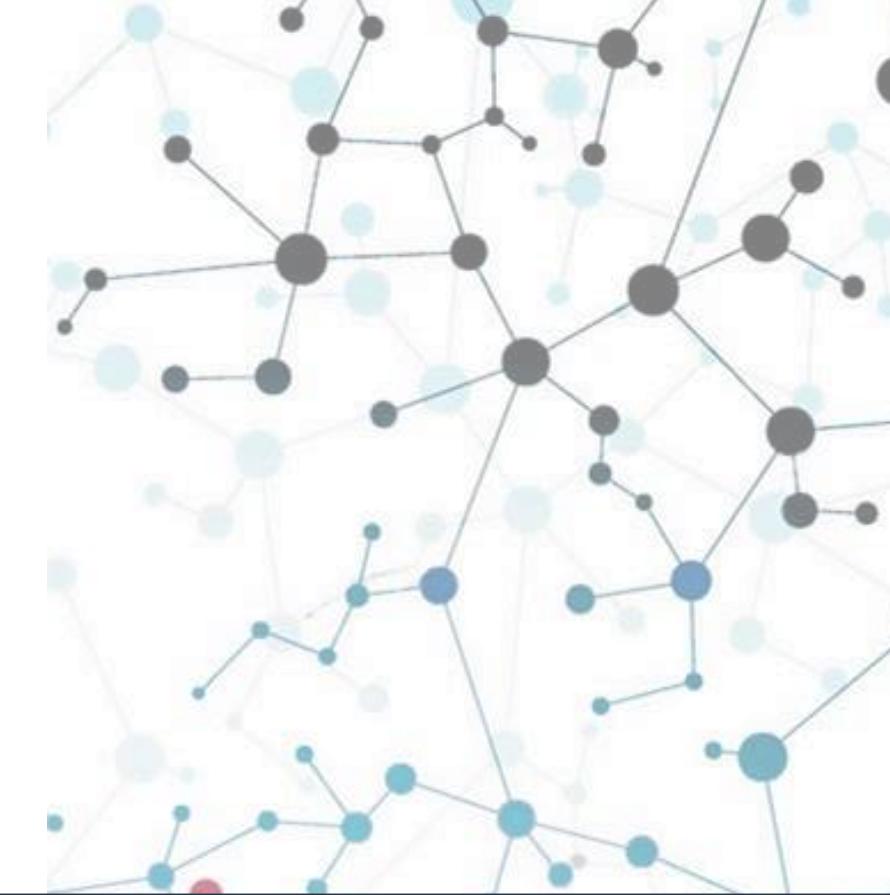
## SUND Data Lab:

- Courses & Workshops, Seminars, etc.
- Health Data Science Consultations
- Commissioned Research & Supervision
- Hub for Data Science (Matchmaking)

Data Science Laboratory (DSL) - <https://datalab.science.ku.dk/>



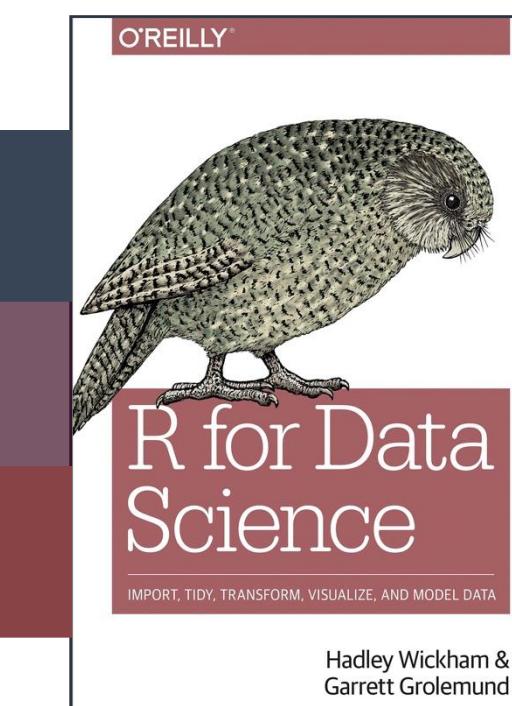
# THE PRACTICALS



Two days: 9.00-16.00. There will be coffee breaks, we promise ☕

“R for Data Science” - a generally useful book on R, also for this course

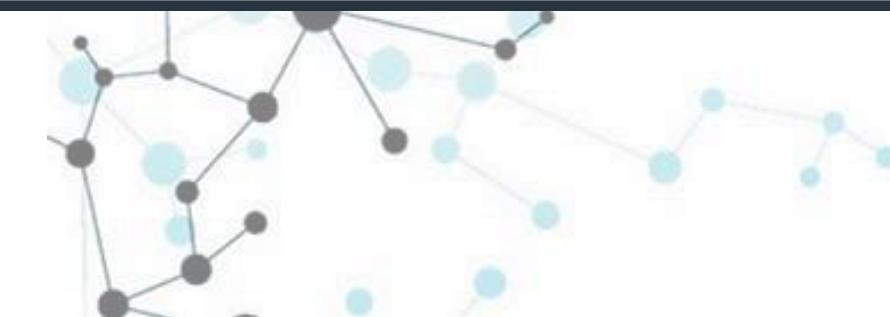
The course is build on hands-on presentations & exercises



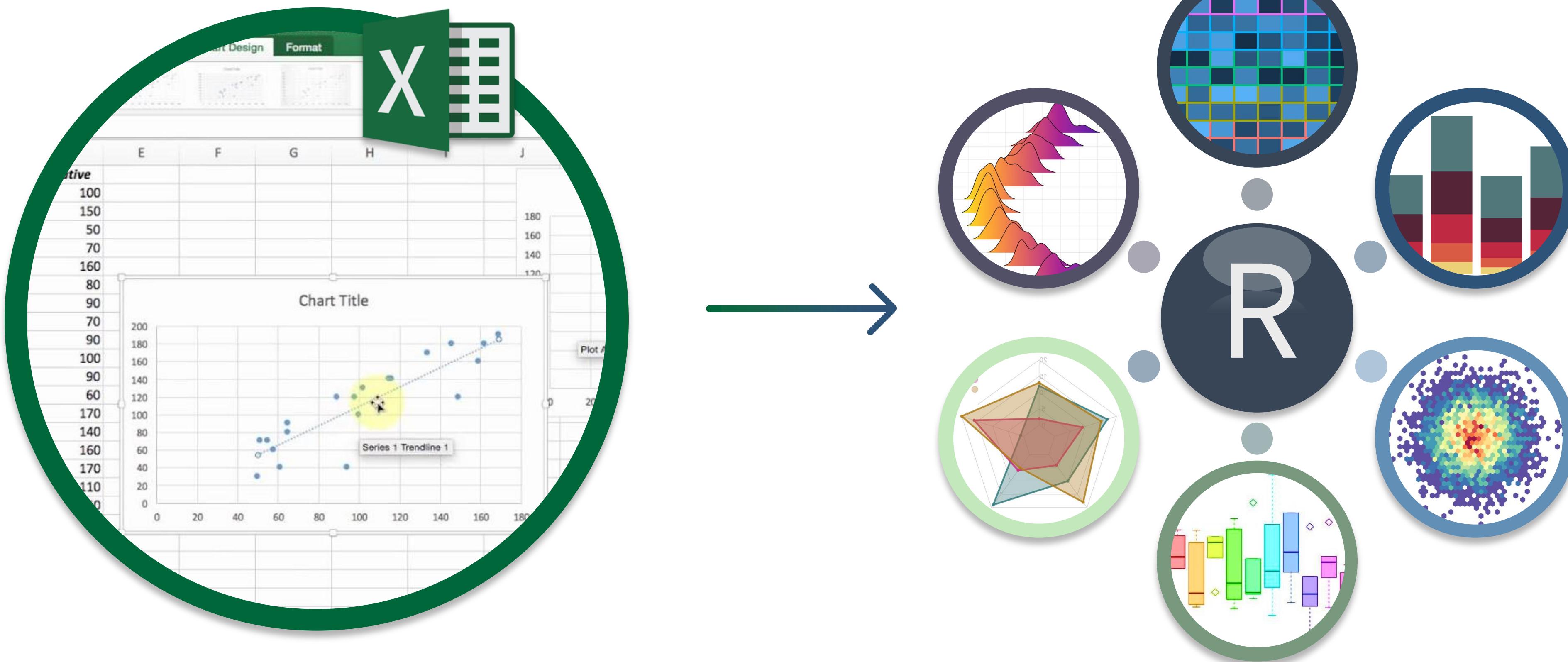
Download and install the newest version of R (<https://cran.r-project.org/>)

Download and install the newest version of R-studio (<https://posit.co/download/rstudio-desktop/>)

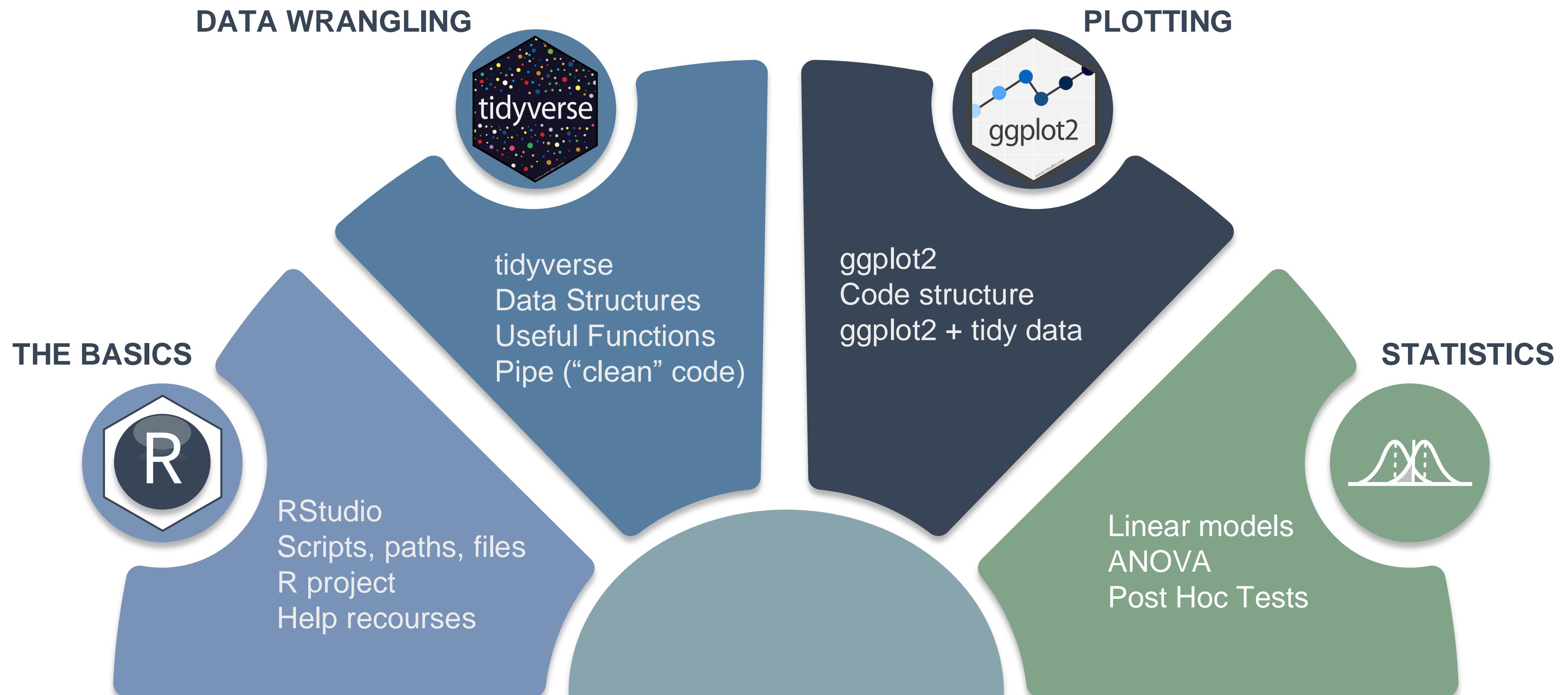
Go to course website: <https://center-for-health-data-science.github.io/FromExceltoR/>



— WELCOME TO  
FROM EXCEL TO R



# WHAT WILL I LEARN?



# PROGRAM

## DAY 1

08:30 - Installation Issues + Coffee  
09:45 - Introduction to R  
09:45 - Exercise 0  
10:30 - Introduction to Quarto  
11:00 - Exercise 1  
12:00 - Lunch  
13:00 - Tidyverse  
14:15 - Tidyverse Exercise  
16:00 - See you tomorrow

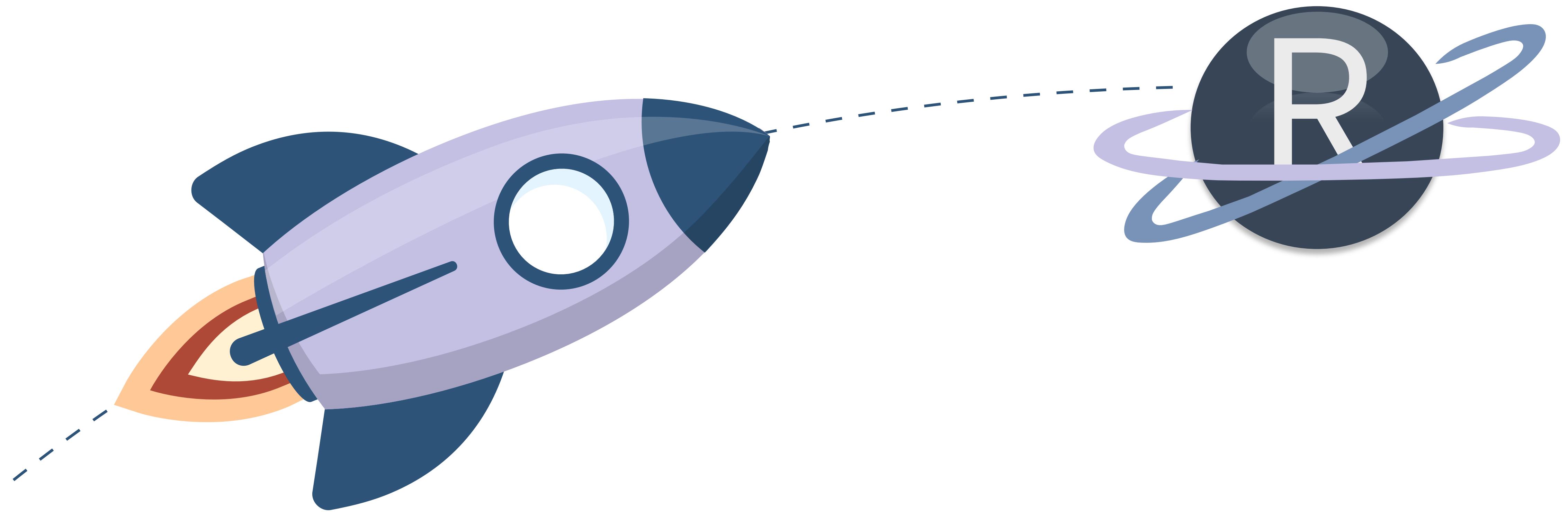
## DAY 2

08:30 - Coffee + Optional Q&A  
09:00 - ggplot2  
10:00 - ggplot2 Exercises  
12:00 - Lunch  
13:00 - Applied Statistics  
14:45 - Data Analysis Exercise  
15:45 - Cool things in R + Course Evaluation  
16:00 - Bye Bye Bye!

2\*15 minutes break every day

— FROM EXCEL TO R

# LET'S GET STARTED



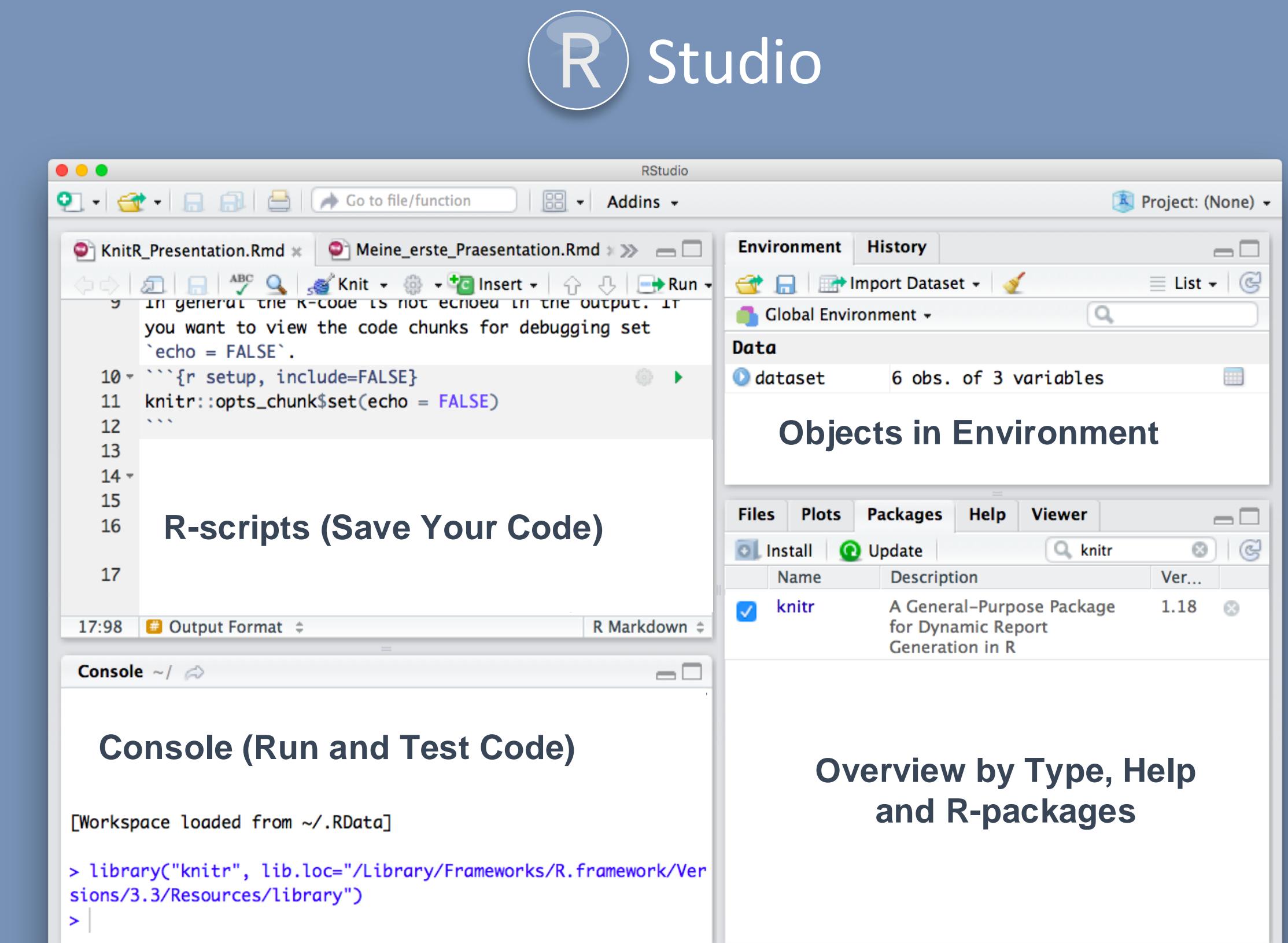
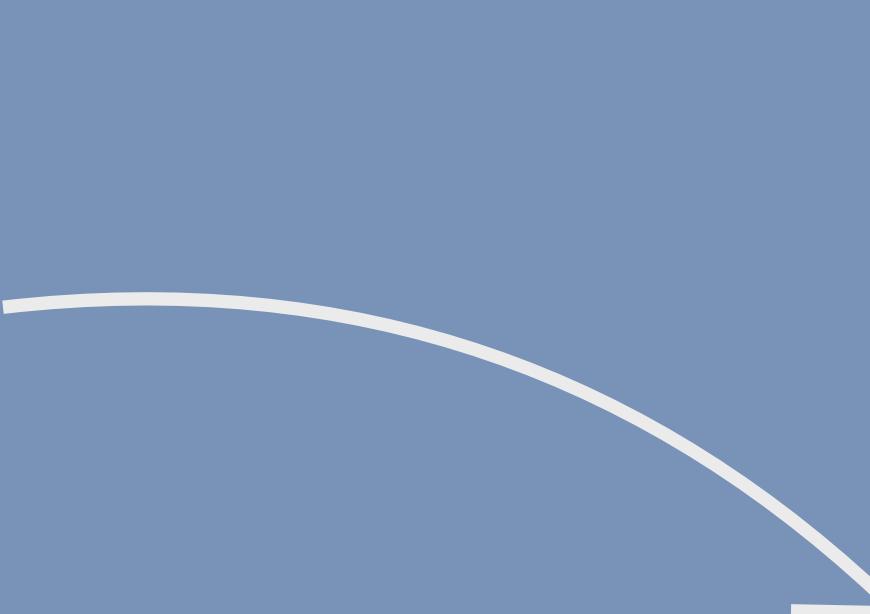
## R & FRIENDS



Scripting / Programming Language



Reports (html, pdf, word)



R Code Interpreter and Editor

# THE ANATOMY OF R

The **programming language**  may be used from within in the **Code Editor** 

The R code you write may be saved in **scripts** with extensions:



**Functions** perform actions based on **input arguments** and return an output:

`mean(x)`  
`sd(x)`

**Packages** are bundles/libraries of functions.



# QUARTO DOCUMENTS



- Tool which supports **reproducible** coding/publication (reports)
- Quarto works with a **markup language**
- A markup language is **text-coding system** which specifies structure & format of a document and the text within it
- We **render** (compile) a Quarto → html, pdf, word, website

## Pointers for quarto:

- Separate sections with headers
- Do not overfill code chunks
- Write meaningful and precise comments

90% of all code comments:

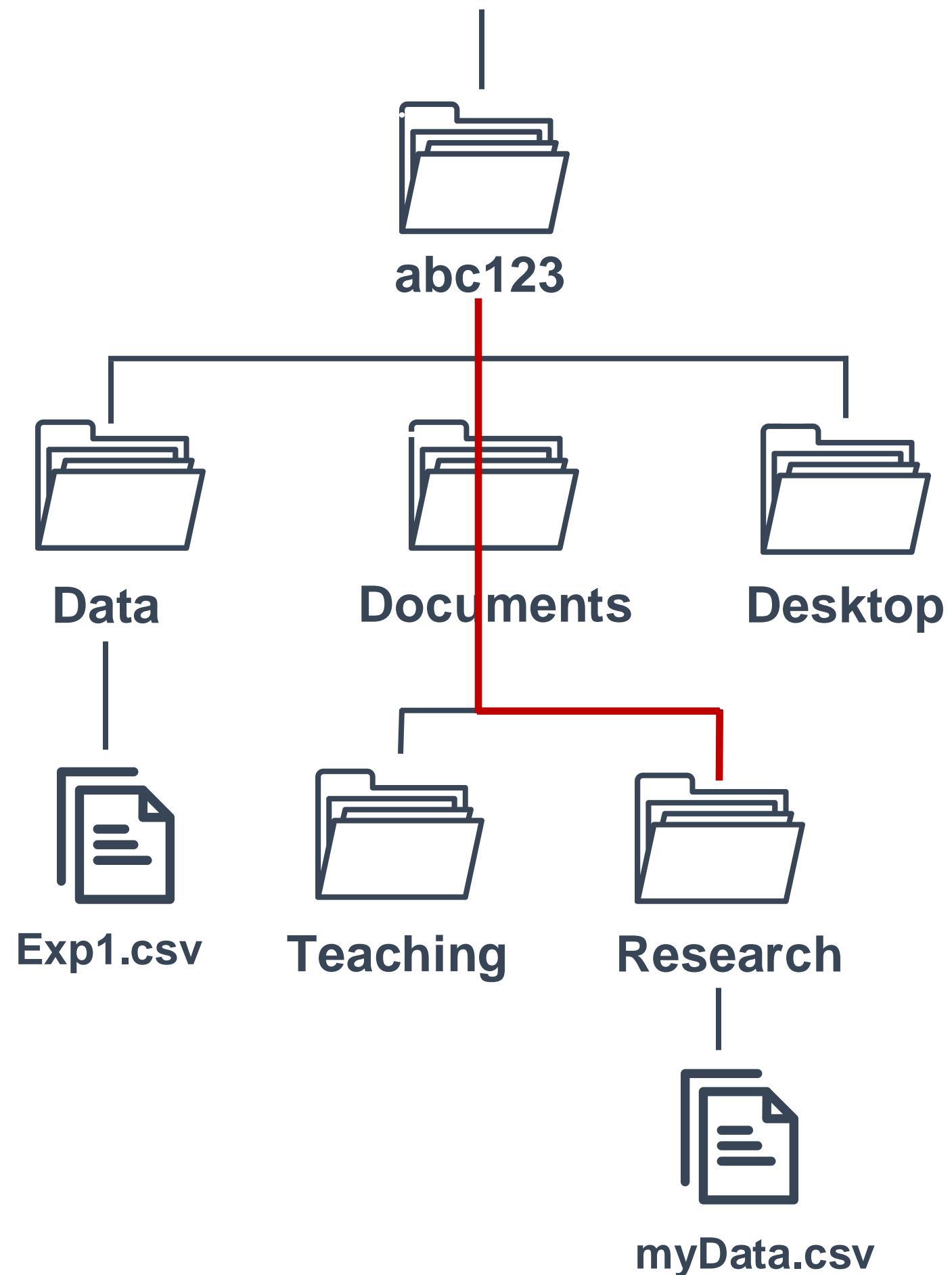


# PATHS – LOCATION, LOCATION, LOCATION

- The directories on your computer are organized in a **File Tree**
- **Move** between directories or **point to** a place in the tree with a specific file

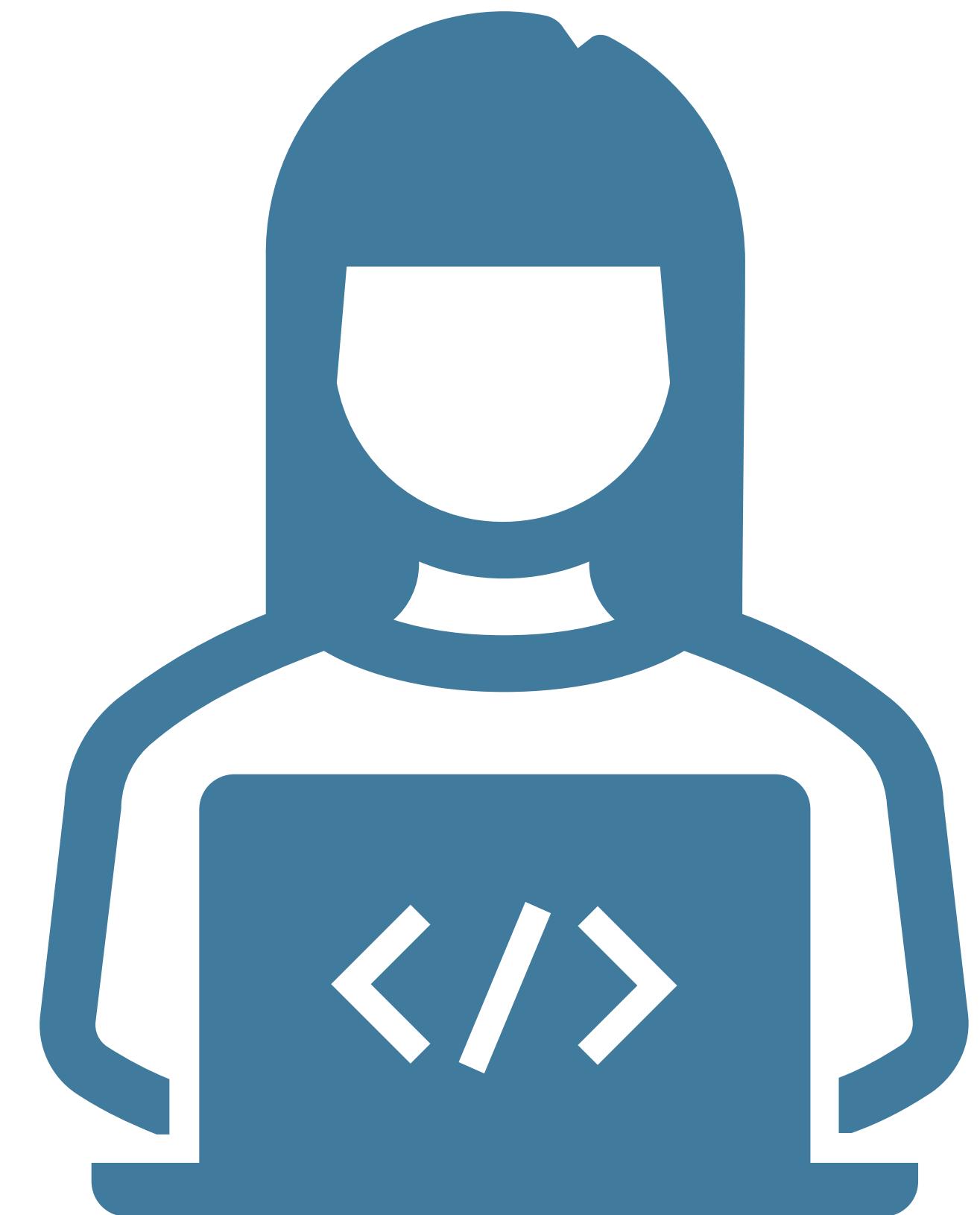
We do this by specifying a **path**:

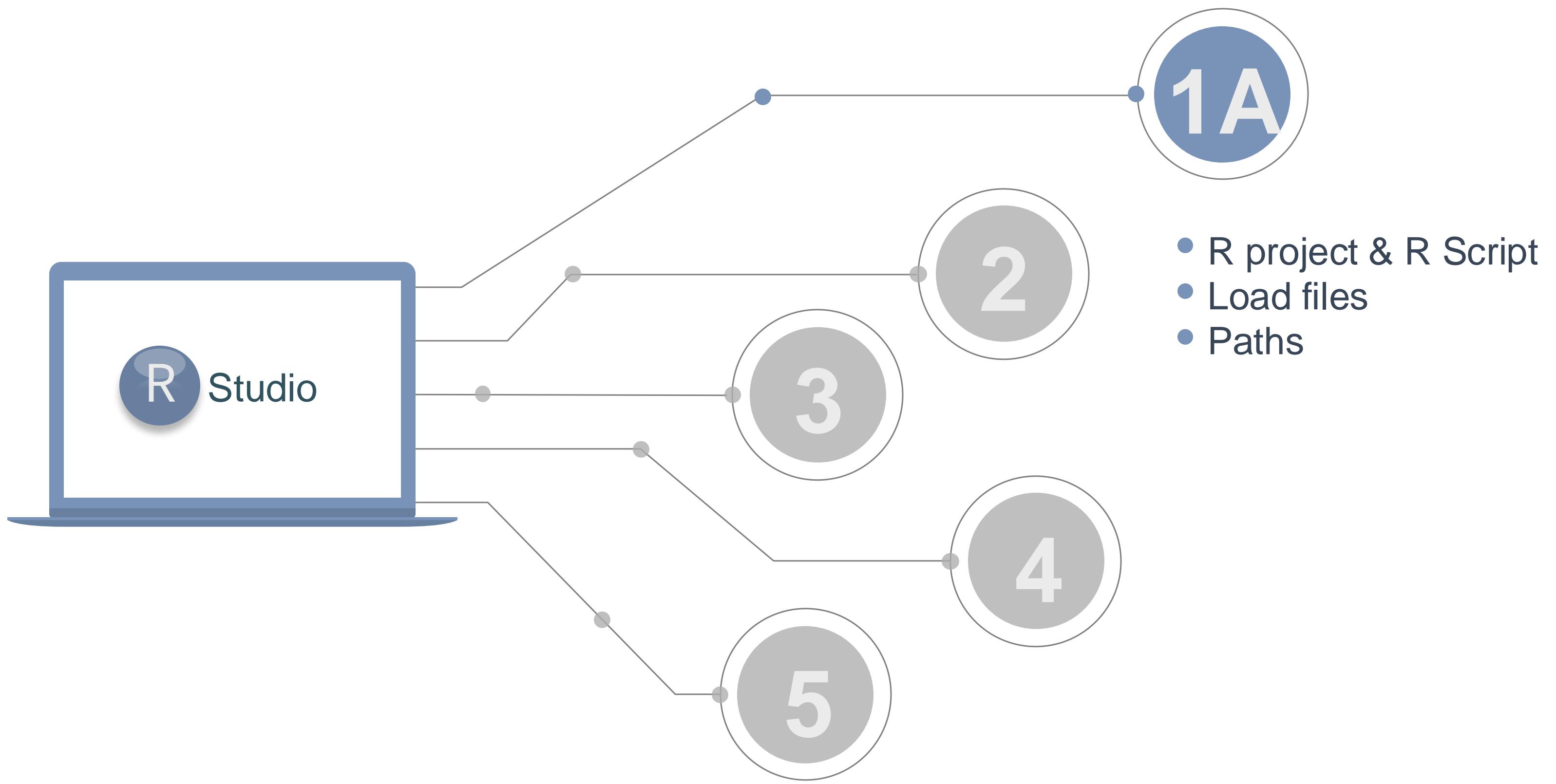
- **Move to:** /abc123/Documents/Research
- **Point to:** /abc123/Documents/Research/myData.csv
- The place you are, right now, is called the **working directory** (wd)  
Where am I: `getwd()`  
Go to : `setwd('path')`



— FROM EXCEL TO R

# LIVE CODING 1A – INTRO TO R





— FUNDAMENTALS  
**EXERCISE 1A**

# QUARTO CHEAT SHEET

## YAML parameter:

```
---
```

```
title: My Project Name
```

```
output:
```

```
    html_document (pdf_document, ...)
```

```
---
```

## Code Chunk:



**Source mode:**  
```{r}  
# some R code  
```

**Visual mode:**  
{r}  
# some R code

## Code Options:

```
{r echo = FALSE} # don't print code (default is TRUE)  
{r eval = FALSE} # don't run code (default is TRUE)  
{r error = FALSE} # don't display error message (default is TRUE)  
(Can also be set for warning and message)
```

## Figure Options:

```
fig.align (= 'left', 'right', 'center')  
fig.cap (= 'my figure caption')  
fig.height (= n), fig.width (= n)
```

## GETTING STARTED

## CHUNK OPTIONS

## Source mode:

### Header

Header size ranging from largest (one #) to smallest (six #):  
# my.text, ## my.text, ### my.text, etc.

## Text

\*italics\*  
\*\*bold\*\*  
`highlighted`

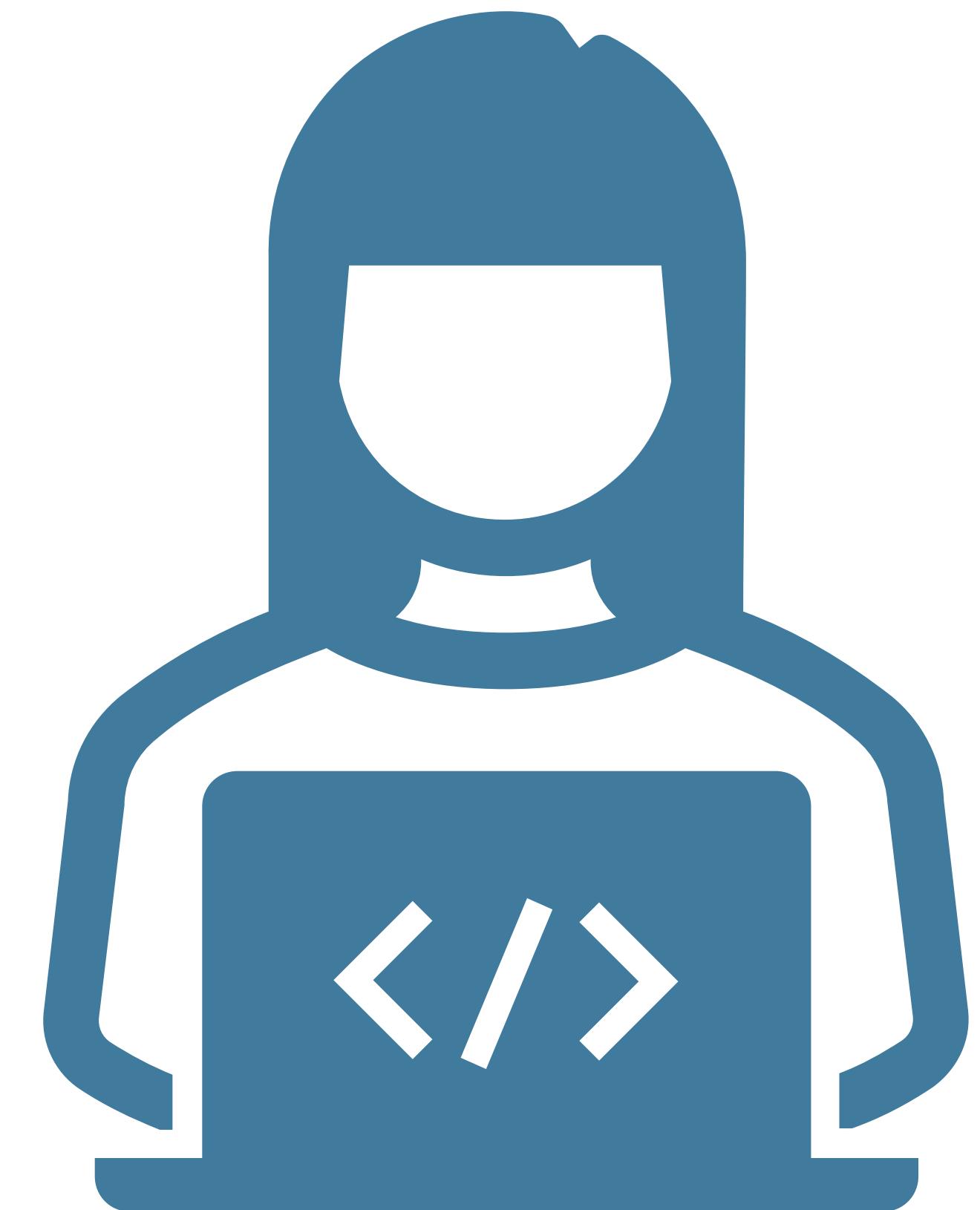
## Lists

- \* List item1 (filled dot)
  - + sub-item1 (open dot)
- 1. List item1 (numbered)
  - i) sub-item1 (roman)

## TEXT

— FROM EXCEL TO R

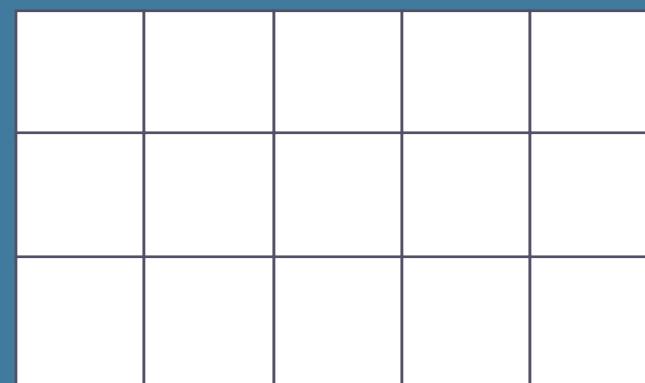
# LIVE CODING 1B – INTRO TO R



# FROM EXCEL TO R

## R DATA TYPES & STRUCTURES

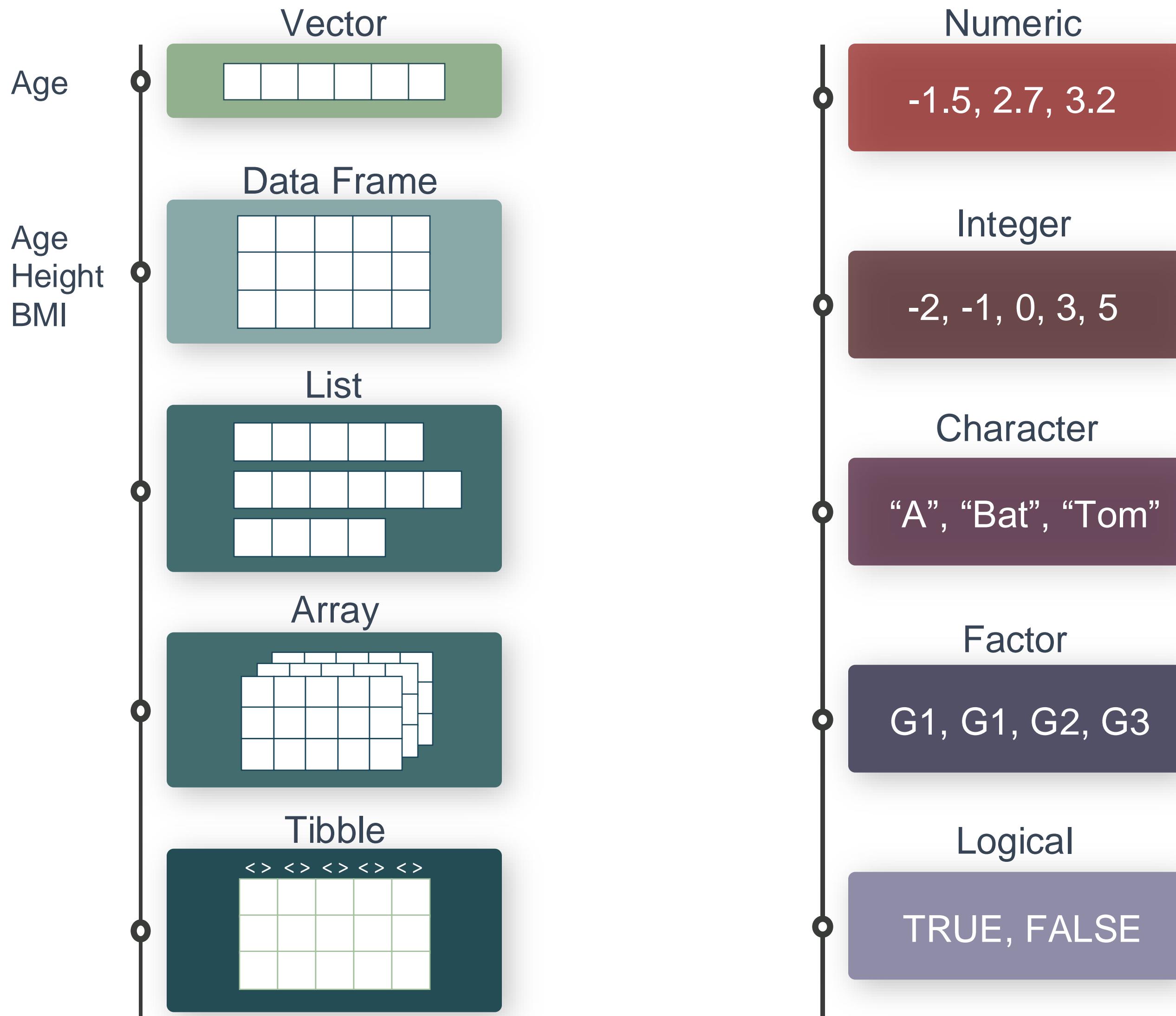
VARIABLES



OBSERVATIONS

## DATA STRUCTURES

## DATA TYPES



# INTRO CHEAT SHEET

## Basics:

```
getwd() # location  
install.packages("package_name") # install packages  
library(package_name) # load packages
```

## Overview:

```
head(df, n=10), tail(df, n=10) # first or last 10 rows  
unique(), table(), count() # unique vals, count vals
```

## Type/Class:

```
class() # get data type/class  
is.numeric(x), is.character(), is.factor() # is data type  
as.numeric(x), as.character(), as.factor() # change data type
```

## Summary Stats:

```
summary() # summary statistics  
mean(), median(), sd(), sum(), log(), max(),  
min(), quantile(), var()
```

## Read in Data:

```
read.xlsx("name.xlsx") # library(readxl)  
read.delim("name.txt", sep ="\t")  
read.csv("name.csv", sep=";")
```

```
view() # view data as table  
df$col1 # extract column from dataframe  
nrow(df), ncol(df) # number of rows/columns
```

## Conditions:

```
a == b    a != b    a > b    a < b  
a >= b   a <= b   is.na() is.null()
```

## Plots:

```
plot(x)  
plot(x, y) or plot(col1, col2, df) # scatter  
hist(x) # histogram
```

## GETTING STARTED

## OVERVIEW

## DATA TYPES & CONDITIONS

## STATISTICS & BASE PLOTS

# ONLINE RESOURCES FOR R

<https://www.r-project.org/>



## GET STARTED

<https://rseek.org/>

[https://rstudio.com/resources/c\\_heatsheets/](https://rstudio.com/resources/c_heatsheets/)

<http://www.cookbook-r.com/>

[https://www.statmethods.net/r\\_tutorial/index.html](https://www.statmethods.net/r_tutorial/index.html)



## GRAPHICS

<https://www.r-graph-gallery.com/>

[http://r-statistics.co/Top50\\_Ggplot2-Visualizations-MasterList-R-Code.html](http://r-statistics.co/Top50_Ggplot2-Visualizations-MasterList-R-Code.html)



## BOOKS & COURSES

<https://www.r-bloggers.com/best-books-to-learn-r-programming/>

<https://www.datacamp.com/>

<https://www.codecademy.com/>

<https://www.coursera.org/>



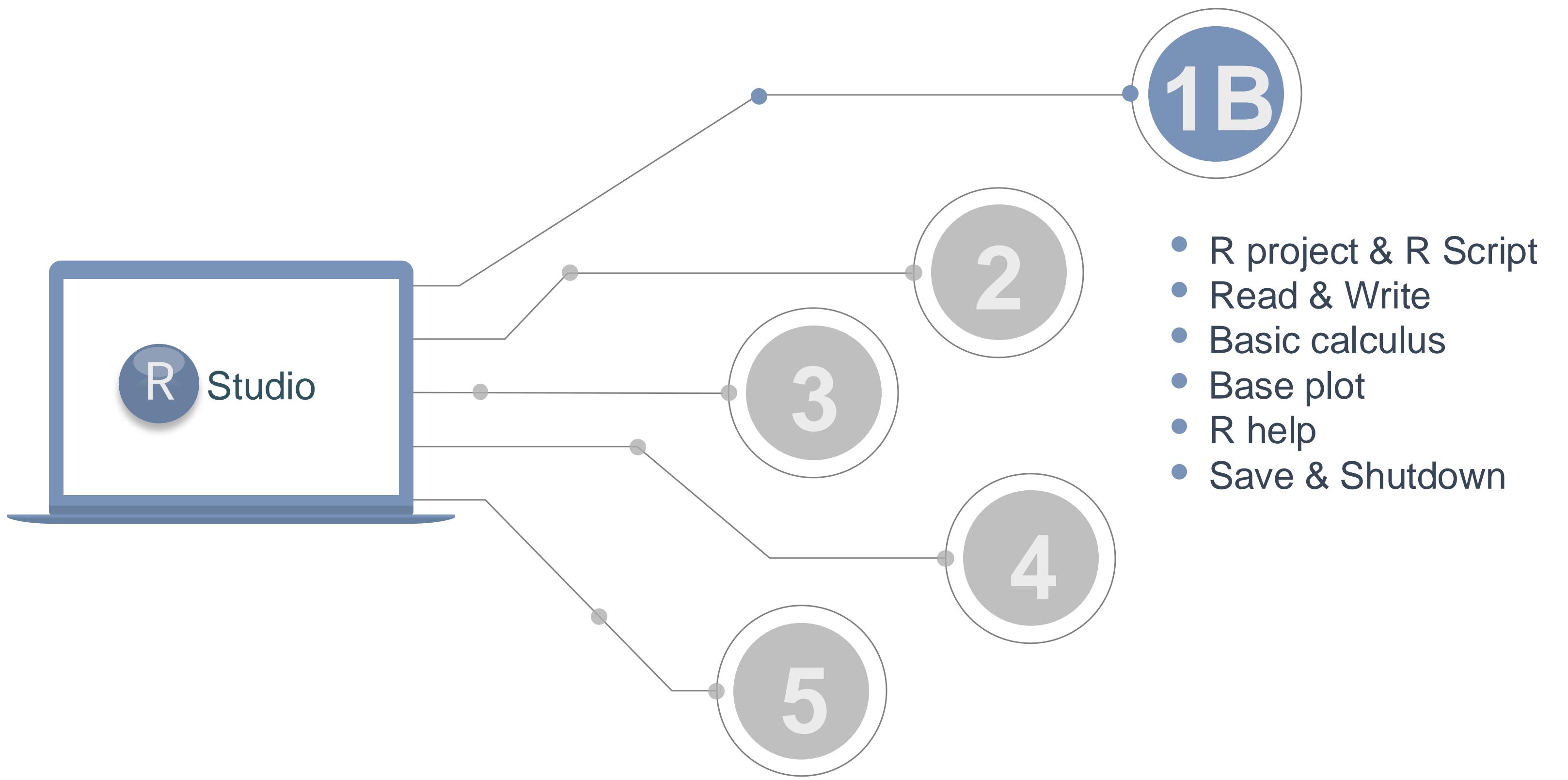
## OTHER RESOURCES

<https://github.com/trending/r>

[https://blog.revolutionanalytic\\_s.com/](https://blog.revolutionanalytic_s.com/)

<https://stackoverflow.com/questions/tagged/r>





— FUNDAMENTALS  
**EXERCISE 1B**

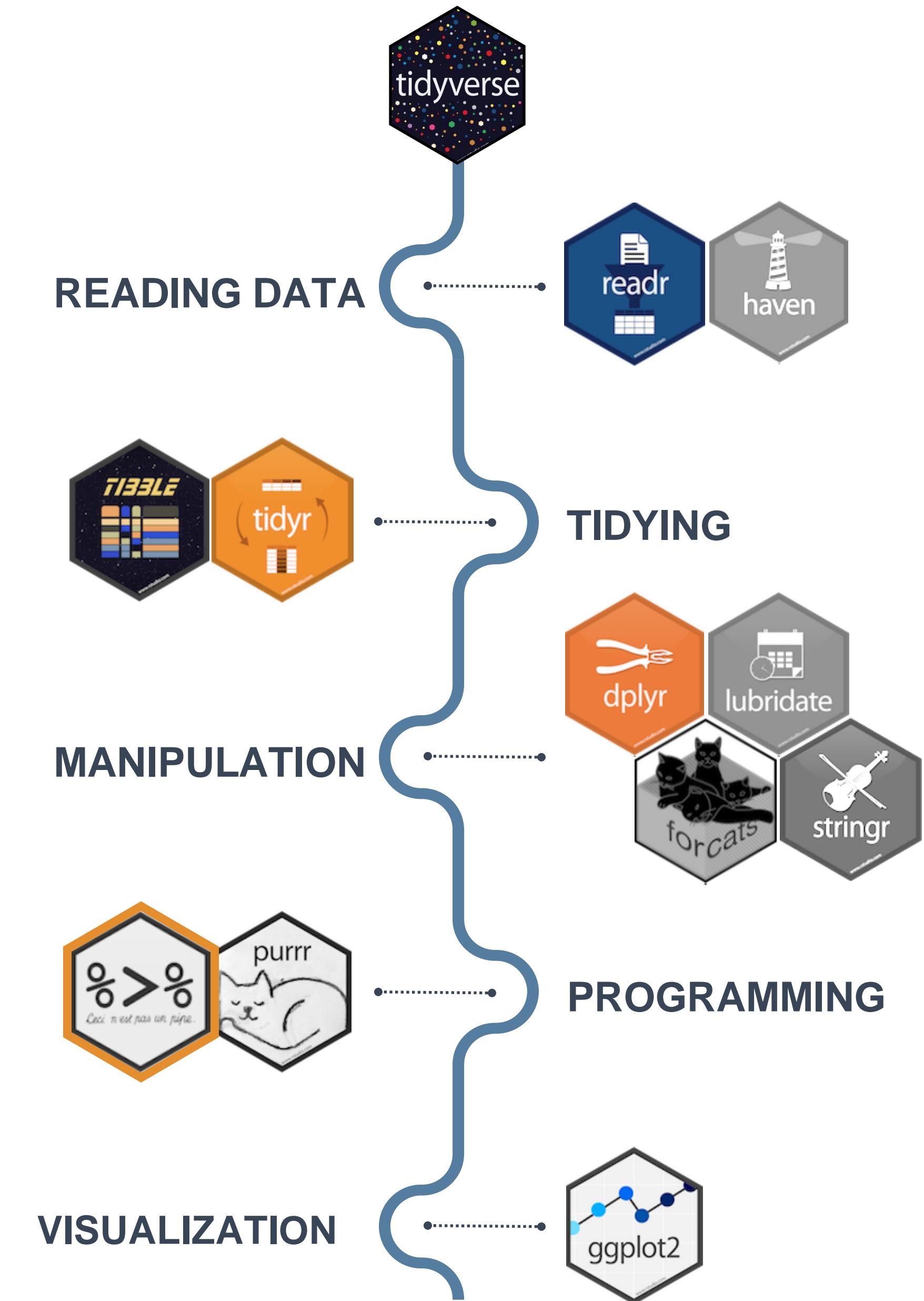
# TIDYVERSE

<https://www.tidyverse.org/>

tidyverse is a collection of R packages for data science

“The packages share an underlying design philosophy, grammar, and data structures.” *Wickham and Grolemund*

tidyverse is used to “tidy up” your datasets, so they are easy to work with



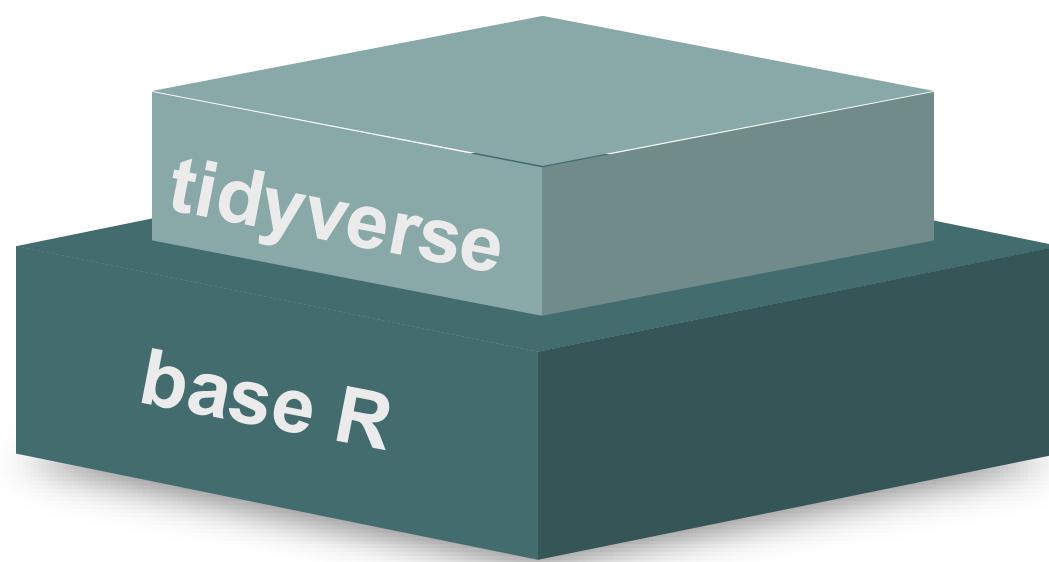
# CECI N'EST PAS UNE PIPE

## %>%

- You do NOT have to “choose” between tidyverse and base R

### BENEFITS

- Short & well-organised code
- Tidy datasets, easy to work with
- Great documentation
- Functions with logical names & inputs



### CONSIDERATIONS

- Can be less stable
- “Different syntax”
- Can be computationally slow

### base R

```
# think from the inside out  
g(f(x), z)
```

### tidyverse

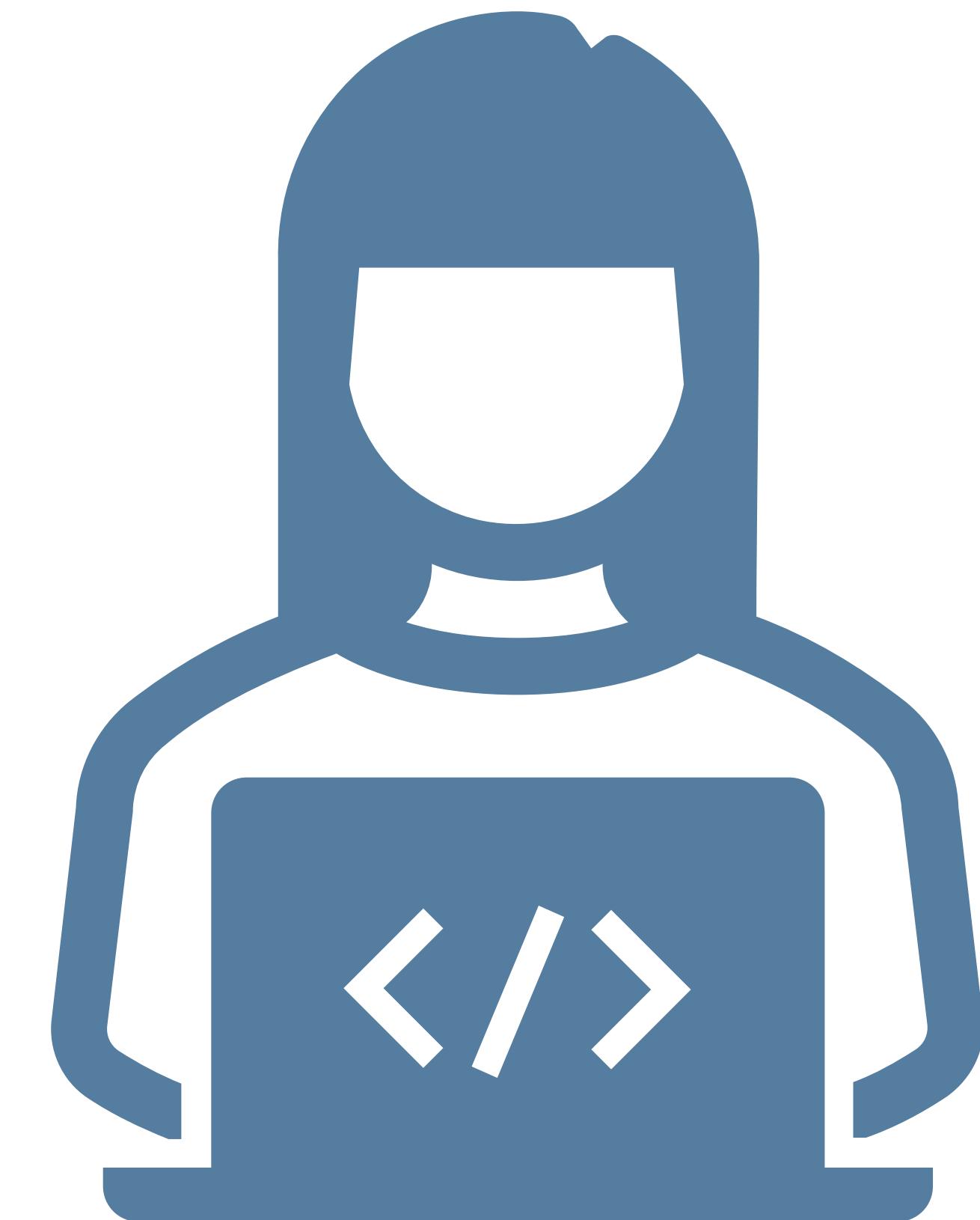
```
# no brain acrobatics  
x %>% f(y) %>% g(z)
```



pipe symbol

— FROM EXCEL TO R

# LIVE CODING 2 – TIDYVERSE



# TIDYVERSE CHEAT SHEET

*readr, tidyverse, dplyr, ...*

## Read Data (*readr*)

### Reading tabular data

There are solutions for multiple data types  
`read_excel()` # using *readxl* package  
`read_table()`  
`read_csv()`

### Useful arguments

Skip lines: `read_csv(file, skip=1)`  
Read subset: `read_csv(file, n_max=1)`

### Data types

*readr* guesses the types of each column and tells you about it  
("Parsed with column specifications: ...")

## Workflow

### Tidyverse workflow

```
df %>%  
  select(col1)  
  
df %>%  
  filter(col1 < x)  
  
df %>%  
  summarize(n_1 = n(),  
            avg_1 = mean(col1),  
            sd_1 = sd(col1))
```

### Select column

```
df$col1
```

## Data Manipulation (*dplyr*)

### Summary

```
summarize()  
count()
```

### Group

```
group_by()
```

Functions will manipulate each group separately and combine results.

### Extract and sort observations (rows)

```
filter() # subset rows by condition  
distinct() # subset to unique values  
top_n() # subset by position  
arrange() # sort low->high, other way with desc()
```

### Manipulate variables (columns)

```
select() # subset rows by condition  
mutate(new_name = f(column))  
mutate(new_name = ifelse(col1 < x, "Yes", "No"))  
mutate(new_name = col1 + col2)
```

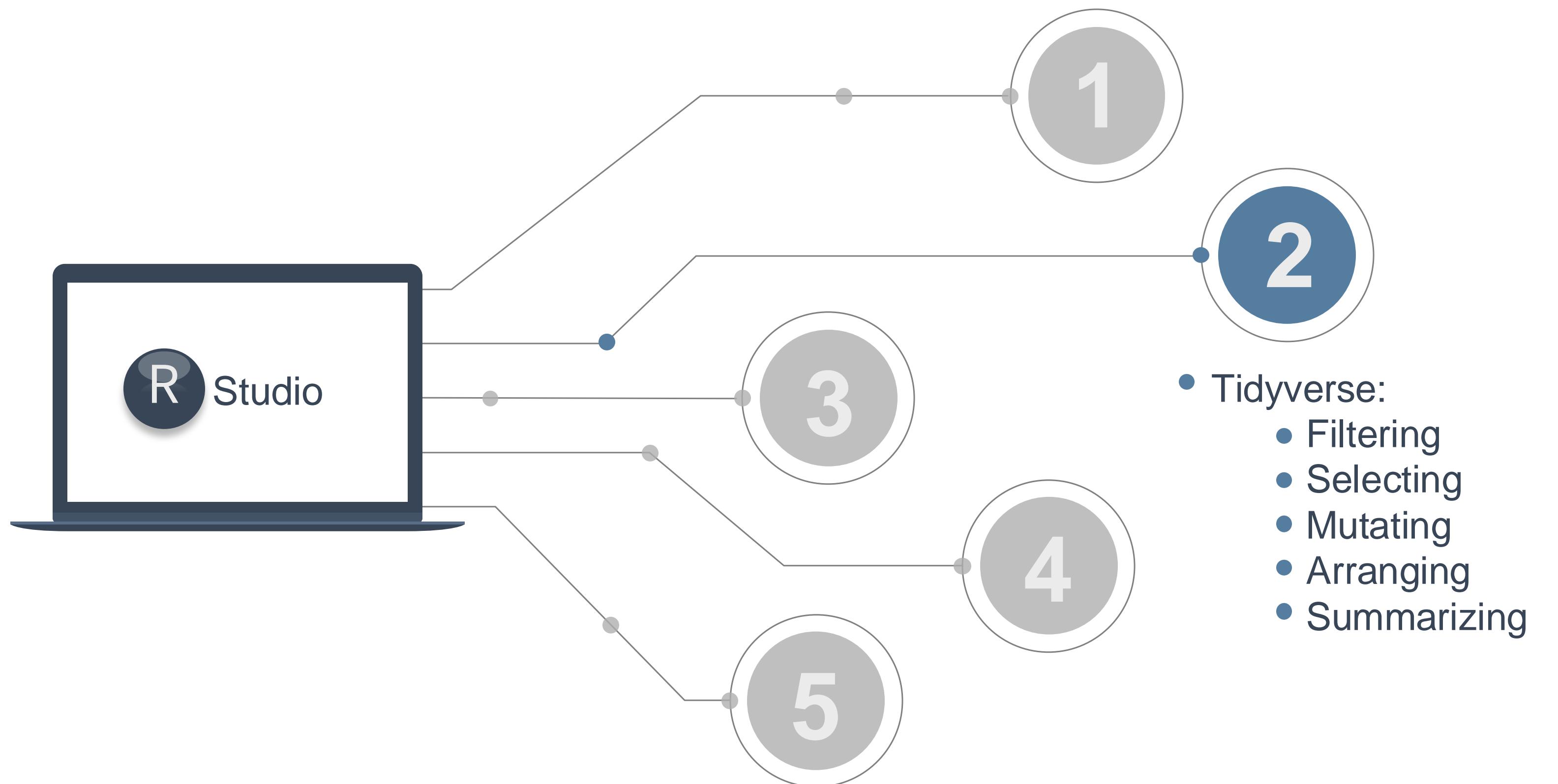
## HELP

R Documentation (e.g. enter `?dplyr::filter` and see examples)

Much more info and detailed cheat sheets:

<https://brianward1428.medium.com/introduction-to-tidyverse-7b3dbf2337d5>

It also helps to google "tidyverse + whatever you want to do"

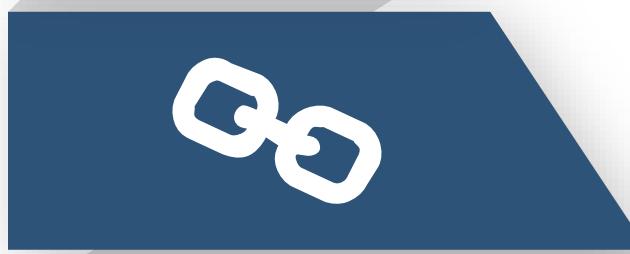
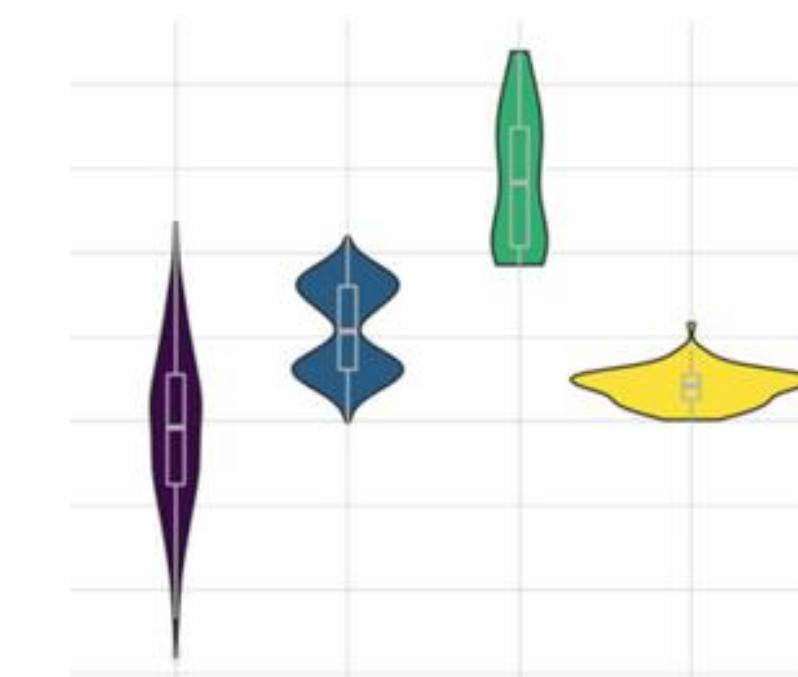


## TIDYVERSE EXERCISE 2

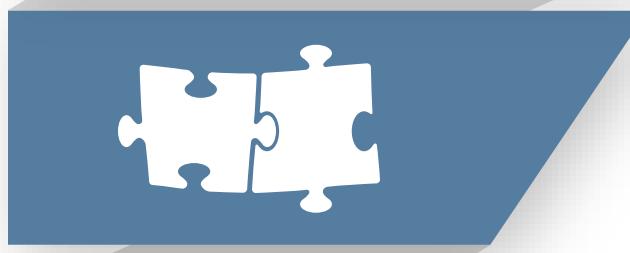
# GGPLOT2 - EASY GRAPHICS



Aesthetically pleasing graphics.



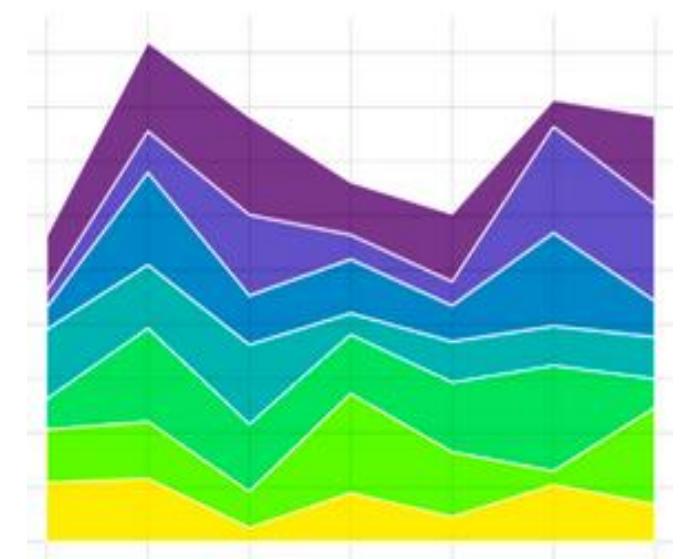
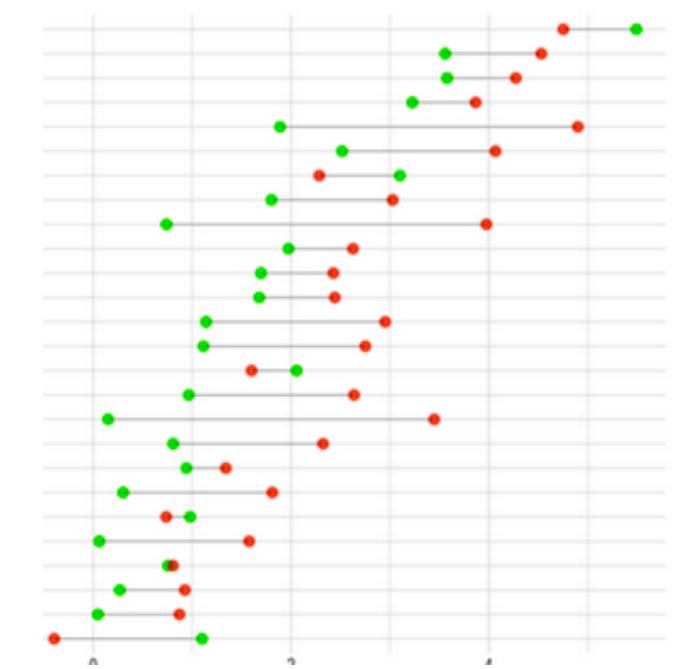
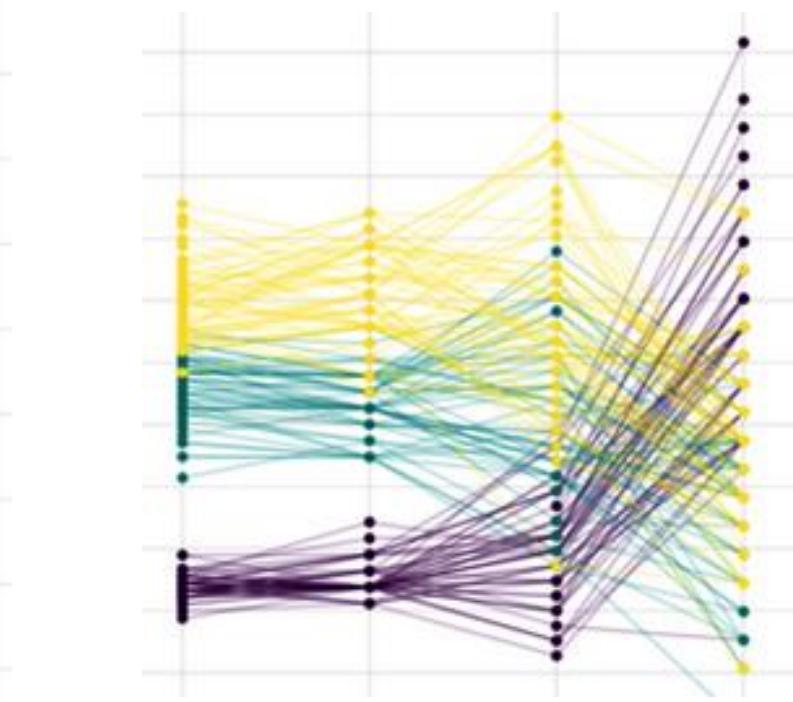
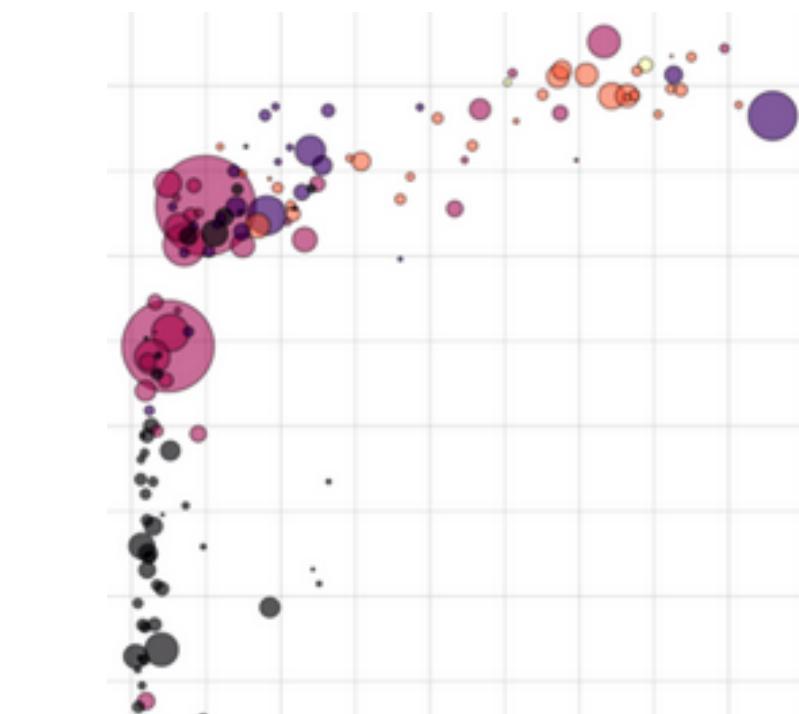
Well-defined “additive” (+) structure.



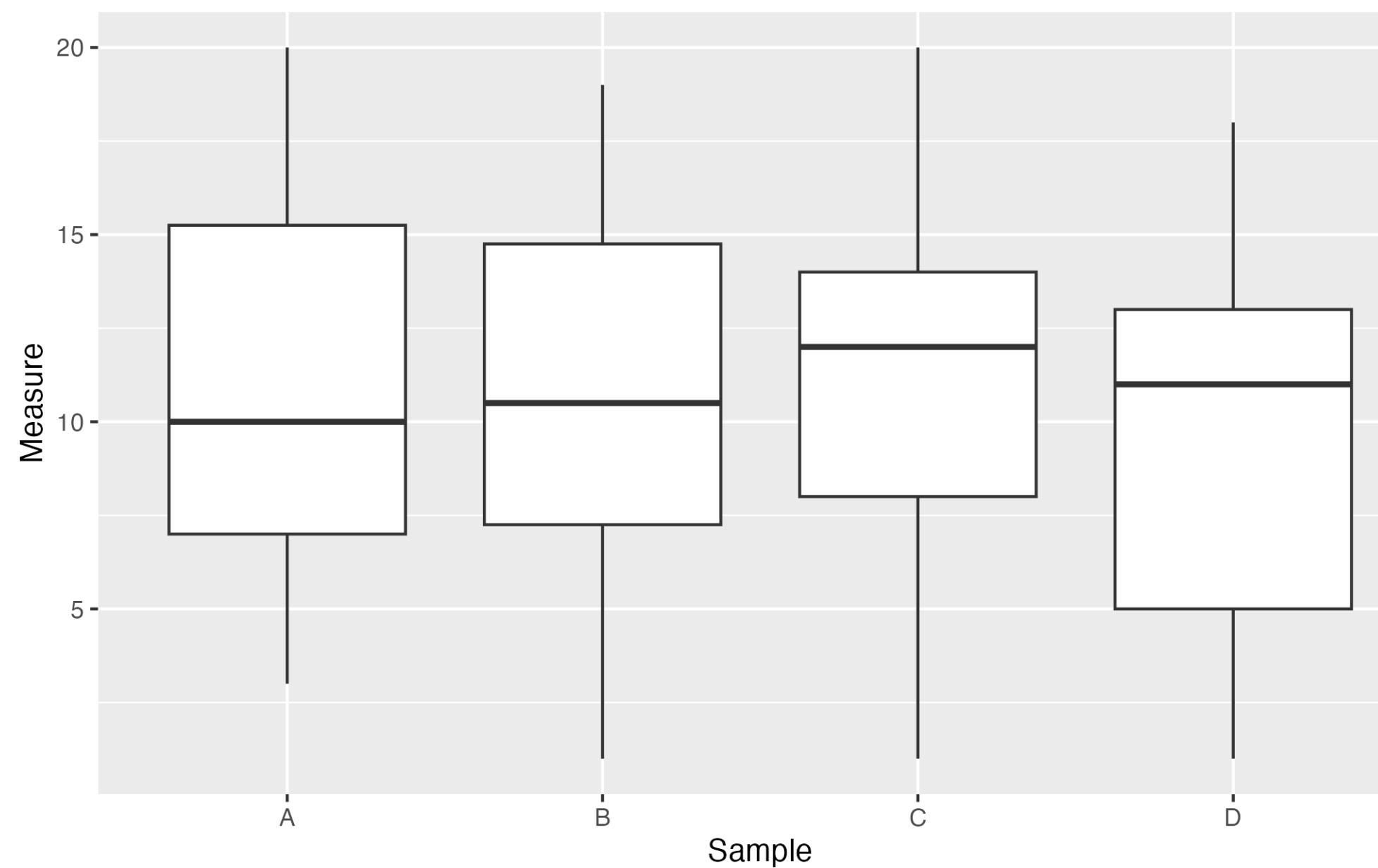
Integrates perfectly with tidy data.



Great documentation & community

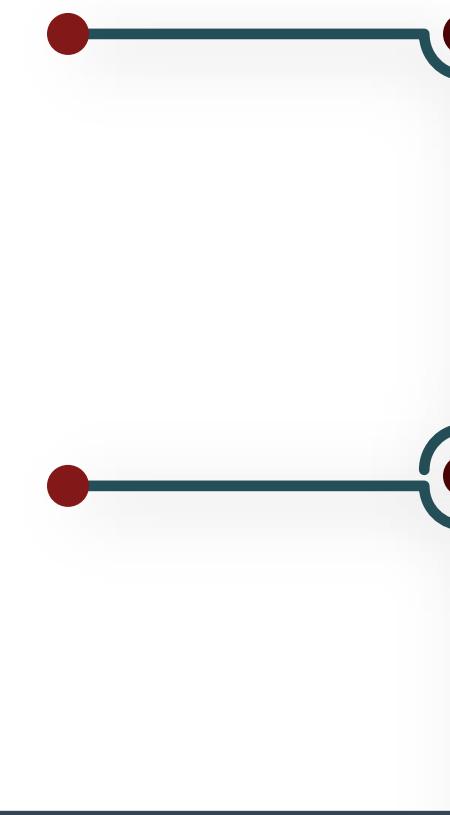


# GGPLOT2 ADDITIVE STRUCTURE



DATASET, SAMPLES  
& OBSERVATIONS

DEFINE PLOT TYPE



```
ggplot(df,  
       aes(x = Sample, y = Measure))  
  
ggplot(df,  
       aes(x = Sample, y = Measure)) +  
  geom_boxplot()
```

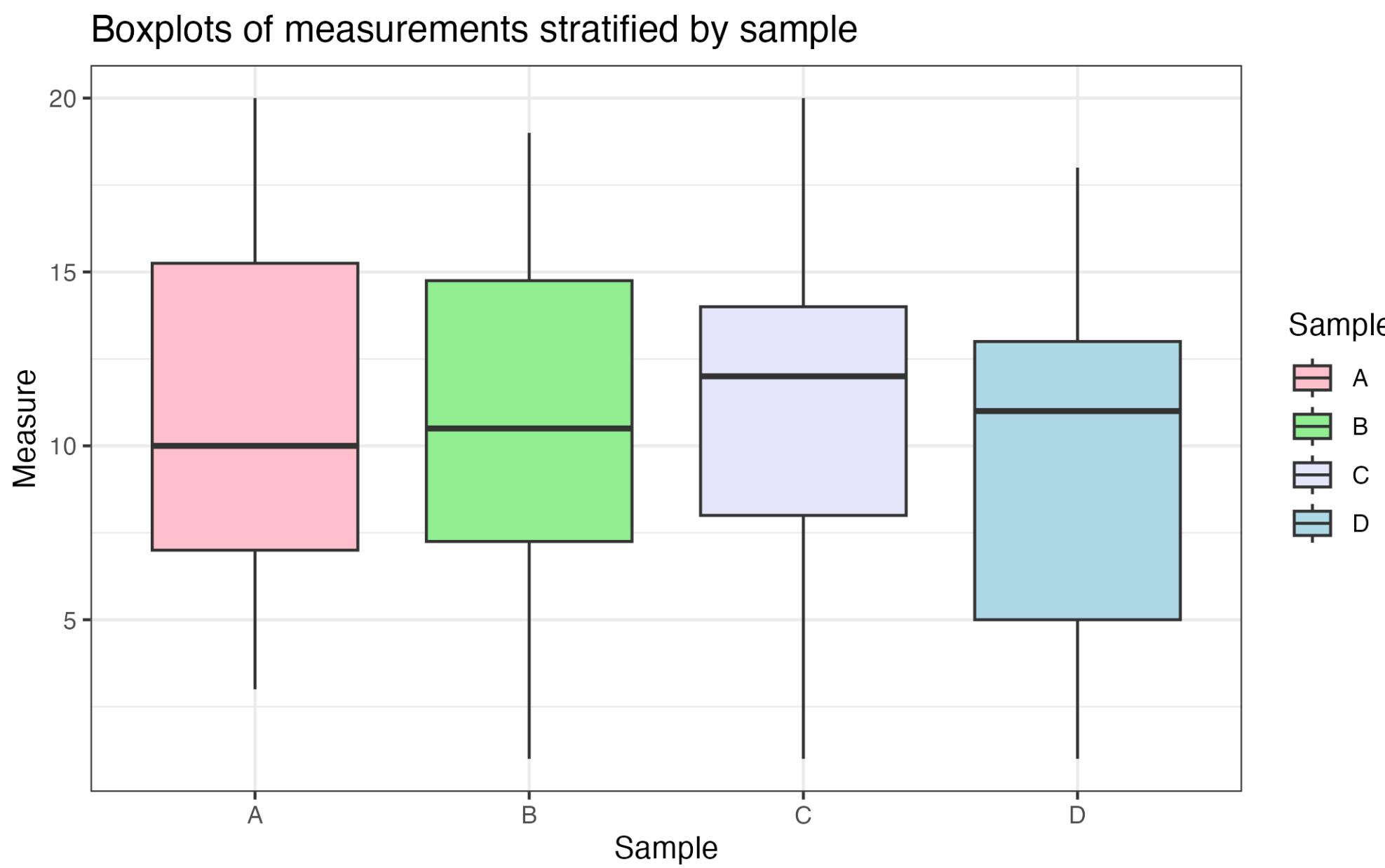
head(df)

Description: df [6 x 2]

	Sample	Measure
1	C	20
2	C	14
3	C	3
4	B	8
5	C	16
6	B	12

6 rows

# GGPLOT2 ADDITIVE STRUCTURE



Dataset, Samples & Observations



```
ggplot(df,
```

```
  aes(x = Sample, y = Measure))
```

Define Plot Type



```
ggplot(df,
```

```
  aes(x = Sample, y = Measure)) +  
  geom_boxplot()
```

Color by Group



```
ggplot(df,
```

```
  aes(x = Sample, y = Measure,  
      fill = Sample)) +  
  geom_boxplot()
```

Title and Legend



```
... +  
  labs(title = "Boxplots of  
measurements stratified by sample")
```

Custom Colors



```
... +  
  scale_fill_manual(values =  
c("pink", "lightgreen", "lavender",  
"lightblue"))
```

Background

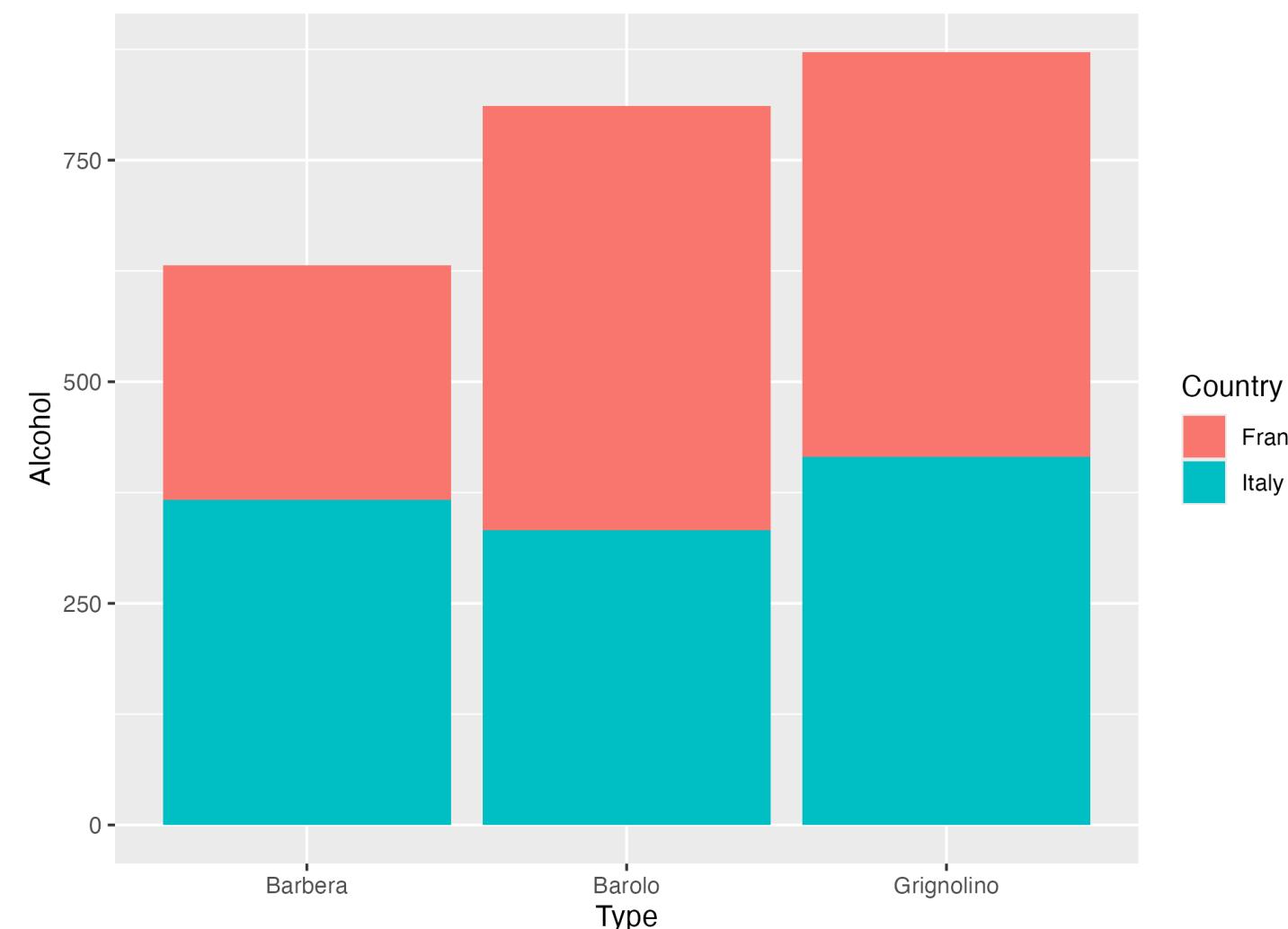


```
... +  
  theme_bw()
```

# GGPLOT BASIC STRUCTURE

Geoms inherit the parameters from the ggplot they are added to:

```
ggplot(wine,
       aes(x = Type,
           y = Alcohol,
           fill = Country)) +
  geom_col()
```



head(wine)

Description: df [6 × 5]

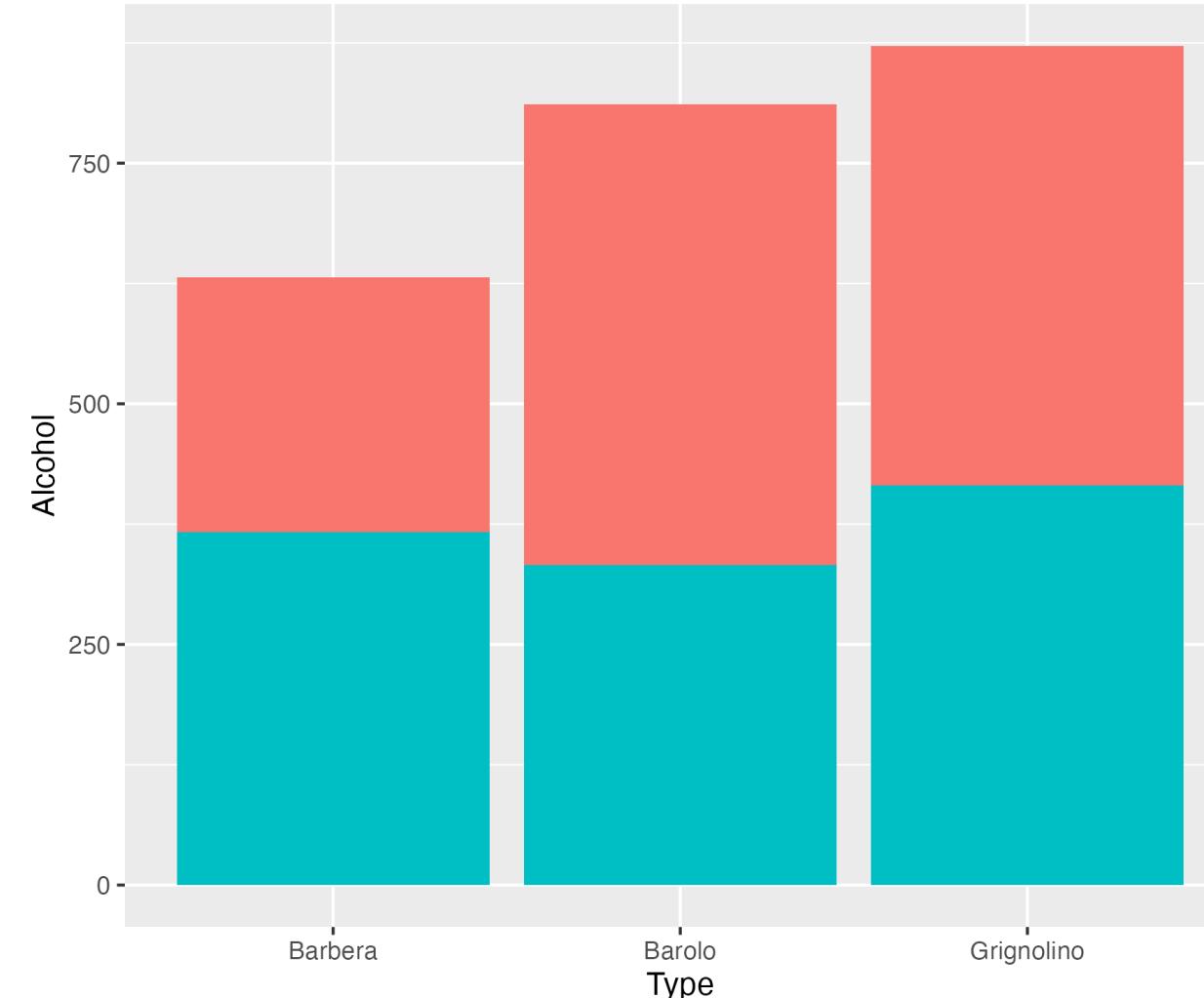
	Type	Alcohol	Country	Magnesium	Phenols
	<fctr>	<dbl>	<chr>	<int>	<dbl>
1	Barolo	14.23	France	127	2.80
2	Barolo	13.20	France	100	2.65
3	Barolo	13.16	France	101	2.80
4	Barolo	14.37	Italy	113	3.85
5	Barolo	13.24	France	118	2.80
6	Barolo	14.20	Italy	112	3.27

6 rows

# GGPLOT BASIC STRUCTURE

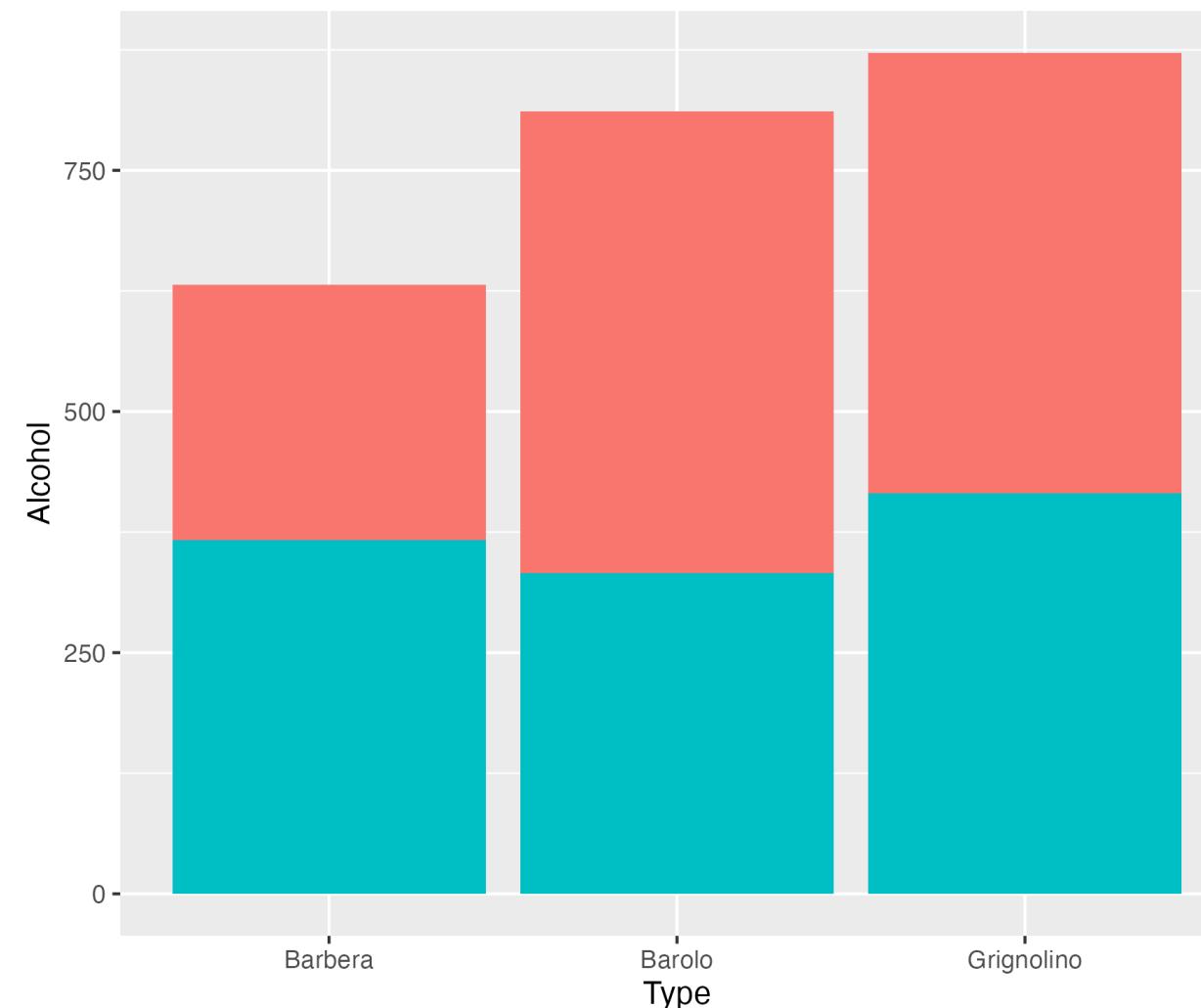
Geoms inherit the parameters from the ggplot they are added to:

```
ggplot(wine,
       aes(x = Type,
           y = Alcohol,
           fill = Country)) +
  geom_col()
```



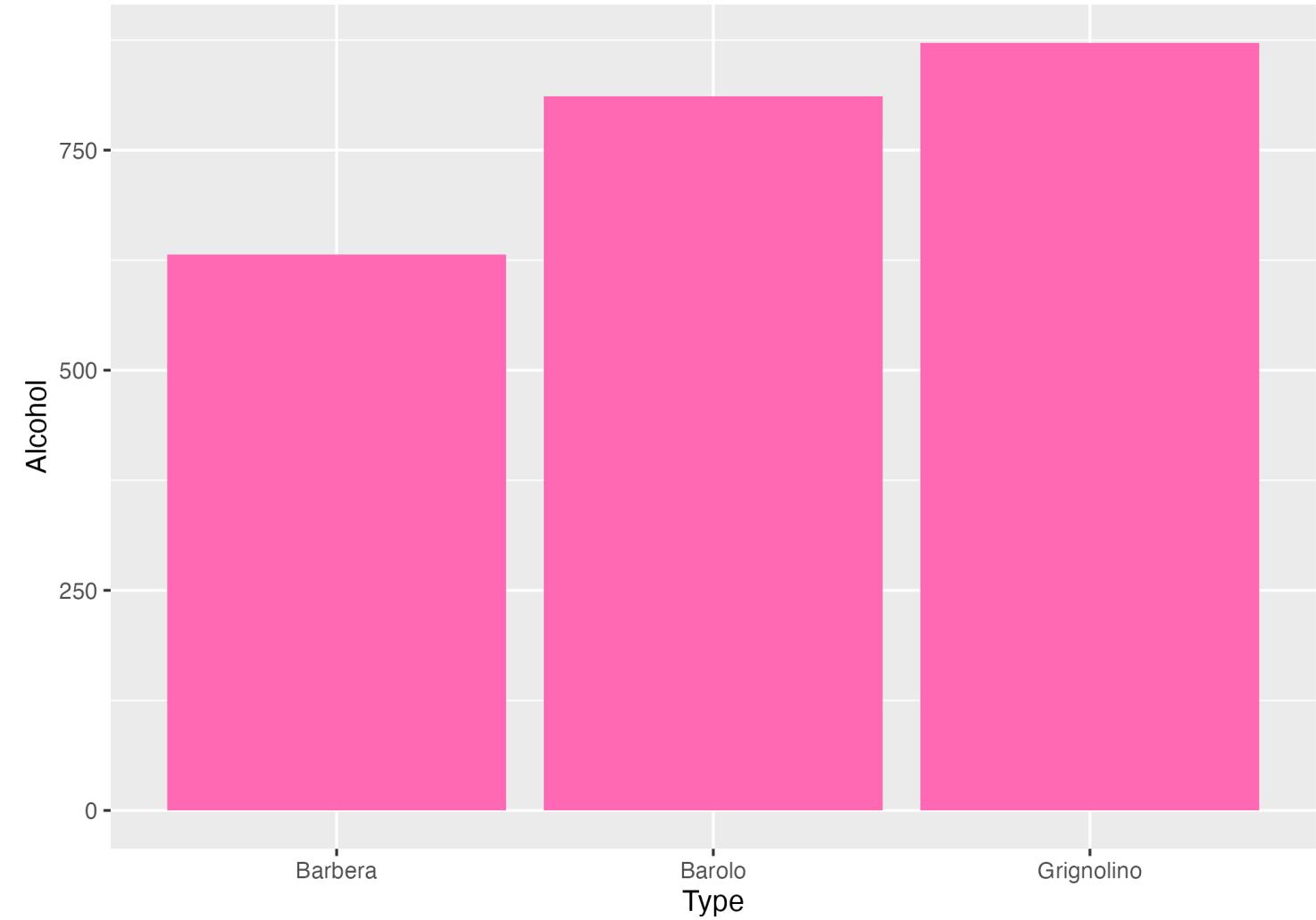
Alternatively, you can specify additional parameters directly in the geom:

```
ggplot(wine,
       aes(x = Type,
           y = Alcohol)) +
  geom_col(aes(fill = Country))
```



Things outside the aes are applied to everything!

```
ggplot(wine,
       aes(x = Type,
           y = Alcohol)) +
  geom_col(fill = "hotpink")
```



— FROM EXCEL TO R

# LIVE CODING 3 – GGPLOT 2



# GGPLOT CHEAT SHEET

## Define Plot:

```
ggplot(data = my.data,  
       aes(x = x.var,  
            y = y.var))
```

## Add Plot Type:

```
... + geom_point() # scatter plot  
... + geom_line()  
... + geom_boxplot()
```

```
... + geom_col()  
... + geom_density()  
... + geom_histogram()
```

## One Color:

```
ggplot(..., aes(...),  
       color = "green")
```

## Color Fill by Group:

```
ggplot(..., aes(...,  
               fill = z.var))
```

## Custom Colors:

```
... + scale_*_manual(values = c())  
ex: scale_color_manual(values = c("blue", "pink"))
```

## More Colors:

```
... + scale_fill_grey(start = 0.2, end = 0.8)  
... + scale_fill_gradient(low="white", high="red")
```

## Labels:

```
... + labs(title = "Title",  
          x = "X label",  
          y = "Y label")
```

**Theme:**

```
... + theme_bw()  
... + theme_minimal()  
... + theme_dark()  
... + theme_classic()
```

## Text:

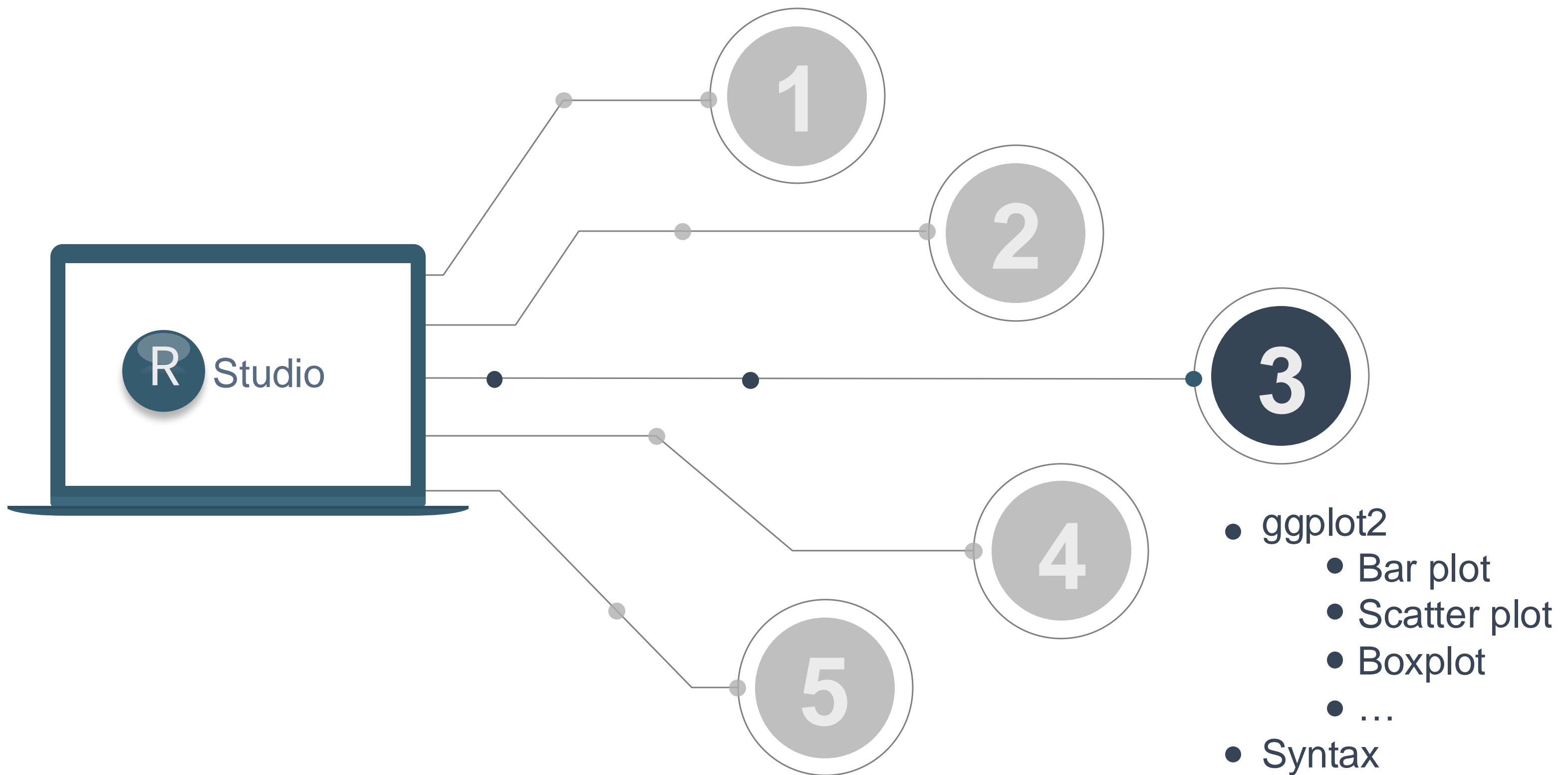
```
... + theme(legend.position = *)  
* = "none", "top", "bottom", "left", "right"
```

GET  
STARTED

COLORS

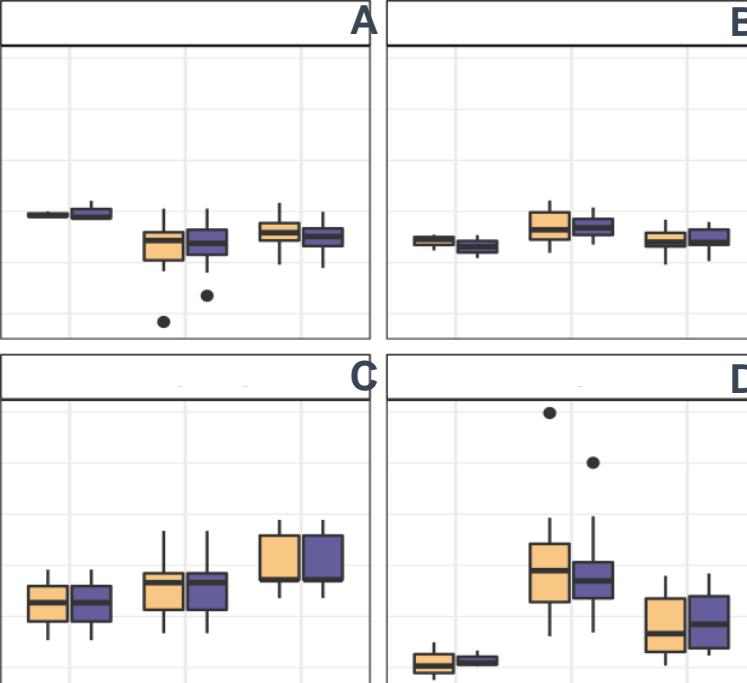
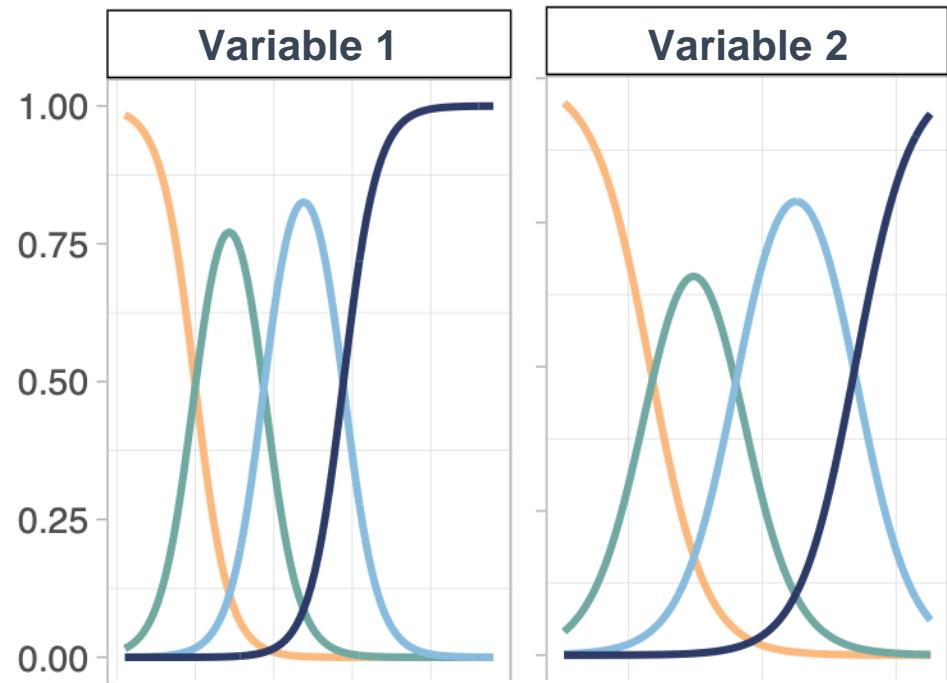
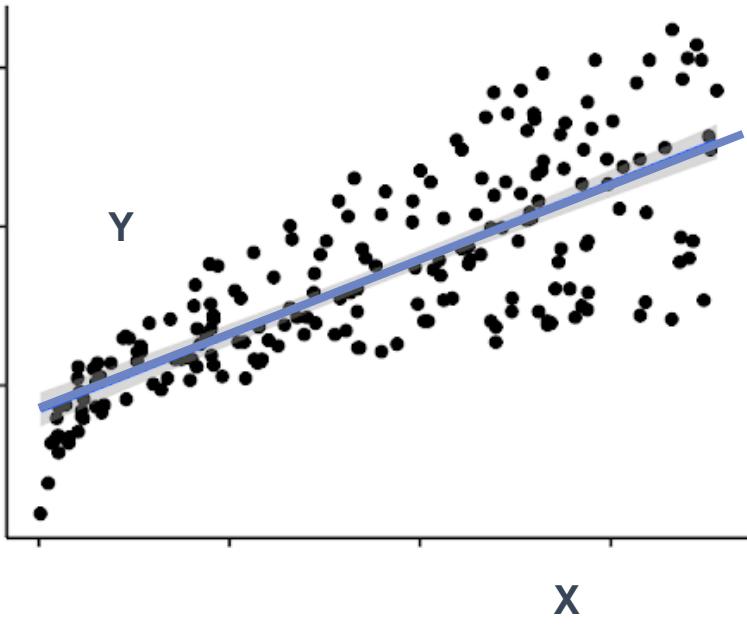
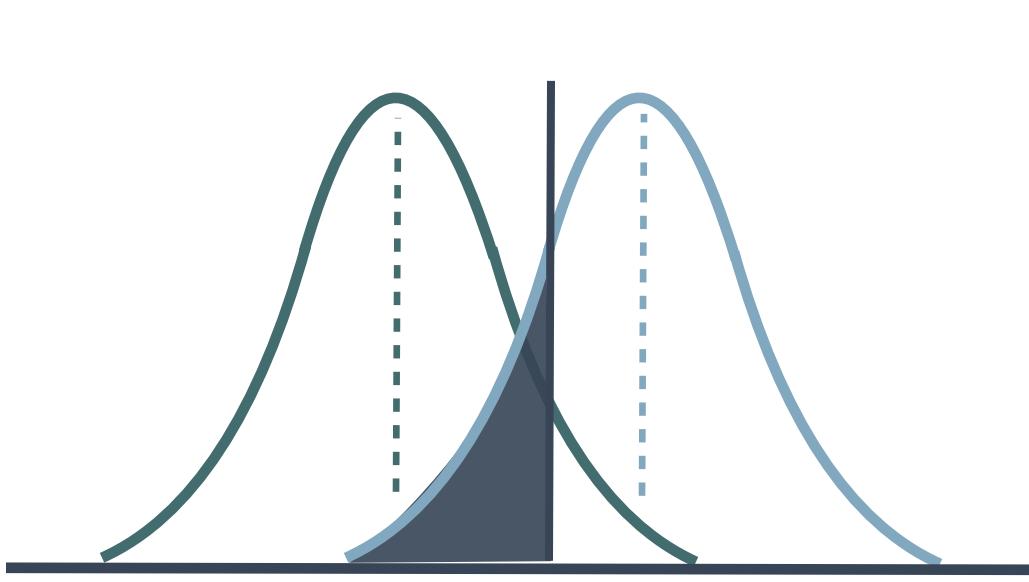
COLOR SCALES  
& THEMES

TEXT



## — GG PLOT2 EXERCISE 3

# R - A STATISTICAL SCRIPTING LANGUAGE



## MODEL FUNCTIONS

`lm()`, `glm()`,  
`lmer()`, `glmer()`,  
`nls()`, ...

## EMMEANS PACKAGE

`emmeans()`,  
`pairs()`, `cld()`

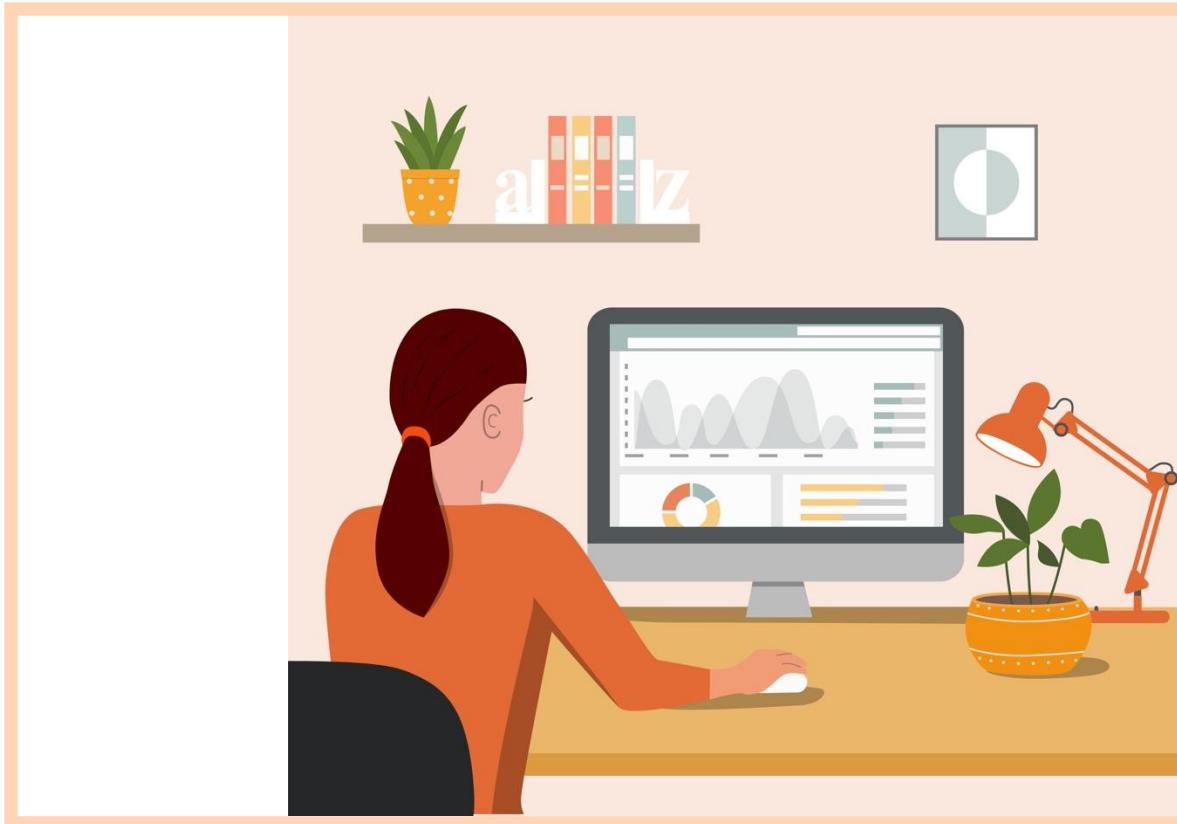
## APPLY TO MODEL

`summary()`, `anova()`,  
`confint()`, `predict()`,  
`drop1()`, `update()`,  
`step()`, ...

## MORE FUNCTIONS

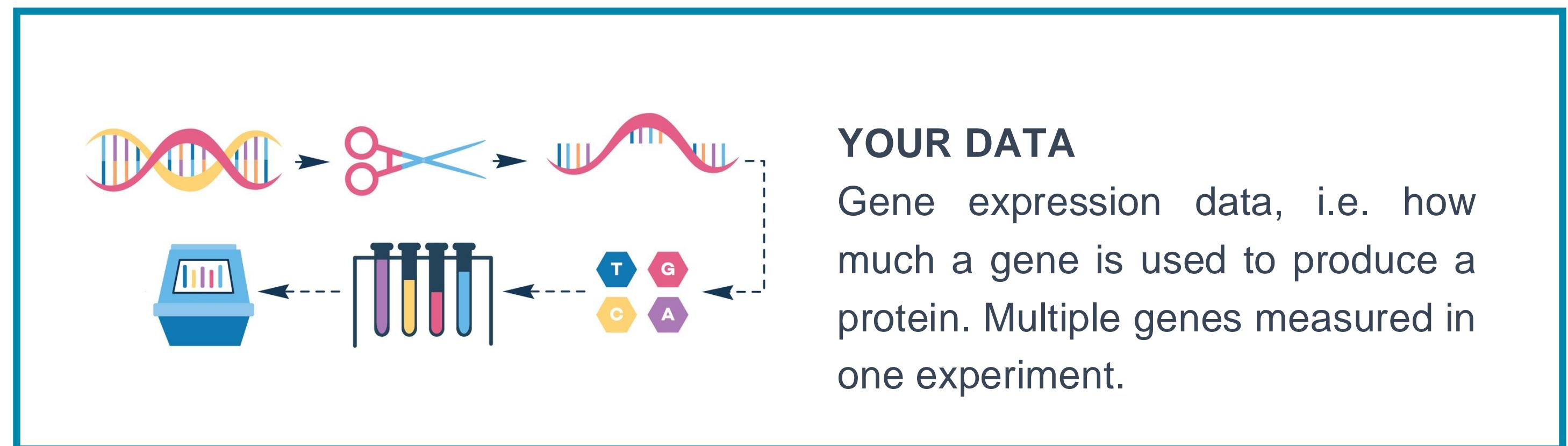
`t.test()`, `cor()`,  
`cor.test()`, `aov()`,  
`quantile()`,  
`p.adjust()`,  
`rank()`, ...

# Let's use R in a statistical analysis



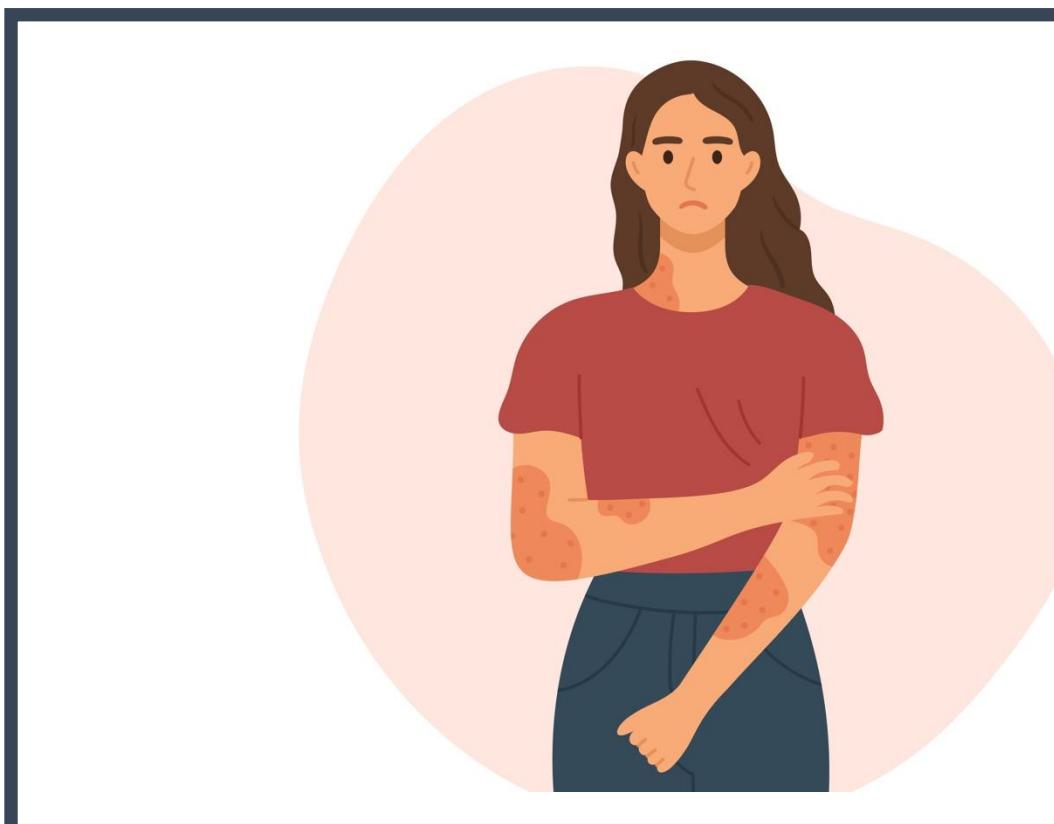
**YOU**

The researcher with R skills!



**YOUR DATA**

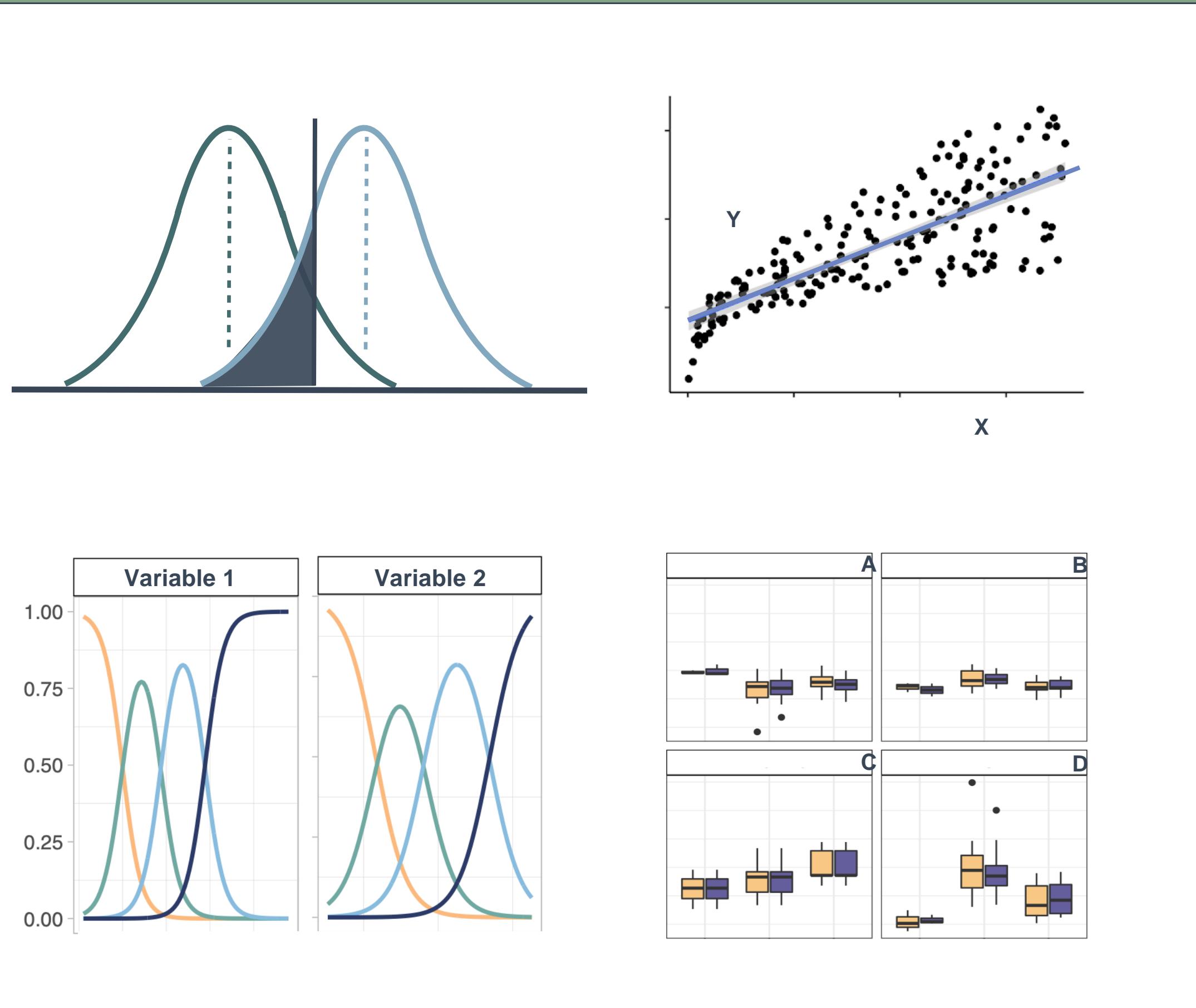
Gene expression data, i.e. how much a gene is used to produce a protein. Multiple genes measured in one experiment.



**YOUR DISEASE OF INTEREST**

Psoriasis, an immune-mediated skin disorder.

# R - A STATISTICAL SCRIPTING LANGUAGE

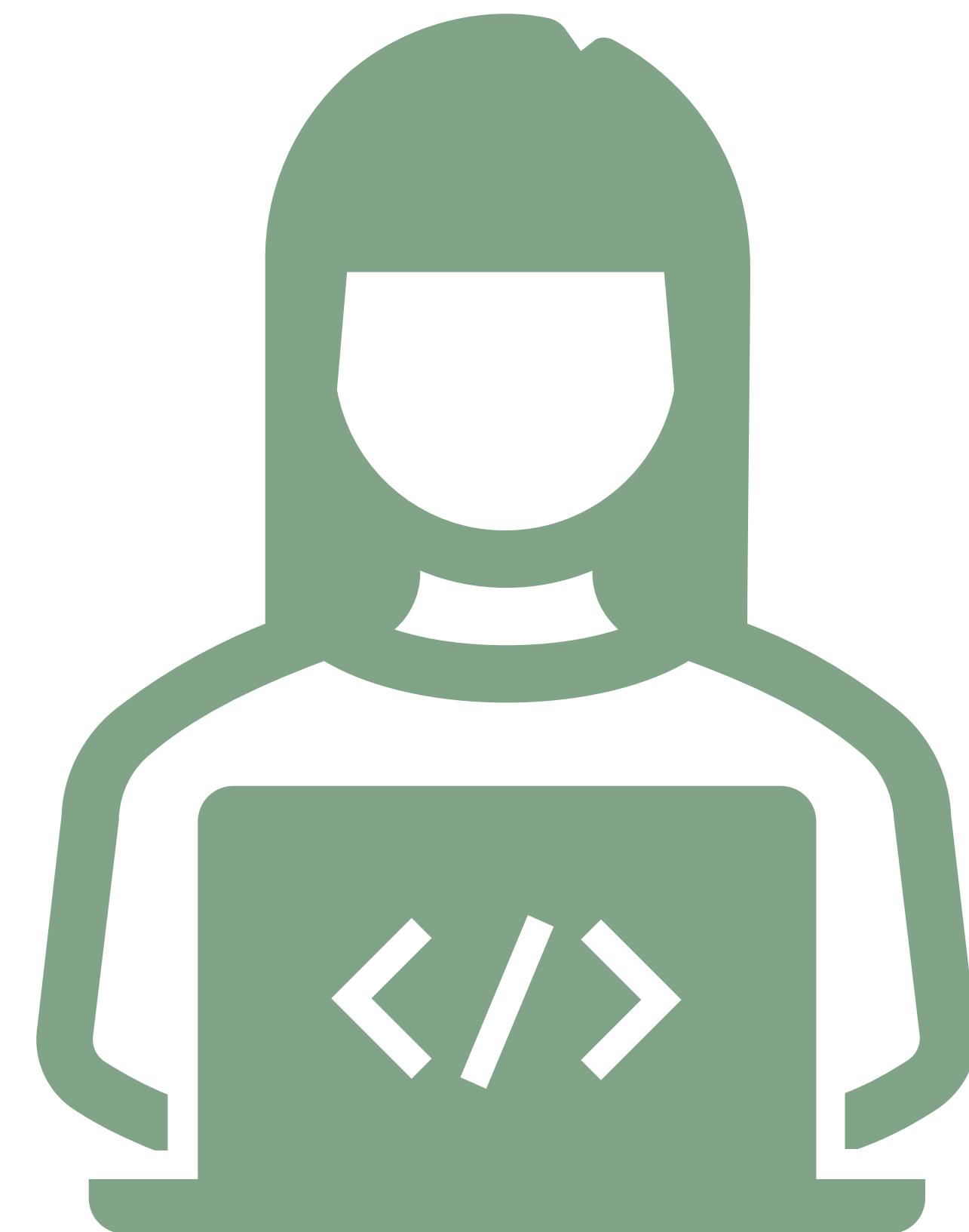


## During this session:

- *Cooperatively* discuss and share ideas about the data
- Apply steps of basic statistical analysis for hypothesis testing consistent with the given data
- Suggest conclusions based on your analysis, regarding the association between psoriasis and gene expression levels

— FROM EXCEL TO R

# LIVE CODING 4 – APPLIED STATS



# STATS CHEAT SHEET

## Import Data:

```
read_excel("my.data.xlsx")
```

## Overview of Data:

```
summary(my.data)  
nrow(my.data)
```

```
length(my.data)  
names(my.data)
```

## Linear:

```
lm(y~x, data=my.data)  
confint(model)
```

## Logistic:

```
glm(y~x,  
data=my.data)
```

## Linear Mixed:

```
lmer(y~x + (1|z),  
data=my.data)
```

## Check Model:

```
summary(model)  
par(mfrow=c(2,2))  
plot(model)
```

## ANOVA:

```
anova(model2, model1)
```

## F-Test:

```
drop1(model, test="F")
```

## Emmeans:

```
emmeans(model, ~x)  
pairs(emmeans(model, ~x))
```

## Check Type:

```
table(my.data$x)  
is.numeric(my.data$x)  
is.factor(my.data$x)
```

## Change Type:

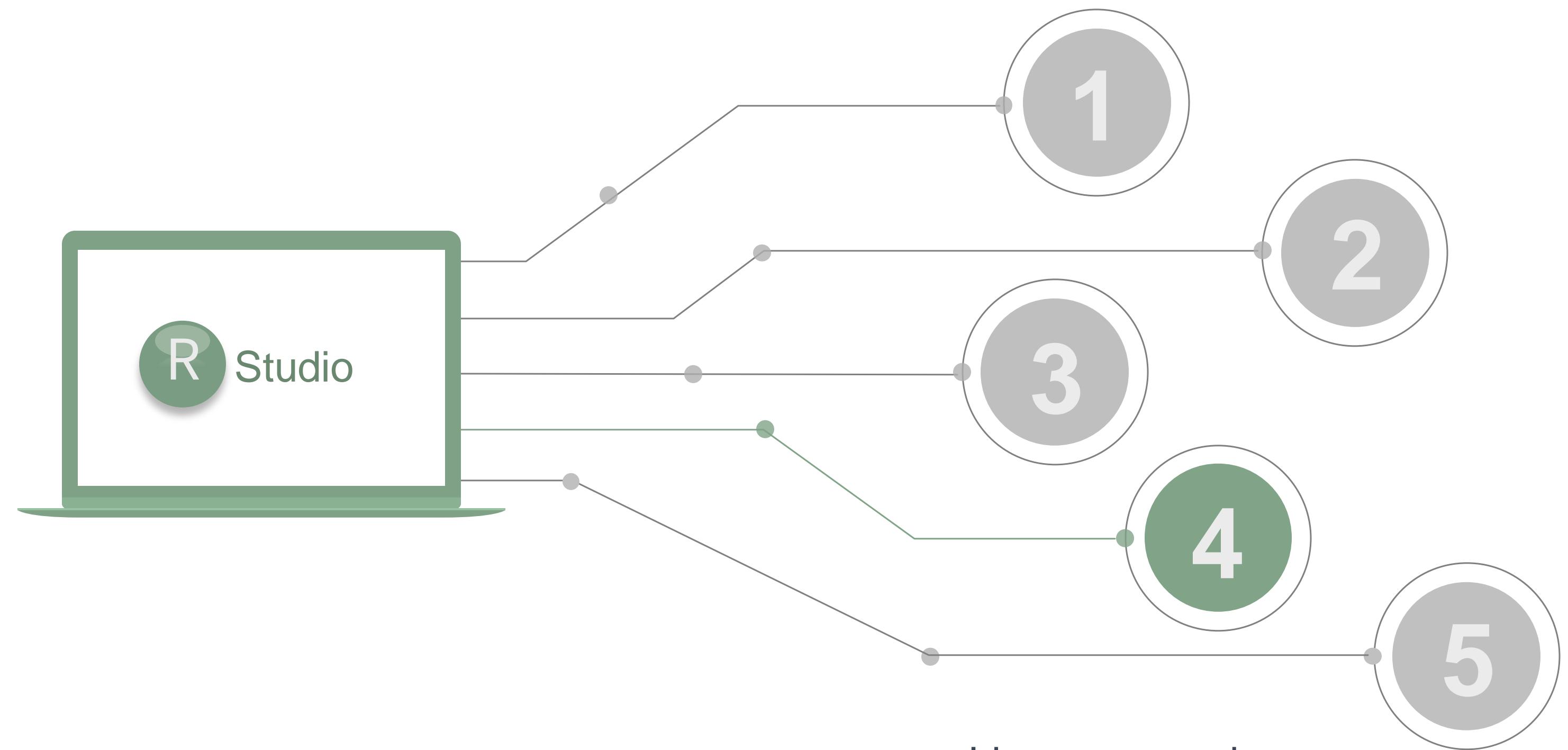
```
my.data <- mutate(my.data, x = factor(x))  
my.data$z <- as.numeric(my.data$z)
```

GET  
STARTED

REGRESSION  
MODELS

TESTS/COMPARISONS

VARIABLES

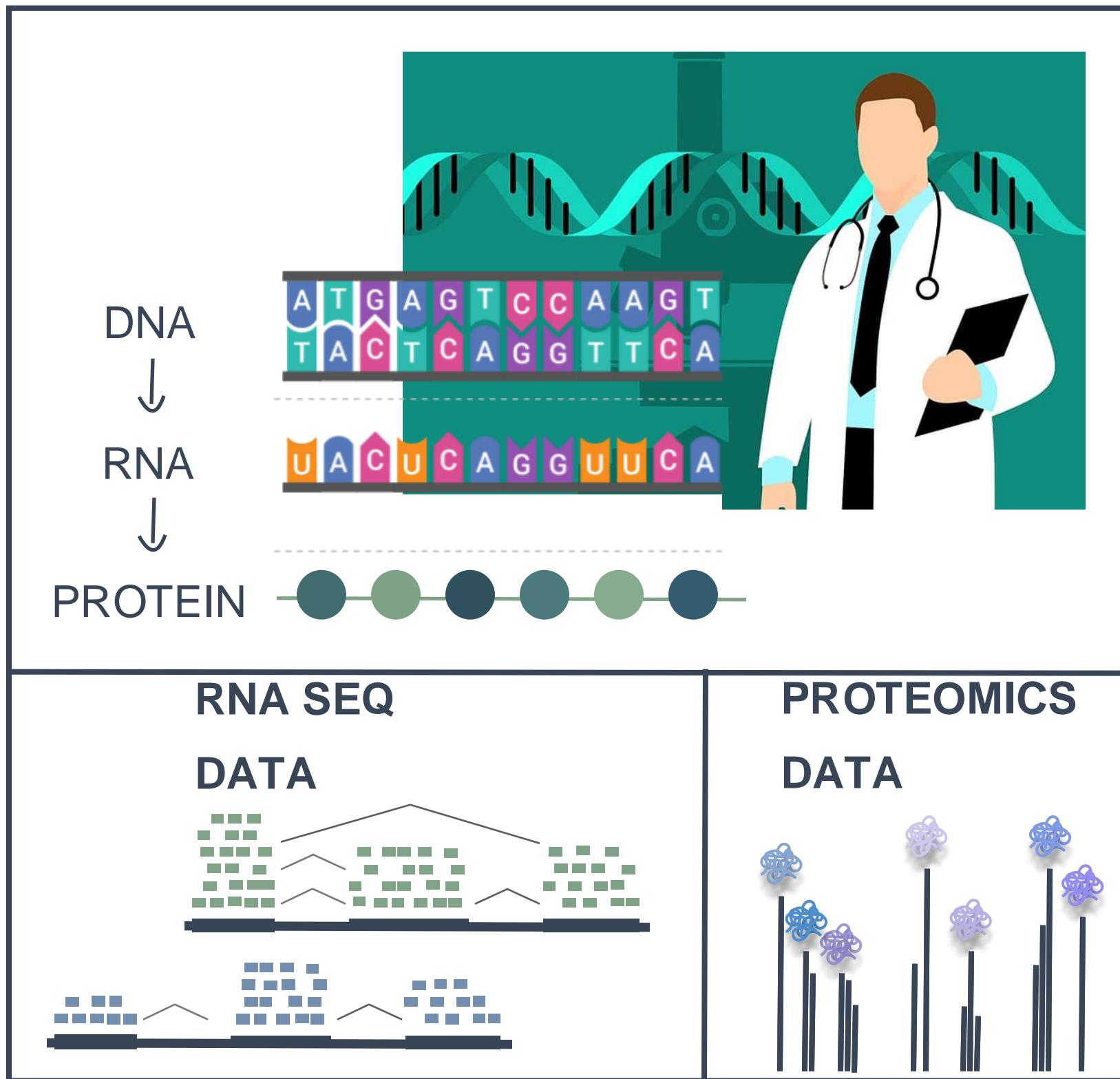


- Linear regression
- Summary Statistics
- ANOVA
- Logistic regression
- Clustering
- Correlation

— Statistics in R  
**EXERCISE 4**

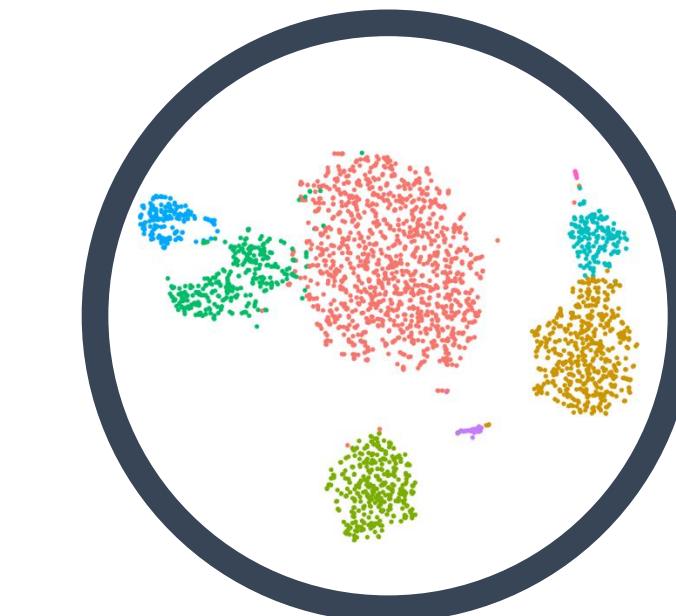
# BIOINFORMATICS IN R

## HIGH THROUGHPUT DATA



## BIOINFORMATIC ANALYSIS

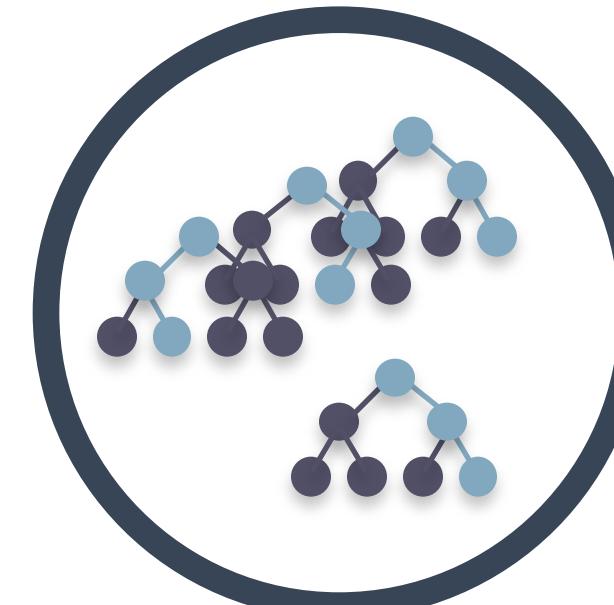
### DIMENSIONALITY REDUCTION



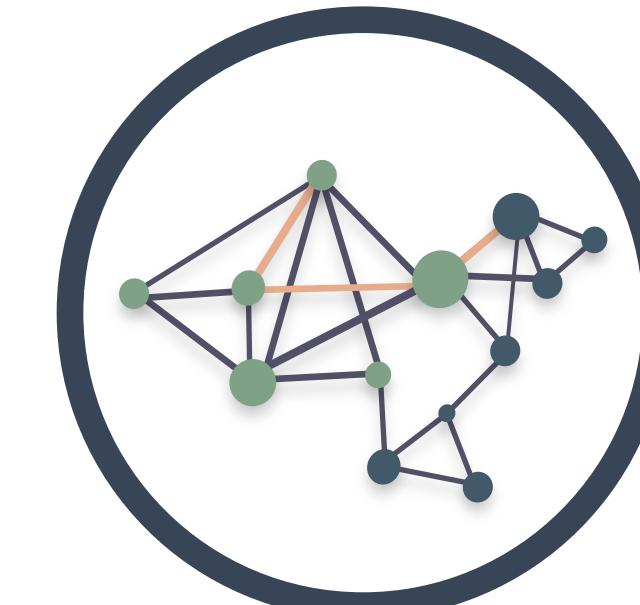
### CLUSTERING

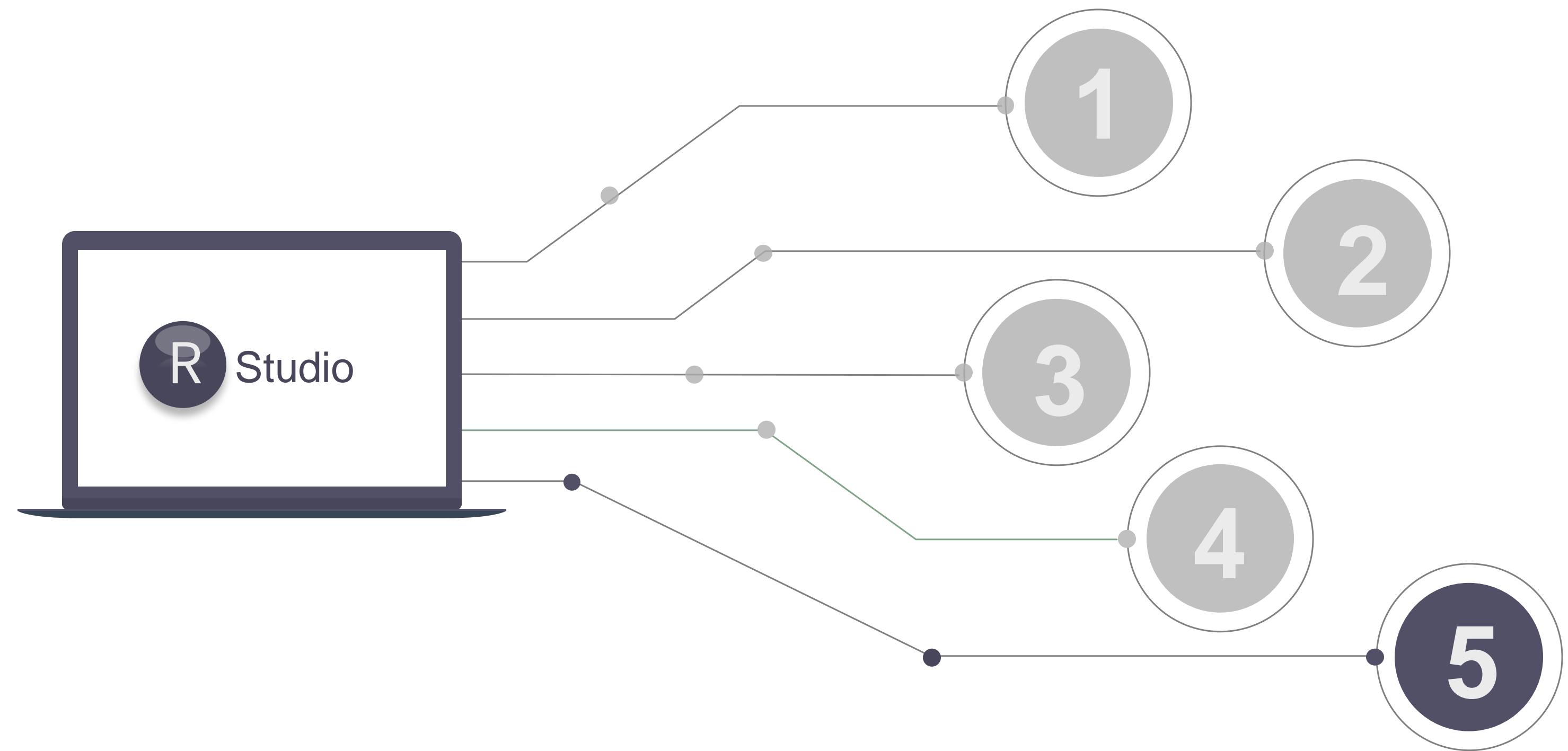


### MACHINE LEARNING



### NETWORK ANALYSIS





- Tidyverse
- ggplot
- Stats
- Quarto

— Statistics in R  
**EXERCISE 5**

# THE TOP OF THE R ICEBERG



## STATISTICAL ANALYSIS

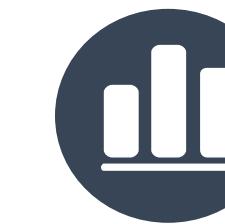
Statistical models (linear, generalized, mixed, ...)

Statistical tests (t-test, chisq, anova, ...)

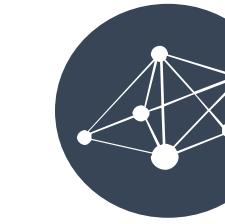
Survival analysis (Cox, Kaplan meier)



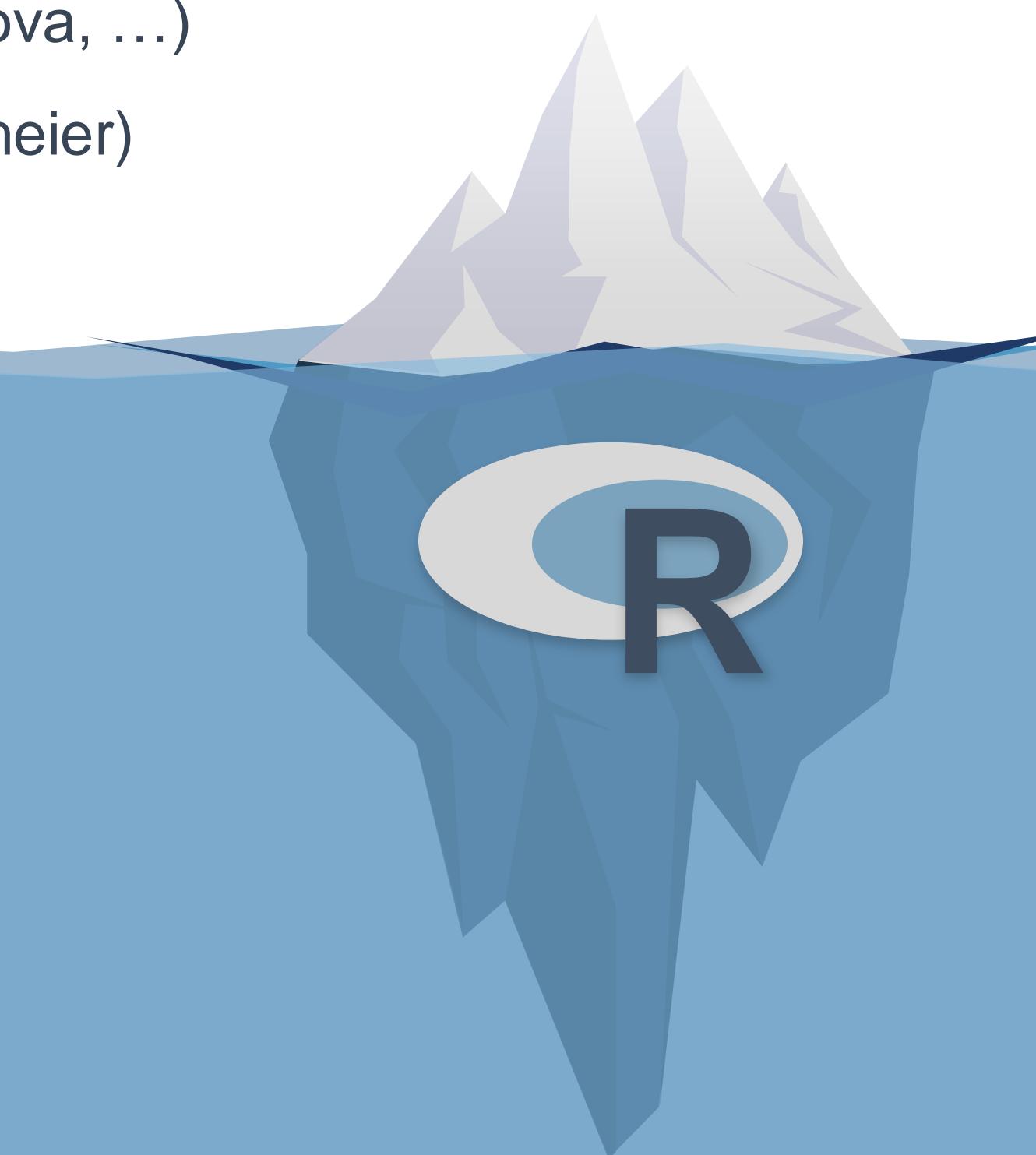
## DATA MANGEMENT



## EASY PLOTTING



## BIOINFORMATIC ANALYSIS



— FROM EXCEL TO R

## WANT MO-R-E?



The Section for Biostatistics offers a number statistics-oriented R courses:

### Spring

[Basic Statistics for Health Researchers \(Danish course\)](#)

ECTS: 9,0

[Epidemiological methods in medical research](#)

ECTS: 7

[Advanced topics in health research B](#)

ECTS: 2,8

[Statistical methods in bioinformatics](#)

ECTS: 3,5

[Statistical analysis of survival data](#)

ECTS: 4,9

<https://publichealth.ku.dk/about-the-department/biostat/>

[Programming and statistical modelling in R](#)

ECTS: 1,6

[Bayesian methods in biomedical research](#)

ECTS: 2,4

[Psychometric validation of patient reported outcome measures](#)

ECTS: 2,5

[Introduction to validation of patient reported outcome measures](#)

[Causal inference I](#)

ECTS: 2,5

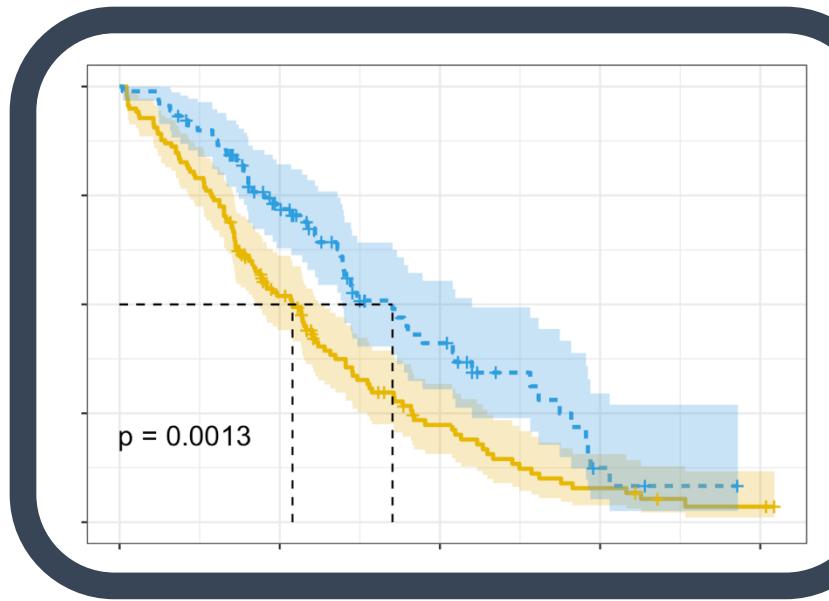
[Use of the statistical software R](#)

ECTS: 2,1

\* These are screenshots. Go to the website and scroll down to 'Teaching'

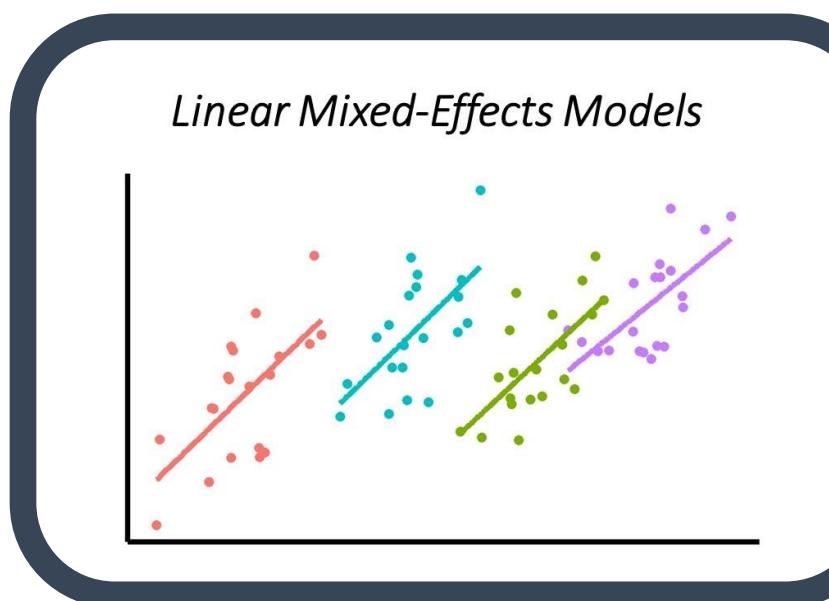


# — TEASER STATISTICS in R



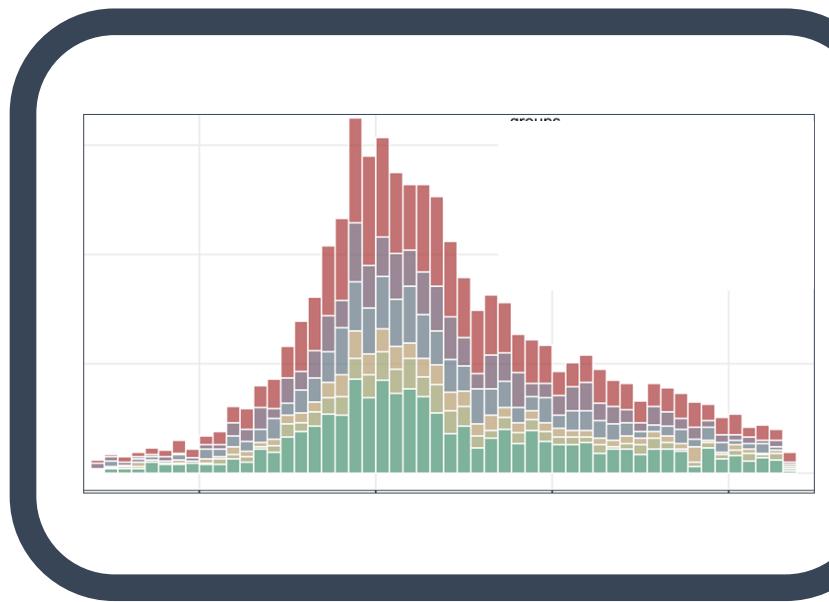
## Survival Analysis

**survival:** <https://rviews.rstudio.com/2017/09/25/survival-analysis-with-r/>  
**survminer:** <https://cran.r-project.org/web/packages/survminer/survminer.pdf>  
(<https://rpkgs.datanovia.com/survminer/>)



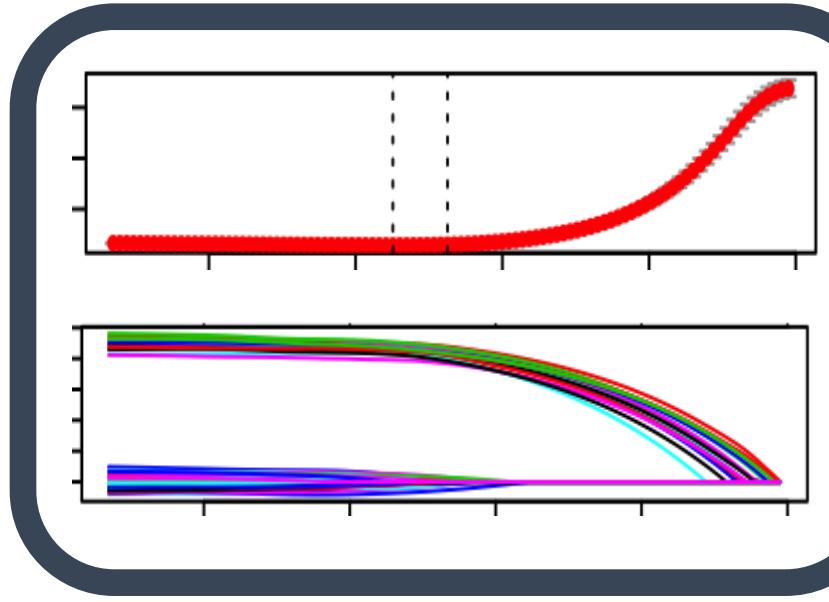
## Mixed-Effects Models

**lme4:** <https://cran.r-project.org/web/packages/lme4/vignettes/lmer.pdf>  
<https://cran.microsoft.com/snapshot/2017-08-01/web/packages/sjPlot/vignettes/sjplmer.html>  
**glmmTMB:** <https://cran.r-project.org/web/packages/glmmTMB/index.html>



## Epidemiological Analysis

**Epi:** <https://cran.r-project.org/web/packages/Epi/index.html>  
**pubh:** <https://rviews.rstudio.com/2020/03/05/covid-19-epidemiology-with-r/>  
[https://cran.r-project.org/web/packages/incidence/vignettes/customize\\_plot.html](https://cran.r-project.org/web/packages/incidence/vignettes/customize_plot.html)  
<https://rviews.rstudio.com/2020/03/05/covid-19-epidemiology-with-r/>



## Elastic-Net Regression

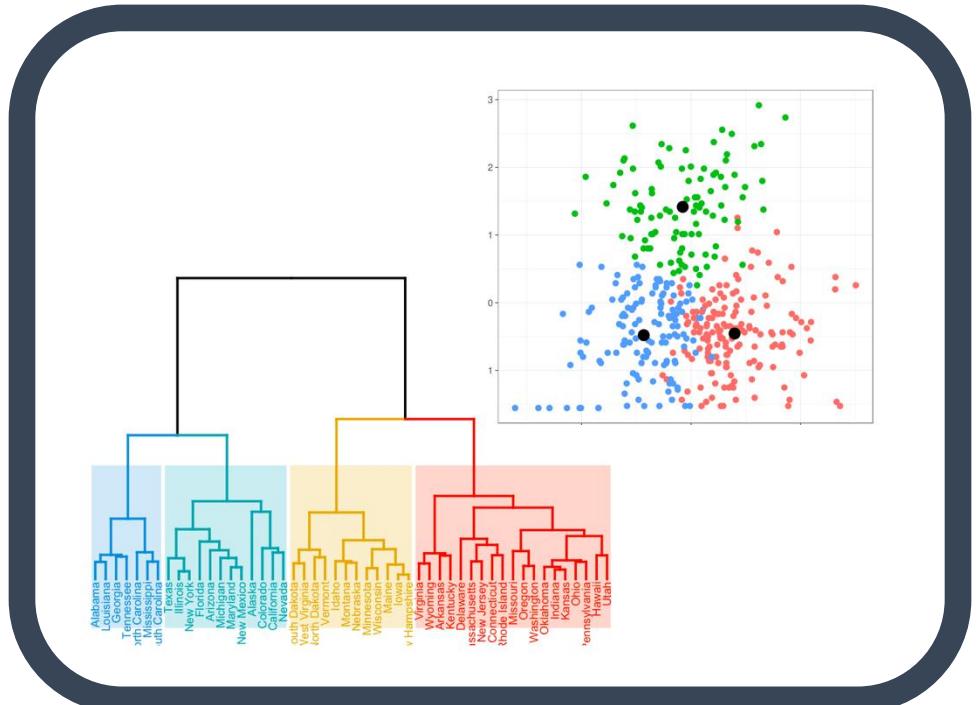
**(R)**  
**glmnet:** <https://cran.r-project.org/web/packages/glmnet/glmnet.pdf>  
**elasticnet:** <https://cran.r-project.org/web/packages/elasticnet/elasticnet.pdf>  
<https://www.datacamp.com/community/tutorials/tutorial-ridge-lasso-elastic-net>

## TEASER

# Machine Learning

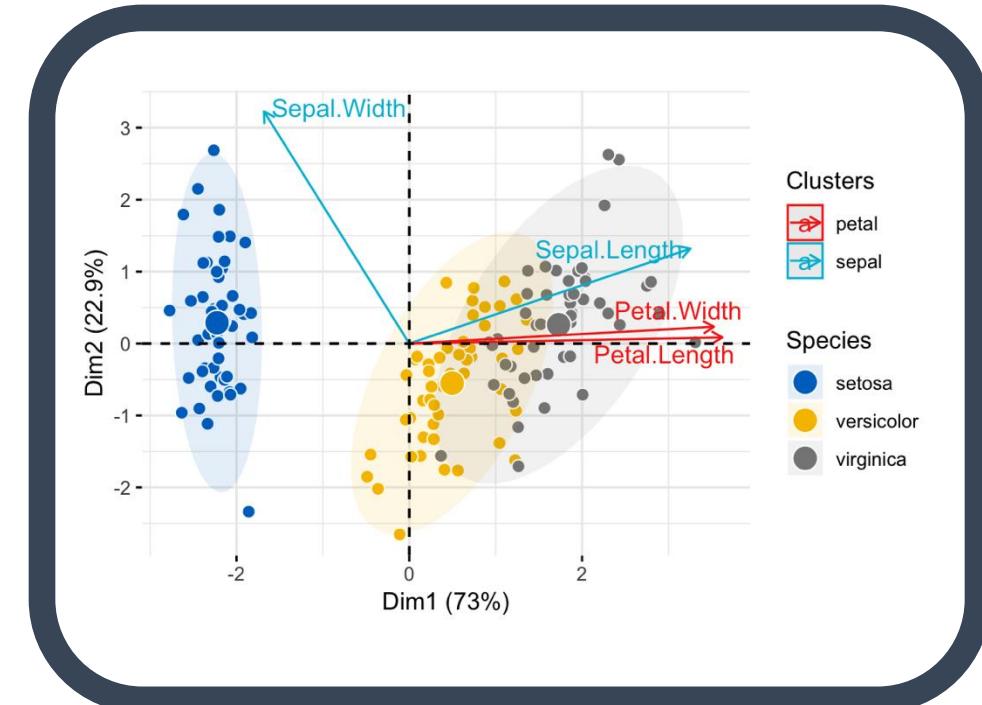
<https://lgatto.github.io/IntroMachineLearningWithR/an-introduction-to-machine-learning-with-r.html>

## Clustering



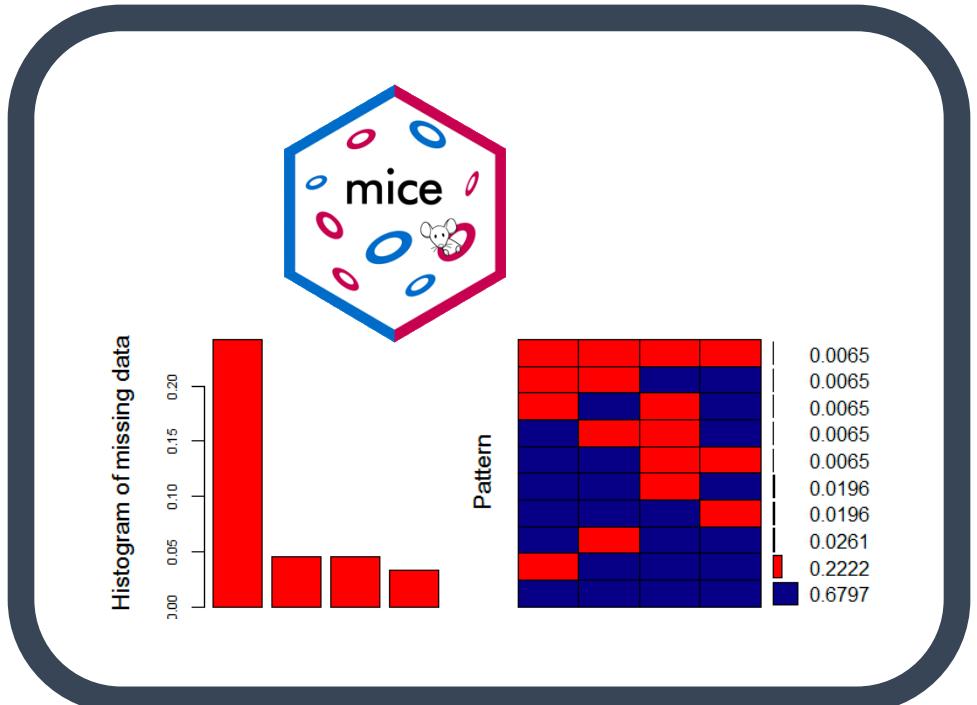
<https://statsandr.com/blog/clustering-analysis-k-means-and-hierarchical-clustering-by-hand-and-in-r/>

## Feature Selection: PCA



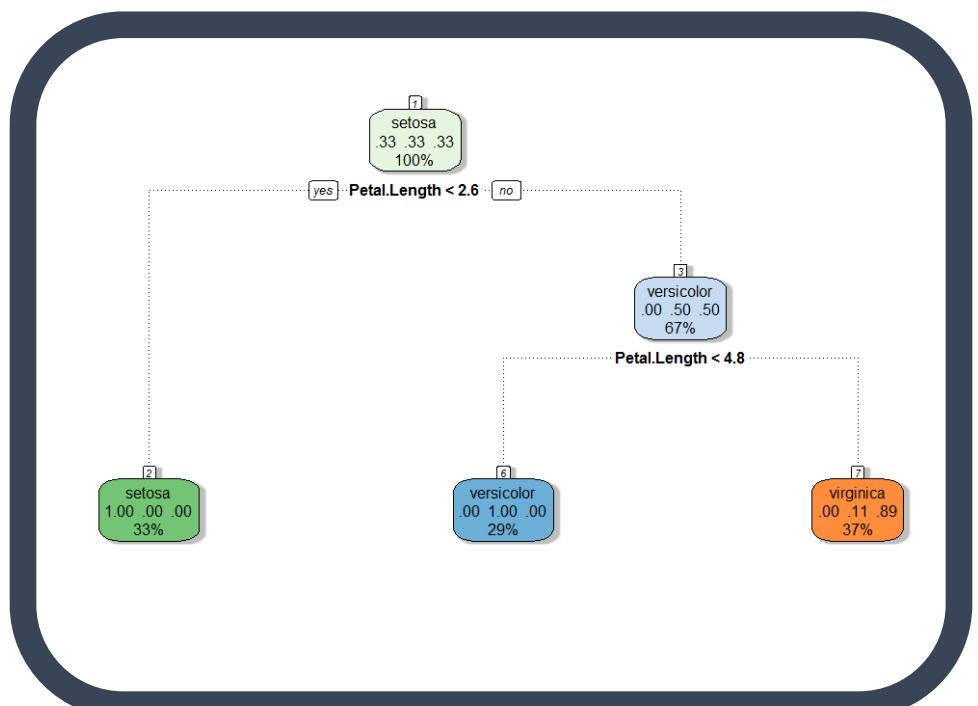
<https://bioconductor.org/packages/release/bioc/vignettes/PCAtools/inst/doc/PCAtools.html>

## Missing Data



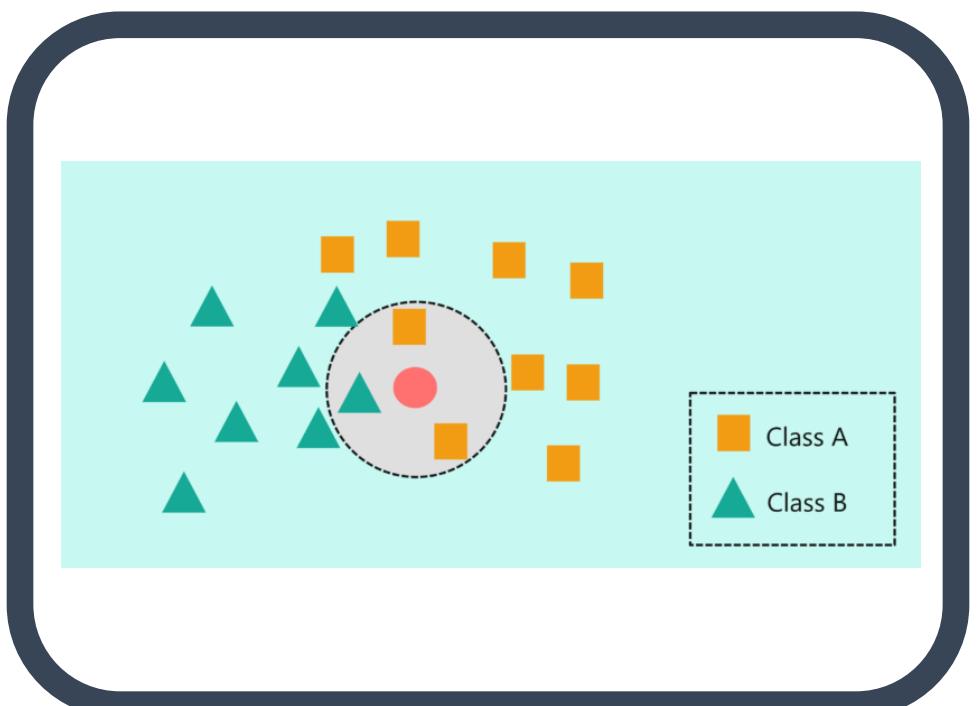
<https://amices.org/mice/>  
<https://datascienceplus.com/imputing-missing-data-with-r-mice-package/>

## Random Forest



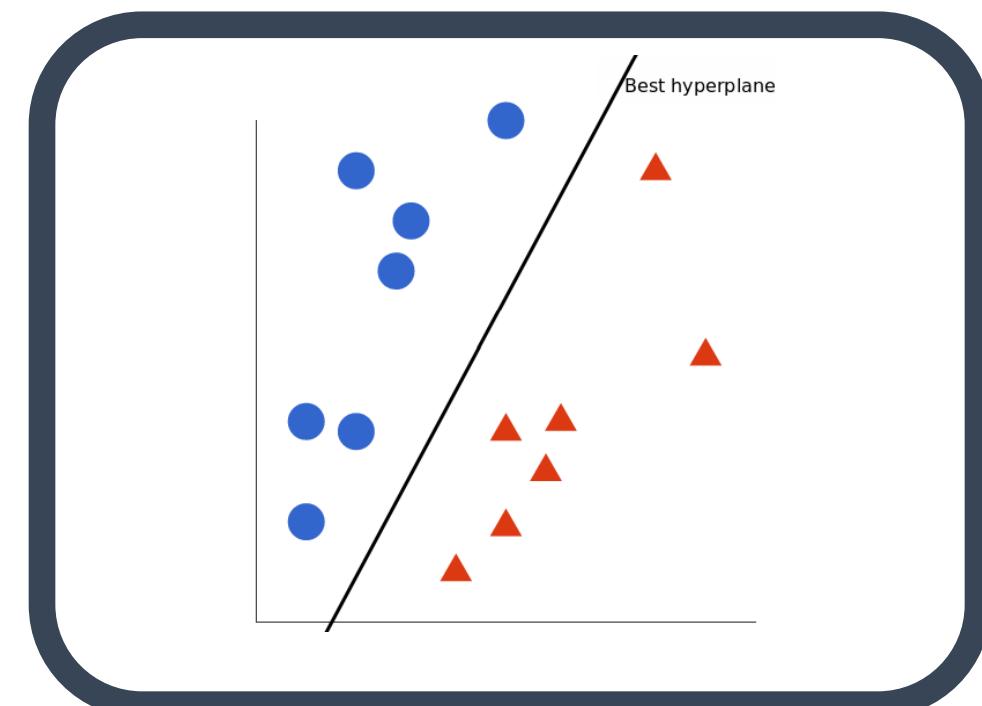
<https://www.blopig.com/blog/2017/04/a-very-basic-introduction-to-random-forests-using-r/>

## kNN



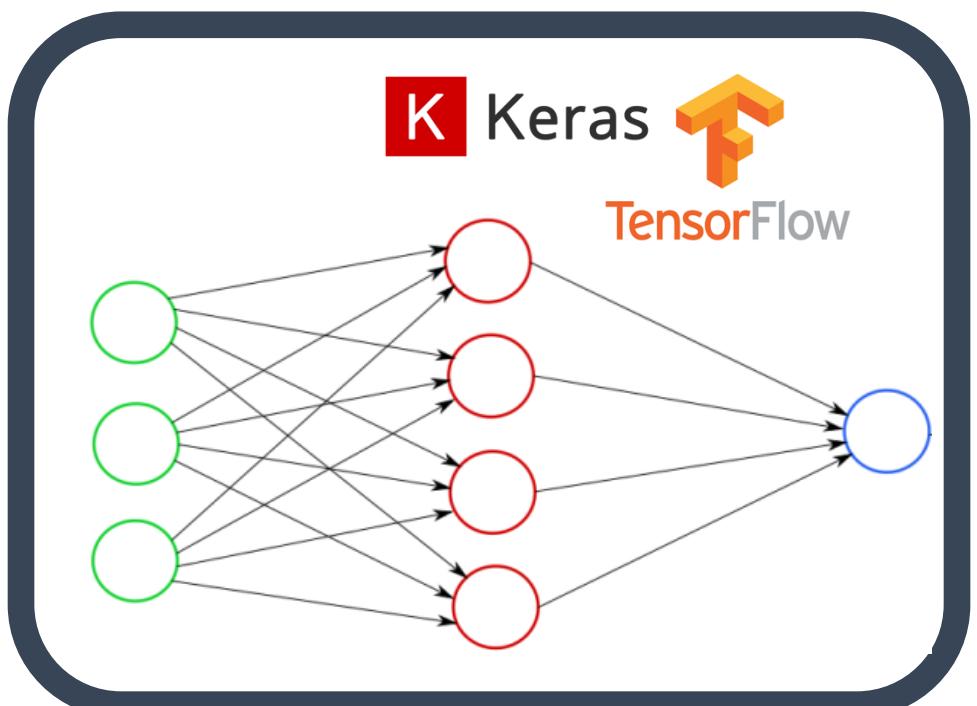
<https://www.edureka.co/blog/knn-algorithm-in-r/>

## SVM



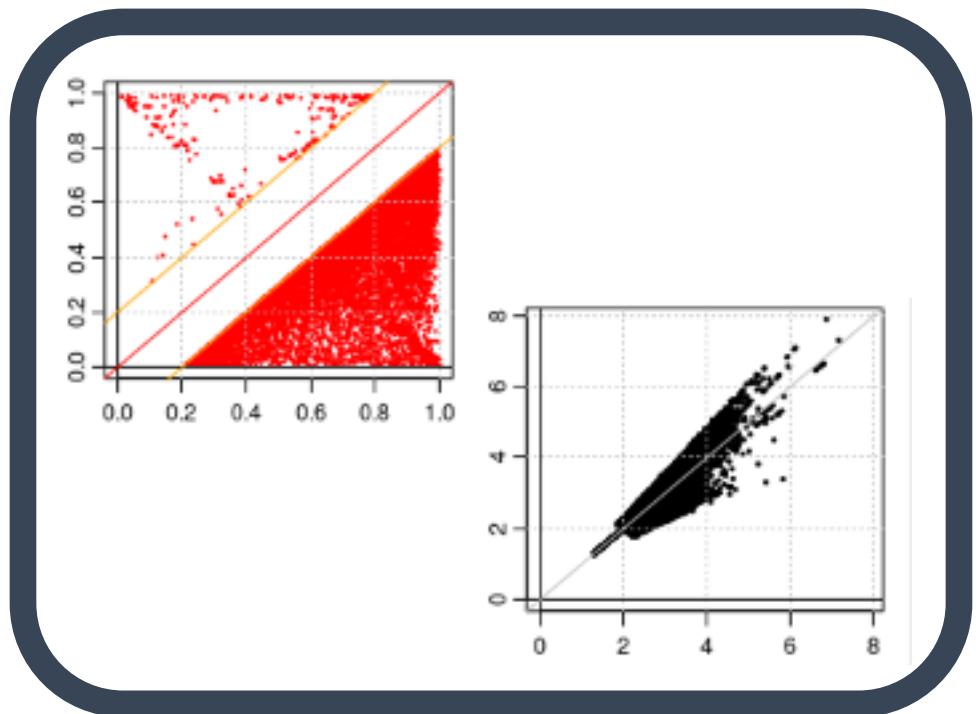
<https://cran.r-project.org/web/packages/e1071/vignettes/svmdoc.pdf>

## Neural Networks



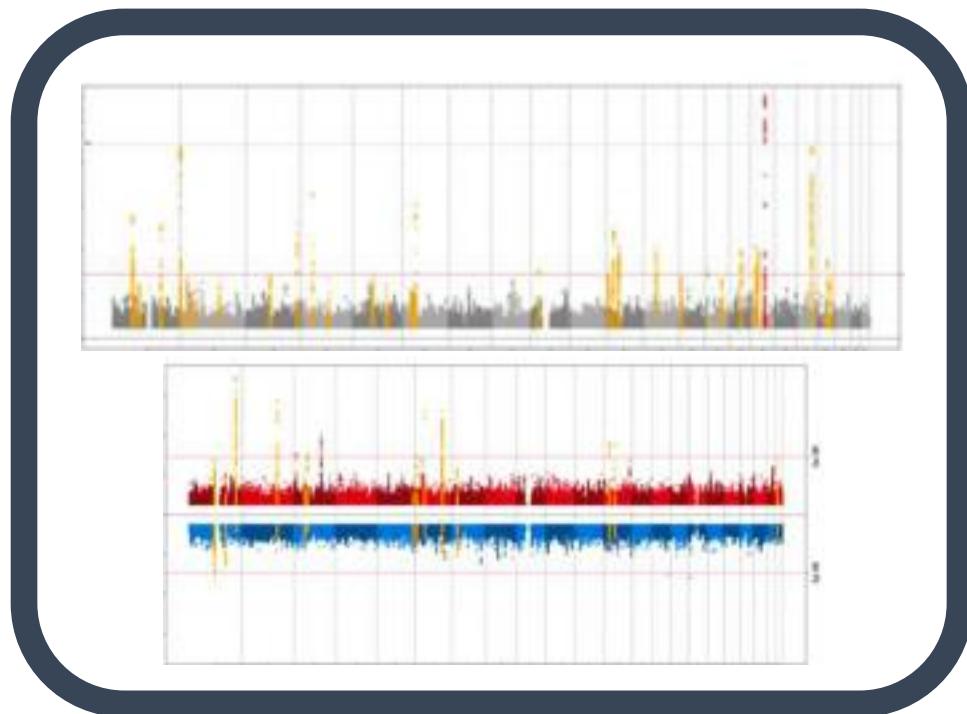
<https://keras.rstudio.com/>  
<https://tensorflow.rstudio.com/>

## GWAS - QC & Data Harmonization



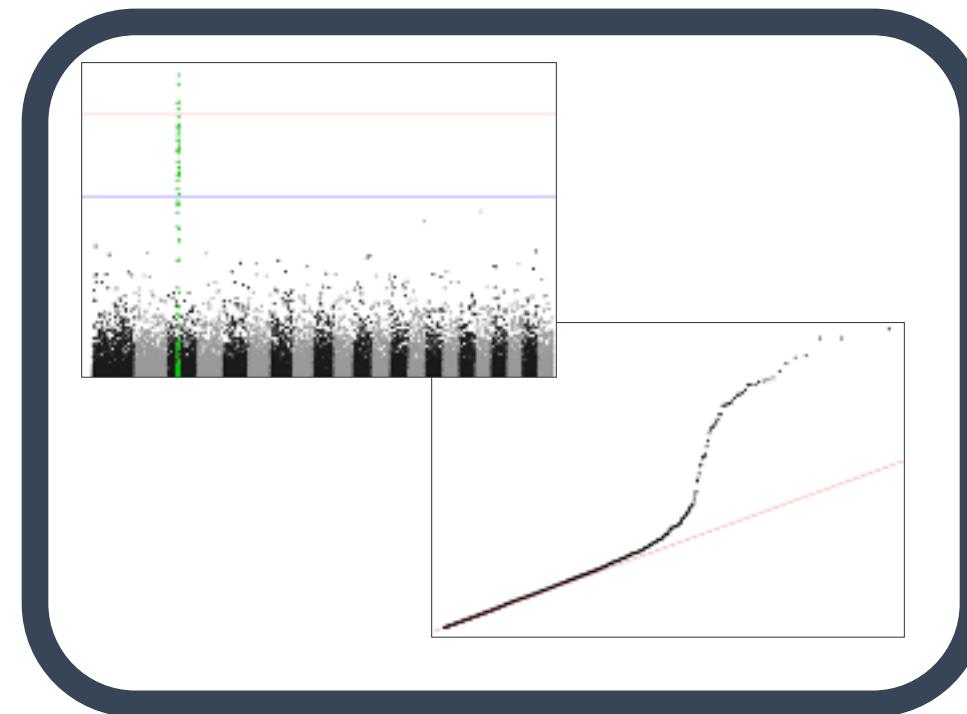
EasyQC: <https://www.uni-regensburg.de/medizin/epidemiologie-praeventivmedizin/genetische-epidemiologie/software/>

## GWAS Data Management & Plots



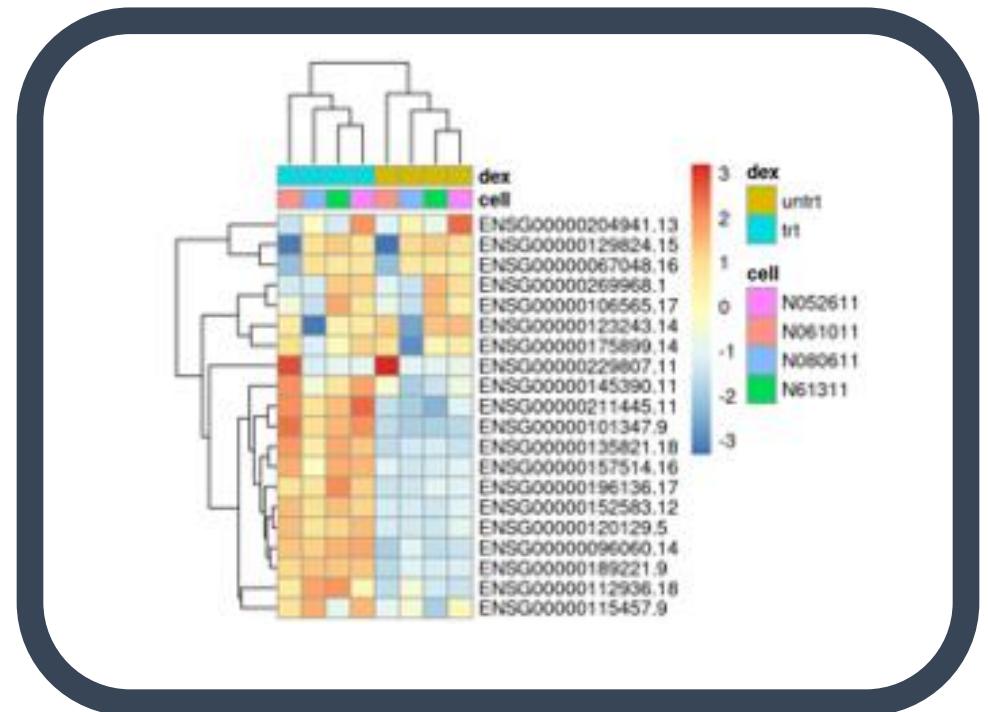
EasyStrata: <https://www.uni-regensburg.de/medizin/epidemiologie-praeventivmedizin/genetische-epidemiologie/software/>

## More Plotting...



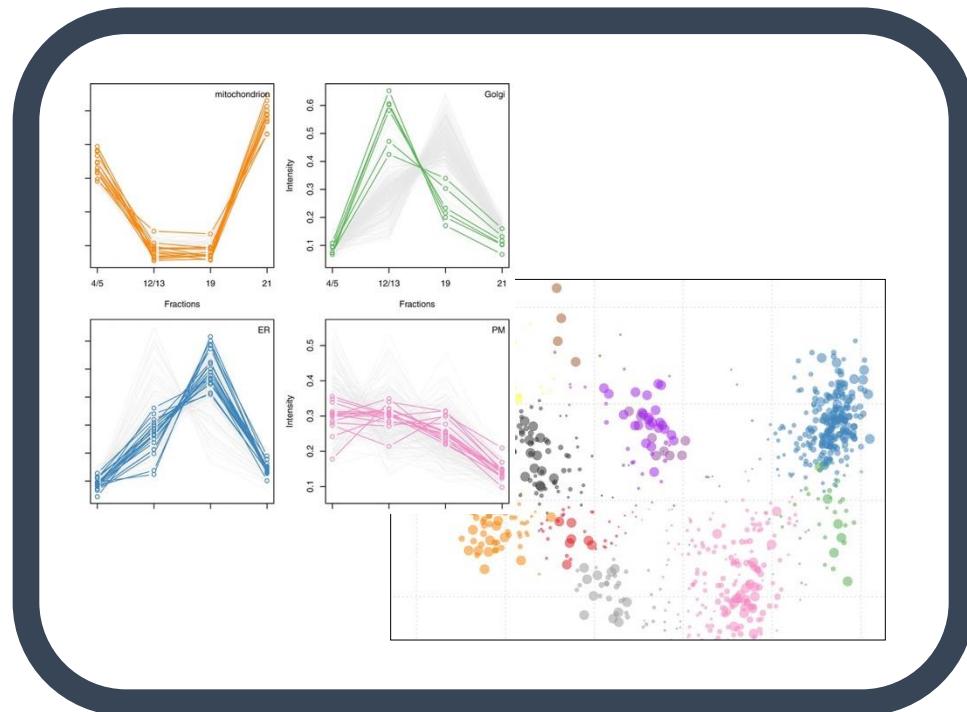
Manhattan and QQ plots:  
<https://cran.r-project.org/web/packages/qqman/vignettes/qqman.html>

## Gene Expression Analysis



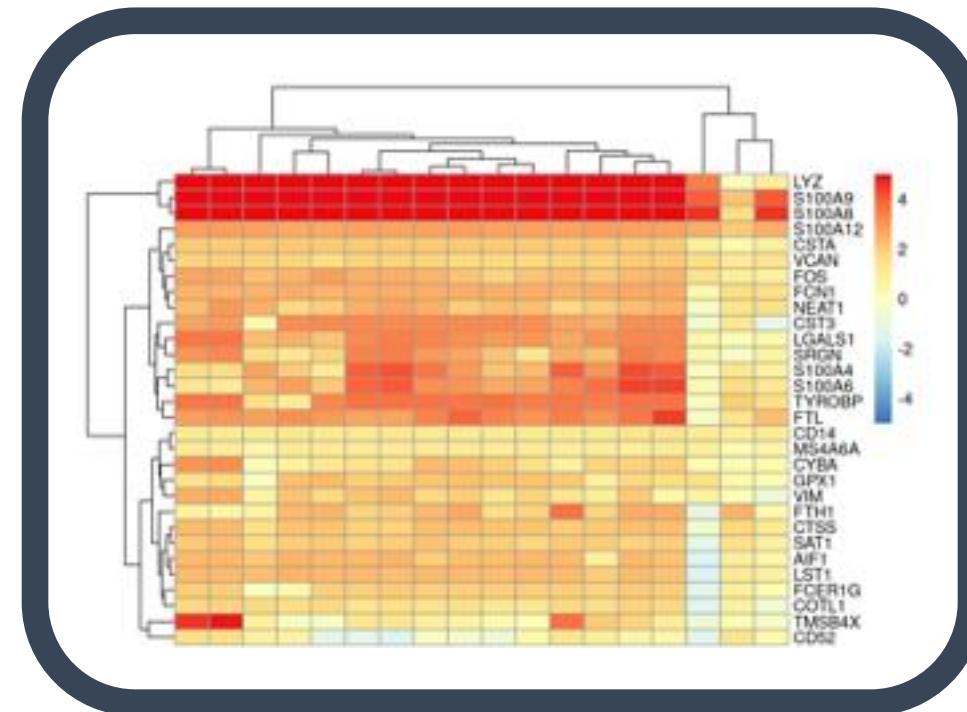
DESeq2, limma, EdgeR, etc.:  
[http://www.bioconductor.org/packages/release/BiocViews.html#\\_RNASeq](http://www.bioconductor.org/packages/release/BiocViews.html#_RNASeq)

## Proteomics Analysis



RforProteomics:  
[https://www.bioconductor.org/packages/release/BiocViews.html#\\_Proteomics](https://www.bioconductor.org/packages/release/BiocViews.html#_Proteomics)

## Single-Cell RNASeq



## — TEASER

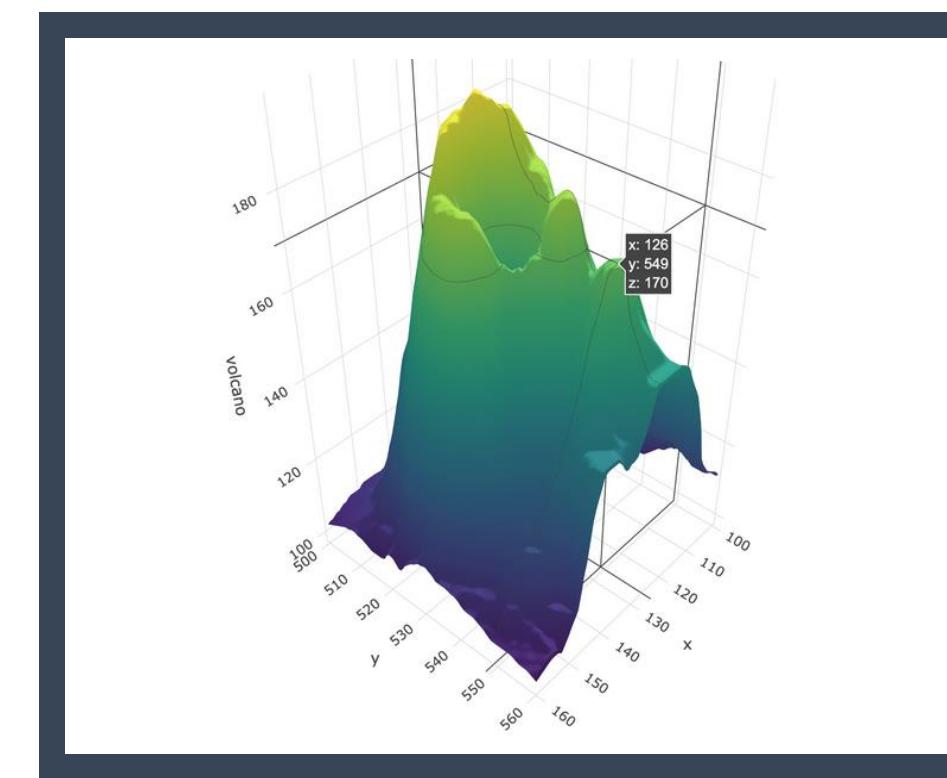
# Omics Data

<http://www.bioconductor.org/packages/release/BiocViews.html>

# COOL STUFF IN R

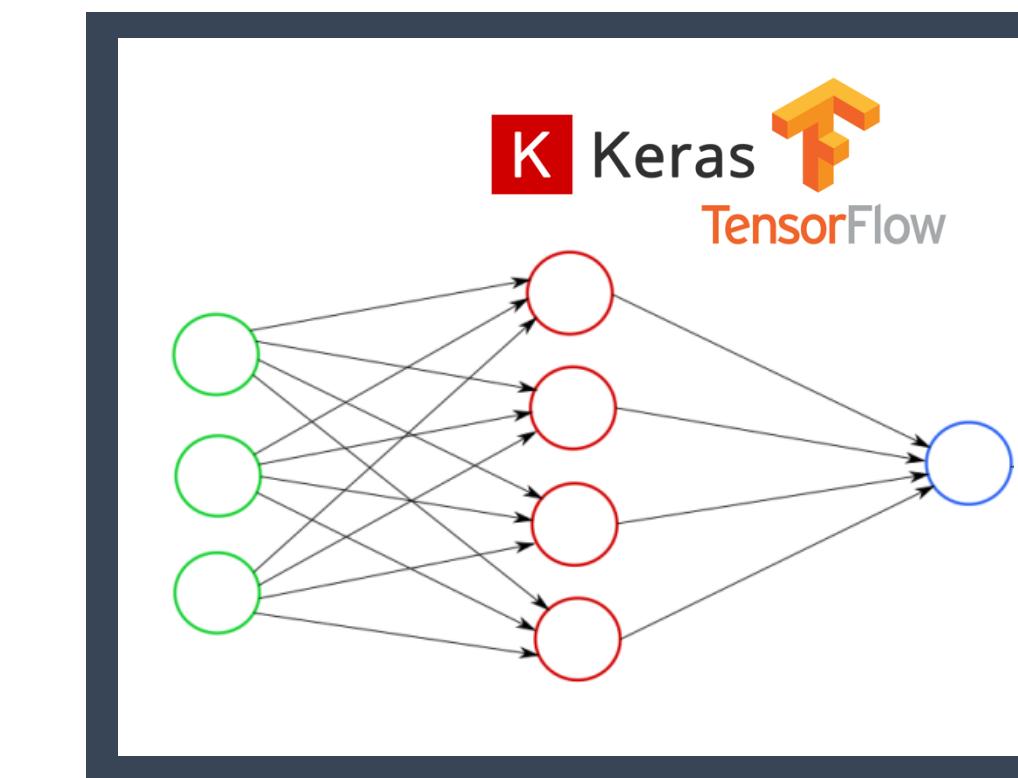
— FROM EXCEL TO R

## PLOTTING IN 3D



<https://plotly-r.com/d-charts.html>

## DEEP LEARNING



<https://keras.rstudio.com/>  
<https://tensorflow.rstudio.com/>

## BAYESIAN STATISTICS



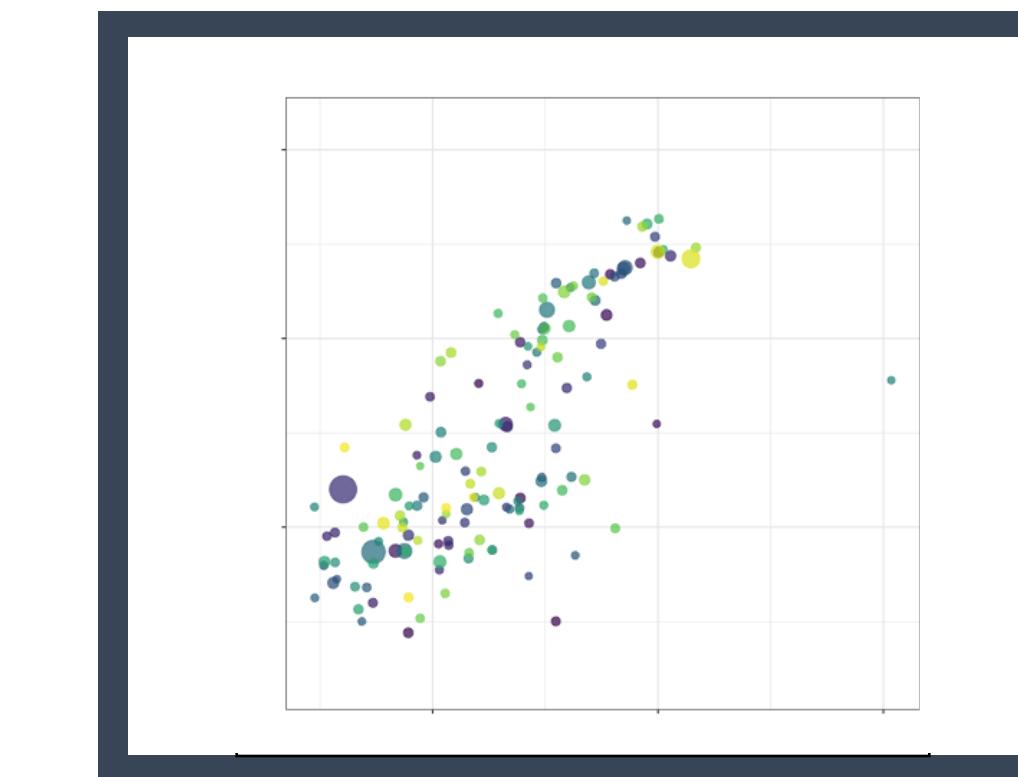
<https://mc-stan.org/users/interfaces/rstan>

## WEBPAGE WITH R SHINY



<https://shiny.rstudio.com/>

## INTERACTIVE PLOTS



<https://gganimate.com/articles/gganimate.html>

## MAIL AND MESSAGES



<https://github.com/briandconnelly/pushoverr>

# DATA SCIENCE WITH HEADS DATA LAB

- Drop-in Thursday (13-15)
- Consultations
- Commission Research & Supervision



Read more on HeaDS Website!

<https://heads.ku.dk>

- Events and Conferences
- Course Reminders



Follow HeaDS on LinkedIn!

<https://www.linkedin.com/company/ucph-heads/>

— FROM EXCEL TO R

# TALKING HEADS

# THANK YOU FOR LISTENING



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