FROM EXCEL TO R

KU DATA SCIENCE LABS

WHO ARE WE?

Center for Health Data Science (HeaDS) **- https://heads.ku.dk/**

SUND Center, which includes a KU data lab

- **Consultation & Collaboration:**
  - Data science and bioinformatics analyses, e.g. big data, -omics analysis, machine learning.
- **Teaching; Courses & Workshops, Seminars, etc.**

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

Dep. of Math and Computer Science, Faculty of SCIENCE

Thilde Terkelsen

Diana Andrejeva

Tugce Karaderi

Henrike Zschach

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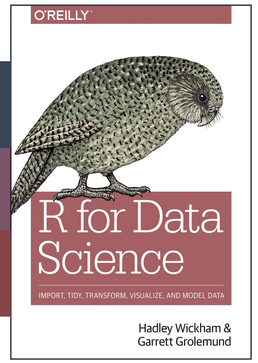
Helle Sørensen

THE PRACTICALS

Two days: 9.00-16.30. 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 (.R, .Rmd) & exercises



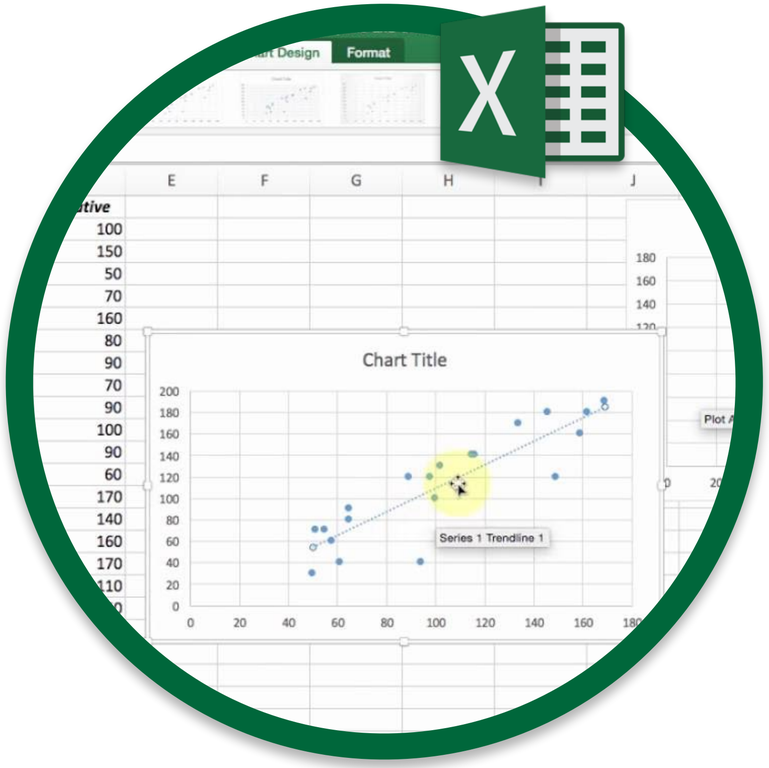
Download and install the newest version of R (https://cran.r-project.org/)

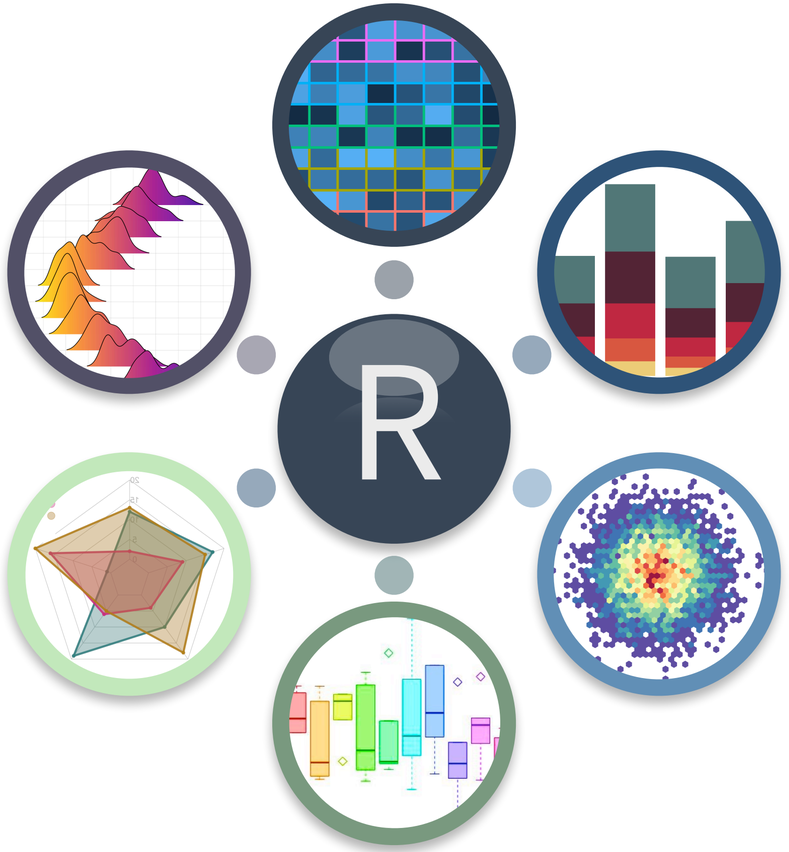
Download and install the newest version of R-studio (http://www.rstudio.com/download)

Download the course material and place it somewhere you can find it again!
https://github.com/Center-for-Health-Data-Science/FromExceltoR

WELCOME TO

FROM EXCEL TO R

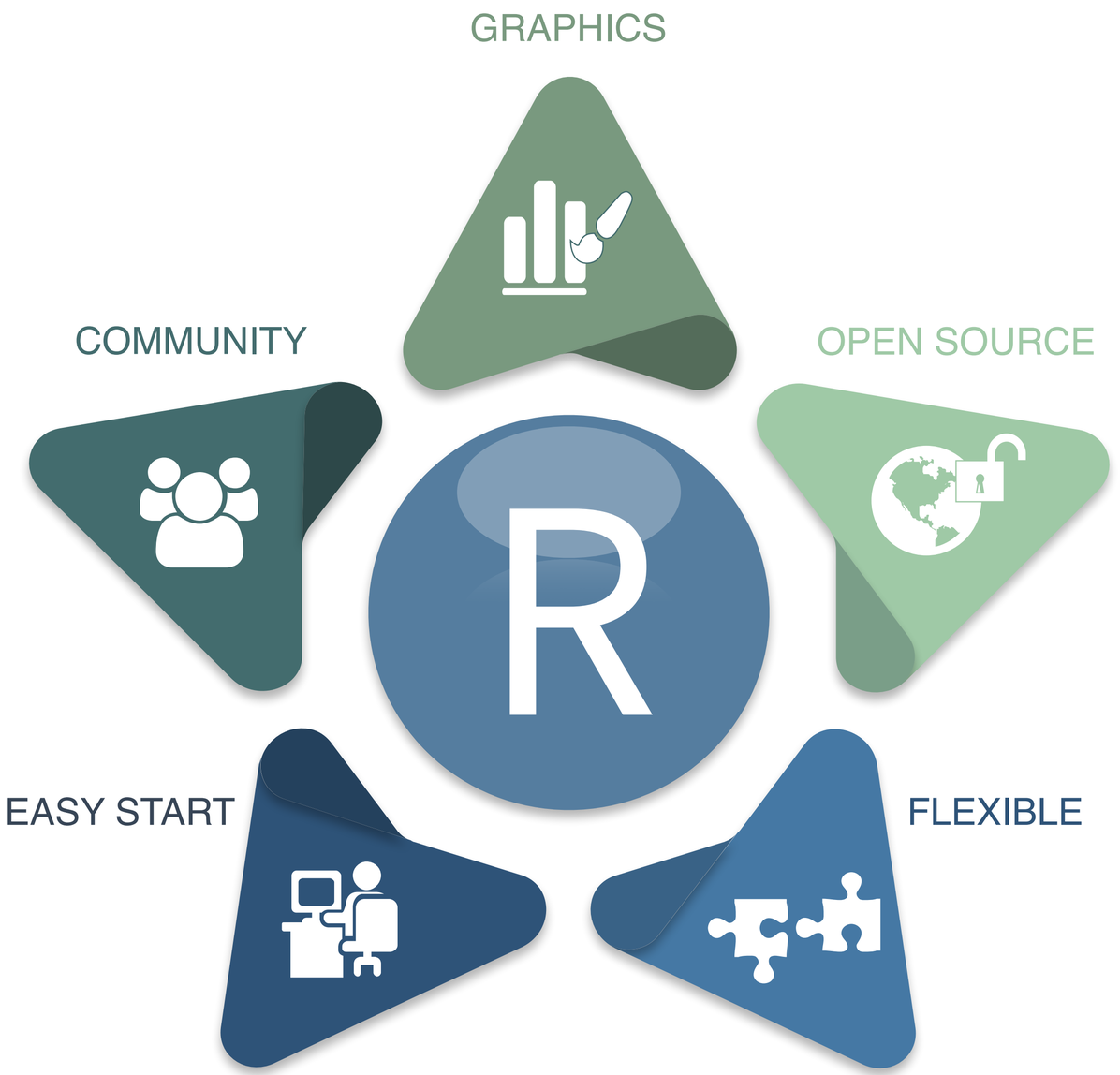




WHY **R** ?

- **Open Source**
- **Easy to get started with:**
  Compatible with all systems, great support
- **Large Community:**
  R-packages, pipelines, tutorials, help pages
- **Flexible Language:**
  Plugins, C++, Python, git/github, markdown
- **Customisable Graphics**

R has its **limitations**, but now fewer than ever



A COMPARISON

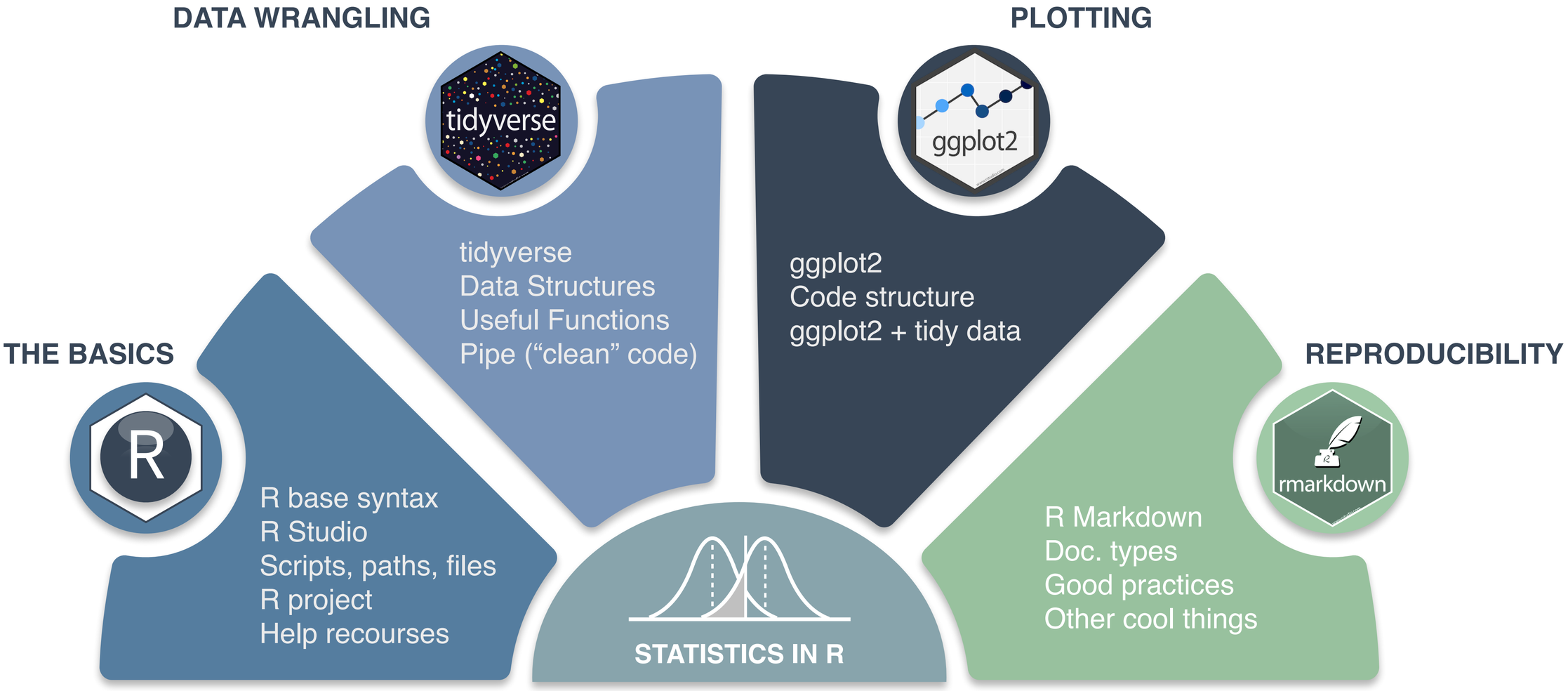
FROM EXCEL TO R

Max: 1000000 rows and 16000 cols
Limited to some operations
Some Stats, mostly math
Okay for the basics
“Bad” - cells are mutable
Great for small/medium data

Upper limit of an object in R is 2^31
Super flexible, almost everything
Stats/bioinf., etc. different fields
Highly customised plots
Markdown, Git, shiny, etc.
Especially great for big data

Big Dataset
Data Wrangling
Data Analysis
Plotting
Reproducibility
Quick Overview

WHAT WILL YOU LEARN IN THIS COURSE?



PROGRAM

DATES: 15-06 & 16-06, 2022

PLACE: Faculty of Health and Medical Sciences, Panum, Holst Auditorium

DAY 1

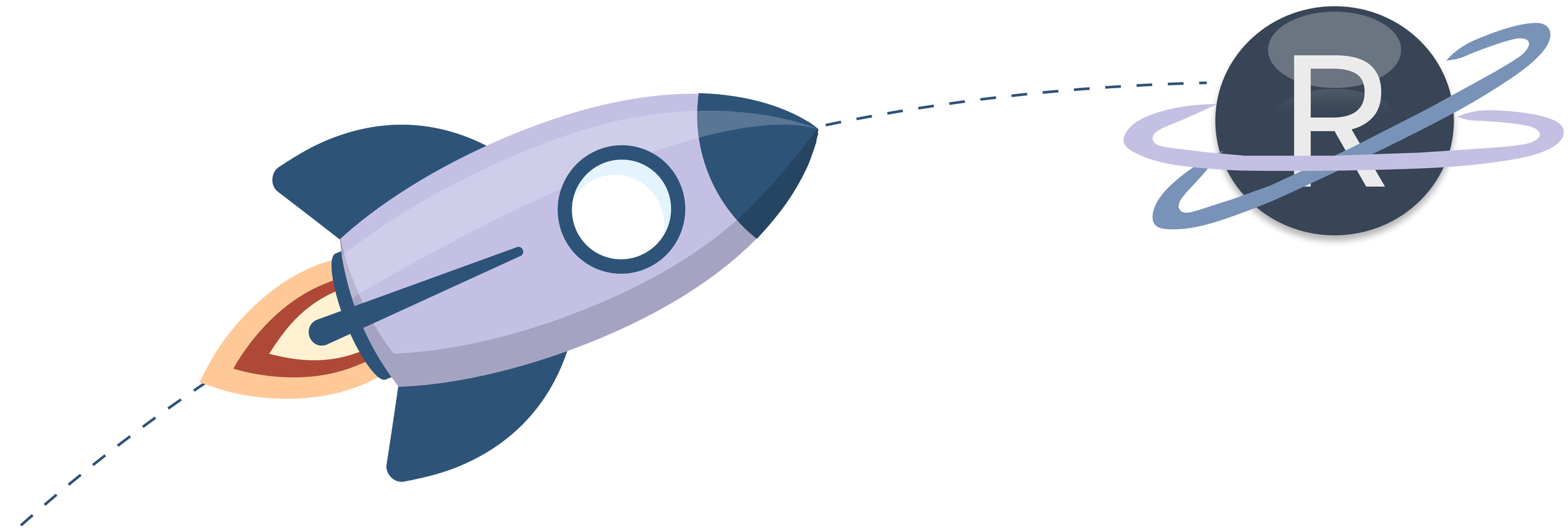
08:30 - Installation issues & Coffee
09:00 - Introduction to R
09:30 - R Basics
09:45 - Rstudio Exercise
10:15 - Break
10:30 - tidyverse
11:30 - tidyverse Exercise
12:00 - Lunch
13:00 - tidyverse Exercise
14:00 - ggplot2
14:45 - Break
15:00 - ggplot2 Exercise
16:30 - See you tomorrow

DAY 2

09:00 - Q&A
09:20 - Rmarkdown
09:50 - Rmarkdown Exercise
10:15 - Break
10:30 - Statistics in R
12:00 - Lunch
13:00 - Statistics Exercise
14:00 - Q&A
14:15 - Break & Course Evaluation
14:30 - Own Dataset Exercise
16:00 - Other cool things in R
16:15 - Wrap up and see you

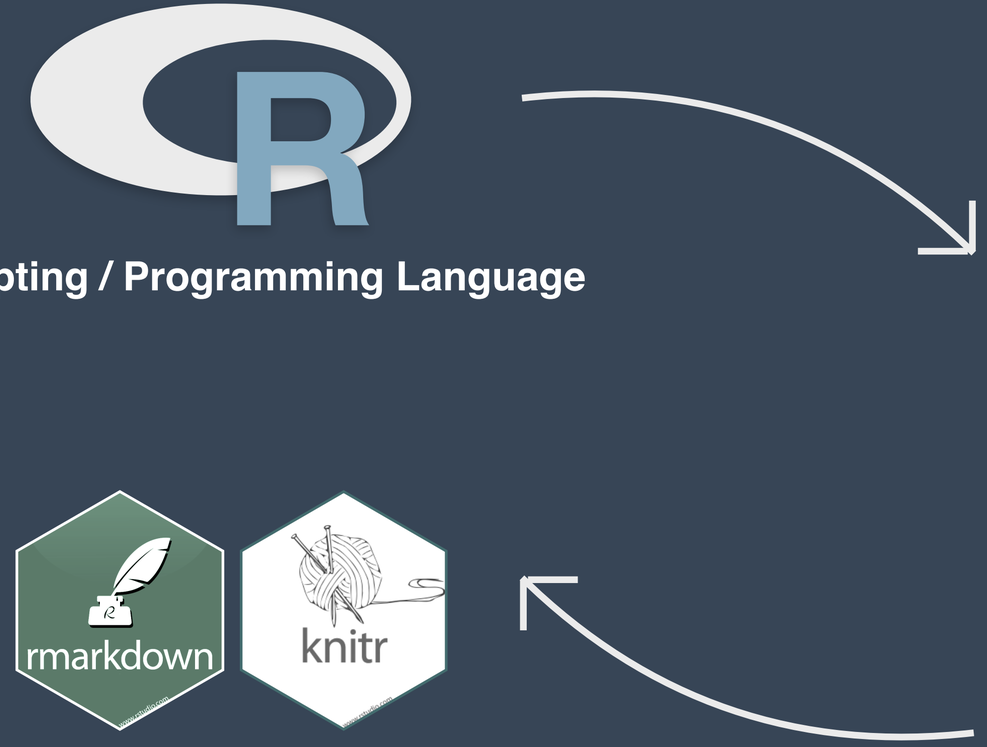
FROM EXCEL TO R

LET'S GET STARTED



R & FRIENDS

Scripting / Programming Language



Reports (html, pdf, latex)

R Code Interpreter and Editor

FIRST TIME IN **R**?

PACKAGES & FUNCTIONS
?my.package, ?my.function
What is it? Input?

install.packages(), remove.packages()

TIPS
Arrows↑↓ to find the code you ran

R studio tips: view, diagnostics
Auto-complete with tab

R-cheat sheets (https://rstudio.com/resources/cheatsheets/)

WORKING DIRECTORY
setwd(), getwd(), list.files(), list.dirs()
Were am I working from? Full/relative path.

SAVE YOUR WORK
.R, (or .Rmd)
The file with my code. Save it!

R project
Save Session, everything together

RUN CODE
Run button, highlight enter, short-cut

R STUDIO BASICS

1. R Project

File —> New Project —> New/Existing —> Create Project

2. Set Path

getwd() - Get directory
setwd() - Set directory

setwd(“/Users/Tom/Rstuff”) - Full path
setwd(“./Rstuff”) - Relative path

Session —> Set Working Directory —> Choose Directory

3. R Script

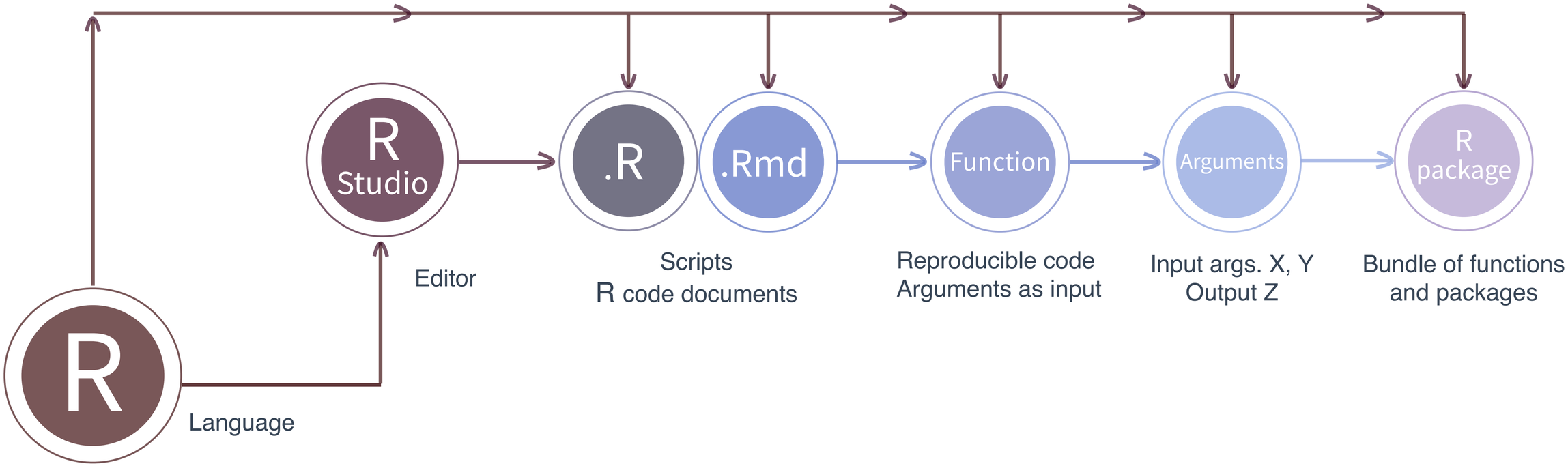
Script Icon —> R Script —> File —> Save as …

4. Install and load a R package.

install.packages(“my.package”**)**
library (my.package**)** - Load package.

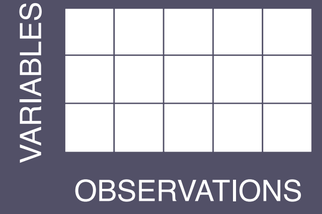
Tools —> Install packages —> my.package

THE ANATOMY OF R



FROM EXCEL TO R

R DATA TYPES & STRUCTURES



DATA STRUCTURES

Vector

Age

Data Frame

Age
Height
BMI

List

Array

Tibble

<> <> <> <> <>

DATA TYPES

Numeric

-1.5, 2.7, 3.2

Integer

-2, -1, 0, 3, 5

Character

“A”, “Bat”, “Tom”

Factor

G1, G1, G2, G3

Logical

TRUE, FALSE

https://rstudio.com/resources/cheatsheets/

R BASE SYNTAX - RUN THROUGH

VARIABLE ASSIGNMENT

```
> a <- 'apple'
> a
[1] 'apple'
```

```
> x <- c(1.5, 2.6, 1.7, 3.2, 3.0, 2.9, …)
> x
> [1] 1.5  2.6  1.7  3.2  3.0  2.9 …
```

READING AND WRITING DATA

Input	Ouput	Description
`df <- read.table('file.txt')`	`write.table(df, 'file.txt')`	Read and write a delimited text file.
`df <- read.csv('file.csv')`	`write.csv(df, 'file.csv')`	Read and write a comma separated value file. This is a special case of read.table/ write.table.
`load('file.RData')`	`save(df, file = 'file.Rdata')`	Read and write an R data file, a file type special for R.

DON'T USE

```
Spaces in names

Special characters
% ? / | \ & $ @

Unspecific names

Short/long names
```

https://rstudio.com/resources/cheatsheets/

R BASE SYNTAX - RUN THROUGH

SELECTING ELEMENTS

`x[4]`	The fourth element.
`x[-4]`	All but the fourth.
`x[2:4]`	Elements two to four.
`x[-(2:4)]`	All elements except two to four.
`x[c(1, 5)]`	Elements one and five.

By Value

`x[x == 10]`	Elements which are equal to 10.
`x[x < 0]`	All elements less than zero.
`x[x %in% c(1, 2, 5)]`	Elements in the set 1, 2, 5.

R-BASE FUNCTIONS

`log(x)`	Natural log.	`sum(x)`	Sum.
`exp(x)`	Exponential.	`mean(x)`	Mean.
`max(x)`	Largest element.	`median(x)`	Median.
`min(x)`	Smallest element.	`quantile(x)`	Percentage quantiles.
`round(x, n)`	Round to n decimal places.	`rank(x)`	Rank of elements.
`sig.fig(x, n)`	Round to n significant figures.	`var(x)`	The variance.
`cor(x, y)`	Correlation.	`sd(x)`	The standard deviation.

CONDITIONS

`a == b`	Are equal	`a > b`	Greater than	`a >= b`	Greater than or equal to	`is.na(a)`	Is missing
`a != b`	Not equal	`a < b`	Less than	`a <= b`	Less than or equal to	`is.null(a)`	Is null

https://www.rstudio.com/wp-content/uploads/2016/10/r-cheat-sheet-3.pdf

BASE R CHEAT SHEET

Basics:

```
getwd(), setwd() # location
install.packages('pname'), library(pname)
ls(), rm() # list, remove objects
load(), data(), save() # load, save as .Rdata
```

Read in data:

```
read.xlsx('name.xlsx'),
read.delim('name.txt', sep ='\t')
read.csv('name.csv', sep=';')
```

GETTING STARTED

Overview:

```
head(df, n=10), df[1:10,] tail(df, n=10)
# first or last 10 rows
class() # data structure
unique(), table() # unique vals, count vals
```

Make Data:

```
c() # vector
data.frame(x=x,y=y)
matrix(x, nrow = 3, ncol = 3))
list(x=x, y=y)
```

DATA STRUCTURES & OVERVIEW

Is/As type:

```
is.numeric(x) (character, factor, integer, etc.)
as.numeric(x) (factor, matrix, data.frame, etc.)
```

Strings:

```
paste(x, y, sep = '')
grep('pattern', x) # find str pattern
gsub('pattern', 'replace', x) # replace with
```

DATA TYPES & STRINGS

Other:

```
seq(1, 10, by = 1.0) # sequence from-to
rep(x, times) # replicate n times
sort(), reverse() # sort or reverse vector
```

Plots:

```
plot(x)
plot(x,y) # scatter
hist(x) # histogram
```

VECTORS & BASE PLOTS

ONLINE RESOURCES FOR **R**

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

GET STARTED

https://rseek.org/

https://rstudio.com/resources/cheatsheets/

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

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

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.revolutionanalytics.com/

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

GETTING **HELP**

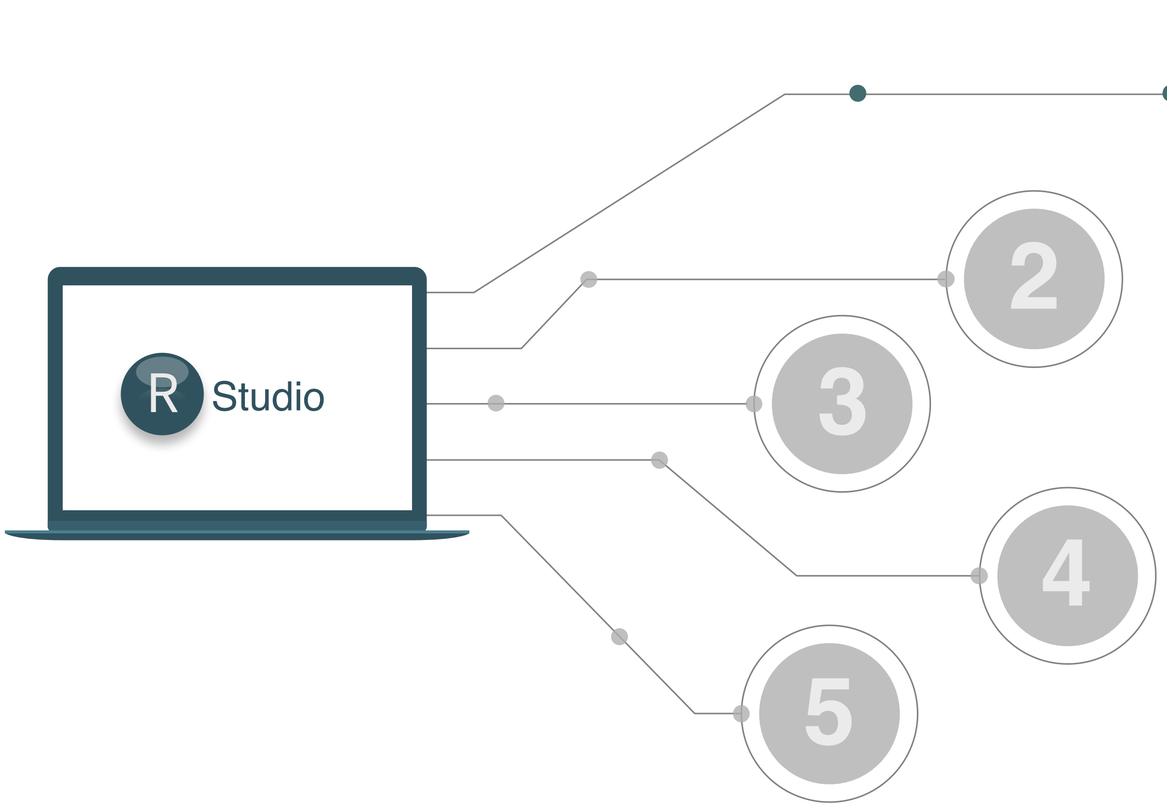
02

GETTING HELP

1. Ask us, and ask people next to you.
2. Look at the R presentations we go through.
3. Use the **cheat sheets** in this presentation and online: https://rstudio.com/resources/cheatsheets/

Google it! Most important skill of all.

You will get the **solutions** to the exercises near the end of the day.



- R project & R Script
- Read & Write
- Basic calculus
- Base plot
- R help
- Save & Shutdown

FUNDAMENTALS

EXERCISE **1**

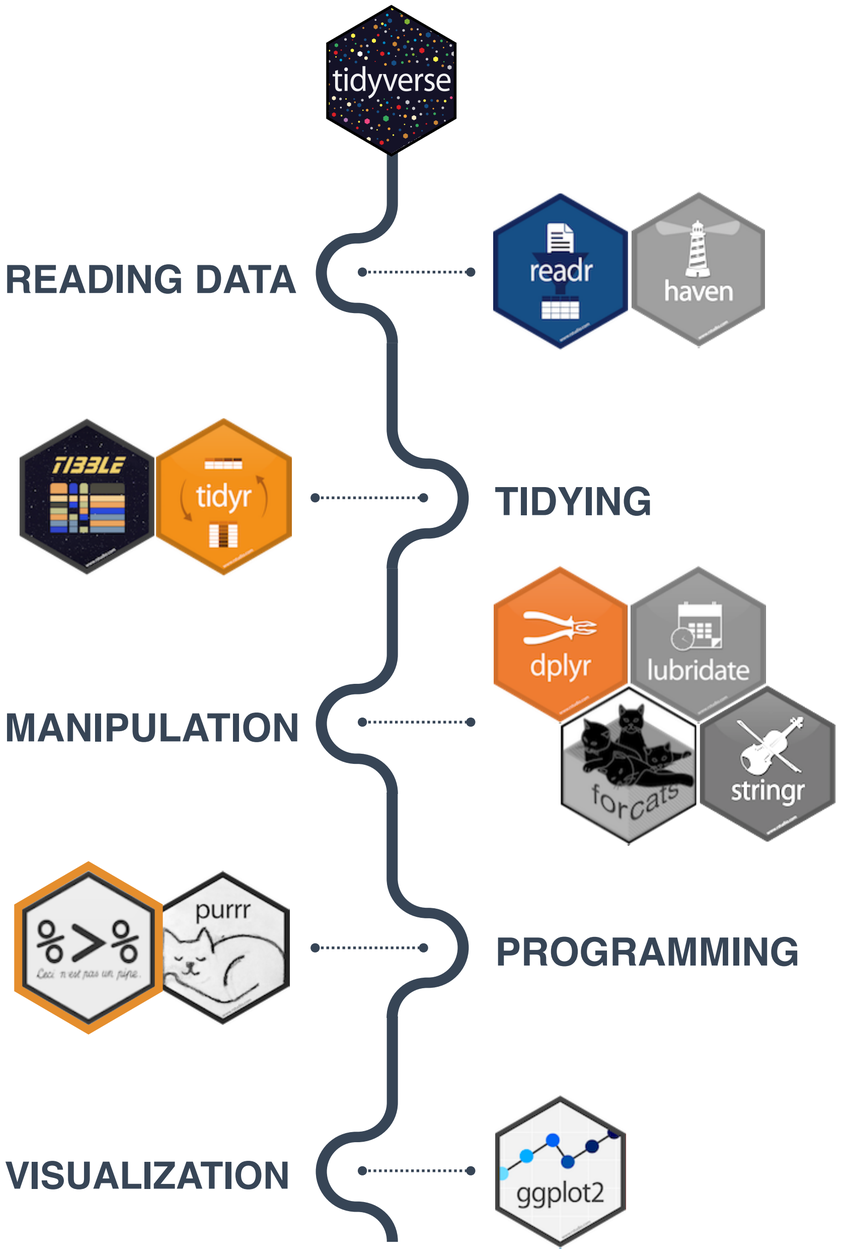
https://www.tidyverse.org/

TIDYVERSE

tidyverse is a collection of R packages for data science

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

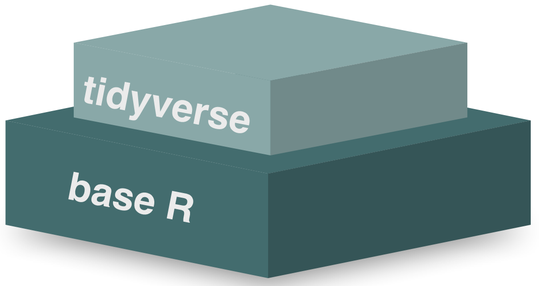
tidyverse is used to "tidy up" your datasets, so they are easy to work with



https://www.tidyverse.org/

CECI N'EST PAS UNE PIPE
%>%

- You do NOT have to “chose” 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”
- Remember what tidyverse is made for!

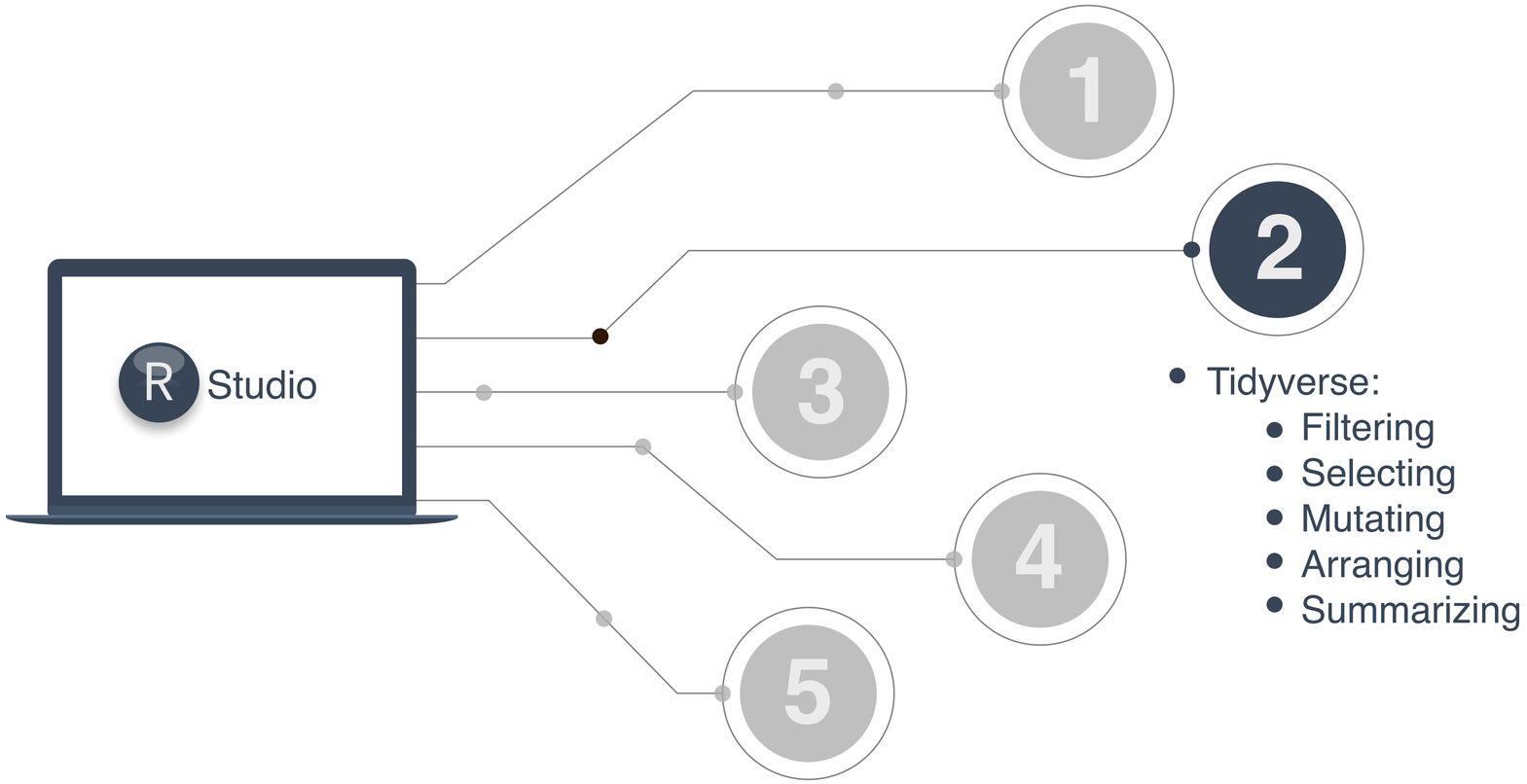
base R

```
# think from the inside out

g(f(x,y),z)
```

tidyverse

```
# no brain acrobatics

x %>% f(y) %>% g(z)
```

pipe symbol



- Tidyverse:
  - Filtering
  - Selecting
  - Mutating
  - Arranging
  - Summarizing

TIDYVERSE

EXERCISE **2**

https://www.tidyverse.org/

TIDYVERSE CHEAT SHEET

readr, tidyr, 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: …")`

Data Tidying (*tidyr*)

Handle missing values

```
drop_na()
fill()
replace_na()
```

Subsetting

```
tibble[:,1:5] # returns a tibble
tibble$colname # returns a vector
```

(same as tibble[[colname]])

Reorganize layout

Change between long and wide format

```
gather() # wide to long
spread() # long to wide
```

Data Manipulation (*dplyr*)

Summary

```
summarise()/summarize()
count()
```

Group

```
group_by()
```

Functions will manipulate each group separately and combine results.

Extract and sort observations # i.e. rows

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

Manipulate variables # i.e. columns

```
select()
mutate(new_name = f(column))
```

Vectorised functions

Ranking: `percent_rank()`

Math: `Any arithmetic or logical operations, between(), near()`

```
if_else()
```

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*"

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

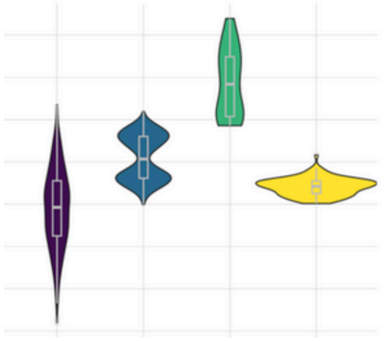
GGPLOT2 - EASY GRAPHICS

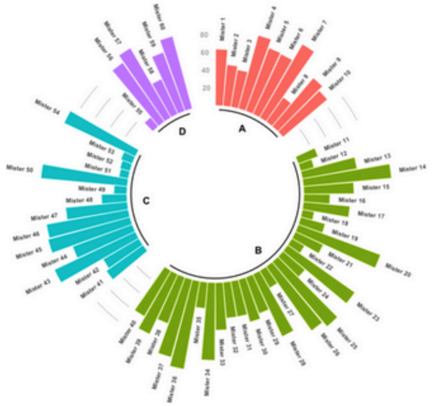
Aesthetically pleasing graphics.

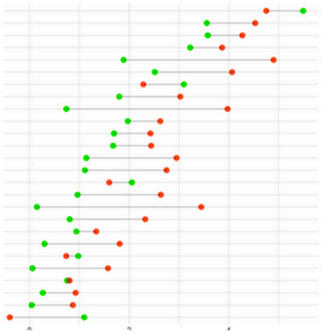
Well-defined “additive” (+) structure.

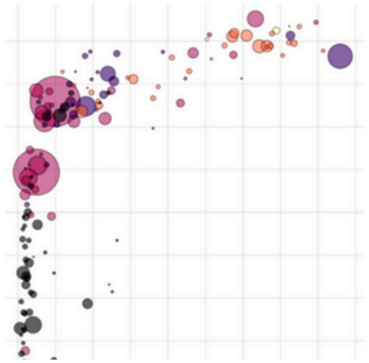
Integrates perfectly with tidy data.

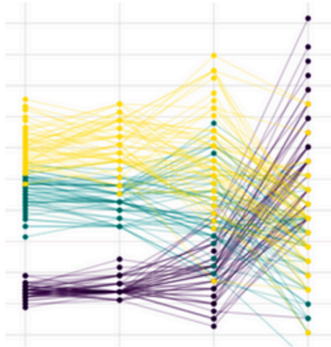
Great documentation & community

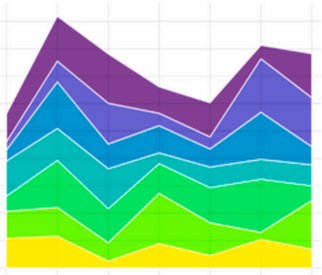






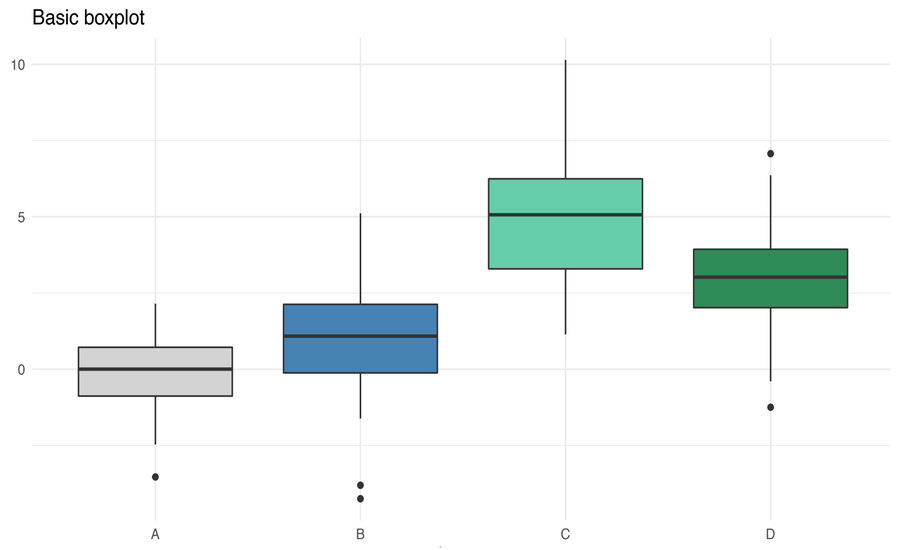






http://tutorials.iq.harvard.edu/R/Rgraphics/Rgraphics.html

GGPLOT2 ADDITIVE STRUCTURE



DATASET, SAMPLES & OBSERVATIONS

```
ggplot(my.DS, aes(x=alphabet,
y=measure))
```

DEFINE PLOT TYPE

```
ggplot(my.DS, aes(x=alphabet,
y=measure))
+ geom_boxplot()
```

COLOR BY GROUP

```
ggplot(my.DS, aes(x=alphabet,
y=measure, fill=alphabet))
+ geom_boxplot()
```

TITLE AND LEGEND

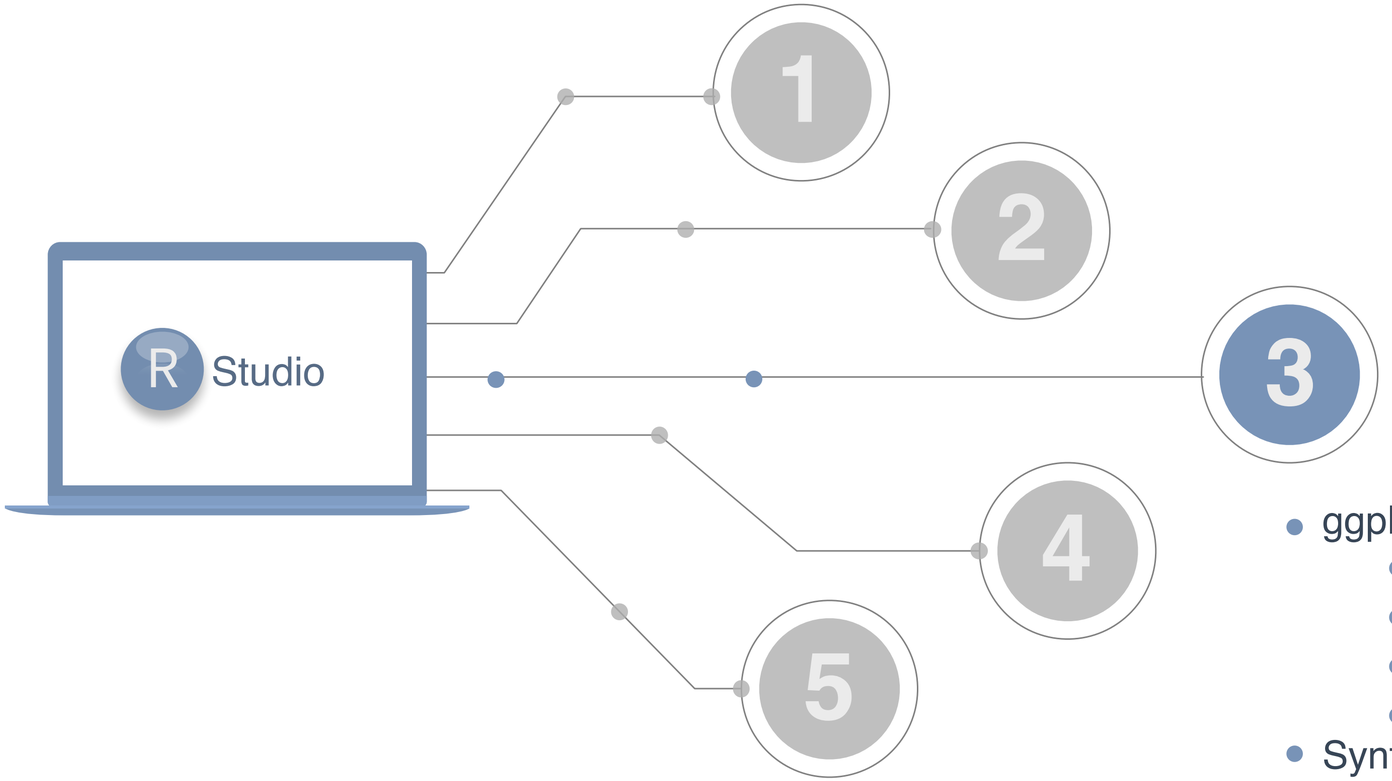
```
 … + ggtitle("Basic boxplot") +
theme(legend.position=“none”,
plot.title = element_text(size=11))
```

CUSTOM COLORS

```
 … + scale_fill_manual(values =
c("lightgray", "steelblue",
“aquamarine3", "seagreen4"))
```

BACKGROUND

```
+ theme_minimal()
```



- ggplot2
  - Bar plot
  - Scatter plot
  - Boxplot
  - …
- Syntax
- Aesthetics

GGPLOT2

EXERCISE 3

https://rstudio.com/wp-content/uploads/2016/11/ggplot2-cheatsheet-2.1.pdf

GGPLOT CHEAT SHEET

GET STARTED

Define Plot:

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

Add Plot Type:

```
+ geom_point()
+ geom_line()
+ geom_boxplot()
+ geom_col()
+ geom_density()
+ geom_histogram()
```

COLORS

One Color:

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

Color Fill by Group:

```
ggplot(…, aes(…,
fill = group.var))
```

Custom Colors:

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

COLOR SCALES & THEMES

More Colors:

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

Grid Theme:

```
+ theme_bw()
+ theme_minimal()
+ theme_dark()
+ theme_*()
```

TEXT

Labels:

```
+ ggtitle("…")
+ xlab("…")
+ ylab("…")
```

Text:

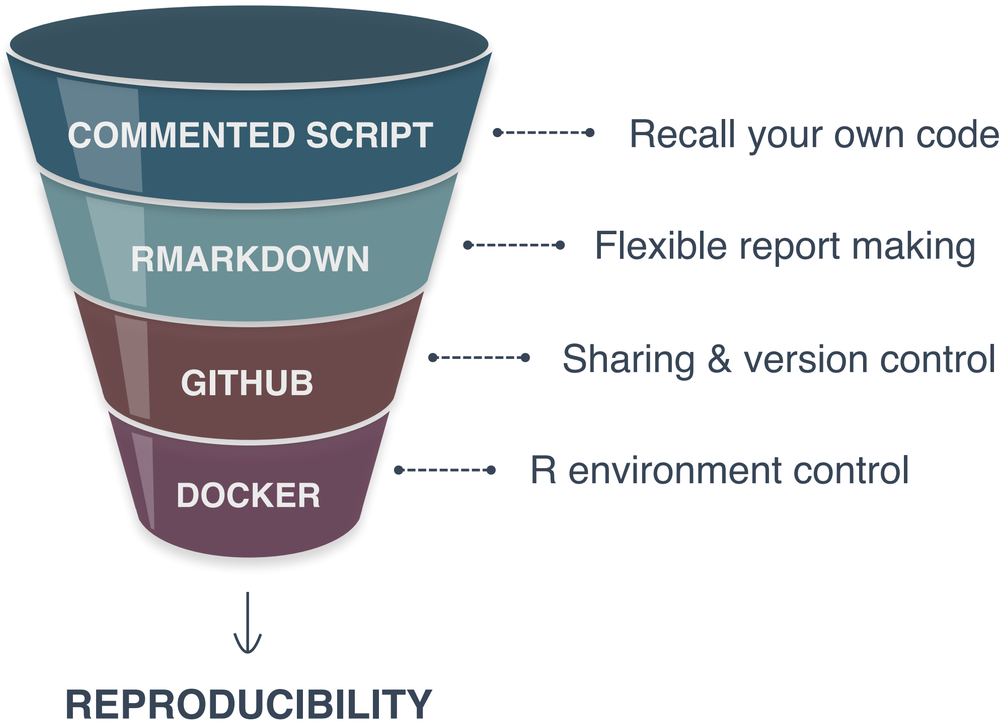
```
+ theme(* = element_text())
+ theme(axis.title = element_text(angle = 90, colour= "red"),
legend.text = element_text(size = 8, face = "bold"))
```

https://github.com/aaronpeikert/reproducible-research

REPRODUCIBILITY IN R

REPRODUCIBLE ANALYSIS

- Perform an analysis multiple times
- Sharing code with collaborators
- Salvage older code in case of mistakes
- Required for publication in journals



- A markup language
- Plain text format
- Converted into HTML, PDF, LATEX

- Finds code embedded in text
- Evaluates the code
- “Knits” the results into the document

https://www.markdowntutorial.com/

R SCRIPT & RMARKDOWN

HOW TO

- Write code as normal
- Comment text with #

USE FOR

- Testing new code
- Big data analysis
- Software development

.R SCRIPT

.Rmd SCRIPT

HOW TO

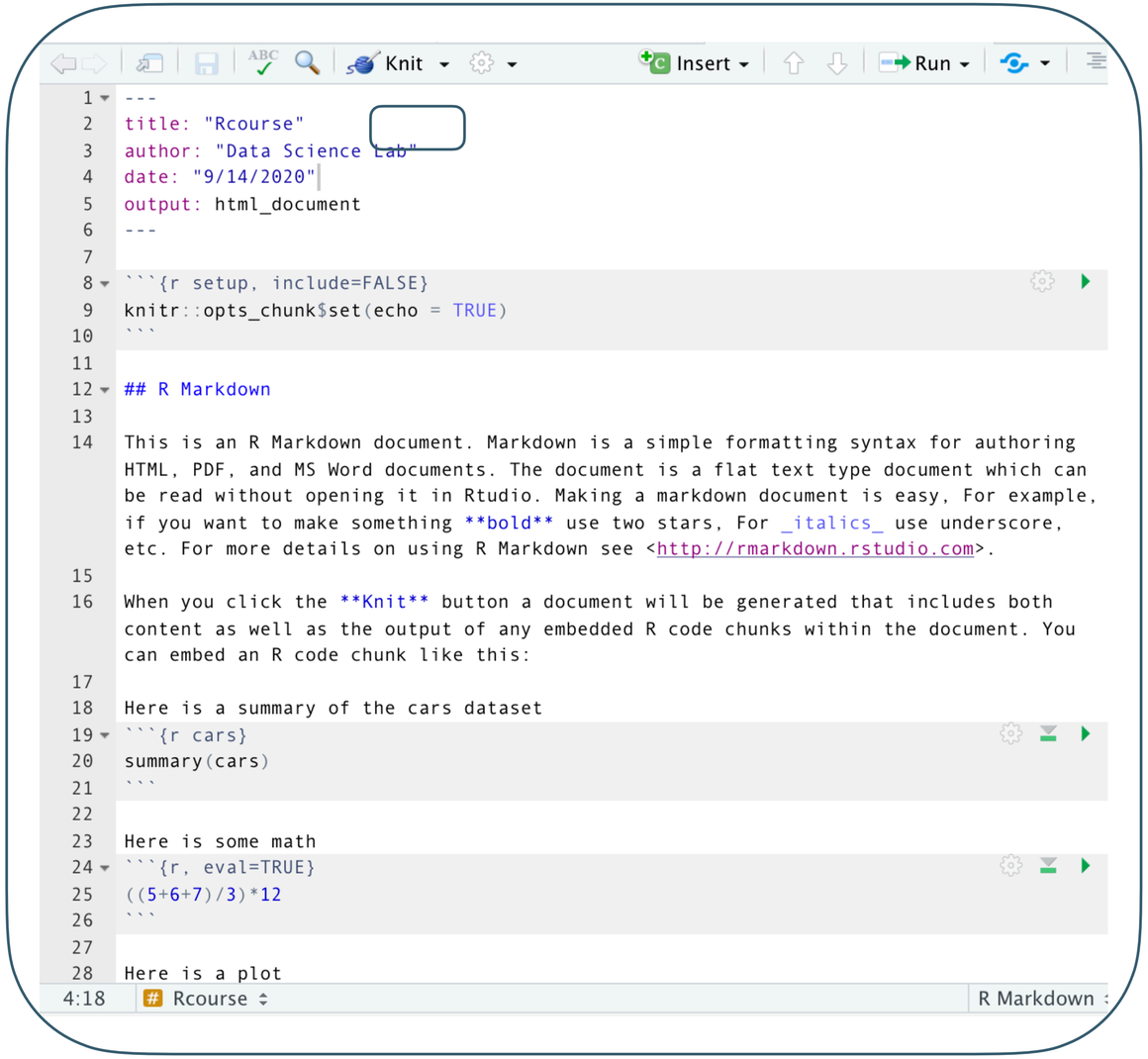
- Write text as normal
- Embed code ```{r} my.code```

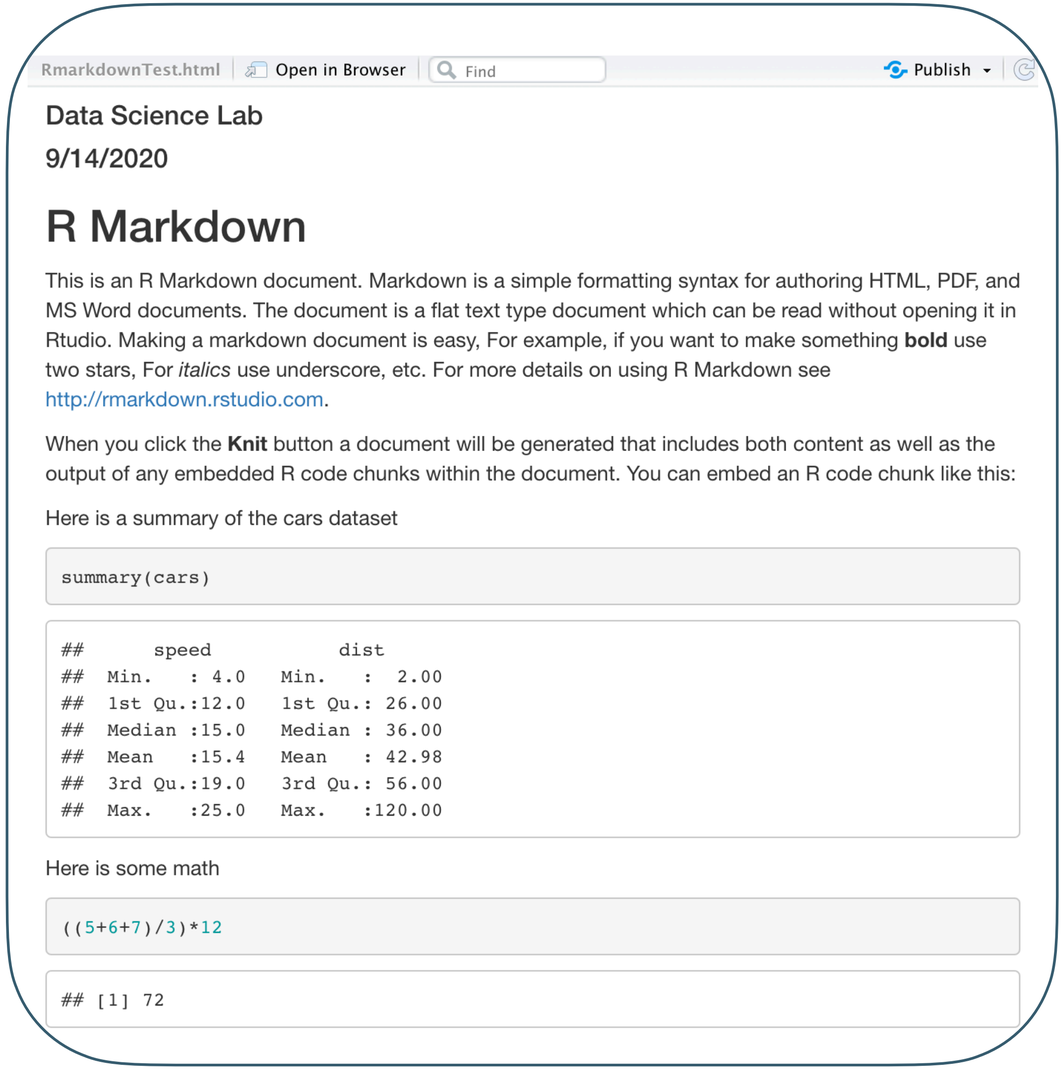
USE FOR

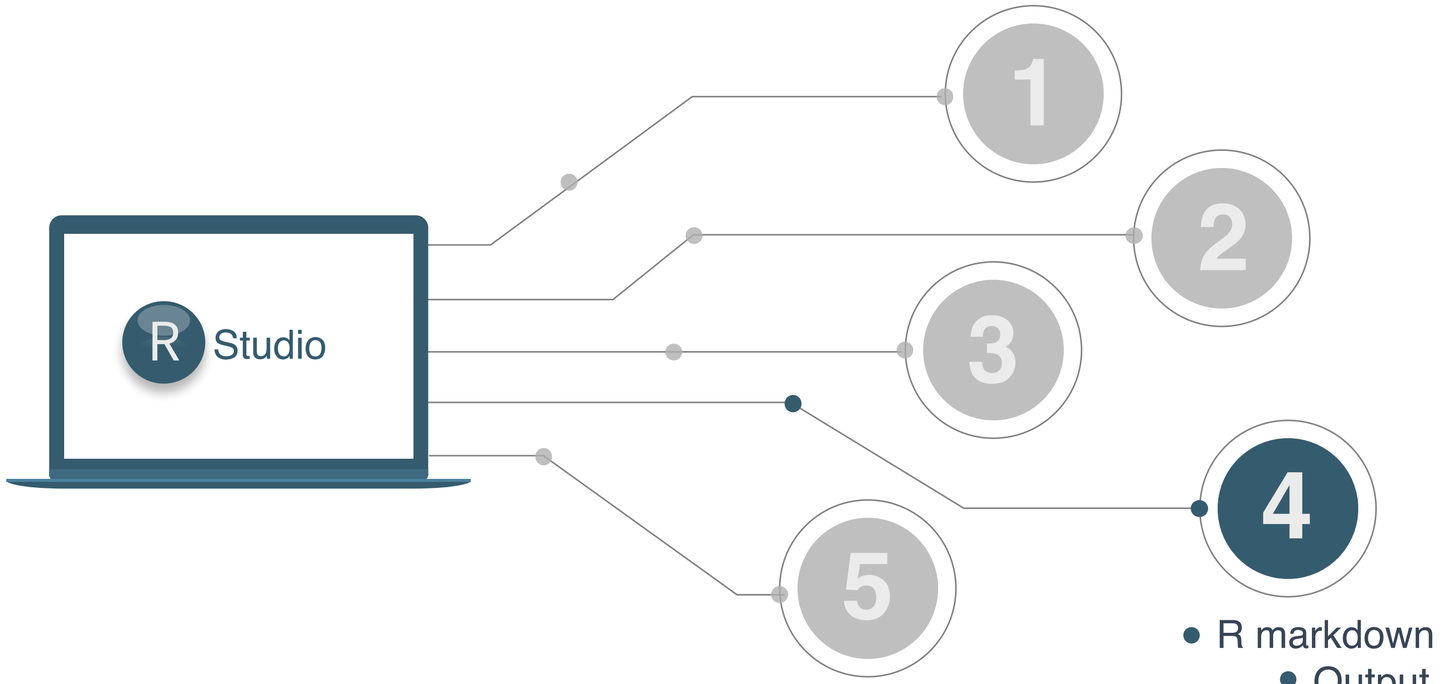
- Reports for yourself
- Reports for collaborators
- Tutorials

https://www.markdowntutorial.com/

RMARKDOWN







- R markdown
  - Output
  - Syntax
  - Tables
  - Plots
  - Images

R markdown

EXERCISE **4**

https://rstudio.com/wp-content/uploads/2016/03/rmarkdown-cheatsheet-2.0.pdf

RMARKDOWN CHEAT

Begin .Rmd:

```
---
title: My Project Name
output:
      html_document (pdf_document, …)
---
```

Code Chunk:

````
```{r}
some R code
```
````

Global Option:

````
```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```
````

GETTING STARTED

Code Options:

```
echo (= TRUE or FALSE - print my code)
eval (= TRUE or FALSE - run my code)
warning (= TRUE or FALSE display warning messages)
```

Figure Options:

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

CHUNK OPTIONS

Header:

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

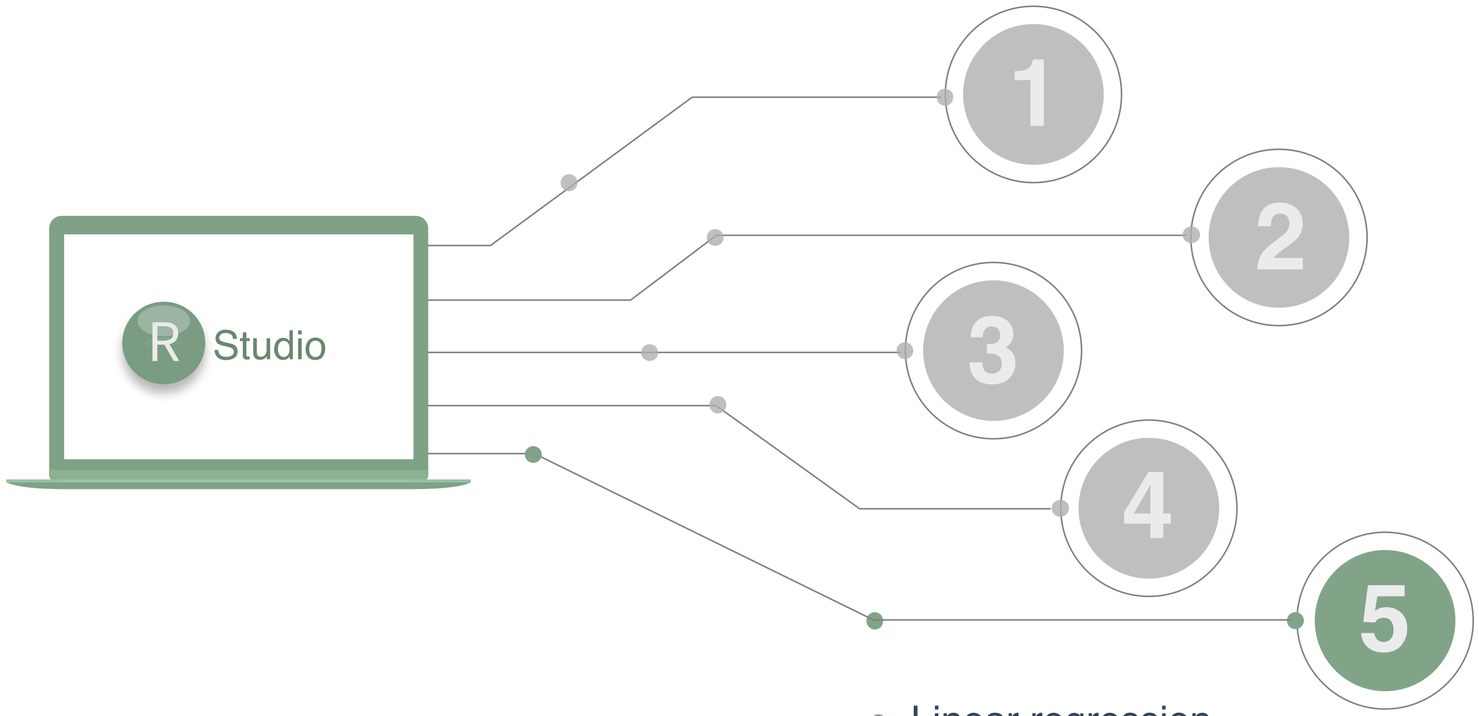
Text:

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

Lists:

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

TEXT



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

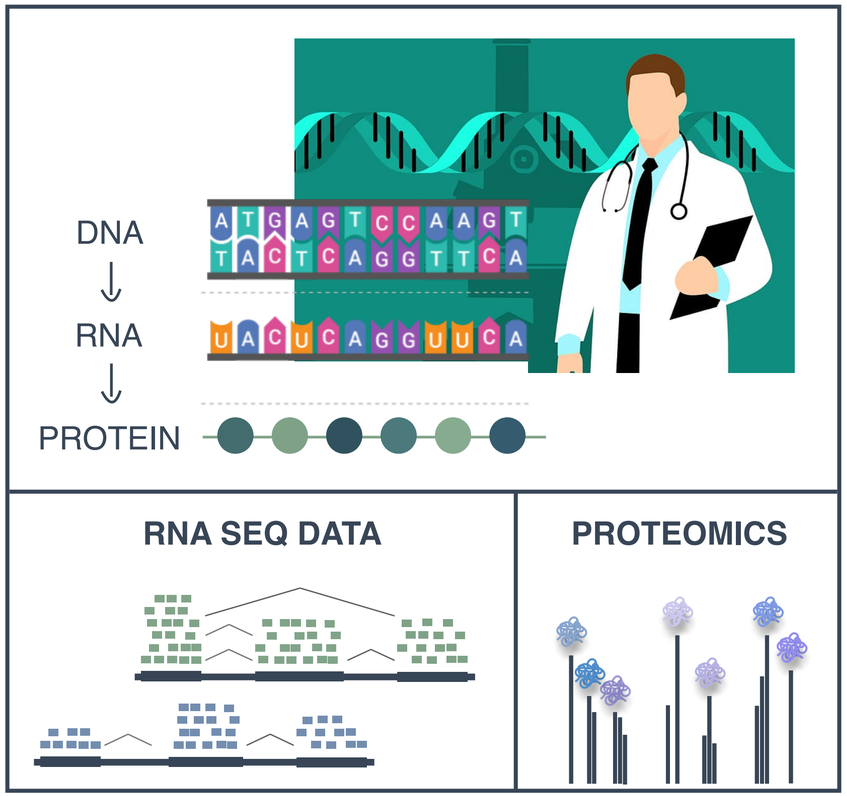
Statistics in R

EXERCISE **5**

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

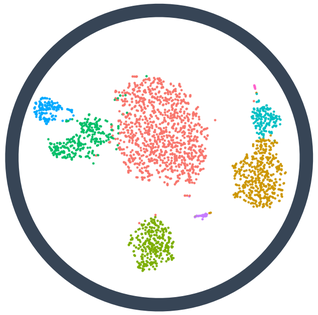
BIOINFORMATICS IN **R**

HIGH THROUGHPUT DATA

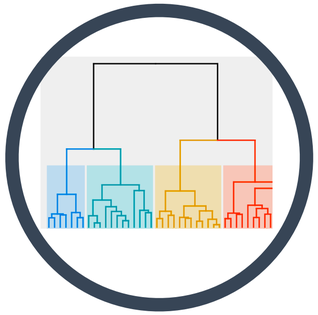


BIOINFORMATIC ANALYSIS

DIMENSIONALITY REDUCTION

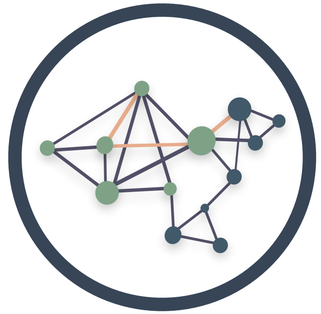


CLUSTERING



MACHINE LEARNING

NETWORK ANALYSIS



THE TOP OF THE R ICEBERG

STATISTICAL ANALYSIS

Statistical models (linear, generalized, mixed, …)

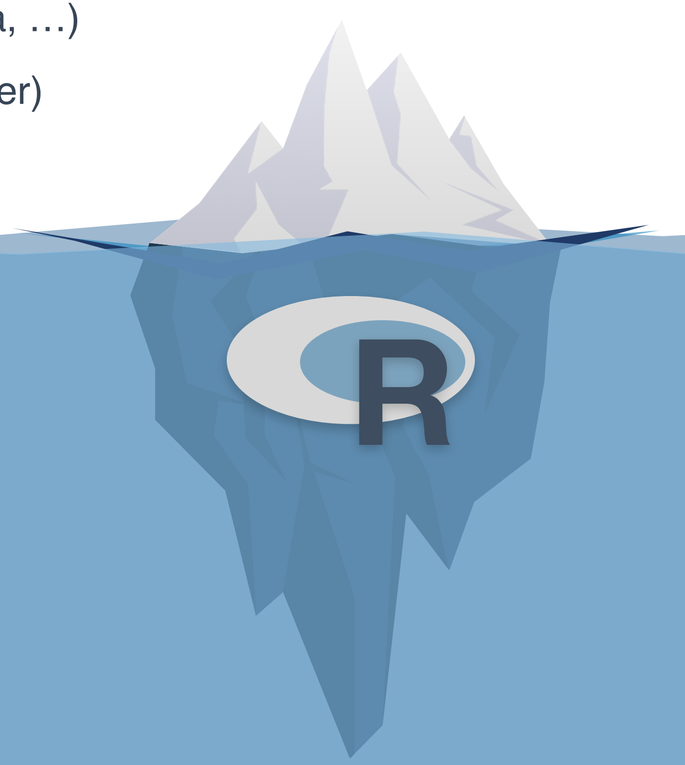
Statistical tests (t-test, chisq, anova, …)

Survival analysis (Cox, Kaplan meier)

DATA MANGEMENT

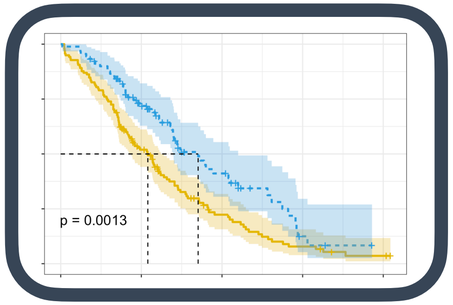
EASY PLOTTING

BIOINFORMATIC ANALYSIS



TEASER

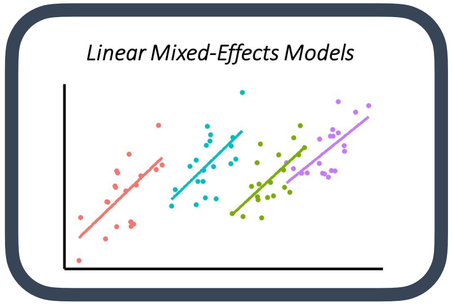
STATISTICS in **R**



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/)

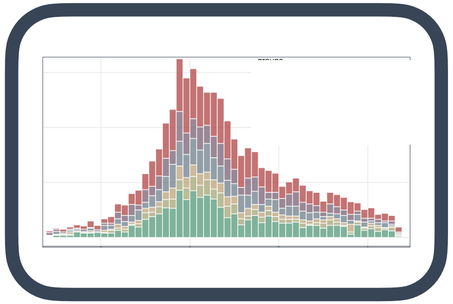


Mixed-Effects Models

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

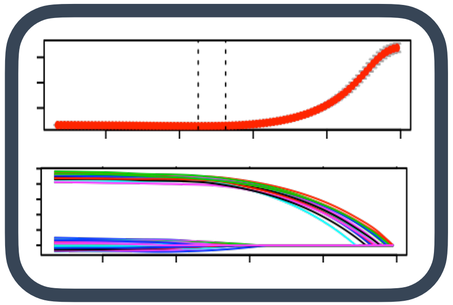


Epidemiological Analysis

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://rviews.rstudio.com/2020/03/05/covid-19-epidemiology-with-r/



Elastic-Net Regression

glmnet: https://cran.r-project.org/web/packages/glmnet/glmnet.pdf

elasticnet: https://cran.r-project.org/web/packages/elasticnet/elasticnet.pdf

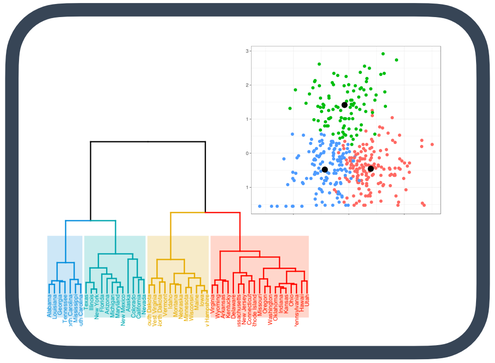
https://www.datacamp.com/community/tutorials/tutorial-ridge-lasso-elastic-net

TEASER

Machine Learning

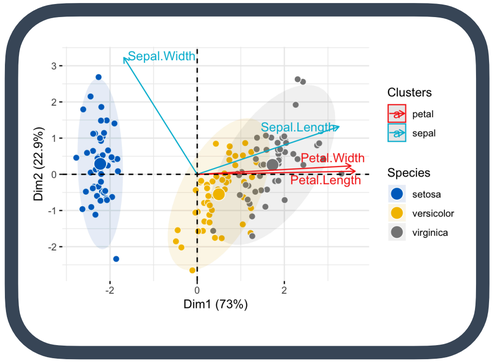
https://lgatto.github.io/IntroMachineLearningWithR/an-introduction-to-machine-learning-with-r.html

Clustering



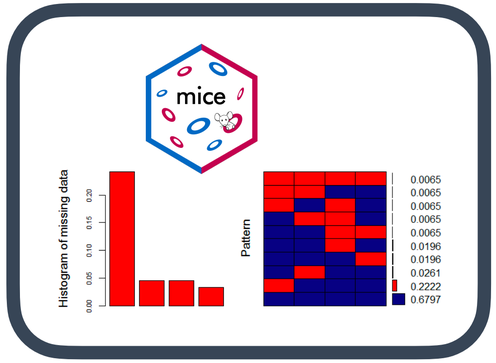
https://statsandr.com/blog/clustering-analysis-k-means-and-hierarchical-clustering-by-hand-and-in-r/

Feature Selection: PCA



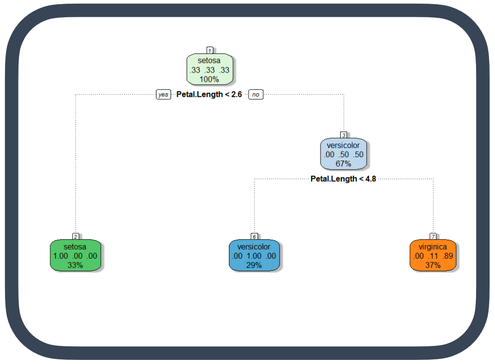
https://bioconductor.org/packages/release/bioc/vignettes/PCAtools/inst/doc/PCAtools.html

Missing Data



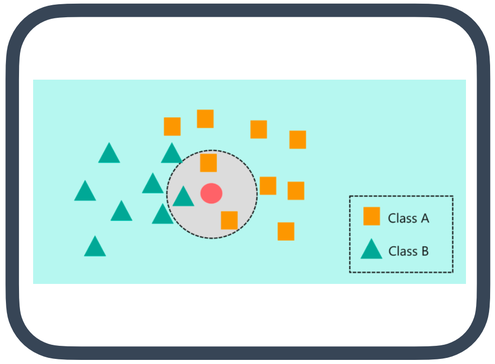
https://amices.org/mice/
https://datascienceplus.com/imputing-missing-data-with-r-mice-package/

Random Forest



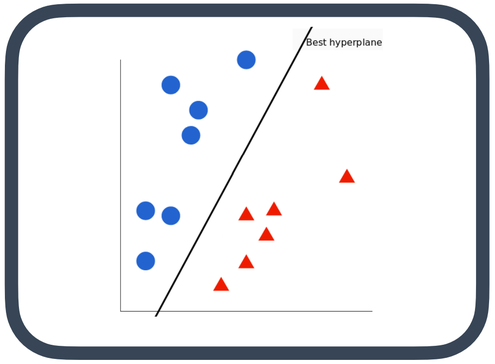
https://www.blopig.com/blog/2017/04/a-very-basic-introduction-to-random-forests-using-r/

kNN



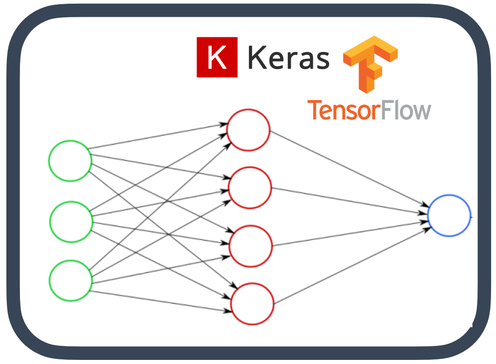
https://www.edureka.co/blog/knn-algorithm-in-r/

SVM



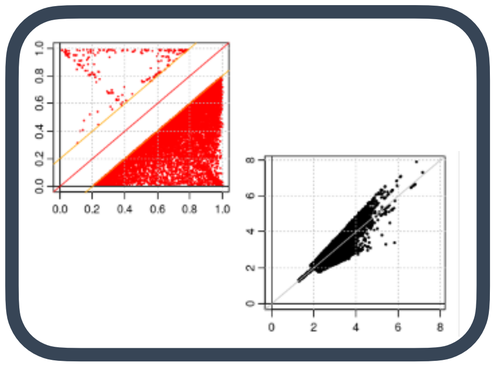
https://cran.r-project.org/web/packages/e1071/vignettes/svmdoc.pdf

Neural Networks



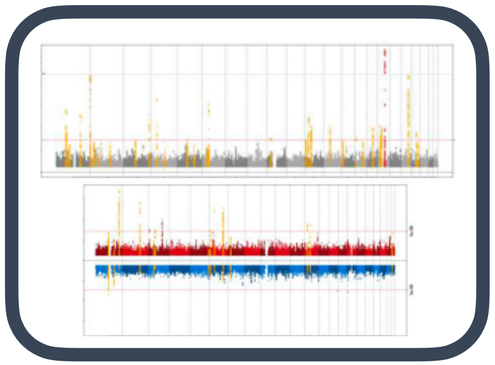
https://keras.rstudio.com/
https://tensorflow.rstudio.com/

GWAS - QC & Data Harmonization



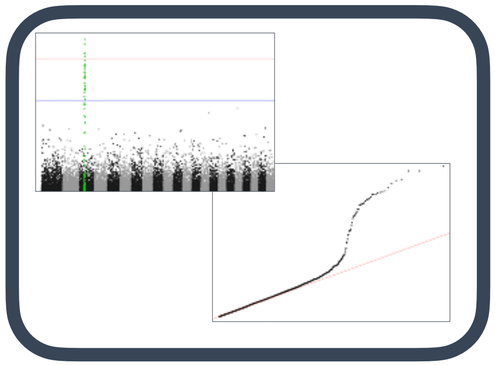
EasyQC: https://www.uni-regensburg.de/medizin/epidemiologie-praeventivmedizin/genetische-epidemiologie/software/

GWAS Data Management & Plots



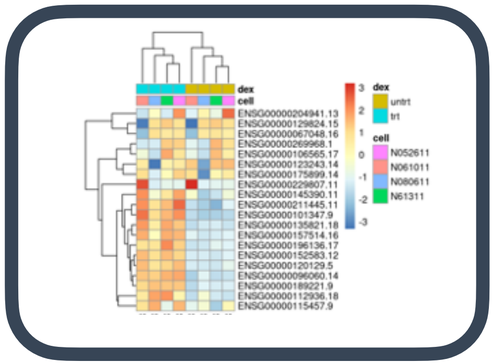
EasyStrata: https://www.uni-regensburg.de/medizin/epidemiologie-praeventivmedizin/genetische-epidemiologie/software/

More Plotting…



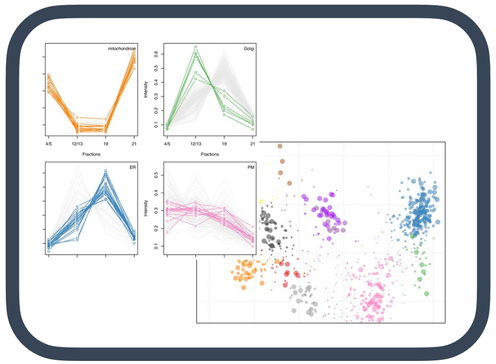
Manhattan and QQ plots: https://cran.r-project.org/web/packages/qqman/vignettes/qqman.html

Gene Expression Analysis



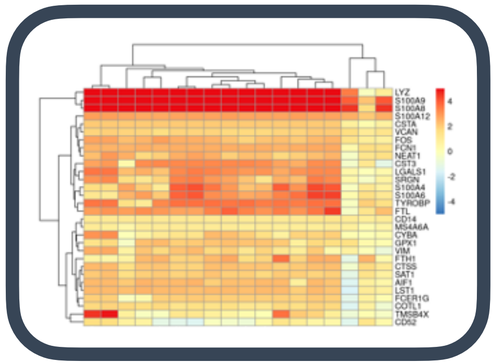
DESeq2, limma, EdgeR, etc.: http://www.bioconductor.org/packages/release/BiocViews.html#___RNASeq

Proteomics Analysis



RforProteomics: http://www.bioconductor.org/packages/release/BiocViews.html#___Proteomics

Single-Cell RNASeq



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

TEASER

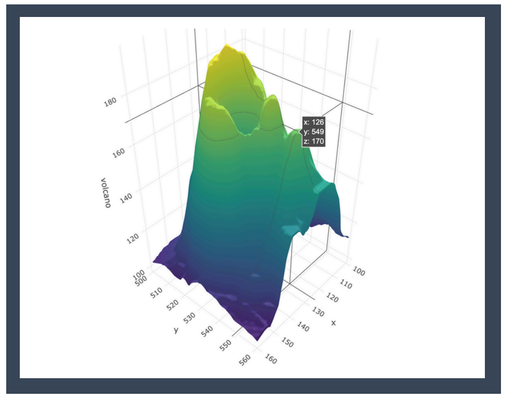
Omics Data

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

FROM EXCEL TO R

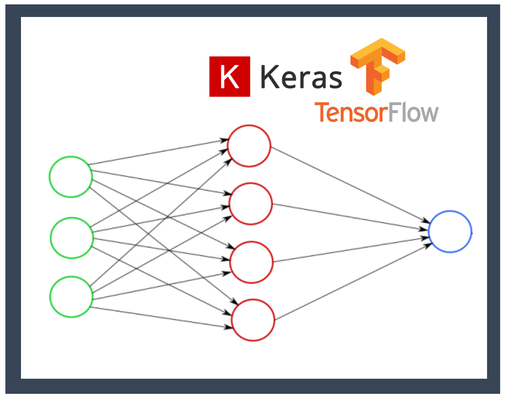
COOL STUFF IN R

PLOTTING IN 3D



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

DEEP LEARNING



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

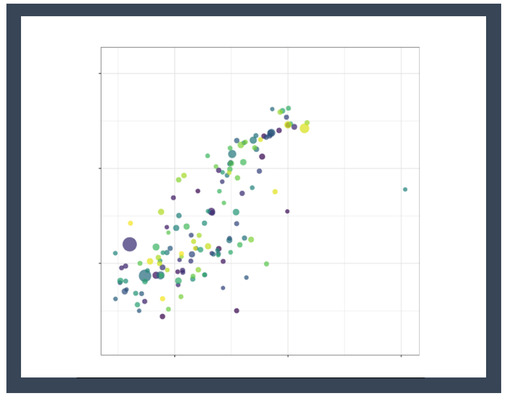
BAYESIAN STATISTICS

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

THANK YOU FOR LISTENING