Welcome!

Please download the course material:

---

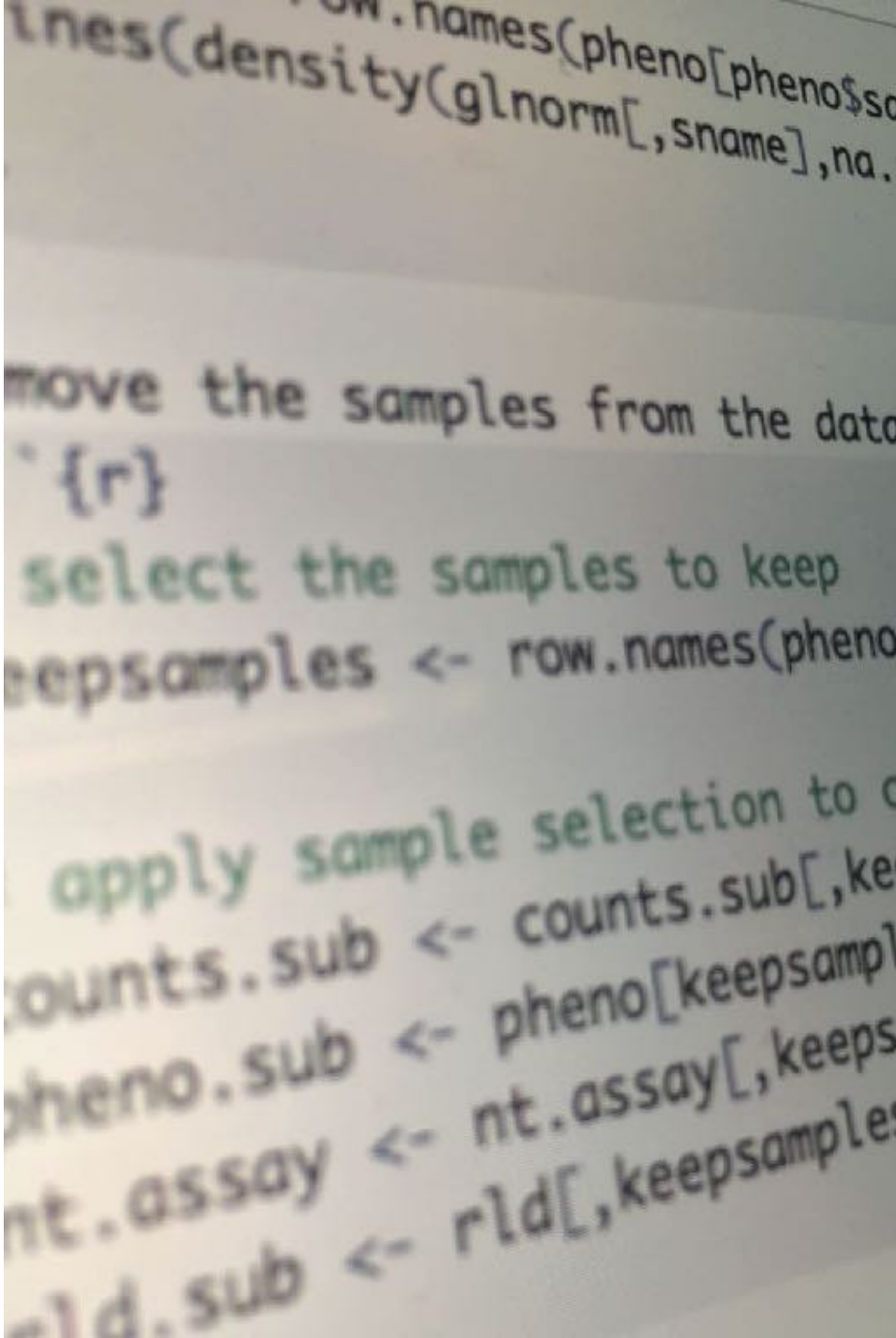
tinyurl.com/introRData >  > 

and store it in a single, accessible folder on your computer.

Introduction to R & data

Outline

- Part I: Basics of R
- Lunch (~12:15)
- Part II: Modern R with tidyverse
- Final remarks (~17:00)



Quick intro: who are you?

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Introduction to R & data

Part 1: Basics of R

What is R?

- Widely used programming language for data analysis
- Based on statistical programming language **S** (1976)
- Developed by **R**oss Ihaka & **R**obert Gentleman (1995)
- Very active community, with many (often subject-specific) packages

We will work in RStudio

- Integrated Development Environment for R
- Founded by JJ Allaire, available since 2010
- Bloody useful! Let’s take a look: please open RStudio!

Have you downloaded the course material?

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R syntax & the RStudio console

Variable assignment

```
>
```

Variable assignment

```
> x <- 1
```

Variable assignment

```
> x <- 1
```

```
> 1 -> x
```

```
> x = 1
```

```
> 1 = x
Error in 1 = x : invalid (do_set) left-hand side to assignment
```

Variable assignment

```
> x <- 6

> hi <- "hello world"

> x * 3
[1] 18

> y <- x + 2

> log2(y)
[1] 3
```

Base R
Cheat Sheet

Maths 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.
`signif(x, n)`	Round to n significant figures.	`var(x)`	The variance.
`cor(x, y)`	Correlation.	`sd(x)`	The standard deviation.

Variable Assignment

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

Creating vectors

```
> 1:5
[1] 1  2  3  4  5
> seq(5)
[1] 1  2  3  4  5
> seq(3,5,by=0.5)
[1] 3.0  3.5  4.0  4.5  5.0
> rep(4,6)
[1] 4 4 4 4 4 4
> c(1,61,101)
[1] 1 61 101
> c(2:4,rep(8,3))
[1] 2 3 4 8 8 8
```

an integer

vs.

a float, or 'floating point'

Vector functions

```
> p <- 1:5
> mean(p)
[1] 3
> p * 2
[1] 2 4 6 8 10
> q <- 5:1
> p * q
[1] 5 8 9 8 5
> sort(p*q)
[1] 5 5 8 8 9
> table(p*q)
5 8 9
2 2 1
```

p * 2

p	2	
1	2	2
2	2	4
3	2	6
4	2	8
5	2	10

p * q

p	q	
1	5	5
2	4	8
3	3	9
4	2	8
5	1	5

Exercise

1. Write a line of code that produces the following vector:

(Note: there are multiple possible answers!)

```
[1]  4 4 4 10 15 20 10 7 4
```

2. Divide the vector by 3. Round up to 1 decimal.

(Hint: check the cheat sheet element ‘Maths Functions’.)

Exercise

1. Write a line of code that produces the following vector:

(Note: there are multiple possible answers!)

```
> c(rep(4,3),seq(10,20,by=5),seq(10,4,by=-3))
[1]  4 4 4 10 15 20 10 7 4
```

2. Divide the vector by 3. Round up to 1 decimal.

(Hint: check the cheat sheet element 'Maths Functions'.)

```
> v <- c(rep(4,3),seq(10,20,by=5),seq(10,4,by=-3))
> round(v/3,1)
[1] 1.3 1.3 1.3 3.3 5.0 6.7 3.3 2.3 1.3
```

Another data type: logical

```
> T
[1] TRUE
> FALSE
[1] FALSE
> 1==1
[1] TRUE
> 3>=5
[1] FALSE
> 2!=4
[1] TRUE
> 6<2
[1] FALSE
> is.logical(FALSE)
[1] TRUE
```

==	is equal to
!=	is not
>=	larger than or equal to
<	smaller than

Vectors and factors

```
> fc <- c("a","b","a","c")
> fc
[1] "a" "b" "a" "c"
> fc <- factor(fc)
> fc
[1] a b a c
Levels: a b c
> fn <- 2:5
> fn
[1] 2 3 4 5
> fn <- factor(fn)
> fn
[1] 2 3 4 5
Levels: 2 3 4 5
> as.numeric(fn)
[1] 1 2 3 4
```

Note that vectors may consist of characters!

A factor is defined by its levels. Turning a factor into numeric specifies the order of the levels, but loses their content.

Exercise

1. Generate a vector that contains numeric, logical, and character elements.

2. Turn it into a factor.

3. See what happens to the content when you convert this factor into numeric, logical, and character vectors.

(Hint: check the cheat sheet element ‘Types’ for the functions.)

Exercise

1. Generate a vector that contains numeric, logical, and character elements.

```
> ft <- c(T,F,2,4,"apple","orange")
```

2. Turn it into a factor.

```
> ft <- factor(ft)
```

3. See what happens to the content when you convert this factor into numeric, logical, and character vectors.

(Hint: check the cheat sheet element 'Types' for the functions.)

```
> as.numeric(ft)
[1] 5 5 1 2 3 4
> as.logical(ft)
[1] TRUE FALSE   NA   NA   NA   NA
> as.character(ft)
[1] "TRUE"   "FALSE"   "2"       "4"       "apple"   "orange"
```

But what if there *is no data?* Introducing: NA

```
> ft <- c(T,F,2,4,"apple","orange")
> ft <- as.logical(ft)
> ft
[1] TRUE FALSE    NA    NA    NA    NA
> factor(ft)
[1] TRUE FALSE <NA> <NA> <NA> <NA>
Levels: TRUE FALSE
```

NA = **N**ot **A**vailable

Name	Age	Pet
Ann	33	Cat
Bob	25	**None**
Chloe	21	Iguana
Dan	45	**NA**

In other words:

We **know** that Bob has **no pets**.

We **do not know** if Dan has pets.

Exercise

```
> a <- NA
> b <- NA
```

Test if a equals b. Before you do: predict what the answer will be.

Exercise

```
> a <- NA
> b <- NA
```

Test if a equals b. Before you do: predict what the answer will be.

```
> a == b
[1] NA
```

NA != NULL

```
> is.na(a)
[1] TRUE

> c <- NULL
> is.null(c)
[1] TRUE
```

`NA` Information is **Not Available**

`NULL` Information **does not exist**

`"None"` Data entry specifying **"None"**

Exercise: try to predict the results!

```
> is.na(NA)
[1] TRUE
> is.null(NULL)
[1] TRUE
```

Predict the results. Does the (real) answer make sense to you?

```
> is.null(NA)

> is.na(NULL)
```

Exercise: try to predict the results!

```
> is.na(NA)
[1] TRUE
> is.null(NULL)
[1] TRUE
```

Predict the results. Does the (real) answer make sense to you?

```
> is.null(NA)
[1] FALSE
> is.na(NULL)
[1] logical(0)
Warning message:
In is.na(NULL) : is.na() applied to non-(list or vector) of
type 'NULL'
```

Selecting vector elements by position

```
> m <- 8:4
> m
[1] 8 7 6 5 4
> m[2]
[1] 7
> m[1:3]
[1] 8 7 6
> m[-(2:4)]
[1] 8 4
```

Selecting vector elements by value

```
> m <- 8:4
> m
[1] 8 7 6 5 4
> m[m>5]
[1] 8 7 6
> m>5
[1] TRUE TRUE TRUE FALSE FALSE
> n <- 5:10
> m[m %in% n]
[1] 8 7 6 5
> m[NA]
[1] NA NA NA NA NA
```

m	m>5	result
8	TRUE	8
7	TRUE	7
6	TRUE	6
5	FALSE	
4	FALSE	

Which bracket does what?

[ ] **Indexing** vectors, lists, dataframes…

( ) Passing **arguments** to functions

{ } **Defining content** of loops, functions, etc.

```
> myvector[length(myvector)]
```

Vectors, lists, and data frames

```
> v1 <- 4:6
> v2 <- rep(3,3)
> v <- c(v1,v2)
> v
[1] 4 5 6 3 3 3
> mylist <- list(v1,v2)
> mylist
[[1]]
[1] 4 5 6

[[2]]
[1] 3 3 3
> df <- data.frame(v1,v2)
> df
  v1 v2
1  4  3
2  5  3
3  6  3
```

	how many dimensions?	function
vector	1	`c()`
list	any number	`list()`
data frame	2	`data.frame()`

Indexing lists

```
> v1 <- 4:6
> v2 <- rep(3,3)
> mylist <- list(v1,v2)
> mylist[1]
[[1]]
[1] 4 5 6
```

```
> mylist[[1]]
[1] 4 5 6
```

Exercise

How would you select the second vector element of the first list-element?

A. `> mylist[1][2]`

B. `> mylist[[1]][2]`

Exercise

How would you select the second vector element of the first list-element?

A.
```
> mylist[1][2]
[[1]]
NULL
```

B.
```
> mylist[[1]][2]
[1] 5
```

Indexing a data frame

```
> name <- c("Ann","Bob","Chloe","Dan")
> age <- c(33,25,21,45)
> df <- data.frame(name,age)
> df
   name  age
1   Ann   33
2   Bob   25
3 Chloe   21
4   Dan   45
```

Indexing a data frame

```
> df$age
[1] 33 25 21 45
> df[,2]
[1] 33 25 21 45
> df[2,]
  name age
2  Bob  25
> df[2,2]
[1] 25
```

Matrix subsetting

df[, 2]

df[2,]

row

column

df[2, 2]

Exercise

Return the names of everyone in your data frame under 30.

Hint: make good use of vectors as part of your index!

Exercise

Return the names of everyone in your data frame under 30.

Hint: make good use of vectors as part of your index!

```
> df[df$age<30,"name"]
```

OR

```
> df[df$age<30,1]
[1] Bob   Chloe
Levels: Ann Bob Chloe Dan
```

Question: what happened to the ‘name’ column?

Let's breathe and recap!

What data types have you encountered so far?

`logical`
`numeric`
`integer`
`character`
`factor`

And what data collections have you encountered?

`vector` (one dimension)
`data frame` (two dimensions)
`list` (++ dimensions)

Functions

What functions have you encountered so far?

```
> c()
> rep()
> seq()
> round()
> sort()
> table()
...
```

And do you still know what they mean? And how to use them? **No?**

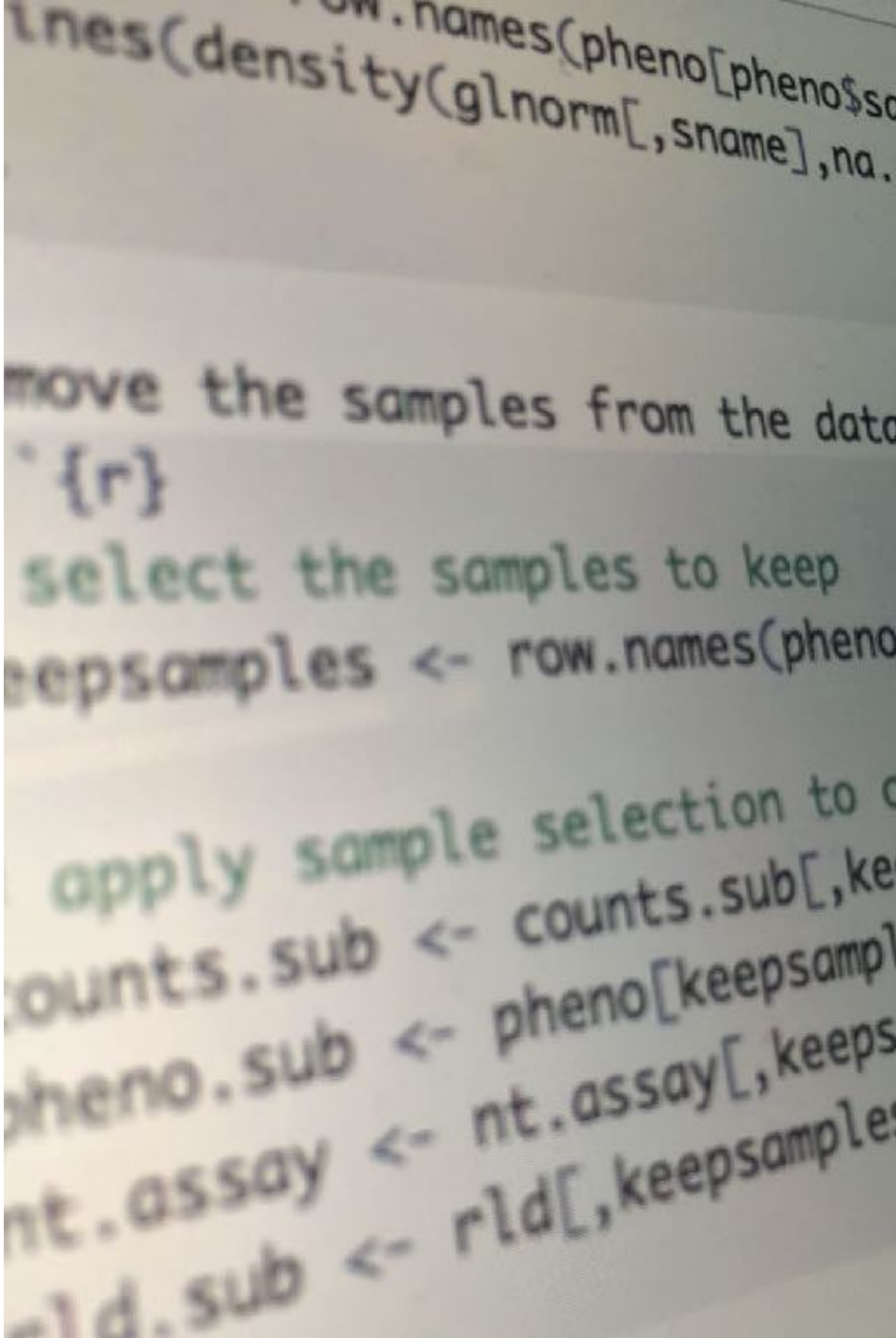
```
> ?table()
> help.search("standard deviation")
```

(or use the Help window to the right of your console)

Take a break!

Ready?

- Writing your first script
- Programming with loops and functions
- Handling and processing a dataset

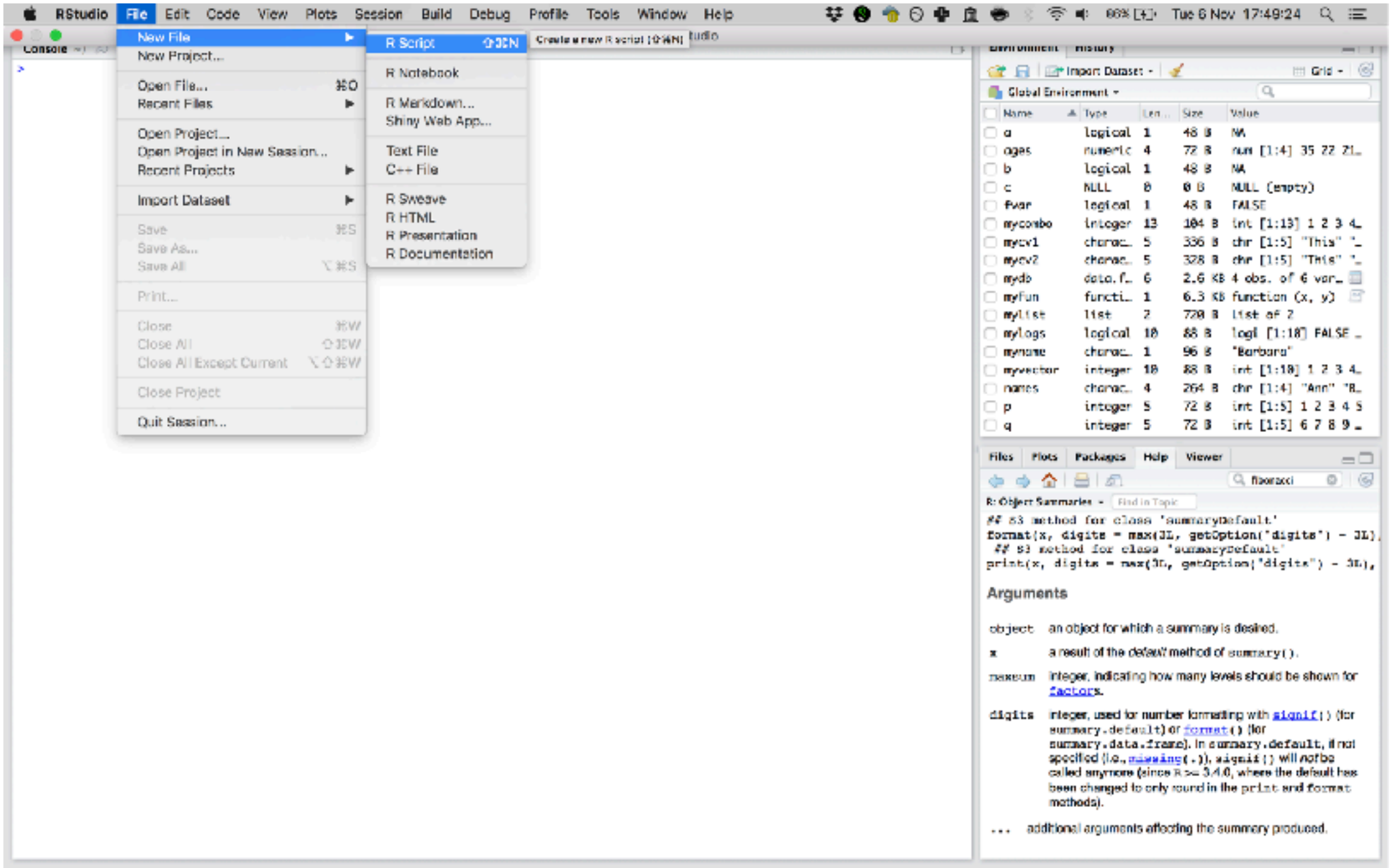


Console and Scripts

Console	Code execution	-
Script	Code	Extension: .R (example_script.R)
Rmarkdown	Code + Narrative	Extension: .Rmd (example_report.Rmd)

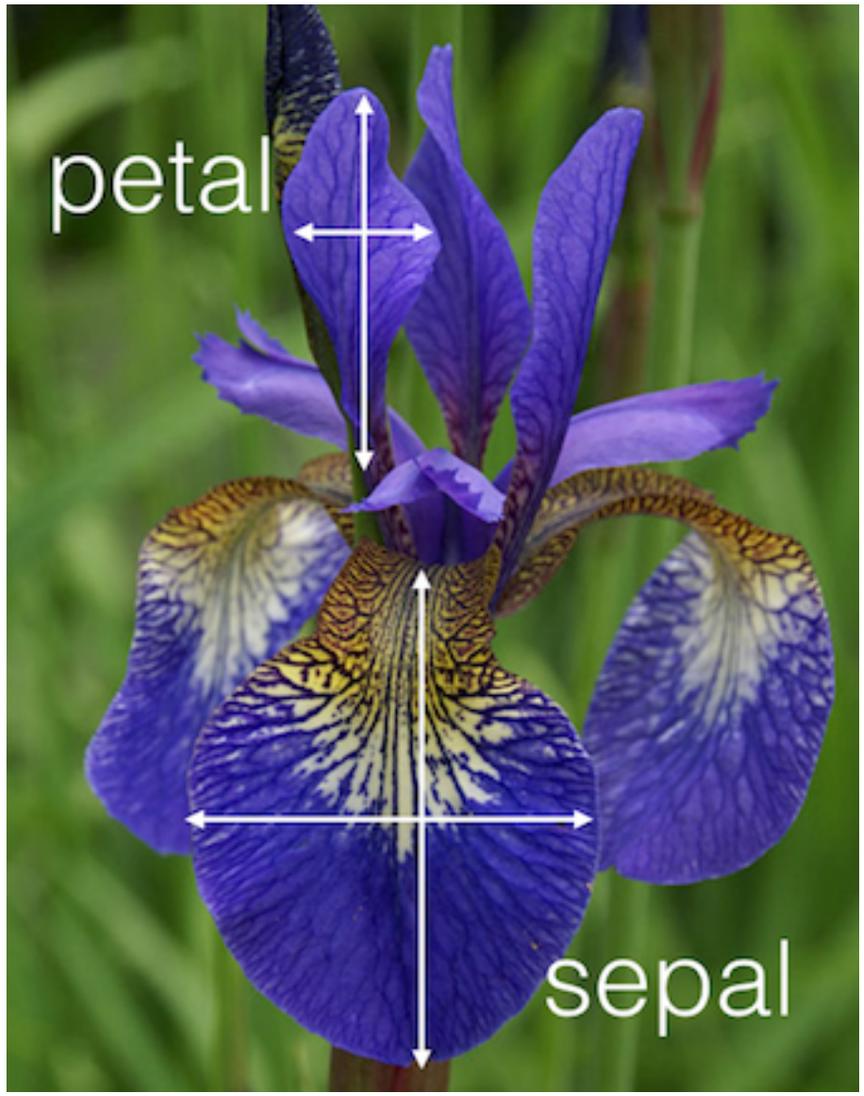
Ready to script?

RStudio > File > New File > R Script



Introducing a sample dataset

- Dataset: ‘iris’
- Standard dataset in R, measurements on 3 species of iris flowers



Introducing a sample dataset

- Dataset: ‘iris’

- Standard dataset in R, measurements on 3 species of iris flowers

```
> head(iris)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width          Species
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100   setosa     :50
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300   versicolor:50
 Median :5.800   Median :3.000   Median :4.350   Median :1.300   virginica :50
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
```

Selecting data

 # indicates comment
computer stops reading
(but you should not!)

```
# Let's select from the data frame only those rows
# which are 'setosa' species:
iris.setosa <- iris[iris$Species=="setosa",]

# How many are there?
# Let's check the dimensions of the original data set
dim(iris)
[1] 150   5

# And the new data set
dim(iris.setosa)
[1] 50   5
```

Maths functions on selected data

```
# What is the mean sepal width of setosa flowers?
set.SW.mean <- mean(iris.setosa$Sepal.Width)

# And what is the standard deviation?
set.SW.sd <- sd(iris.setosa$Sepal.Width)

# What is the minimum petal width of virginica flowers?
vir.PW.min <- min(iris$Petal.Width[iris$Species==“virginica”])
```

Exercise

Exercise: make a new data set that contains **only petals that are longer** than the **average versicolor** petal length.

Hint: work stepwise!

Exercise

Exercise: make a new data set that contains **only petals that are longer** than the **average versicolor** petal length.

Hint: work stepwise!

```
# What is the average versicolor petal length?
# First, select only versicolor petals


# Then calculate the mean


# Select from the main dataset
```

Exercise

Exercise: make a new data set that contains **only petals that are longer** than the **average versicolor** petal length.

Hint: work stepwise!

```
# What is the average versicolor petal length?
# First, select only versicolor petals
ver.PL <- iris[iris$Species==“versicolor","Petal.Length"]

# Then calculate the mean
ver.PL.mean <- mean(ver.PL)

# Select from the main dataset
iris.largepetals <- iris[iris$Petal.Length>ver.PL.mean,]
```

Programming: if statement

```
# Determine whether the mean setosa sepal width is large
if(set.SW.mean>3){
  print("Sepal width is large.")
} else{
  print("Sepal width is small.")
}
```

Programming: for loop

```
# Iterate over 10 values
for(i in 1:10){
  print(i)
}
```

```
[1] 1
[1] 2
[1] 3
[1] 4
[1] 5
[1] 6
[1] 7
[1] 8
[1] 9
[1] 10
```

Programming: for loop

```
j <- 0

# Iterate over 10 values
for(i in 1:10){
  j = j + i
}
```

```
> j
[1] 55
```

Exercise: combine if statement and for loop

Design a for loop that **iterates from 1-10**, and determines for each value whether it is **larger than the mean sepal width** of the entire iris dataset.

Let the loop print both **the value**, and the **information that it is larger (or not)** than the mean sepal width. *(For extra oomph: check out the function* `paste()`*.)*

Exercise: combine if statement and for loop

Design a for loop that **iterates from 1-10**, and determines for each value whether it is **larger than the mean sepal width** of the entire iris dataset.

Let the loop print both **the value**, and the **information that it is larger (or not)** than the mean sepal width. *(For extra oomph: check out the function* `paste()`*.)*

```
# define mean sepal width
SW.mean <- mean(iris$Sepal.Width)

for(i in 1:10){ # iterate from 1-10
  if(i > SW.mean){ # test if the value > mean sepal width
    print(paste(i, "is larger than the mean sepal width",
collapse=" “))
  } else{
    print(paste(i, "is not yet larger than the mean sepal
width", collapse=" "))
  }
}
```

Programming: functions

```
myFun <- function(x){
  return(x)
}
```

```
> myFun(1)
[1] 1
```

Programming: functions

```
myFun <- function(x){
  x <- x*20
  return(x)
}

> myFun(1)
[1] 20
```

Programming: functions

```
myFun <- function(x,y){
   z <- x*y
   return(z)
}

> myFun(2,4)
[1] 8
```

Exercise

Write a function that takes two arguments, and returns a vector with 2x the first argument, and 4x the second argument.

E.g.:

```
> myFun(3,6)
[1] 3 3 6 6 6 6
```

Exercise

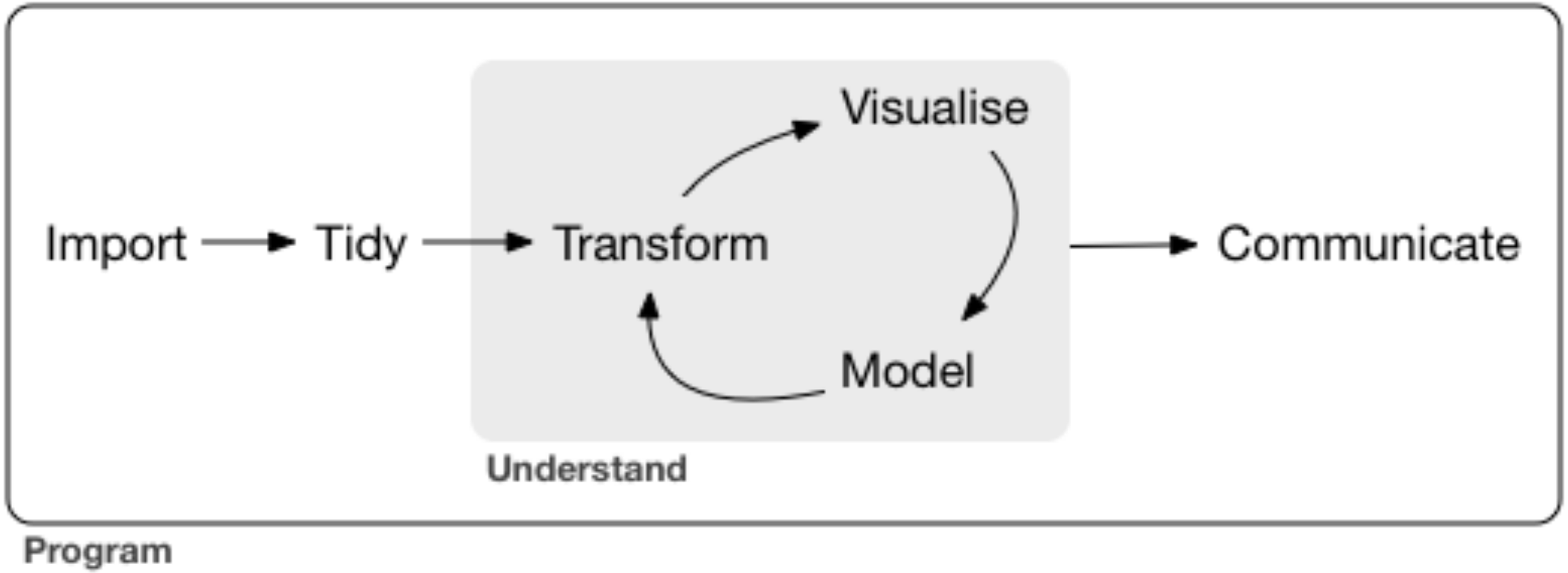
Write a function that takes two arguments, and returns a vector with 2x the first argument, and 4x the second argument.

```
myFun <- function(x,y){
  z <- c(rep(x,2),rep(y,4))
  return(z)
}

> myFun(3,6)
[1] 3 3 6 6 6 6
```

Data science workflow: scripting is crucial

- Scripting combines commands to a comprehensive set of instructions.
- A script is code that can be **saved, reused, shared, published**!
- In short: a crucial step towards reproducible data analysis.



a single script for a single purpose!

Starting the script: write a header

```
## Date: 7 November 2018
## Author: Barbara Vreede
## This script was written as part of the R course
## "Introduction to R & Data", at Utrecht University
```

Load packages and dependencies

```
## Date: 7 November 2018
## Author: Barbara Vreede
## This script was written as part of the R course
## "Introduction to R & Data", at Utrecht University

# Load required packages
library(dplyr)
library(tidyr)
library(ggplot2)
```

Custom functions

```
## Date: 7 November 2018
## Author: Barbara Vreede
## This script was written as part of the R course
## "Introduction to R & Data", at Utrecht University

# Load required packages
library(dplyr)
library(tidyr)
library(ggplot2)

# Functions
myFun <- function(var){
  var <- var*2*pi
  return(var)
}
```

Starting your script: header, packages, functions

```
## Date: 7 November 2018
## Author: Barbara Vreede
## This script was written as part of the R course
## "Introduction to R & Data", at Utrecht University
```

```
# Load required packages
library(dplyr)
library(tidyr)
library(ggplot2)
```

```
# Functions
myFun <- function(var){
  var <- var*2*pi
  return(var)
}
```

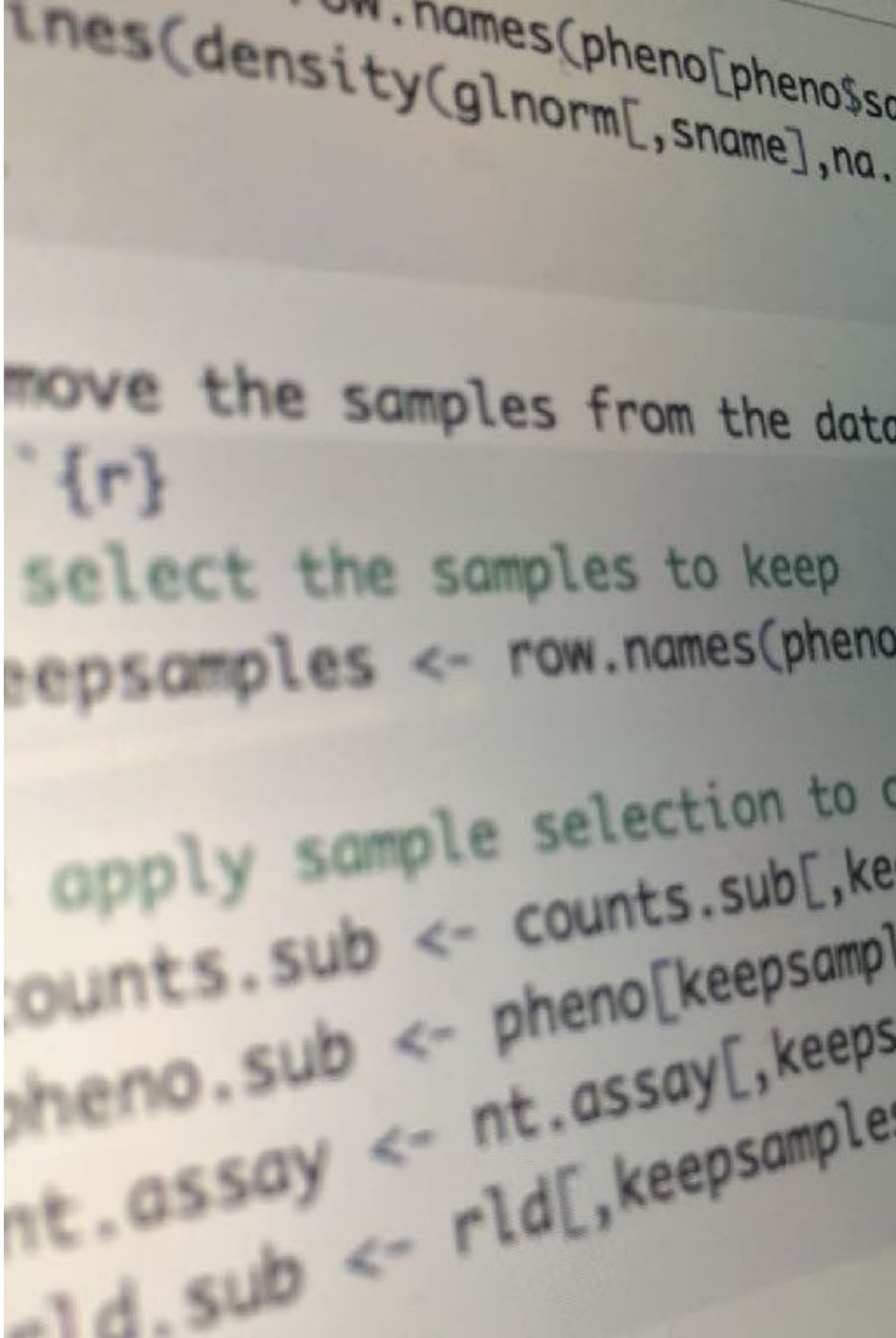
Enjoy your lunch!

Introduction to R & data

Part II: Modern R with tidyverse

Outline part II

- Load and save data with **readr**
- [break]
- Data visualisation with **ggplot**
- [break]
- Data transformation with **tidyr** and **dplyr**



Your afternoon roadmap

- A short explanation on screen (~15 minutes)
- Exercises in a document on your computer (~45 minutes)
  - 2-3 basic exercises
  - optional exercises, for further practice
  - reading exercises, for some extra insight into Tidyverse
- We will work with a new data set
- The exercises are presented in Rmarkdown format. Explained later.

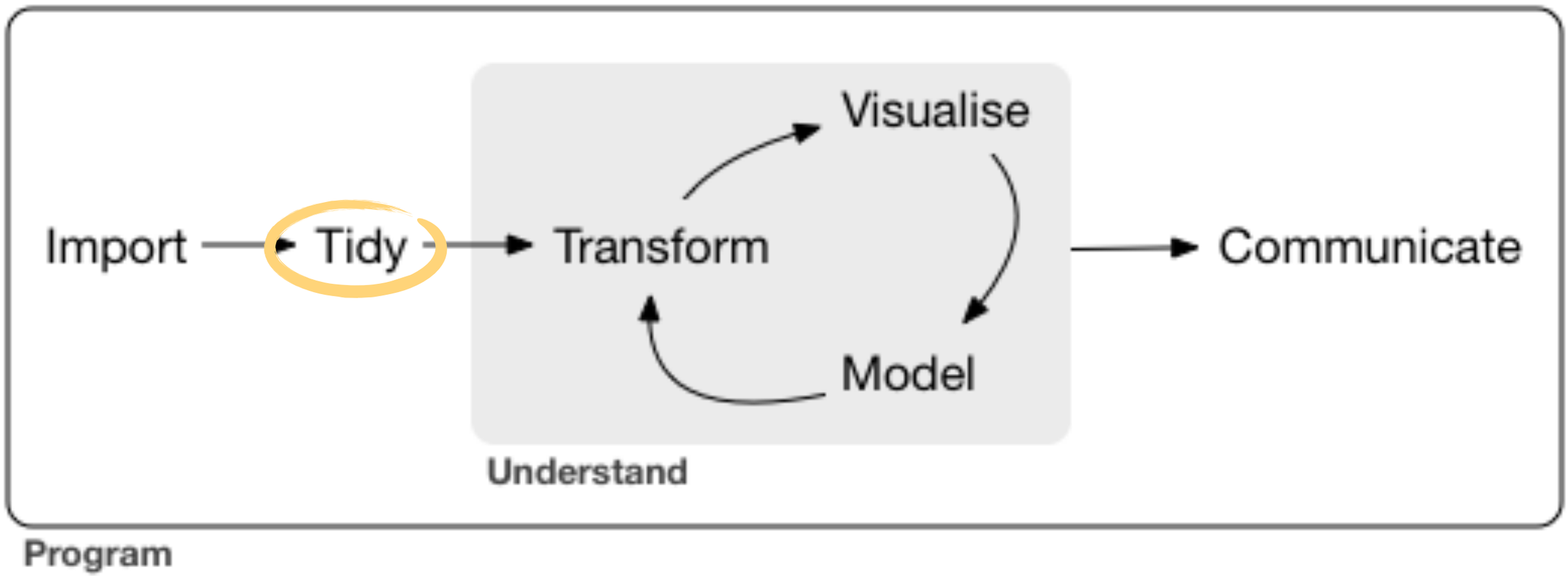
Tidyverse

Modern R for data science

"The tidyverse is an opinionated collection of R packages designed for data science. All packages share an underlying design philosophy, grammar, and data structures."

– tidyverse.org (2018)

Data science workflow



Tidy data ensures that further processing can be done efficiently, and reproducibly.

Tidy data is easy to manipulate, model, and visualize.

Tidy data

- Each **variable** is a column and contains **values**
- Each **observation** is a row
- Each type of **observational unit** forms a table

values in column names

Patient	BP	Med_A	BP_after_A	Med_B	BP_after_B
122030	120-82	300	119_85	NA	NA
122021	131-91	NA	NA	85	125_90
124500	118-86	300	119_70	NA	NA
126098	99-67			100	110_71

multiple data points in a single cell

Tidy data

- Each **variable** is a column and contains **values**
- Each **observation** is a row
- Each type of **observational unit** forms a table

Patient	Sys	Dia	Treatment	Sys_after	Dia_after
122030	120	82	A	119	85
122021	131	91	B	125	90
124500	118	86	A	119	70
126098	99	67	B	110	71

Load tidyverse

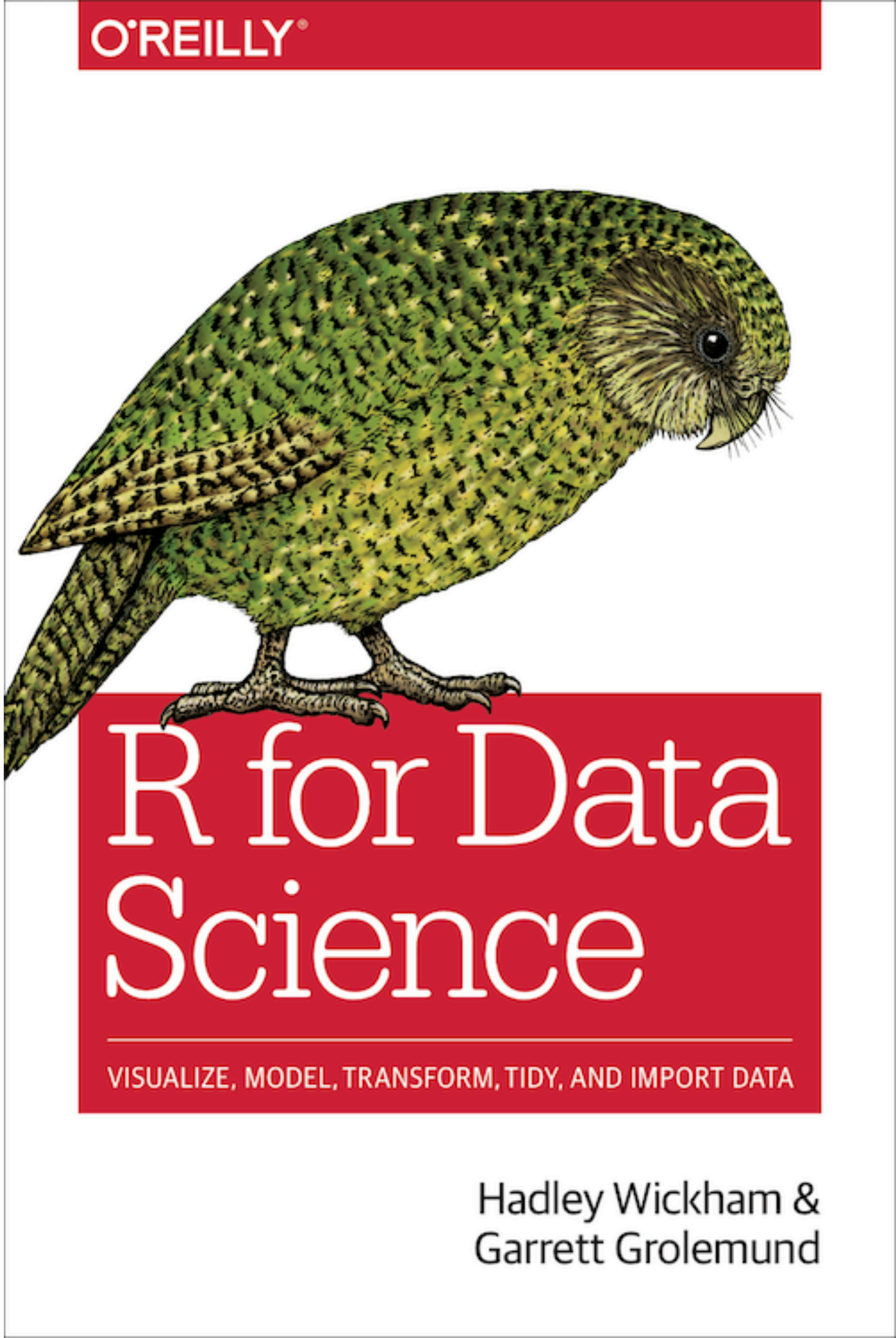
```
> library(tidyverse)
```

Load tidyverse

```
> library(tidyverse)
── Attaching packages ─────────────────────────────────────
tidyverse 1.2.1 ──
✔ ggplot2 2.2.1     ✔ purrr   0.2.4
✔ tibble  1.4.2     ✔ dplyr   0.7.4
✔ tidyr   0.8.0     ✔ stringr 1.3.1
✔ readr   1.1.1     ✔ forcats 0.3.0
── Conflicts ────────────────────────────────────────────────
tidyverse_conflicts() ──
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag()    masks stats::lag()
```

Learn tidyverse

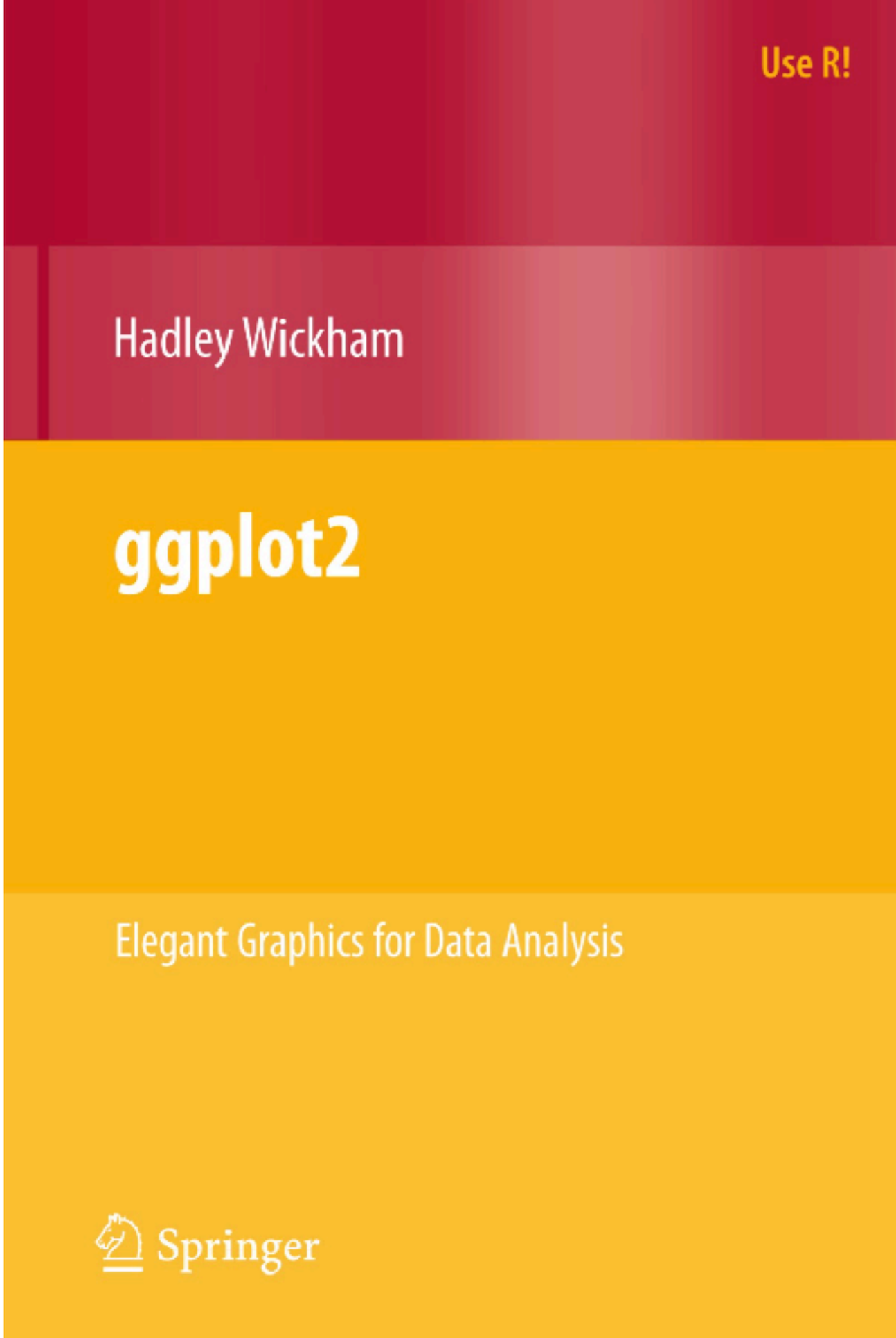
- R for Data Science (book)
  Freely available on:
  [r4ds.had.co.nz/](r4ds.had.co.nz/)



Learn tidyverse

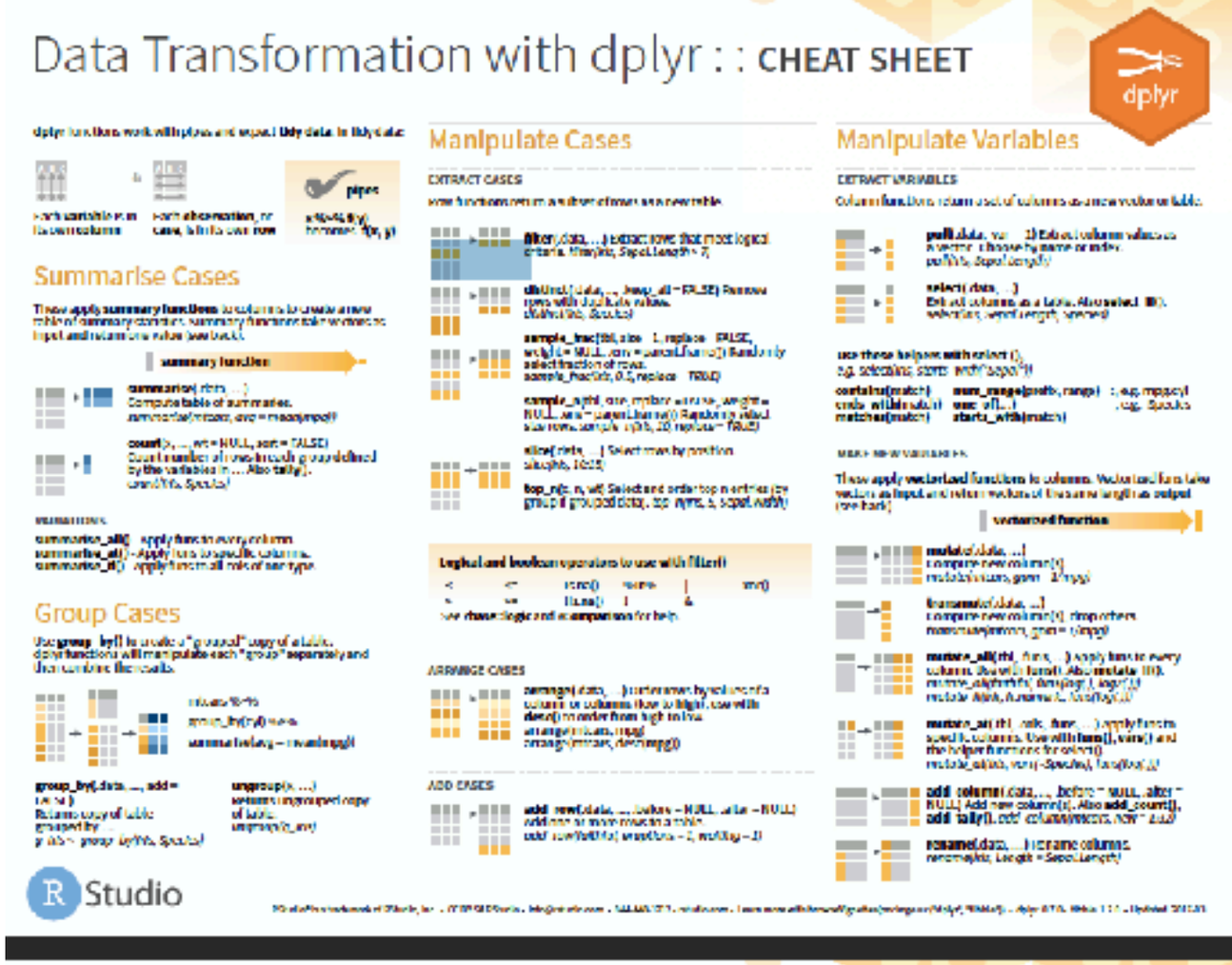
- R for Data Science (book)
  Freely available on:
  [r4ds.had.co.nz/](r4ds.had.co.nz/)

- ggplot2 (book)



Learn tidyverse

- R for Data Science (book)
  Freely available on:
  [r4ds.had.co.nz/](r4ds.had.co.nz/)
- ggplot2 (book)
- cheatsheets
  www.rstudio.com/resources/cheatsheets/



From code to document

Turn your analyses into high quality documents with Rmarkdown

R Markdown

- **Combine code with narrative (R with markdown)**

- Turn your analyses into high quality documents, reports, presentations and dashboards.

- … or your note book.

- Rmarkdown is different from a R script

- Rmarkdown files have file extension **.Rmd** (R scripts have extension **.R**)

Console, Scripts and Rmarkdown

Console	Code execution	-
Script	Code	Extension: .R (example_script.R)
Rmarkdown	Code + Narrative	Extension: .Rmd (example_report.Rmd)

Markdown

```
# title

Some text about your project

## Section

More text about your project

```{r}
max(iris$Petal.Length)
min(iris@Petal.Length
```
```

Exercise: open the exercise Rmarkdown

1. RStudio > File > Open Project > introduction-to-R-and-data-github.Rproj

2. From the ‘files’ menu (bottom right), select modernR_exercises.Rmd

package: Tibble

Improved data frames

"Tibbles are data frames, but they tweak some older behaviours to make life a little easier."

– Hadley Wickham (creator of Tidyverse)

Tibbles

```
> tibble(a = 1:26, b = letters)
# A tibble: 26 x 2
       a b
   <int> <chr>
 1     1 a
 2     2 b
 3     3 c
 4     4 d
 5     5 e
 6     6 f
 7     7 g
 8     8 h
 9     9 i
10    10 j
# ... with 16 more rows
```

Tibbles: from data.frame to tibble

```
> as_tibble(iris)
# A tibble: 150 x 5
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
          <dbl>       <dbl>        <dbl>       <dbl> <fct>
 1          5.10        3.50         1.40       0.200 setosa
 2          4.90        3.00         1.40       0.200 setosa
 3          4.70        3.20         1.30       0.200 setosa
 4          4.60        3.10         1.50       0.200 setosa
 5          5.00        3.60         1.40       0.200 setosa
 6          5.40        3.90         1.70       0.400 setosa
 7          4.60        3.40         1.40       0.300 setosa
 8          5.00        3.40         1.50       0.200 setosa
 9          4.40        2.90         1.40       0.200 setosa
10          4.90        3.10         1.50       0.100 setosa
# ... with 140 more rows
```

Tibbles: from tibble to data.frame

```
> iris_tibble <- as_tibble(iris)
> as.data.frame(iris_tibble)
    Sepal.Length Sepal.Width Petal.Length Petal.Width
Species
1            5.1         3.5          1.4         0.2
setosa
2            4.9         3.0          1.4         0.2
setosa
3            4.7         3.2          1.3         0.2
setosa
4            4.6         3.1          1.5         0.2
setosa
5            5.0         3.6          1.4         0.2
setosa
6            5.4         3.9          1.7         0.4
setosa
```

Load and save data

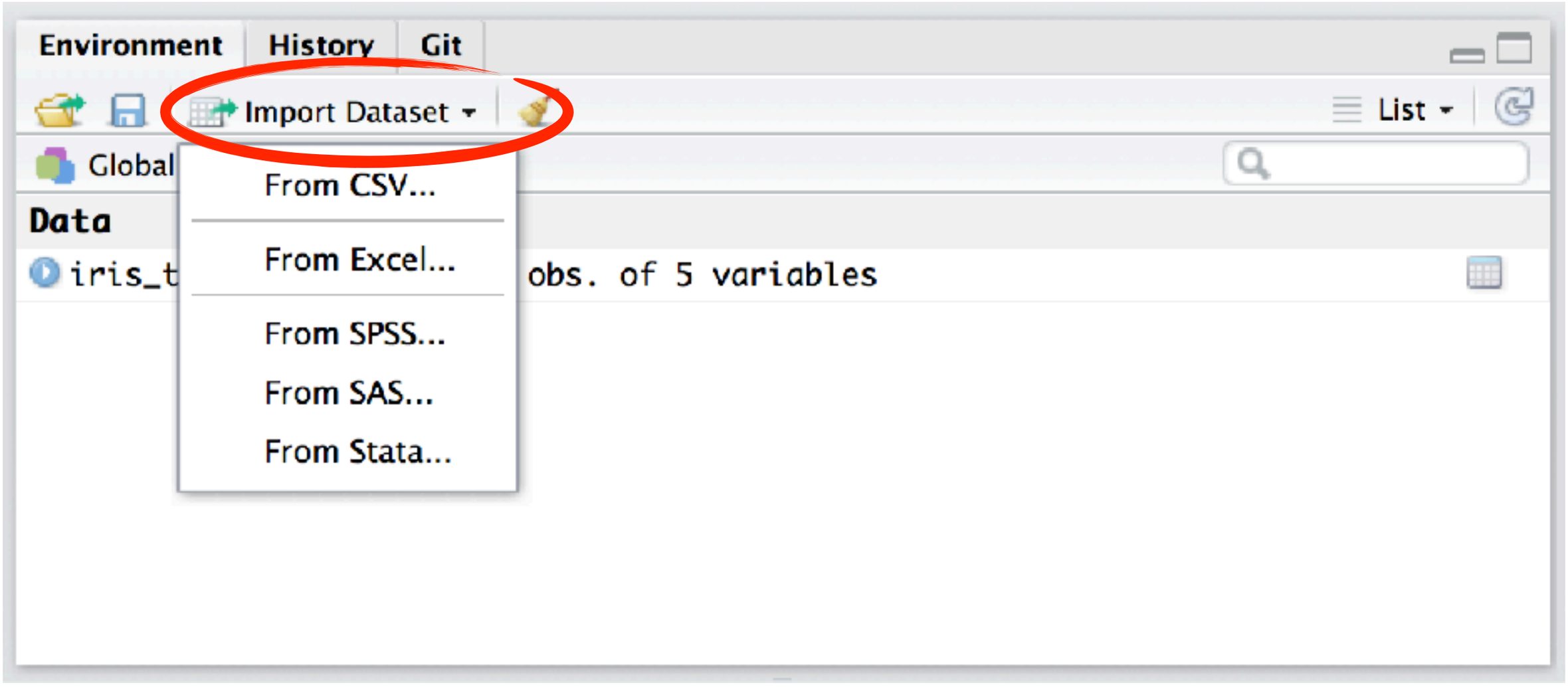
The basics of readr

Flat data files

- Most common format: Comma-separated values (CSV)
- Delimiter-separated values (also stored as CSV)
- Common delimiters:
  - comma ,
  - semicolon ;
  - tab \t

```
mpg;cyl;disp;hp;drat;wt;qsec;v
21;6;160;110;3.9;2.62;16.46;0;
21;6;160;110;3.9;2.875;17.02;0
22.8;4;108;93;3.85;2.32;18.61;
21.4;6;258;110;3.08;3.215;19.4
18.7;8;360;175;3.15;3.44;17.02
18.1;6;225;105;2.76;3.46;20.22
14.3;8;360;245;3.21;3.57;15.84
24.4;4;146.7;62;3.69;3.19;20;1
22.8;4;140.8;95;3.92;3.15;22.9
19.2;6;167.6;123;3.92;3.44;18.
17.8;6;167.6;123;3.92;3.44;18.
16.4;8;275.8;180;3.07;4.07;17.
17.3;8;275.8;180;3.07;3.73;17.
15.2;8;275.8;180;3.07;3.78;18;
10.4;8;472;205;2.93;5.25;17.98
10.4;8;460;215;3;5.424;17.82;0
14.7;8;440;230;3.23;5.345;17.4
32.4;4;78.7;66;4.08;2.2;19.47;
30.4;4;75.7;52;4.93;1.615;18.5
33.9;4;71.1;65;4.22;1.835;19.9
21.5;4;120.1;97;3.7;2.465;20.0
```

Load data by using buttons



Load data by using buttons

Import Text Data

File/Url:

~/surfdrive/Projects/presentations/workshops/introduction-to-R-and-data-github/data/iris.csv

Browse...

Data Preview:

Sepal.Length (double)	Sepal.Width (double)	Petal.Length (double)	Petal.Width (double)	Species (character)
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.0	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa
5.4	3.7	1.5	0.2	setosa

Previewing first 50 entries.

Import Options:

Name: iris

Skip: 0

First Row as Names

Trim Spaces

Open Data Viewer

Delimiter: Comma

Quotes: Default

Locale: Configure...

Escape: None

Comment: Default

NA: Default

Code Preview:

```
library(readr)
iris <- read_csv("~/surfdrive/Projects/presentations/workshops/introduction-to-R-and-data-github/data/iris.csv")
View(iris)
```

Import

Cancel

Read flat files

```
> library(readr)
> data_iris <- read_delim("data/iris.csv", delim=',')
```

Read flat files

```
> library(readr)
> data_iris <- read_delim("data/iris.csv", delim=',')
Parsed with column specification:
cols(
  Sepal.Length = col_double(),
  Sepal.Width = col_double(),
  Petal.Length = col_double(),
  Petal.Width = col_double(),
  Species = col_character()
)
```

Read flat files

```
> library(readr)
> data_iris <- read_csv("data/iris.csv")
Parsed with column specification:
cols(
  Sepal.Length = col_double(),
  Sepal.Width = col_double(),
  Petal.Length = col_double(),
  Petal.Width = col_double(),
  Species = col_character()
)
```

Exercises

Please do Basic exercises 1.1 and 1.2

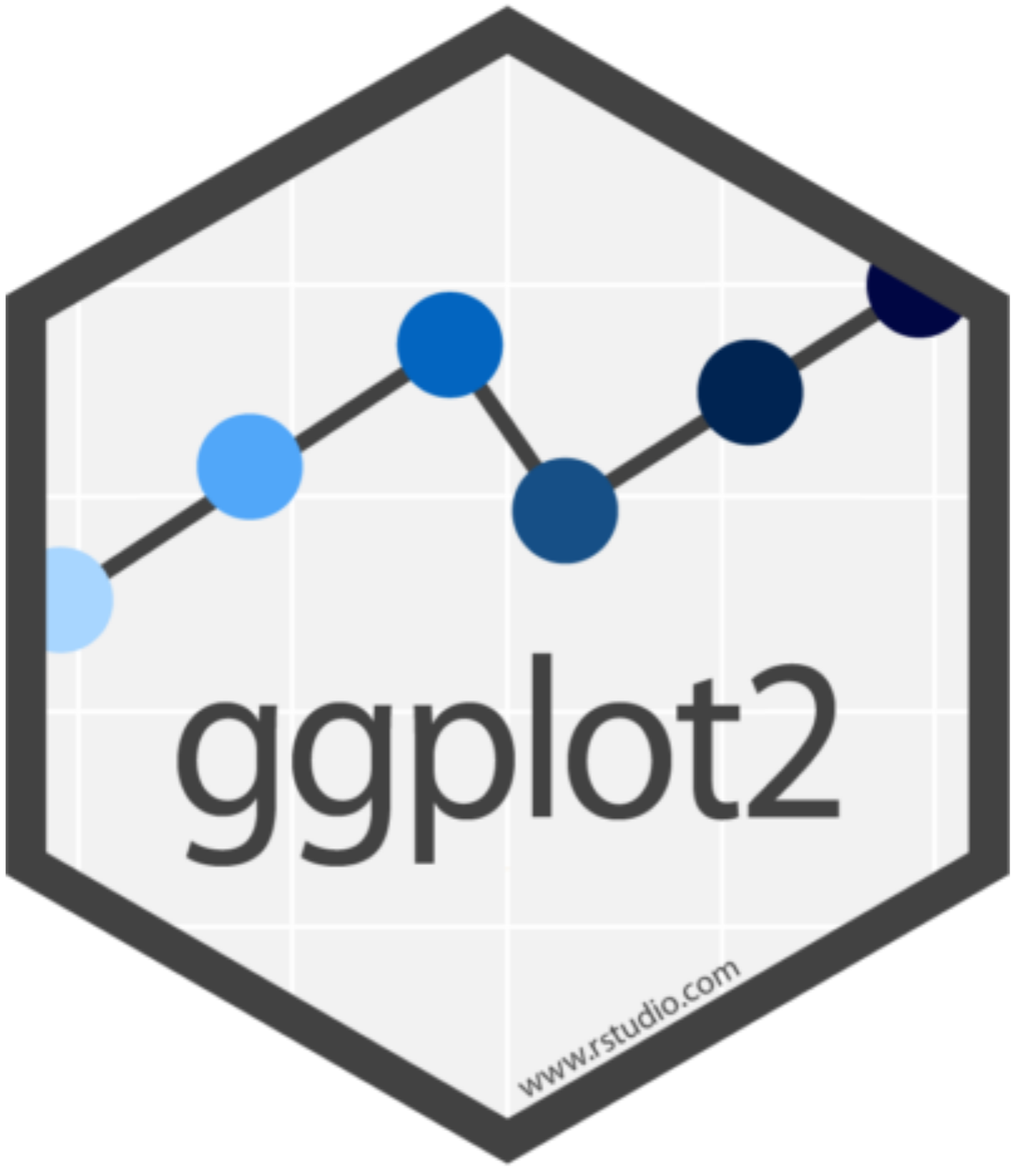
Time left? Opt for a reading exercise or optional exercise!

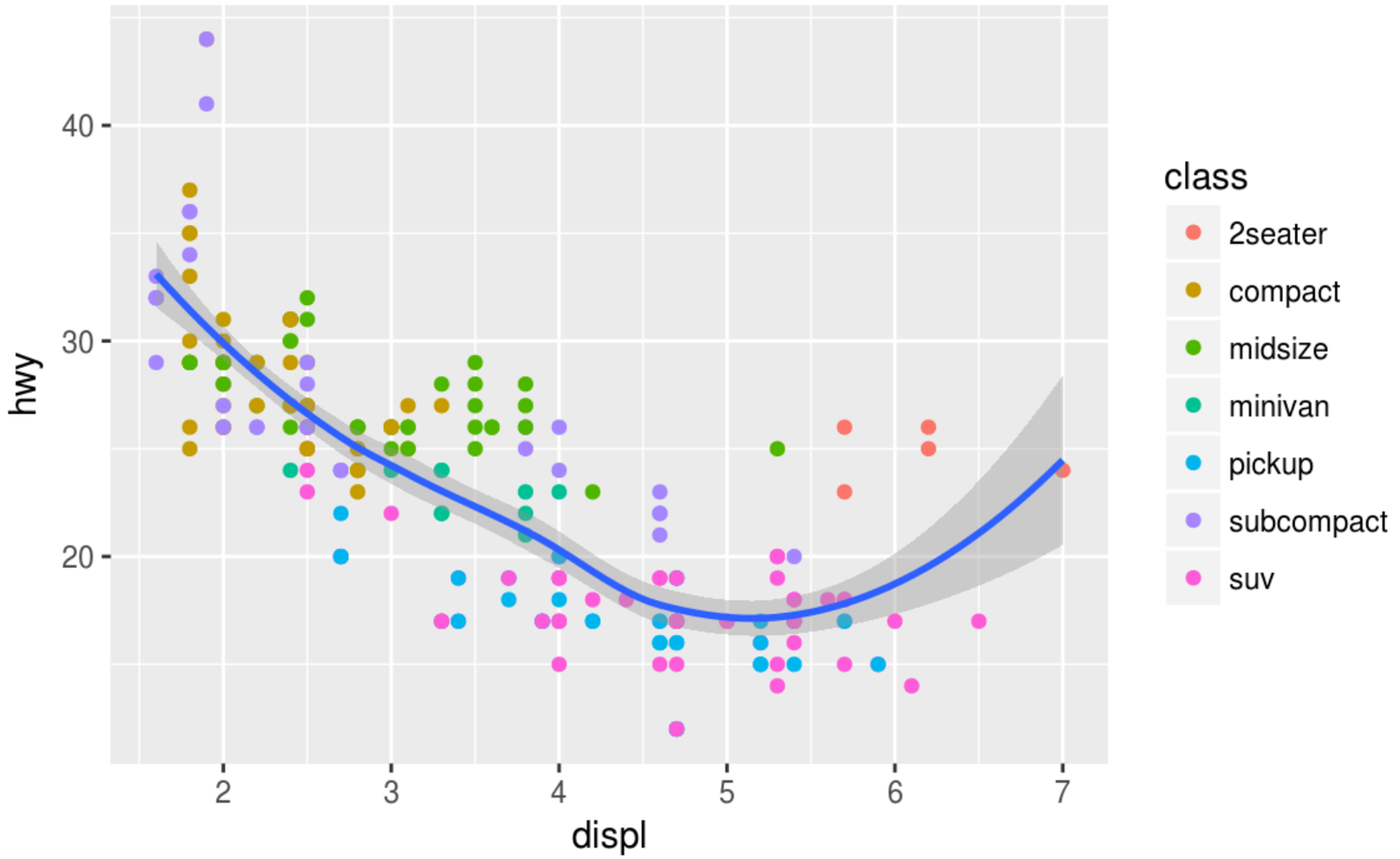
Exercise dataset

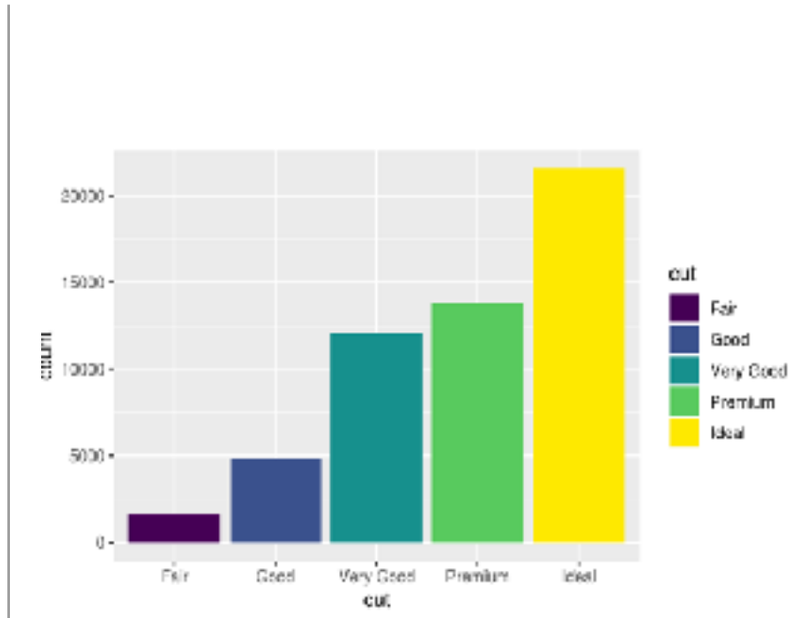
- GPS data from 39 tagged individual cranes during fall migration of 2017
- Courtesy of Sasha Pekarsky at the Hebrew University of Jerusalem, Israel
- In the ‘data’ folder of your course materials.

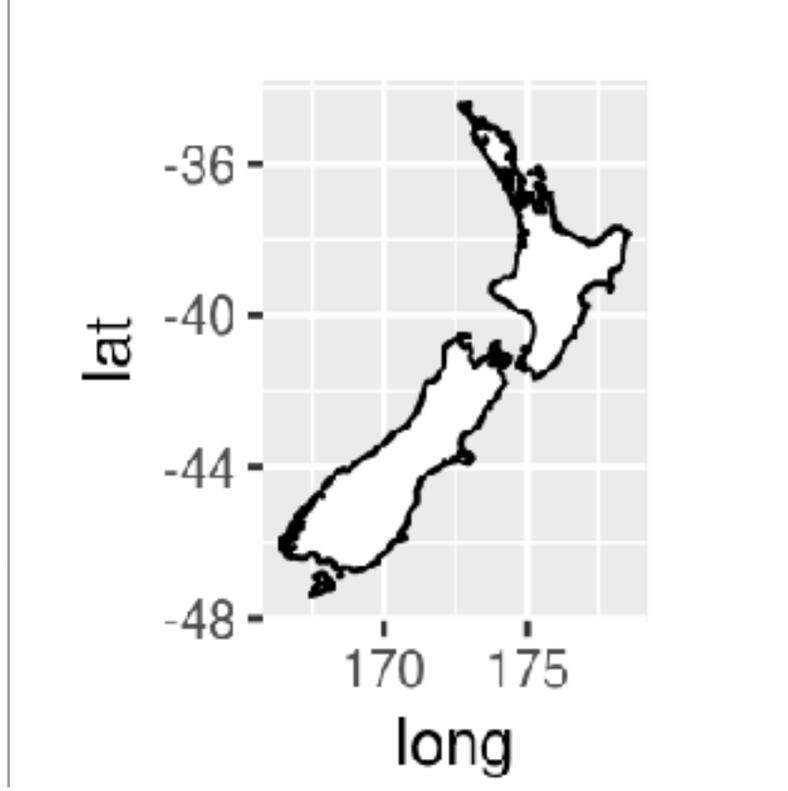
Data visualisation

Create eye candy with ggplot2







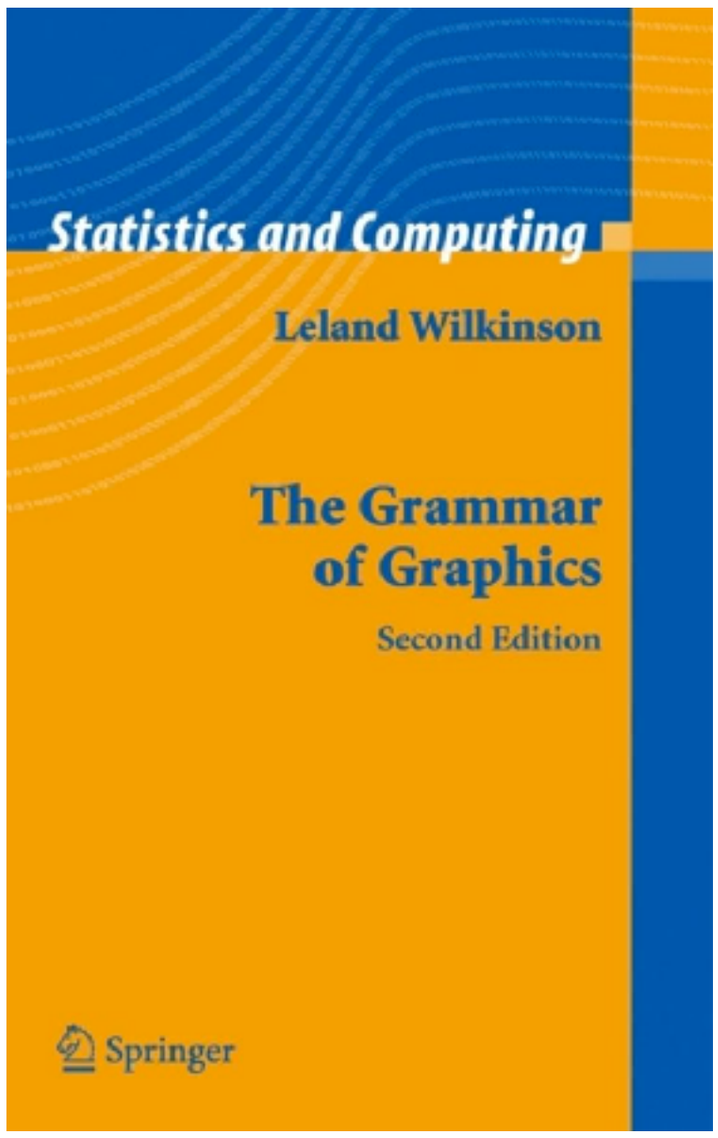


Examples of plots with R (and ggplot2)

Data visualisation with ggplot2

- **ggplot2** is an extremely popular data visualisation package for R
- Simple syntax, easy to learn, nice plots
- Developed and maintained by Hadley Wickham
- Based on the book: The Grammar of Graphics (Wilkinson, 2005)

The grammar of graphics



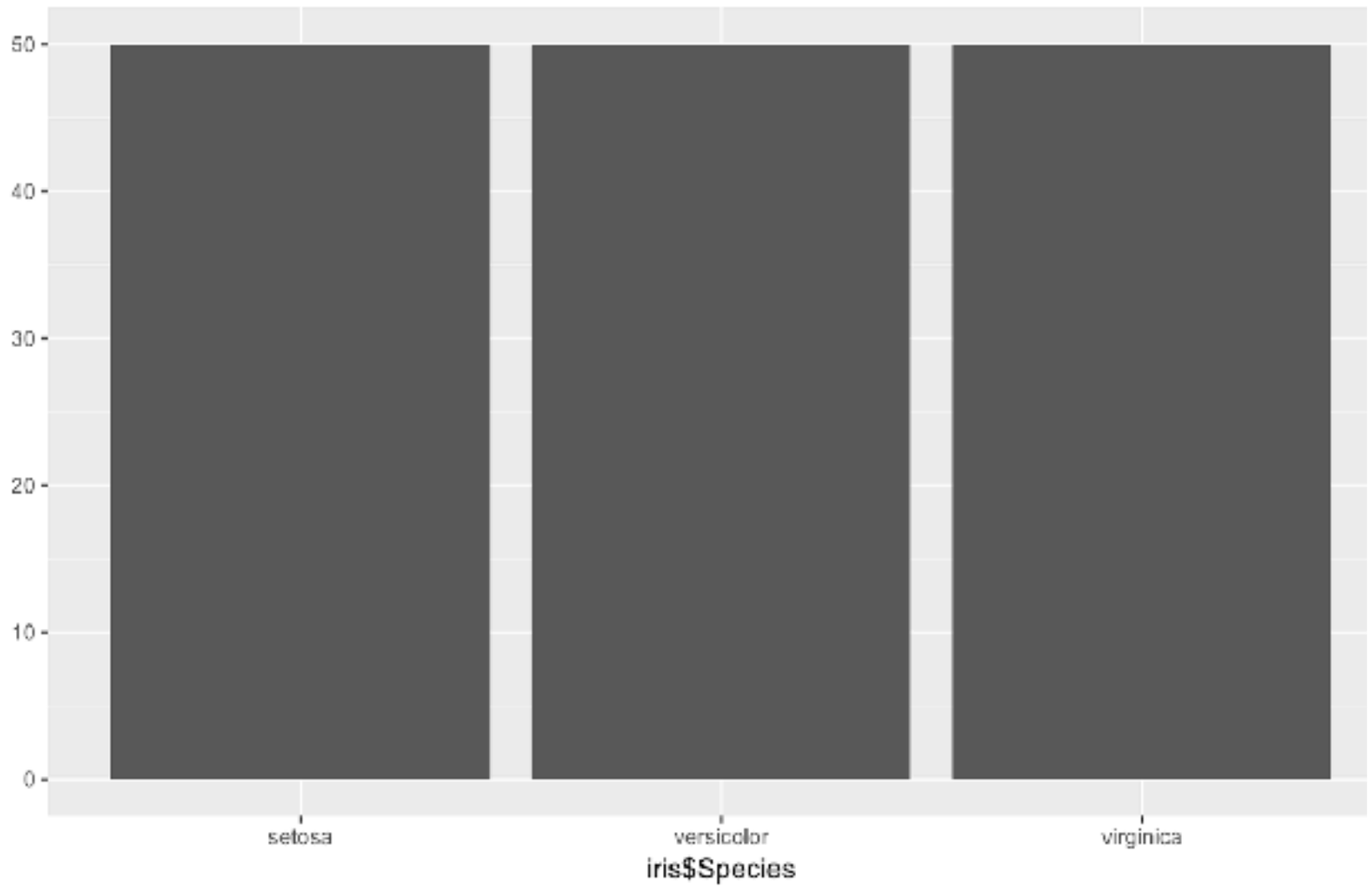
Data	The variables in a tibble or data.frame
Aesthetics	x- and y-axis, colour, size, alpha, shape
Geometries	point, line, bar, histogram

Source: https://www.youtube.com/watch?v=uiTc55clwuA

Quick plotting

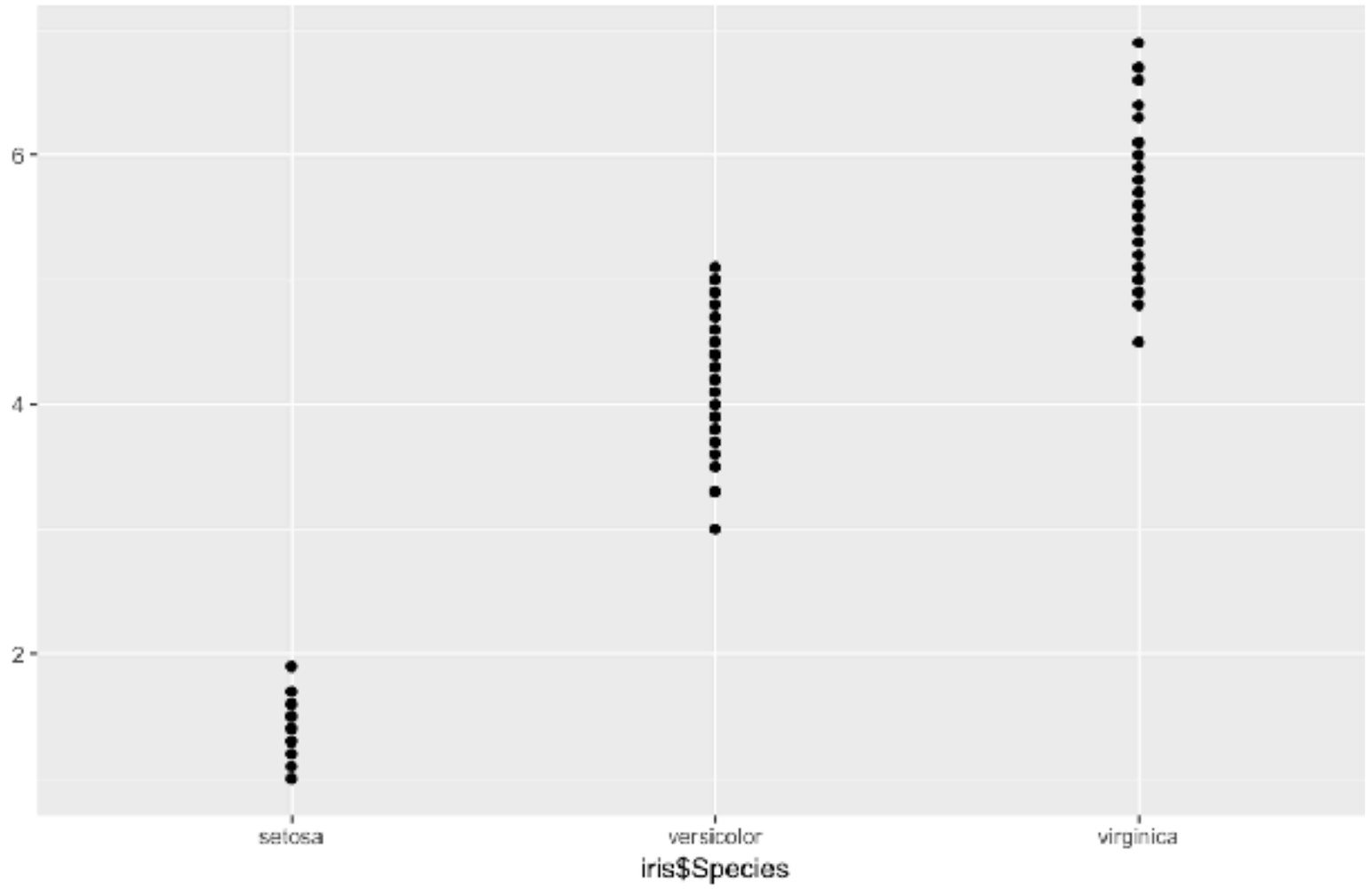
Quick plots

```
> qplot(Species, data = iris)
```



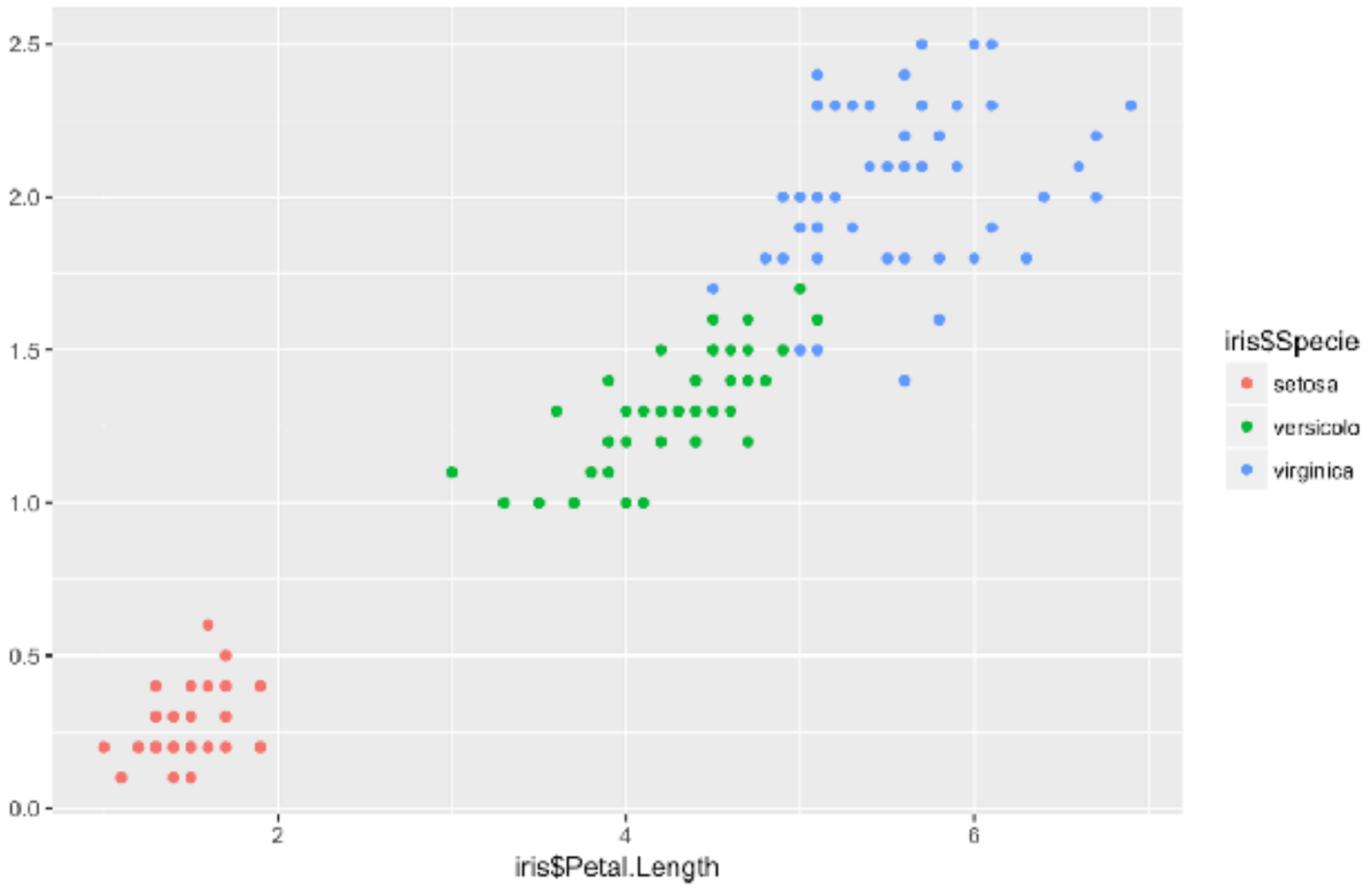
Quick plots

```
> qplot(Species, data = iris)
> qplot(Species, Petal.Length, data = iris)
```



Quick plots

```
> qplot(Species, data = iris)
> qplot(Species, Petal.Length, data = iris)
> qplot(Petal.Length, Petal.Width, data = iris, colour=Species)
```



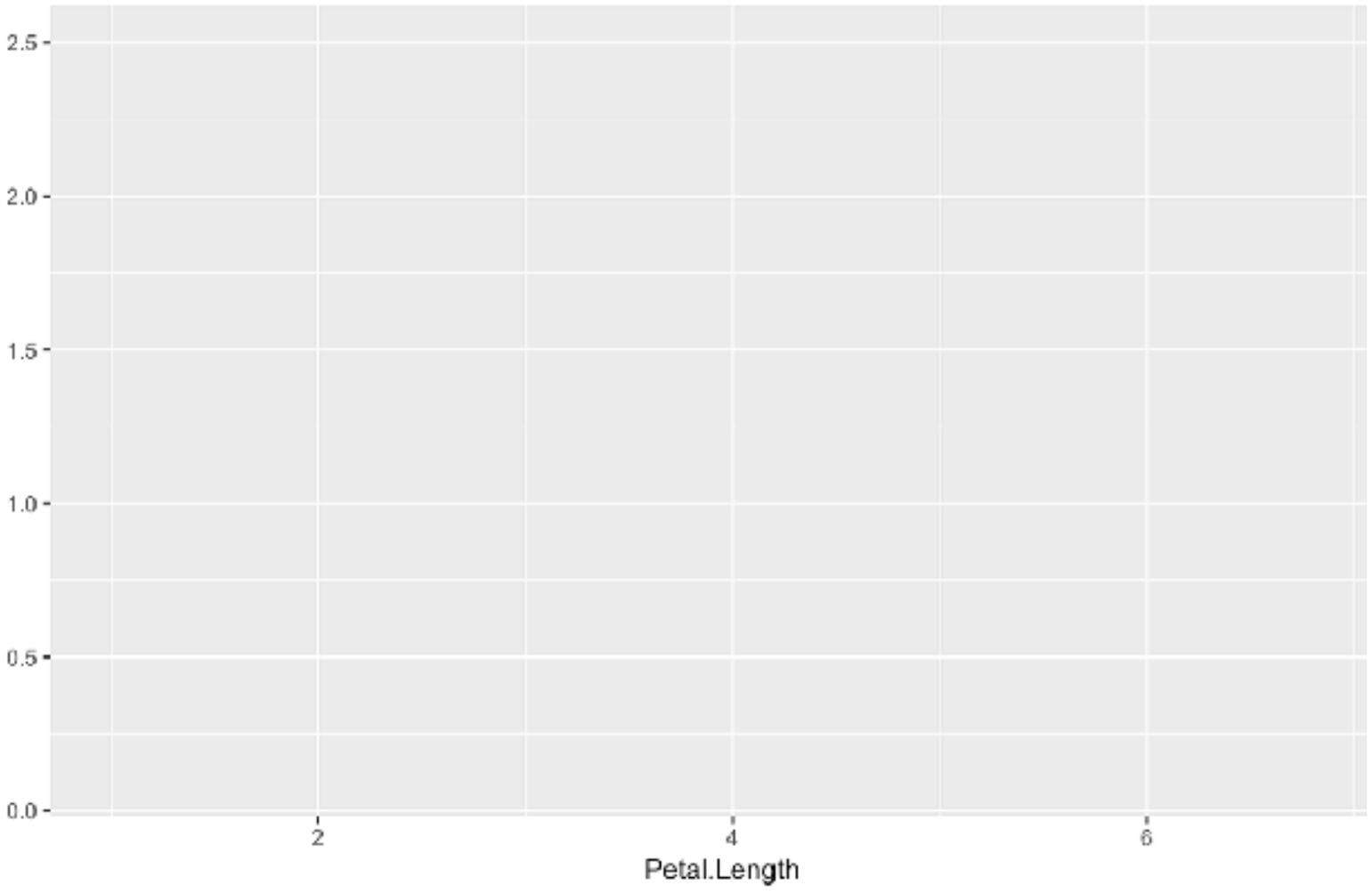
ggplot (grammar of graphics)

ggplot: Data, aesthetics, geometrics

```
> ggplot(iris)
```

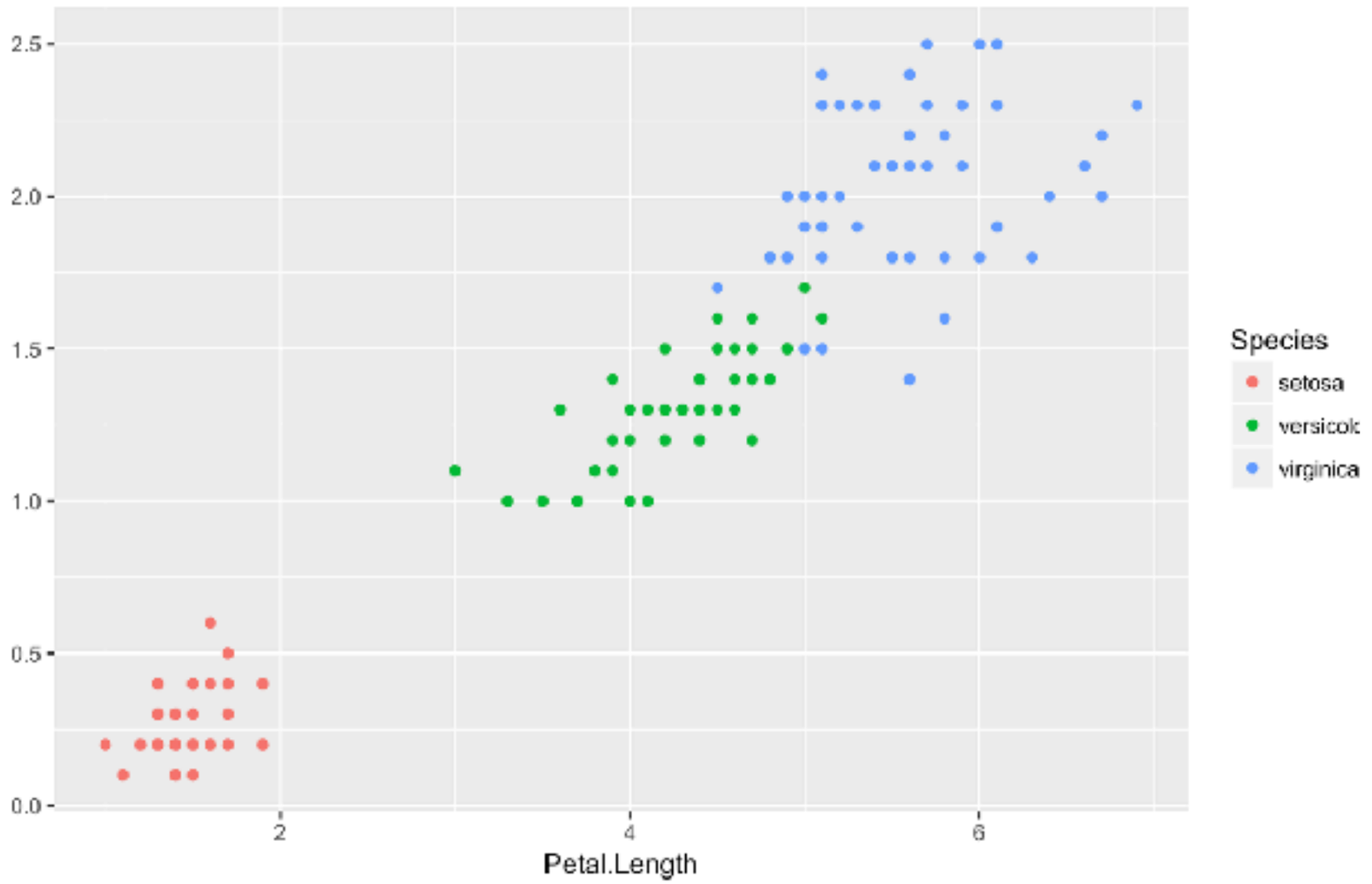
ggplot: Data, aesthetics, geometrics

```
> ggplot(iris)
> ggplot(iris, aes(x = Petal.Length, y = Petal.Width, colour=Species))
```



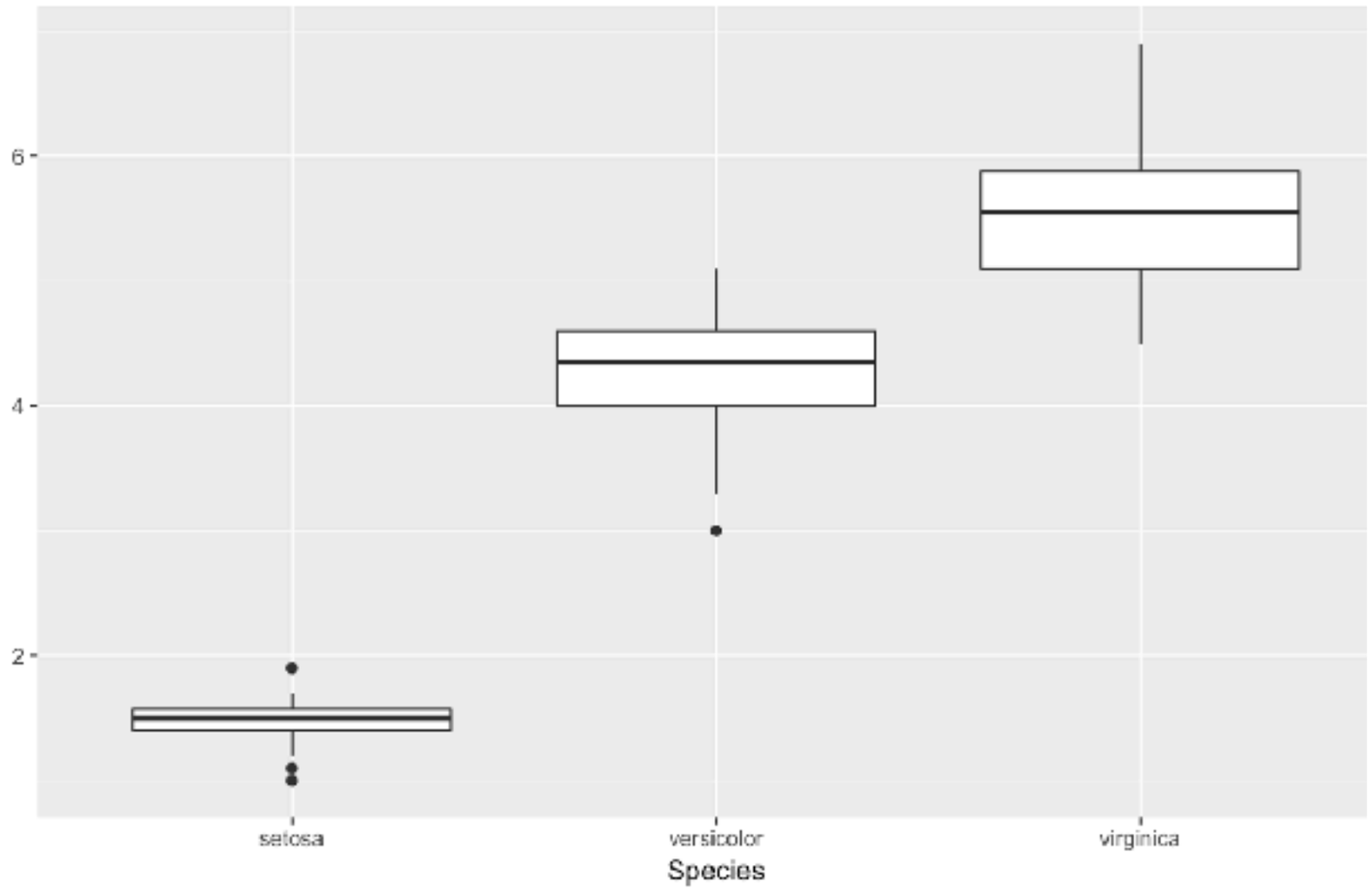
ggplot: Data, aesthetics, geometrics

```
> ggplot(iris)
> ggplot(iris, aes(x = Petal.Length, y = Petal.Width, colour=Species))
> ggplot(iris, aes(x = Petal.Length, y = Petal.Width, colour=Species)) +
    geom_point()
```



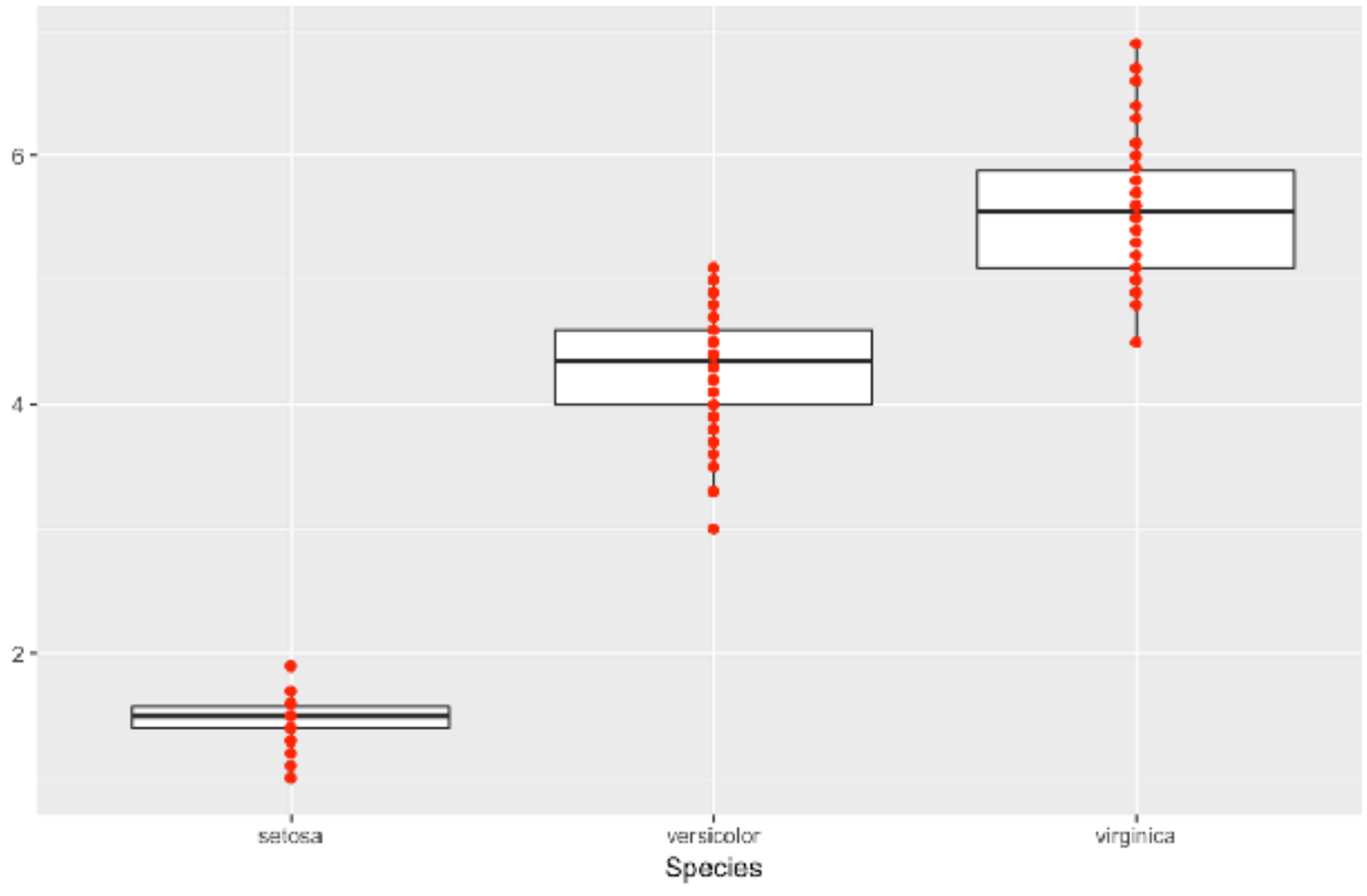
ggplot: Multiple geometric layers

```
> ggplot(iris, aes(x = Species, y = Petal.Length)) +
      geom_boxplot()
```



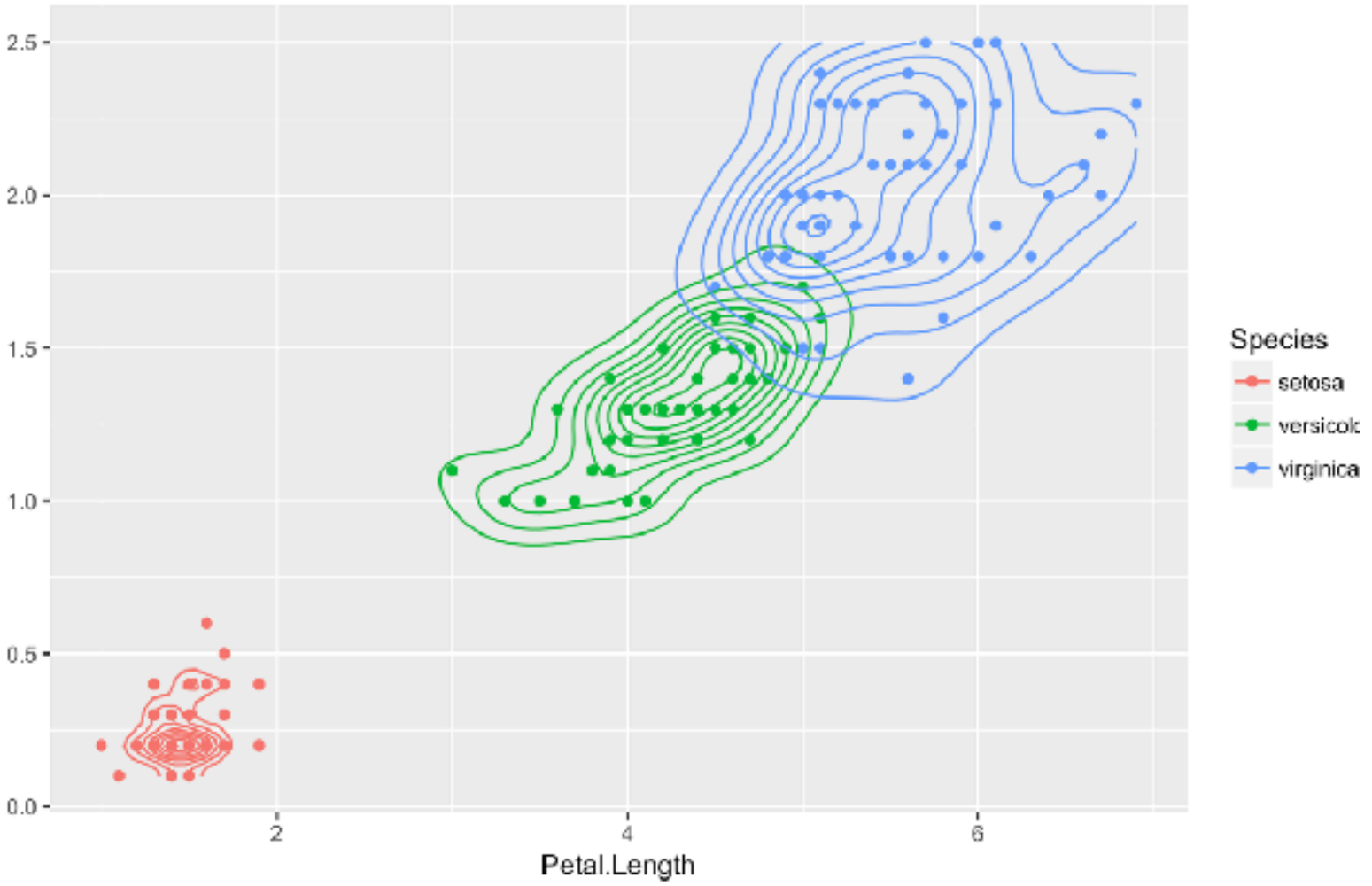
ggplot: Multiple geometric layers

```
> ggplot(iris, aes(x = Species, y = Petal.Length)) +
      geom_boxplot() +
      geom_point(colour='red')
```



ggplot: Statistical layers

```
> ggplot(iris, aes(x = Petal.Length, y = Petal.Width, colour=Species)) +
    geom_point() +
    stat_density_2d()
```



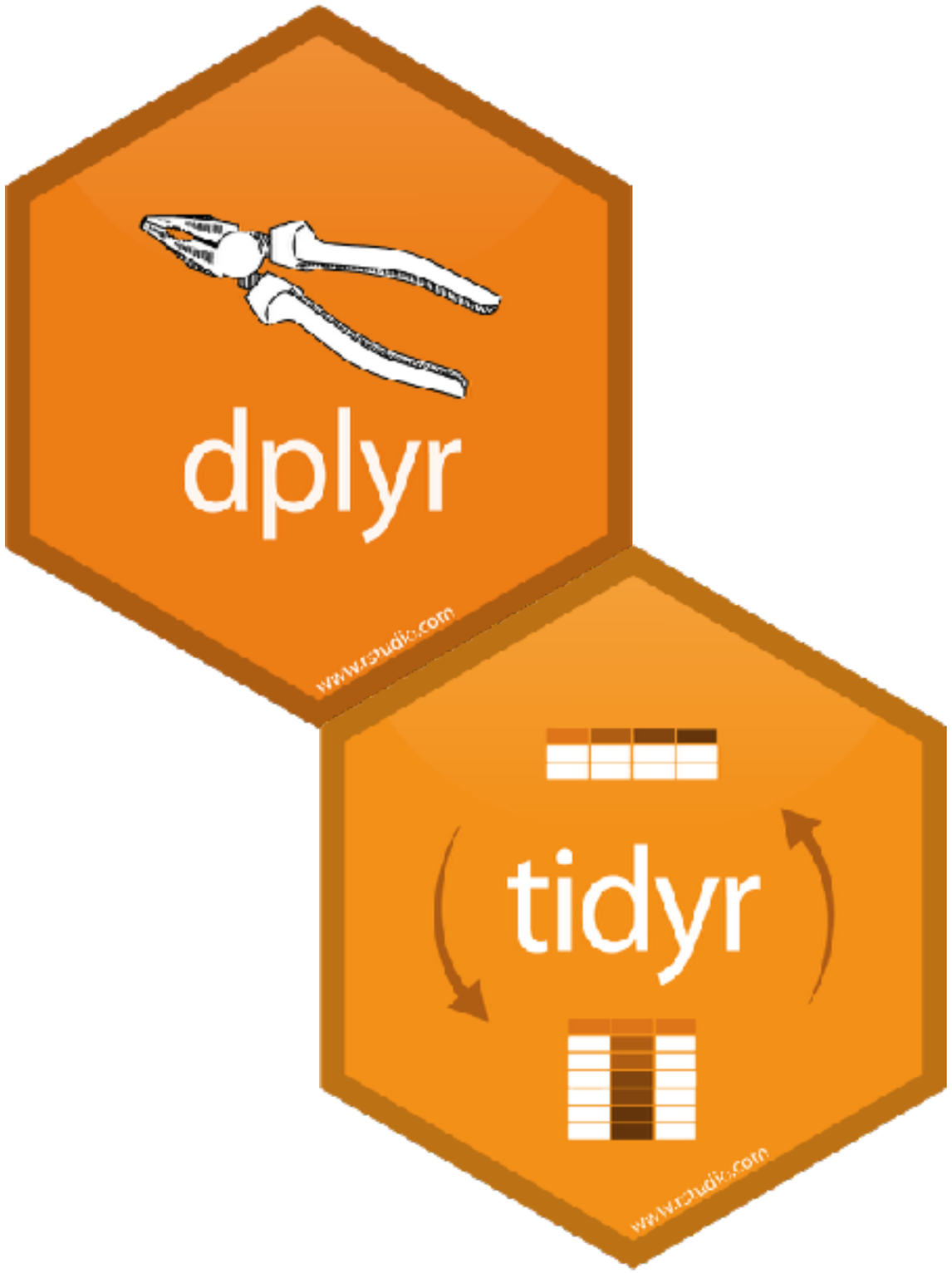
Exercises

Please do Basic exercises 2.1 and 2.2

Time left? Opt for a reading exercise or optional exercise!

Data transformation

Explore the power of dplyr and tidyr



Data Wrangling
with dplyr and tidyr
Cheat Sheet

RStudio

Syntax - Helpful conventions for wrangling

dplyr::**tbl_df(iris)**

Converts data to tbl class. tbl's are easier to examine than data frames. R displays only the data that fits onscreen:

```
Source: local data frame [150 x 5]

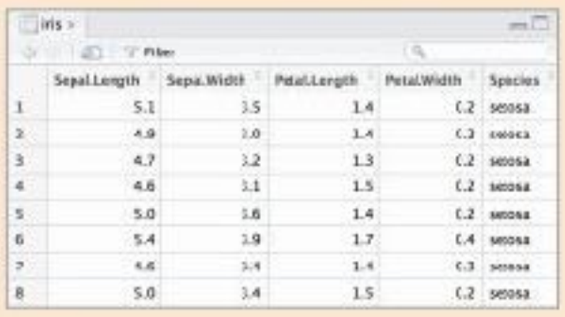
   Sepal.Length Sepal.Width Petal.Length
1           5.1         3.5          1.4
2           4.9         3.0          1.4
3           4.7         3.2          1.3
4           4.6         3.1          1.5
5           5.0         3.6          1.4
..          ...         ...          ...
Variables not shown: Petal.Width (dbl),
  Species (fctr)
```

dplyr::**glimpse(iris)**

Information dense summary of tbl data.

utils::**View(iris)**

View data set in spreadsheet-like display (note capital V).



dplyr::**%>%**

Passes object on left hand side as first argument (or . argument) of function on righthand side.

`x %>% f(y)` *is the same as* `f(x, y)`

`y %>% f(x, ., z)` *is the same as* `f(x, y, z )`

"Piping" with %>% makes code more readable, e.g.

```
iris %>%
  group_by(Species) %>%
  summarise(avg = mean(Sepal.Width)) %>%
  arrange(avg)
```

Tidy Data - A foundation for wrangling in R

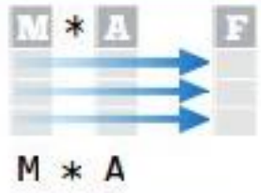
In a tidy data set:

Each **variable** is saved in its own **column**

&

Each **observation** is saved in its own **row**

Tidy data complements R's **vectorized operations**. R will automatically preserve observations as you manipulate variables. No other format works as intuitively with R.



Reshaping Data - Change the layout of a data set

tidyr::**gather(cases, "year", "n", 2:4)**

Gather columns into rows.

tidyr::**spread(pollution, size, amount)**

Spread rows into columns.

tidyr::**separate(storms, date, c("y", "m", "d"))**

Separate one column into several.

tidyr::**unite(data, col, ..., sep)**

Unite several columns into one.

dplyr::**data_frame(a = 1:3, b = 4:6)**

Combine vectors into data frame (optimized).

dplyr::**arrange(mtcars, mpg)**

Order rows by values of a column (low to high).

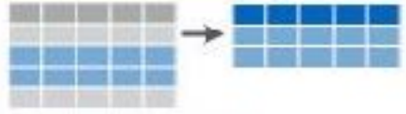
dplyr::**arrange(mtcars, desc(mpg))**

Order rows by values of a column (high to low).

dplyr::**rename(tb, y = year)**

Rename the columns of a data frame.

Subset Observations (Rows)



dplyr::**filter(iris, Sepal.Length > 7)**

Extract rows that meet logical criteria.

dplyr::**distinct(iris)**

Remove duplicate rows.

dplyr::**sample_frac(iris, 0.5, replace = TRUE)**

Randomly select fraction of rows.

dplyr::**sample_n(iris, 10, replace = TRUE)**

Randomly select n rows.

dplyr::**slice(iris, 10:15)**

Select rows by position.

dplyr::**top_n(storms, 2, date)**

Select and order top n entries (by group if grouped data).

Logic in R - ?Comparison, ?base::Logic

<	Less than	!=	Not equal to
>	Greater than	%in%	Group membership
==	Equal to	is.na	Is NA
<=	Less than or equal to	!is.na	Is not NA
>=	Greater than or equal to	&, |, !, xor, any, all	Boolean operators

Subset Variables (Columns)

dplyr::**select(iris, Sepal.Width, Petal.Length, Species)**

Select columns by name or helper function.

Helper functions for select - ?select

select(iris, **contains(".")**)

Select columns whose name contains a character string.

select(iris, **ends_with("Length")**)

Select columns whose name ends with a character string.

select(iris, **everything()**)

Select every column.

select(iris, **matches("..")**)

Select columns whose name matches a regular expression.

select(iris, **num_range("x", 1:5)**)

Select columns named x1, x2, x3, x4, x5.

select(iris, **one_of(c("Species", "Genus"))**)

Select columns whose names are in a group of names.

select(iris, **starts_with("Sepal")**)

Select columns whose name starts with a character string.

select(iris, Sepal.Length:Petal.Width)

Select all columns between Sepal.Length and Petal.Width (inclusive).

select(iris, -Species)

Select all columns except Species.

filter()

Function: filter()

```
> filter(iris, Species=="virginica")
```

Function: filter()

```
> filter(iris, Species=="virginica")
# A tibble: 50 x 5
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
          <dbl>       <dbl>        <dbl>       <dbl> <fct>
 1          6.30        3.30         6.00        2.50 virginica
 2          5.80        2.70         5.10        1.90 virginica
 3          7.10        3.00         5.90        2.10 virginica
 4          6.30        2.90         5.60        1.80 virginica
 5          6.50        3.00         5.80        2.20 virginica
 6          7.60        3.00         6.60        2.10 virginica
 7          4.90        2.50         4.50        1.70 virginica
 8          7.30        2.90         6.30        1.80 virginica
 9          6.70        2.50         5.80        1.80 virginica
10          7.20        3.60         6.10        2.50 virginica
# ... with 40 more rows
```

Function: filter()

```
> filter(iris, Species=="virginica", Sepal.Length>= 7.5)
```

Function: filter()

```
> filter(iris, Species=="virginica", Sepal.Length>= 7.5)
# A tibble: 6 x 5
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
         <dbl>       <dbl>        <dbl>       <dbl> <fct>
1          7.60        3.00         6.60        2.10 virginica
2          7.70        3.80         6.70        2.20 virginica
3          7.70        2.60         6.90        2.30 virginica
4          7.70        2.80         6.70        2.00 virginica
5          7.90        3.80         6.40        2.00 virginica
6          7.70        3.00         6.10        2.30 virginica
```

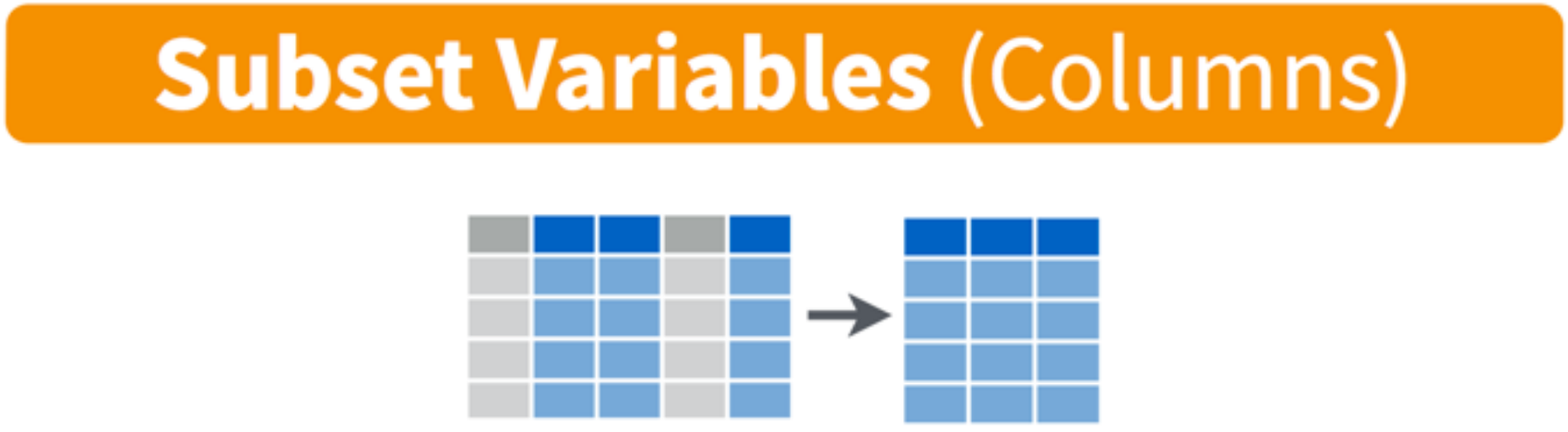
Function: filter()

```
> filter(iris, Species=="virginica", Sepal.Length>= 7.5)
# A tibble: 6 x 5
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
         <dbl>       <dbl>        <dbl>       <dbl> <fct>
1          7.60        3.00         6.60        2.10 virginica
2          7.70        3.80         6.70        2.20 virginica
3          7.70        2.60         6.90        2.30 virginica
4          7.70        2.80         6.70        2.00 virginica
5          7.90        3.80         6.40        2.00 virginica
6          7.70        3.00         6.10        2.30 virginica
```

Same as:

```
> filter(iris, Species=="virginica" & Sepal.Length>= 7.5)
```

select()



Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
```

Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
# A tibble: 150 x 3
   Sepal.Length Sepal.Width Species
          <dbl>       <dbl> <fct>
 1          5.10        3.50 setosa
 2          4.90        3.00 setosa
 3          4.70        3.20 setosa
 4          4.60        3.10 setosa
 5          5.00        3.60 setosa
 6          5.40        3.90 setosa
 7          4.60        3.40 setosa
 8          5.00        3.40 setosa
 9          4.40        2.90 setosa
10          4.90        3.10 setosa
# ... with 140 more rows
```

Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
> select(iris, starts_with("Sepal"), Species)
```

Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
> select(iris, starts_with("Sepal"), Species)
# A tibble: 150 x 3
   Sepal.Length Sepal.Width Species
          <dbl>       <dbl> <fct>
 1          5.10        3.50 setosa
 2          4.90        3.00 setosa
 3          4.70        3.20 setosa
 4          4.60        3.10 setosa
 5          5.00        3.60 setosa
 6          5.40        3.90 setosa
 7          4.60        3.40 setosa
 8          5.00        3.40 setosa
 9          4.40        2.90 setosa
10          4.90        3.10 setosa
# ... with 140 more rows
```

Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
> select(iris, starts_with("Sepal"), Species)
> select(iris, -starts_with("Petal"))
```

Function: select()

```
> select(iris, Sepal.Length, Sepal.Width, Species)
> select(iris, starts_with("Sepal"), Species)
> select(iris, -starts_with("Petal"))
# A tibble: 150 x 3
   Sepal.Length Sepal.Width Species
          <dbl>       <dbl> <fct>
 1          5.10        3.50 setosa
 2          4.90        3.00 setosa
 3          4.70        3.20 setosa
 4          4.60        3.10 setosa
 5          5.00        3.60 setosa
 6          5.40        3.90 setosa
 7          4.60        3.40 setosa
 8          5.00        3.40 setosa
 9          4.40        2.90 setosa
10          4.90        3.10 setosa
# ... with 140 more rows
```

mutate()

Function: mutate()

```
> mutate(iris,
         petal_area = pi * Petal.Length * Petal.Width)
```

Function: mutate()

```
> mutate(iris,
         petal_area = pi * Petal.Length * Petal.Width)
# A tibble: 150 x 6
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species petal_area
          <dbl>       <dbl>        <dbl>       <dbl> <fct>        <dbl>
 1          5.10        3.50         1.40       0.200 setosa       0.880
 2          4.90        3.00         1.40       0.200 setosa       0.880
 3          4.70        3.20         1.30       0.200 setosa       0.817
 4          4.60        3.10         1.50       0.200 setosa       0.942
 5          5.00        3.60         1.40       0.200 setosa       0.880
 6          5.40        3.90         1.70       0.400 setosa       2.14
 7          4.60        3.40         1.40       0.300 setosa       1.32
 8          5.00        3.40         1.50       0.200 setosa       0.942
 9          4.40        2.90         1.40       0.200 setosa       0.880
10          4.90        3.10         1.50       0.100 setosa       0.471
# ... with 140 more rows
```

Function: mutate()

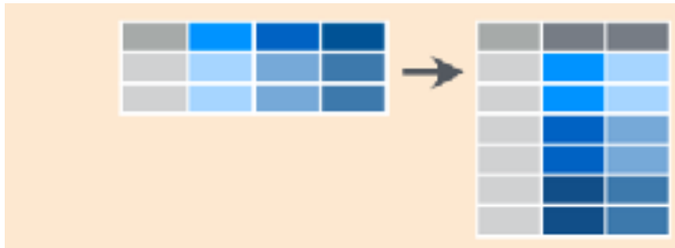
```
> mutate(iris,
         # compute the area of a single petal
         petal_area = pi * Petal.Length * Petal.Width,
         # abbreviate the name of the species
         Species_abbr = substring(Species, 1, 3)
)
```

Function: mutate()

```
> mutate(iris,
         # compute the area of a single petal
         petal_area = pi * Petal.Length * Petal.Width,
         # abbreviate the name of the species
         Species_abbr = substring(Species, 1, 3)
)
```

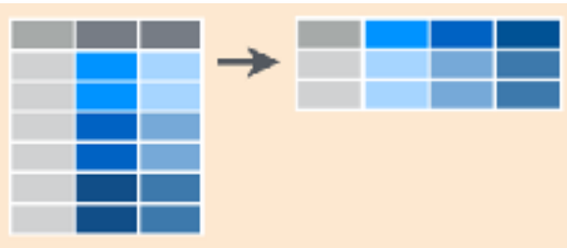
```
# A tibble: 6 x 7
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species petal_area Species_abbr
         <dbl>       <dbl>        <dbl>       <dbl> <fct>        <dbl> <chr>
1          5.10        3.50         1.40       0.200 setosa       0.880 set
2          4.90        3.00         1.40       0.200 setosa       0.880 set
3          4.70        3.20         1.30       0.200 setosa       0.817 set
4          4.60        3.10         1.50       0.200 setosa       0.942 set
5          5.00        3.60         1.40       0.200 setosa       0.880 set
6          5.40        3.90         1.70       0.400 setosa       2.14  set
```

gather() and spread()



tidyr::**gather(cases, "year", "n", 2:4)**

Gather columns into rows.



tidyr::**spread(pollution, size, amount)**

Spread rows into columns.

Function: gather()

```
> iris_obs <- mutate(iris, observation = 1:n())
> iris_obs
```

Function: gather()

```
> iris_obs <- mutate(iris, observation = 1:n())
> iris_obs
# A tibble: 150 x 6
   Sepal.Length Sepal.Width Petal.Length Petal.Width Species observation
          <dbl>       <dbl>        <dbl>       <dbl> <chr>          <int>
 1          5.10        3.50         1.40       0.200 setosa             1
 2          4.90        3.00         1.40       0.200 setosa             2
 3          4.70        3.20         1.30       0.200 setosa             3
 4          4.60        3.10         1.50       0.200 setosa             4
 5          5.00        3.60         1.40       0.200 setosa             5
 6          5.40        3.90         1.70       0.400 setosa             6
 7          4.60        3.40         1.40       0.300 setosa             7
 8          5.00        3.40         1.50       0.200 setosa             8
 9          4.40        2.90         1.40       0.200 setosa             9
10          4.90        3.10         1.50       0.100 setosa            10
# ... with 140 more rows
```

Function: gather()

```
> iris_obs <- mutate(iris, observation = 1:n())
> iris_obs
> iris_long <- gather(iris_obs, measurement, value, -Species, -observation)
> iris_long
```

Function: gather()

```
> iris_obs <- mutate(iris, observation = 1:n())
> iris_obs
> iris_long <- gather(iris_obs, measurement, value, -Species, -observation)
> iris_long
# A tibble: 600 x 4
   Species observation measurement  value
   <chr>         <int> <chr>        <dbl>
 1 setosa            1 Sepal.Length 5.10
 2 setosa            1 Sepal.Width  3.50
 3 setosa            1 Petal.Length 1.40
 4 setosa            1 Petal.Width  0.200
 5 setosa            2 Sepal.Length 4.90
 6 setosa            2 Sepal.Width  3.00
 7 setosa            2 Petal.Length 1.40
 8 setosa            2 Petal.Width  0.200
 9 setosa            3 Sepal.Length 4.70
10 setosa            3 Sepal.Width  3.20
```

Function: spread()

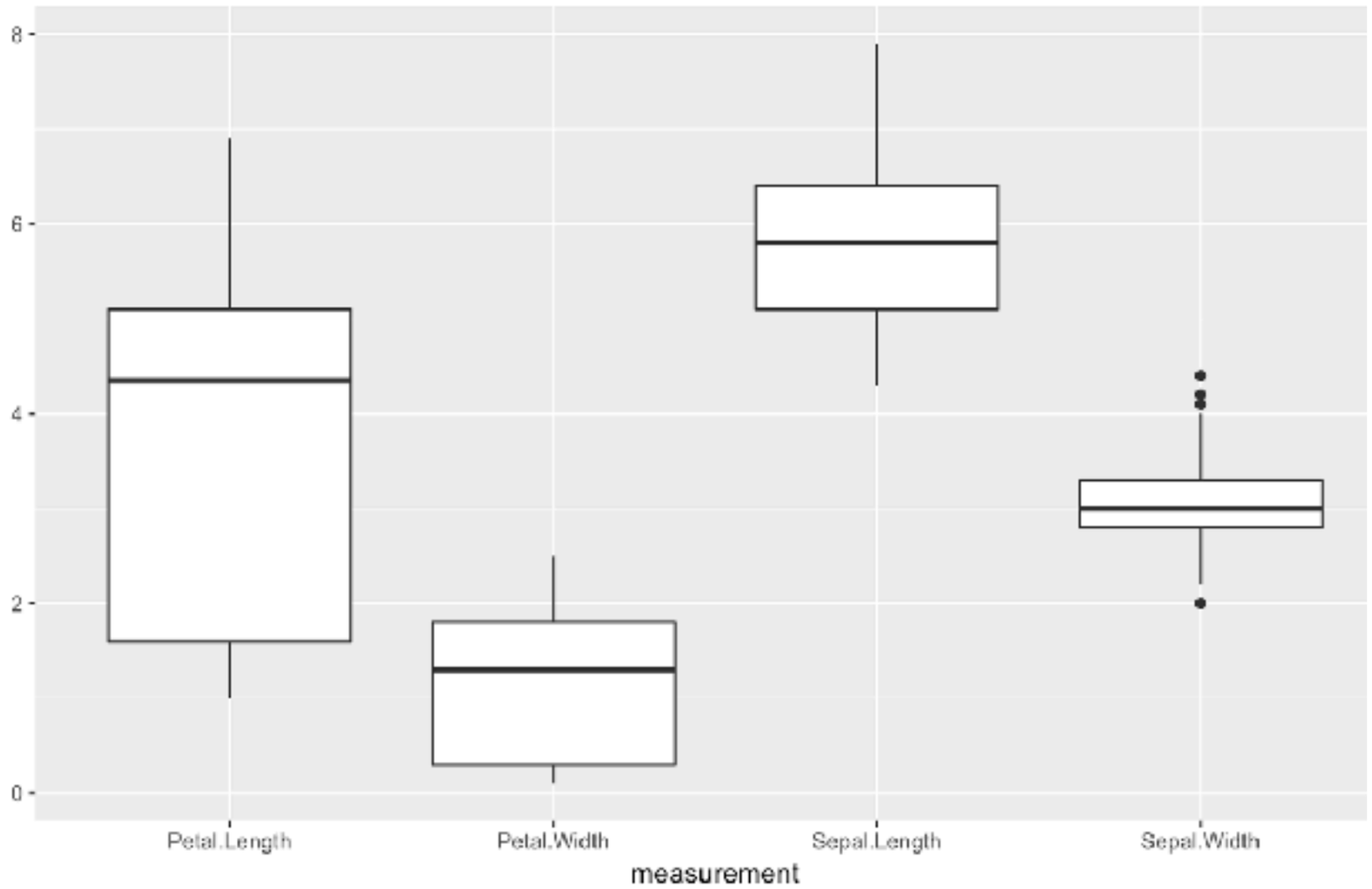
```
> iris_wide <- spread(iris_long, measurement, value)
> iris_wide
```

Function: spread()

```
> iris_wide <- spread(iris_long, measurement, value)
> iris_wide
# A tibble: 150 x 6
   Species observation Petal.Length Petal.Width Sepal.Length Sepal.Width
   <chr>         <int>        <dbl>       <dbl>        <dbl>       <dbl>
 1 setosa            1         1.40       0.200         5.10        3.50
 2 setosa            2         1.40       0.200         4.90        3.00
 3 setosa            3         1.30       0.200         4.70        3.20
 4 setosa            4         1.50       0.200         4.60        3.10
 5 setosa            5         1.40       0.200         5.00        3.60
 6 setosa            6         1.70       0.400         5.40        3.90
 7 setosa            7         1.40       0.300         4.60        3.40
 8 setosa            8         1.50       0.200         5.00        3.40
 9 setosa            9         1.40       0.200         4.40        2.90
10 setosa           10         1.50       0.100         4.90        3.10
# ... with 140 more rows
```

Quick plots

```
> ggplot(iris_long, aes(measurement, value)) + geom_boxplot()
```

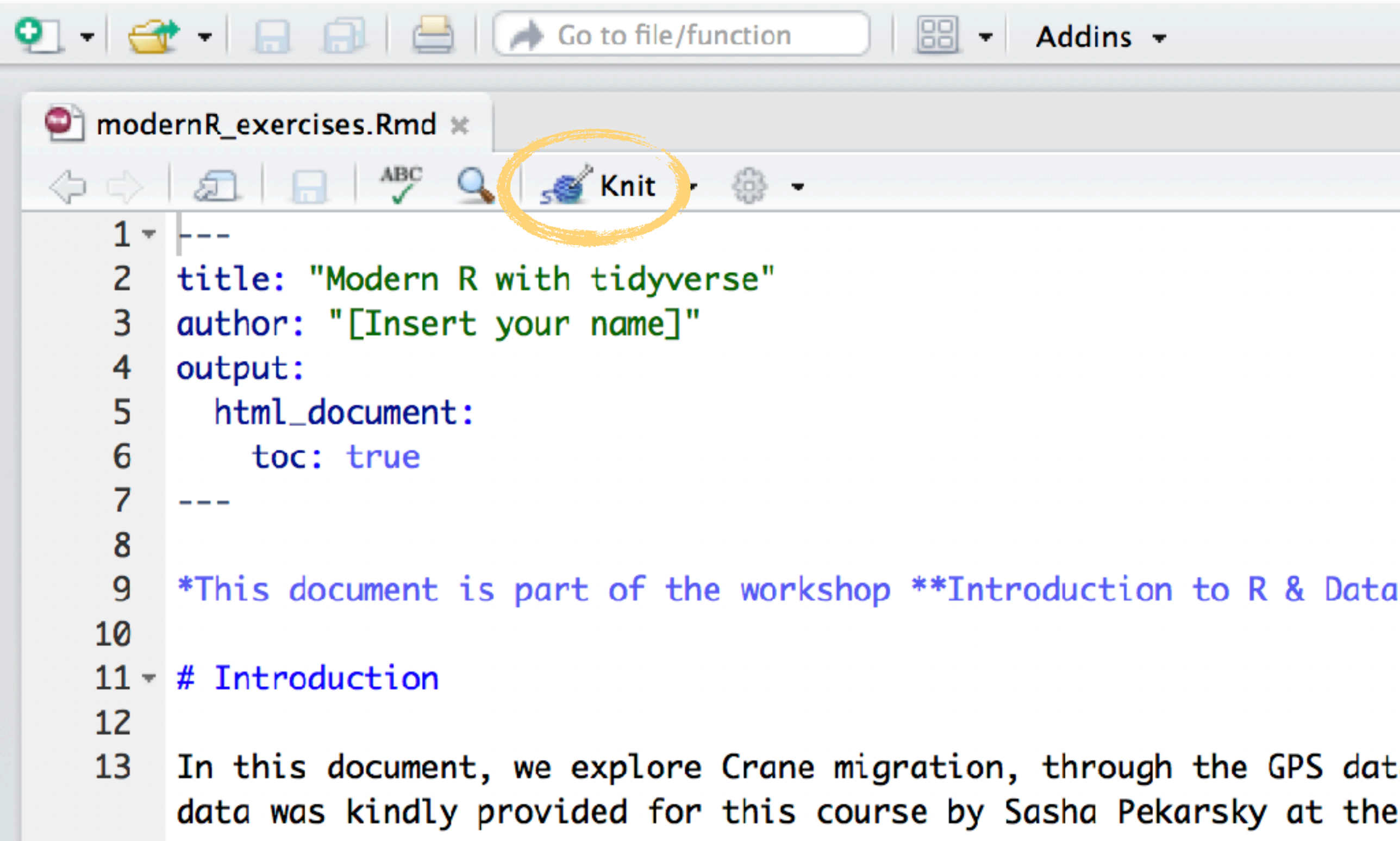


Exercises

Please do basic exercises 3.1 and 3.2.

Time left? Opt for a reading exercise or optional exercise!

All done? Time to knit!



Introduction to R & data

Before you leave…

Other RDM workshops

- https://www.uu.nl/en/research/research-data-management/tools-services/training-and-workshops

- Learn to write your Data Management Plan (online course)
  - Research Data Management basics
  - Introduction to Python & Data (coming soon)
  - Introduction to computational reproducibility (coming soon)

R Cafe

- Monthly event for R programmers
- Join the R community
- Work on your project with the ability to ask questions
- Subscribe to the newsletter or follow RDM support website
- Check https://github.com/UtrechtUniversity/R-data-cafe
- Next edition: **Monday 10/12!**

Feedback is cool.

Please send your feedback, remarks, questions to us:

Barbara: b.m.i.vreede@uu.nl
Jonathan: j.debruin1@uu.nl

```
useR <- function(){
    print("Good luck and see you!")
}
useR()
```