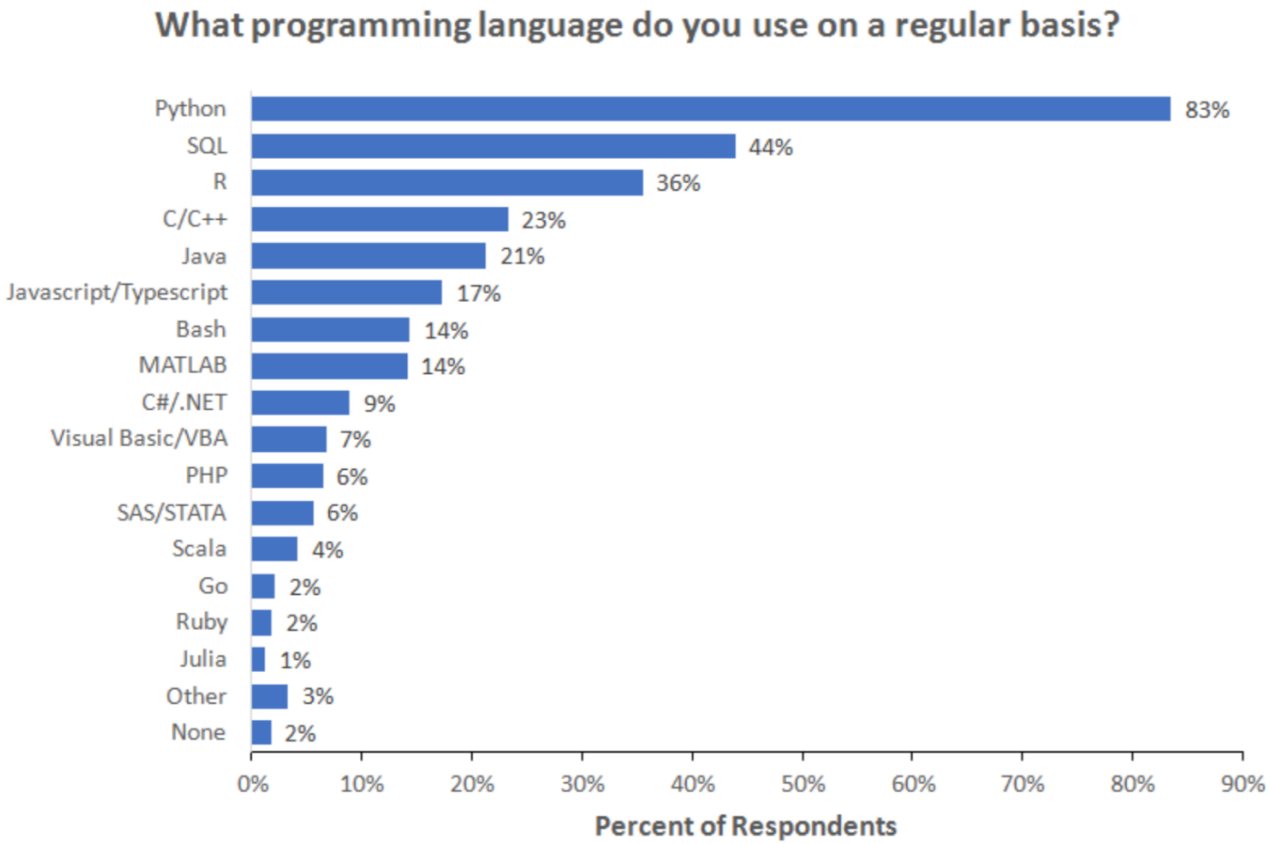
Unit 1: R Software

What is R?

- R is the most popular software used in statistical analysis.
- It is flexible and programmable.
- It provides the user with total control.
- It works from a command line.

R: Statistical programming language

- R is among the most popular languages for 'data science'.



Note: Data are from the 2018 Kaggle Machine Learning and Data Science Survey. You can learn more about the study here: http://www.kaggle.com/kaggle/kaggle-survey-2018. A total of 18827 respondents answered the question.

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R: Statistical programming language

- R is used by corporations:

Top Tier Companies using R

The following is a list of top brands or large organizations using R.

1. Facebook – For behavior analysis related to status updates and profile pictures.
2. Google – For advertising effectiveness and economic forecasting.
3. Twitter – For data visualization and semantic clustering
4. Microsoft – Acquired Revolution R company and use it for a variety of purposes.
5. Uber – For statistical analysis
6. Airbnb – Scale data science.
7. IBM – Joined R Consortium Group
8. ANZ – For credit risk modeling
9. HP
10. Ford
11. Novartis
12. Roche
13. New York Times – For data visualization
14. Mckinsey
15. BCG
16. Bain

Financial Institutions

It includes major US and European Banks, Insurance Companies and Other financial institutions using R.

1. American Express
2. ANZ
3. Bank of America
4. Barclays Bank
5. Bazaj allianz Insurance
6. Bharti Axa insurance
7. Blackrock
8. Citibank
9. Dun &Bradstreet
10. Fidelity
11. HSBC
12. JP Morgan
13. KeyBank
14. Lloyds Banking
15. RBS
16. Standard Chartered
17. UBS
18. Wells Fargo
19. Goldman Sachs
20. Morgan Stanley
21. PNC Bank
22. Citizens Bank
23. Fifth Third Bank

Analytics and Consulting Companies using R

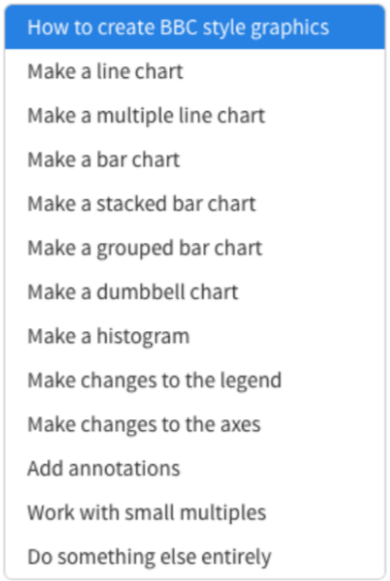
The below list comprises of niche analytics companies as well as co
companies providing analytics or market research services.

1. A.T. Kearney
2. AbsolutData
3. AC Nielsen
4. Accenture
5. Bain & Company
6. Booz Allen Hamilton
7. Capgemini
8. Convergytics
9. Deloitte Consulting
10. Evalueserve
11. EXL
12. EY
13. Fractal Analytics
14. Gartner
15. Genpact
16. IBM
17. KPMG
18. Latent View
19. Manthan Systems
20. McKinsey & Company
21. Mu Sigma
22. PricewaterhouseCoopers
23. SIBIA Analytics
24. Simplify360
25. SmartCube
26. Target
27. The Boston Consulting Group
28. Tiger Analytics
29. Tower Watson
30. WNS
31. ZS Associate

https://www.r-bloggers.com/companies-using-r/

R: Statistical programming language

- R is used for journalism.



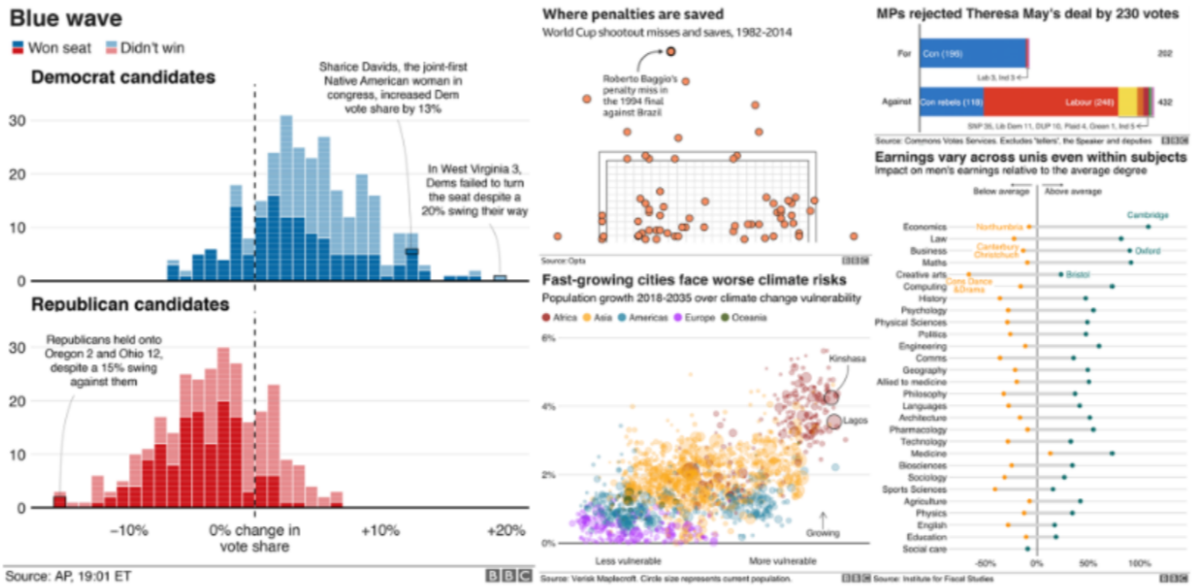
BBC Visual Journalism data team's cookbook for R graphics

Last updated: 2019-01-16

How to create BBC style graphics

At the BBC data team, we have developed an R package and an R cookbook to make the process of creating publication-ready graphics in our in-house style using R's ggplot2 library a more reproducible process, as well as making it easier for people new to R to create graphics.

The cookbook below should hopefully help anyone who wants to make graphics like these:



We'll get to how you can put together the various elements of these graphics, but **let's get the admin out of the way first...**

Getting R and RStudio

- You can download your own copy from R Project (CRAN) homepage at `http://www.r-project.org/`.
- The introductory tutorial for R can be found at `http://cran.r-project.org/doc/manuals/R-intro.pdf`.
- Once R is installed, then RStudio can be downloaded from `https://posit.co/download/rstudio-desktop/`.

Getting started with R

- We can work with R through its console as shown below:


```
R version 4.0.2 (2020-06-22) -- "Taking Off Again"
Copyright (C) 2020 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin17.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[R.app GUI 1.72 (7847) x86_64-apple-darwin17.0]

[History restored from /Users/katherinedavies/.Rapp.history]

>
```

- The other option, which is becoming increasingly popular, is through RStudio.

RStudio

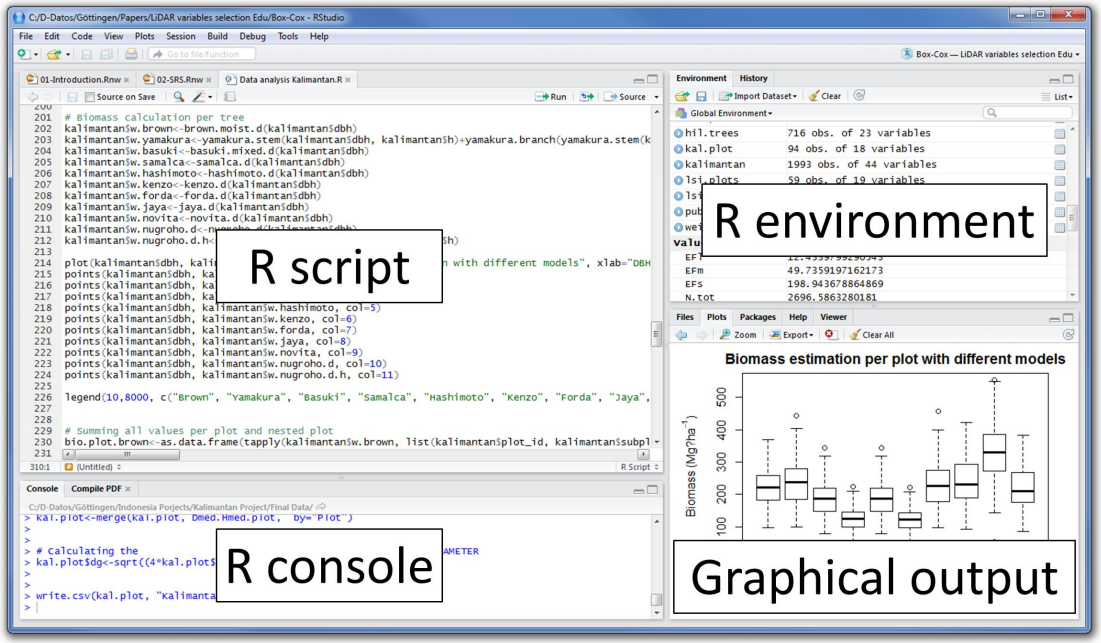
- RStudio is an Integrated Development Environment which makes using R a bit smoother.
- RStudio can be thought of as the “dashboard" that most people use to “drive" R.

R: Engine	RStudio: Dashboard
	

http://moderndive.com/

RStudio

- In RStudio , there are 4 panels;
  1. Top left: R script
  2. Bottom left: R console
  3. Top right: R environment
  4. Bottom right: Graphical output



https://www.analyticsvidhya.com/blog/2016/02/complete-tutorial-learn-data-science-scratch/

R coding at a glance

- R code can be comprised of a variety of things, such as functions, calculations and plots.
- It is recommended to always create your code in an R Script file (an .R file), and in addition, to comment your code (explain what you are doing) using #; these comments are for you (and others to read) but R will ignore.
- In R, you would have the script file open and copy and paste into R; in RStudio, you would also open the script file (and it would appear in the top left panel) and highlight the lines of code you want to execute and click Run.

R syntax

- In both platforms, the command line is indicated by a $>$; this is where we tell R what to do (give it commands).
- On the command line, to redo a previous command, you can use the up arrow key (▲ or ↑).
- Here is a simple example of code on the command line:

```
>
> simple.command <- "R welcomes 2150 students!"
> print(simple.command)
[1] "R welcomes 2150 students!"
```

  where we first defined a string using $<-$ which means assign (note, an $=$ can be used instead), and then we asked R to print the string.

R syntax

- Hers'a another simple example where we define two variables and ask R to perform some simple mathematical calculations with them:

```
> x <- 8
> y <- 2
> x+y
[1] 10
> x-y
[1] 6
> x/y
[1] 4
> x*y
[1] 16
```

- Basically R can be used as a calculator!

R objects and classes

- When something is created in R, it is an object, such as a number, vector or matrix.
- R objects are divided by classes; the main types of classes are string, numeric, matrix, data frame and lists.
- We already saw what a string looked like; a string consists of *characters* and needs to have quotation marks around it (to tell R it is a string).
- numeric is used for objects consisting of numbers, e.g. 1.26, 4 or 1e5.
- There are multiple classes within numeric itself, with a common one being integer.

R objects

- A vector in R (which can be in the numeric or character class) consists of a sequence of components which are of the same class, e.g. a list of the numbers 2, 3 and 7; we use square brackets to define or access elements of vectors.

- A matrix in R is a generalization of a vector in that it contains many elements of the same type but they are arranged in rows and columns; a vector is a special case of a matrix in that it is a matrix with one row (or column). Like a vector, we use square brackets to define or access elements of matrices.

R objects

- A data frame is a two-dimensional array-like structure which is separated into columns each of equal length; each column is typically associated with a variable and the data on these variables can be of different forms (numeric, character, etc).

- Lists are R structures which contain objects of *different* types and even lengths; we use double square brackets to define and access elements of lists. Furthermore, lists can be nested, i.e., an element of a list can be a list itself.

R objects

- Oftentimes R objects are defined (and are empty) and then we fill them in (though this isn't always the case, for instance with imported data).

```
> a.vector <- double(5)
> a.vector[1] <- 1
> a.vector[2] <- 1.4
> a.vector[3] <- 2
> a.vector[4] <- 4
> a.vector[5] <- 6.3
> a.vector
[1] 1.0 1.4 2.0 4.0 6.3
```

```
> a.matrix <- matrix(nrow=2,ncol=2)
> a.matrix[1,1] <- 4
> a.matrix[1,2] <- 6
> a.matrix[2,1] <- 3
> a.matrix[2,2] <- 4
> a.matrix
     [,1] [,2]
[1,]    4    6
[2,]    3    4
```

R objects

- Sometimes loops (to be discussed soon!) are used to fill in objects.
- Let us use a loop to fill in the elements of a vector:

```
> test.vector <- double(5)
> for(i in 1:5){test.vector[i] <- i^2}
> test.vector
[1]  1  4  9 16 25
```

and of a matrix:

```
> test.matrix <- matrix(nrow=2,ncol=2)
> for(i in 1:2){
+ for(j in 1:2){
+ test.matrix[i,j] <- i+j}}
> test.matrix
     [,1] [,2]
[1,]    2    3
[2,]    3    4
```

R objects

- Here is a list composed of different types of objects:

```
> test.list <- list()
> test.list[[1]] <- a.vector
> test.list[[2]] <- simple.command
> test.list[[3]] <- matrix(1:4,nrow=2,byrow=T)
> test.list
[[1]]
[1] 1.0 1.4 2.0 4.0 6.3

[[2]]
[1] "R welcomes 2150 students!"

[[3]]
     [,1] [,2]
[1,]    1    2
[2,]    3    4
```

R objects

- The function class can be used to determine an object's class:

```
> test.matrix
     [,1] [,2]
[1,]    2    3
[2,]    3    4
> class(test.matrix)
[1] "matrix" "array"
> test.vector
 [1]   1   4   9  16  25  36  49  64  81 100
> class(test.vector)
[1] "numeric"
> simple.command
[1] "R welcomes 2150 students!"
> class(simple.command)
[1] "character"
```

- Notice this though:

```
> test.vector2 <- seq(1:5)
> test.vector2
[1] 1 2 3 4 5
> class(test.vector2)
[1] "integer"
```

Built-in functions

- In addition to basic mathematical calculations, you have already seen some built-in commands/functions in R , such as print and class; in fact, R has many built-in functions to carry out simple tasks.
- Here are some commonly other used functions that you should familiarize yourself with:

length	*dim*	*which*
t	*rep*	*abs*
cbind	*rbind*	*rm*
sqrt	*log*	*exp*
sum	*mean*	*median*
min	*max*	*seq*
sort	*order*	*round*

- To see how they work, type a question mark and the name of the function, i.e., ?round.

Some simple commands

```
> data <- c(1,4,0,2,8)
> mean(data)
[1] 3
> min(data)
[1] 0
> max(data)
[1] 8
> data[1]+data[4]
[1] 3
> sort(data)
[1] 0 1 2 4 8
> order(data)
[1] 3 1 4 2 5
> data^2
[1]  1 16  0  4 64
```

*Note the difference between sort and order!

Libraries and packages

- A package in R is just a collection of functions, usually with some connecting theme.
- Packages are stored in libraries; there are packages for almost everything:
  - numDeriv - Methods for calculating (usually) accurate numerical first and second order derivatives
  - mgcv - Generalized Additive Models
  - survival - Tools for survival analysis
  - extraDist - Provides functions dealing with special probability distributions
- R comes with a standard set of packages. Others packages need to be downloaded (installed); this is done in RStudio in the bottom right on the Packages tab or using install.packages("*packagename*"). Packages are then loaded using the command library, i.e., library(numDeriv).

Reading data

- One of the main uses of R is data analysis; exploratory data analysis will be the focus of Unit 2, but first we need to learn how to get the data into R.
- Data can come from a variety of places; let's start with some data already in R, called built-in data sets.
- To see the list of these built-in data sets, simply type data().
- To get a summary of a particular data set, for instance, mtcars, simply type summary(mtcars).
- These data sets are data frames; you can access, manipulate and explore all the components of the data set; we will look at this more in Unit 2.

Importing data

- Data can also be imported from the internet, your computer (or some other local directory) into R .
- Let us start with importing a data set, in the form of an excel file, from a directory.
- Suppose you have an Excel file. To import it in R , you can use the drop down menus: File - Import Dataset - From Excel.
- Note that R may need to install or update packages to do this.

Importing data

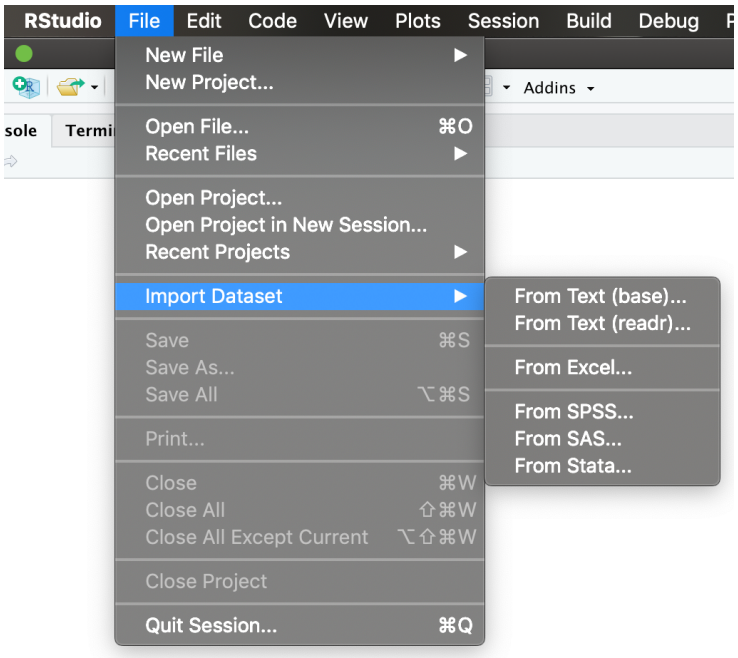
- Now suppose you have what is called a csv file, i.e., a comma separated file.
- The procedure for importing this is similar to an excel file.
- Here is a fake data set viewed in TextEdit and beside it, in Excel:

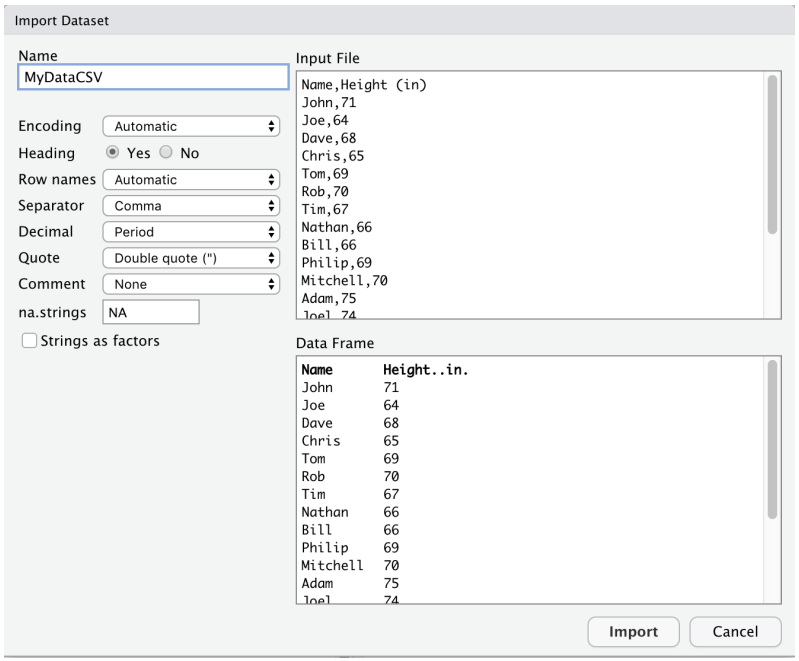
```
Name,Height (in)
John,71
Joe,64
Dave,68
Chris,65
Tom,69
Rob,70
Tim,67
Nathan,66
Bill,66
Philip,69
Mitchell,70
Adam,75
Joel,74
Matthew,67
Cole,66
Henry,68
Derek,70
Riley,72
Steve,69
```

	Name	Height (in)
1	Name	Height (in)
2	John	71
3	Joe	64
4	Dave	68
5	Chris	65
6	Tom	69
7	Rob	70
8	Tim	67
9	Nathan	66
10	Bill	66
11	Philip	69
12	Mitchell	70
13	Adam	75
14	Joel	74
15	Matthew	67
16	Cole	66
17	Henry	68
18	Derek	70
19	Riley	72
20	Steve	69

Importing data

- We can import using the dropdown menu (in RStudio) by selecting File - Import Dataset - From Text (base), for instance, and then a box will show you how it is being imported and you click Import.





- Or we can import from the command line:

```
> mydata <- read.csv(file="~/Desktop/MyDataCSV.csv", header=TRUE)
```

- Note "header=TRUE" tells R that the top row has column names.

Importing data

- Suppose a website contains a data set you would like to import into R.
- The simplest method is to use the function read.table:

```
> web.data <- read.table(url("http://www.stats.ox.ac.uk/pub/datasets/csb/ch11b.dat"))
```

- Alternatively, the function fread from the package data.table can be used:

```
> library(data.table)
> web.data<- fread('http://www.stats.ox.ac.uk/pub/datasets/csb/ch11b.dat')
```

- This information is from :
  `https://www.r-bloggers.com/getting-data-from-an-online-source/`.

Entering data

- We can enter data directly into R :

```
> Height <- c(71,64,68,65,69,70,67,66,66,69,70,75,74,67,66,68,70,72,69)
> Name <- c('John', 'Joe', 'Dave', 'Chris','Tom','Rob','Tim','Nathan','Bill','Philli
p','Mitchell','Adam','Joel','Matthew','Cole','Henry','Derek','Riley','Steve')
> mydataframe <- data.frame(Name,Height)
> summary(mydataframe)
     Name                Height
 Length:19          Min.   :64.00
 Class :character   1st Qu.:66.50
 Mode  :character   Median :69.00
                    Mean   :68.74
                    3rd Qu.:70.00
                    Max.   :75.00
```

Augmenting a data frame

- We can also add to this data frame, say Weight, in two ways:

```
> Weight <- c(180,150,165,175,180,165,200,195,180,163,178,169,184,170,162,150,181,190,176)
> MyNewDataframe <- data.frame(Name,Weight,Height)
> summary(MyNewDataframe)
     Name               Weight          Height
 Length:19          Min.   :150.0   Min.   :64.00
 Class :character   1st Qu.:165.0   1st Qu.:66.50
 Mode  :character   Median :176.0   Median :69.00
                    Mean   :174.4   Mean   :68.74
                    3rd Qu.:180.5   3rd Qu.:70.00
                    Max.   :200.0   Max.   :75.00
> MyNewDataframe <- data.frame(mydataframe,Weight)
> summary(MyNewDataframe)
     Name               Height          Weight
 Length:19          Min.   :64.00   Min.   :150.0
 Class :character   1st Qu.:66.50   1st Qu.:165.0
 Mode  :character   Median :69.00   Median :176.0
                    Mean   :68.74   Mean   :174.4
                    3rd Qu.:70.00   3rd Qu.:180.5
                    Max.   :75.00   Max.   :200.0
```

- When all the elements of a data set are numbers, matrices are commonly used to organize and store it.
- We will get more practice with data sets in Unit 2.

Exporting data and saving images

- Depending on the format you'd like to export the data as, there are various ways to do this.
- The function write.table takes a matrix or data frame and exports it as a .txt to the working directory. The function write.csv exports as a .csv. Examples:

```
write.table(mydata,"testexport.txt")
write.csv(mydata,"testexport.csv")
```

- There is also the function write.xlsx as part of the package xlsx in order to export as a spreadsheet.
- To save an image in R, there are various functions such as jpeg and pdf(); when using such functions, make sure to always type dev.off() after your create the plot, to close the device.
- In RStudio, simply go to the output panel and click Export.

Writing a function

- An R function is an object containing instructions for particular purpose and can be reused; it typically has 4 main pieces:

  (1) Name

  (2) Arguments: inputs to the function

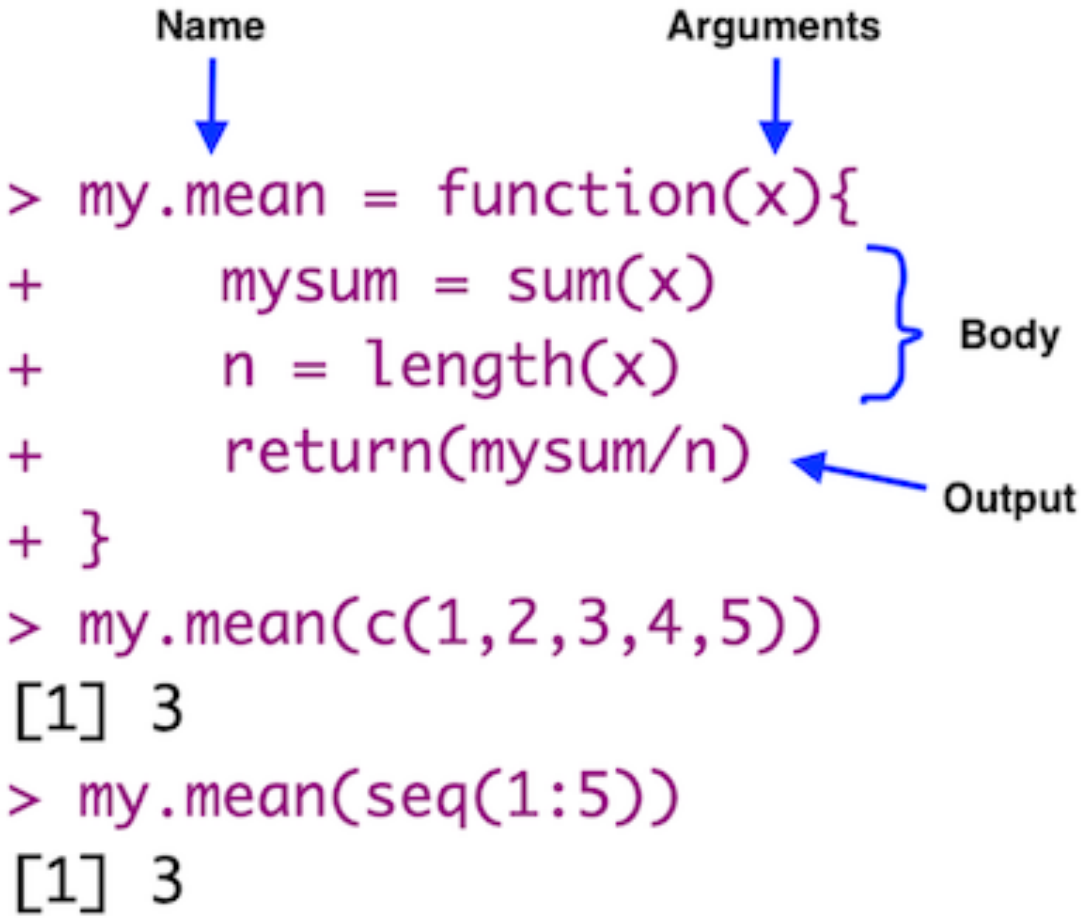
  (3) Body: does the work of the function

  (4) Output: what is returned once the function is executed

- Arguments of functions can be assigned default values. If you do not specify a value for an argument, it will use the default values.

Writing and calling a function

- Let's make a function to find the mean of a list of numbers:



More on functions

- We can write a function which calls another function:

```
> diffs <- function(x=c(1,2)){
+ return(x[2]-x[1])
+ }
> new.fun <- function(x=c(1,2)){
+ temp <- diffs(x)
+ return(exp(temp))
+ }
> new.fun(c(6,3))
[1] 0.04978707
```

- The function new.fun takes a vector of length 2 (see the default), applies the function diffs then applies the built-in function exp.

Logical operators

- The standard logical operators in R are &, | and !, which correspond to and, or and not, respectively.

- In addition, and in conjunction with these operators, the following are commonly used:

$<$ (less than)	$<=$ (less than or equal to)
$>$ (greater than)	$>=$ (greater than or equal to)
$==$ (equal to)	$!=$ (not equal to)

Conditionals

- Conditionals are expressions which tell R to compute something depending on whether a condition is satisfied or not.
- The commonly used conditionals are if and ifelse.
- We can use conditionals on the command line directly:

```
> ifelse(1<2,3,2)
[1] 3
> if(1<2){w<-3}else{w<-2}
> w
[1] 3
```

or inside functions:

```
> cond.function <- function(x){
+ if(x>0){print("Non-negative number")}else{print("Negative number")}
+ }
> cond.function(-2)
[1] "Negative number"
> cond.function(2)
[1] "Non-negative number"
```

Loops

- Loops are way to automate repetition of steps/calculations.
- There are primarily two types of loops: for and while.
- In a for loop, a sequence is supplied and the statement/function is evaluated/executed on each item in the sequence; the loop is exited once the last item is reached.
- In a while loop, the loop is only entered if some condition is satisfied, and if so, the statement/function is evaluated/executed; once executed, the condition needs to be re-evaluated and if not satisfied, the loop terminates and exits (otherwise, it repeats).

Examples of loops

- A for loop:

```
> test.loop <- double(10)
> for(i in 1:10){
+ test.loop[i] <- i^2}
> test.loop
 [1]   1   4   9  16  25  36  49  64  81 100
```

- A while loop:

```
> i<-1
> while(i<10){
+ print(i)
+ i <- i+1}
[1] 1
[1] 2
[1] 3
[1] 4
[1] 5
[1] 6
[1] 7
[1] 8
[1] 9
```

A word of warning

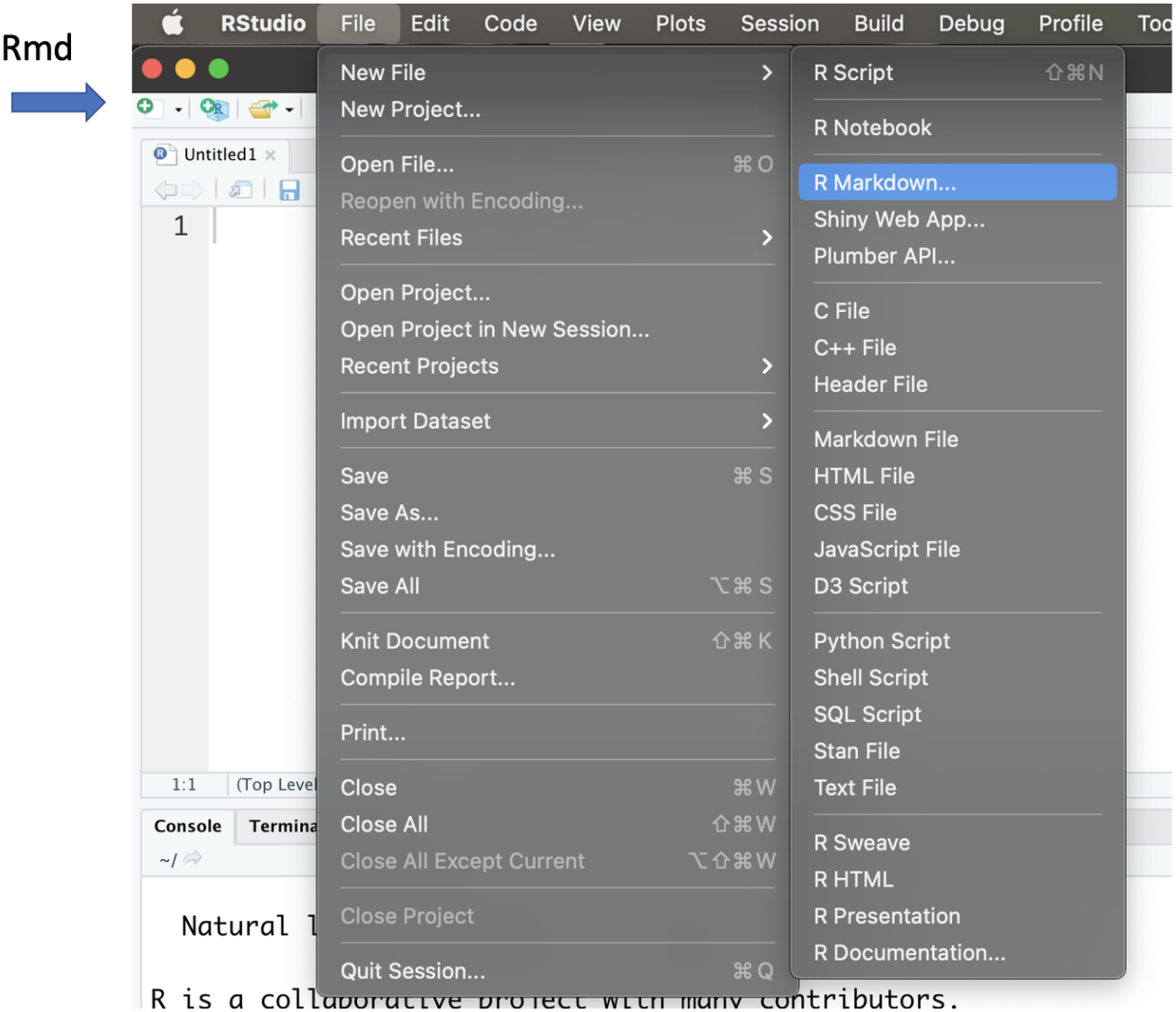
- When you work in R (the console directly or using RStudio), you are working in a workspace.
- When you save your workspace, an .RData file is created in your working directory and all the objects (variables, functions, etc) will be stored in that file.
- When you re-open R (or RStudio), and you are using the same working directory, it will open whatever workspace was used last; so if the last workspace was saved, it will open that workspace.
- It is therefore highly recommended to not save your workspace when closing R (or RStudio)!

RMarkdown

- RMarkdown is a relatively new tool for R users; it was introduced in 2004 but it has been within the last few years that it has really become popular.
- RMarkdown is only available when using RStudio.
- With a single RMarkdown file (which are saved as .Rmd) you can save and execute code as well as generate reports in various formats; common formats for the output are html and pdf.
- To use RMarkdown, you may need to install packages, such as: knitr and rmarkdown.

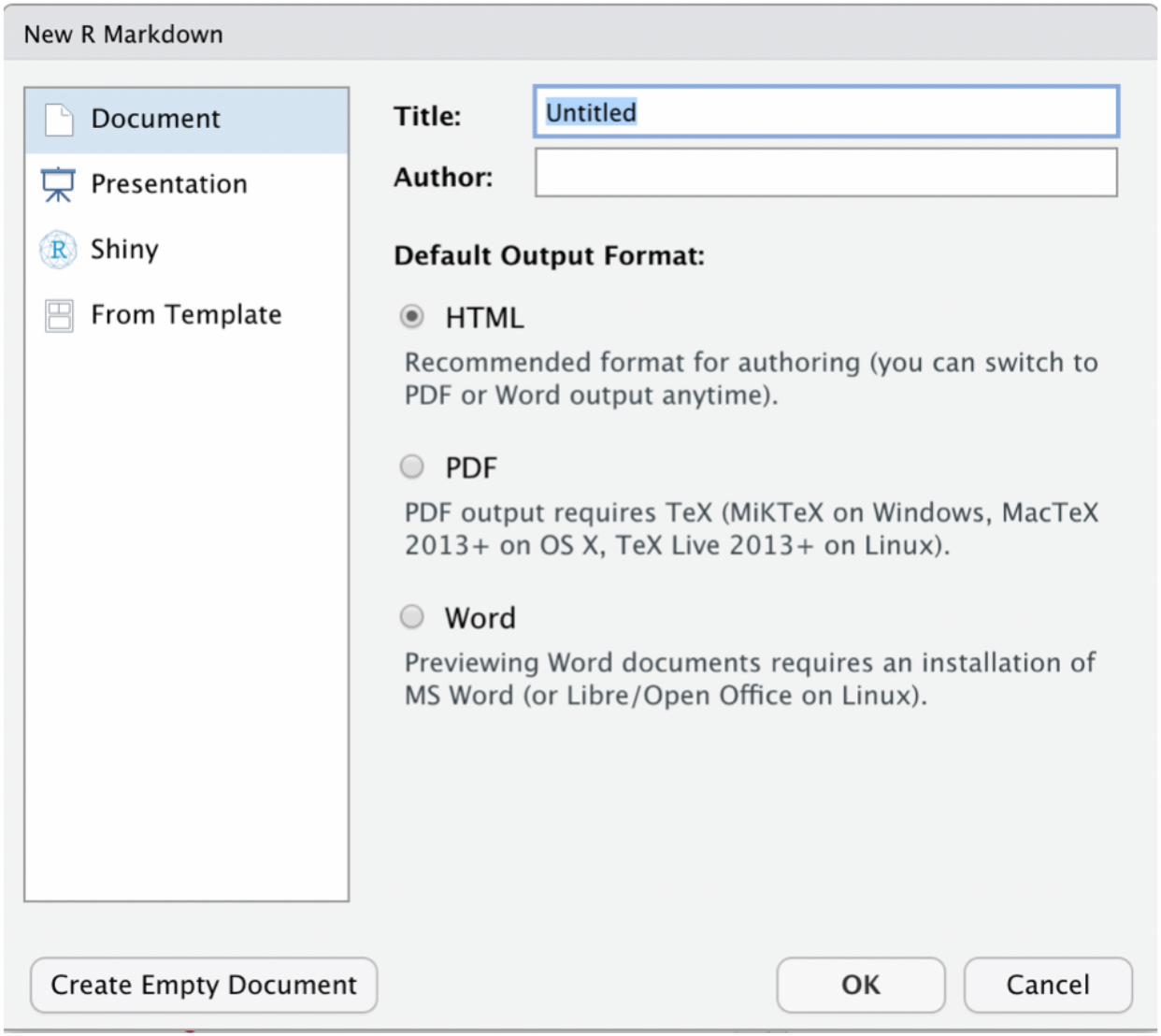
Creating an RMarkdown (.Rmd) file

Step 1: Creating an .Rmd file



Creating an RMarkdown file

Step 2: Choosing format and name of output



In this course, our output format will be PDF.

RMarkdown syntax

- Under the automated information about the file, you can simply start typing text.
- Headers can be inserted by typing #, i.e., # Section 1.
- There are ways to highlight or emphasize text:
  - Italics: *italic*
  - Bold: **bold**
- We can also make lists:
  - Unordered:

```
Unordered list

* Item 1
* Item 2
  + sub-item 2a
  + sub-item 2b
* Item 3
```

  - Ordered:

```
Ordered list

1. Item 1
2. Item 2
3. Item 3
  + sub-item 3a
  + sub-item 3b
```

Code chunks in RMarkdown

- Executable R code can be embedded into the .Rmd file.

- To insert R code (often referred to as code chunks), you must type three back tick marks, r, the curly brackets, the code and then three more tick marks:

```
```{r echo=TRUE}
mean(c(2,5,8))
```
```

- Note that echo=TRUE means we want our code displayed in the output file.

Plots and figures in RMarkdown

- We can name a code chunk and we can have R generate figures for display (or not) in the output file.

````
```{r Inserting a plot, echo=FALSE}
mydata <- read.csv(file="~/Desktop/MyDataCSV.csv", header=TRUE)
hist(mydata$Height,xlab="Height")
```
````

- If there is a local image (for which you can determine the path) to be inserted, simply type:

```
![Caption](filepath)
```

- Notice the difference between the two ways to produce figures in your output file: one is R code (a code “chunk") and one is pure RMarkdown syntax.

Tables in RMarkdown

- Tables can be made in various ways, many of which rely on R functions from various R packages such as:
  - knitr
  - xtable
  - stargazer
  - tables
- Tables can also be created manually.
- Some tables look better in certain formats (pdf versus html, for instance).

Tables in RMarkdown

- Making a simple table from raw data using RMarkdown syntax:

```
Name              Faculty          Years in Position
---------------   --------------   -----------------
Chris Sanders     Medicine          5
Suzanne Clay      Arts              10
Joe Smith         Science           8
Ross Watson       Engineering       18
---------------   --------------   -----------------
```

- The output pdf file displays the table as:

Name	Faculty	Years in Position
Chris Sanders	Medicine	5
Suzanne Clay	Arts	10
Joe Smith	Science	8
Ross Watson	Engineering	18

Tables in RMarkdown

- Loading knitr and using its function kable:

Here is a sample table

```
```{r loading mtcars data set and making a table, results="asis"}
library(knitr)
kable(mtcars[1:4,], caption="A simple table")
```
```

- And here's how it looks in a pdf file:

Table 2: A simple table

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1

How to knit

- To produce the output file (pdf, or whatever you chose), you need to knit; do not pick up some yarn and knitting needles!

- In RStudio simply click the Knit button at the top; if the output file is a pdf, it will open in the appropriate software; if the output file is html, the file typically is opened immediately for viewing.
- Assuming the necessary figures and other files are available, anyone who has the .Rmd file can reproduce the same output using RMarkdown.

Other R and RMarkdown resources

- Besides using help files in R, the internet is full of suggestions and help using R.
- A quick internet search of any issue you're having is likely to find a solution (though it may not be a good one).
- The official R Short Reference Card contains some basic useful functions.
- There are also many online resources for RMarkdown, including videos, cheat sheets and examples.