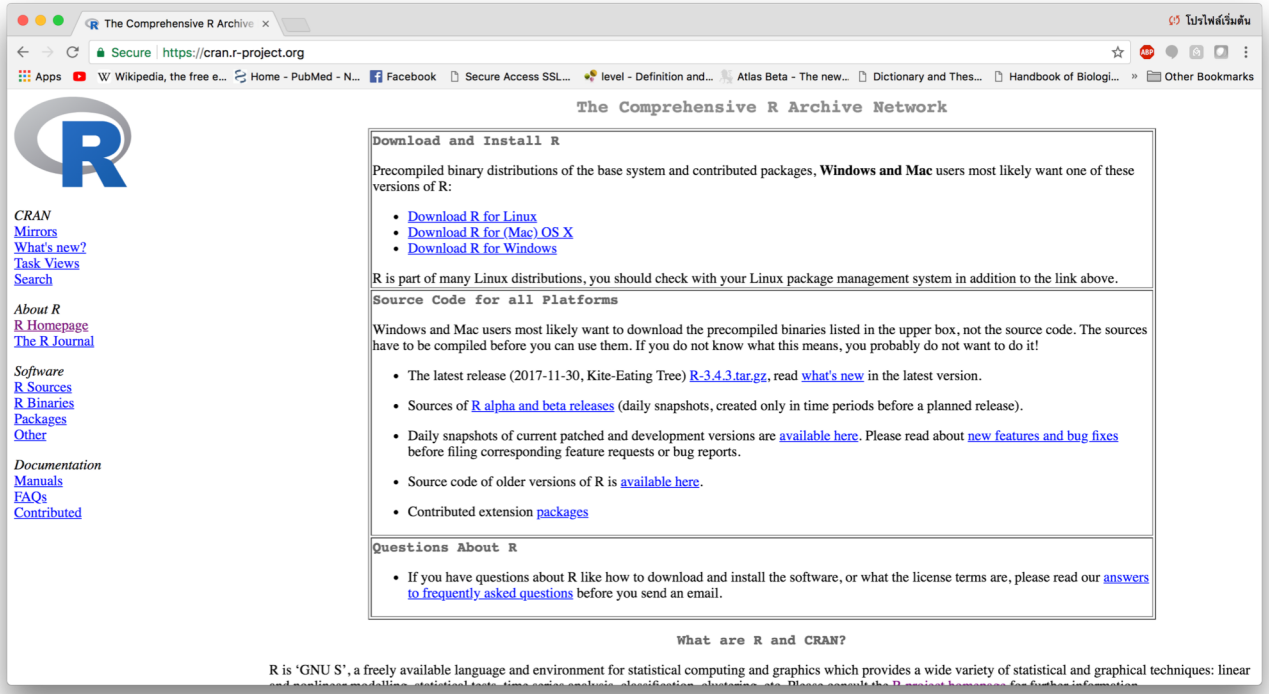
SIRE506

Data Management, Data wrangling, EDA

(Introduction to R programming)

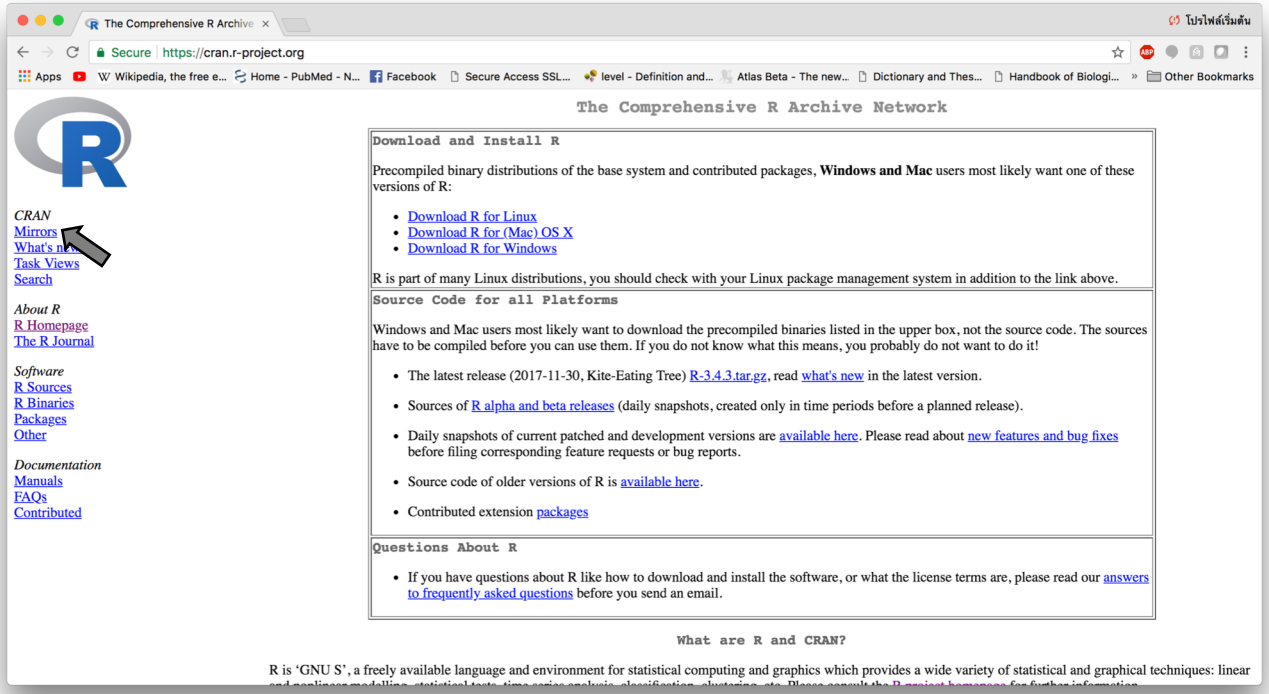
Let’s get R

- Download the latest version of R at https://cran.r-project.org/



Let’s get R

- Choose a proper ”mirror” to download faster



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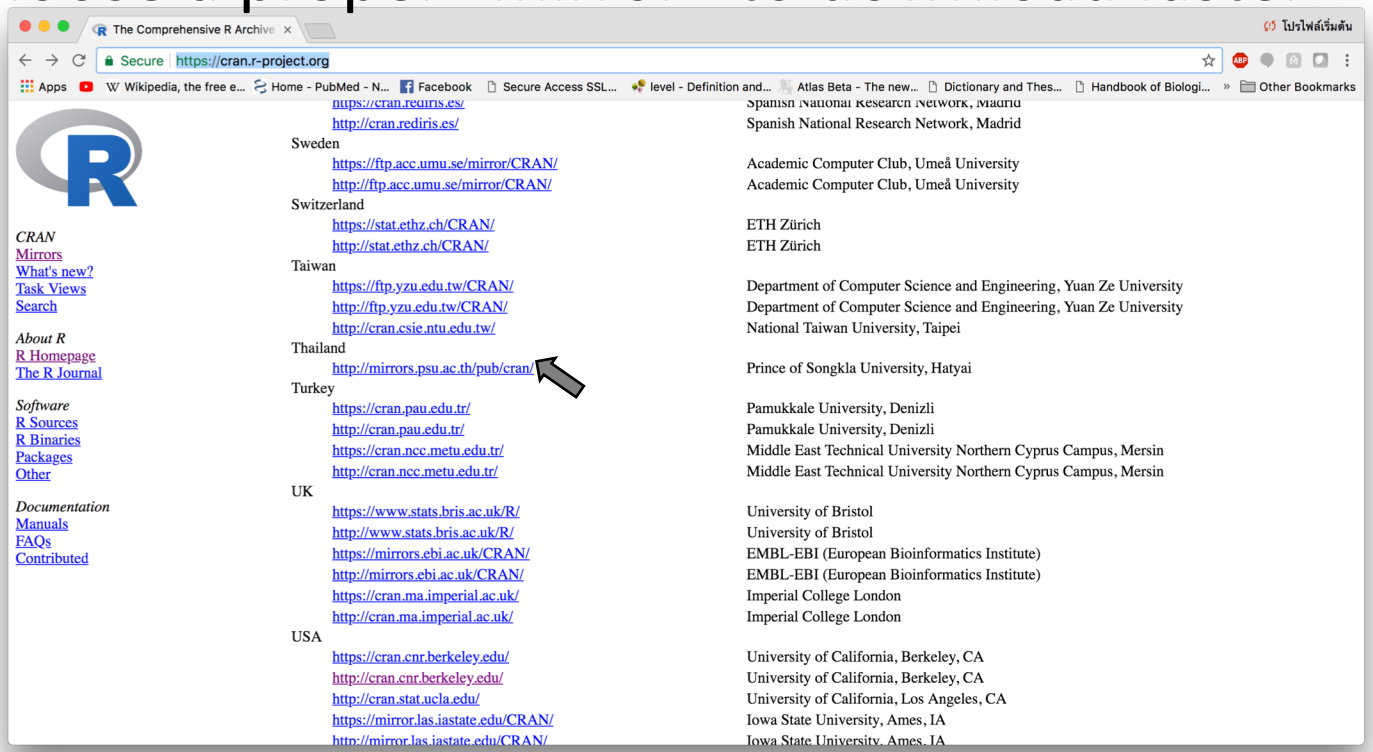

Let’s get R

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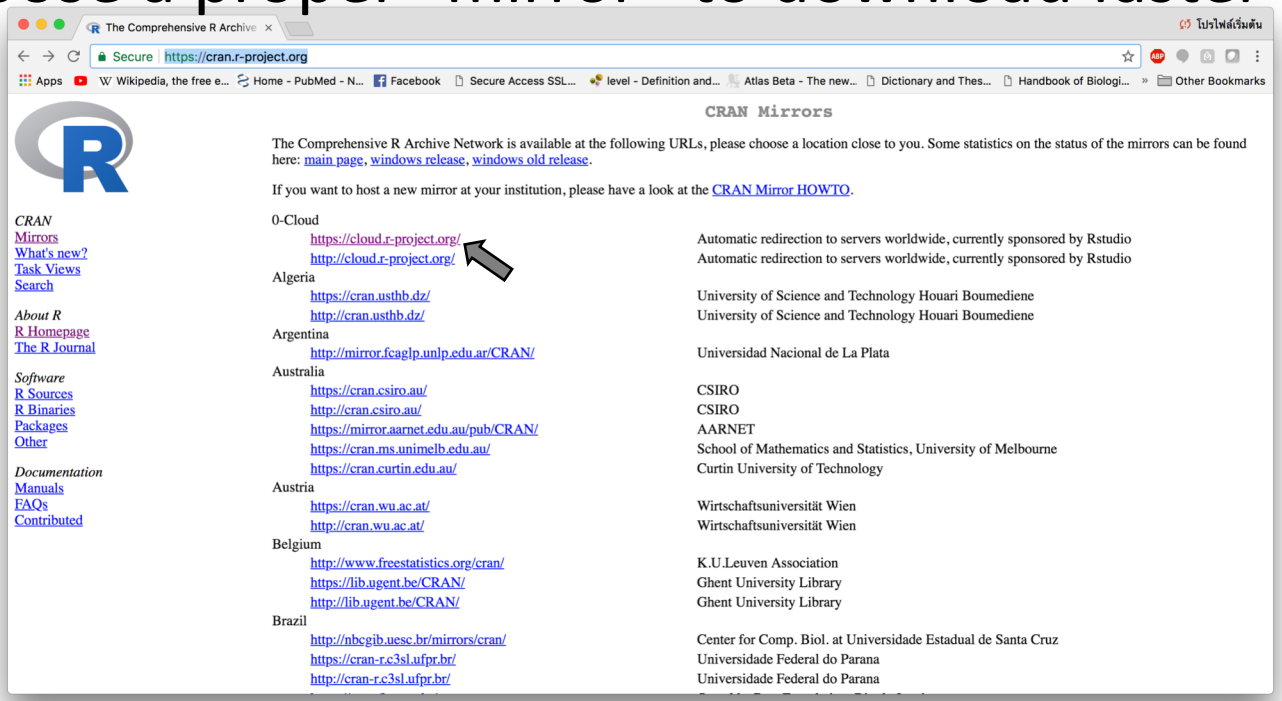
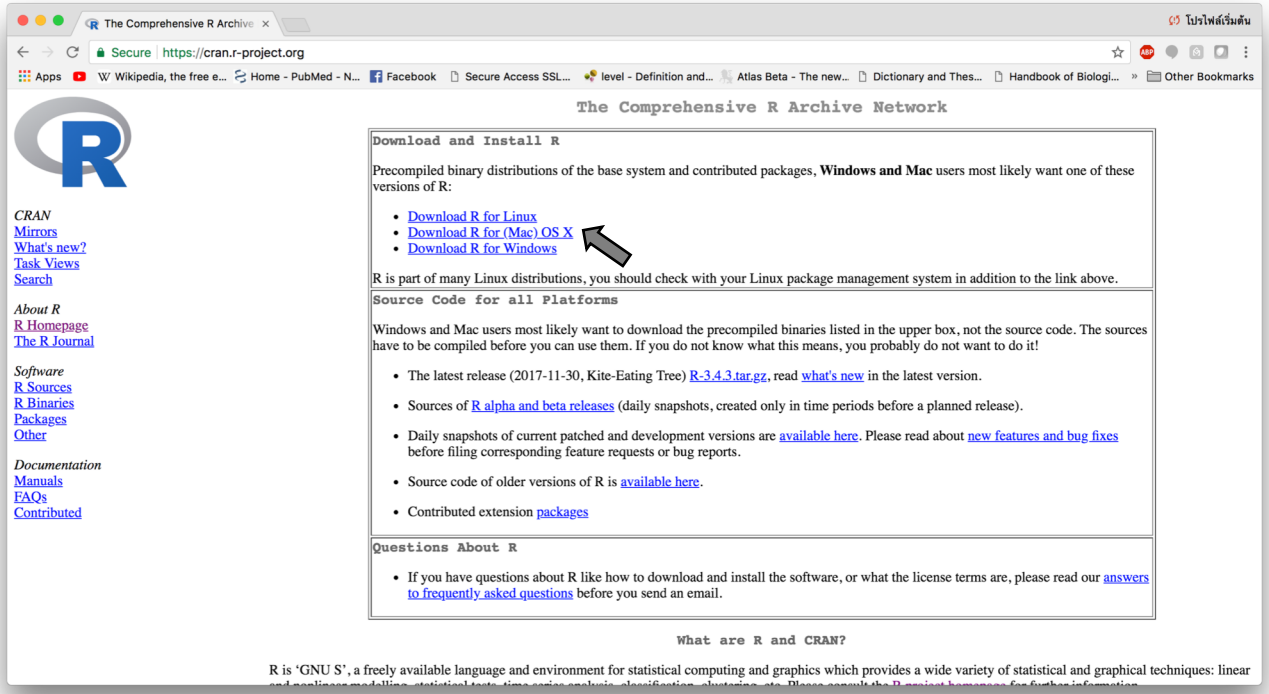


Let’s get R

- Choose your OS



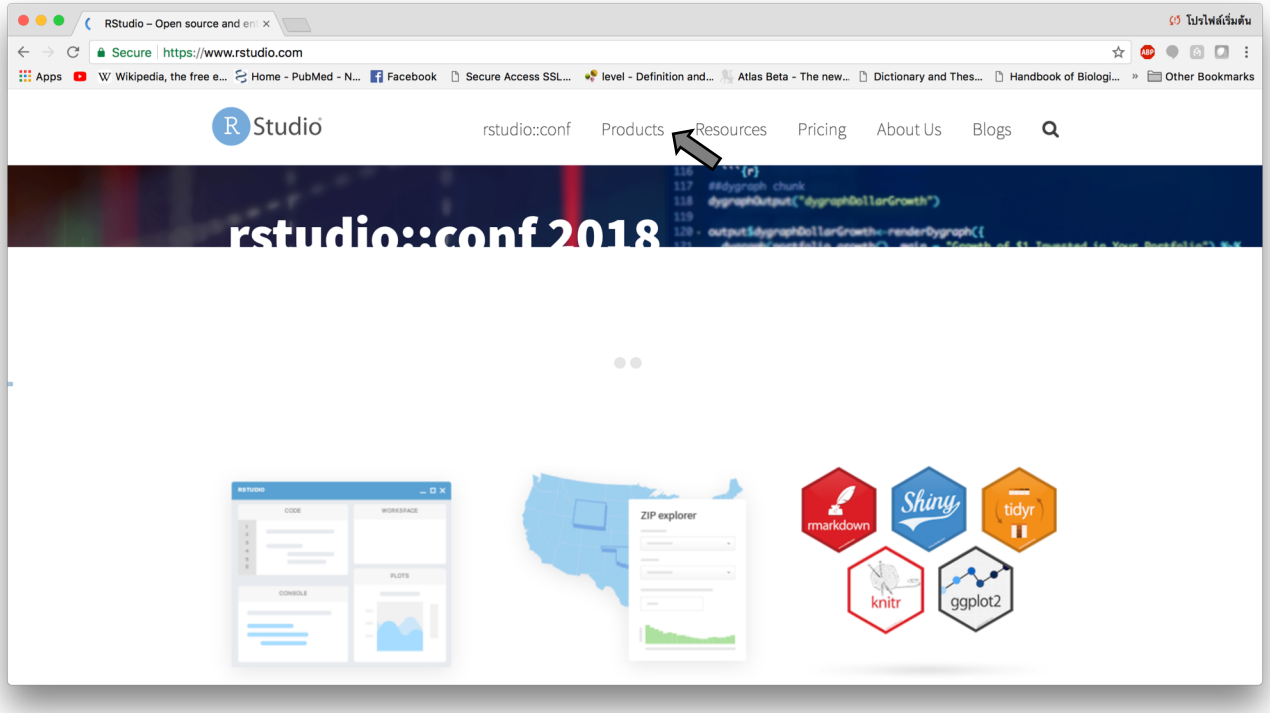
RStudio

- Integrated development environment (IDE) for R
- Organizing your R coding environment
- Facilitate datasets loading
- Facilitate graph and plot resizing and saving

*****ALWAYS install R before Rstudio*****

Let’s get RStudio

- Download the latest version of RStudio at https://www.rstudio.com/



Let’s get RStudio

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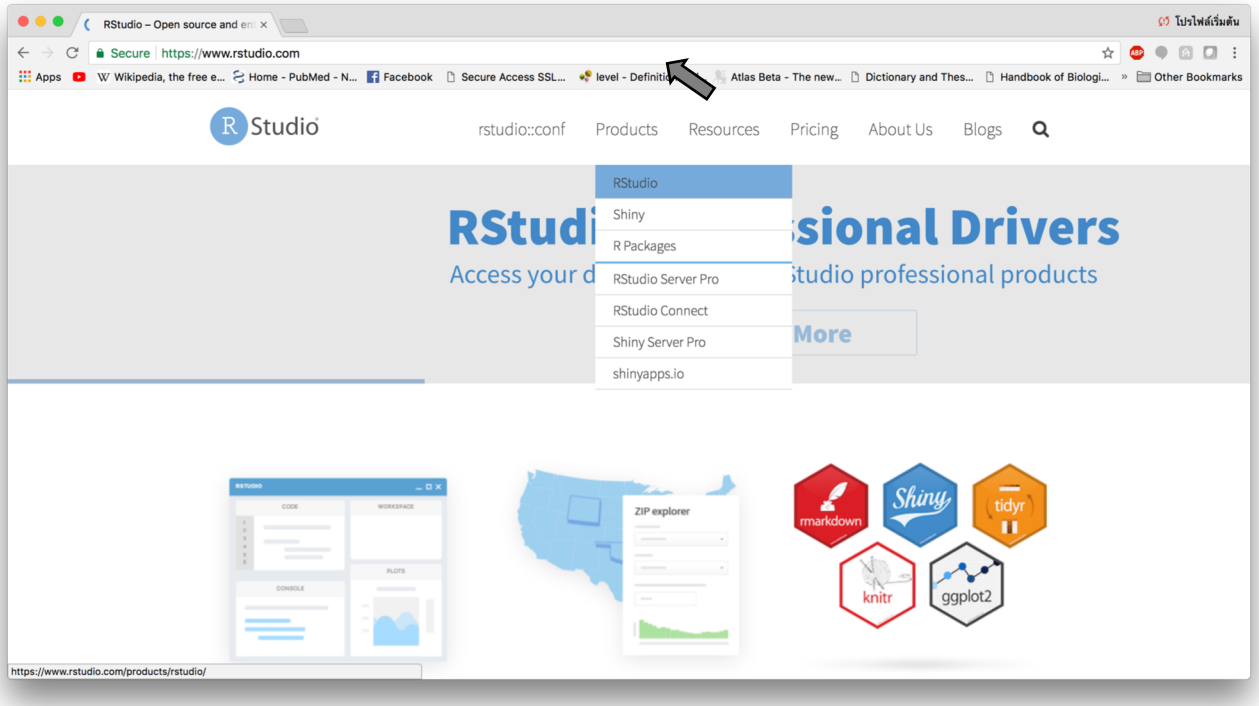
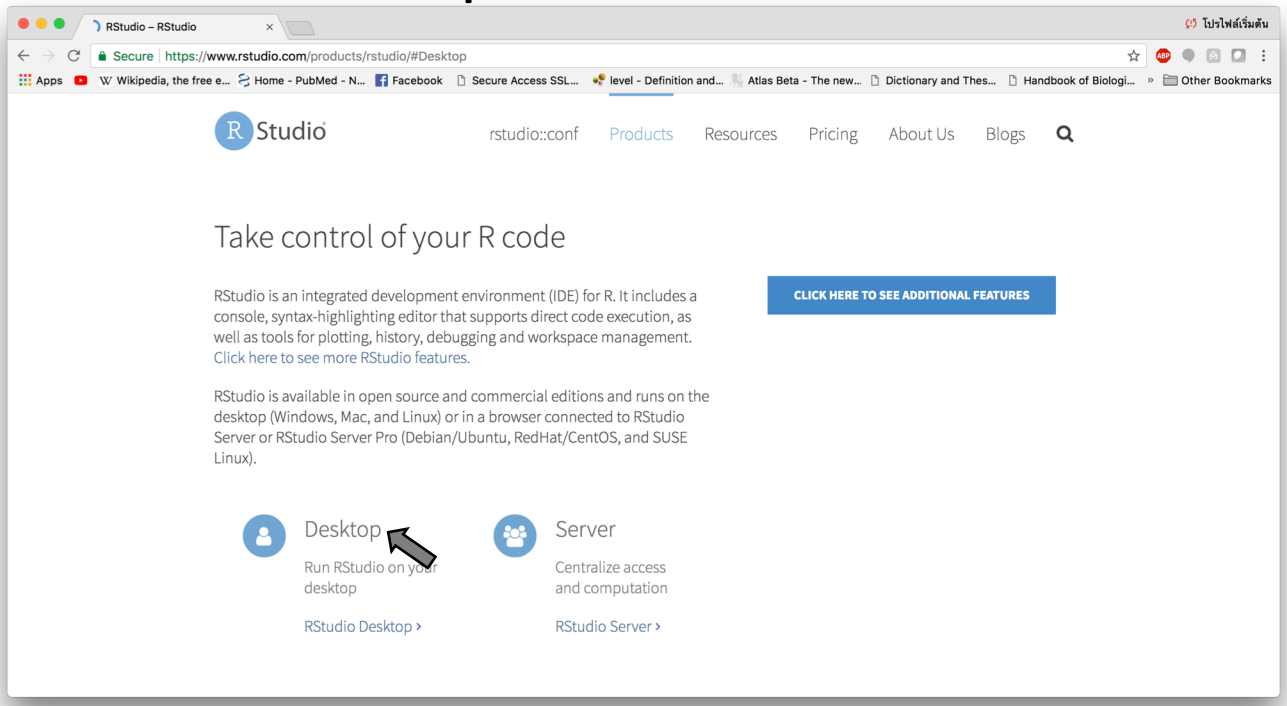


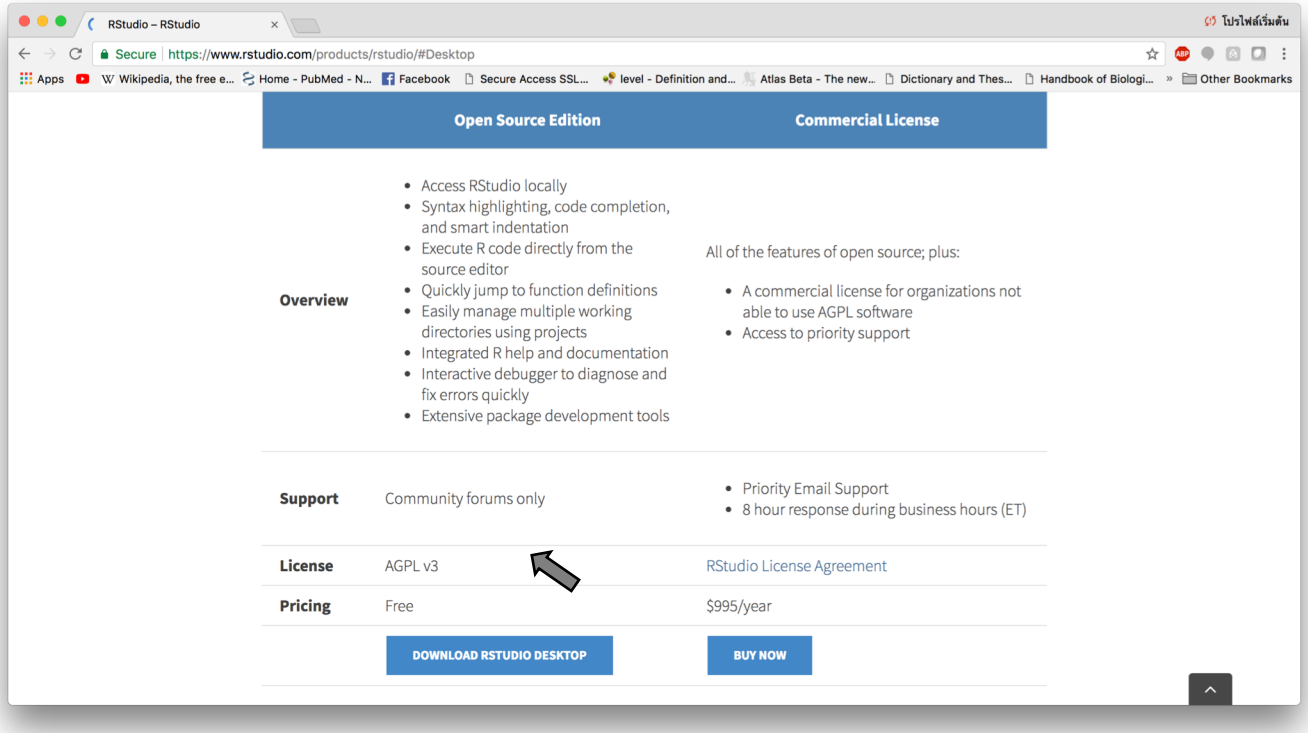
Let’s get RStudio

- Choose a “Desktop” version



Let’s get RStudio

- Choose a “Open Source” edition (Or buy it if you want)



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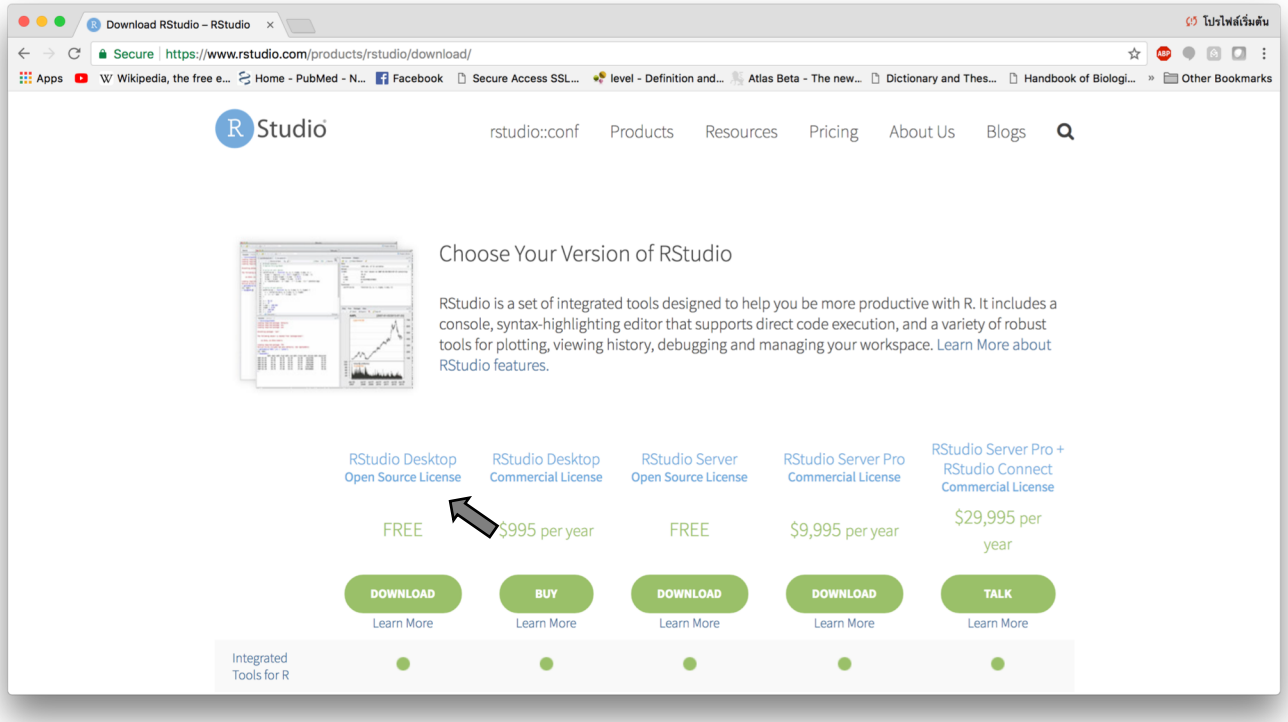
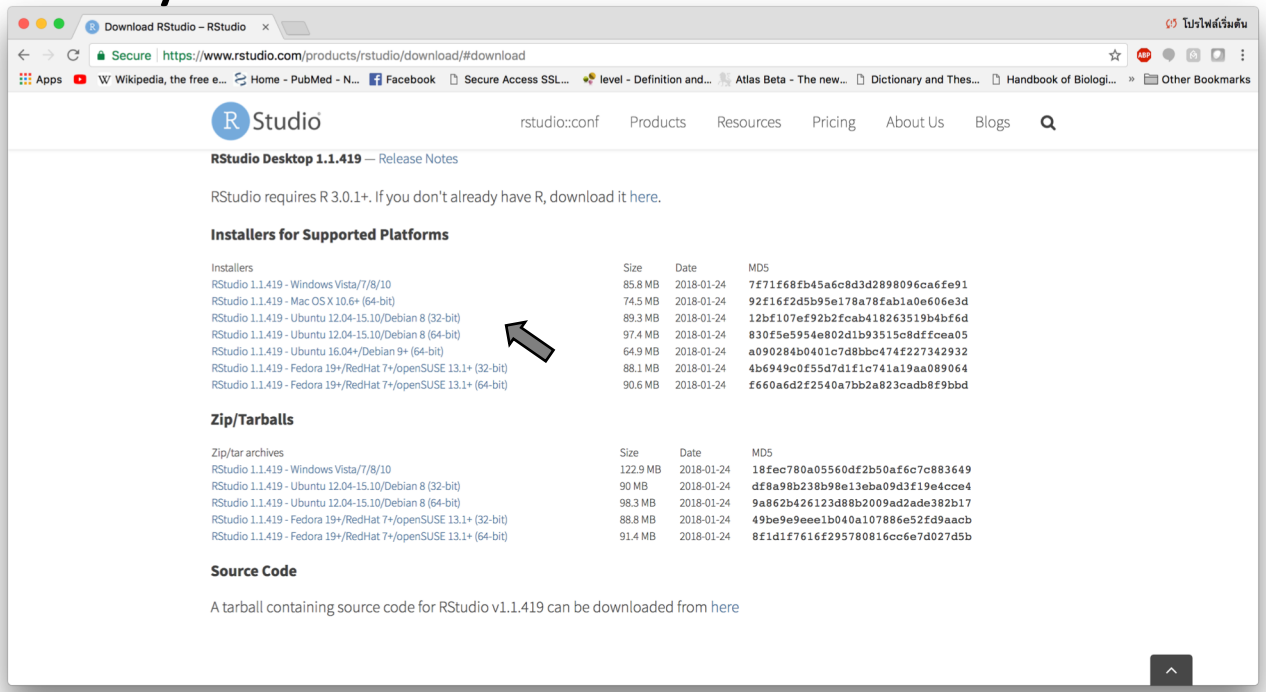
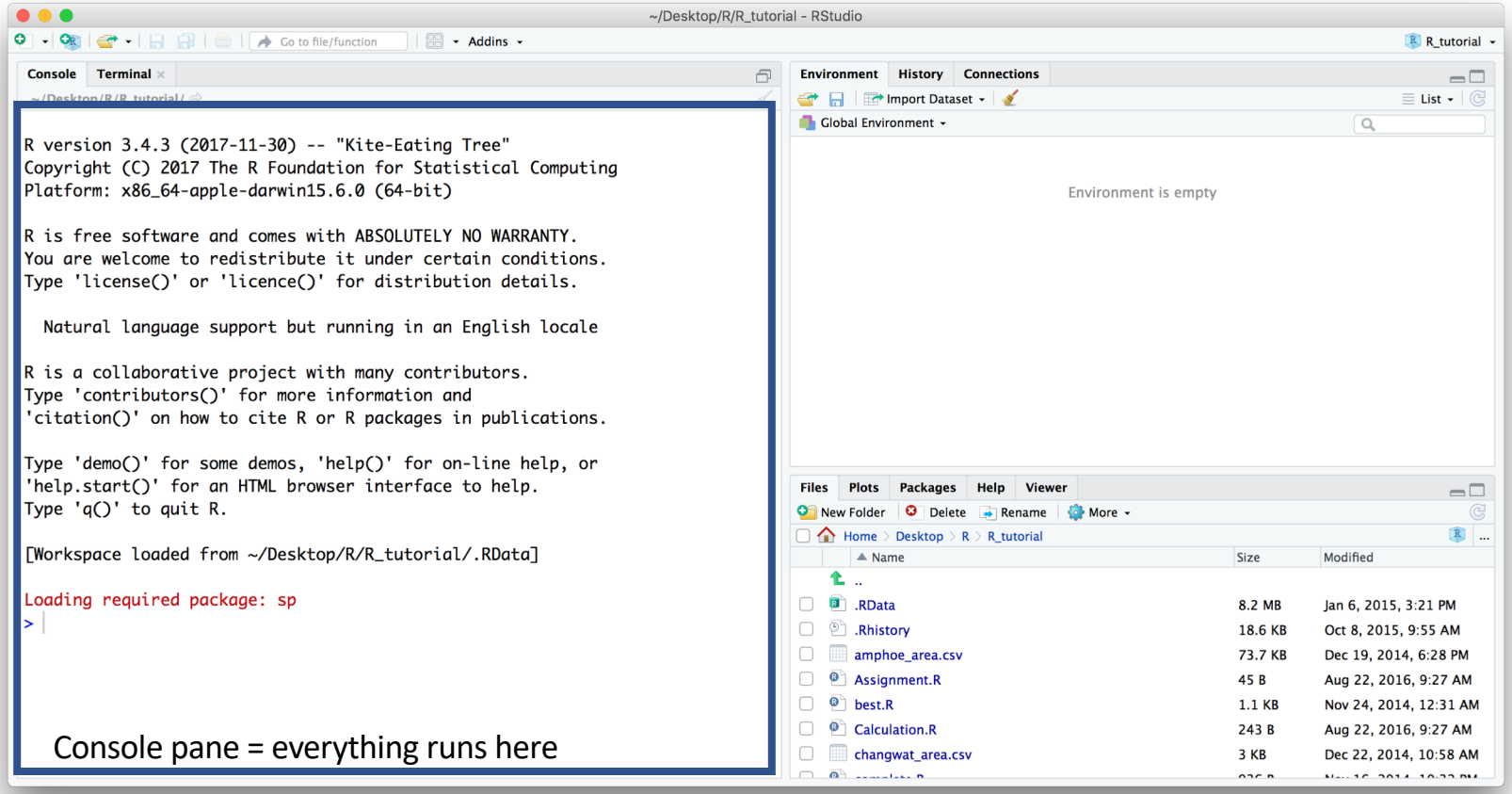


Let’s get RStudio

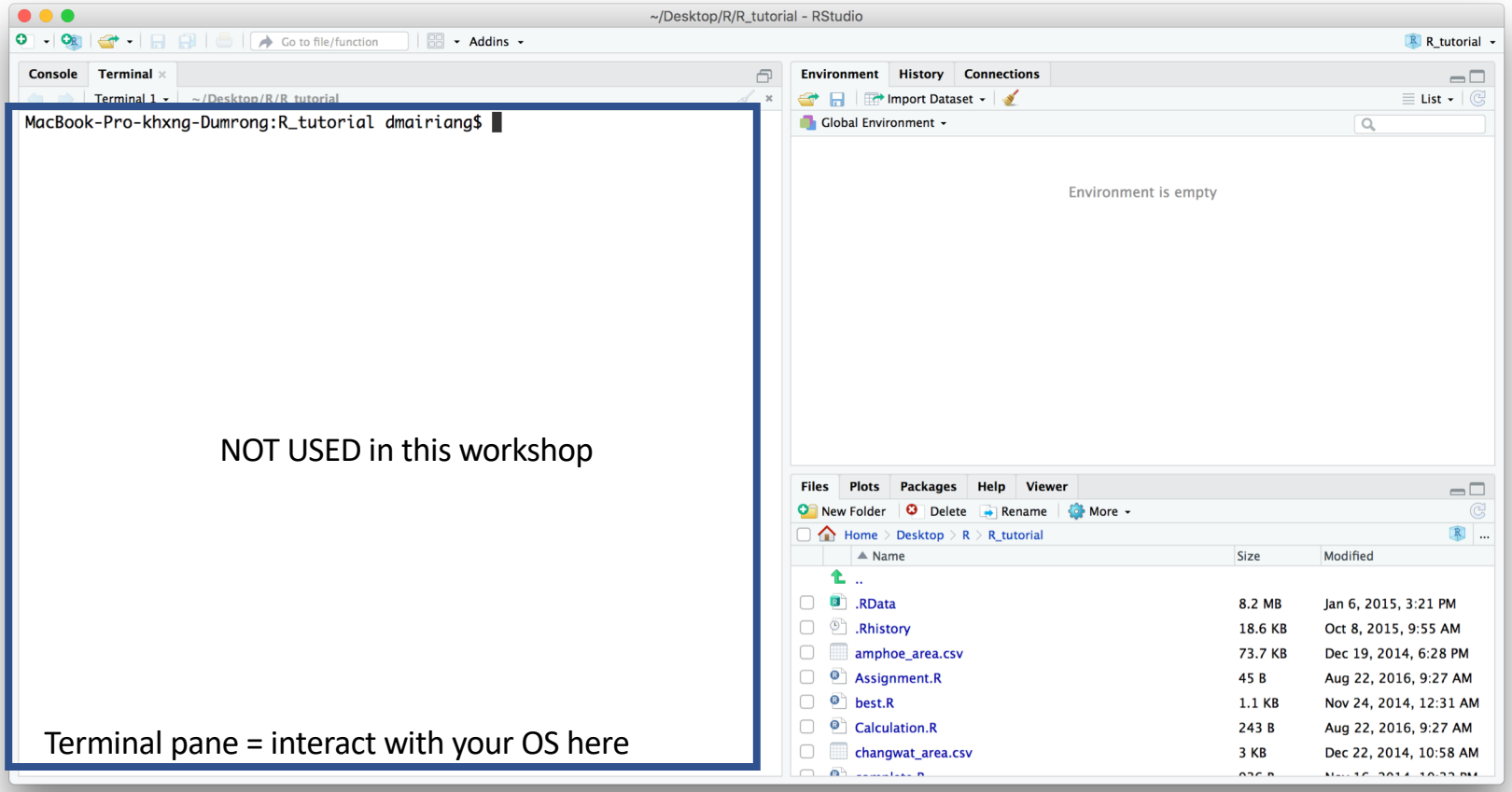
- Choose your OS



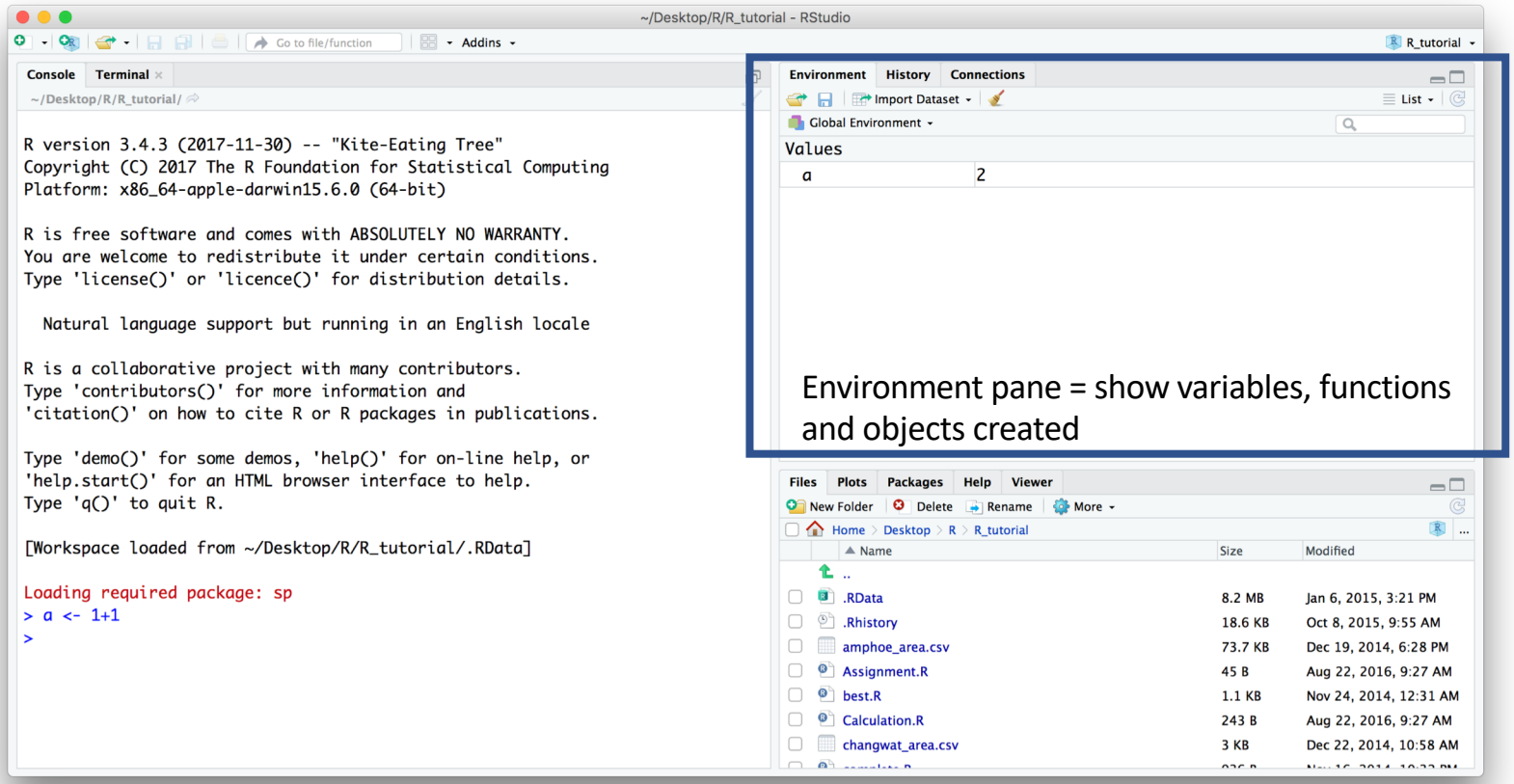
Panes of RStudio



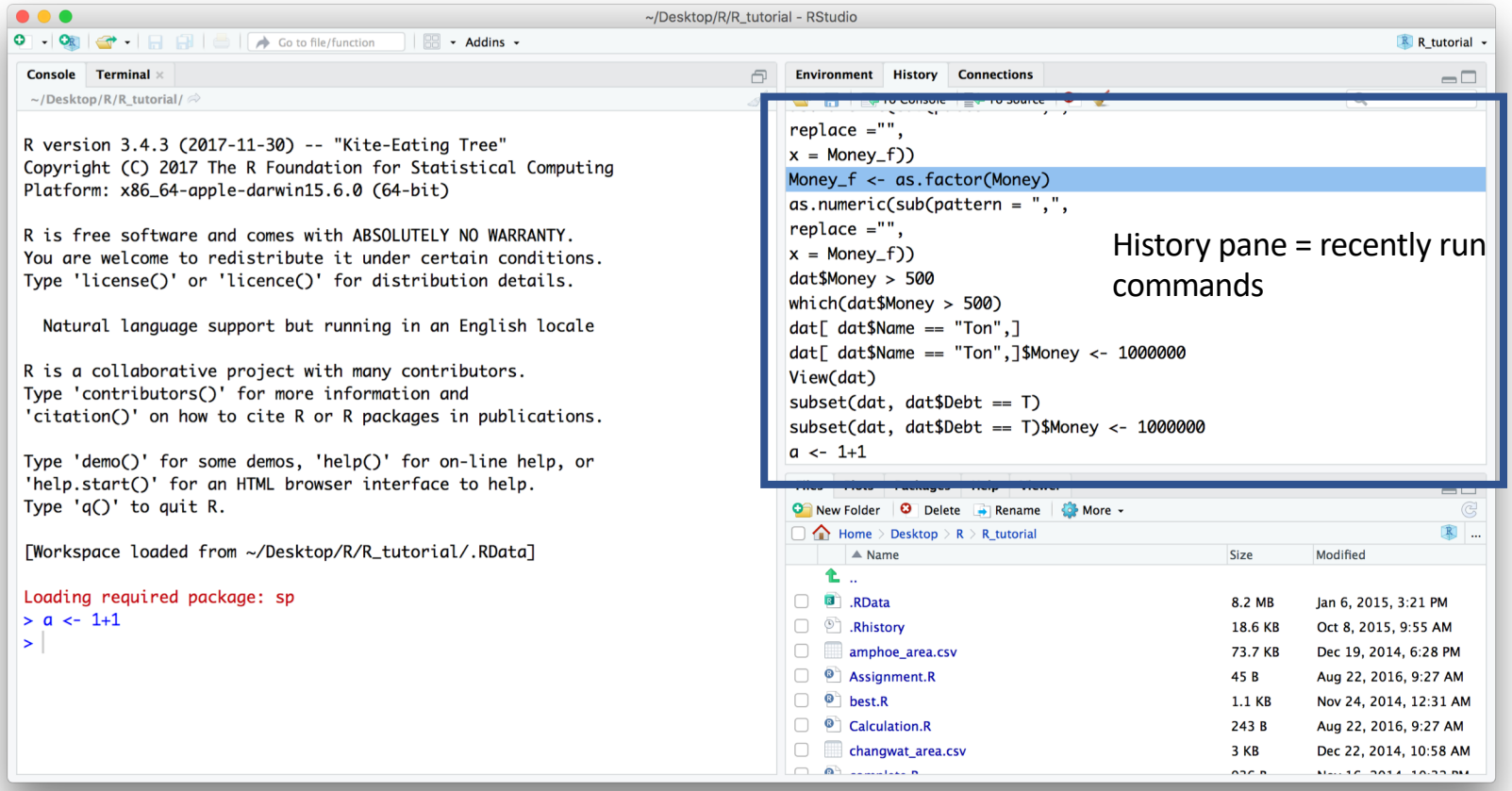
Panes of RStudio



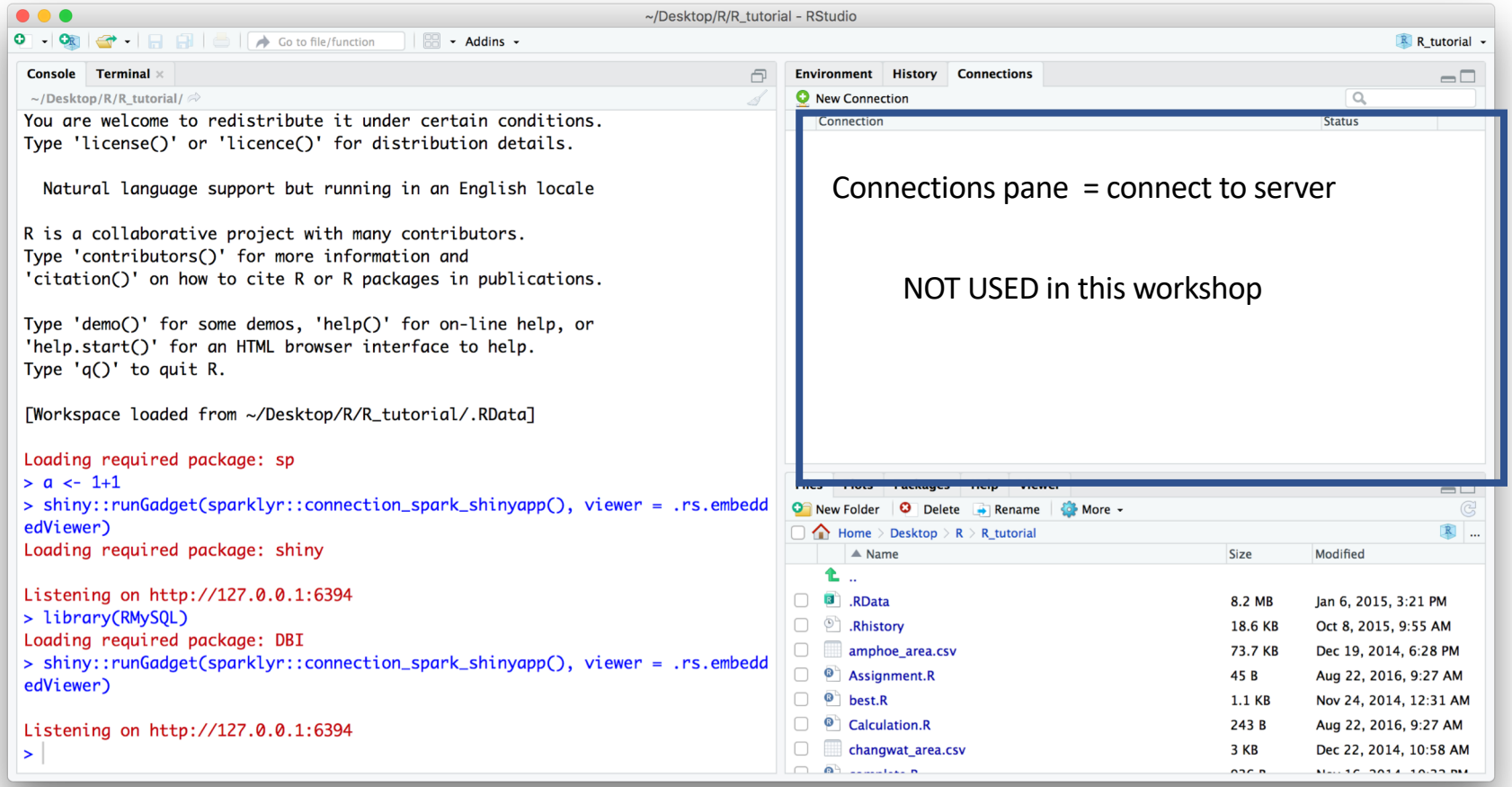
Panes of RStudio



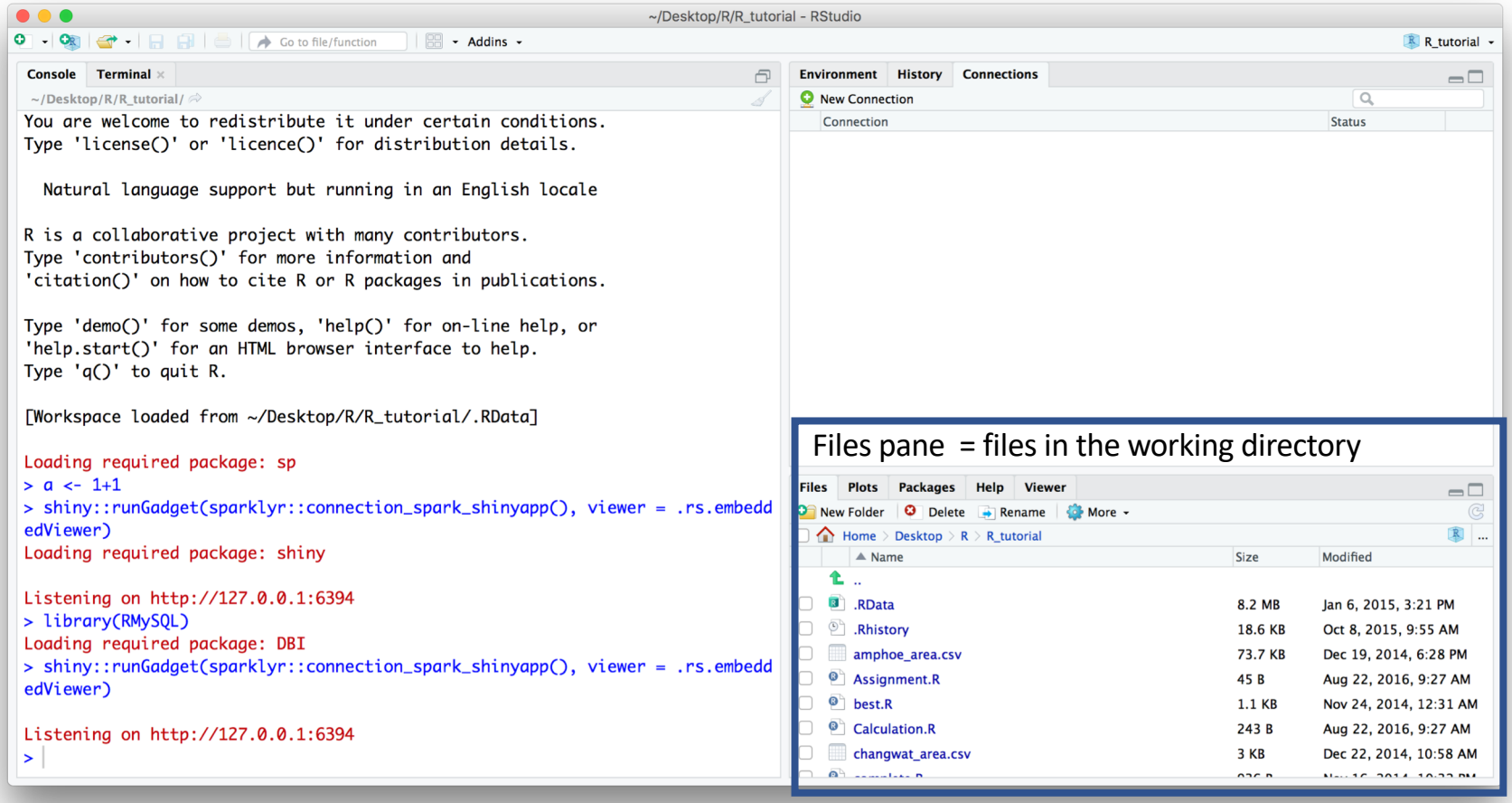
Panes of RStudio



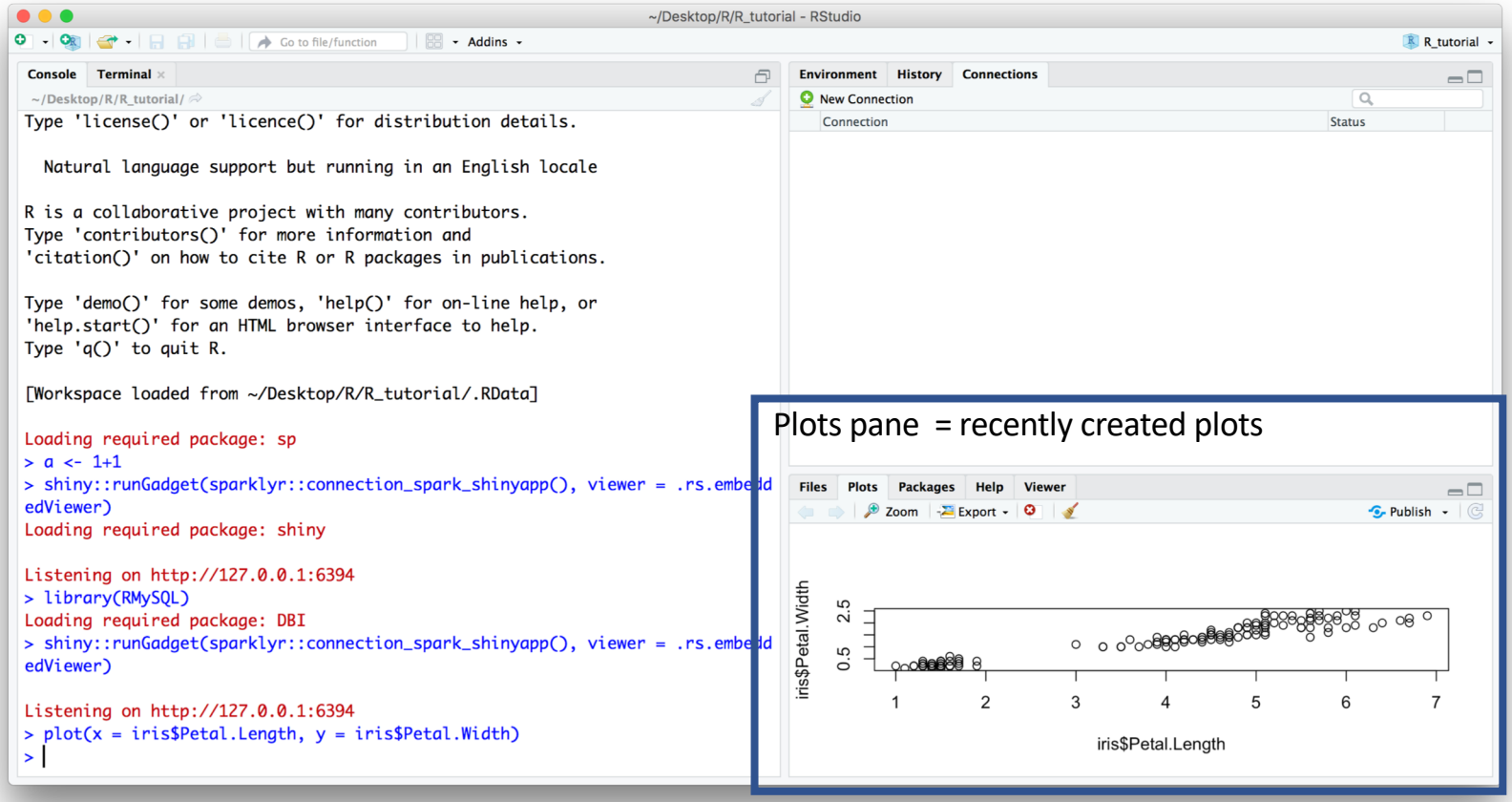
Panes of RStudio



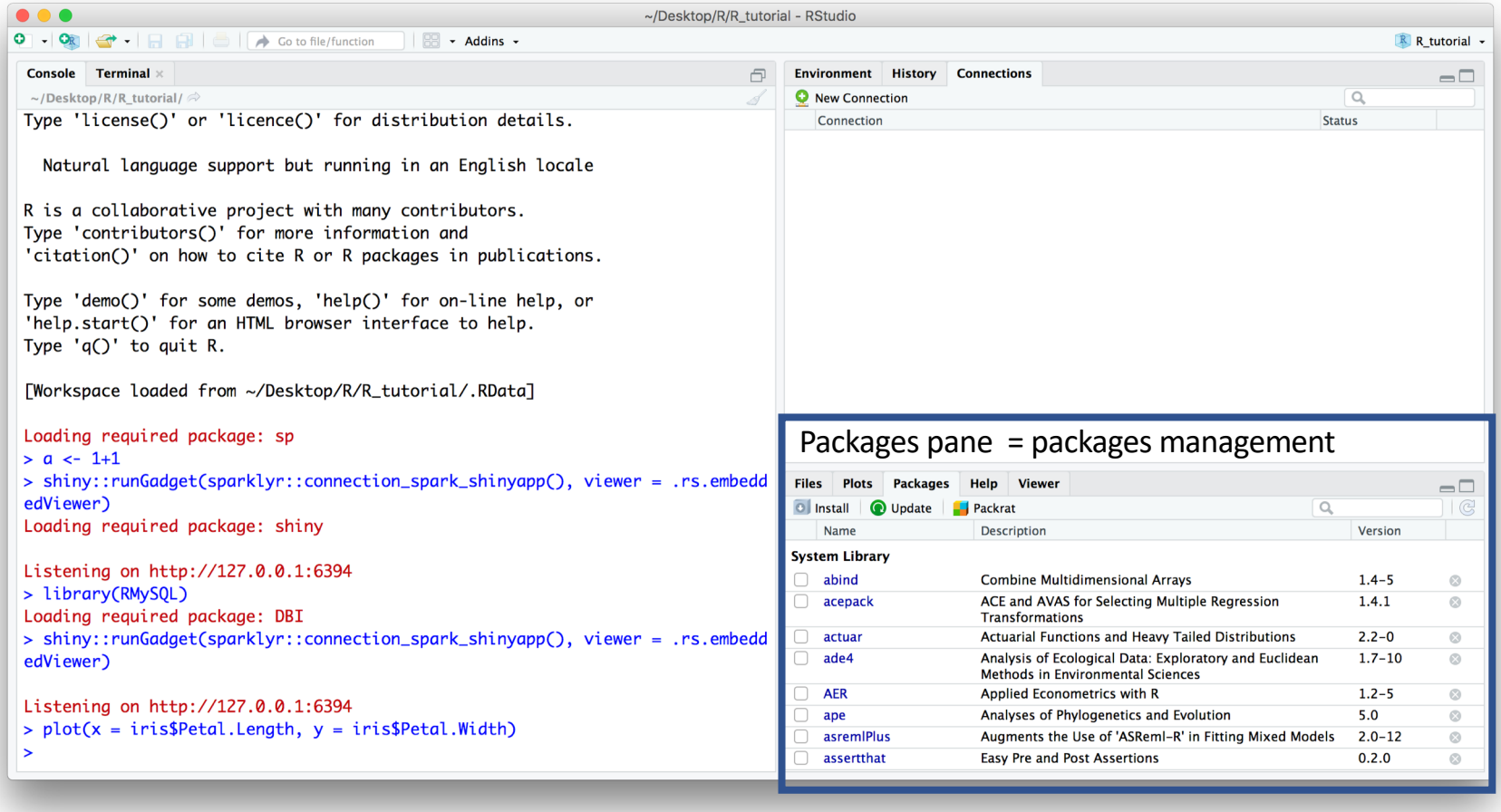
Panes of RStudio



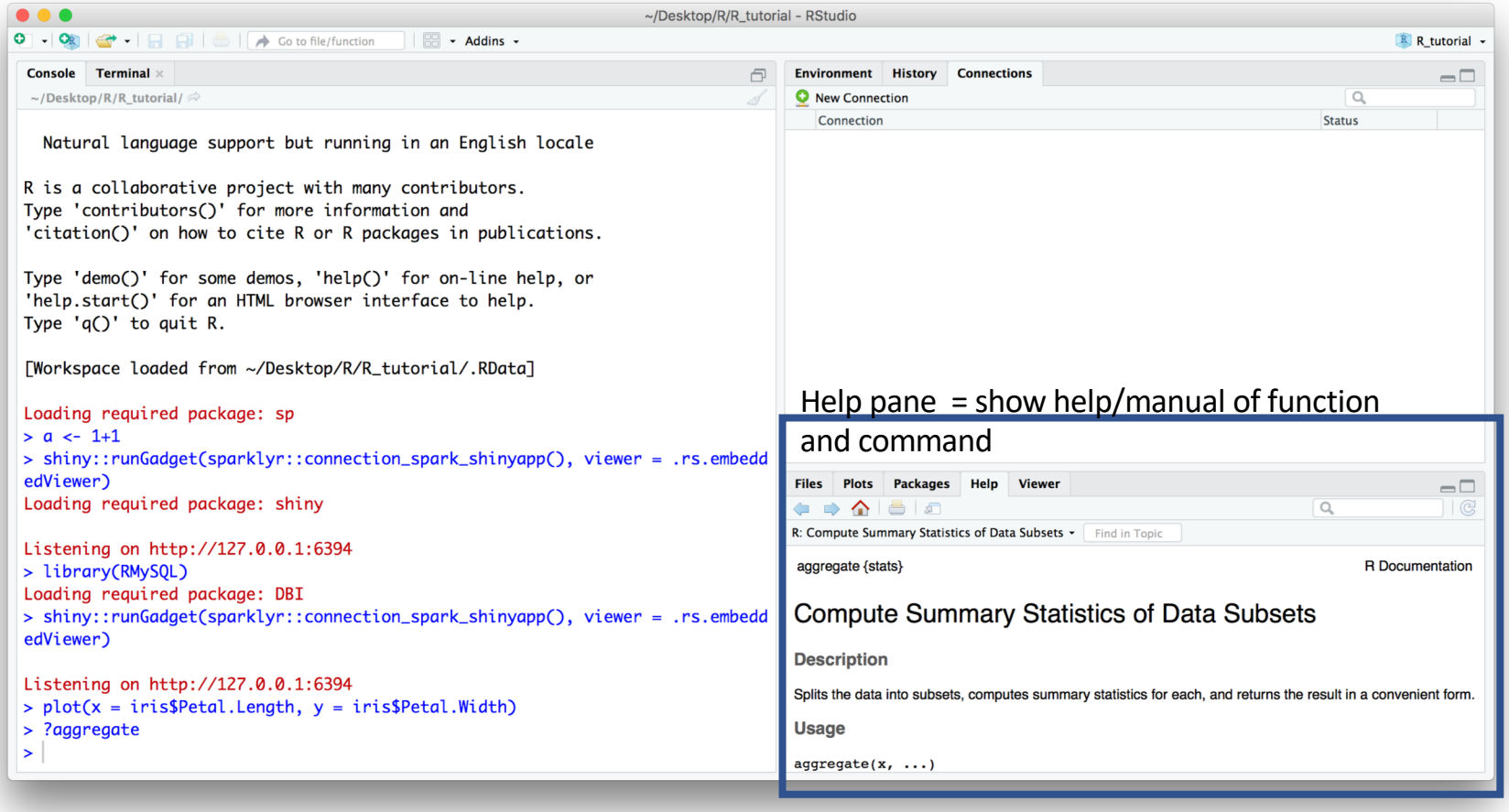
Panes of RStudio



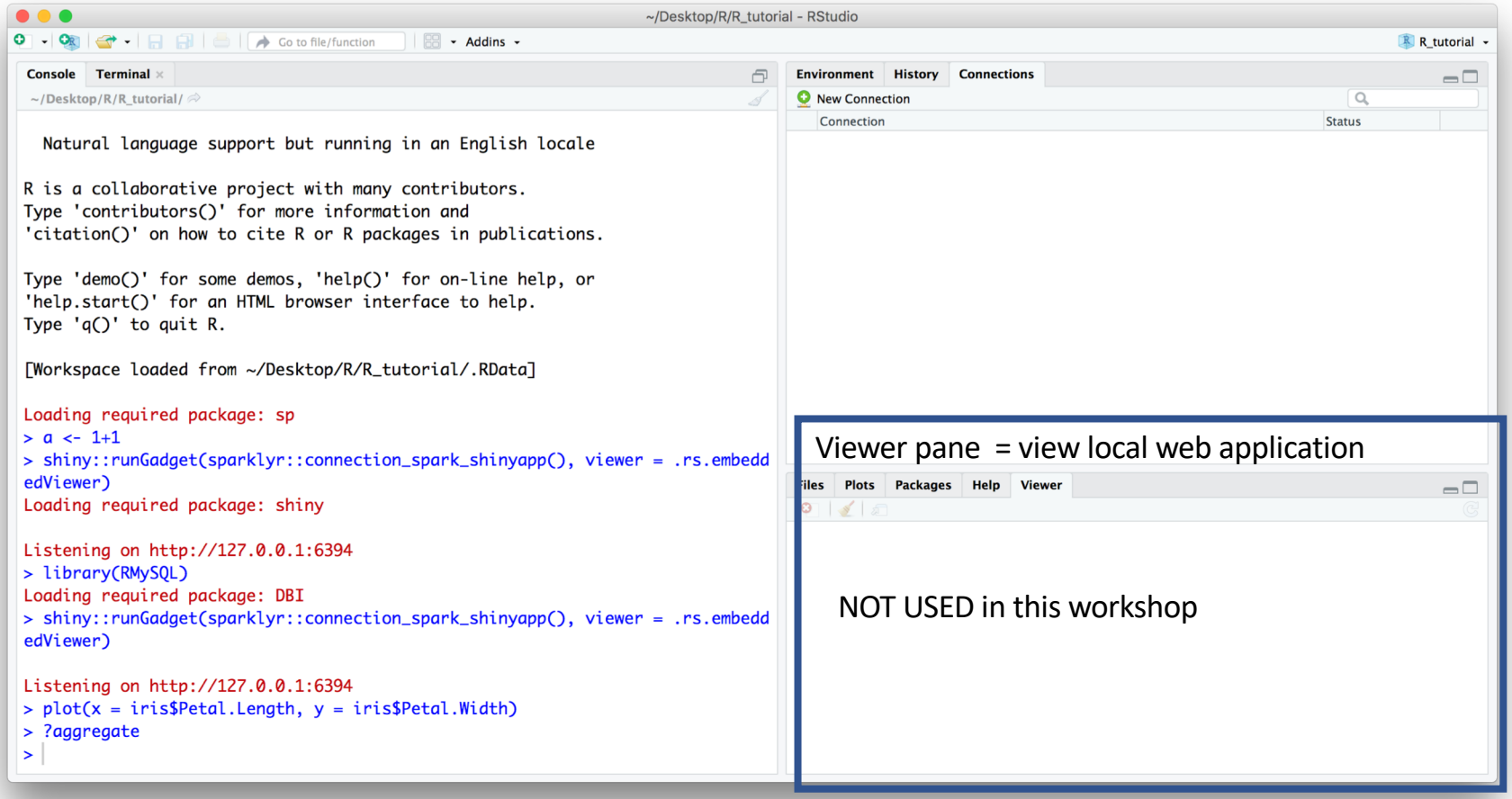
Panes of RStudio



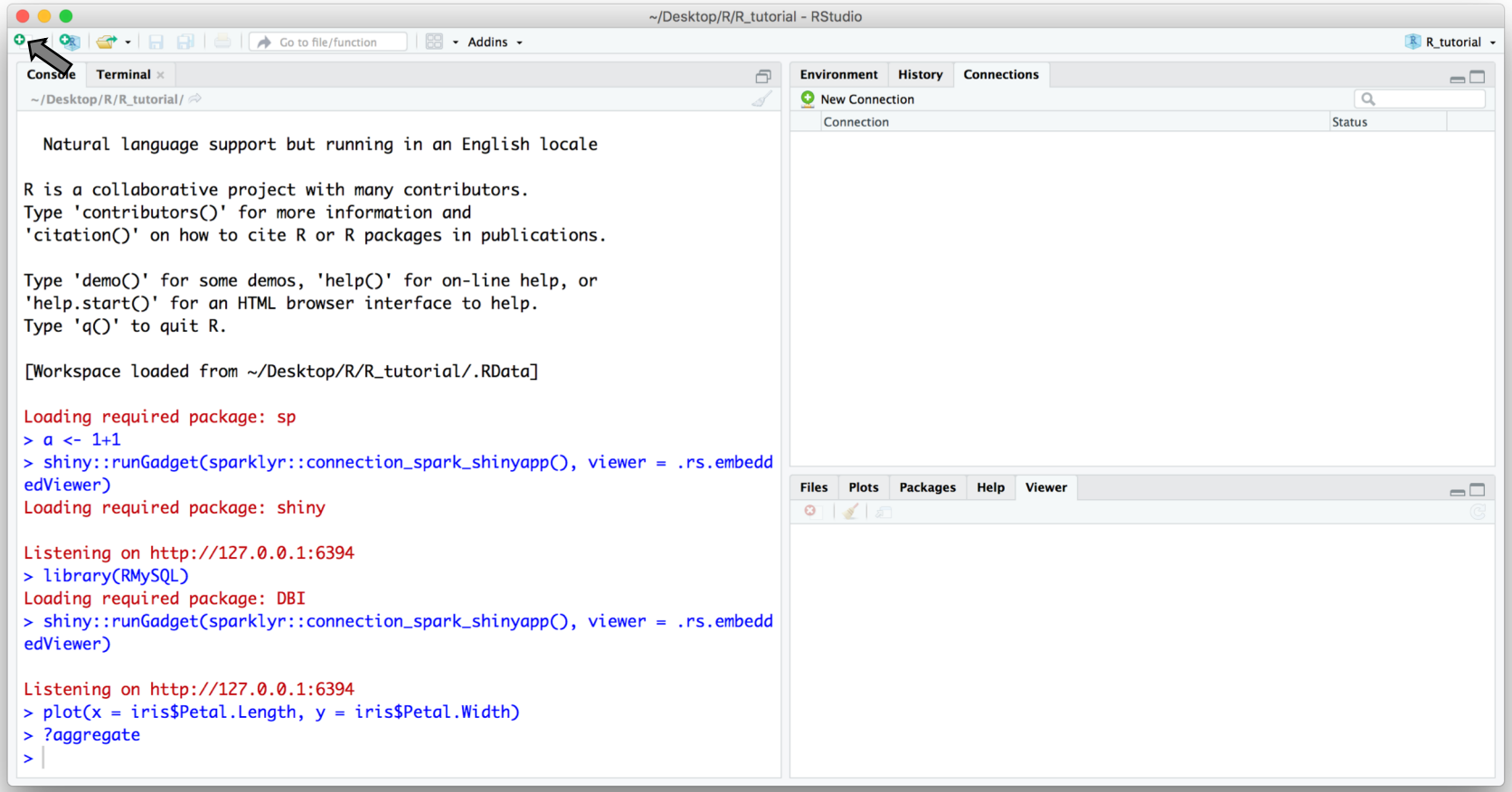
Panes of RStudio



Panes of RStudio



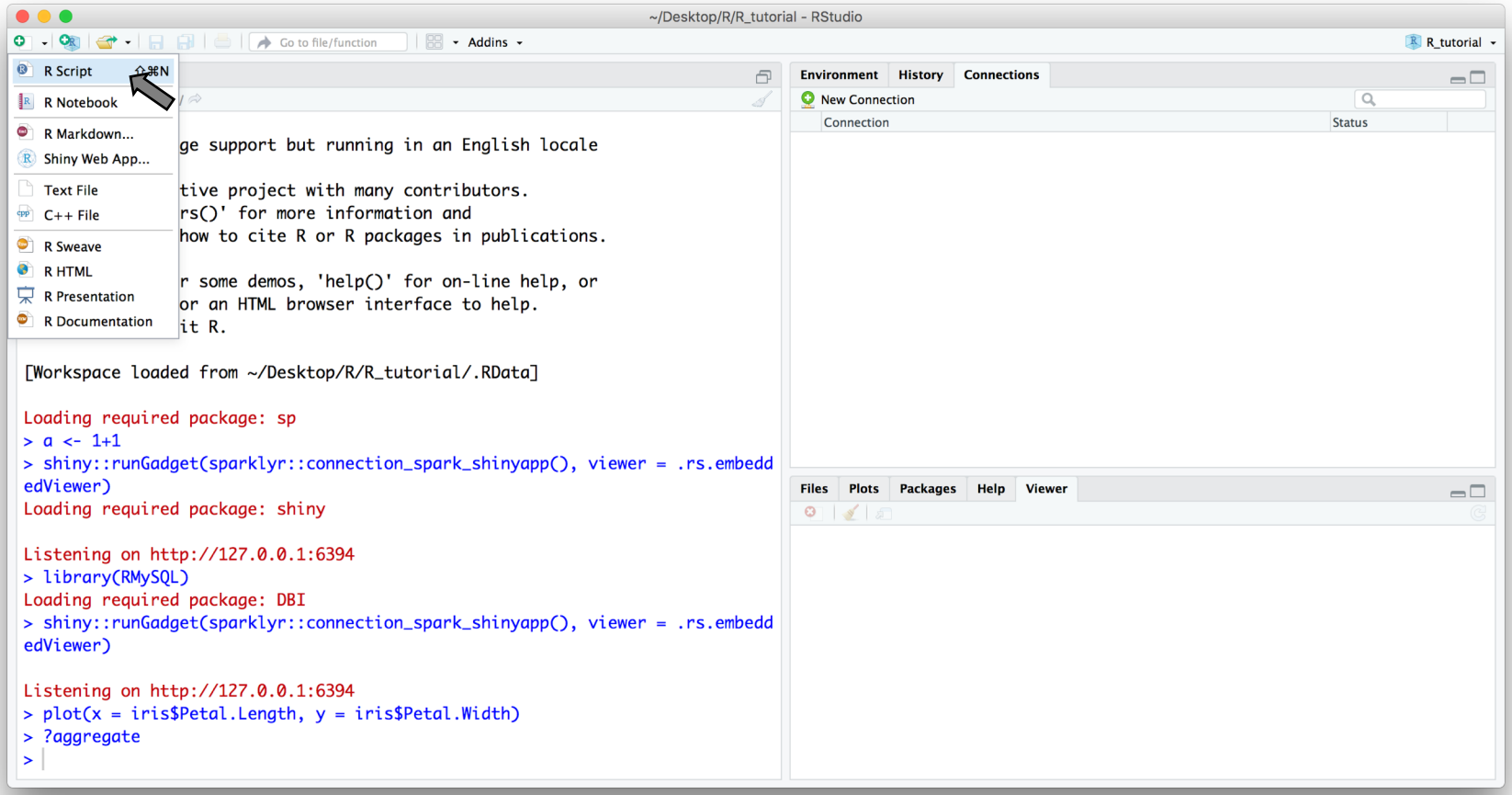
Panes of RStudio



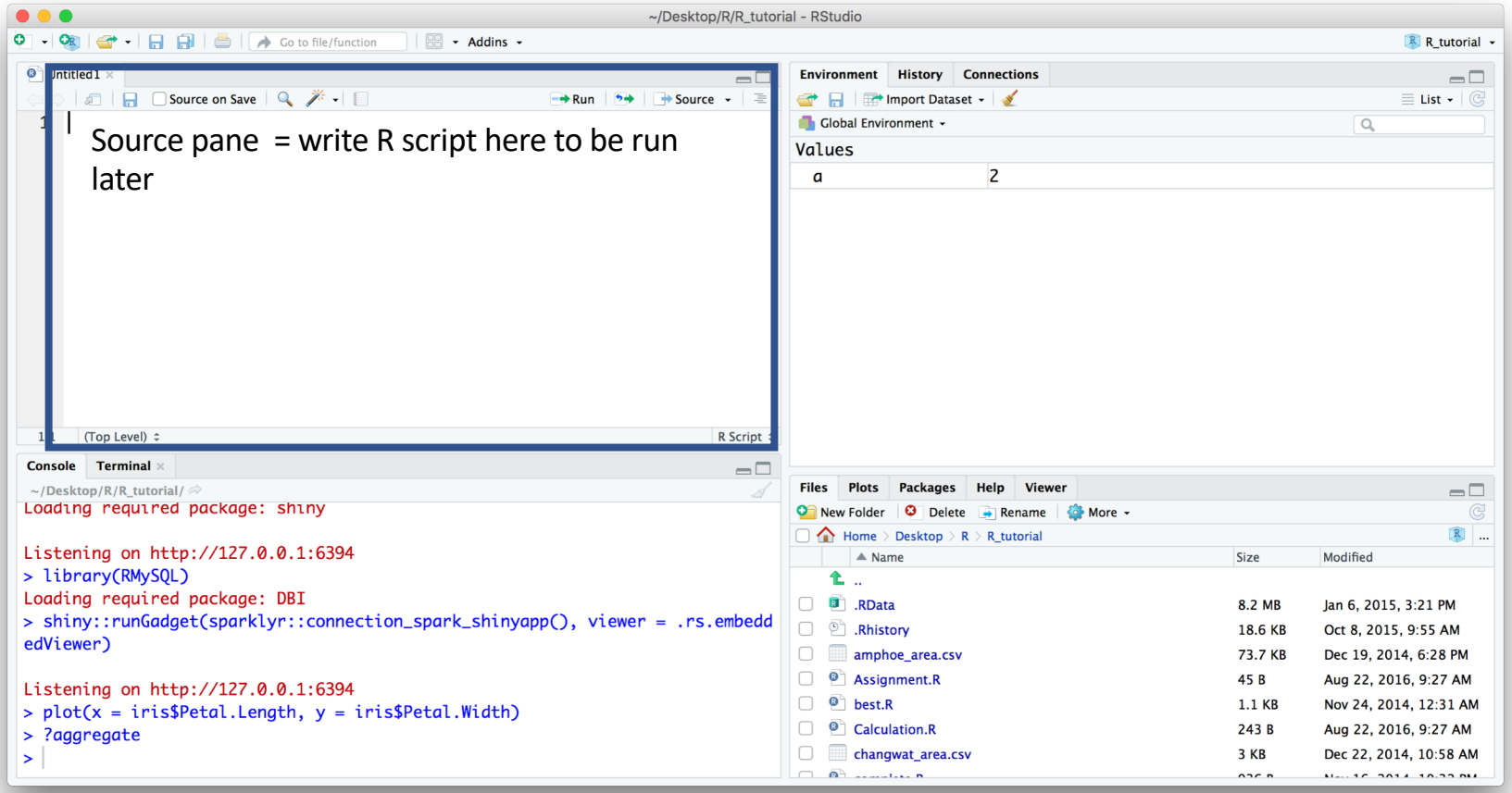
Source Panes

- Commands entered in the Console Pane will be immediately executed.
- To rerun the commands, they must be retyped in the Console Pane or reloaded from the History Pane
- Source pane
  - Write commands in this pane to be saved and executed later.
  - Develop R script here

Open Source Pane



Open Source Pane

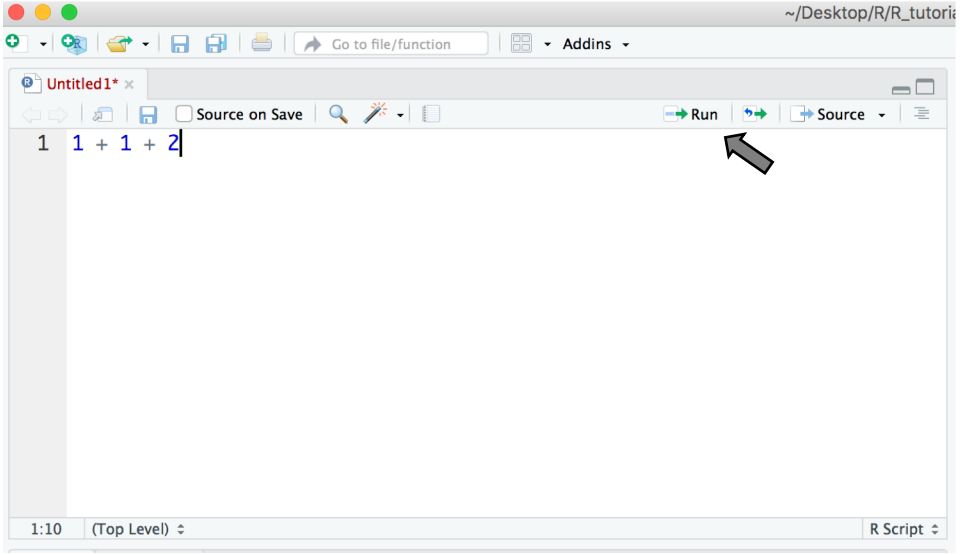


Run scripts in Source Pane

Run a single line of the script

- Leave a cursor at a line
- Click or 

- Ctrl + Enter or
- Mac: Command + Enter

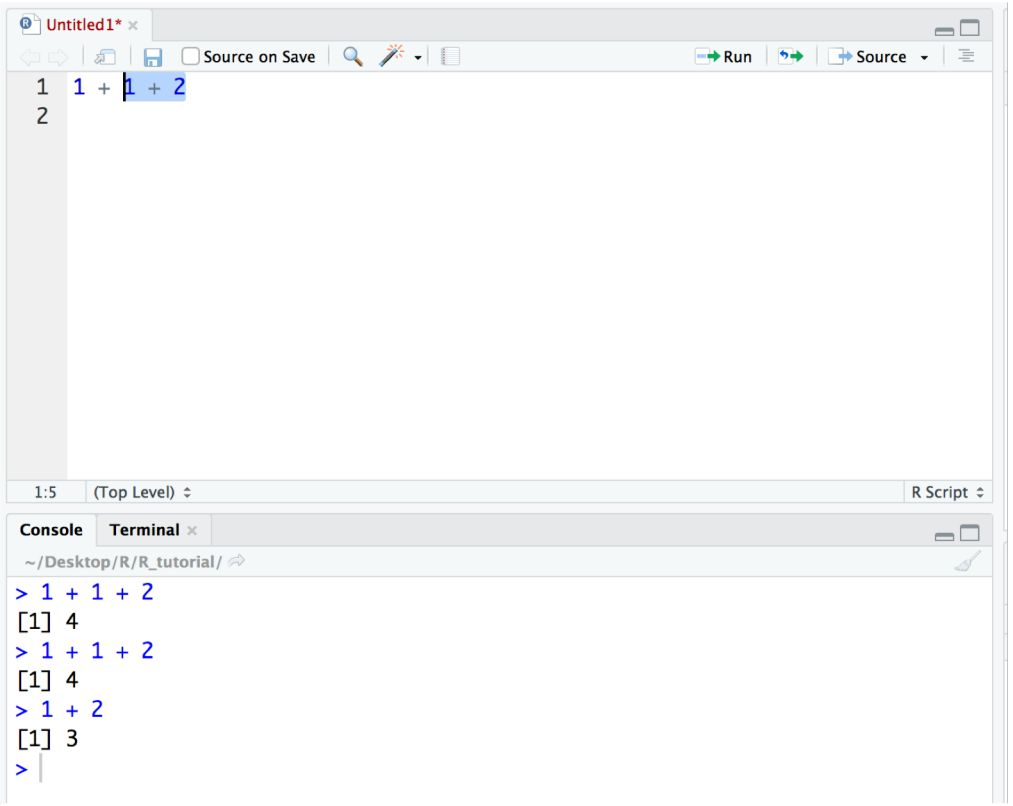


Run scripts in Source Pane

Run a part of the script

- Highlight the part
- Click or 

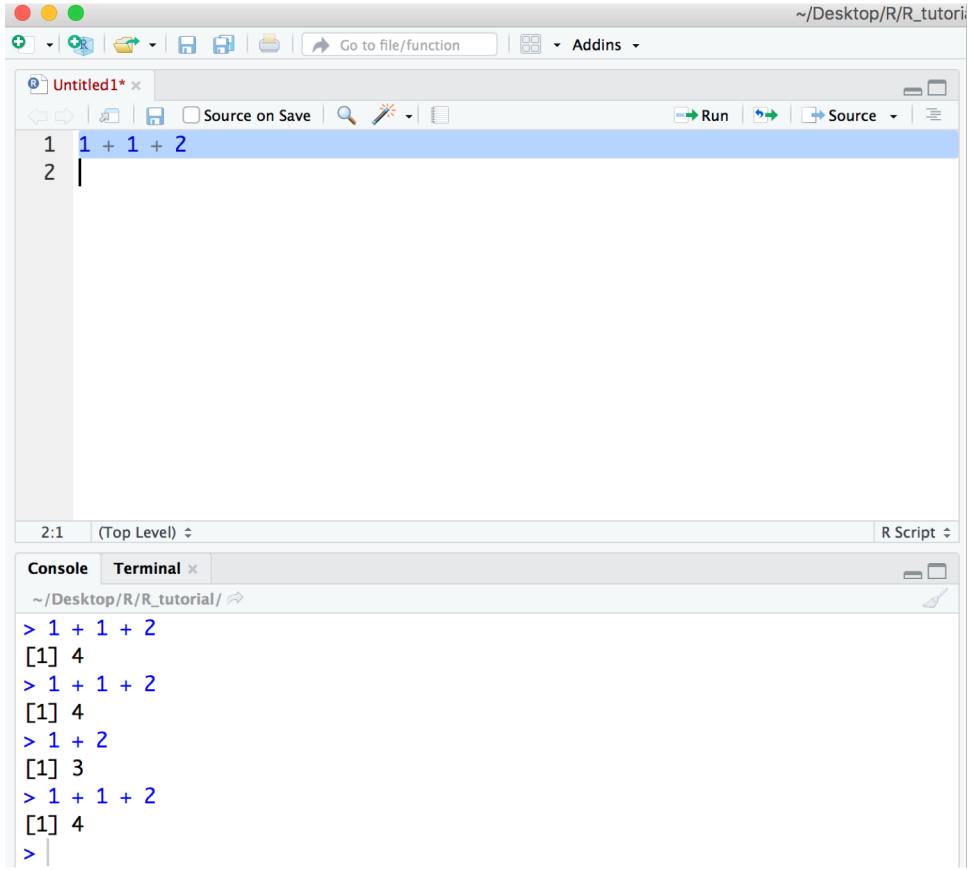
- Ctrl + Enter or
- Mac: Command + Enter



Run scripts in Source Pane

Run all lines of the script

- Click the source pane
- Ctrl/Command + A
- Click or Run
- Ctrl/Command + Enter



Useful keyboard shortcuts

- Ctrl + S = Save the script
- Ctrl + L = Clear the console pane
- Ctrl + Z =Undo and Ctrl + Y = Redo
- Ctrl + X =Cut, Ctrl + C = Copy, Ctrl + V =Paste
- **Tab = ***Autofill*****
- **↑ = ***Recall previously executed command*****
- Ctrl + Shift + F10 = Restart R session
- Ctrl + Q = Quit R

More shortcuts: Tools –> Keyboard Shortcuts Help

Practical: Packages

- R is powerful and versatile because of “Packages”
- “Packages” are codes/scripts created by users and shared to the R community
- 12,102 available packages deposited at CRAN

Practical: Packages

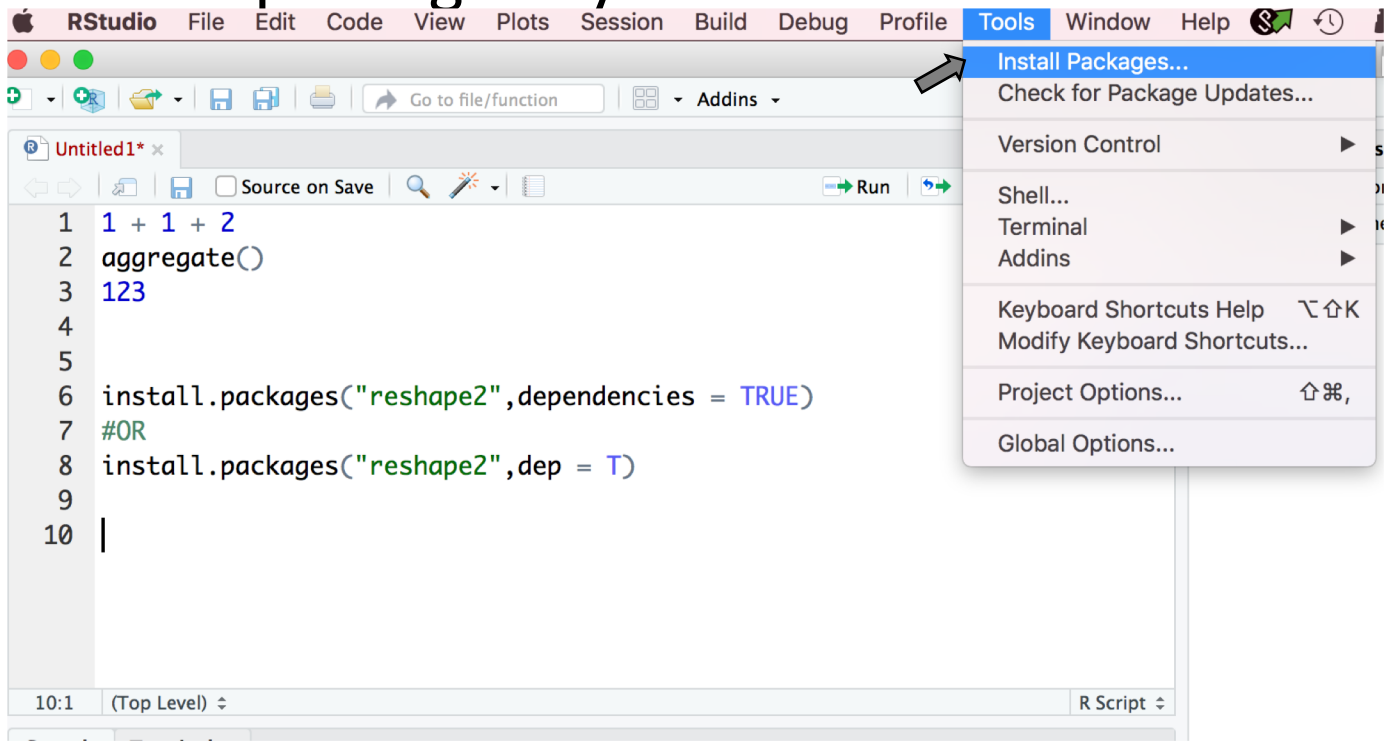
- To install packages by a command line

```
install.packages("reshape2",dependencies = TRUE)
#OR
install.packages("reshape2",dep = T)
```

- install.packages("name of the package in quotation marks", dependencies = TRUE)
- "dependencies = TRUE" means other packages required by this package will also be downloaded

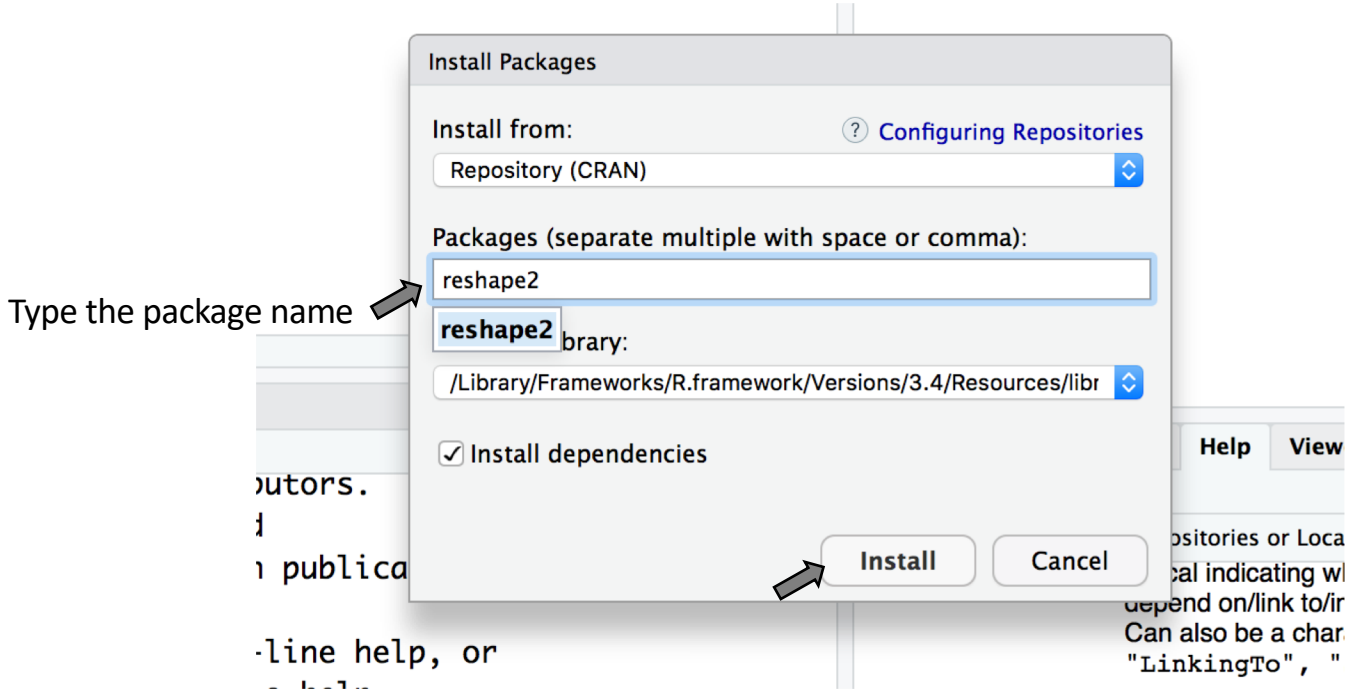
Practical: Packages

- To install packages by RStudio



Practical: Packages

- To install packages by RStudio

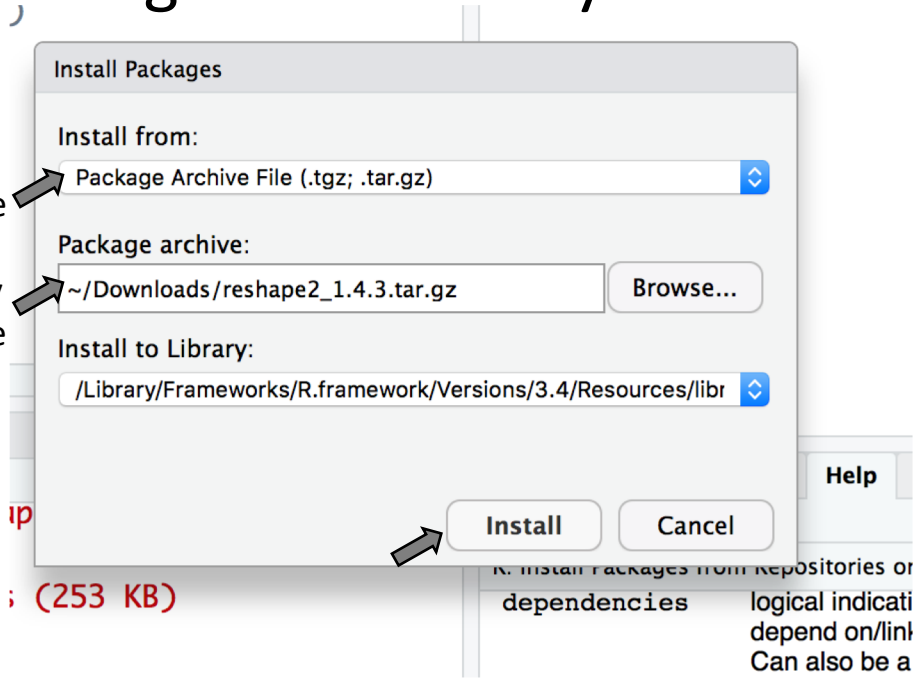


Practical: Packages

- To install packages “offline” by RStudio

Change from CRAN to File

Browse for the previously download package

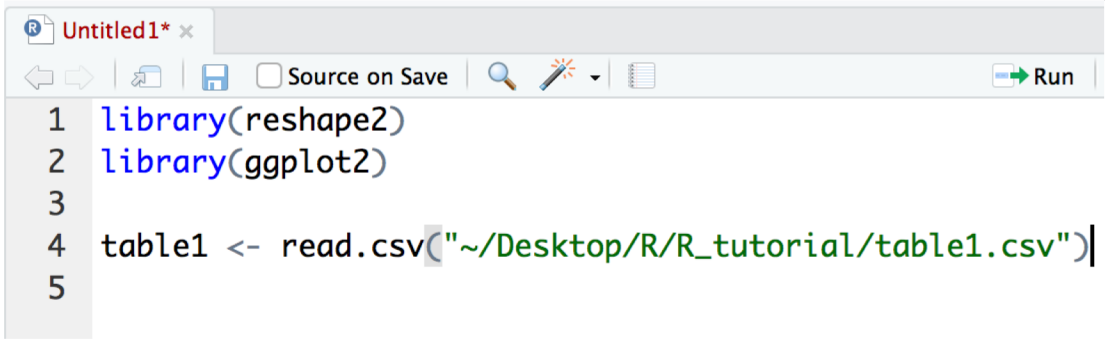


Practical: Packages

- To invoke the package

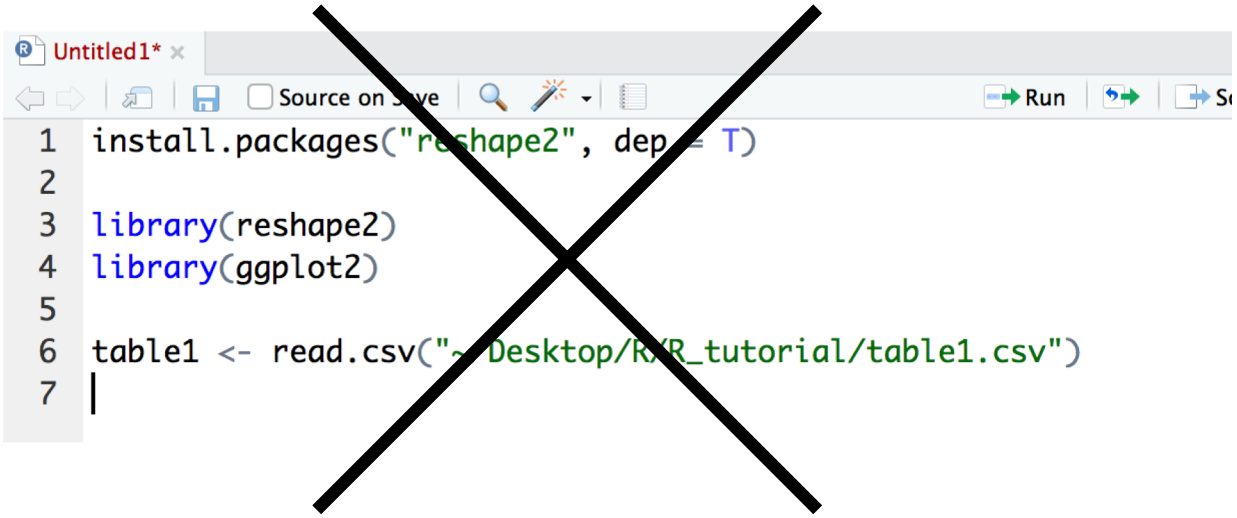
```
library(reshape2) #In your script
#OR
require(rehape2) #In the function/package
```

- Usually at the top of your script/code



Practical: Packages

- DO NOT include “install.packages()” in your script/code
- This will result in reinstalling packages every time the script is run



Practical: Packages

- Your turn:
  - Install and invoke the following packages:
    - reshape2
    - lubridate
    - MASS
    - car
    - Exact
    - hflights
    - readr
    - readxl

Programming Concepts in R

FILE:R2018_Programming_Concepts.R

Before we start…

- R scripts for demonstration are prepared
  - Workshop files
  - Run scripts and see what happens in your machine
    - Tell us if you see any strange or different results
  - Feel free to copy and modify the scripts for your own work

Calculator

Basic Mathematical Operations

```
1  ####Basic Mathematical Operations pt 1####
2  1 + 2 #Addition
3  1 - 2 #Substraction
4  1 / 2 #Division
5  1 * 2 #Multiplication
6  2 ^ 5 #Power
7  sqrt(4) #Square root
8  5 %/% 2 #Integer division
9  5 %% 2 #Modulo
```

- TIP: '#' = comment sign; Nothing after # to the end of the line will be run!!!

Basic Mathematical Operations

```
11 ####Basic Mathematical Operations pt 2####
12 log10(100) #Logarithm base 10
13 log(100, base = 10) #Logarithm base 10
14 log(100) #Natural logarithm
15 exp(1) #Exponential i.e. e^1
16 round(2.111, digits = 1) #Rounding
17 floor(2.111) #Round down to integer
18 ceiling(2.111) #Round up to integer
19 abs(-123) #Absolute value
```

Basic Logical Operations

```
####Basic Logical Operations pt 1####
20 == 18 #Comparing whether 'left' equals to 'right.'

20 = 18 #This is wrong. Try and see what happens.

20 != 18 #Comparing whether 'left' does not equal to 'right.'
20 < 18 #Comparing whether 'left' is less than 'right.'
20 > 18 #Comparing whether 'left' is greater than 'right.'
20 <= 18 #Comparing whether 'left' is less than or equal to 'right.'
20 >= 18 #Comparing whether 'left' is greater than or equal to 'right.'

20 =< 18 #This is wrong. Try and see what happens.
20 => 18 #This is wrong. Try and see what happens.
```

Basic Logical Operations

```
35 ####Basic Logical Operations pt 2####
36 (20 > 18) & (20 < 18) #'AND' operation
37 (20 > 18) | (20 < 18) #'OR' operation
38 !(20 < 18) #'NOT' operation
```

Variable Assignment

Variable assignment

```
40 ####Variable assignment pt 1####
41 (20 > 18) & (20 < 18)
42 #Versus
43 a <- (20 > 18)
44 b <- (20 < 18)
45 c <- a & b
46 print(c) #'print()' is to show the values of the variable
47
48 d <- (20 == 18)
49 e <- c | d #Versus ((20 > 18) & (20 < 18)) | (20 == 18)
50 print(e)
```

- Critical concept in programming
- Save results/outputs for later
- Make your code more legible
- More legible = Easier for debugging

Variable assignment

- How to assign values to variables

```
52 ####Variable assignment pt 2####
53 a = 1 #Generic: Assign the 'right' value to the 'left' variable
54
55 a <- 1 #R: Assign the 'right' value to the 'left' variable
56 1 -> a #R: Assign the 'left' value to the 'right' variable
57 a <- 1 -> b #R: Multiple assignments
58 a <- b <- 1 #R: Multiple assignments
```

- ‘ = ‘ and ‘<– ‘ are mostly interchangeable
- Personally, I prefer ‘<-’ to avoid the confusion between ‘=‘ and ‘==‘

Variable assignment

- Naming your variables
  - Start with alphabet or ‘ . ’
  - No space or special character in the name except ‘ . ’ and ‘_’
  - Be careful! R is case-sensitive

```
####Variable assignment pt 3####
a <- 123 #Correct
a1 <- 123 #Correct
1a <- 123 #Incorrect
a 1 <- 123 #Incorrect
a_1 <- 123 #Correct
a.1 <- 123 #Correct #Different meaning in Java or Python
a! <- 123 #Incorrect
a? <- 123 #Incorrect
.a <- 123 #Correct
print(a1) #R is case-sensitive
print(A1) #R is case-sensitive
```

Types of Data

Basic types of data

```r
####Types of data pt 1####
a <- 2 #numeric
b <- TRUE #logical
c <- "Hello, World!" #character #Must be in " " or ' '
c <- Hello, World! #Try and see
d <- NA #missing (logical)
e <- NaN #'Not a Number' = ill-defined e.g. 0/0 (logical)

typeof(a) #Check the 'R internal' type of data by 'typeof()'
class(a) #Check the 'customized' type of data by 'class()'
#class() is used more often.

is.logical(b) #'is.logical()' is for checking if the data is 'logical'
is.logical(d)
is.na(b) #'is.na()' is an essential function for managing missing data.
is.na(d)
#is.nan(); is.numeric(); is.character() and others
```

Complex types of data

- More complex types of data or ‘objects’
- Containing multiple elements of basic data types (i.e. They are still based on basic types of data).
- Some types were developed for certain applications (e.g. spatial objects, survival objects)
- They might be converted to basic types of data.

Factor

- Recoding ‘categorical’ or ‘ordinal’ values to calculable values
  - Character + Numeric
- Example: Categorical variables in regression analysis

```
####Types of data pt 2####
a <- "good"
class(a)
typeof(a)
af <- factor(a, levels = c("terrible","bad","neutral","good","excellent"))
print(af)
class(af)
typeof(af)
as.numeric(af) #Convert to numeric, i.e. extracting numerical elements
as.character(af) #Convert to character, i.e. extracting character elements
```

Date' and 'Time'

- Recoding texts of 'date', 'time' or 'datetime' data to calculable values
- Example: Used in time series analyses, survival analyses

```
####Types of data pt 3####
library(lubridate)

a <- "27-3-2018"
class(a)
typeof(a)
ad <- dmy(a) #function in lubridate package converting 'character' to 'date'
print(ad)
class(ad)
typeof(ad)
as.numeric(ad) #Convert to numeric (i.e. Days since 1-1-1970)
as.character(ad) #Convert to character, i.e. extracting character elements
```

Data type conversion

- Frequently used commands for data type conversion

```
####Conversion####
a <- 1
print(a)
as.character(a) #Convert to character
as.factor(a) #Convert to factor; cannot change levels or labels
factor(a, levels = c(3,2,1)) #Specify levels
factor(a, levels = c(1,2,3), labels = c("one","two","three")) #Specify labels

b <- "111"
as.numeric(b)
c <- "1,111"
as.numeric(c) #CAUTION: Data conversion may introduce missing data
d <- "1111"
as.numeric(d)
```

Data Structure
(Data container)

Vector

- One-dimensional container
- Every member in the vector must be the same type
- c() to construct a vector

```
114 ####Vector pt 1####
115 A <- c(1,2,3,4)
116 print(A)
117 class(A)
118
119 B <- c("a","b","c","d")
120 print(B)
121 class(B)
122
123 C <- c(TRUE, FALSE, T, F)
124 print(C)
125 class(C)
```

```
127 ####Vector pt 2####
128 D <- c(1,NA,3,0/0)
129 print(D)
130 class(D)
131
132 E <- c(1,TRUE,0/0,"a")
133 print(E)
134 class(E)
```

Matrix

- Two-dimensional container
- Every member in the matrix must be the same type
- matrix() to construct a matrix

```
####Matrix pt 1####
a <- 1:8 #a <- c(1,2,3,4,5,6,7,8) or a <- seq(from=1,to=8,by=1)
print(a) #vector of data
A <- matrix(data = a,nrow = 4)
#load 'a' vector into a matrix
#nrow' indicates number of rows
print(A)

B <- matrix(data = a,ncol = 4) #'ncol' indicates number of columns
print(B)

C <- matrix(data = a,ncol = 4, byrow = T)
#'byrow' fill values by row
# Default is by column (i.e. byrow = F)
print(C)
```

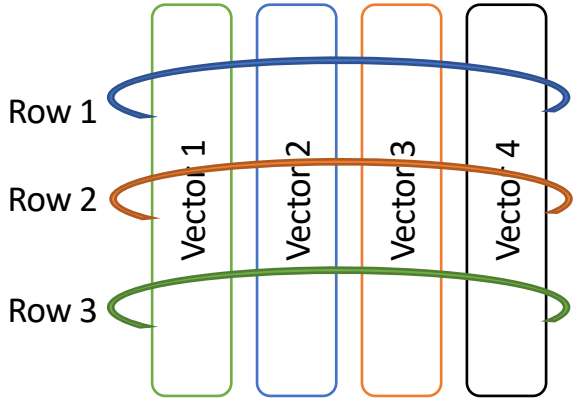
Matrix

- Two-dimensional container
- Every member in the matrix must be the same type
- matrix() to construct a matrix

```
152 ####Matrix pt 2####
153 D <- matrix(data = c(1:6,NA,T),ncol = 4, byrow = T)
154 print(D) #Look at the last member of the matrix
155
156 E <- matrix(data = c(1:6,T,"a"),ncol = 4, byrow = T)
157 print(E) #Look at the type of data in the matrix
```

Data frame

- Two-dimensional container
- In the “data handling” section of this workshop, we will mostly use data frames
- Every member in each “column” of the data frame must be the same type
- Each row can contain different types of data
- Imagine multiple vectors with identical lengths with each member at the same position bound together as a ‘row.'



Data frame

- data.frame() to construct a data frame

```
159 ####Data frame pt 1####
160 A <- data.frame( name = c("A","B","C"), #Vector 1 assigned as 'name' column
161                 weight = c(50,60,55), #Vector 2 assigned as 'weight' column
162                 height = c(150,166,162)) #Vector 3 assigned as 'height' column
163 print(A)
164
165 A2 <- data.frame(c("A","B","C"), #No column names assignment
166                 c(50,60,55),
167                 c(150,166,162))
168 print(A2)
169
170 B <- data.frame( name = c("B","C"),
171                 weight = c(50,60,55),
172                 height = c(150,166,162)) #Try and see what happens
```

Data frame

- data.frame() to construct a data frame

```
175 ####Data frame pt 2####
176 C <- data.frame( name = c("A","B","C"),
177                  weight = c(50,60,"Not measured"),
178                  height = c(150,166,162))
179 print(C) #Try and see
180 A$weight #'A$weight' is for calling the 'weight' column of 'A' data frame
181 #We will get into how to access data in the data frame in the later session
182 class(A$weight)
183
184 C$weight
185 class(C$weight)
```

List

- Multi-dimensional container
- Each member in the list can be any type of data, or even data container (i.e. a data frame in a list > two dimensions)
- No restriction of length for each member
- Used as a container of results of analysis (e.g. regression results)

List

- list() to construct a list

```
188 ####List####
189 a <- c(T,F)
190 b <- 1:6
191 c <- c("A","E","I","O","U")
192 
193 A <- list(a,b,c) #Combine vectors as a list
194 print(A)
195 
196 A2 <- list(col1 = a, col2 = b, col3 = c) #'name' can be assigned to each member
197 print(A2)
198 
199 d <- data.frame( name = c("A","B","C"),
200                                  weight = c(50,60,55),
201                                  height = c(150,166,162))
202 B <- list(A,d) #list and data frame in the list
203 print(B)
```

Practical 1

Practical 1: Data type conversion

- Numerical data are sometimes created or imported to R as ‘factor’ data.
- Incorrectly using factor data can be problematic

```
C <- data.frame( name = c("A","B","C"),
                 weight = c(50,60,"Not measured"),
                 height = c(150,166,162))
weight <- C$weight
#Convert weight from kilograms to pounds
#1 Kilo = 2.2 pounds
weight * 2.2 #Try and see
```

Practical 1: Data type conversion

1. Convert 'weight' to numerical data
2. Convert 'weight' to pound (1 kilo ~ 2.2 pound)

- HINT1: Correct answer = c(110, 132, NA)
- HINT2: as.numeric(); as.character() for data type conversion

```
C <- data.frame( name = c("A","B","C"),
                 weight = c(50,60,"Not measured"),
                 height = c(150,166,162))
weight <- C$weight
#Convert weight from kilograms to pounds
#1 Kilo = 2.2 pounds
weight * 2.2 #Try and see
```

Flow Control

Curly brackets { }

- ‘if-else’, ‘for’, ’while’ and ‘function’

```
command(conditions or values){
        do something
        do something
        do something
}
```

If and Else

- Modify the behavior of the code based on the input
- Evaluate the input -> Select what to do -> Generate the output
- Note: If-Else must address all possible conditions

```
####If and else####
A <- 1 #Assign the input here

if(!is.numeric(A)){
  print("A is not a number")
}else if(A %% 2 == 0){
  print("A is even")
}else if(A %% 2 == 1){
  print("A is odd")
}else{
  print("A is not an integer")
}

#Try changing A to 2, 1.1, NA and 0/0
```

For loop

- Repeating an operations with changing inputs
- NOTE: ‘For loop’ in R is slow (try row/column operations and apply())

```
####For loop####
A <- c(1,2,3,4,5,6,7)
for(i in A){
  #'i' is a temporary variable with its value = each member of A
  #Reassignment of 'i' occured at every new round
  print(i)
}

B <- letters #letters and LETTERS are built-in vectors containing alphabets
for(j in B){
  #'j' is a temporary variable with its value = each member of A
  #Reassignment of 'j' occured at every new round
  print(j)
}
```

While loop

- Repeating an operations until the ‘breaking condition’ is triggered
- CAUTION: ‘Infinite loop’ = the ‘breaking condition’ is never triggered
- NOTE: ‘While loop’ in R is slow

```
####While loop####
i <- 1

while(i < 100){ #Breaking/Exiting condition
  print(i) #Do something here
  i <- i + 1 #DO NOT forget to the change breaking condition!!!
}
```

Practical 2

Practical 2: For loop

- ‘paste()’ is a function that combines two or more text data into one
- Try paste("I", "love", "you.")
- ‘paste0()’ is a function that combines two or more text data into one without adding a space between texts
- Try paste0("I", "love", "you.")

Practical 2: For loop

1. Our input is 2005:2018 (i.e. 2005, 2006,…,2017, 2018)
2. We will use the for loop and the ‘paste’ function to generate the following sentences:
   - This year is 2005.
   - This year is 2006.
   - This year is 2007.
   - …
   - …
   - This year is 2018.

```
1 for(k in 2005:2018){
2   #Do something with k
3   #print(something)
4 }
```

Practical 2: For loop

CHALLENGE

1. Leap years are divisible by 4
2. For leap years, add ‘This is a leap year.’ at the end of the sentence
3. Generate the following sentences:
   - This year is 2005.
   - …
   - This year is 2008. This is a leap year.
   - …
   - This year is 2018.

- HINT 1: If-else
- HINT 2: Modulo

Function

Function

- You can customize your own function
- Function calls multiple lines of code in a simple command
- NOTE: “Package” is a bundle of functions, manual/documentations and sample datasets

```
####If and else####
A <- 1 #Assign the input here

if(!is.numeric(A)){
  print("A is not a number")
}else if(A %% 2 == 0){
  print("A is even")
}else if(A %% 2 == 1){
  print("A is odd")
}else{
  print("A is not an integer")
}
```

Function

- Function should be defined at the beginning of the code after loading packages

```
####Function pt 1####
library(reshape2) #Nothing to do with the code
#Just demo how the code should look like
odd_even <- function(A){ #Define the 'odd_even' function
  if(!is.numeric(A) | is.nan(A)){#Debugged for NaN
    result <-  "Your input is not a number"
  }else if(A %% 2 == 0){
    result <-  "Your input is even"
  }else if(A %% 2 == 1){
    result <-  "Your input is odd"
  }else{
    result <-  "Your input is not an integer"
  }
  return(result)
}

odd_even(A = 12) #Call the function by name
odd_even(0/0)
```

Function

- Function can take multiple arguments
- Default value may be defined

```
####Function pt 2####
testFn <- function(A,B,C = 2){#C is 2 by default
  result <- (A+B)*C
  return(result)
}

testFn(A = 1, B = 2) #C is 2 by default
testFn(A = 2, B = 3, C = 4)
testFn(0,4,1) #A = 0, B = 4, C = 1 -> Assign by the order of arguments
testFn(C = 0,B = 4, A = 1) #Specifically assign value to A,B,C
```

Help!!!

Help!!!

- General programming concepts in R are similar to other languages
- Tough parts are ‘function’
- Find the right function and learn to use it can be difficult

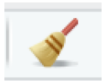
```
260 ####Help####
261 help("shapiro.test")
262 ?shapiro.test
263 ??shapiro.test
```

Prepare your workspace

Working directory

- getwd() = the current working directory
  - Anything saved without a specified path will be here
- setwd() = change to the new working directory
  - Organizing the location in which files will be read and written

Before running your codes

- Restart “R session”: Session -> Restart R
- Clear the environment 
- Check your working directory

Practical 3

Practical 3: Customize your function

- Quadratic equation
  - $ax^2 + bx + c = 0$
- Quadratic formula is the solution of the quadratic equation
  - $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Practical 3: Customize your function

1. Create a function ‘quardForm()’ that takes input a, b, c from a quadratic equation to solve for x
2. Test your function with the following equations:
   - $x^2 + 4x - 21 = 0$
   - $10x^2 + 13x - 3 = 0$
   - $x^2 - 25 = 0$
   - $x^2 + 4 = 0$

Practical 3: Customize your function

- HINT: quadratic formula needs to return two values

```
quadForm <- function(A,B,C){
  #answer1 <- ???
  #answer2 <- ???
  return(c(answer1, answer2))
}
```

Data Handling

FILE:R2018_Data_Handling_pt1.R

Indexing

Accessing data container

- Accessing data in the data container (e.g. vector, matrix, data frame and list) is critical
- You must understand how to access data in the container to use R to the full potential
- Please pay your best attentions

General concepts

- Square brackets, ‘[ ]’, are used for indexing (i.e. accessing data in the containers)
- Notes to programmers
  - The first position of the member in the container is **‘1’ in R not ‘0’**
  - ‘-n’ is used to exclude the member at position ‘n’, not for accessing the n^{th} member counting from the last position

Vector

- Know your vector

```
####Accessing vector pt 1####
letters #'letters' is a built-in vector containing lower case alphabets

print(letters) #Show everything in the vector

length(letters) #Number of members

class(letters) #Type of data in the vector
typeof(letters) #Type of data in the vector

summary(letters) #Summary of the vector
str(letters) #Structure of the vector

```

Vector

- Accessing by number

```
####Accessing vector pt 2####
letters[1] #First member
letters[20] #Twentieth member
letters[30] #Try and see what happens

letters[1:10] #First to tenth
letters[c(1,10)] #First AND tenth
letters[c(1,10,20)] #First, tenth and Twentieth
letters[c(1:10,20)] #First to tenth and Twentieth
letters[seq(from = 1, to = 26, by =2)] #Every other members

letters[-26] #Drop the last member
length(letters)
letters[-length(letters)] #Drop the last member
letters[-seq(from = 1, to = 26, by =2)]

#Drop the last 7 members of 'letters' vector
#letters[???]
```

Vector

- Accessing by condition/logic

```
####Accessing vector pt 3####
vowel <- c("a","e","i","o","u")
letters #Built-in vector for lower case alphabets

flags <- which(letters %in% vowel)
letters[flags] #Flagged positions
letters[-flags] #Un-flagged positions

#'%in%' tests each member in the 'letters' vector whether it is "in"
#the 'vowel' vector
letters %in% vowel
#'which' returns the position of TRUE
which(letters %in% vowel)

#Advanced user; Code might be more confusing
letters[which(letters %in% vowel)]
letters[which(!(letters %in% vowel))]
letters[-which(letters %in% vowel)]
```

Vector

- Accessing by condition/logic

```
####Accessing vector pt 4####
a <- runif(n = 100,min = 1,max = 10)
#Randomly generate 100 real numbers greater than 1, but smaller than 10

flags <- which(a >= 9)
a[flags]
a[-flags]

#Advanced user; Code might be more confusing
a[a>=9]
a[!(a>=9)]

#Why use "which"? NA and NaN
b <- c(a,NA,0/0)
print(b)
flags <- which(b >= 9)
b[flags]
b[b >= 9] #Look at the last two members
```

Matrix

- Know your matrix

```
71  ####Accessing matrix pt 1####
72  a <- runif(n = 12,min = 1,max = 10)
73  am <- matrix(data = a, nrow = 4)
74
75  print(am) #Show everything in the matrix
76
77  dim(am) #Dimension of the matrix; row column
78  nrow(am) #Number of rows
79  ncol(am) #Nuber of columns
80
81  class(am) #Container type
82  typeof(am) #Type of data in the matrix
83
84  summary(am) #Summary of the matrix
85  str(am) #Structure of the matrix
```

Matrix

- Accessing by number

```r
####Accessing matrix pt 2####
a <- runif(n = 12,min = 1,max = 10)
am <- matrix(data = a, nrow = 4)

print(am)
#Matrix[Row,Column]
am[1, ] #Row 1; 'All' columns -> Vector
am[ ,1] #All rows; Column 1 -> Vector
am[1,1] #Row 1, Column 1 -> Cell/Single value

am[c(1,2,4), c(1,3)] #Row 1, 2 and 4; Column 1 and 3
am[-3,-2] #Drop row 3; Drop column 2 (i.e. H4 x W3 -> H3 x W2)

am[nrow(am),ncol(am)] #Last row, Last column -> Cell/Single value

#Row 2 to 4, Column1
#am[???]
```

Data frame

- Know your data frame

```
105 ####Accessing data frame pt 1####
106 ?mtcars #'mtcars' is a built-in data frame for 'Motor Trend Car Road Tests'
107
108 print(mtcars) #Show everything in the data frame
109 View(mtcars) #Nice way to look at the data frame
110
111 dim(mtcars) #Dimension of the data frame; row column
112 nrow(mtcars) #Number of rows
113 ncol(mtcars) #Nuber of columns
114
115 class(mtcars) #Container type
116 typeof(mtcars) #Container type
117
118 summary(mtcars) #Summary of the data frame
119 str(mtcars) #Structure of the data frame
```

Data frame

- Accessing by name

```
120 ####Accessing data frame pt 2####
121 names(mtcars) #Names in the data frame
122 colnames(mtcars) #Names of columns
123 rownames(mtcars) #Names of rows
124 
125 #Call a column by name
126 mtcars$mpg #All data in column 'mpg' -> vector
127 mtcars["mpg"]#All data in column 'mpg' -> data.frame
128 mtcars[["mpg"]]  #All data in column 'mpg' -> vector
129 mtcars[ ,"mpg"] #All row; Column 'mpg' -> vector
130 
131 #Call a row by name
132 mtcars["Mazda RX4",]
133 
134 #Call a raw and columns by names
135 mtcars["Mazda RX4",c("mpg","hp","gear")]
```

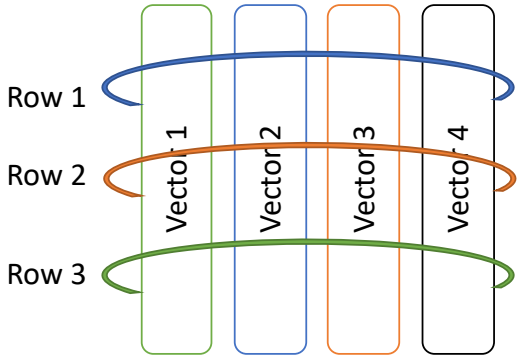
Data frame

- Accessing by number

```
138 ####Accessing data frame pt 3####
139 mtcars[10,] #Tenth row
140 mtcars[,10] #Tenth column == mtcars$gear
141 mtcars[10,10] #Tenth row; Tenth column
142
143 #Mixed with "names"
144 mtcars$mpg[1:10] #Column 'mpg'; Row 1 to 10 -> vector
145 mtcars[1:10,"mpg"] #Row 1 to 10, Column 'mpg' -> vector
146 mtcars[1:10,]$mpg #Row 1 to 10, Column 'mpg' -> vector
147
148 mtcars[c(1,10,12), c("mpg","gear")] #Row 1, 10 and 12; Column 'mpg' and 'gear'
```

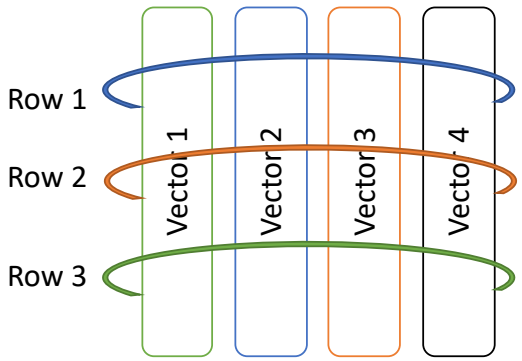
Data frame

- Accessing by condition/logic
- Imagine multiple vectors with identical lengths bound together into “rows”
- Member 1 of Column(vector) 1 is linked to Member 1 of Column 2, Member 1 of Column 3, …,and Member 1 of Column N = Row 1



Data frame

- Accessing by condition/logic
- Apply logic/condition to one column to get the positions of members of that column
- Use the positions of members in this column to get the member in other columns
- In other words, use the positions of members in this column to get the rows to which these members belong



Data frame

- Accessing by condition/logic

```
####Accessing data frame pt 4####
flags <- which(mtcars$gear < 4) #Which row has gear < 4

print(mtcars$gear < 4)
print(which(mtcars$gear < 4))

mtcars[flags, ] #Use row number to select row; all columns -> data frame
mtcars[flags, ]$mpg  #Use row number to select row; Column 'mpg' -> vector
mtcars[flags,"mpg"]  #Use row number to select row; Column 'mpg' -> vector
mtcars$mpg[flags] #Column 'mpg'; Use row number to select row -> vector
mtcars[flags,c("mpg","hp")]  #Use row number to select row; Column 'mpg' and 'hp'

flags <- which(mtcars$gear < 4 & mtcars$hp < 100)
#Which row has gear < 4 and hp < 100
mtcars[flags, ]
#Advanced user
mtcars[ which(mtcars$gear < 4 & mtcars$hp < 100),]
```

List

- Know your list

```
####Accessing list pt 1####
A <- list(a = c(T,F), b = 1:6, c = letters, d = mtcars)

print(A) #Show everything in the list

class(A) #Container type
typeof(A) #Container type

summary(A) #Summary of the list
str(A) #Structure of the list (More useful)
```

List

- Accessing by number

```
178 ####Accessing list pt 2####
179 A[1] #Member 1 of the list -> list
180 A[[1]] #Member 1 of the list -> vector
181 
182 A[[1]][2] #Member 2 of Member 1 of the list
183 A[1][2] #Try and see what happens
```

List

- Accessing by name

```
185 ####Accessing list pt 3####
186 names(A) #Names in list A
187 str(A) #Structure of list A
188 
189 A$a #Return vector
190 A["a"] #Return list (Not useful)
191 A[["a"]] #Return vector
192 
193 A["d"] #Return list (Not useful)
194 A$d #Return data frame
195 A$d$mpg #Access column of the data frame in the list
```

Practical 1

Practical 1: Exploring data frame

- We will explore “hflights” dataset

1. Find number of columns
2. Find number of rows
3. How many flights were flying to "JFK" airport (Hint: "Dest" is 'JFK’)
4. How many flights were flying to "DTW" airport on January 31, 2011
5. What airlines were flying to "DTW" airport on January 31, 2011 (Hint:'UniqueCarrier')

```
1  library(hflights)
2
3  ?hflights #Description of the dataset
```

Practical 2

Practical 2: Exploring regression results

- Summary of regression results is in a data container
- There are many components in the summary
- We might need extract a few information from the summary
- We will explore the regression results of ‘ChickWeight’ dataset

```r
?ChickWeight #Description of the dataset

####Do not worry about regression, yet. Just run the commands
model1 <- lm(weight ~ Time , data = ChickWeight) #Fitting model
sum1 <- summary(model1) #Summarize the fitting results

print(sum1)
```

Practical 2: Exploring regression results

1. What is the type of data container of 'sum1' (i.e. data frame or list)?
2. How many components are in "sum1"?
3. Extract "r.squared”
4. Extract p-value (i.e. Pr(>|t|)) of 'Time' (Hint: 'coefficients')

```r
?ChickWeight #Description of the dataset

####Do not worry about regression, yet. Just run the commands
model1 <- lm(weight ~ Time , data = ChickWeight) #Fitting model
sum1 <- summary(model1) #Summarize the fitting results

print(sum1)
```

Import and Export Data

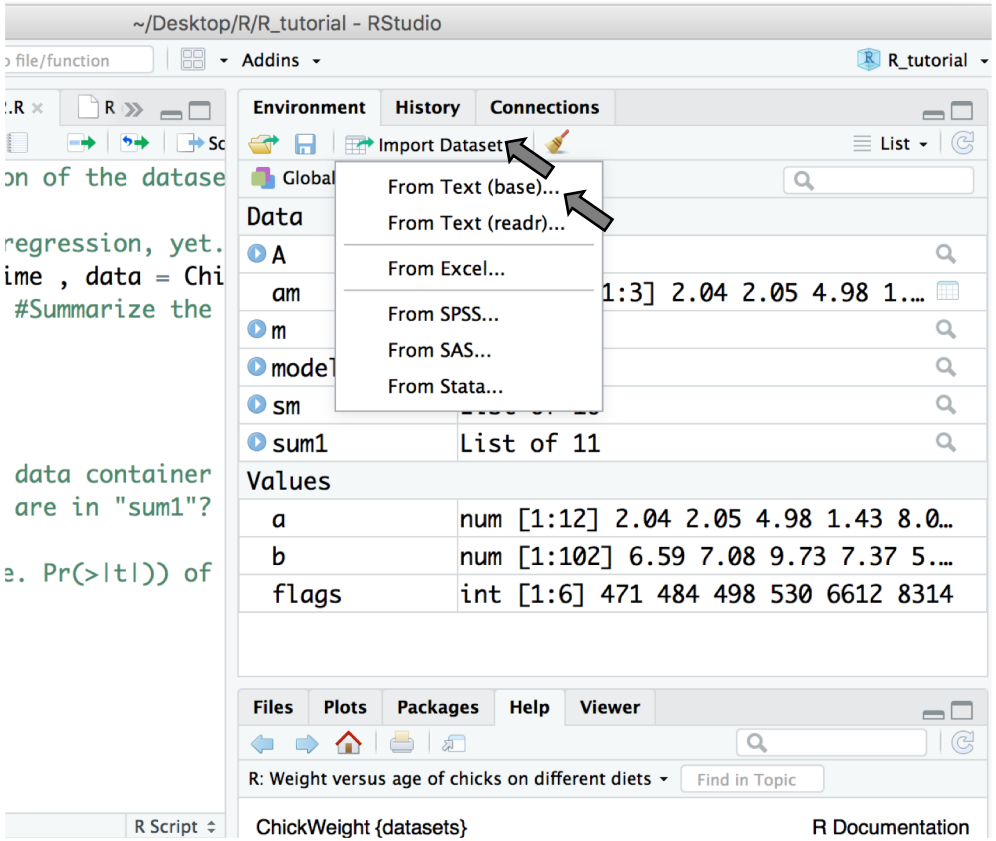
Data formats

- **Text file: e.g. CSV and Tab delimited**
- **MS Excel**
- Other statistical software: SPSS, SAS and STATA
- Database: e.g. SQL, MS Access and noSQL
- Website

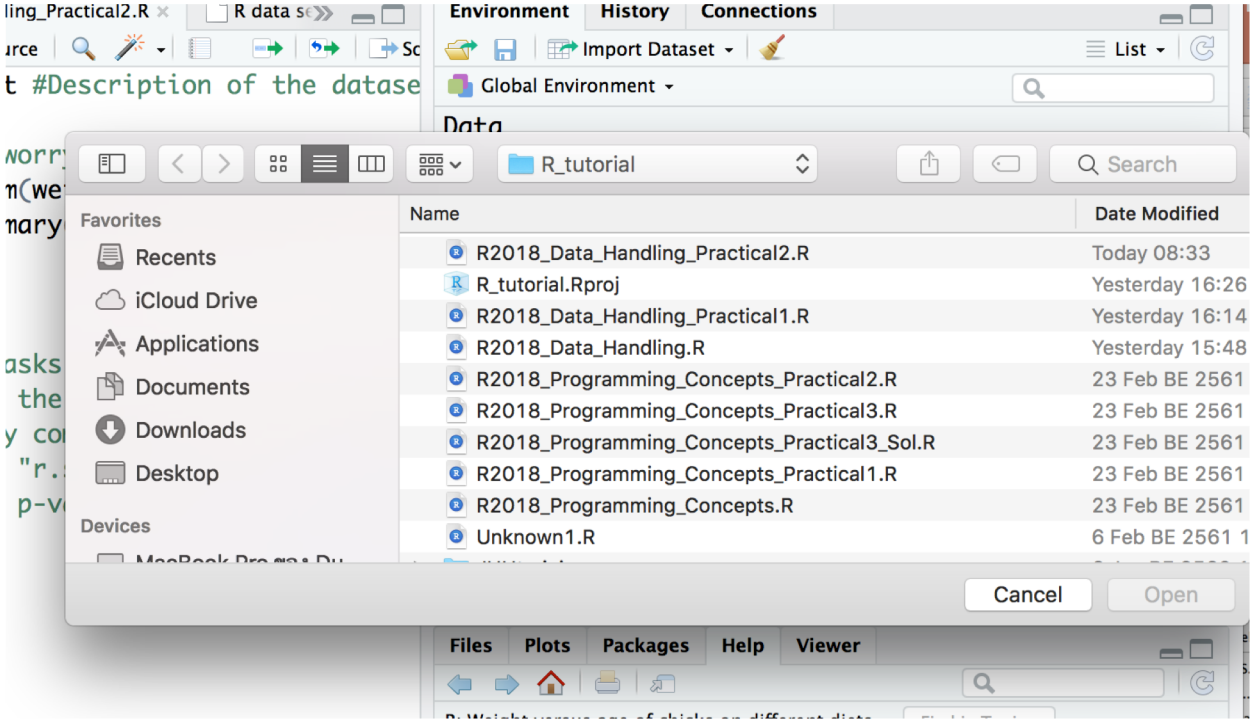
Text files

- The simplest format for importing/exporting
- Unlikely to generate an error during importing/exporting
- The current version of RStudio provides interfaces helping import data

Text files

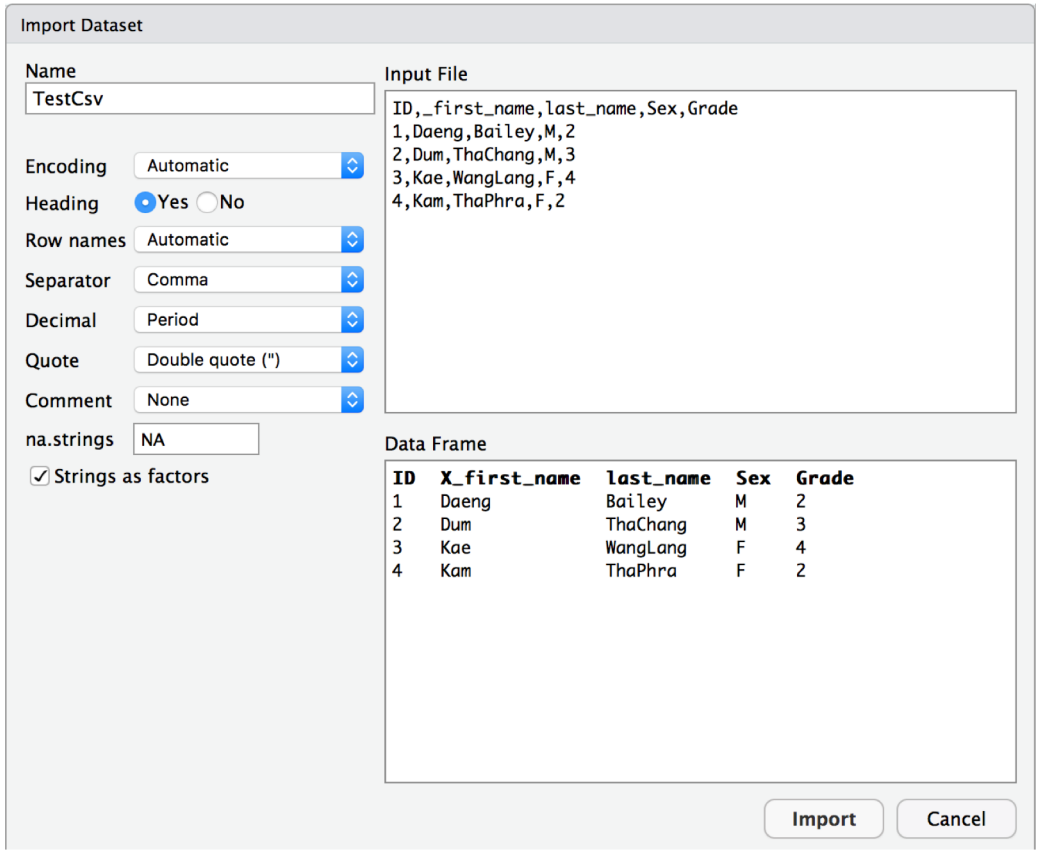

~/Desktop/R/R_tutorial - RStudio
Addins
R_tutorial
Environment
History
Connections
Import Dataset
List
From Text (base)...
From Text (readr)...
From Excel...
From SPSS...
From SAS...
From Stata...
Data
A
am
m
model
sm
sum1
List of 11
Values
a
num [1:12] 2.04 2.05 4.98 1.43 8.0…
b
num [1:102] 6.59 7.08 9.73 7.37 5.…
flags
int [1:6] 471 484 498 530 6612 8314
Files
Plots
Packages
Help
Viewer
R: Weight versus age of chicks on different diets
Find in Topic
ChickWeight {datasets}
R Documentation
R Script

Text files



Choose your file

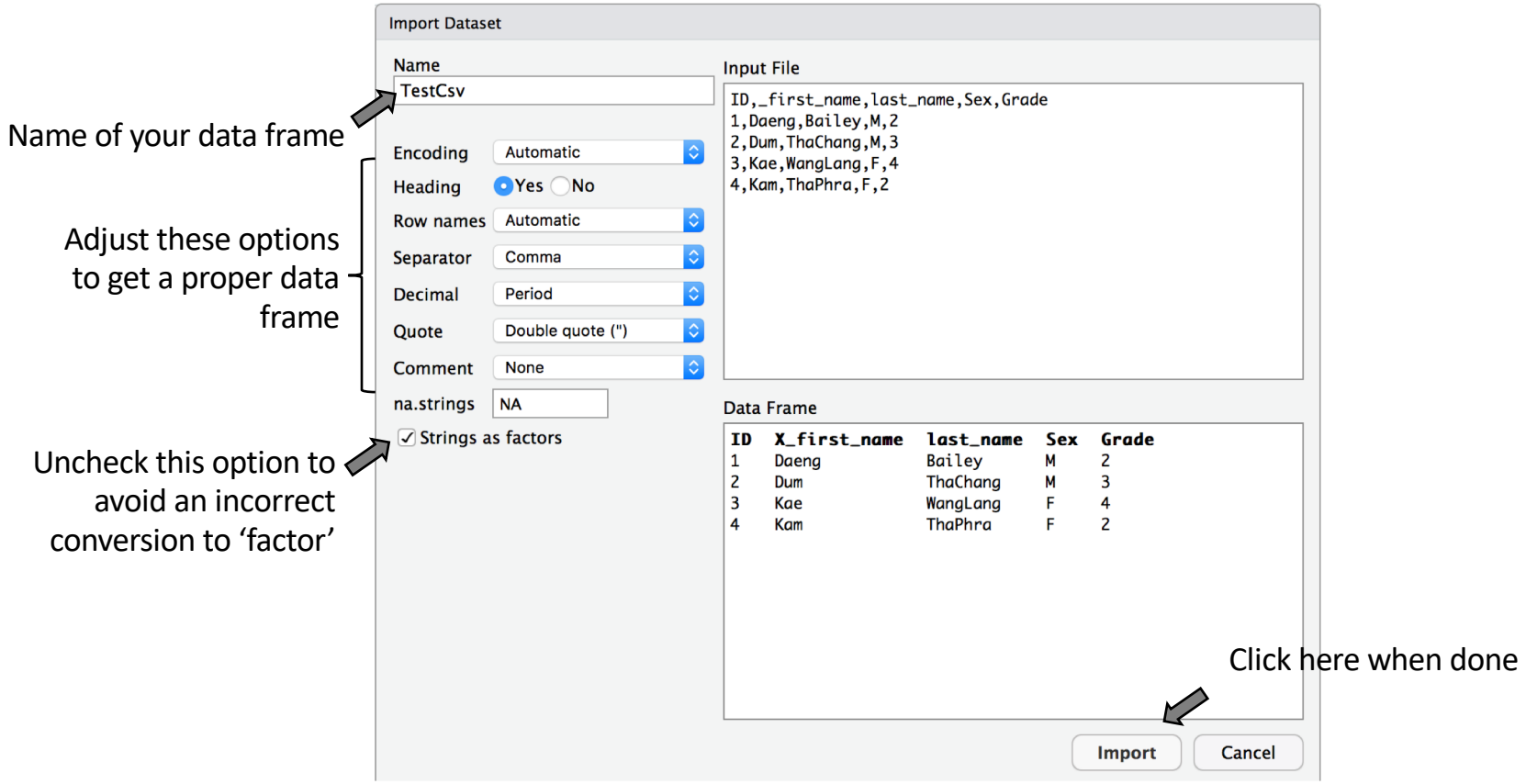
Text files



RAW input

Preview imported data

Text files


Name of your data frame
Adjust these options to get a proper data frame
Uncheck this option to avoid an incorrect conversion to 'factor'
Import Dataset
Name
TestCsv
Encoding
Automatic
Heading
Yes
No
Row names
Automatic
Separator
Comma
Decimal
Period
Quote
Double quote (")
Comment
None
na.strings
NA
Strings as factors
Input File
ID,_first_name,last_name,Sex,Grade
1,Daeng,Bailey,M,2
2,Dum,ThaChang,M,3
3,Kae,WangLang,F,4
4,Kam,ThaPhra,F,2
Data Frame
ID X_first_name last_name Sex Grade
1 Daeng Bailey M 2
2 Dum ThaChang M 3
3 Kae WangLang F 4
4 Kam ThaPhra F 2
Click here when done
Import
Cancel

Text files

- By clicking “Import,” RStudio will auto-generate an importing command in the console panel
- The text file will be imported and shown in the Viewer
- **BEST Practice:** the auto-generated command for importing data should be copied from the console panel and included in your R code
  - Otherwise, you will have to browser the file again if the R code must be re-run

Excel files

- Frequently used format
- MS Excel has a lot of tools for data preparation

Excel files

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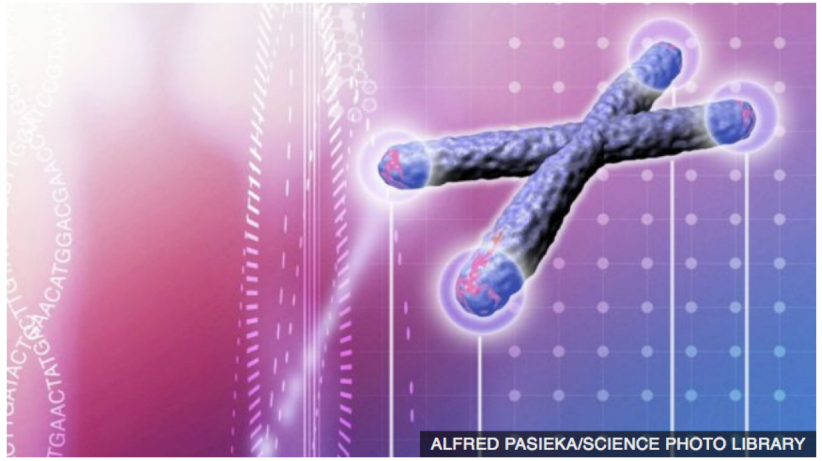
NEWS

Home | Video | World | Asia | UK | Business | Tech | Science | Stories | Entertainment & Arts | Health | World News TV | More

Technology

Microsoft Excel blamed for gene study errors

25 August 2016 Share



Microsoft's Excel has been blamed for errors in academic papers on genomics.

Researchers trying to raise awareness of the issue claim that the spreadsheet software automatically converts the names of certain genes into dates.

Gene symbols like SEPT2 (Septin 2) were found to be altered to "September 2".

Top Stories

N Korea 'helping Syria chemical weapons'
Pyongyang has been sending equipment to the country, media reports say, citing a UN report.
3 hours ago

Kushner loses top-level security clearance
4 hours ago

Dog catches carjacker after wild chase
4 hours ago

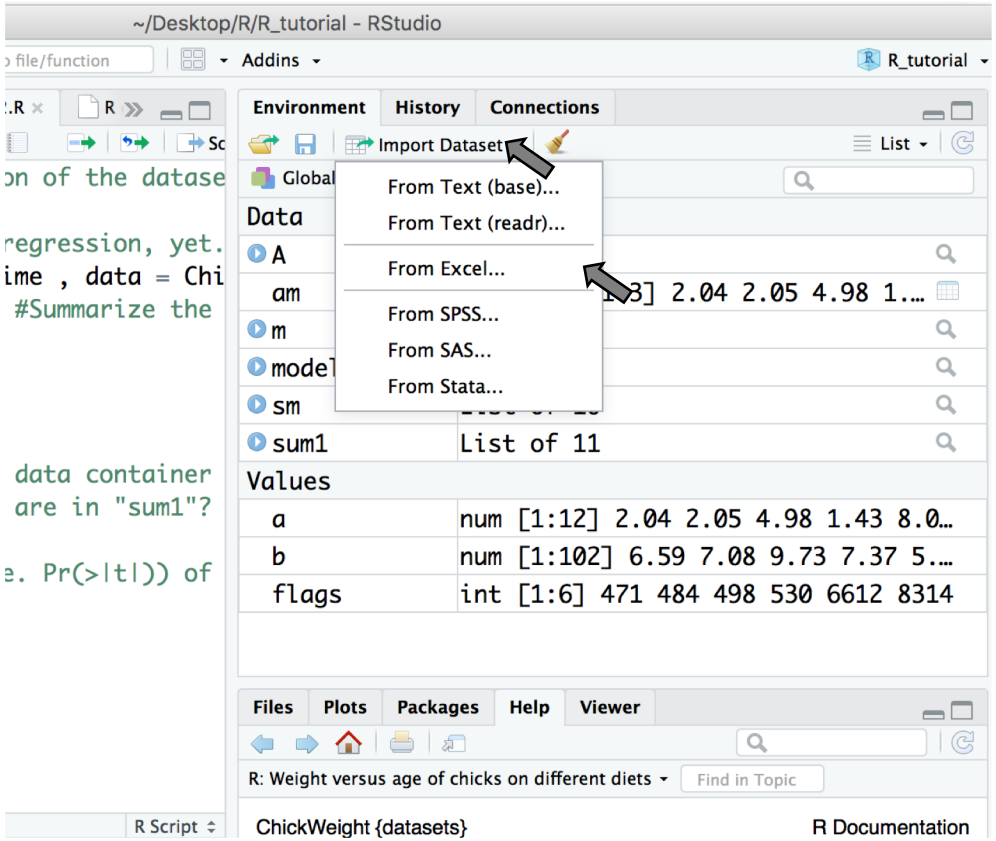
Features

China crackdown: Who might be next?

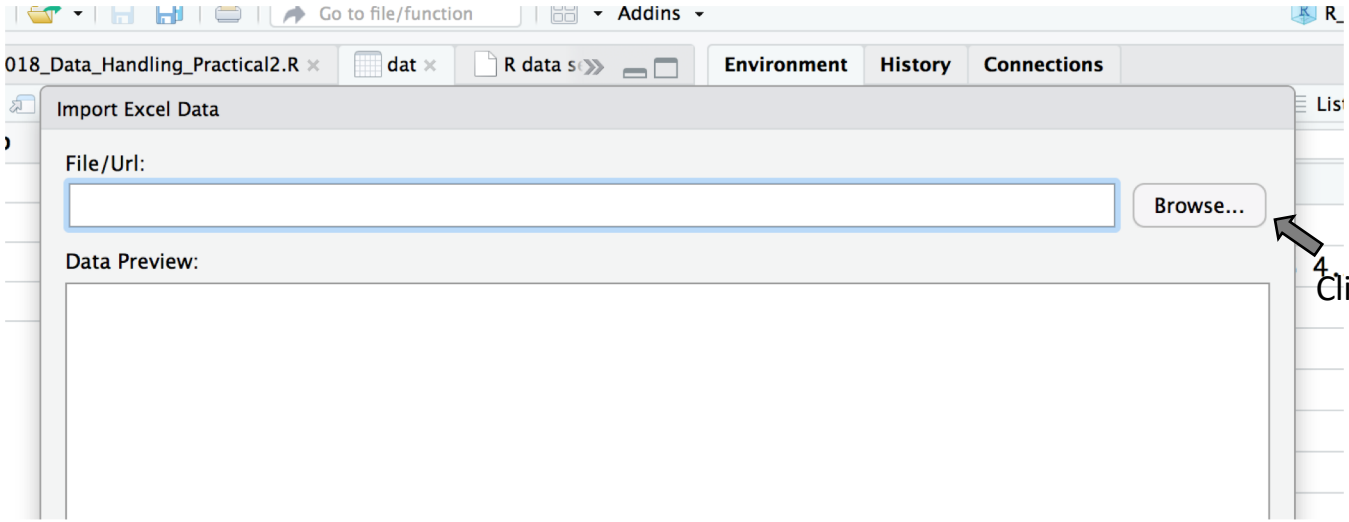
Excel files

- **CAUTION 1:** Excel's automatic data conversion can generate critical errors
- **CAUTION 2:** Avoid opening and saving your CSV and TAB files in MS Excel
- If you need to import the data from Excel files
  - If possible, convert the file to CSV before importing
  - Thoroughly check imported data

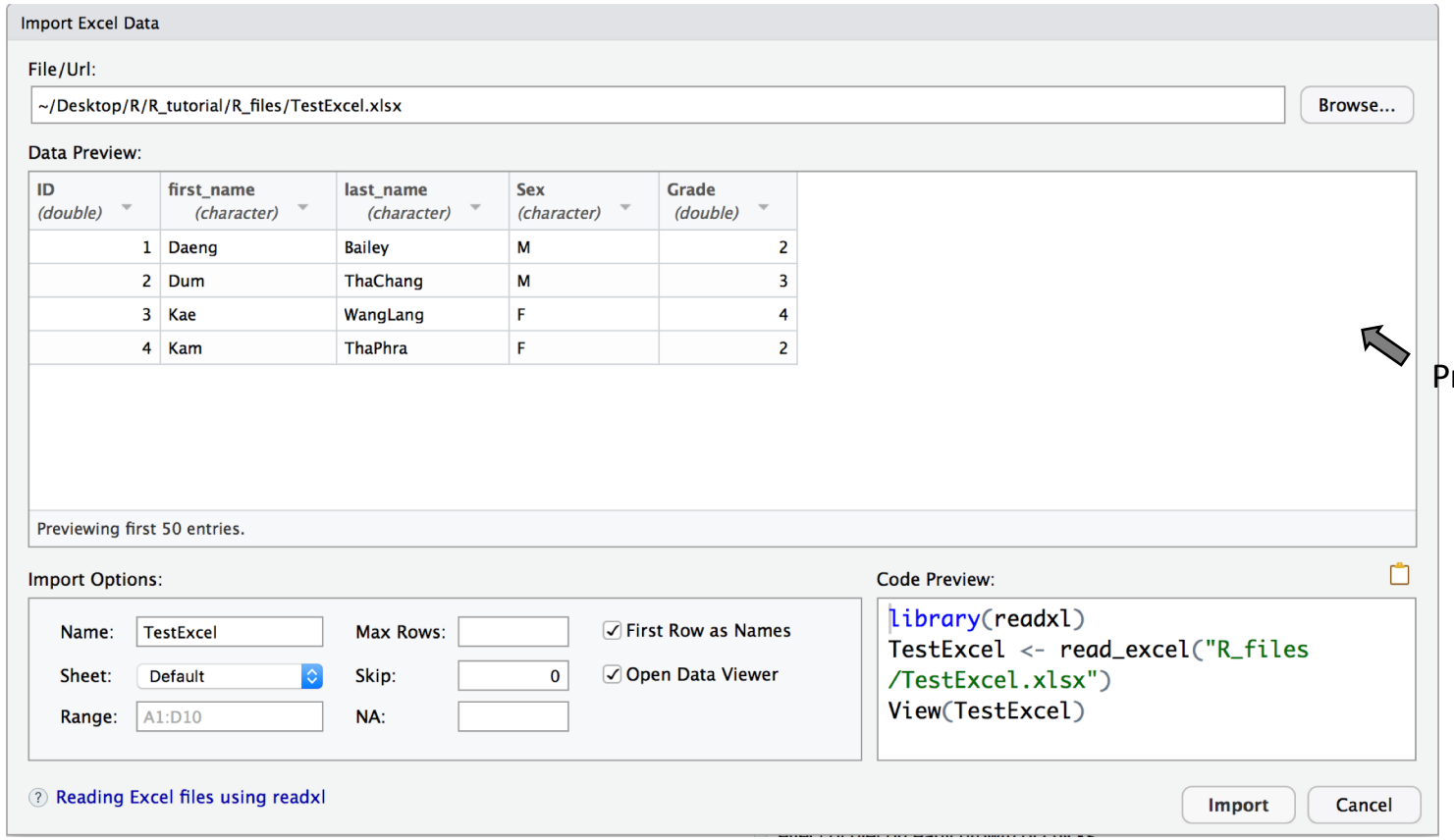
Excel files


~/Desktop/R/R_tutorial - RStudio
Addins
R_tutorial
Environment
History
Connections
Import Dataset
List
From Text (base)...
From Text (readr)...
From Excel...
From SPSS...
From SAS...
From Stata...
Data
A
am
m
model
sm
sum1
List of 11
Values
a
num [1:12] 2.04 2.05 4.98 1.43 8.0…
b
num [1:102] 6.59 7.08 9.73 7.37 5.…
flags
int [1:6] 471 484 498 530 6612 8314
Files
Plots
Packages
Help
Viewer
R: Weight versus age of chicks on different diets
Find in Topic
ChickWeight {datasets}
R Documentation
R Script

Excel files

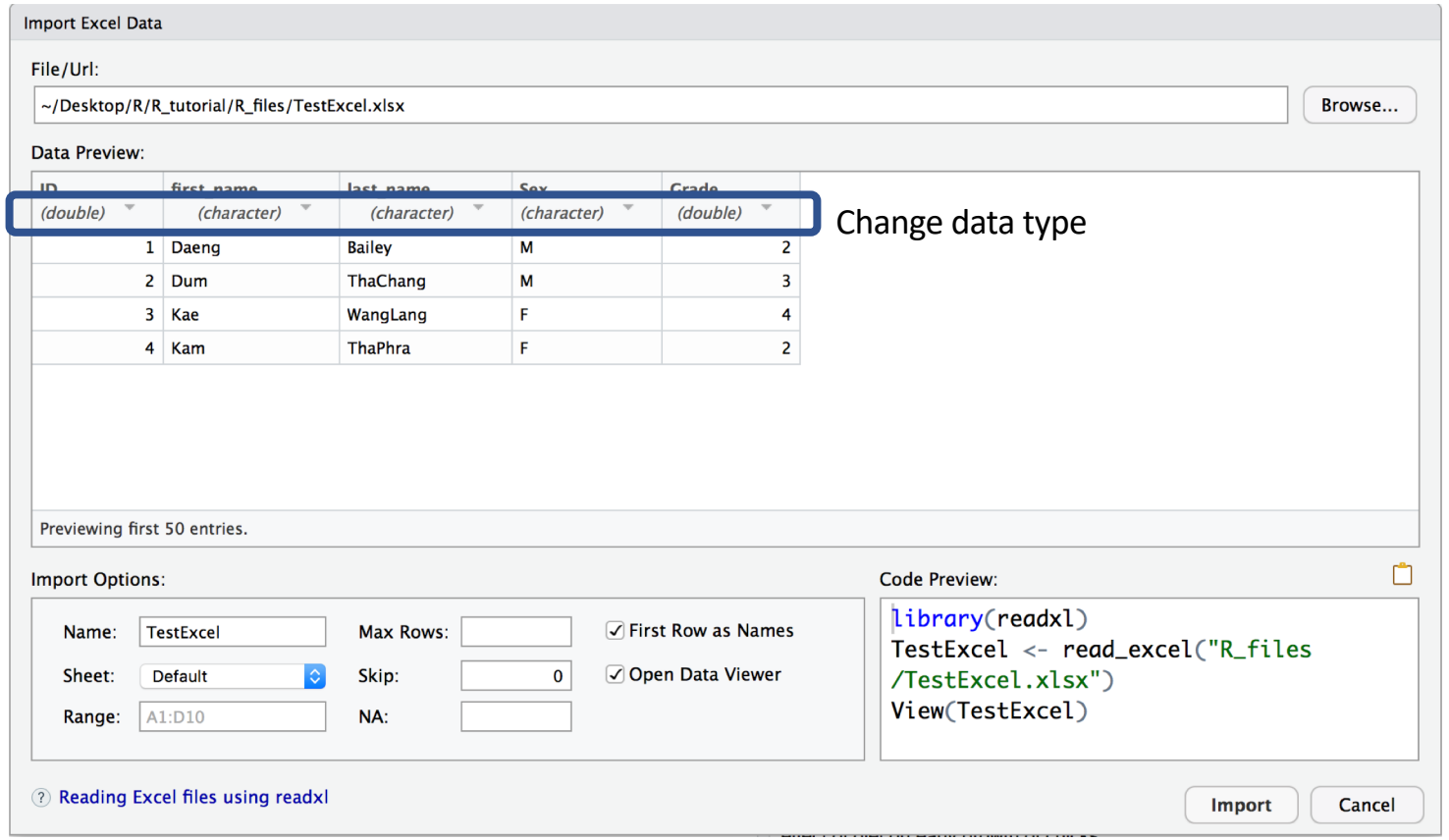

Go to file/function
Addins
018_Data_Handling_Practical2.R
dat
R data s
Environment
History
Connections
Import Excel Data
File/Url:
Browse...
Data Preview:
4.
Click and select your file

Excel files

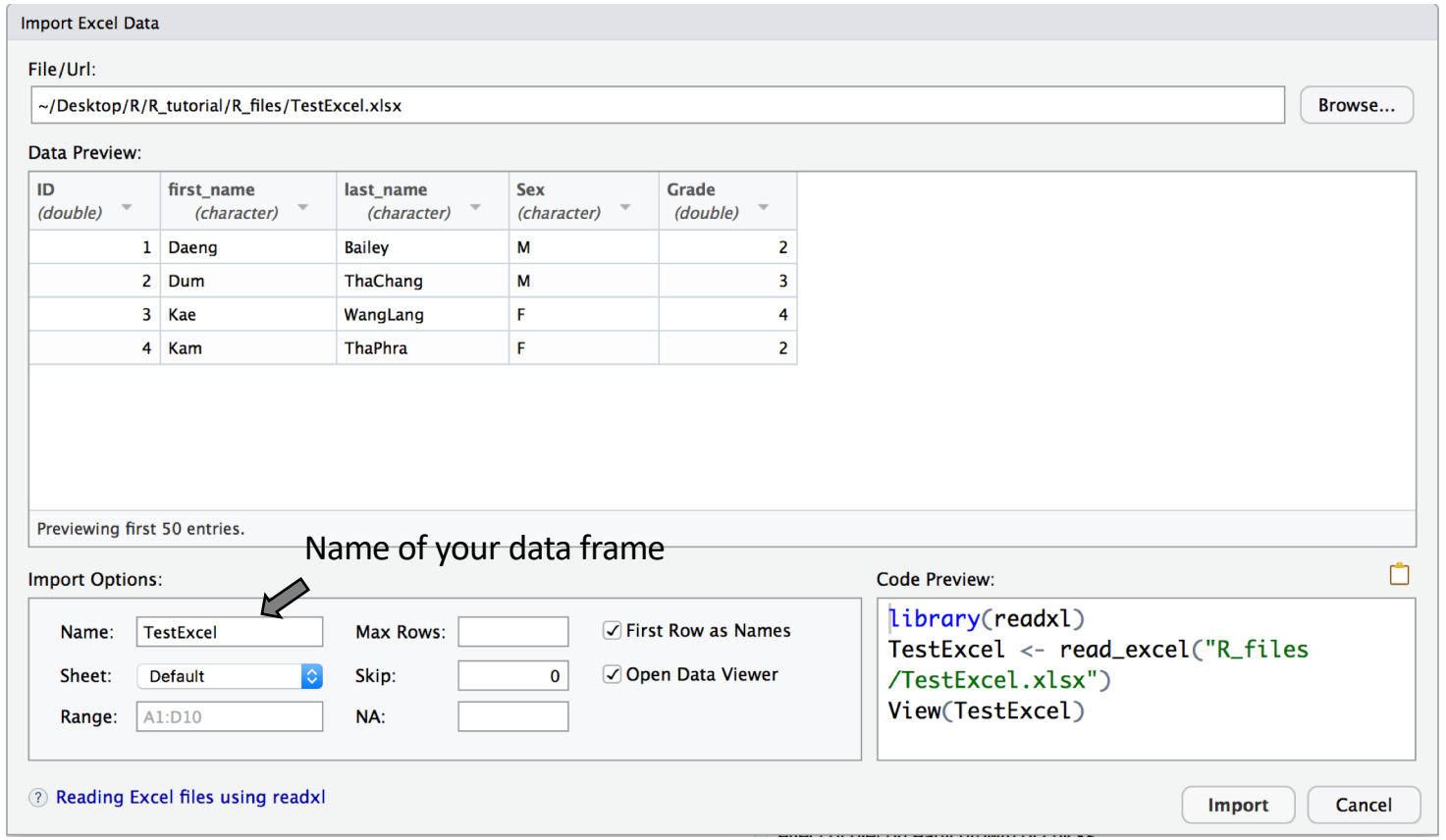


Preview of imported data

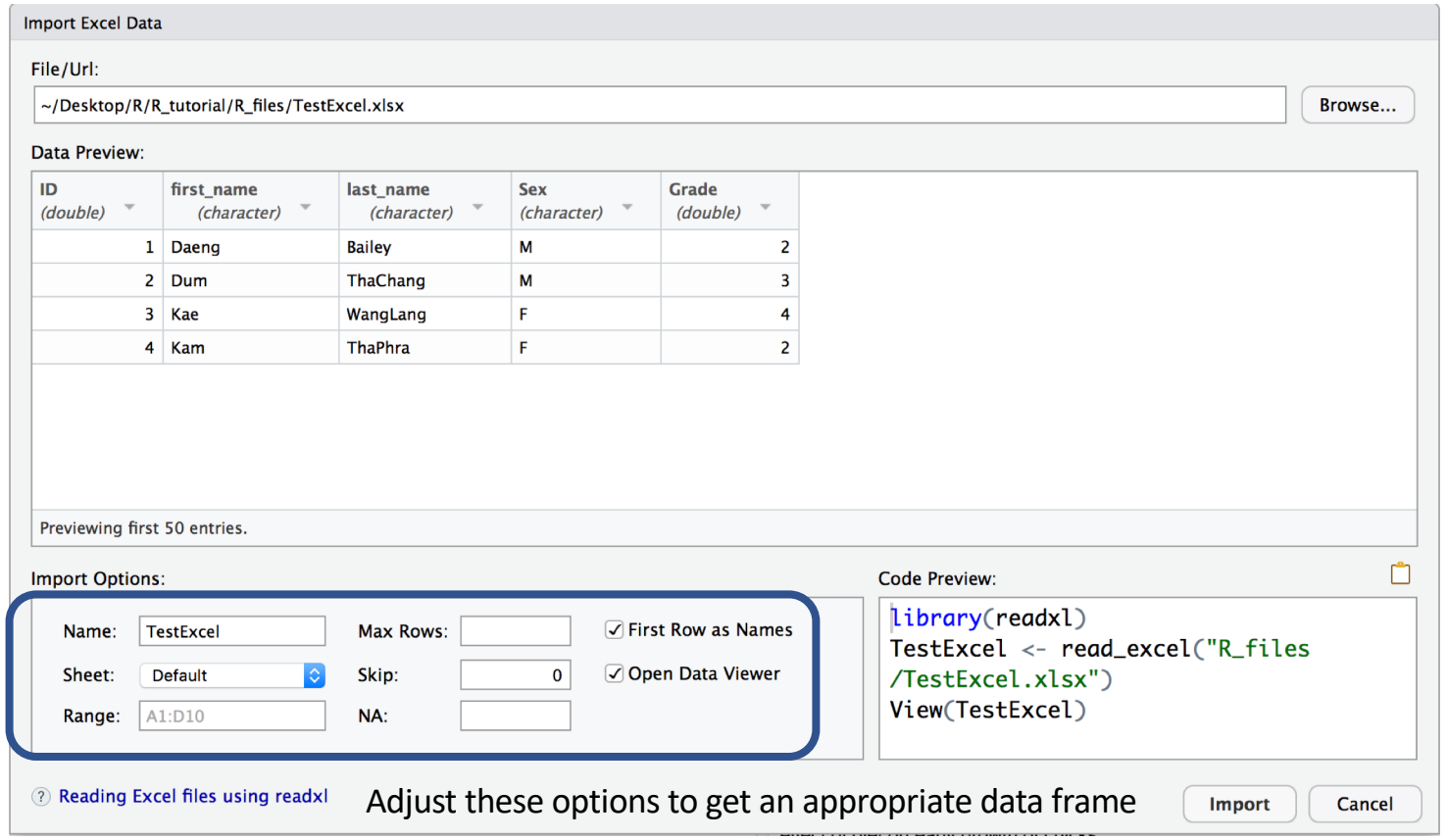
Excel files


Import Excel Data
File/Url:
~/Desktop/R/R_tutorial/R_files/TestExcel.xlsx
Browse...
Data Preview:
ID (double)
first_name (character)
last_name (character)
Sex (character)
Grade (double)
1 Daeng Bailey M 2
2 Dum ThaChang M 3
3 Kae WangLang F 4
4 Kam ThaPhra F 2
Change data type
Previewing first 50 entries.
Import Options:
Name: TestExcel
Sheet: Default
Range: A1:D10
Max Rows:
Skip: 0
NA:
First Row as Names
Open Data Viewer
Code Preview:
library(readxl)
TestExcel <- read_excel("R_files
/TestExcel.xlsx")
View(TestExcel)
Reading Excel files using readxl
Import
Cancel

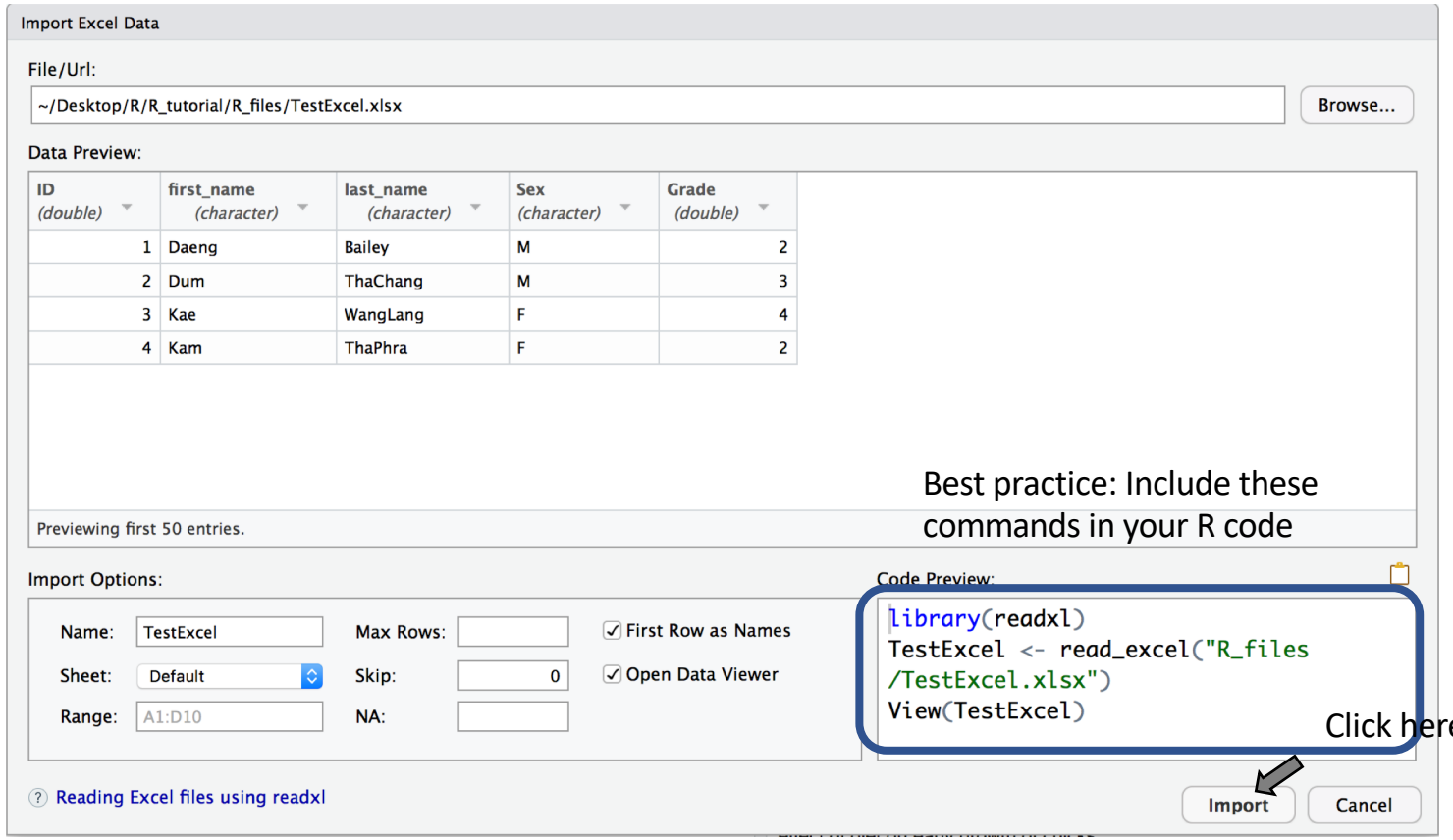
Excel files


Import Excel Data
File/Url:
~/Desktop/R/R_tutorial/R_files/TestExcel.xlsx
Browse...
Data Preview:
ID (double)
first_name (character)
last_name (character)
Sex (character)
Grade (double)
1 Daeng Bailey M 2
2 Dum ThaChang M 3
3 Kae WangLang F 4
4 Kam ThaPhra F 2
Previewing first 50 entries.
Name of your data frame
Import Options:
Name: TestExcel
Sheet: Default
Range: A1:D10
Max Rows:
Skip: 0
NA:
First Row as Names
Open Data Viewer
Code Preview:
library(readxl)
TestExcel <- read_excel("R_files
/TestExcel.xlsx")
View(TestExcel)
Reading Excel files using readxl
Import
Cancel

Excel files


Import Excel Data
File/Url:
~/Desktop/R/R_tutorial/R_files/TestExcel.xlsx
Browse...
Data Preview:
ID (double)
first_name (character)
last_name (character)
Sex (character)
Grade (double)
1 Daeng Bailey M 2
2 Dum ThaChang M 3
3 Kae WangLang F 4
4 Kam ThaPhra F 2
Previewing first 50 entries.
Import Options:
Name: TestExcel
Sheet: Default
Range: A1:D10
Max Rows:
Skip: 0
NA:
First Row as Names
Open Data Viewer
Code Preview:
library(readxl)
TestExcel <- read_excel("R_files
/TestExcel.xlsx")
View(TestExcel)
Reading Excel files using readxl
Adjust these options to get an appropriate data frame
Import
Cancel

Excel files

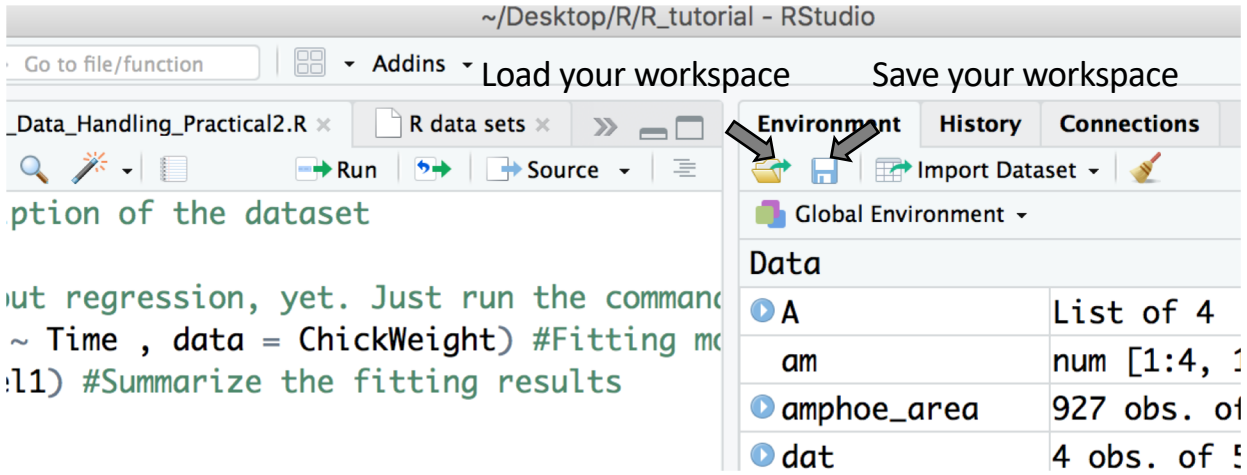


Best practice: Include these commands in your R code

Click here when done

Save/Export your data

- Save your “workspace” as .Rdata file
- The simplest method
- Your data frame will looked the same when reloaded
- Your data will **not** be accessible by text editor or Excel



Save/Export your data

- Save your data as a text file (e.g. CSV, TAB)
- Your data will be accessible by text editor and Excel
- Your data can be later converted to Excel file

```
####Saving your data####
?mtcars #Description of the data frame
?write.csv #Description of the command for saving the data

write.csv(x = mtcars, #Specify your data.frame to be saved
  file = "~/Desktop/R/mtcars.csv", #Specify the file name and path
  na = '', #OPTIONAL: How will the missing data be shown (default = 'NA')
  row.names = FALSE #OPTIONAL: Show row.names or not (default = TRUE)
  )

write.csv(x = mtcars,
          file = "~/Desktop/R/mtcars2.csv"
)
```

Other ways to import/export data

- Package ‘xlsx’ -> Save/Load your data as excel
- Package ‘RMySQL’ -> Interact with SQL database
- Package ‘haven’ -> Save/Load your data in SAS, SPSS and STATA formats
- Package ‘RCurl’ -> Interact with web application

Practical 3

Practical 3: Import your data

- Create a table in MS Excel with the first two rows of data as follows

	A	B	C	D	E	F	G
1	ID	First_Name	Last_Name	Birth_Date	Sex	Weight	Height
2	1	John	Doe	12/8/1970	M	75	167
3	2	Jane	Doe	17/12/2000	F	Not Measured	159
4							

- Add at least 2 more rows with any random data
- Save the file as Excel (.xlsx or .xls)
- Save another copy as CSV (.csv in “Save As”)

Practical 3: Import your data

- Import Excel and CSV files into R
- Check if they are imported correctly (summary() and str())
  - Data
  - Data type
- Correct data types
- Save your data as CSV with a new name

Data Frame Operations

FILE:R2018_Data_Handling_pt2.R

Data Frame Operations

- Each column can be used as a variable for calculation
- New column can be assigned to store new variable from the calculation

```r
####Data Frame Operations pt 1####
?women #Description of the data frame
str(women)

#Create new columns with calculated/transformed data from other column
print(women$height_m) #Before assignment
women$height_m <- women$height * 0.0254 #Convert inch to meter
print(women$height_m) #After assignment

women$weight_kg <- women$weight * 0.4536 #Convert pound to kilogram
women$BMI <- women$weight_kg/(women$height_m ^ 2)

print(women)
```

Data Frame Operations

- ‘cbind()’ for adding new column to the data frame

```
####Data Frame Operations pt 2####
nrow(women)
vector1 <- 1:nrow(women)
ID <- data.frame(id = vector1) #vector1 assigned as 'id' column
print(ID)

n_women <- cbind(women,ID)
print(n_women)

#What if number of rows does not match?
vector2 <- 1:10
ID2 <- data.frame(id2 = vector2)
print(ID2)
n_women <- cbind(women,ID2) #Try and see what happens
```

Data Frame Operations

- ‘rbind()’ for adding new row (record) to the data frame

```r
####Data Frame Operations pt 3####
data(women) #Load the original women data set
print(women)

new_record <- data.frame(height = 55, weight = 100 )
print(new_record)
new_women <- rbind(women,new_record)
print(new_women)

#What if number of column does not match?
new_record2 <- data.frame( weight = 120 )
print(new_record2)
new_women <- rbind(women,new_record2) #Try and see what happens
```

Data Frame Operations

- ‘merge()’ for joining two data frames
- Similar to ‘JOIN’ in SQL

```
####Data Frame Operations pt 4####
#a = transaction data
a <- data.frame(ID = 1:5,
                buyer = c("DM","PS","AC","KP","YT"),
                seller = c("A","A","B","D","E"))
#b = seller information
b <- data.frame(abbre = c("A","B","C","D"),
                full = c("Apple","Banana","Carrot","Durian"),
                phone = c("111","222","333","444"))
print(a)
print(b)
```

Data Frame Operations

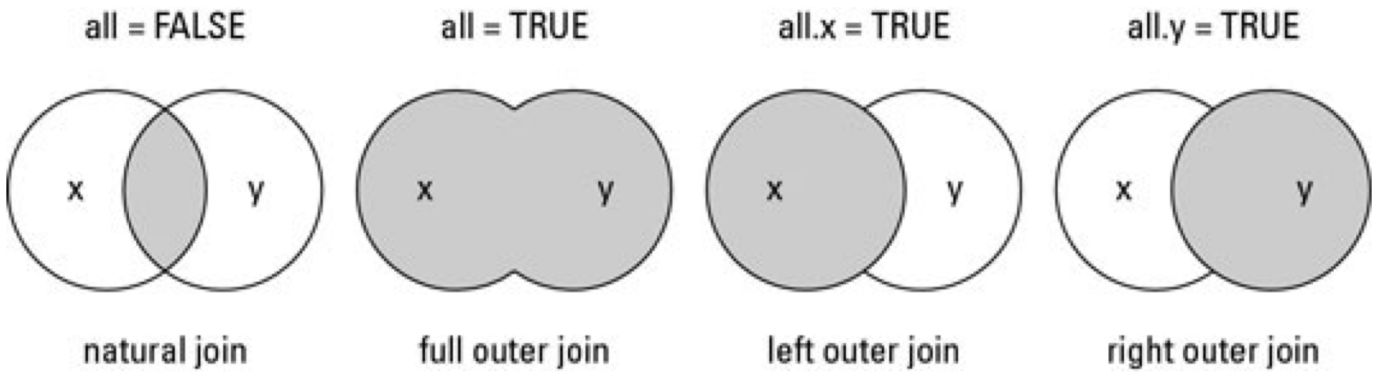
- ‘merge()’ requires:
  - ‘x’ = table 1
  - ‘y’ = table 2
  - ‘by.x’ = names of the column of table 1 to be used for merging
  - ‘by.y’ = names of the column of table 2 to be used for merging
  - ‘all’, ‘all.x’ or ‘all.y’ = whether all rows will be kept with or without matched rows

Data Frame Operations

```
####Data Frame Operations pt 5####
result <- merge(x=a,y=b, by.x = "seller",by.y = "abbre") #Inner join
print(result) #Drop all unmatched

result <- merge(x=a,y=b, by.x = "seller",by.y = "abbre", all.x = T) #Left join
print(result) #Drop unmatched in 'b' (i.e. y or right)

result <- merge(x=a,y=b, by.x = "seller",by.y = "abbre", all.y = T) #Right join
print(result) #Drop unmatched in 'a' (i.e. x or left)

result <- merge(x=a,y=b, by.x = "seller",by.y = "abbre", all = T) #Outer join
print(result) #Do not drop any unmatched

result <- merge(x=a,y=b, by=NULL) #Cross join
print(result) #All combinations
```

Data Frame Operations

- ‘merge()’ for joining two data frames
- Similar to ‘JOIN’ in SQL



http://www.dummies.com/programming/r/how-to-use-the-merge-function-with-data-sets-in-r/

Useful Functions For Data Preparation

Quick look at your data

- View(); **not view()**
- head()
- tail()

```
67  ####Quick look####
68  View(mtcars)
69
70  head(mtcars)
71  head(mtcars, n = 2)
72
73  tail(mtcars)
74  tail(mtcars, n = 3)
```

‘attach()’

- Attach your data frame so that you can call each column directly
- **CAUTION:** If you are working with more than one data frame, referring columns from several attached data frames might be confusing

```
67 ####attach()####
68 ?mtcars
69
70 mtcars$mpg #Call column 'mpg' from 'mtcars' data frame
71 mpg #Try and see what happens
72
73 attach(mtcars)
74 mpg
75 gear
76 hp
77
78 detach(mtcars) #Detach the data frame
79 mpg #Try and see what happens
```

‘unique()’

- Deduplication

```
####unique pt 1####
?mtcars
print(mtcars)

new_mtcars <- rbind(mtcars, mtcars[5:10,])
u_mtcars <- unique(new_mtcars)
print(new_mtcars)
print(u_mtcars) #Deduplicate new_mtcars

dim(mtcars)
dim(new_mtcars)
dim(u_mtcars)

identical(mtcars,new_mtcars) #Check if two objects are identical
identical(mtcars,u_mtcars)
```

‘unique()’ vs ‘levels()’ vs ‘table()’

- Checking for unique values
  - unique(): generic;
  - levels(): for ‘factor’ data
  - table(): tallying up unique values

```
97  ####unique pt 2####
98  ?iris
99
100 iris$Species
101 unique(iris$Species)
102 levels(iris$Species)
103 table(iris$Species)
104
105 c_species <- as.character(iris$Species) #Covert from 'factor' to 'character'
106 levels(c_species) #Try and see what happesn
107 unique(c_species)
108 table(c_species)
```

‘paste()’ and ‘paste0()’

- Combine/Concatenate texts

```
110 ####paste and paste0####
111 paste("I","love","you.")
112 paste0("I","love","you.")
113 paste("I","love","you.", sep = "")
114 
115 library(hflights)
116 ?hflights
117 
118 #Let's create complete flight number (e.g. TG001)
119 hflights$CF_num <- paste0(hflights$UniqueCarrier,hflights$FlightNum)
120 
121 #Convert a vector to a single text with collapse
122 test <- paste0(hflights$UniqueCarrier,hflights$FlightNum, collapse = " ")
123 length(test)
124 nchar(test)
```

‘cut()’

- Grouping numerical data into “ordinal” data
- Easier for regression model/scoring system and interpretation

```
140 ####cut####
141 ?women
142 women$weight
143 #Let's group data by weight
144 #-Inf------150]------Inf (i.e Grp 1 = -Inf to 150 and Grp2 = >150 to Inf)
145 cut(women$weight,breaks = c(-Inf,150,Inf) )
146
147 #-Inf---120]---130]---140]---150]---Inf
148 cut(women$weight,breaks = c(-Inf,120,130,140,150,Inf) )
149
150 #-Inf---120)---130)---140)---150)---Inf
151 cut(women$weight,breaks = c(-Inf,120,130,140,150,Inf), right = F )
152
153 #-Inf---120]---130]---140]---150]---Inf
154 #Rename group with labels
155 cut(women$weight,breaks = c(-Inf,120,130,140,150,Inf),
156     labels =  c("very underweight","underweight","normal","overweight","obese"))
```

‘lubridate’ package

- Commands in lubridate package guess date&time data from text

```
####lubridate####
library(lubridate)
today() #Current date
now() #Current date & time

ymd(c("2010-1-1","2010/2/2","2010 3 3")) #Texts are written in Year-Month-Day
mdy(c("Feb 2,2011", "November 21st, 2012")) #Texts are written in Month-Day-Year
dmy_hms(c("11/11/2011 11:11:11", "7 April 2001 1:05:11 PM")) #Texts are written
#in Day-Month-Year-Hour-Minute-Second

dmy(c("12/11/2016","2001-1-11")) #Try and see what happens

a <- dmy_hm("5/6/2014 3:40 PM")#Texts are written in Day-Month-Year-Hour-Minute
b <- dmy_hm("6/6/2014 8:20 AM")

print(a)#Default format of date&time
paste0(day(a),"/",month(a),"/",year(a)," ",hour(a),":",minute(a))#Extract each
#element and re-format date&time
b-a #Simple calculation
difftime(b,a, units = "mins") #Specify units
difftime(b,a, units = "days") #Specify units
```

Practical 4

Practical 4: Merge and tally

1. Merge 'airlines' to 'hflights'
2. Count total flights of these airlines

- HINT: airlines$code matches with hflight$???

```
1  library(hflights)
2  ?hflights
3
4  airlines <- data.frame(code = c("XE","CO","WN","OO","MQ","NW"),
5                         name = c("ExpressJet Airlines, Inc.",
6                                  "Continental Airlines, Inc.",
7                                  "Southwest Airlines Co.",
8                                  "SkyWest  Airlines",
9                                  "Envoy Air Inc.",
10                                 "Northwest Airlines Corp."))
11 print(airlines)
```

Practical 5

Practical 5: Create date data from text

1. Create 'hflights$txt_date' storing texts of complete dates
2. Create 'hflights$date' by converting 'hflights$txt_date' to date data

- HINT 1: paste
- HINT 2: lubridate

```
1  library(hflights)
2  ?hflights
3
4  hflights[,c("Year","Month","DayofMonth")]
```

Practical 6

Practical 6: Create ‘ordinal’ data

1. Classify ‘TaxiOut’ times as follows:
   - 0 to 15 as 'Fast’
   - >15 to 30 as 'Regular’
   - >30 to 60 as 'Slow’
   - >60 as 'Problematic’
2. Tally classified ‘TaxiOut’ times

```
1  library(hflights)
2  ?hflights
3
4  summary(hflights$TaxiOut)
```

‘~’ tilde (For Thai participants)

- If you use ‘~’ for changing language input, you will not be able to simply type ‘~’.
- Solutions:

1. Keep pressing Shift + ~ , or
2. `?lm` and copy ‘~’ from the help pane, or
3. Change buttons for changing language input

Wrap up

- After the first day of the workshop
  - Understand basic programming concepts in R
  - Understand indexing (i.e. how to use ‘[ ]’)
  - Import and export your data
  - Prepare your data for statistical analysis

Want to learn more?

- https://stackoverflow.com
  - Solution for your errors
  - How to?
- https://www.r-bloggers.com
  - Useful packages
  - Tutorials

Data Transformation
(Optional materials)

‘aggregate()’

1. Group data by variables
2. Analyze each group with a specified function simultaneously (i.e. faster)

- `aggregate(measure.col ~ grp.col1 + grp.col2, data, FUN, argument_for_function)`

  - measure.col = column to be calculated/analyzed
  - grp.col1, grp.col2,…,grp.coln = columns used for grouping data
  - data = the data frame to be analyzed
  - FUN = function to be used for calculation
  - argument_for_function = additional arguments to be passed to the function

‘aggregate()’

- aggregate(measure.col ~ grp.col1 + grp.col2, data, FUN, argument_for_function)

```
####aggregate####
?iris
print(iris)

#Median of ‘Petal.Length’ by ’Species’
median(iris$Petal.Length, na.rm = T)
unique(iris$Species)
#1) For loop method
for(s in unique(iris$Species)){
  print(s)
  flags <- which(iris$Species == s)
  result <- median(iris[flags,"Petal.Length"], na.rm = T)
  print(result)
}
#2) Aggregate method
aggregate(Petal.Length ~ Species, data = iris, FUN = median, na.rm = T)
```

‘t()’

- Transpose matrix and data frame (2D container)
- Rows <-> Columns
- CAUTION: Data type conversion

```
####t####
?iris
t_iris <- t(iris)

print(iris)
print(t_iris)

summary(iris)
summary(t_iris)
```

‘reshape2’ package: Wide vs Long data format

- Repeated measurement data and time series can be represent in either wide or long format

PatientID	Measurement	BloodSugar
1	1	210
1	2	208
1	3	170
1	4	145
1	5	120
2	1	180
2	2	190
2	3	215
2	4	200
2	5	205

LONG (Row = 1 Measurement)

PatientID	BloodSugar1	BloodSugar2	BloodSugar3	BloodSugar4	BloodSugar5
1	210	208	170	145	120
2	180	190	215	200	205

Wide (Column = 1 Measurement)

‘reshape2’ package: Wide vs Long data format

- R: Data analysis and visualization require “long” formatted data
  - 1 Row = 1 Observation/Measurement
- SPSS and GraphPad require “wide” formatted data
  - Every measurement must be added as a column
- Table for long formatted data usually takes more space
- Table for wide formatted data is easier to read

‘melt()’: Wide -> Long

- Wikipedia PPP data from 1980 to 1989

```
####melt pt 1####
#install.packages("rvest", dep = T)
library(rvest)
library(reshape2)

####For importing data from html source; Do not worry about this####
url <- 'https://en.wikipedia.org/wiki/List_of_countries_by_past_and_projected_GDP_(PPP)'
test <- read_html(url)
tbls <- html_nodes(test, "table")
ttt <- html_table(tbls, fill = T)
tb4 <- ttt[[4]]
#####

str(tb4)
View(tb4)
```

‘melt()’: Wide -> Long

- Identify your “id.vars” = columns you want to keep

	Country (or dependent territory)	1980	1981	1982	1983	1984	1985	198
1	Afghanistan							
2	Albania	5,547	6,410	7,005	7,362	7,776	7,904	8,5
3	Algeria	86,629	97,559	110,243	120,783	132,073	143,933	146
4	Angola	14,949	15,626	16,595	17,975	19,729	21,073	22,
5	Antigua and Barbuda	267	303	322	352	402	446	508
6	Argentina	176,595	181,994	187,200	201,854	213,199	204,727	223
7	Armenia							
8	Australia	154,525	175,927	186,959	193,419	212,994	231,803	242
9	Austria	84,466	92,261	99,855	106,708	110,861	116,975	122
10	Azerbaijan							
11	Bahamas	1,967	2,089	2,358	2,618	2,776	2,982	3,1
12	Bahrain	6,199	6,967	7,873	8,756	9,446	9,658	9,9
13	Bangladesh	42,099	47,445	52,005	56,549	61,002	65,312	69,
14	Barbados	1,355	1,453	1,467	1,533	1,645	1,716	1,8

‘melt()’: Wide -> Long

- Identify your “id.vars” = columns you want to keep

	Country (or dependent territory)	1980	1981	1982	1983	1984	1985	198
1	Afghanistan							
2	Albania	5,547	6,410	7,005	7,362	7,776	7,904	8,5
3	Algeria	86,629	97,559	110,243	120,783	132,073	143,933	146
4	Angola	14,949	15,626	16,595	17,975	19,729	21,073	22,
5	Antigua and Barbuda	267	303	322	352	402	446	508
6	Argentina	176,595	181,994	187,200	201,854	213,199	204,727	223
7	Armenia							
8	Australia	154,525	175,927	186,959	193,419	212,994	231,803	242
9	Austria	84,466	92,261	99,855	106,708	110,861	116,975	122
10	Azerbaijan							
11	Bahamas	1,967	2,089	2,358	2,618	2,776	2,982	3,1
12	Bahrain	6,199	6,967	7,873	8,756	9,446	9,658	9,9
13	Bangladesh	42,099	47,445	52,005	56,549	61,002	65,312	69,
14	Barbados	1,355	1,453	1,467	1,533	1,645	1,716	1,8

‘melt()’: Wide -> Long

- melt(“name_of_your_data”, id.vars = c(“column_to_keep1”, “column_to_keep2”, …))

```
208 ####melt pt 2####
209 mtb4 <- melt(tb4, id.vars = c('Country (or dependent territory)'))
210 View(mtb4)
```

‘melt()’: Wide -> Long

	Country (or dependent territory)	1980	1981	1982	1983	1984	1985	198
1	Afghanistan							
2	Albania	5,547	6,410	7,005	7,362	7,776	7,904	8,5
3	Algeria	86,629	97,559	110,243	120,783	132,073	143,933	146
4	Angola	14,949	15,626	16,595	17,975	19,729	21,073	22,
5	Antigua and Barbuda	267	303	322	352	402	446	508
6	Argentina	176,595	181,994	187,200	201,854	213,199	204,727	223
7	Armenia							
8	Australia	154,525	175,927	186,959	193,419	212,994	231,803	242
9	Austria	84,466	92,261	99,855	106,708	110,861	116,975	122
10	Azerbaijan							
11	Bahamas	1,967	2,089	2,358	2,618	2,776	2,982	3,1
12	Bahrain	6,199	6,967	7,873	8,756	9,446	9,658	9,9
13	Bangladesh	42,099	47,445	52,005	56,549	61,002	65,312	69,
14	Barbados	1,355	1,453	1,467	1,533	1,645	1,716	1,8

	Country (or dependent territory)	variable	value
1	Afghanistan	1980	
2	Albania	1980	5,547
3	Algeria	1980	86,629
4	Angola	1980	14,949
5	Antigua and Barbuda	1980	267
6	Argentina	1980	176,595
7	Armenia	1980	
8	Australia	1980	154,525
9	Austria	1980	84,466
10	Azerbaijan	1980	
11	Bahamas	1980	1,967
12	Bahrain	1980	6,199
13	Bangladesh	1980	42,099
14	Barbados	1980	1,355
15	Belarus	1980	

‘dcast()’:Long -> Wide

- ‘ChickWeight’ data
- Identify 3 types of columns
  1. Columns to be kept (similar to id.vars of ‘melt())
  2. Columns to be converted to column names (usually columns showing time of measurement)
  3. **A column** storing values to be shown in each cell of the ‘dcasted’ table

	weight	time	chick	diet
1	42	0	1	1
2	51	2	1	1
3	59	4	1	1
4	64	6	1	1
5	76	8	1	1
6	93	10	1	1
7	106	12	1	1
8	125	14	1	1
9	149	16	1	1
10	171	18	1	1
11	199	20	1	1
12	205	21	1	1
13	40	0	2	1

‘dcast()’:Long -> Wide

- ‘ChickWeight’ data
- Identify 3 types of columns
  1. Columns to be kept (similar to id.vars of ‘melt())
  2. Column to be converted to column names (usually column showing time of measurement)
  3. A column storing values to be shown in each cell of the ‘dcasted’ table

	3	2	1	
	weight	time	chick	diet
1	42	0	1	1
2	51	2	1	1
3	59	4	1	1
4	64	6	1	1
5	76	8	1	1
6	93	10	1	1
7	106	12	1	1
8	125	14	1	1
9	149	16	1	1
10	171	18	1	1
11	199	20	1	1
12	205	21	1	1
13	40	0	2	1

‘dcast()’:Long -> Wide

- ‘ChickWeight’ data
- dcast(“data name”, “Columns to be kept1+Columns to be kept2+…” ~ “timing column1 + timing column2”, value.vars = column storing values)
- TYPOS in the demo R-script!

```
221 ####dcast pt####
222 library(reshape2)
223
224 View(ChickWeight)
225
226 cast_CW <- dcast(ChickWeight, Chick + Diet ~ Time, value.var = "weight")
227
228 View(cast_CW)
```

‘dcast()’:Long -> Wide

- ‘ChickWeight’ data

	chick	diet	0	2	4	6	8	10	12
1	18	1	39	35	NA	NA	NA	NA	
2	16	1	41	45	49	51	57	51	
3	15	1	41	49	56	64	68	68	
4	13	1	41	48	53	60	65	67	
5	9	1	42	51	59	68	85	96	
6	20	1	41	47	54	58	65	73	
7	10	1	41	44	52	63	74	81	
8	8	1	42	50	61	71	84	93	1
9	17	1	42	51	61	72	83	89	
10	19	1	43	48	55	62	65	71	
11	4	1	42	49	56	67	74	87	1

‘dcast()’:Long -> Wide

- ‘ChickWeight’ data

	3	2	1	
	weight	time	chick	diet
1	42	0	1	1
2	51	2	1	1
3	59	4	1	1
4	64	6	1	1
5	76	8	1	1
6	93	10	1	1
7	106	12	1	1
8	125	14	1	1
9	149	16	1	1
10	171	18	1	1
11	199	20	1	1
12	205	21	1	1
13	40	0	2	1

	1		2						
	chick	diet	0	2	4	6	8	10	12
1	18	1	39	35	NA	NA	NA	NA	
2	16	1	41	45	49	51	57	51	
3	15	1	41	49	56	64	68	68	
4	13	1	41	48	53	60	65	67	
5	9	1	42	51	59	68	85	96	
6	20	1	41	47	54	58	65	73	
7	10	1	41	44	52	63	74	81	
8	8	1	42	50	61	71	84	93	1
9	17	1	42	51	61	72	83	89	
10	19	1	43	48	55	62	65	71	
11	4	1	42	49	56	67	74	87	1
			3						

Practical 7

Practical 7: Melt and Aggregate

1. Melt table 'tb’
2. Correct data type of each column
3. Use 'aggregate()' to find mean PPP from 2000 to 2009 for each country

```r
library(rvest)
library(reshape2)

####For importing data from html source; Do not worry about this####
url <- 'https://en.wikipedia.org/wiki/List_of_countries_by_past_and_projected_GDP_(PPP)'
test <- read_html(url)
tbls <- html_nodes(test, "table")
ttt <- html_table(tbls, fill = T)
tb <- ttt[[10]]
colnames(tb)[1] <- "country" #Change the name of the first column
for(i in 2:ncol(tb)){
  tb[,i] <- gsub(pattern = ",",replacement = "",x = tb[,i]) #Remove ',' from numbers
}
```

Practical 8

Practical 8: dcast

- Use 'dcast' to create a wide format table for 'sleepstudy' data

```
1  #install.packages("lme4",dep = T)
2  library(lme4)
3  library(reshape2)
4
5  ?sleepstudy
6  View(sleepstudy)
7
```