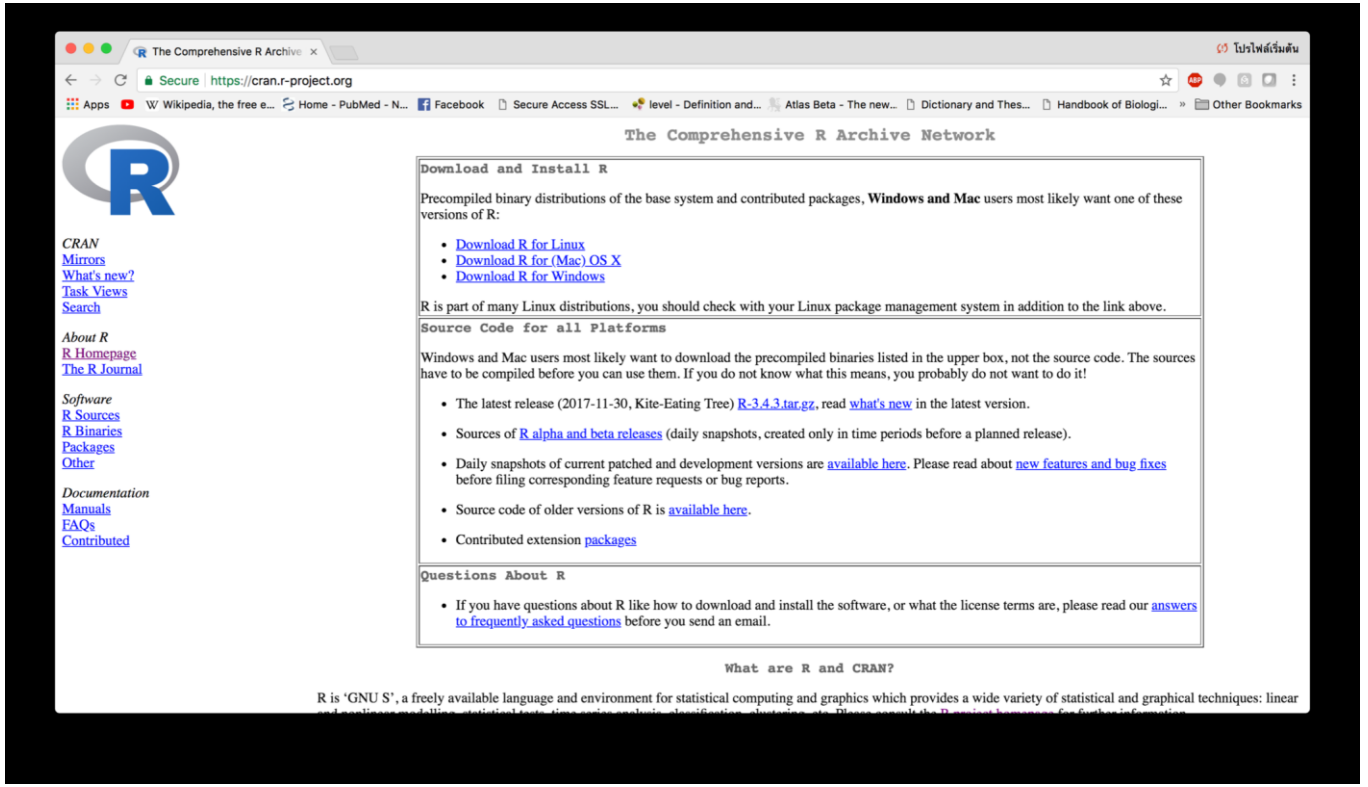
SIRE516

Week1: Introduction to R programming

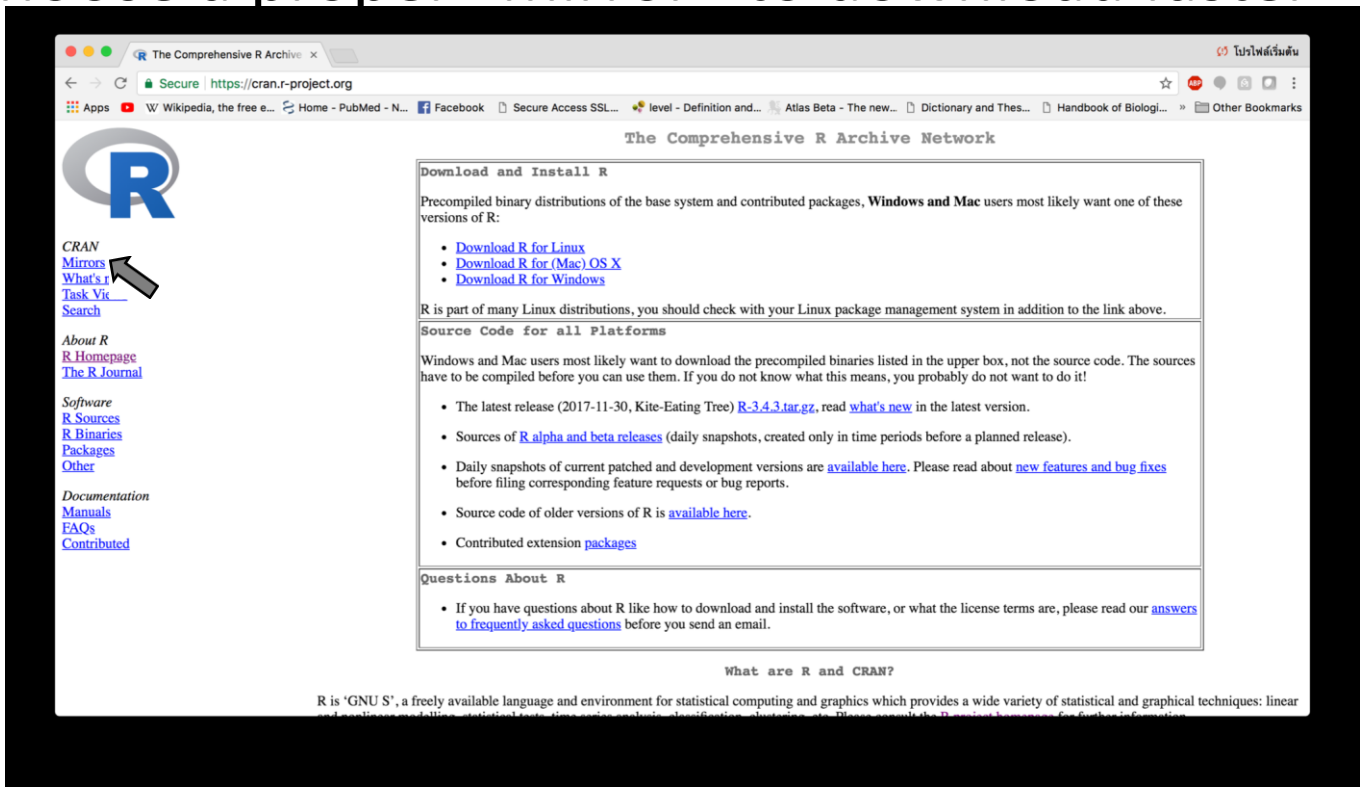
Let's get R

- 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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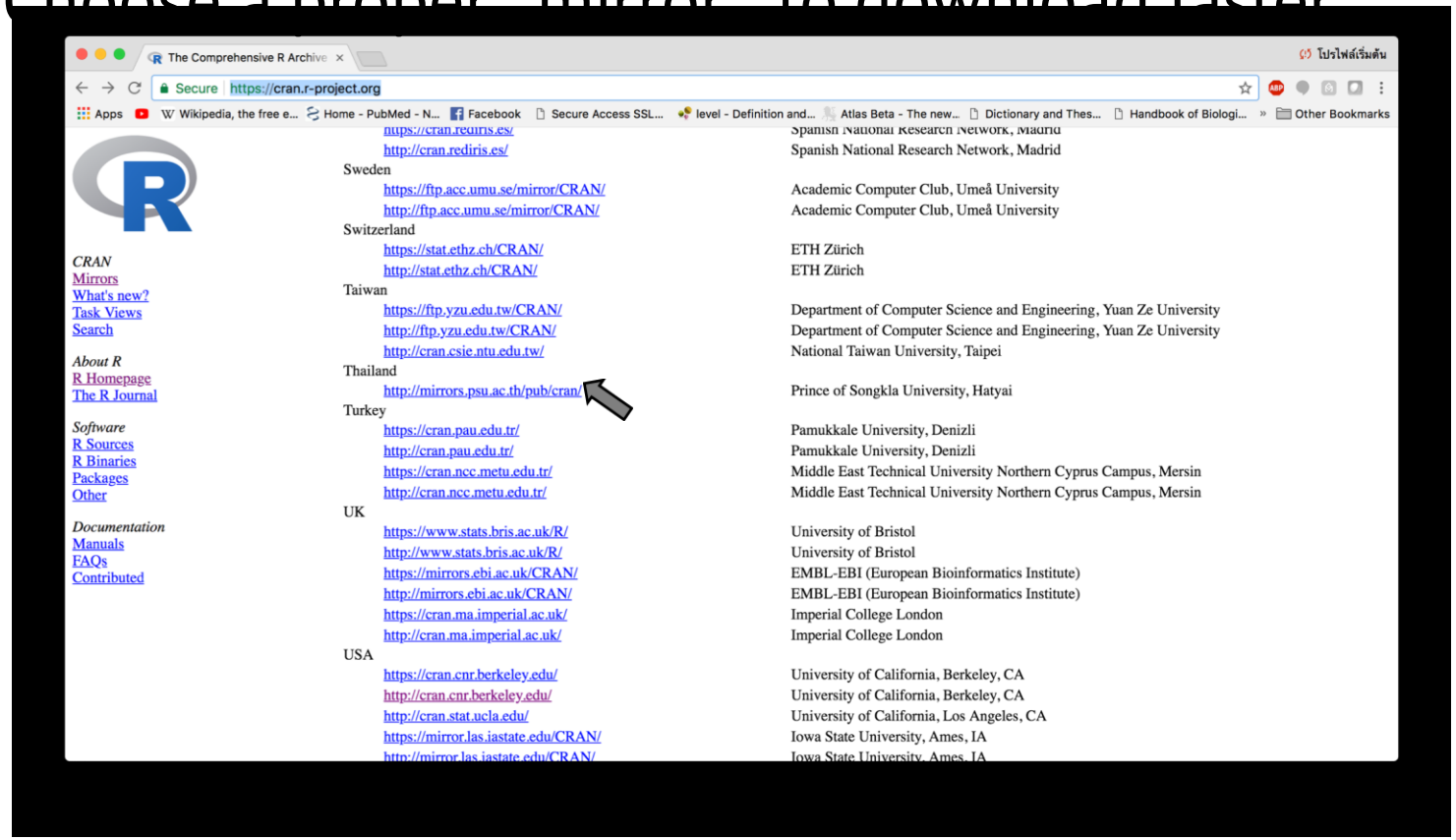

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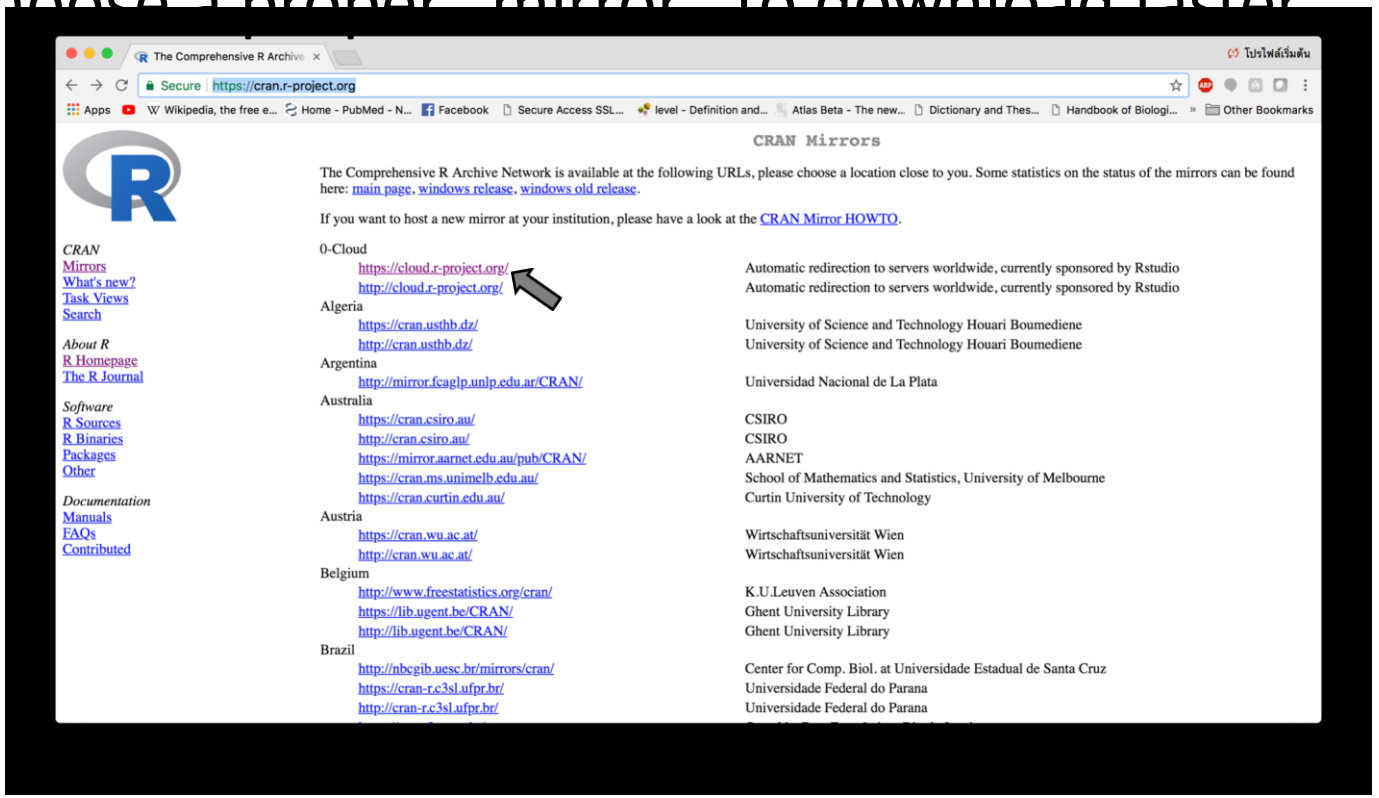
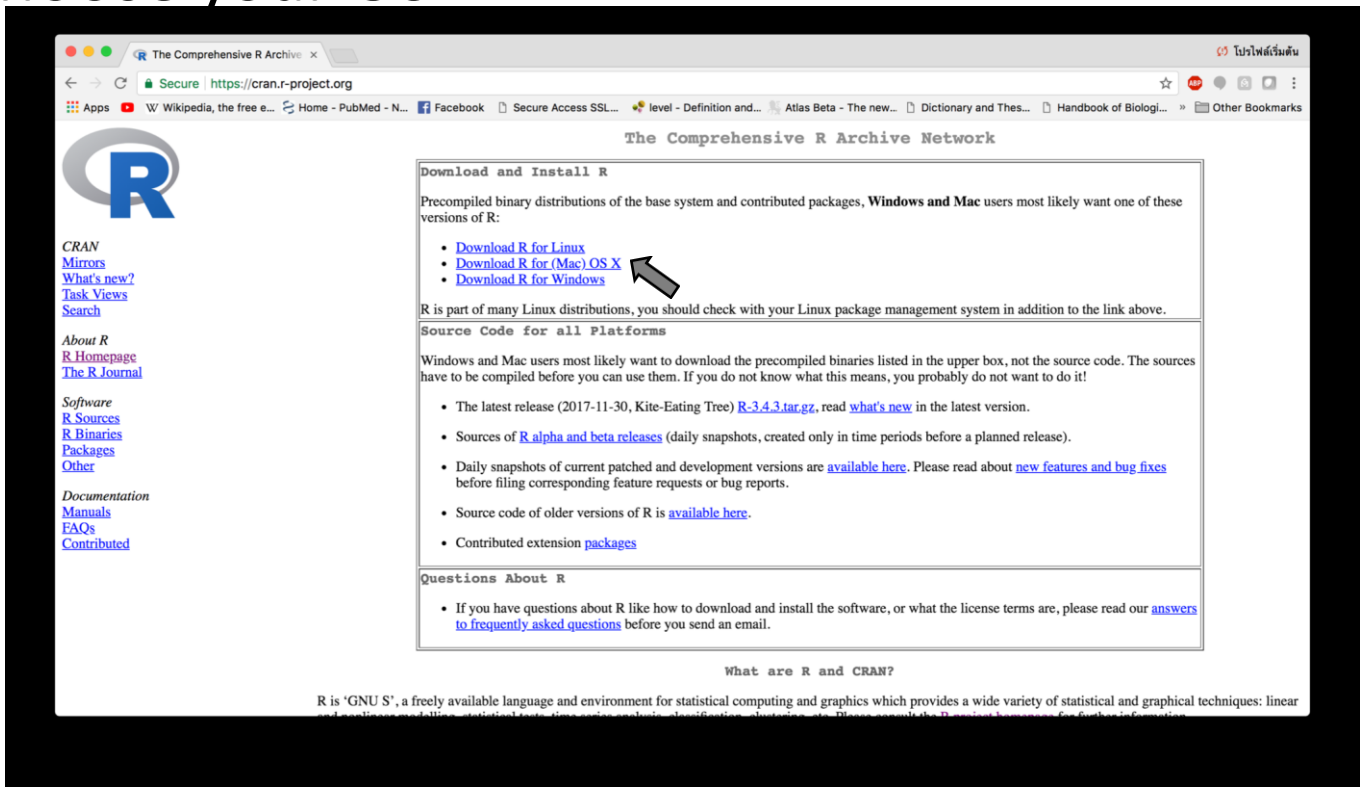


Let's get R

- Choose your OS



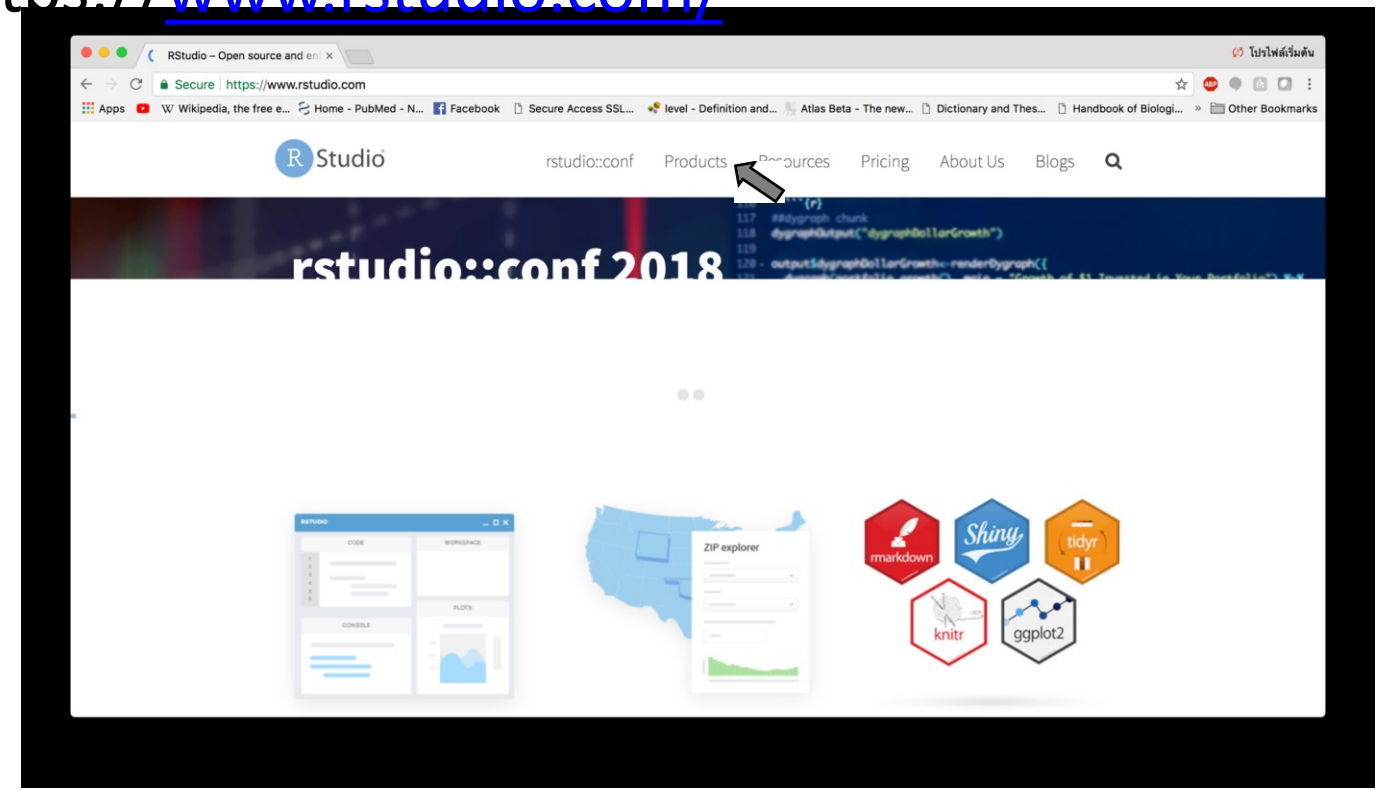
RStudio

- 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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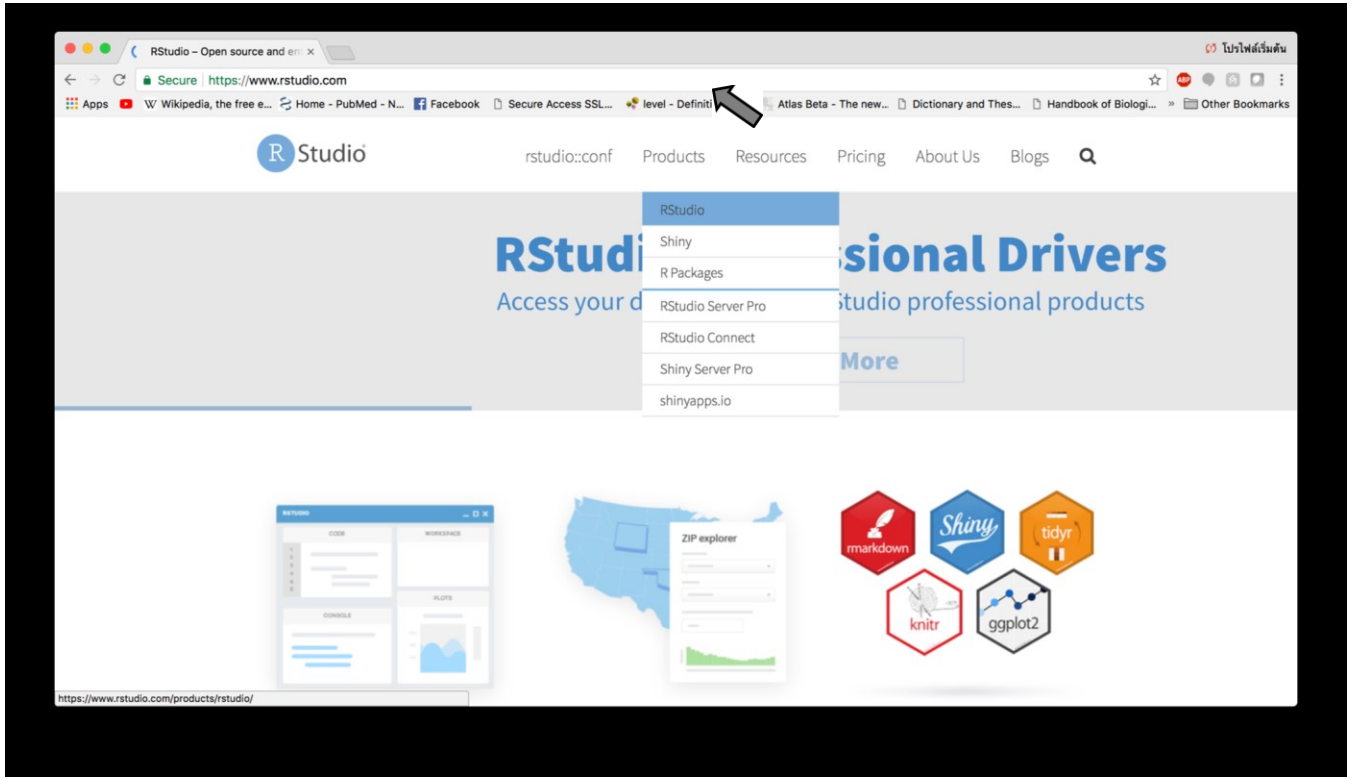
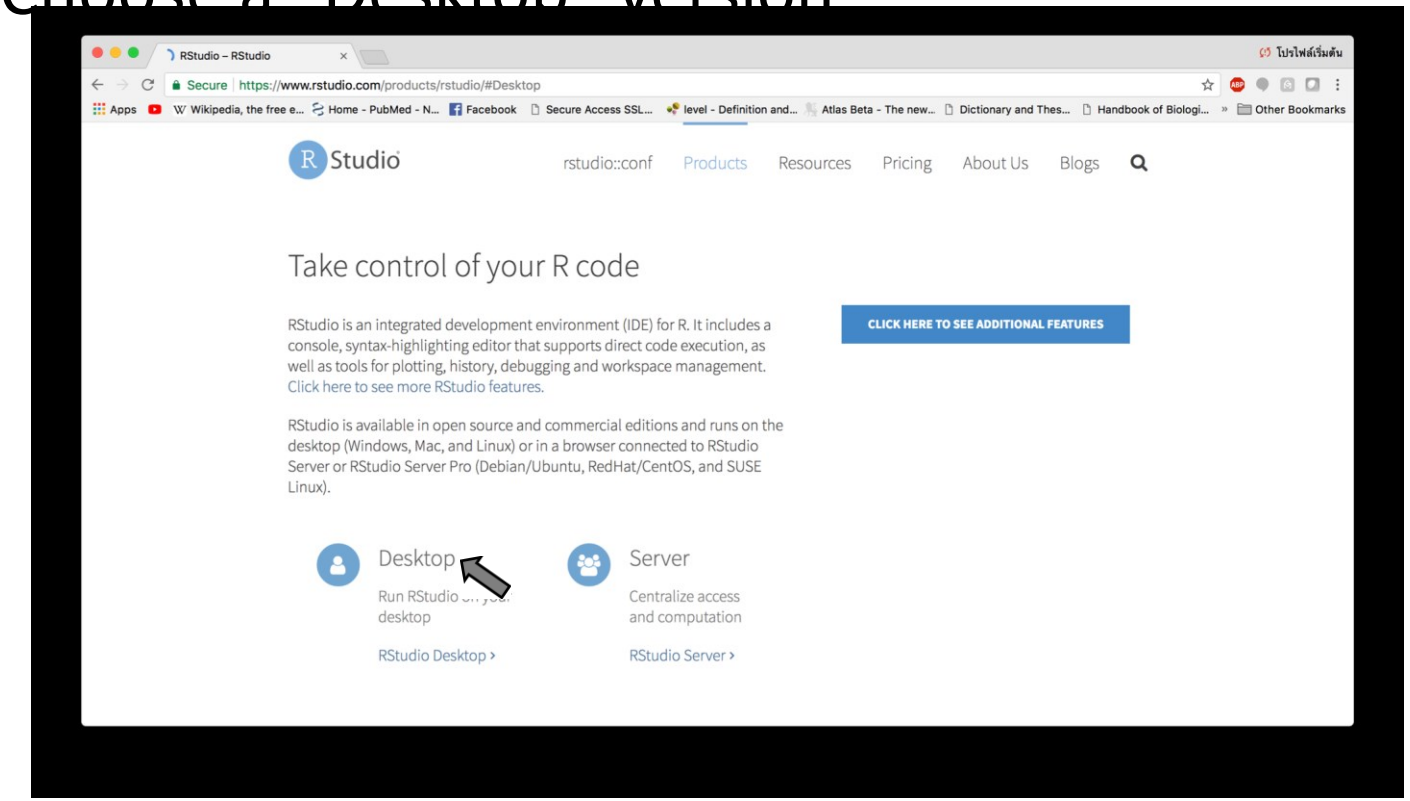


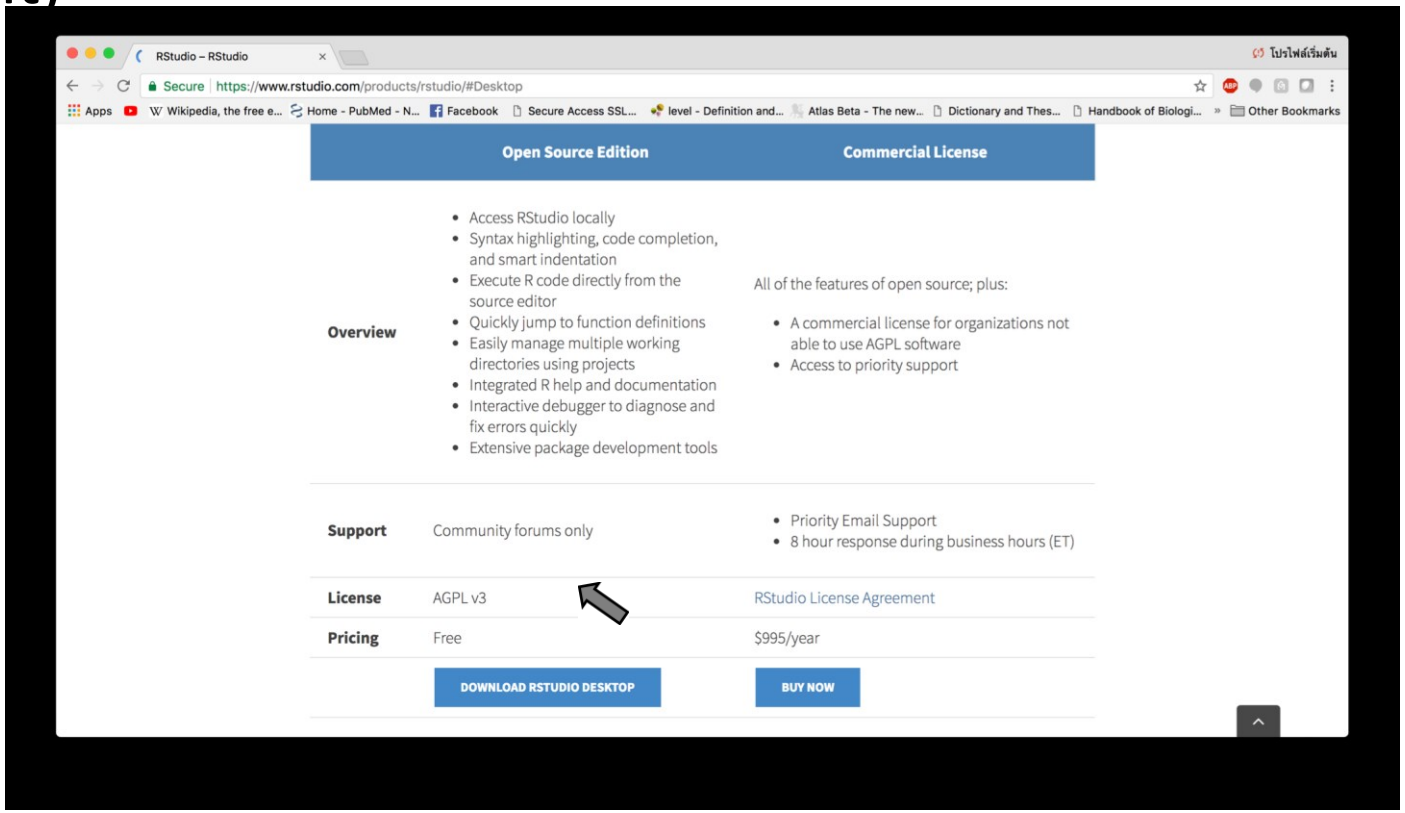
Let’s get RStudio

- Choose a “Desktop” version



Let’s get RStudio

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



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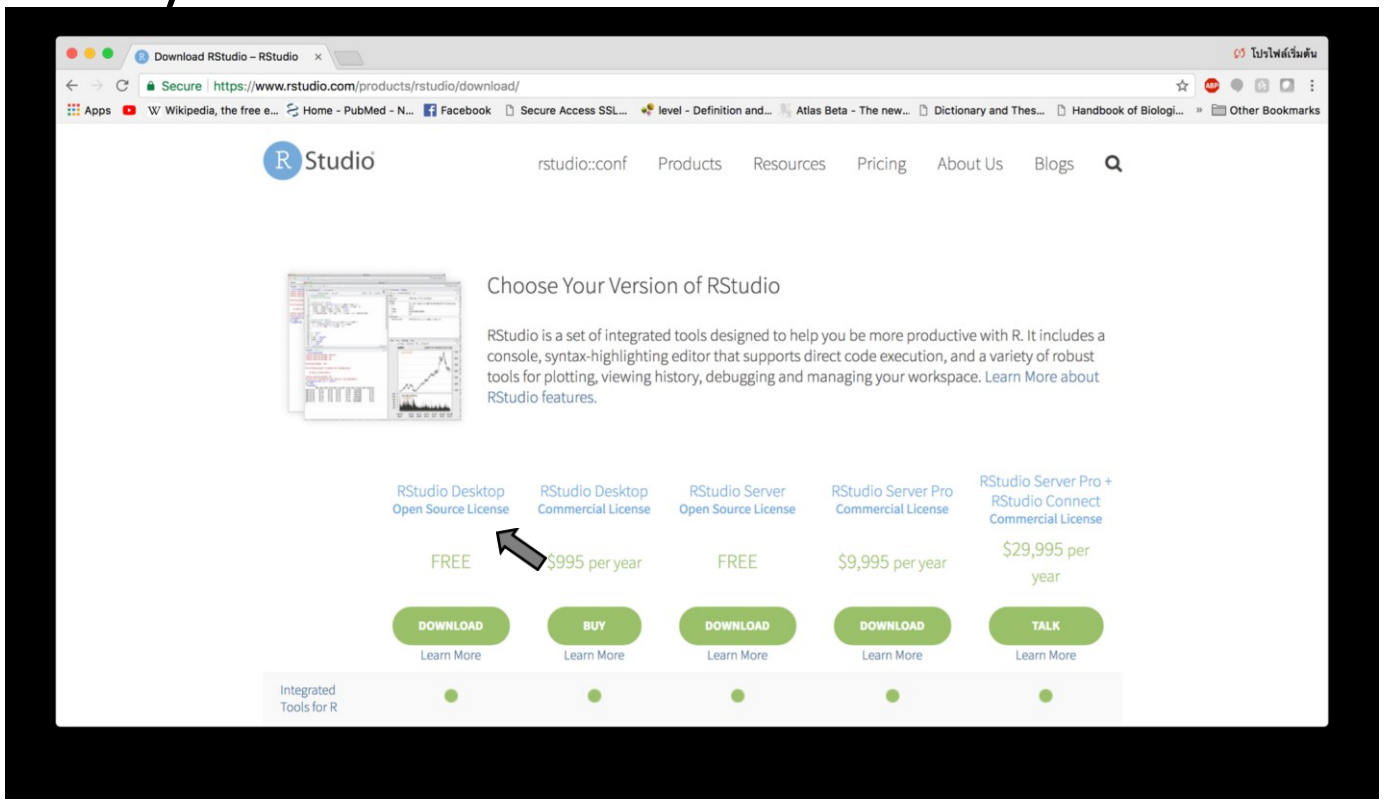
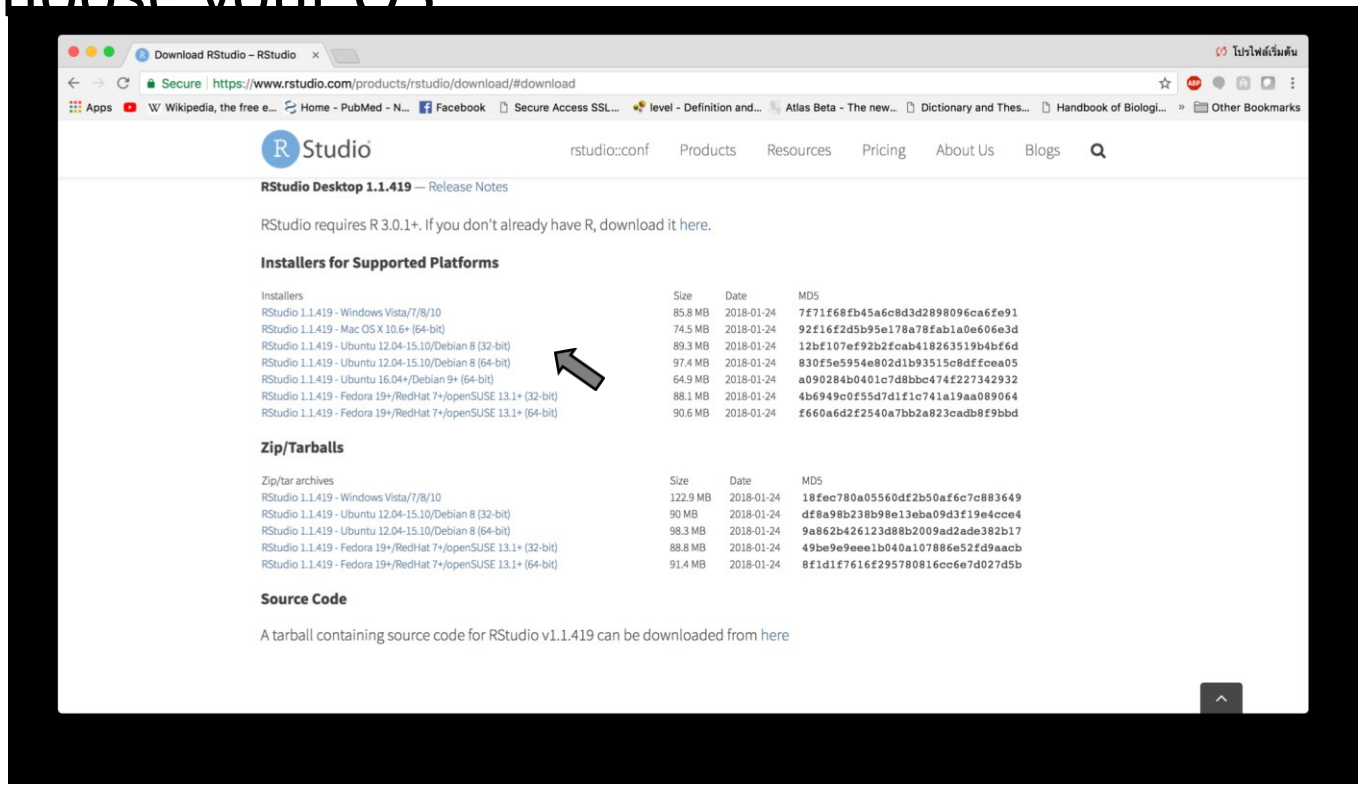
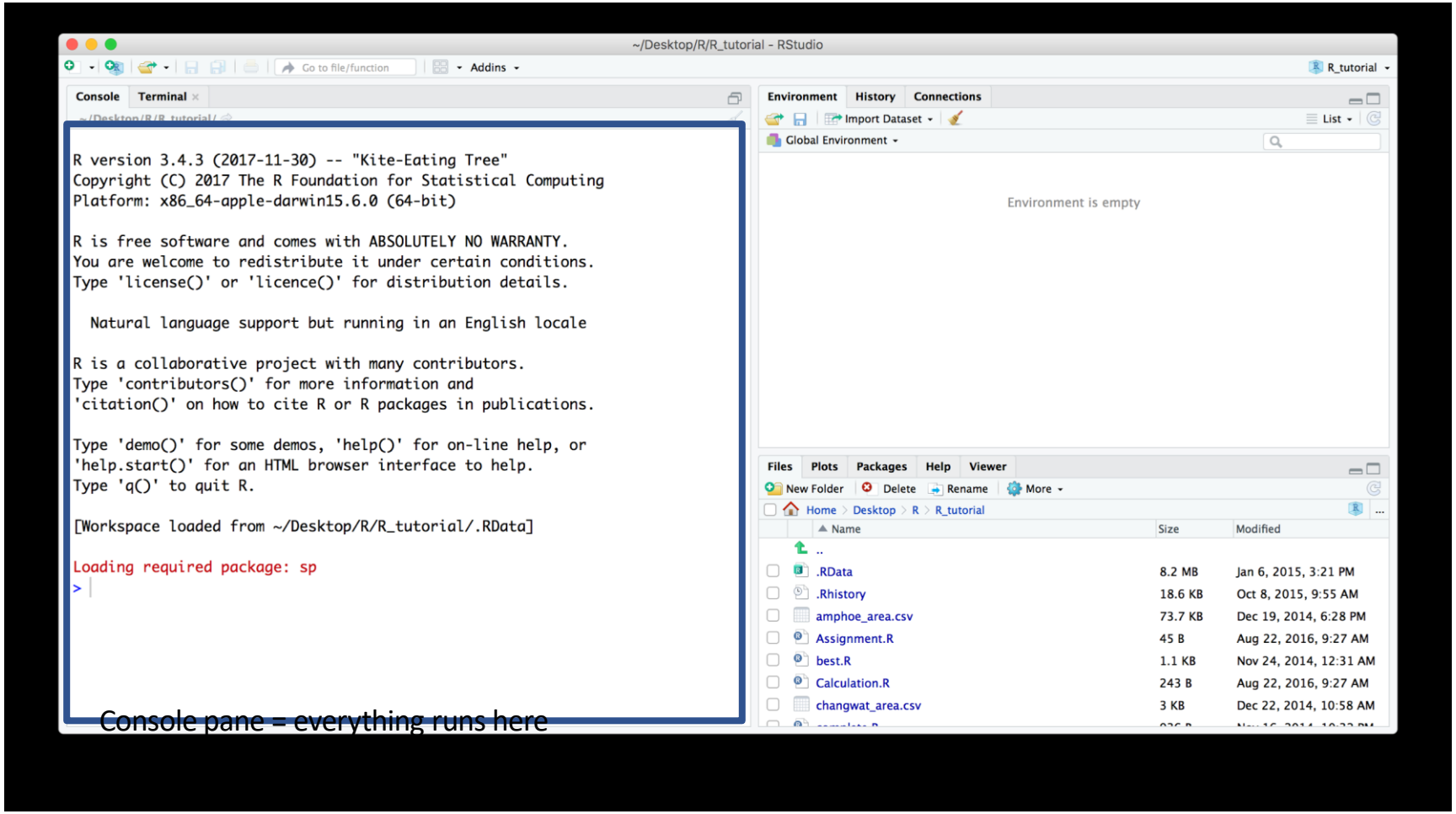


Let’s get RStudio

- Choose your OS



Panes of RStudio



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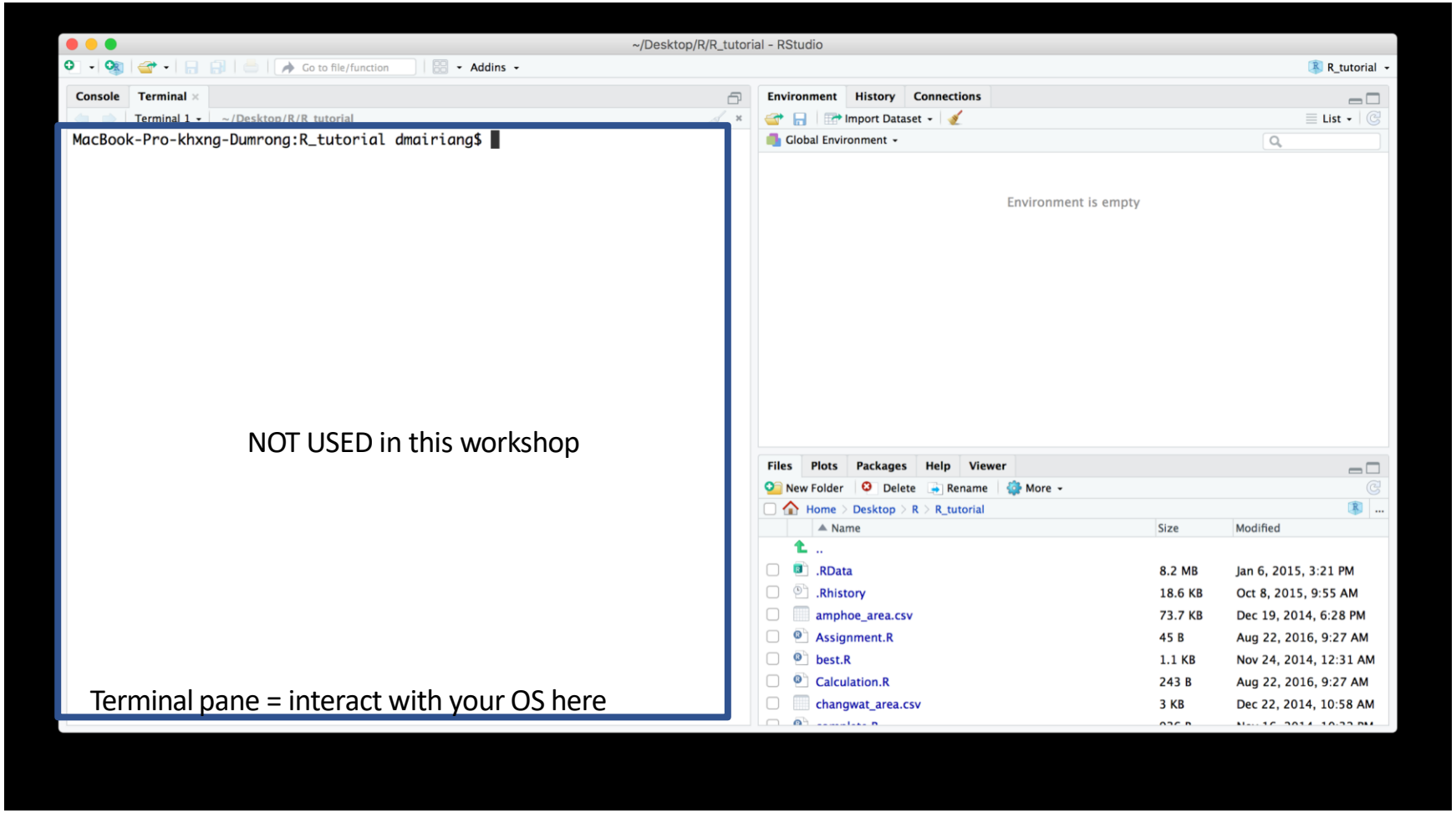

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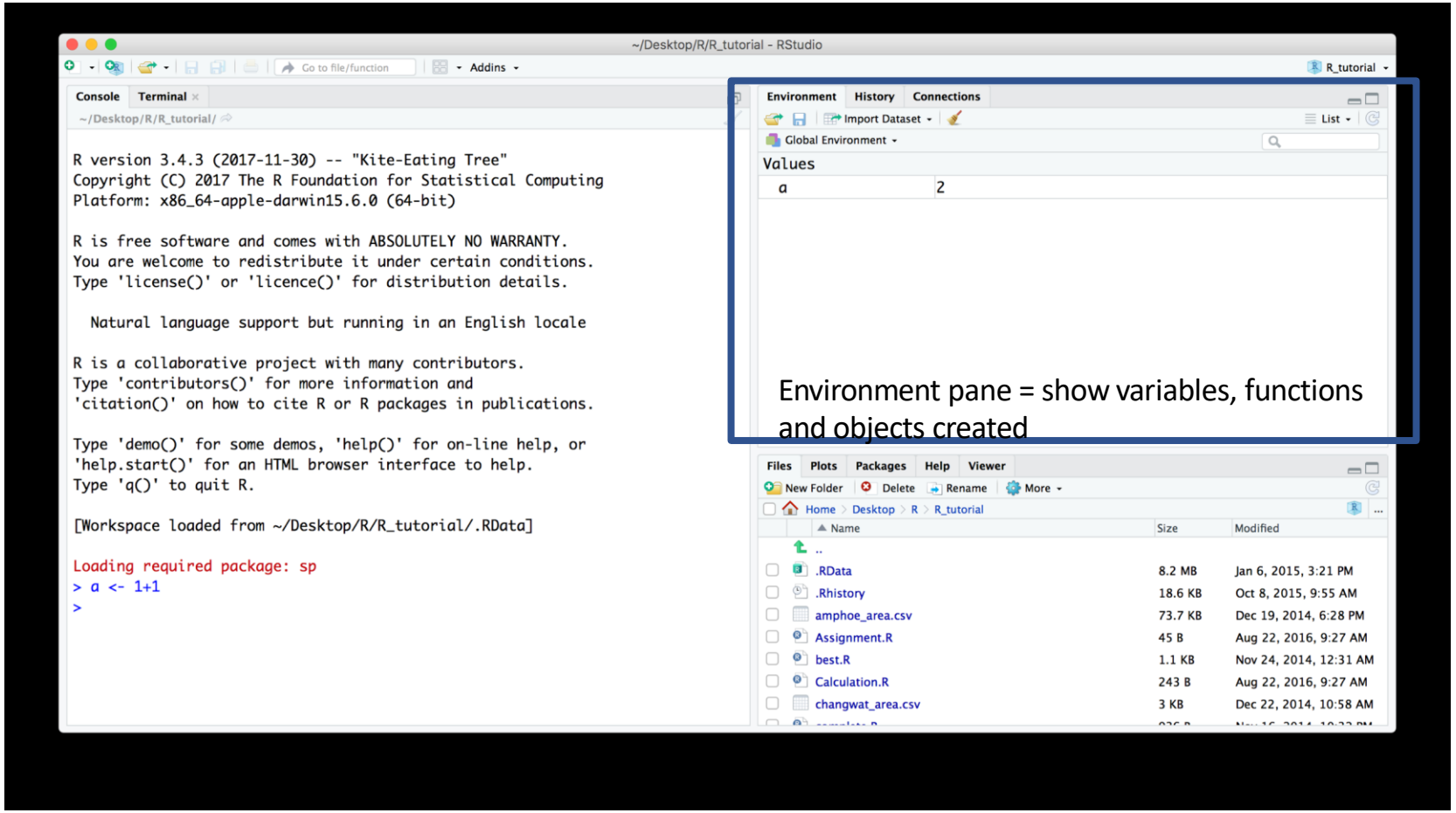
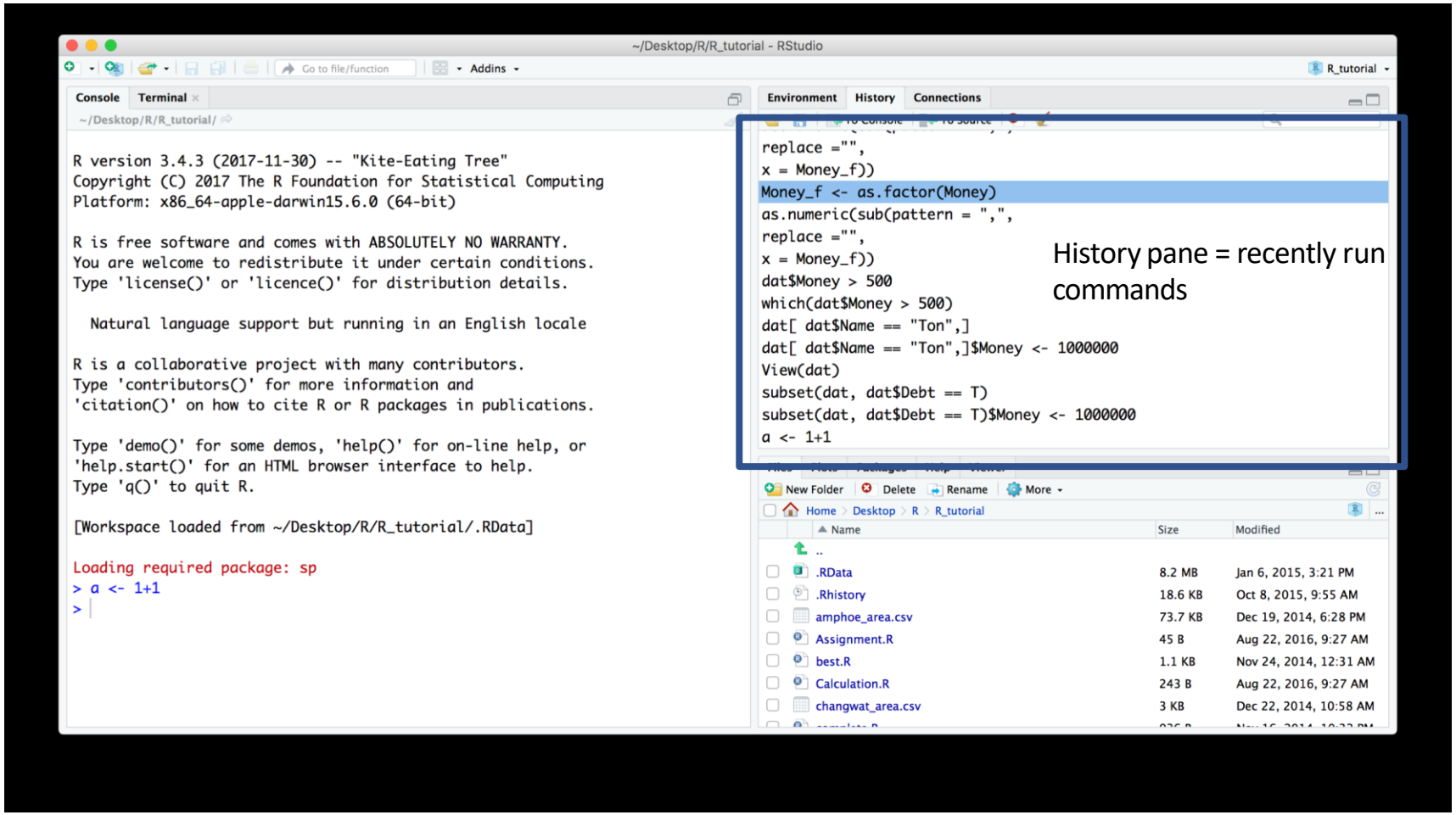
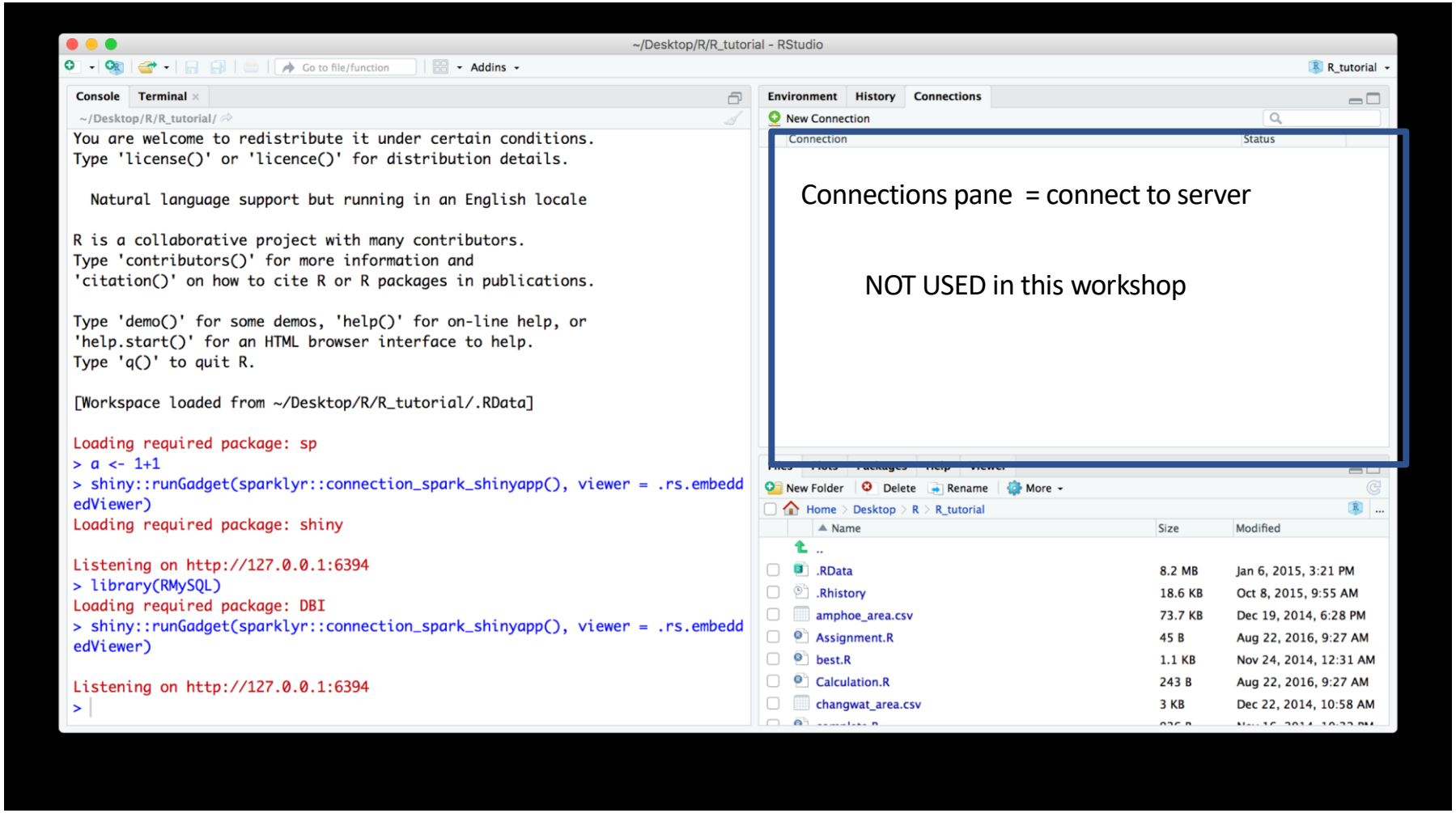


Panes of RStudio



Panes of RStudio



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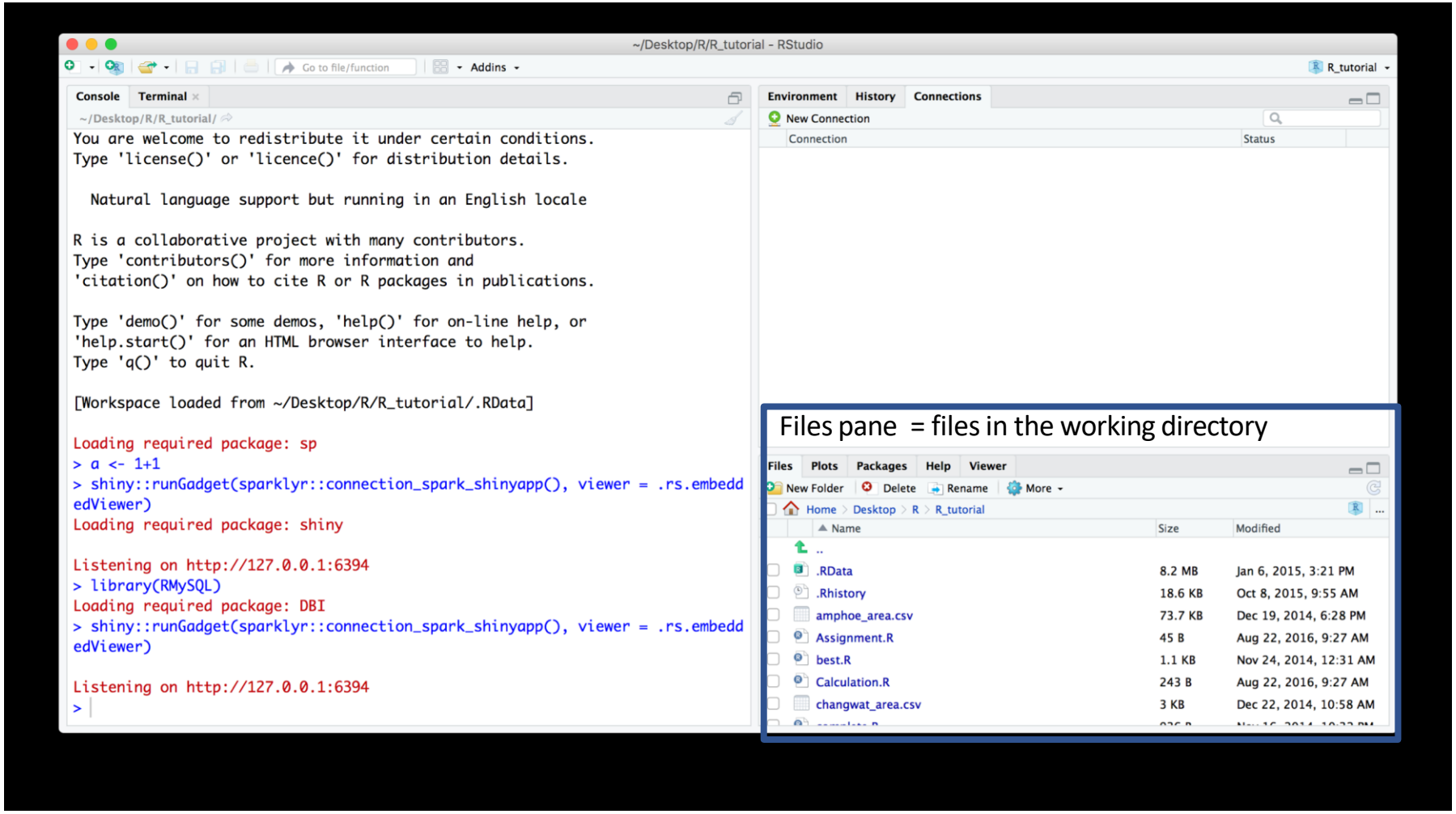
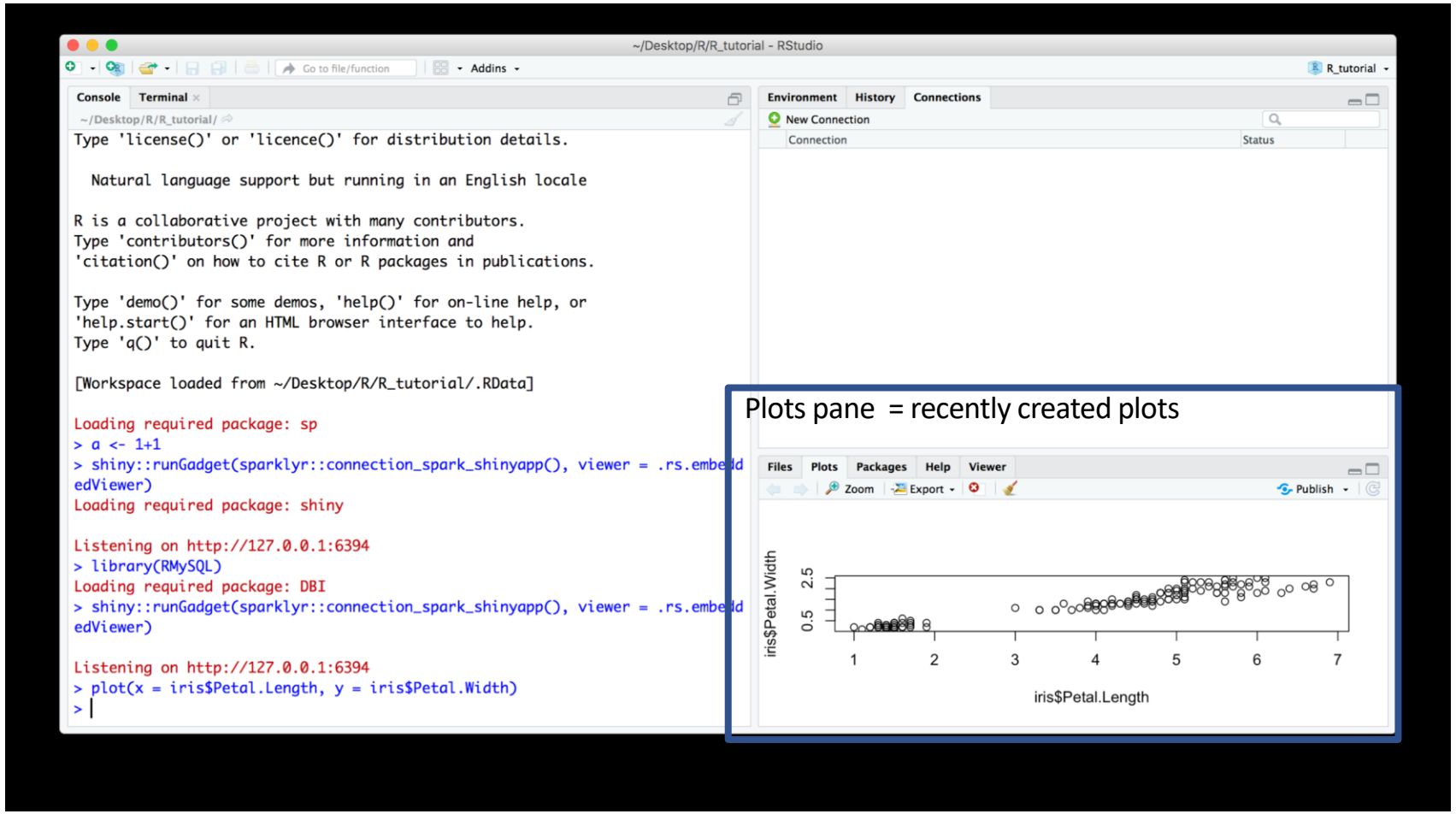
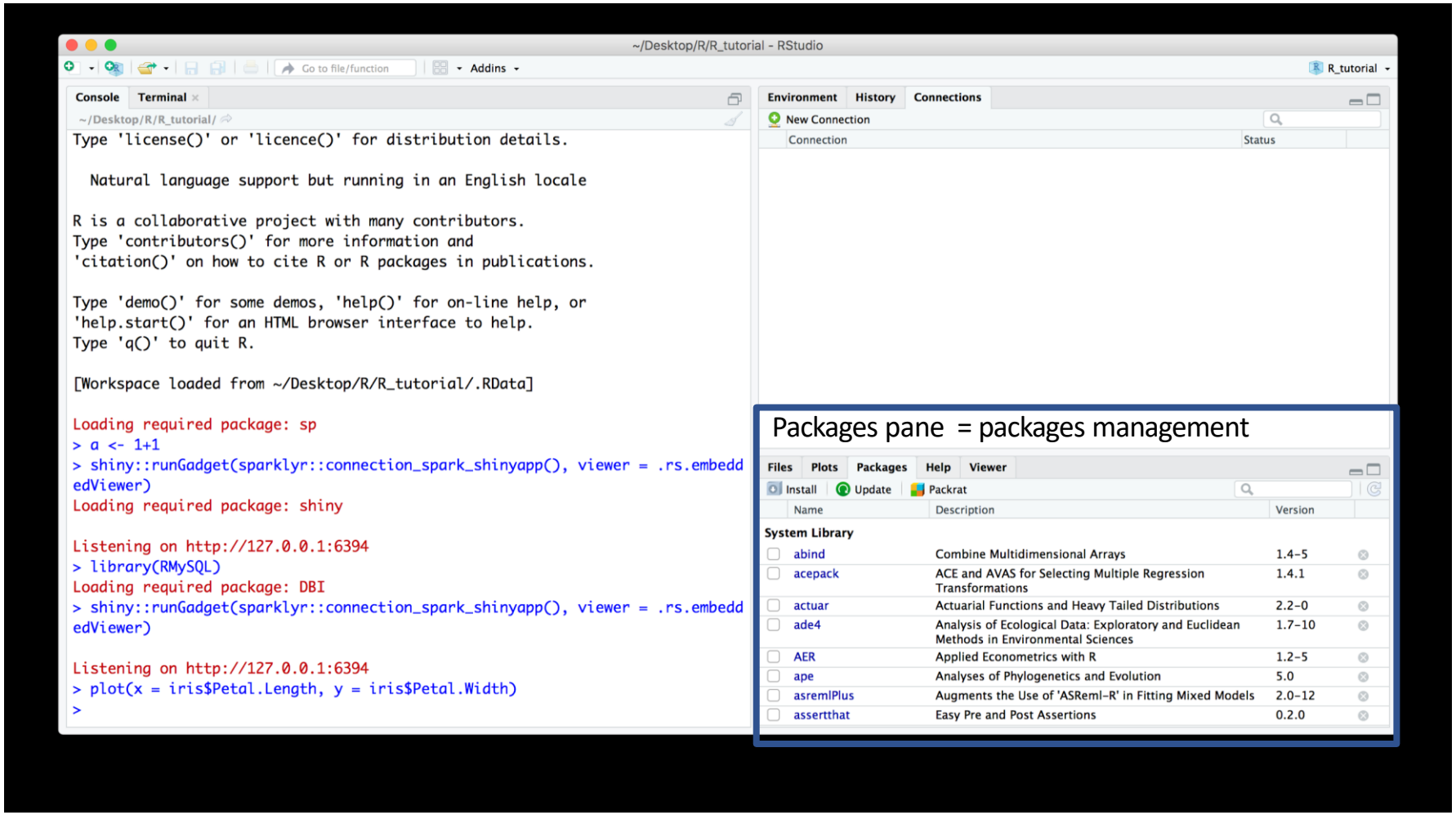


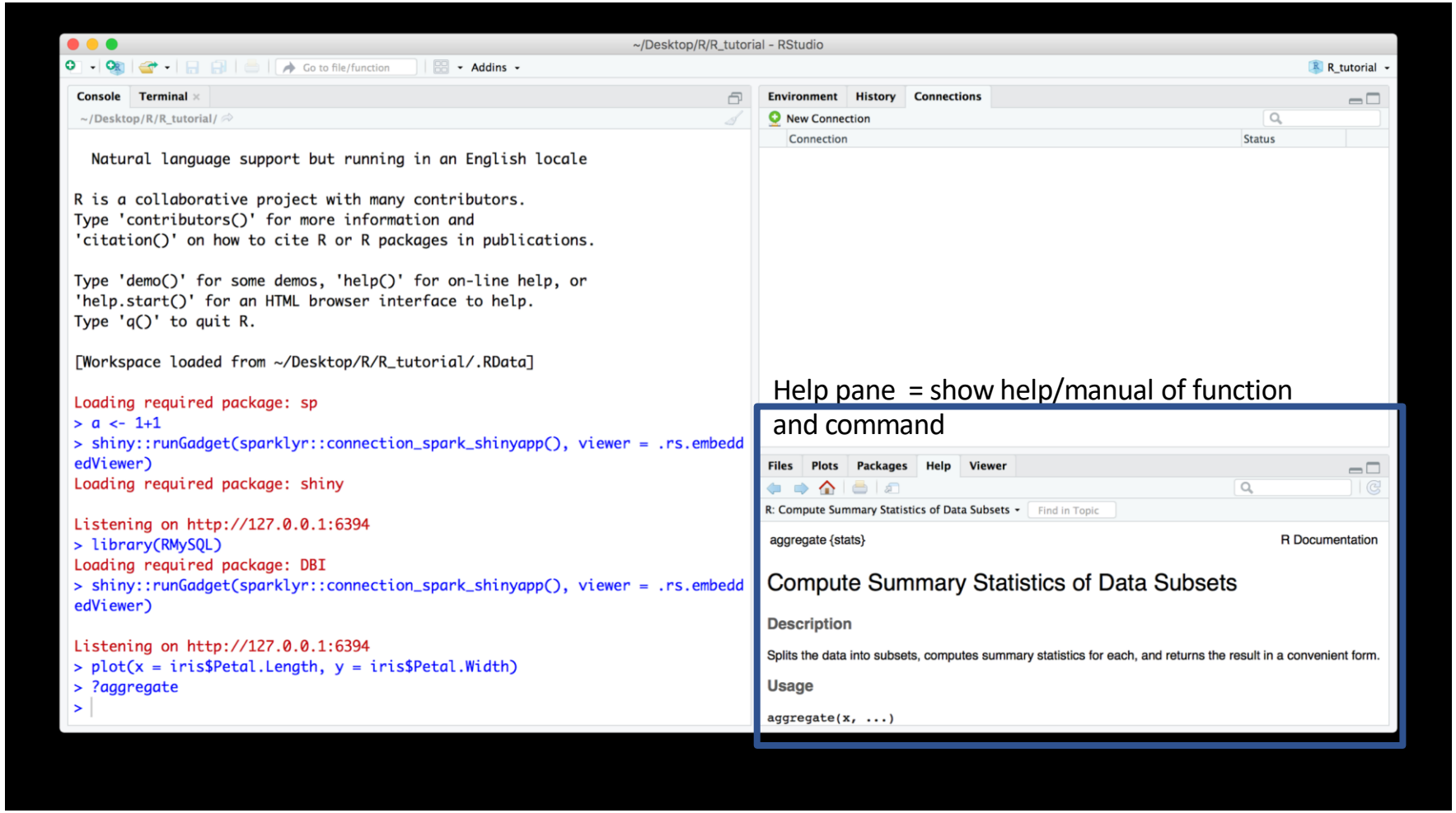
Panes of RStudio



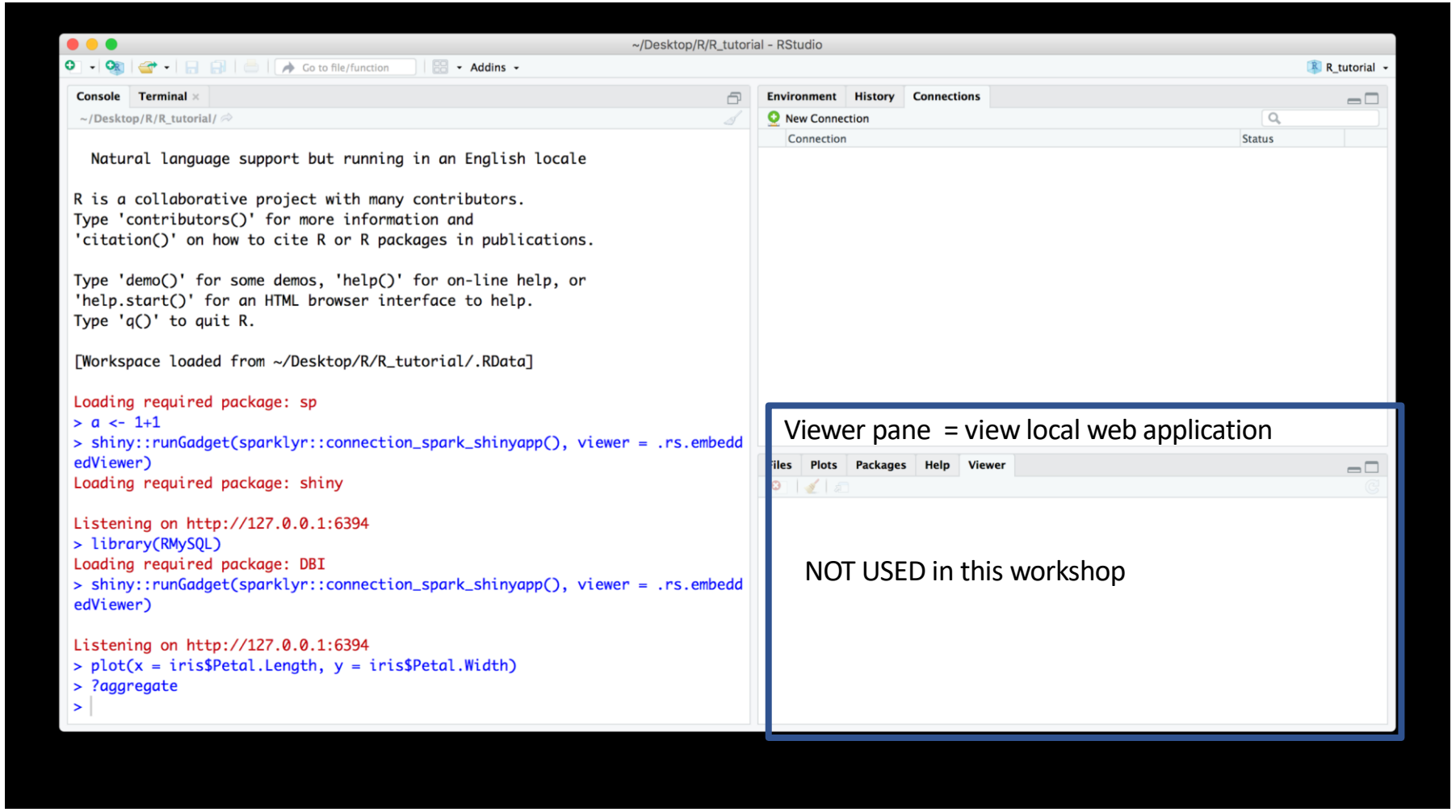
Panes of RStudio



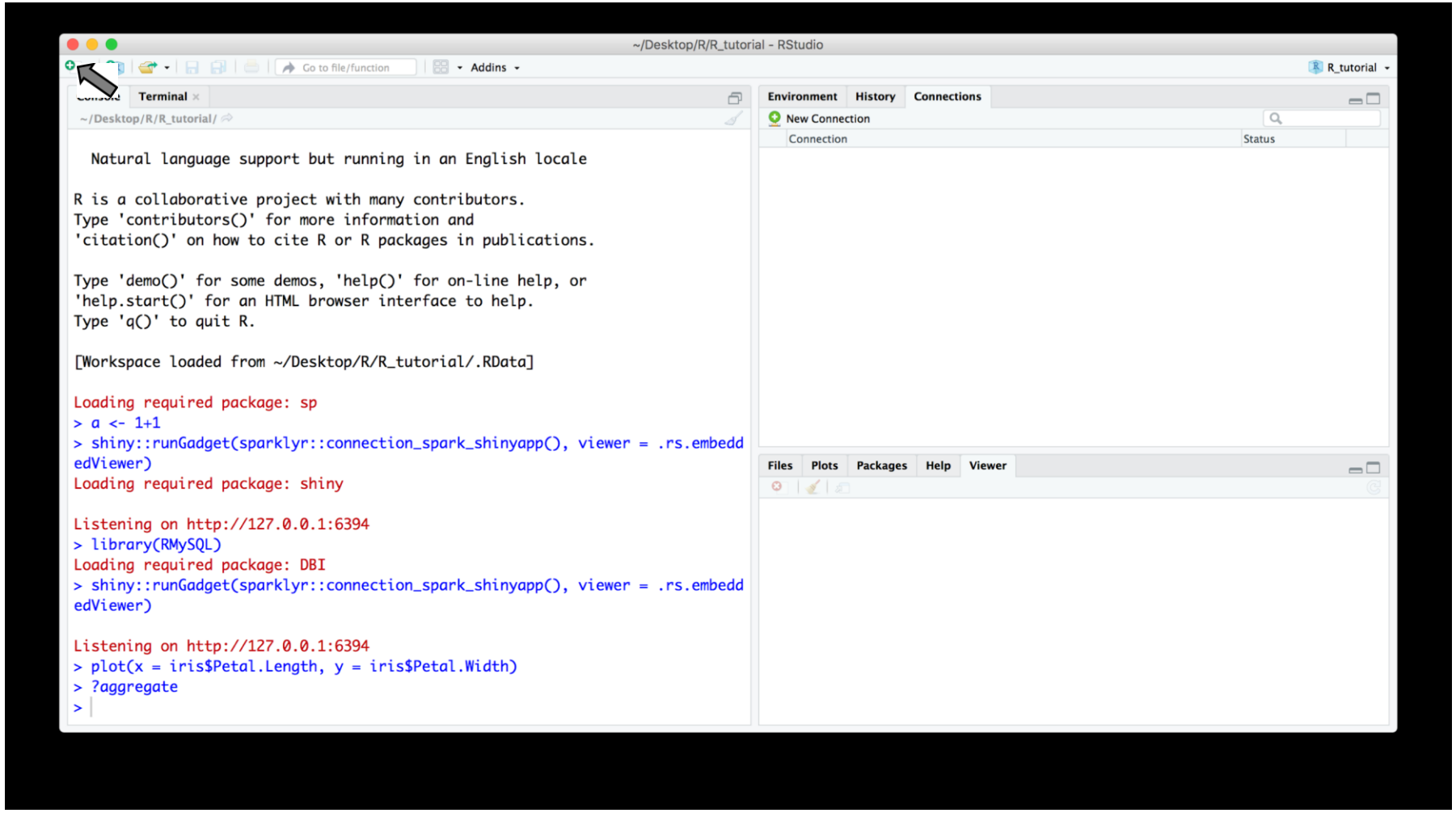
Panes of RStudio



Panes of RStudio



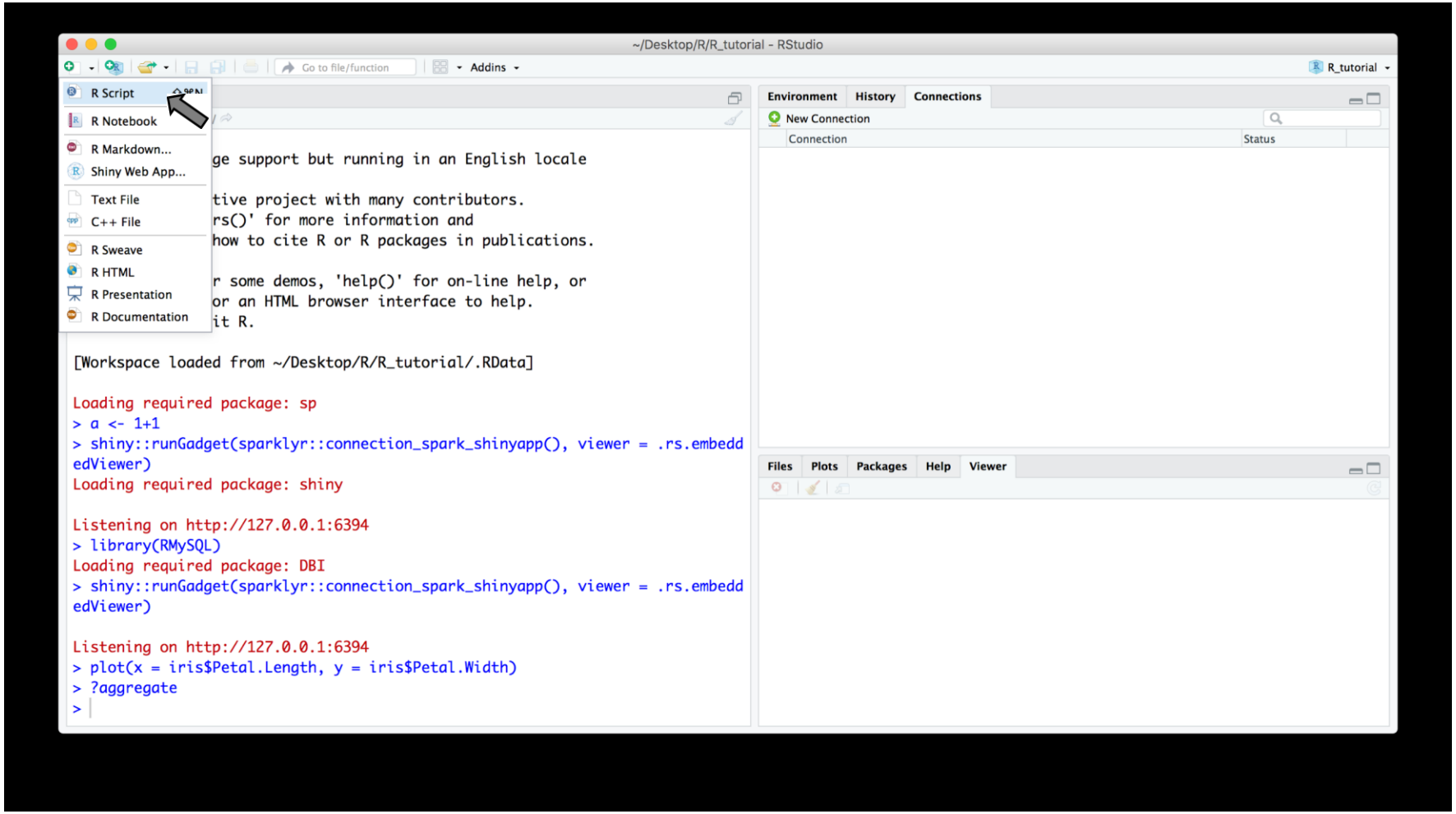
Panes of RStudio



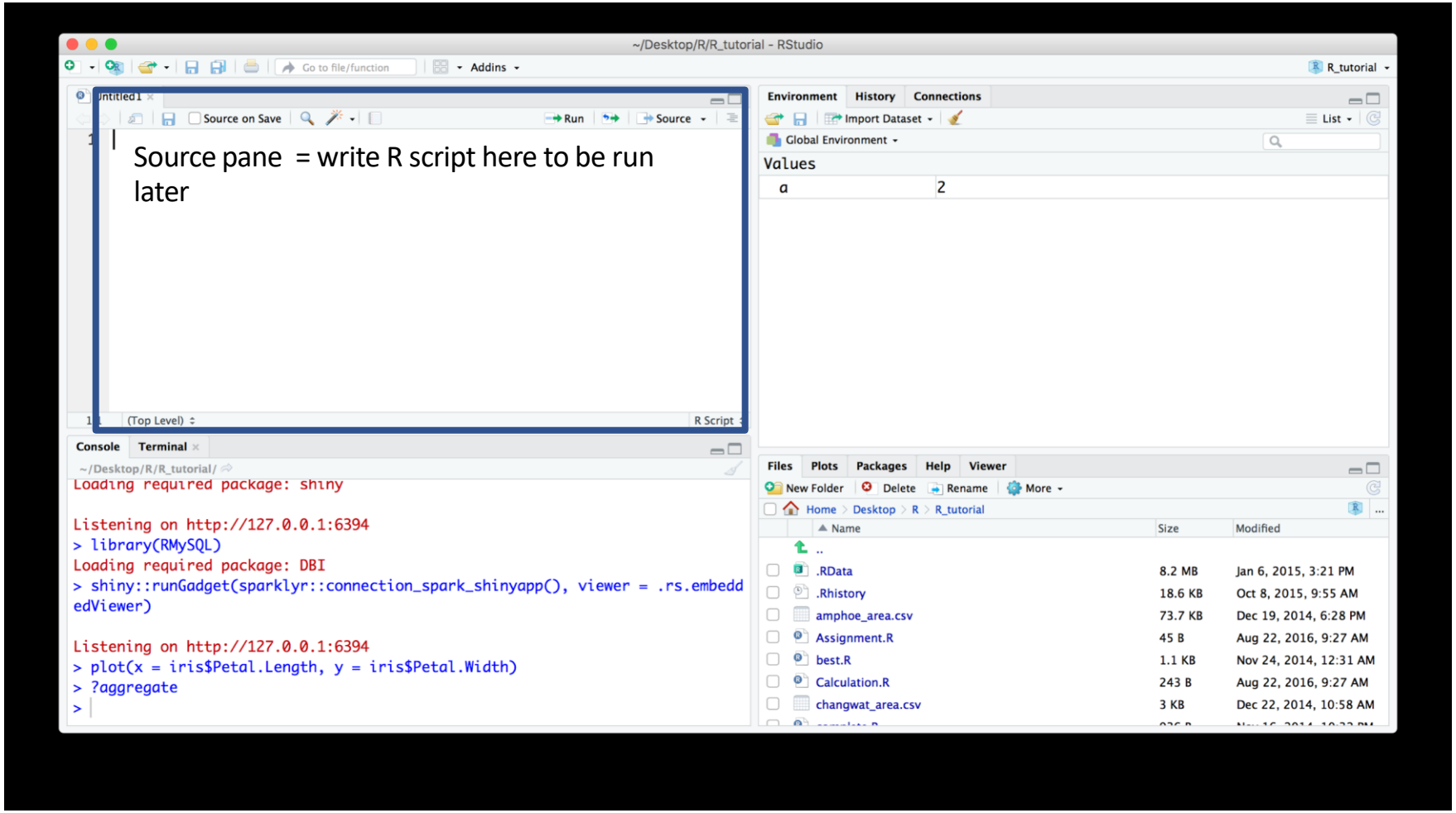
Source Panes

- 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

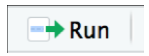


Open Source Pane

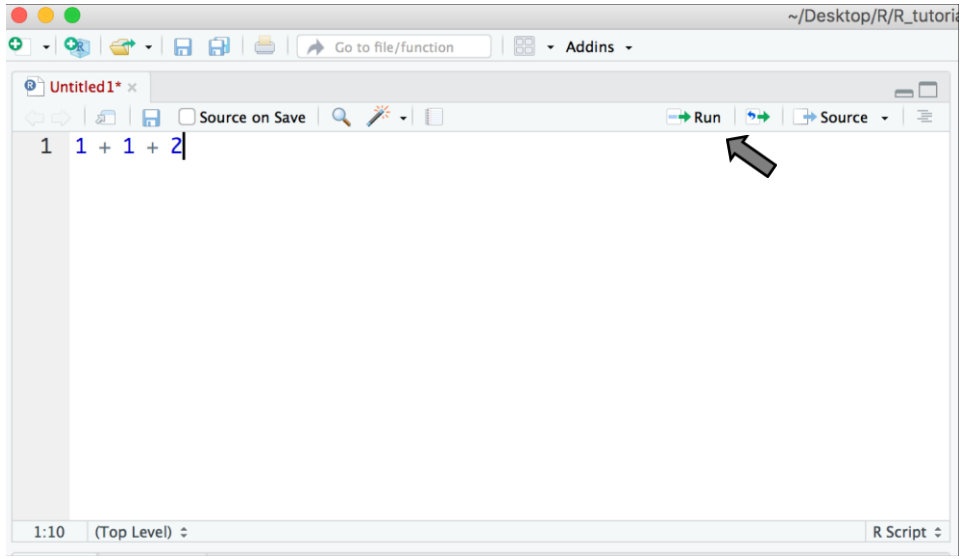


Run scripts in Source Pane

Run a single line of the script

- Leave a cursor at a line
- Click or 

- Ctrl + Enter or
- Mac: Command + Enter

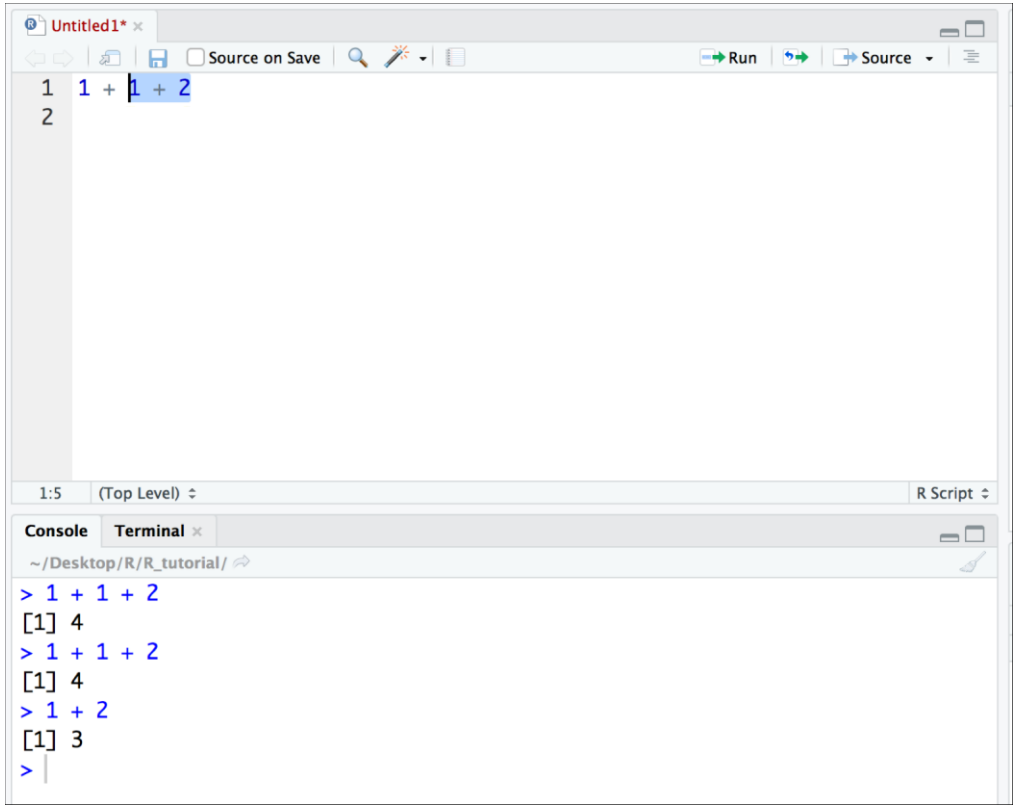


Run scripts in Source Pane

Run a part of the script

- Highlight the part
- Click or 

- Ctrl + Enter or
- Mac: Command + Enter

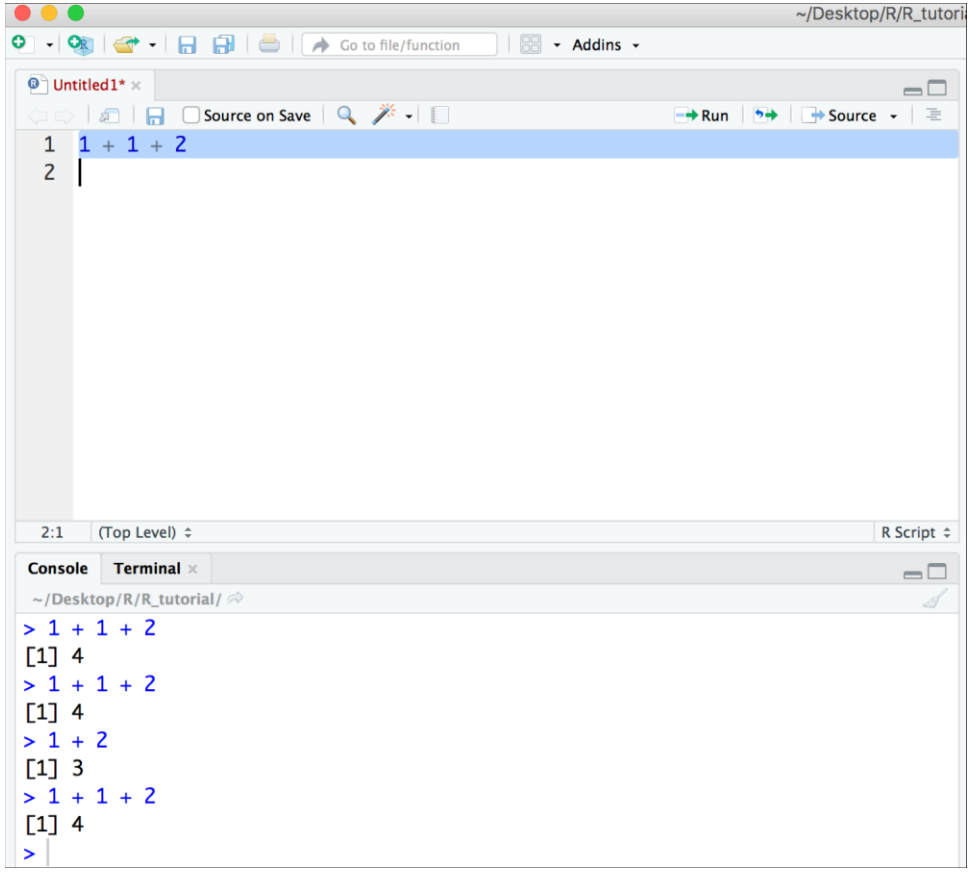


Run scripts in Source Pane

Run all lines of the script

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

- 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

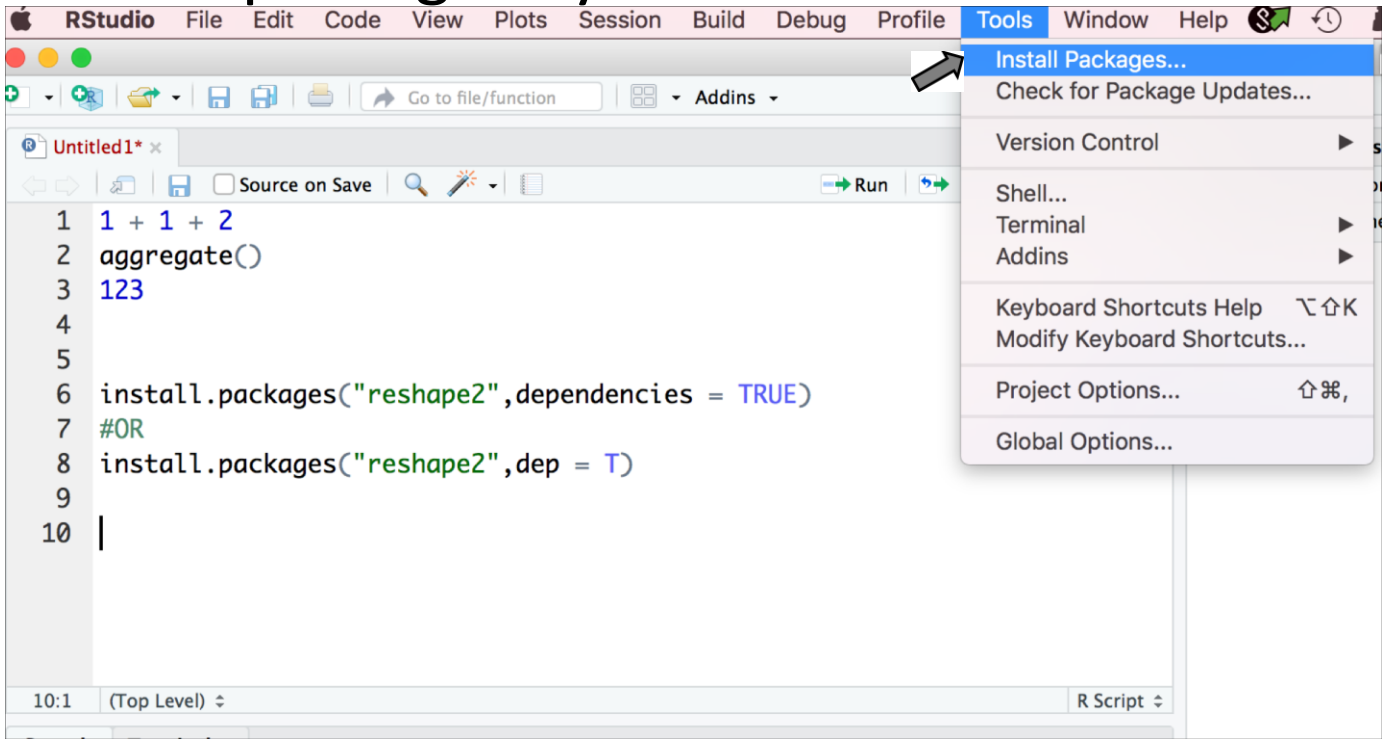
- To install packages by a command line

```
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

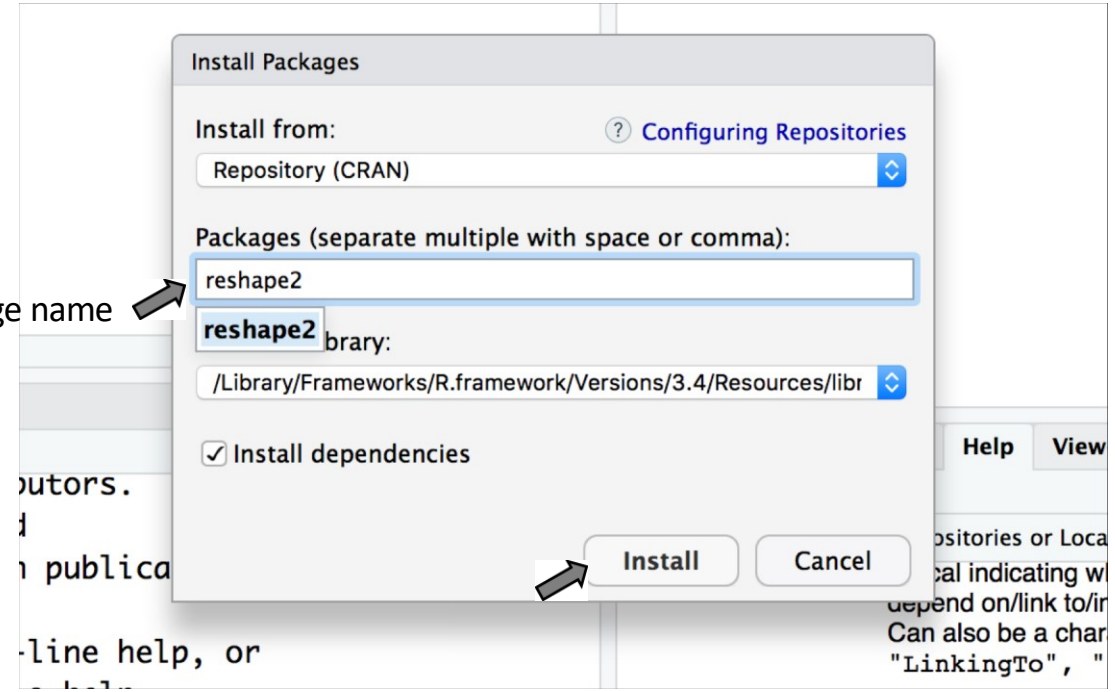
- To install packages by RStudio



Practical: Packages

- To install packages by RStudio

Type the package name

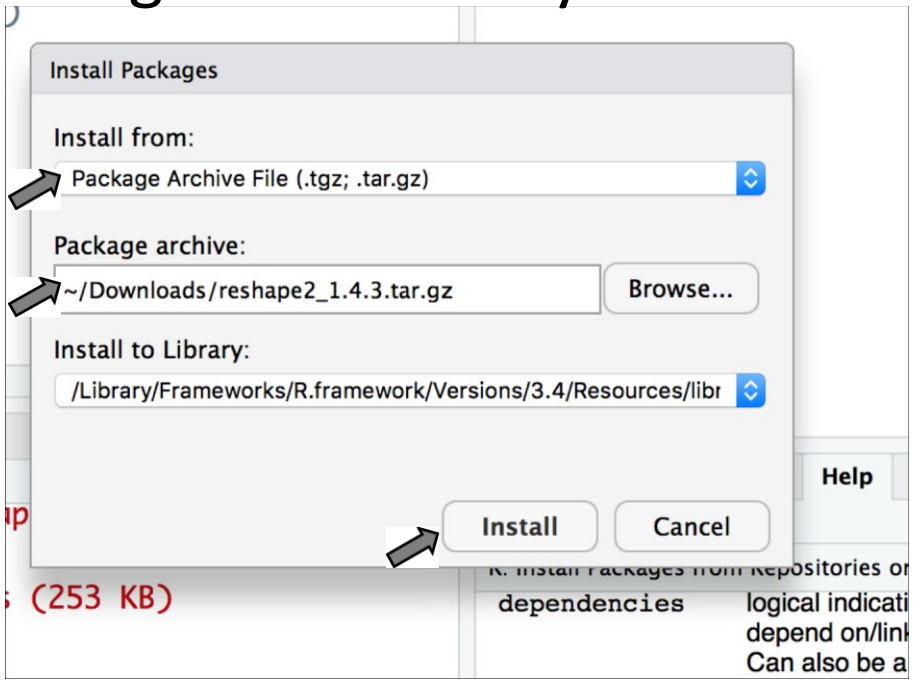


Practical: Packages

- To install packages “offline” by RStudio

Change from CRAN to File

Browse for the previously download package

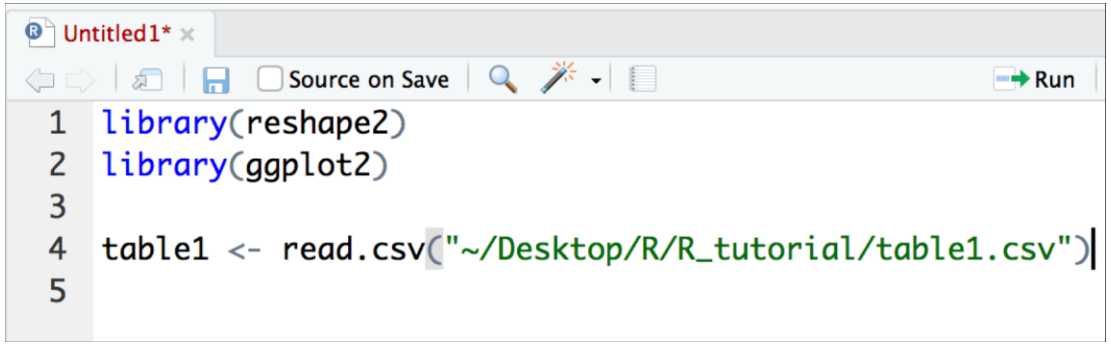


Practical: Packages

- To invoke the package

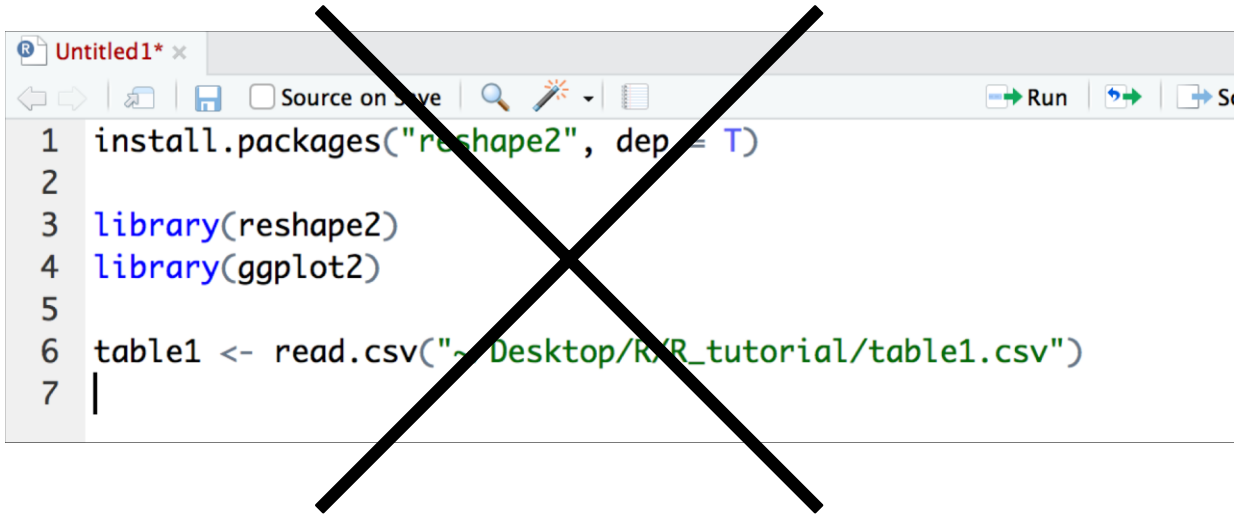
```
library(reshape2) #In your script
#OR
require(rehape2) #In the function/package
```

- 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
  - 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

```
####Basic Mathematical Operations pt 2####
log10(100) #Logarithm base 10
log(100, base = 10) #Logarithm base 10
log(100) #Natural logarithm
exp(1) #Exponential i.e. e^1
round(2.111, digits = 1) #Rounding
floor(2.111) #Round down to integer
ceiling(2.111) #Round up to integer
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

```
90  ####Types of data pt 2####
91  a <- "good"
92  class(a)
93  typeof(a)
94  af <- factor(a, levels = c("terrible","bad","neutral","good","excellent"))
95  print(af)
96  class(af)
97  typeof(af)
98  as.numeric(af) #Convert to numeric, i.e. extracting numerical elements
99  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)
```

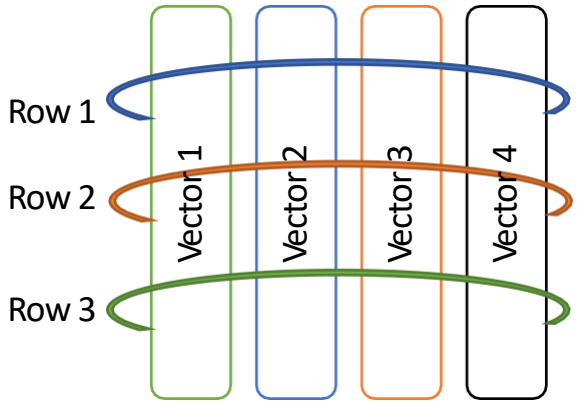
Matrix

- 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

```
192 ####If and else####
193 A <- 1 #Assign the input here
194 
195 if(!is.numeric(A)){
196   print("A is not a number")
197 }else if(A %% 2 == 0){
198   print("A is even")
199 }else if(A %% 2 == 1){
200   print("A is odd")
201 }else{
202   print("A is not an integer")
203 }
204 
205 #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

```
222 ####While loop####
223 i <- 1
224 
225 while(i < 100){ #Breaking/Exiting condition
226   print(i) #Do something here
227   i <- i + 1 #DO NOT forget to the change breaking condition!!!
228 }
```

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

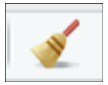
```
260 ####Help####
261 help("shapiro.test")
262 ?shapiro.test
263 ??shapiro.test
```

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

```
1 quadForm <- function(A,B,C){
2   #answer1 <- ???
3   #answer2 <- ???
4   return(c(answer1, answer2))
5 }
```