Lecture 2: Syntax, control flow, functions

October 5, 2017

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- RStudio
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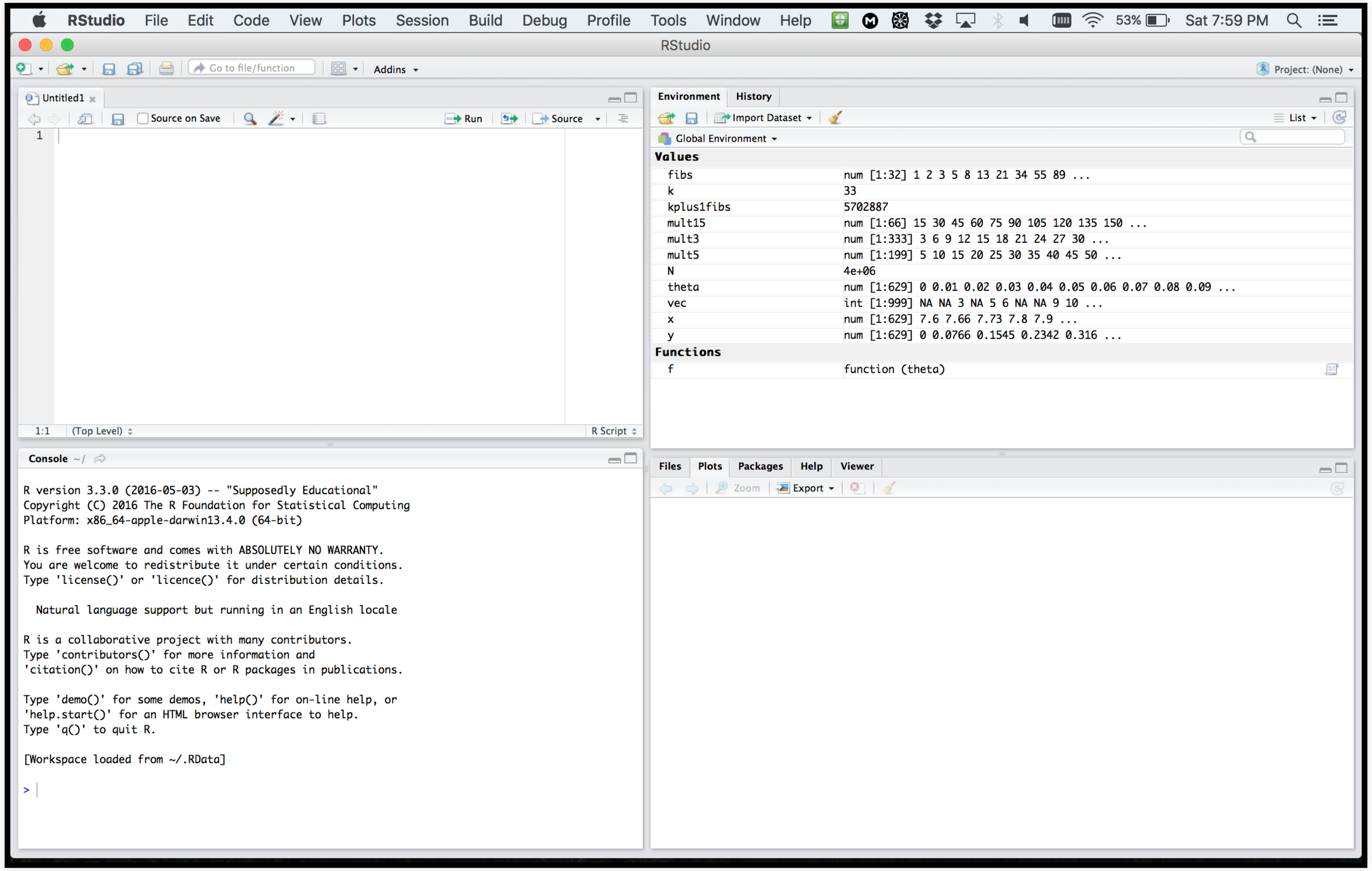
- Functions

RStudio

RStudio window



Values

fibs	num [1:32] 1 2 3 5 8 13 21 34 55 89 ...
k	33
kplus1fibs	5702887
mult15	num [1:66] 15 30 45 60 75 90 105 120 135 150 ...
mult3	num [1:333] 3 6 9 12 15 18 21 24 27 30 ...
mult5	num [1:199] 5 10 15 20 25 30 35 40 45 50 ...
N	4e+06
theta	num [1:629] 0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 ...
vec	int [1:999] NA NA 3 NA 5 6 NA NA 9 10 ...
x	num [1:629] 7.6 7.66 7.73 7.8 7.9 ...
y	num [1:629] 0 0.0766 0.1545 0.2342 0.316 ...

Functions

f	function (theta)

```
R version 3.3.0 (2016-05-03) -- "Supposedly Educational"
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Platform: x86_64-apple-darwin13.4.0 (64-bit)

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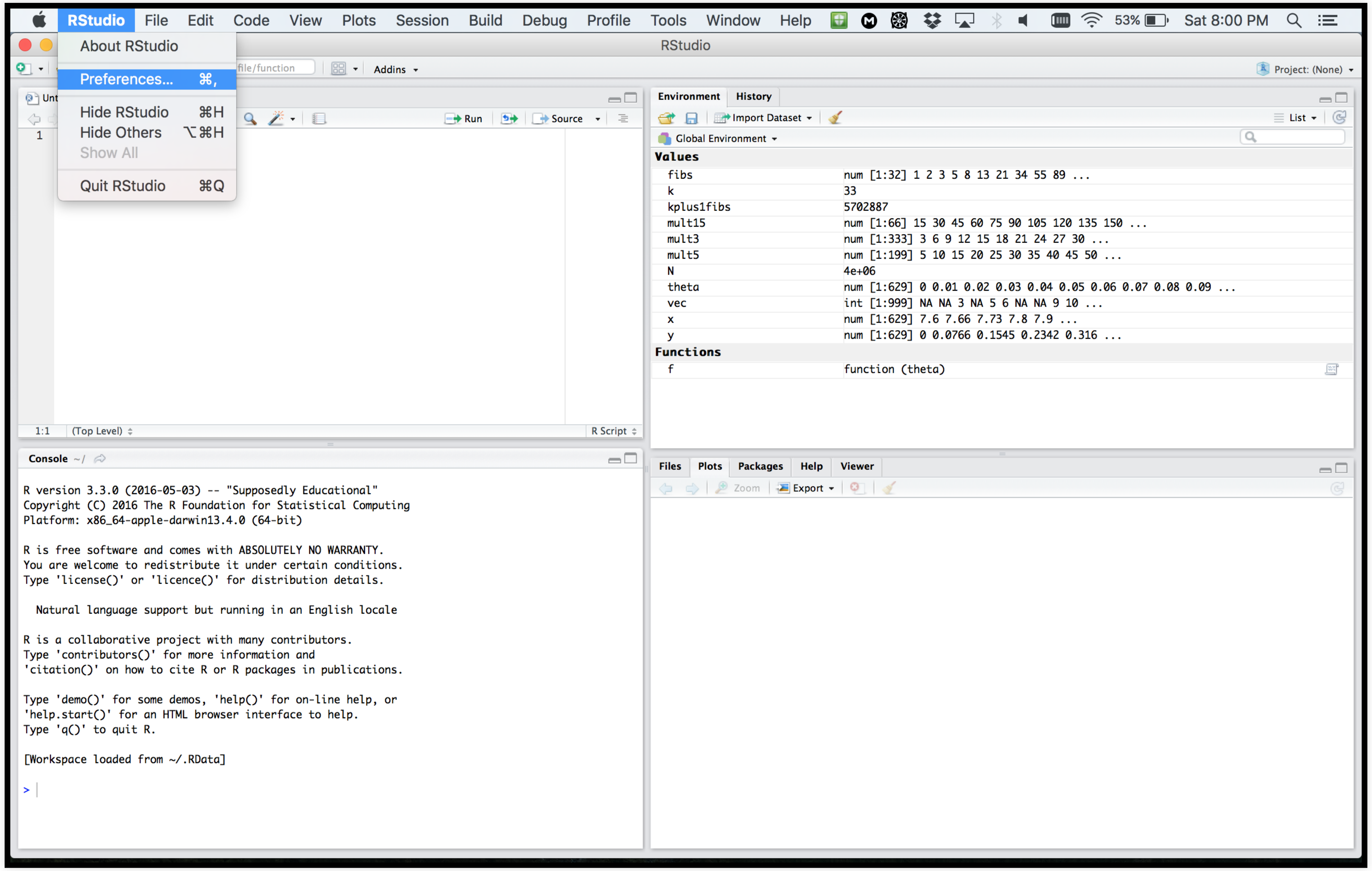
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Workspace loaded from ~/.RData]

>
```

RStudio preferences



```
Values
fibs          num [1:32] 1 2 3 5 8 13 21 34 55 89 ...
k             33
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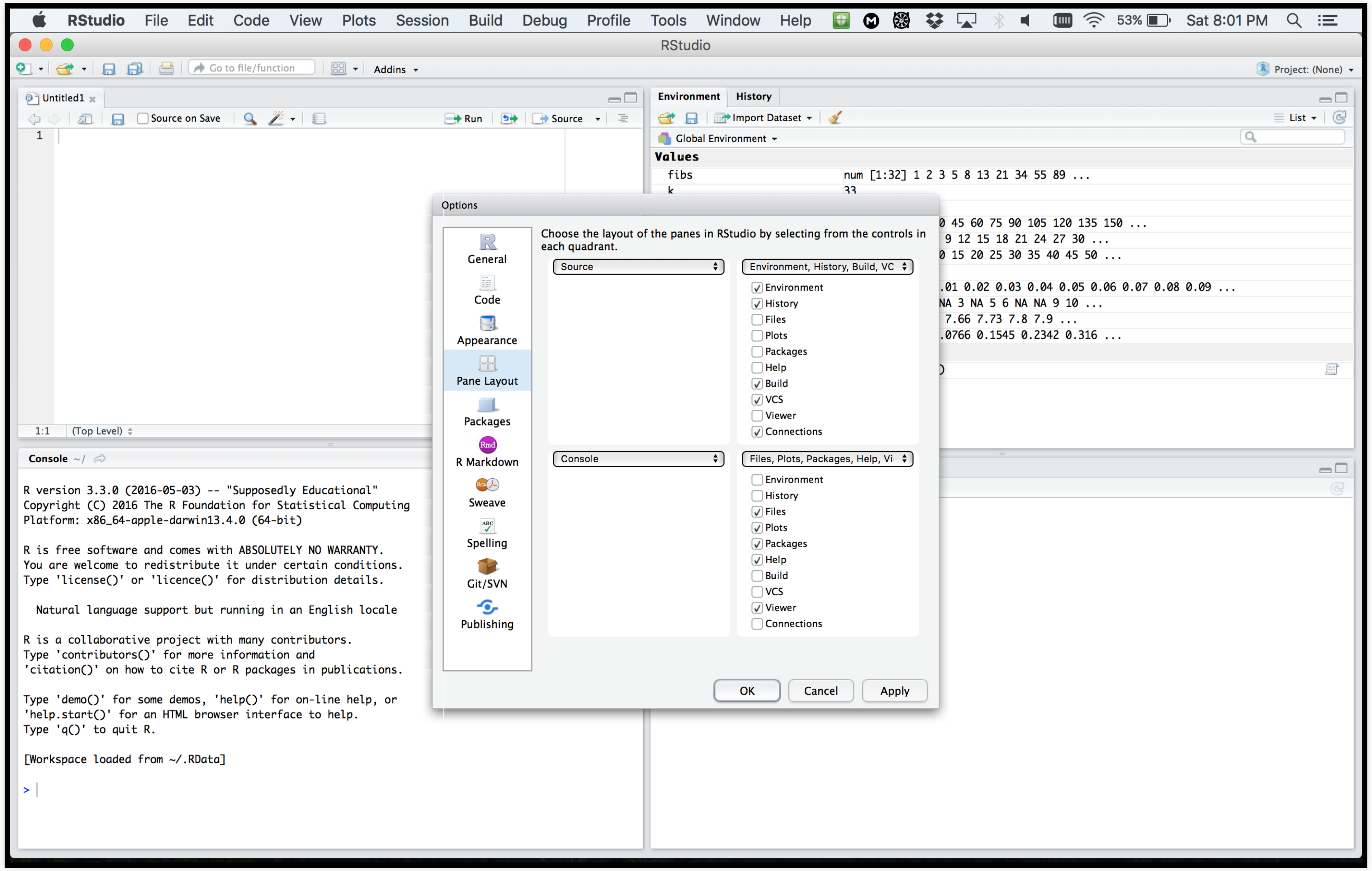
[Workspace loaded from ~/.RData]

>
```

RStudio layout



```
Values
  fibs                 num [1:32] 1 2 3 5 8 13 21 34 55 89 ...
  k                    33
                       0 45 60 75 90 105 120 135 150 ...
                        9 12 15 18 21 24 27 30 ...
                       0 15 20 25 30 35 40 45 50 ...
                       .01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 ...
                       NA 3 NA 5 6 NA NA 9 10 ...
                        7.66 7.73 7.8 7.9 ...
                       .0766 0.1545 0.2342 0.316 ...
```

Choose the layout of the panes in RStudio by selecting from the controls in each quadrant.

Source

Environment, History, Build, VC

- ☑ Environment
- ☑ History
- ☐ Files
- ☐ Plots
- ☐ Packages
- ☐ Help
- ☑ Build
- ☑ VCS
- ☐ Viewer
- ☑ Connections

Console

Files, Plots, Packages, Help, Vi

- ☐ Environment
- ☐ History
- ☑ Files
- ☑ Plots
- ☑ Packages
- ☑ Help
- ☐ Build
- ☐ VCS
- ☑ Viewer
- ☐ Connections

```
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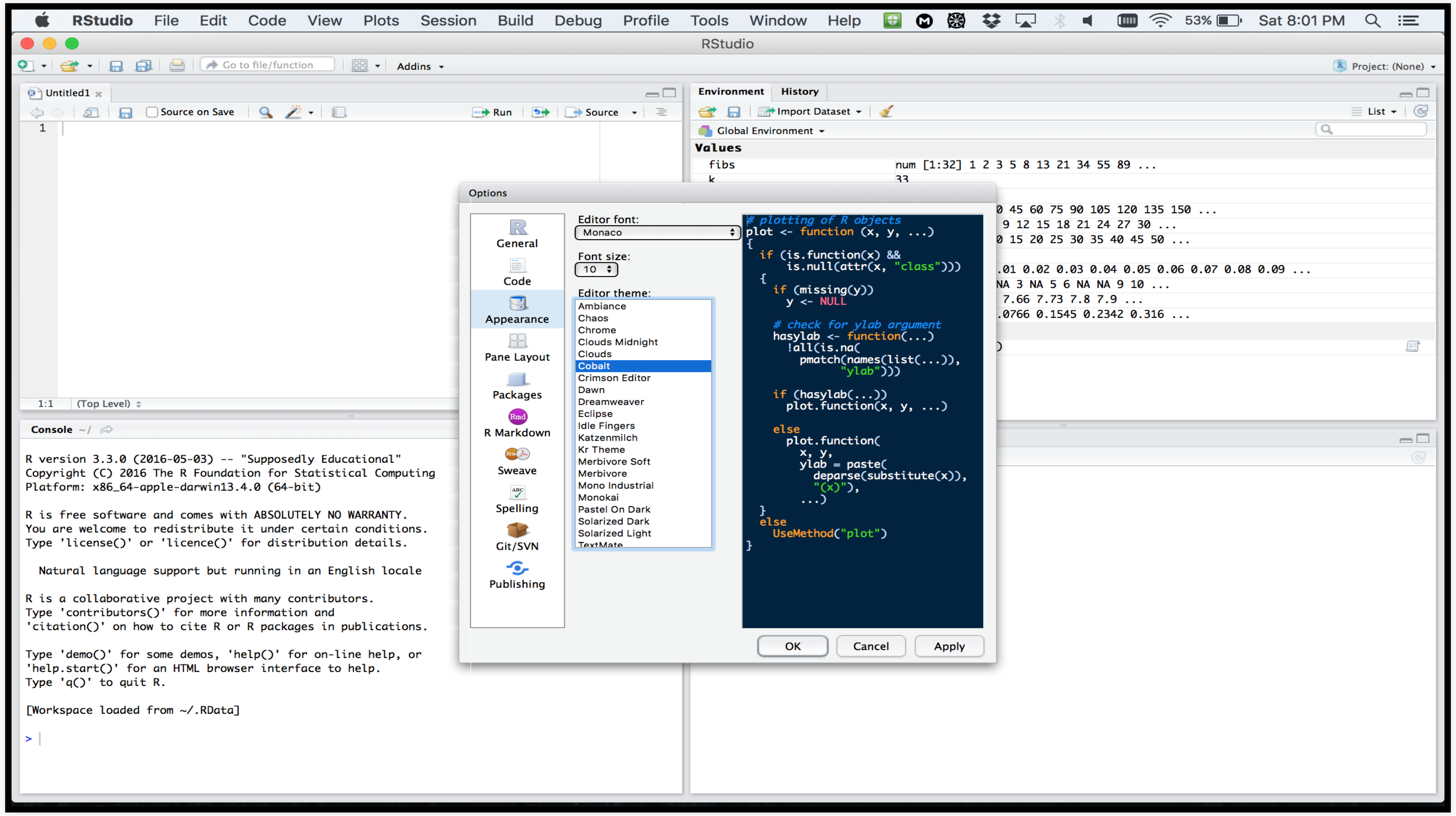
[Workspace loaded from ~/.RData]

> 
```

RStudio apprearance



Editor font: Monaco

Font size: 10

Editor theme: Ambiance, Chaos, Chrome, Clouds Midnight, Clouds, **Cobalt**, Crimson Editor, Dawn, Dreamweaver, Eclipse, Idle Fingers, Katzenmilch, Kr Theme, Merbivore Soft, Merbivore, Mono Industrial, Monokai, Pastel On Dark, Solarized Dark, Solarized Light, TextMate

```
# plotting of R objects
plot <- function (x, y, ...)
{
  if (is.function(x) &&
      is.null(attr(x, "class")))
  {
    if (missing(y))
      y <- NULL

    # check for ylab argument
    hasylab <- function(...)
      !all(is.na(
        pmatch(names(list(...)),
               "ylab")))

    if (hasylab(...))
      plot.function(x, y, ...)

    else
      plot.function(
        x, y,
        ylab = paste(
          deparse(substitute(x)),
          "(x)"),
        ...)
  }
  else
    UseMethod("plot")
}
```

```
Values
  fibs                 num [1:32] 1 2 3 5 8 13 21 34 55 89 ...
  k                    33
0 45 60 75 90 105 120 135 150 ...
 9 12 15 18 21 24 27 30 ...
0 15 20 25 30 35 40 45 50 ...
.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 ...
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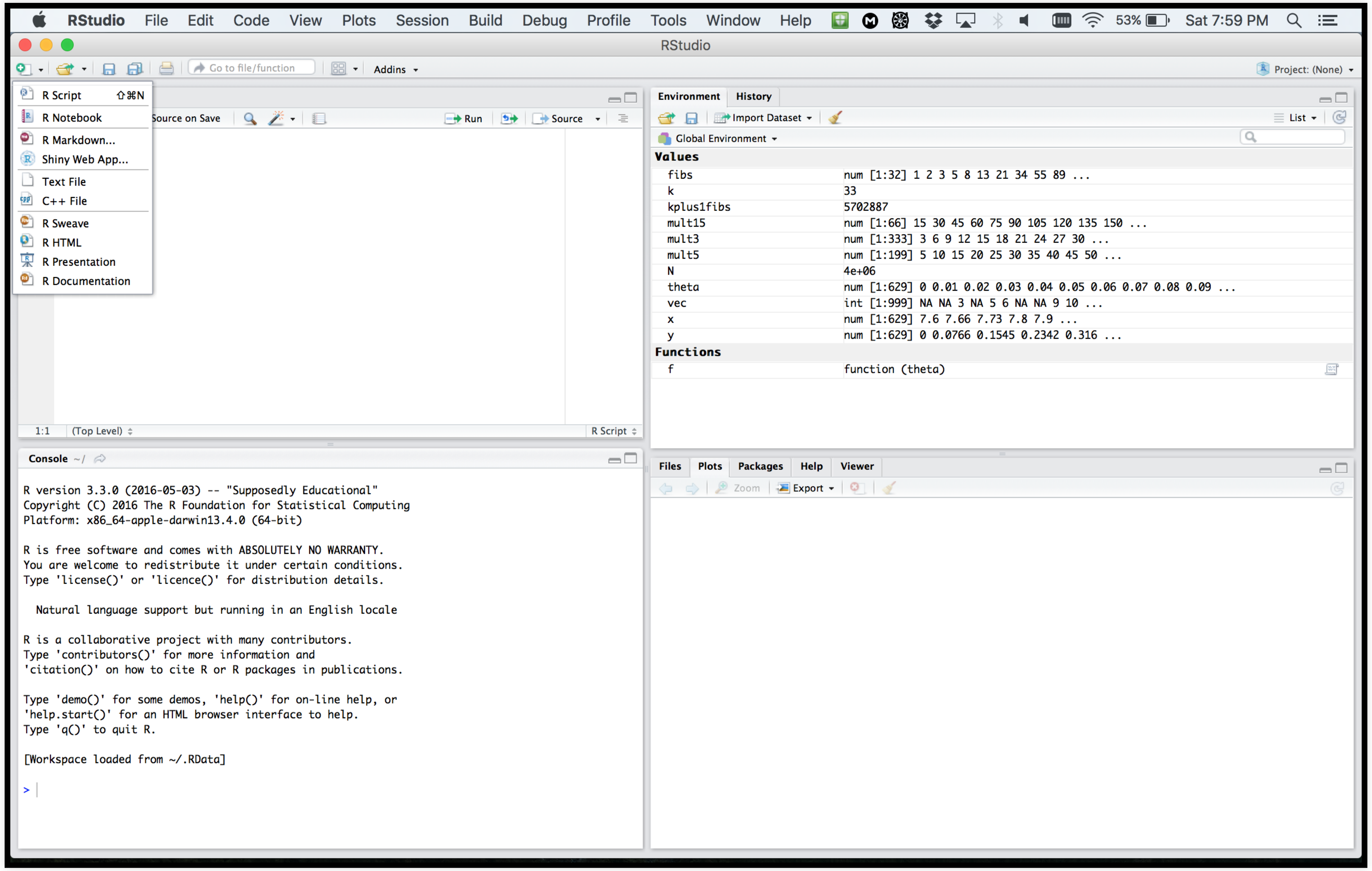
```

More on RStudio cuztomization can be found here

R document types



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[Workspace loaded from ~/.RData]

>
```

R document types

- R Script **a text file** containing R commands stored together.
- R Markdown files can generate high quality reports contatining notes, code and code outputs. **Python and bash code** can also be executed.
- R Notebook is an R Markdown document with **chunks that can be executed independently and interactively**, with output visible immediately beneath the input.
- R presentation let's you author **slides** that make use of R code and LaTeX equations as **straightforward** as possible.
- R Sweave enables the embedding of **R code within LaTeX documents**.

Working with code chunks

Keyboard shortcuts:

- Insert a new code chunk: **Ctrl + Alt + I** (Mac OS: **Cnd + Option + I**)
- Run the current chunk: **Ctrl + Shift + Enter** (Mac OS: **Cmd + Shift + Enter**)
- Run the current statement (the line where the cursor is) **Ctrl + Enter** (Mac OS: **Cmd + Enter**)

Syntax

Style Guide

- There are two main style conventions used in R:
  - Hadley Wickam style
  - Google R style
- You can use either of the two style guides or create your own customized style.
- But you should stay **consistent**, e.g. if you choose to assign variables with <-, stick to it and don't use =.

Identifiers

Google Convention:

- No underscores (_) or hyphens (-) in identifiers.
- **Variable names** all with lower case letters; words separated with dots (‘variable.name’), but ‘variableName’ is also accepte
- **Function names** have initial capital letters and no dots (‘FunctionName’). Function names should be verbs. Constants are named like functions but with an initial k.

```
# Good
avg.clicks            # variable name
CalculateAvgClicks    # function name
# Bad
avg_Clicks                                 # variable name
calculate_avg_clicks , calculateAvgClicks  # function name
```

Identifiers

Hadley Convention:

- Variable and function names should be lowercase.
- Use an underscore (_) to separate words within a name.
- Generally, variable names should be nouns and function names should be verbs.
- Use names that are concise and meaningful.

```
# Good
day_one
day_1

# Bad
first_day_of_the_month
DayOne
dayone
djm1
```

Spacing

- Place spaces around all infix operators (=, +, -, <-, etc.).
- Always put a space after a comma, and never before (just like in regular English).
- Place a space before left parentheses, except in a function call.

```r
# Good
average <- mean(feet / 12 + inches, na.rm = TRUE)
if (debug) do(x)
plot(x, y)
if (debug) do(x)
diamonds[5, ]

# Bad
average<-mean(feet/12+inches,na.rm=TRUE)
if(debug)do(x)
plot (x, y)
if ( debug ) do(x)  # No spaces around debug
x[1,]               # Needs a space after the comma
x[1 ,]              # Space goes after comma not before
```

Code Documentation

- Comment your code! They will be helpful when you read your code a month after you wrote it.
- In R each line of a comment should begin with a comment symbol “#”.

```r
# Function returns the answer to life,
# the universe and everything else
get_answer <- function(){
  return(42)
}
```

- Comments are not subtitles, i.e. don’t repeat the code in the comments.

```r
# Loop through all bananas in the bunch
for(banana in bunch) {
  # make the monkey eat one banana
  MonkeyEat(b)
}
```

- Use commented lines of - and = to break up your file into easily readable chunks.

```r
# Load data ---------------------------
# Plot data ---------------------------
```

Curly braces

- An opening curly brace “`{`” should never go on its own line and should always be followed by a new line.
- A closing curly “`}`” brace should always go on its own line, unless it’s followed by else.
- Always indent the code inside curly braces.
- It’s ok to leave very short statements on the same line

```
# Good
if (y < 0 && debug) {
  message("Y is negative")
}
if (y == 0) {
  log(x)
} else {
  y ^ x
}

# Bad
if (y < 0 && debug)
message("Y is negative")

if (y == 0) {
  log(x)
}
else {
  y ^ x
}
```

```
if (y < 0 && debug) message("Y is negative")
```

File Input/Output

Working Directory

- The **current working directory** (cmd) is the location which R is currently pointing to
- Whenever you try to read or save a file without specifying the path explicitly, the cmd will be used by default.
- When are executing code from an R markdown/notebook code chunk, the cmd is **the location of the document**.

- To see the current working directory use `getwd()`:

```r
getwd()    # with no arguments
```

```
## [1] "/Users/lanhuongnguyen/MEGA/Teaching/cme195_int
```

- To change the working directory use `setwd(path_name)` with a specified path as na argument:

```r
setwd("path/to/directory")
```

Paths and directory names

- In Windows, a directory usually has an address of the following form: `C:\Users\lan\folder`.
- R inherits its file and folder naming conventions from unix, and instead uses forward slashes instead of backslashes, e.g. `C:/Users/lan/folder/`
- The Mac OSX already uses the unix standards, the address is usually of the form: `/home/lan/folder/`.
- So, when working in R use the forward slashes "/".
- Actually for Windows, you can use either "`C:/Path/To/A/File`" or "`C:\\Path\\To\\A\\File`".

Paths and directory names

- R uses forward slashes for the directories, because backslashes serve a different purpose. They are used as escape characters to isolate special characters and stop them from being immediately interpreted.
- To avoid problems, directory names should NOT contain spaces and special characters.
- Use a “`Tab`” for autocompletion to find file paths more easily.

Data import

- **Text Files in a table format** can be read and saved to a selected variable using a `read.table()` function. Use `?read.table` to learn more about the function.
- A common text file format is a **comma delimited text file**, `.csv`. These files use a comma as column separators, e.g:

```
Year,Student,Major
2009, John Doe,Statistics
2009, Bart Simpson, Mathematics I
```

- To read these files use the following command:

```
mydata <- read.table("path/to/filename.csv", header=TRUE,  sep = ",")
# read.csv() has covenient argument defaults for '.csv' files
mydata <- read.csv("path/to/filename.csv")
```

- Optionally, use `row.names` or `col.names` arguments to set the row and column names.

Data import

- **Excel files**. To read the excel files you need to first install a package “xlsx”. Simply run `install.packages("xlsx")`.

```r
# first row contains variable names
library(xlsx)
# read the 1st worksheet
mydata <- read.xlsx("/path/to/filename.xlsx", 1)

# read in the worksheet named mysheet
mydata <- read.xlsx("/path/to/filename.xlsx", sheetName = "mysheet")
```

- **SAS files**. You need to install the `Hmisc` or `foreign` packages first.

```r
# First, save your SAS dataset in trasport (xport) format
libname out xport 'path/to/filename.xpt';
data out.mydata;
set sasuser.mydata;
run;

# Then, in R
library(Hmisc)
mydata <- sasxport.get("path/to/filename.xpt")
# character variables are converted to R factors
# or
library(foreign)
mydata <- read.xport("path/to/filename.xpt")
```

Data export

- **Text files:**

```r
write.table(mydata, "path/to/filename.txt", sep="\t")  # tab-delimited
write.table(mydata, "path/to/filename.csv", sep=",")   # comma-delimited
write.csv(mydata, "path/to/filename.csv")              # comma-delimited
```

- **Excel spreadsheet:**

```r
library(xlsx)
write.xlsx(mydata, "path/to/filename.xlsx")
```

- **SAS** files:

```r
# write out text datafile and an SAS program to read it
library(foreign)
write.foreign(mydata, datafile = "path/to/filename.txt",
              codefile = "path/to/filename.sas",  package="SAS")
```

Here are links to more details on data import and export.

Saving the workspace

- You can choose to **save all objects** currently in the workspace (variables, functions, etc.) into a file e.g. `filename.rda`.
- The file `filename.rda` can be loaded next time you work with R.
- You can also save a single object or a subset of specified objects currently in the workspace.

```r
# save the workspace to file
save.image(file = "path/to/filename.rda")

# save specific objects to a file
save(object_list, file = "path/to/filename.rda")

# save just a single object
saveRDS(object, file = "path/to/filename.rds")
```

- Saved objects/workspace can be loaded back in a new R session.

```r
# load a workspace into the current session
load("path/to/filename.rda")

# read just the previously saved 1 object
object <- readRDS("path/to/filename.rds")
```

Exercise 1

- Download “Lec2_ex.Rmd” file from the Lectures tab on class website.
- Open the file in RStudio.
- Do Exercise 1.

Control flow

Booleans/logicals

Booleans are logical data types (TRUE/FALSE) associated with conditional statements, which allow different actions and change control flow.

```
# equal "==""
5 == 5
```

```
## [1] TRUE
```

```
# not equal: "!=""
5 != 5
```

```
## [1] FALSE
```

```
# greater than: ">""
5 > 4
```

```
## [1] TRUE
```

```
# greater than or equal: ">=""  (# similarly < and <=)
5 >= 5
```

```
## [1] TRUE
```

```
# You can combine multiple boolean expressions
TRUE & TRUE
```

```
## [1] TRUE
```

```
TRUE & FALSE
```

```
## [1] FALSE
```

```
TRUE | FALSE
```

```
## [1] TRUE
```

```
!(TRUE)
```

```
## [1] FALSE
```

Booleans/logicals

In R if you combine 2 vectors of booleans, by each element then use `&`. Rember the **recycling property** for vectors.

```
c(TRUE, TRUE) & c(FALSE, TRUE)
```

```
## [1] FALSE  TRUE
```

```
c(5 < 4, 7 == 0, 1< 2) | c(5==5, 6> 2, !FALSE)
```

```
## [1] TRUE TRUE TRUE
```

```
c(TRUE, TRUE) & c(TRUE, FALSE, TRUE, FALSE)  # recycling
```

```
## [1]  TRUE FALSE  TRUE FALSE
```

Booleans/logicals

If we use double operators `&&` or `||` is used only the first elements are compared:

```
c(TRUE, TRUE) && c(FALSE, TRUE)
```

```
## [1] FALSE
```

```
c(5 < 4, 7 == 0, 1< 2) || c(5==5, 6> 2, !FALSE)
```

```
## [1] TRUE
```

```
c(TRUE, TRUE) && c(TRUE, FALSE, TRUE, FALSE)
```

```
## [1] TRUE
```

Booleans/logicals

- Another possibility to combine booleans is to use `all()` or `any()` functions:

```
all(c(TRUE, FALSE, TRUE))
```

```
## [1] FALSE
```

```
any(c(TRUE, FALSE, TRUE))
```

```
## [1] TRUE
```

```
all(c(5 > -1, 3 >= 1, 1 < 1))
```

```
## [1] FALSE
```

```
any(c(5 > -1, 3 >= 1, 1 < 1))
```

```
## [1] TRUE
```

Control statements

- **Control flow** is the order in which individual statements, instructions or function calls of a program are evaluated.
- Control statements allow you to do more complicated tasks.
- Their execution results in a choice between which of two or more paths should be followed.
  - `If/else`
  - `For`
  - `While`

If statements

- Decide on whether a block of code should be executed based on the associated boolean expression.
- **Syntax**. The if statements are followed by a boolean expression wrapped in parenthesis. The conditional block of code is inside curly braces `{}`.

```
if (traffic_light == "green") {
  print("Go.")
}
```

- ‘if-else’ statements let you introduce more options

```
if (traffic_light == "green") {
   print("Go.")
} else {
   print("Stay.")
}
```

- You can also use `else if()`

```
if (traffic_light == "green") {
   print("Go.")
} else if (traffic_light == "yellow") {
  print("Get ready.")
} else {
   print("Stay.")
}
```

For loops

- A for loop is a statement which **repeats the execution a block of code** a given number of iterations.

```r
for (i in 1:5){
  print(i^2)
}
```

```
## [1] 1
## [1] 4
## [1] 9
## [1] 16
## [1] 25
```

While loops

- Similar to for loops, but repeat the execution as long **as the boolean condition supplied is TRUE**.

```r
i = 1
while(i <= 5) {
  cat("i =", i, "\n")
  i = i + 1
}
```

```
## i = 1
## i = 2
## i = 3
## i = 4
## i = 5
```

Next

- `next` halts the processing of the current iteration and advances the looping index.

```
for (i in 1:10) {
  if (i <= 5) {
    print("skip")
    next
  }
  cat(i, "is greater than 5.\n")
}
```

```
## [1] "skip"
## [1] "skip"
## [1] "skip"
## [1] "skip"
## [1] "skip"
## 6 is greater than 5.
## 7 is greater than 5.
## 8 is greater than 5.
## 9 is greater than 5.
## 10 is greater than 5.
```

- `next` applies only to the innermost of nested loops.

```
for (i in 1:3) {
  cat("Outer-loop i: ", i, ".\n")
  for (j in 1:4) {
    if(j > i) {
      print("skip")
      next
    }
    cat("Inner-loop j:", j, ".\n")
  }
}
```

```
## Outer-loop i:  1 .
## Inner-loop j: 1 .
## [1] "skip"
## [1] "skip"
## [1] "skip"
## Outer-loop i:  2 .
## Inner-loop j: 1 .
## Inner-loop j: 2 .
## [1] "skip"
## [1] "skip"
## Outer-loop i:  3 .
## Inner-loop j: 1 .
## Inner-loop j: 2 .
## Inner-loop j: 3 .
## [1] "skip"
```

Break

- The `break` statement allows us to break out out of a for, while loop (of the smallest enclosing).
- The control is transferred to the first statement outside the inner-most loop.

```
for (i in 1:10)  {
  if (i == 6)  {
    print(paste("Coming out from for loop Where i = ", i))
    break
  }
  print(paste("i is now: ", i))
}
```

```
## [1] "i is now:  1"
## [1] "i is now:  2"
## [1] "i is now:  3"
## [1] "i is now:  4"
## [1] "i is now:  5"
## [1] "Coming out from for loop Where i =  6"
```

Exercise 2

- Go back to “Lec2_ex.Rmd” in RStudio.
- Do Exercise 2.

Functions

Functions

- A **function** is a procedure/routine that performs a specific task.
- Functions are used to **abstract** components of larger program.
- They are like a mathematical functions. They **take some input and then do something to find the result**.
- Functions allow you to **automate common tasks** in a more powerful and general way than copy-and-pasting.
- A general rule is that you should **use a function, whenever you’ve copied and pasted a block of code more than twice**.

Function Definition

- To define a function you assigne a variable name to a `function` object.
- Functions take **arguments, mandatory and optional**.
- Provide the brief **description of your function in comments** before the function definition.

```
# Computes mean and standard deviation
# and optionally prints the results.
mysummary <- function(x, print=TRUE) {
  center <- mean(x)
  spread <- sd(x)
  if (print) {
    cat("Mean =", center, "\n",
        "SD = ", spread, "\n")
  }
  result <- list(mean=center,
                 sd=spread)
  return(result)
}
```

Calling functions

```
x <- rnorm(n = 500, mean = 4, sd = 1)
y <- mysummary(x)
```

```
## Mean = 4.027061
##   SD =   1.02358
```

```
# without printing
y <- mysummary(x, print = FALSE)
```

```
# Results are stored in list "y"
y$mean
```

```
## [1] 4.027061
```

```
y$sd
```

```
## [1] 1.02358
```

```
# The order of arguments does not matter if the names are specified
y <- mysummary(print=FALSE, x = x)
```

Exercise 3

- Go back to “Lec2_ex.Rmd” in RStudio.
- Do Exercise 3.

apply, lapply, sapply functions

- The `apply` family functions, are **functions to manipulate slices of data** from matrices, arrays, lists and dataframes **in a repetitive way**.
- These functions **avoid explicit use of loops**. `apply` might be **computationally more efficient than for loops**, depending on how big your data is. For more details see this link.
- The apply functions allow you to perform operations with **very few lines of code.**
- The family comprises: **apply, lapply , sapply, vapply, mapply, rapply, and tapply**. The difference lies in the structure of input data and the desired format of the output).

lapply/sapply functions

- `lapply()` is used to **repeatedly apply a function to a elements of sequential objects** such as vectors, lists, or data-frames (applies to columns).
- The **output returned is a list** with the same number of elements as the input object.
- `sapply` is the same as `lapply` but returns a “simplified” output.
- user-defined functions can be used with `sapply/lapply`

```
lapply(1:3, function(x) x^2)
```

```
## [[1]]
## [1] 1
##
## [[2]]
## [1] 4
##
## [[3]]
## [1] 9
```

```
unlist(lapply(1:3, function(x) x^2))
```

```
## [1] 1 4 9
```

```
sapply(1:3, function(x) x^2)
```

```
## [1] 1 4 9
```

```
sapply(1:3, function(x) x^2, simplify = F)
```

```
## [[1]]
## [1] 1
##
## [[2]]
## [1] 4
##
## [[3]]
## [1] 9
```

apply function

`apply` operates on arrays/matrices. In the example below we obtain column sums of matrix “X”.

```
(X <- matrix(sample(30), nrow = 5, ncol = 6))
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]    4    5   14   26   11   25
## [2,]    2   12   20    6    8   28
## [3,]   21   10   29   13   17   19
## [4,]   16    1   15   27   22    9
## [5,]   18    7   23    3   30   24
```

```
apply(X, MARGIN = 2 , FUN = sum)
```

```
## [1]  61  35 101  75  88 105
```

Note: that in a matrix `MARGIN=1` indicates rows and `MARGIN=2` indicates columns.

apply function

- `apply` can be used with **user-defined functions**:

```
print(X)
```

```
##      [,1] [,2] [,3] [,4] [,5] [,6]
## [1,]    4    5   14   26   11   25
## [2,]    2   12   20    6    8   28
## [3,]   21   10   29   13   17   19
## [4,]   16    1   15   27   22    9
## [5,]   18    7   23    3   30   24
```

```
apply(X, 2, function(x) sum(x < 15)) # number entries
```

```
## [1] 2 5 1 3 2 1
```

- The function can be defined outside `apply()`,

```
logColMeans <- function(x, eps = NULL) {
  if (!is.null(eps)) x <- x + eps
  return(mean(x))
}
apply(X, 2, logColMeans)
```

```
## [1] 12.2  7.0 20.2 15.0 17.6 21.0
```

```
apply(X, 2, logColMeans, eps = 0.1)
```

```
## [1] 12.3  7.1 20.3 15.1 17.7 21.1
```

mapply functions

- `mapply` stands for 'multivariate' apply. It **applies a function to a multiple list or multiple vectors as arguments**.
- The goal is to vectorize arguments to a function which usually does not accept vectors as arguments.

```
# function word() returns a string of character C repeated k times.
word <- function(C,k) paste(rep.int(C,k), collapse='')
mapply(word, LETTERS[1:6], 6:1, SIMPLIFY = FALSE)
```

```
## $A
## [1] "AAAAAA"
##
## $B
## [1] "BBBBB"
##
## $C
## [1] "CCCC"
##
## $D
## [1] "DDD"
##
## $E
## [1] "EE"
##
## $F
## [1] "F"
```

Exercise 4

- Go back to “Lec2_ex.Rmd” in RStudio.
- Do Exercise 4.