Basic R

Lesson 1 with *Ian Carroll*

Lesson Objectives

- Meet the R "Console", "Editor", and "Environment" within RStudio
- Understand that R "packages" extend it to the "bleeding-edge"
- Join a vast user community ~~within statistics and ecology~~
- Learn what "free software" does for reproducible research

Specific Achievements

- Use R interactively for data exploration
- Create an R script for non-interactive data crunching
- Perform general purpose programming operations

What is R?

- Language: a vocabulary and a syntax (with lots of punctuation!)
- Interpreter: software that evaluates statements in the R language

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Console

The interpreter accepts commands interactively through the console.

Basic math, as you would type it on a calculator, is usually a valid command in the R language:

Console

```
> 1 + 2
```

```
[1] 3
```

Console

```
> 4^2
```

```
[1] 16
```

Question

Why is the output prefixed by `[1]`?

Answer

That's the index, or position in a vector, of the first result.

A command giving a vector of results shows this clearly:

Console

```
> seq(1, 100)
```

```
  [1]   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17
 [18]  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
 [35]  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51
 [52]  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68
 [69]  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85
 [86]  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100
```

The interpreter understands more than arithmatic operations. That last command told it to use (or "call") the function `seq()`.

Most of “learning R” involves getting to know a whole lot of functions, the effect of each function’s arguments (e.g. the input values `1` and `100`), and what each function returns (e.g. the output vector).

R as Calculator

A good place to begin learning R is with its built-in mathematical functionality.

Arithmatic Operators

Try `+`, `-`, `*`, `/`, and `^` (for raising to a power).

```
Console
> 5/3
[1] 1.666667
```

Logical Tests

Test equality with `==` and inequality with `<=`, `<`, `!=`, `>`, or `>=`.

```
Console
> 1/2 == 0.5
[1] TRUE
```

Math Functions

Common mathematical functions like `sin`, `log`, and `sqrt`, exist along side some universal constants.

```
Console
> sin(2 * pi)
[1] -2.449294e-16
```

Generic Functions

Functions do more than math! Functions like ‘rep’, ‘sort’, and ‘range’ are pre-packaged instructions for processing user input.

```
Console
> rep(2, 5)
[1] 2 2 2 2 2
```

Parentheses

Sandwiching something with `(` and `)` has two possible meanings.

Group sub-expressions by parentheses where needed.

```
Console
> (1 + 2) / 3
[1] 1
```

Call functions by typing their name and comma-separated arguments between parentheses.

```
Console
> logb(2, 2)
[1] 1
```

Environment

In the RStudio IDE, the environment tab displays any variables added to R's vocabulary in the current session. In a brand new session, the R interpreter already recognizes many things, despite the environment being "empty".

With an "empty" environment, the interpreter still recognizes:

- any number
- any string of characters
- nearly universal operators (e.g. `+` and `/`)
- operators specific to R (e.g. `$` and `%*%`)
- functions in "base R"

To reference a number or function just type it in as above. To referece a string of characters, surround them in quotation marks.

Console
```
> 'ab.cd'
```
```
[1] "ab.cd"
```

Without quotation marks, the interpreter checks for things in the environment named `ab.cd` and doesn't find anything:

Console
```
> ab.cd
```
```
Error in eval(expr, envir, enclos): object 'ab.cd' not found
```

Question
: Is it better to use `'` or `"`?

Answer
: Neither one is better. You will often encounter stylistic choices like this, so if you don't have a personal preference try to mimic existing styles.

Assignment

You can expand the vocabulary known to the R interpreter by creating a new **variable**. Using the symbol `<-` is referred to as assignment: the output of any command to the right of `<-` gets the name given on its left.

Console
```
> x <- seq(0, 100)
```

You'll notice that nothing prints to the console, because we assigned the output to a variable. We can print the value of `x` by evaluating it without assignment.

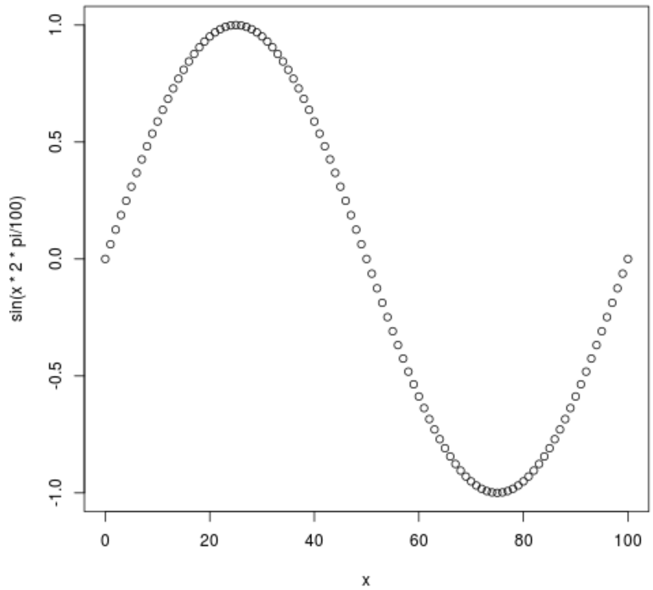
Console
```
> x
```
```
  [1]   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16
 [18]  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33
 [35]  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50
 [52]  51  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67
 [69]  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84
 [86]  85  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100
```

Assigning values to new variables (to the left of a `<-`) is the only time you can reference something previously unknown to the interpreter. All other commands must reference things already in the interpreter's vocabulary.

Once assigned to a variable, a value becomes known to R and you can refer to it in other commands.

Console

```
> plot(x, sin(x * 2 * pi / 100))
```



The environment is dynamic, but under your control!

- Variables do not persist between sessions (unless loaded from .Rdata 😢)
- Variables only change their value on re-assignment

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Editor

The **console** is for evaluating commands you don't intend to keep or reuse. It's useful for testing commands and poking around. The **environment** represents the state of a current session. The **editor** reads and writes files–it is where you head to compose your R scripts.

R scripts are simple text files that contain code you intend to run again and again; code to process data, perform analyses, produce visualizations, and even generate reports. The editor and console work together in the RStudio IDE, which gives you multiple ways to send parts of the script you are editing to the console for immediate evaluation. Alternatively you can "source" the entire script or run it from a shell with `Rscript`.

Open up "worksheet-1.R" in the editor, and follow along by replacing the `...` placeholders with the code here. Then evalute just this line (Ctrl+Enter on Windows, ⌘+Enter on macOS)

worksheet-1.R

```
vals <- seq(1, 100)
```

Our call to the function `seq` could have been much more explicit. We could give the arguments by the names that `seq` is expecting.

worksheet-1.R

```
vals <- seq(from = 1,
  to = 100)
```

Run that code by moving your cursor anywhere within those two lines and clicking "Run", or by using the keyboard shortcut Ctrl-Return or ⌘ Return.

Question

What's an advantage of naming arguments?

Answer

One advantage is that you can put them in any order. A related advantage is that you can then skip some arguments, which is fine to do if each skipped argument has a default value. A third advantage is code readability, which you should always be conscious of while writing in the editor.

Readability

Code readability in the editor cuts both ways: sometimes verbosity is useful, sometimes it is cumbersome.

The `seq()` function has an alternative form available when only the `from` and `to` arguments are needed.

```
Console
> 1:100
```

```
  [1]   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17
 [18]  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34
 [35]  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49  50  51
 [52]  52  53  54  55  56  57  58  59  60  61  62  63  64  65  66  67  68
 [69]  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83  84  85
 [86]  86  87  88  89  90  91  92  93  94  95  96  97  98  99 100
```

The `:` operator should be used whenever possible because it replaces a common, cumbersome function call with an brief, intuitive syntax. Likewise, the `assign` function duplicates the functionallity of the `<-` symbol, but is never used when the simpler operator will suffice.

Function documentation

How would you get to know these properties and the names of a function's arguments?

```
Console
> ?seq
```

How would you even know what function to call?

```
Console
> ??sequence
```

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Load Data

We will use the function `read.csv()` to load data from a Comma Separated Value file. The essential argument for the function to read in data is the path to the file, other optional arguments adjust how the file is read.

Additional file types can be read in using `read.table()`; in fact, `read.csv()` is a simple wrapper for the `read.table()` function having set some default values for some of the optional arguments (e.g. `sep = ","`).

Use the assignment operator "<-" to read data into a variable for subsequent operations.

Type `read.csv(` into the editor and then press **tab** to see what arguments this function takes. Hovering over each item in the list will show a description of that argument from the help documentation about that function. Specify the values to use for an argument using the syntax `name = value`.

```
worksheet-1.R
storm <- read.csv('data/StormEvents.csv')
```

Question

How does `read.csv` determine the field names?

Answer

The `read.csv` command assumes the first row in the file contains column names. Look at `?read.csv` to see the default `header = TRUE` argument. What exactly that means is described down in the "Arguments" section.

After reading in the “StormEvents.csv” file, you can explore what types of data are in each column with the `str` function, short for “structure”.

```
Console
> str(storm)
```

```
'data.frame':	100 obs. of  42 variables:
 $ BEGIN_YEARMONTH   : int  200604 200601 200601 200601 200601 200601 200601 200601 200601 200601 ...
 $ BEGIN_DAY         : int  7 1 1 1 1 30 30 28 28 28 ...
 $ BEGIN_TIME        : int  1515 0 0 0 0 500 500 800 1400 800 ...
 $ END_YEARMONTH     : int  200604 200601 200601 200601 200601 200601 200601 200601 200601 200601 ...
 $ END_DAY           : int  7 31 31 31 31 31 31 29 29 29 ...
 $ END_TIME          : int  1515 2359 2359 2359 2359 1400 1400 1300 500 1600 ...
 $ EPISODE_ID        : int  207534 202408 202409 202409 202409 202394 202394 202395 202396 202397 ...
 $ EVENT_ID          : int  5501658 5482479 5482480 5482481 5482482 5482324 5482325 5482326 5482327 54
 $ STATE             : Factor w/ 19 levels "ALASKA","ARKANSAS",..: 6 3 17 17 17 3 3 3 3 3 ...
 $ STATE_FIPS        : int  18 8 49 49 49 8 8 8 8 8 ...
 $ YEAR              : int  2006 2006 2006 2006 2006 2006 2006 2006 2006 2006 ...
```

The data viewer, opened with `View` or the spreadsheet icon a data frame’s record in the Environment, is useful despite not being a full spreadsheet application.

```
Console
> View(storm)
```

Missing data, as interpreted by the `read.csv` function, is controlled by the `na.strings` argument. Override the default value of `'NA'` with a character vector.

You often need to specify multiple strings to interpret as missing values, such as `na.strings = c("missing", "no data", "< 0.05 mg/L", "XX")`.

```
worksheet-1.R
storm <- read.csv(
  'data/StormEvents.csv',
  na.strings = c('NA', 'UNKNOWN'))
```

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Data Structures

A data frame is a compound object, built up from (eventually) a few basic data types, but there are intermediate objects to understand. Like all data frames, `storm` is actually a “list”.

```
Console
> typeof(storm)
```

```
[1] "list"
```

The “list” is one of three one-dimensional data structurs you will regularly encounter.

- Lists
- Vectors
- Factors

Lists

Lists are one-dimensional and each element is entirely unrestricted; you can put anything in a list.

Create a list called `x` with a string, a sequence, and a function.

worksheet-1.R

```r
x <- list('abc', 1:3, sin)
```

Question

Compare the structure of `storm` and `x` while thinking about the length of each of their elements. Do the elements within list `x` have a length? The same length?

Answer

The elements of `x` all have lengths, and are not all the same. Note that the command `length('abc')` yields `1`.

When you enter a single number or character string in R, you are actually creating a one-dimensional data structure of length 1. There are not really 0-dimensional “scalars” in R. The kind of one-dimensional structure created in this was is called a “vector”.

Vectors

Vectors are an array of values of the same data type. Create a vector by combining elements of the same type together using the function `c()`.

Console

```r
> c(1, 2, 3)
```

```
[1] 1 2 3
```

All elements of an vector must be the same type, so when you attempt to combine different types they will be coerced to the most flexible type.

Console

```r
> c(1, 2, 'c')
```

```
[1] "1" "2" "c"
```

The difference between `c(1, 2, 3)` and `c(1, 2, 'c')` isn’t just in the third element. To understand the difference, we need to recognize data types.

Data Types

A data frame has now been recognized as a list, and the `str` command gives an indication that each field has a data type. The final key property is its dimension.

Console

```r
> dim(storm)
```

```
[1] 100  42
```

A data frame is essentially a list of vectors, with an important constraint. The vectors must all be of the same length, giving a rectangular data structure.

Here is a summary of the data types you frequently encounter in data frames.

Type	Example
double	3.1, 4, Inf, NaN
integer	4L, length(…)
character	‘a’, ‘4’, ‘👏’
logical	TRUE, FALSE

Both the double and integer data types are considered numeric, and while the `str` function tells you that a double is “num”, the `typeof` function will properly identify either numeric type. Missing data created with `NA` actually have a variant for each data type. So you can put `NA` in any vector without breaking the fule that the elements of a vector have the same data type.

Factors

A factor is a vector that can contain only predefined values, and is used to store categorical data. Factors are like integer vectors, but posess a `levels` attribute that assigns names to each level, or possible value in the vector.

Use `factor()` to create a vector with predefined values, which are often character strings.

worksheet-1.R

```
education <- factor(
    c('college', 'highschool', 'college', 'middle', 'middle'),
    levels = c('middle', 'highschool', 'college'))
```

The `str` function notes the labels, but prints the integers assigned in their stead.

Console

```
> str(education)
```

```
 Factor w/ 3 levels "middle","highschool",..: 3 2 3 1 1
```

Data Frames

One last property makes data frames stand out from lists: a data frame is a list of *equal-length* vectors having *unique names*.

The “columns” visible in the data viewer are accessed by the `names` function.

Console

```
> names(storm)
```

```
 [1] "BEGIN_YEARMONTH"   "BEGIN_DAY"         "BEGIN_TIME"
 [4] "END_YEARMONTH"     "END_DAY"           "END_TIME"
 [7] "EPISODE_ID"        "EVENT_ID"          "STATE"
[10] "STATE_FIPS"        "YEAR"              "MONTH_NAME"
[13] "EVENT_TYPE"        "CZ_TYPE"           "CZ_FIPS"
[16] "CZ_NAME"           "WFO"               "BEGIN_DATE_TIME"
[19] "CZ_TIMEZONE"       "END_DATE_TIME"     "INJURIES_DIRECT"
[22] "INJURIES_INDIRECT" "DEATHS_DIRECT"     "DEATHS_INDIRECT"
[25] "DAMAGE_PROPERTY"   "DAMAGE_CROPS"      "SOURCE"
[28] "MAGNITUDE"         "MAGNITUDE_TYPE"    "BEGIN_RANGE"
[31] "BEGIN_AZIMUTH"     "BEGIN_LOCATION"    "END_RANGE"
[34] "END_AZIMUTH"       "END_LOCATION"      "BEGIN_LAT"
[37] "BEGIN_LON"         "END_LAT"           "END_LON"
```

In summary, a data frame is the data structure most similar to a spreadsheet, with a few key differences:

- The columns are **equal-length** vectors.
- As vectors, a column cannot hold values of the wrong type.
- Each column has a unique name.

Creating a data frame from scratch can be done by combining vectors with the `data.frame()` function.

worksheet-1.R

```
income <- c(32000, 28000, 89000, 0, 0)
df <- data.frame(education, income)
```

Remember to use these functions when getting to know a data frame:

`dim()`	dimensions
`nrow()`, `ncol()`	number of rows, columns
`names()`	(column) names
`str()`	structure
`summary()`	summary info

`head()`	shows beginning rows

Matrices

One way to understand the need for another data structure, the matrix, is that a matrix differs from a data frame in terms of the underlying data type.

Dimensions	Homogeneous	Heterogeneous
1-D	`c()`	`list()`
2-D	`matrix()`	`data.frame()`
n-D	`array()`	

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Parts and Subsets

Any single part of a data structure is always accessible, either by its name or by its position, using double square brackets: `[[` and `]]`.

Position

The first element:

Console
```
> income[[1]]
```
```
[1] 32000
```

The third element:

Console
```
> income[[3]]
```
```
[1] 89000
```

Names

Parts of an object may also have a name. The names can be given when you are creating a vector or afterwards using the `names()` function.

Console
```
> df[['education']]
```
```
[1] college    highschool college    middle     middle
Levels: middle highschool college
```

worksheet-1.R
```
names(df) <- c('ed', 'in')
```

Console
```
> df[['ed']]
```
```
[1] college    highschool college    middle     middle
Levels: middle highschool college
```

Question

This use of `<-` with `names(x)` on the left is a little odd. What's going on?

Answer

> We are overwriting an existing variable, but one that is accessed through the output of the function on the left rather than the global environment.

For a multi-dimensional array, separate the dimensions within which a part is requested with a comma.

Console

```
> df[[3, 'ed']]
```

```
[1] college
Levels: middle highschool college
```

It's fine to mix names and indices when selecting parts of an object.

The `$` sign is an additional operator for quick access to a single, named part of some objects. It's most useful when used interactively with "tab completion" on the columns of a data frame.

Console

```
> df$ed
```

```
[1] college    highschool college    middle     middle    
Levels: middle highschool college
```

Subsets

Multiple parts of a data structure are similarly accessed using single square brackets: `[` and `]`. What goes between the brackets, to specify the positions or names of the desired subset, may be of multiple forms.

Parts	Result
positives	elements at given positions
negatives	given positions omitted
logicals	elements where the corresponding position is TRUE
nothing	all the elements

worksheet-1.R

```
days <- c(
  'Sunday', 'Monday', 'Tuesday',
  'Wednesday', 'Thursday', 'Friday',
  'Saturday')
weekdays <- days[2:6]
weekend <- days[c(1, 7)]
```

Console

```
> weekdays
```

```
[1] "Monday"    "Tuesday"   "Wednesday" "Thursday"  "Friday"
```

Console

```
> weekend
```

```
[1] "Sunday"   "Saturday"
```

A logical test applied to a single column produces a vector of `TRUE` and `FALSE` values that's the right length for subsetting the data.

Console

```
> df[df$ed == 'college', ]
```

```
       ed    in
1 college 32000
```

```
3 college 89000
```

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Functions

Functions package up a batch of commands. There are several reasons to develop functions in R for data analysis:

- reuse
- readability
- modularity
- consistency

Writing functions to use multiple times within a project prevents you from duplicating code, a real time-saver when you want to update what the function does. If you see blocks of similar lines of code through your project, those are usually candidates for being moved into functions.

Anatomy of a function

Like all programming languages, R has keywords that are reserved for import activities, like creating functions. Keywords are usually very intuitive, the one we need is `function`.

worksheet-1.R

```
function(...) {
    ...
    return(...)
}
```

Three components:

- **arguments**: control how you can call the function
- **body**: the code inside the function
- **return value**: controls what output the function gives

We'll make a function to extract the first row of its argument, which we give a name to use inside the function:

worksheet-1.R

```
function(a) {
    result <- a[1, ]
    return(result)
}
```

Note that `a` doesn't exist until we call the function, which merely contains the instructions for how any `a` will be handled.

Finally, we need to give the function a name so we can use it like we used `c()` and `seq()` above.

worksheet-1.R

```
first <- function(a) {
    result <- a[1, ]
    return(result)
}
```

Console

```
> first(df)
```

```
       ed    in
1 college 32000
```

Question
Can you explain the result of entering `first(income)` into the console?

Answer

The function caused an error, which prompted the interpreter to print a helpful error message. Never ignore an error message. (It's okay to ignore a "warning".)

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Flow Control

A generic term for causing the interpreter to repeat or skip certain lines, using concepts like "for loops" and conditionals.

The R interpreter's "focus" flows through a script (or any section of code you run) line by line. Without additional instruction, every line is processed from the top to bottom. Flow control refers mostly to the two main ways of directing the interpreter's focus, via loops and conditions.

Flow control happens within blocks of code isolated between curly braces `{` and `}`, known as "statements".

worksheet-1.R

```
if (...) {
    ...
} else {
    ...
}
```

The keyword `if` must be followed by a logical test which determines, at runtime, what to do next. The R interpreter goes to the first statement if the logical value is `TRUE` and to the second statement if it's `FALSE`.

An if/else conditional would allow the `first` function to avoid the error thrown by calling `first(counts)`.

worksheet-1.R

```
first <- function(dat) {
    if (is.vector(dat)) {
        result <- dat[[1]]
    } else {
        result <- dat[1, ]
    }
    return(result)
}
```

Console

```
> first(df)
```

```
       ed    in
1 college 32000
```

Console

```
> first(income)
```

```
[1] 32000
```

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Distributions and Statistics

Since it was designed by statisticians, R can easily draw random numbers from probability distributions and calculate probabilities.

To generate random numbers from a normal distribution, use the function `rnorm()`

worksheet-1.R

```
rnorm(n = 10)
```

```
 [1] -0.2262330 -1.0254656  1.2444628 -0.7458895 -1.0402514  1.5143953
 [7] -0.5442489  0.8525838  0.6985059 -0.8708866
```

Function	Returns	Notes
`rnorm()`	Draw random numbers from normal distribution	Specify `n`, `mean`, `sd`
`dnorm()`	Probability density at a given number	
`pnorm()`	Cumulative probability up to a given number	left-tailed by default
`qnorm()`	The quantile given a cumulative probability	opposite of pnorm

Statistical distributions and their functions. See *Table 14.1* in **R for Everyone** by Jared Lander for a full table.

Distribution	Functions
Normal	*norm
Binomial	*binom
Poisson	*pois
Gamma	*gamma
Exponential	*exp
Uniform	*unif
Logistic	*logis

R has built in functions for handling many statistical tests.

worksheet-1.R

```
x <- rnorm(n = 100, mean = 15, sd = 7)
y <- rbinom(n = 100, size = 20, prob = .85)
```

The samples above are drawn from different distributions with different means. The T-Test should easilly distinguish them, although it does not check assumptions!

Console

```
> t.test(x, y)
```

```

	Welch Two Sample t-test

data:  x and y
t = -3.0895, df = 107.92, p-value = 0.00255
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -3.3562439 -0.7327582
sample estimates:
mean of x mean of y 
  15.2155   17.2600 
```

Shapiro's test of normality provides one routine for verifying assumptions.

Console

```
> shapiro.test(y)
```

```

	Shapiro-Wilk normality test

data:  y
W = 0.94755, p-value = 0.0005739
```

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Review

In this introduction to R, we touched on several key parts of scripting for data analysis.

- RStudio panes
- variable assignment
- data structures
- subsetting data
- functions
- flow control
- probabilities

Special characters in R

Perhaps more than most languages, an R script can appear like a jumble of archaic symbols. Here is a little table of characters to recognize as having special meaning.

Symbol	Meaning
`?`	get help
`#`	comment
`:`	sequence
`::`, `:::`	access namespaces (advanced)
`<-`	assignment
`$`, `[ ]`, `[[ ]]`	subsetting
`% %`	infix operators, e.g. `%*%`
`{ }`	statements
`.`	
`@`	slot (advanced)

The `.` in R has no fixed meaning and is often used as `_` might be used to separate words in a variable name.

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Exercises

Exercise 1

Use the quadratic formula to find x that satisfies the equation $1.5x^2 + 0.3x - 2.9 = 0$.

$$\frac{-0.3 \pm \sqrt{0.3^2 - 4 \times 1.5 \times -2.9}}{2 \times 1.5}$$

Exercise 2

By default, all character data is read in to a data.frame as factors. Use the `read.csv()` argument `stringsAsFactors` to suppress this behavior, then subsequently modify the `STATE` column in `storm` to make it a factor. Remember that columns of a `data.frame` are identified to the R interpreter with the `$` operator, e.g. `storm$STATE`.

Exercise 3

Use the `typeof` function to inspect the data type of `income`, and do the same for another variable to which you assign a `list` of numbers. Why are they different? Use `c` to combine `income` with the new variable you just created and inspect the result with `typeof`. Does `c` always create vectors?

Exercise 4

Create a data frame with two columns, one called “species” with four strings and another called “abund” with four numbers. Store your data frame as a variable called `data`.

Exercise 5

1. Get weekdays using negative integers.
2. Get M-W-F using a vector of postitions generated by `seq()` that uses the `by` argument (don’t forget to `?seq` for help).

Exercise 6

The keywords `else` and `if` can be combined to allow flow control among more than two statements, as below. Expand the `first` function once again to differentiate between `dat` provided as a `matrix` and as a `data.frame`. It’s up to you what the “first” element of a matrix should be!

Exercise
```
if (...) {
  ...
} else if {
  ...
} else {
  ...
}
```

Solutions

Solution 1

Solution
```
(-0.3 + sqrt(0.3 ^ 2 - 4 * 1.5 * -2.9)) / (2 * 1.5)
```

```
[1] 1.294035
```

Solution 2

Solution
```
storm <- read.csv(
  'data/StormEvents.csv',
  stringsAsFactors = TRUE)
storm$STATE <- factor(storm$STATE)
```

Solution 3

Solution
```
x <- list(3, 4, 5, 7)
typeof(x)
```

```
[1] "list"
```

The variable `x` has a data type of `list`, so R does not restrict its elements to a particular type as it does for vectors.

Solution
```
typeof(c(income, x))
```

```
[1] "list"
```

The result of combining a list and vector is a list, because the list is the more flexible data structure.

Solution 4

Solution

```
species <- c('ape', 'bat', 'cat', 'dog')
abund <- 1:4
data <- data.frame(species, abund)
```

Solution 5

Solution

```
days[c(-1, -7)]
```

```
[1] "Monday"    "Tuesday"   "Wednesday" "Thursday"  "Friday"
```

Solution

```
days[seq(2, 7, 2)]
```

```
[1] "Monday"    "Wednesday" "Friday"
```

Solution 6

Solution

```
first <- function(dat) {
    if (is.vector(dat)) {
        result <- dat[[1]]
    } else if (is.matrix(dat)) {
        result <- dat[[1, 1]]
    } else {
        result <- dat[1, ]
    }
    return(result)
}
```

Solution

```
m <- matrix(1:9, nrow = 3, ncol = 3)
first(m)
```

```
[1] 1
```

Top of Section

If you need to catch-up before a section of code will work, just squish it's to copy code above it into your clipboard. Then paste into your interpreter's console, run, and you'll be ready to start in on that section. Code copied by both and will also appear below, where you can edit first, and then copy, paste, and run again.

```
# Nothing here yet!
```