# Introduction To R Programming

## *R objects and functions*

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Created using the "λέξις" theme

# R Programming

R is a versatile language for data wrangling, visualization, and modeling

# Resources

## Link to slides

https://mjfrigaard.github.io/csuc-data-journalism/slides.html

## Link to exercises

https://mjfrigaard.github.io/csuc-data-journalism/lessons-exercises.html

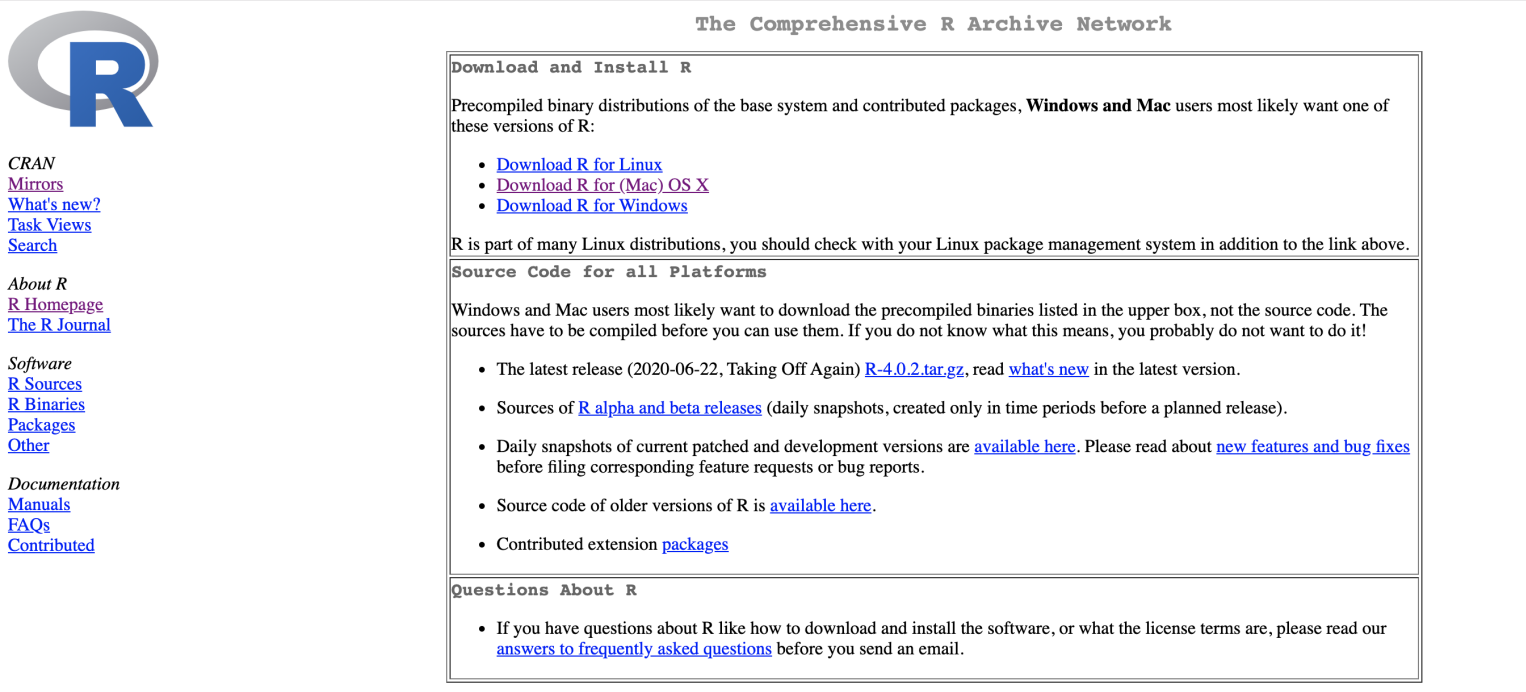
# Getting Started

Image credit: R Project

# Installing R

Install R from the Comprehensive R Archive Network (CRAN):

https://cran.r-project.org/



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**The Comprehensive R Archive Network**

**Download and Install R**

Precompiled binary distributions of the base system and contributed packages, **Windows and Mac** users most likely want one of these versions of R:

- Download R for Linux
- Download R for (Mac) OS X
- Download R for Windows

R is part of many Linux distributions, you should check with your Linux package management system in addition to the link above.

**Source Code for all Platforms**

Windows and Mac users most likely want to download the precompiled binaries listed in the upper box, not the source code. The sources have to be compiled before you can use them. If you do not know what this means, you probably do not want to do it!

- The latest release (2020-06-22, Taking Off Again) R-4.0.2.tar.gz, read what's new in the latest version.
- Sources of R alpha and beta releases (daily snapshots, created only in time periods before a planned release).
- Daily snapshots of current patched and development versions are available here. Please read about new features and bug fixes before filing corresponding feature requests or bug reports.
- Source code of older versions of R is available here.
- Contributed extension packages

**Questions About R**

- If you have questions about R like how to download and install the software, or what the license terms are, please read our answers to frequently asked questions before you send an email.

You are recommended to use the RStudio IDE (*but you do not have to*)

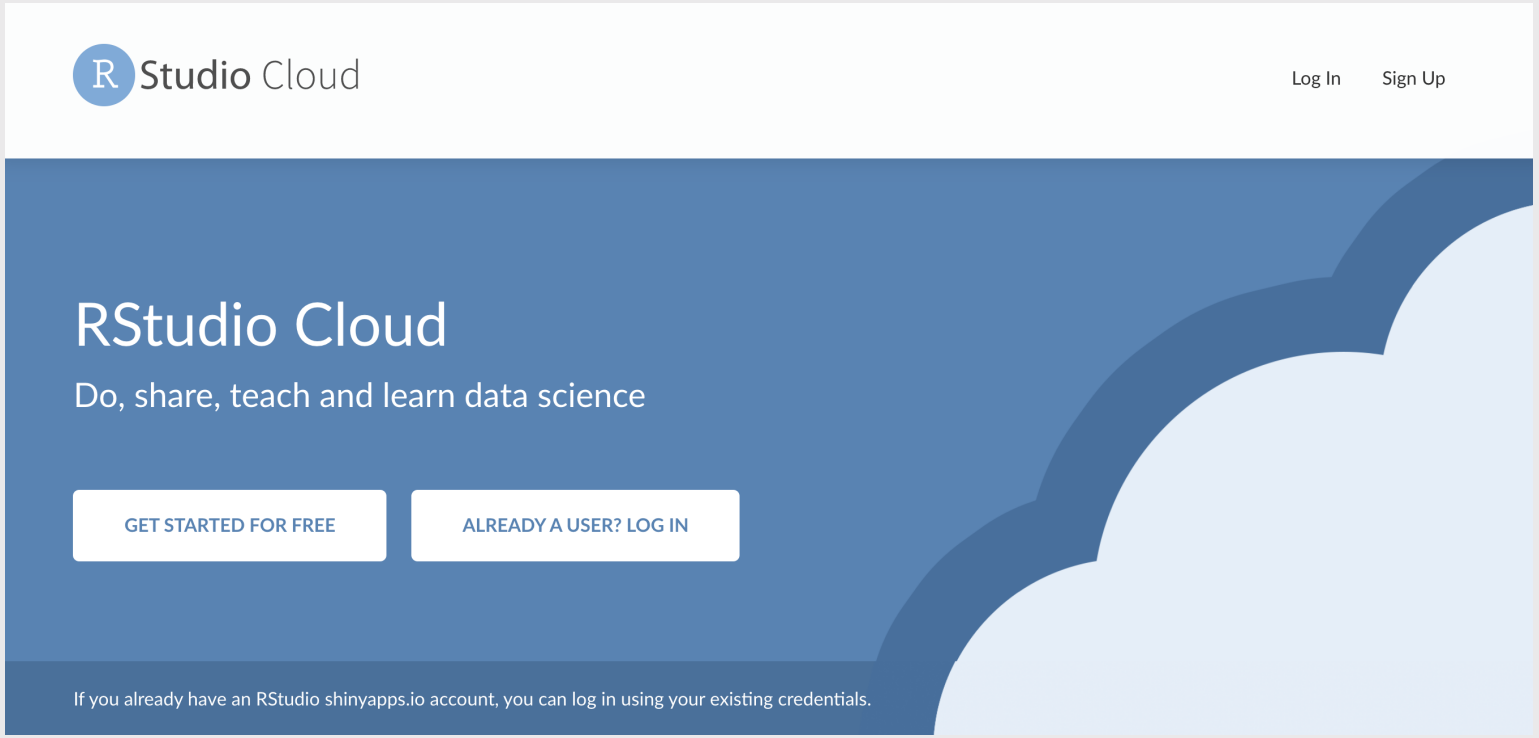
# Download RStudio

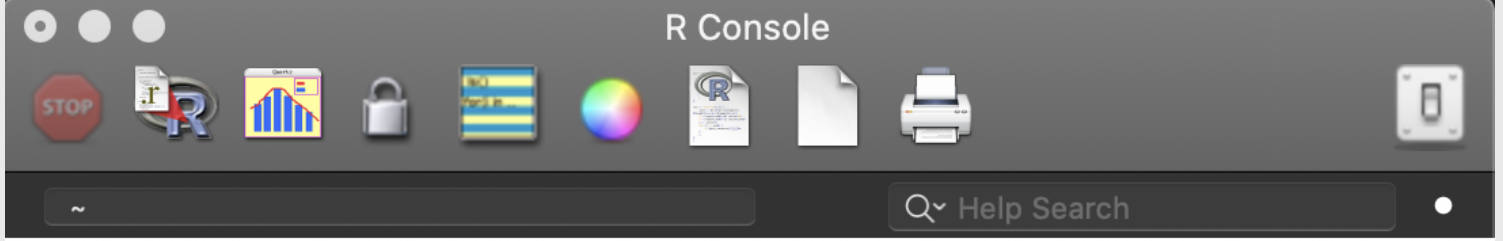
https://rstudio.com/products/rstudio/download/

| OS | Download | Size | SHA-256 |
|---|---|---|---|
| Windows 10/8/7 | RStudio-1.3.1093.exe | 171.62 MB | 62b9e60a |
| macOS 10.13+ | RStudio-1.3.1093.dmg | 148.66 MB | bdc4d3a4 |
| Ubuntu 16 | rstudio-1.3.1093-amd64.deb | 124.33 MB | 72f05048 |
| Ubuntu 18/Debian 10 | rstudio-1.3.1093-amd64.deb | 126.80 MB | ff222177 |
| Fedora 19/Red Hat 7 | rstudio-1.3.1093-x86_64.rpm | 146.96 MB | ed1f6ef8 |
| Fedora 28/Red Hat 8 | rstudio-1.3.1093-x86_64.rpm | 151.05 MB | 01a978f3 |
| Debian 9 | rstudio-1.3.1093-amd64.deb | 127.00 MB | a747f9f9 |
| SLES/OpenSUSE 12 | rstudio-1.3.1093-x86_64.rpm | 119.43 MB | 5016cbcf |
| OpenSUSE 15 | rstudio-1.3.1093-x86_64.rpm | 128.40 MB | cf47e32d |

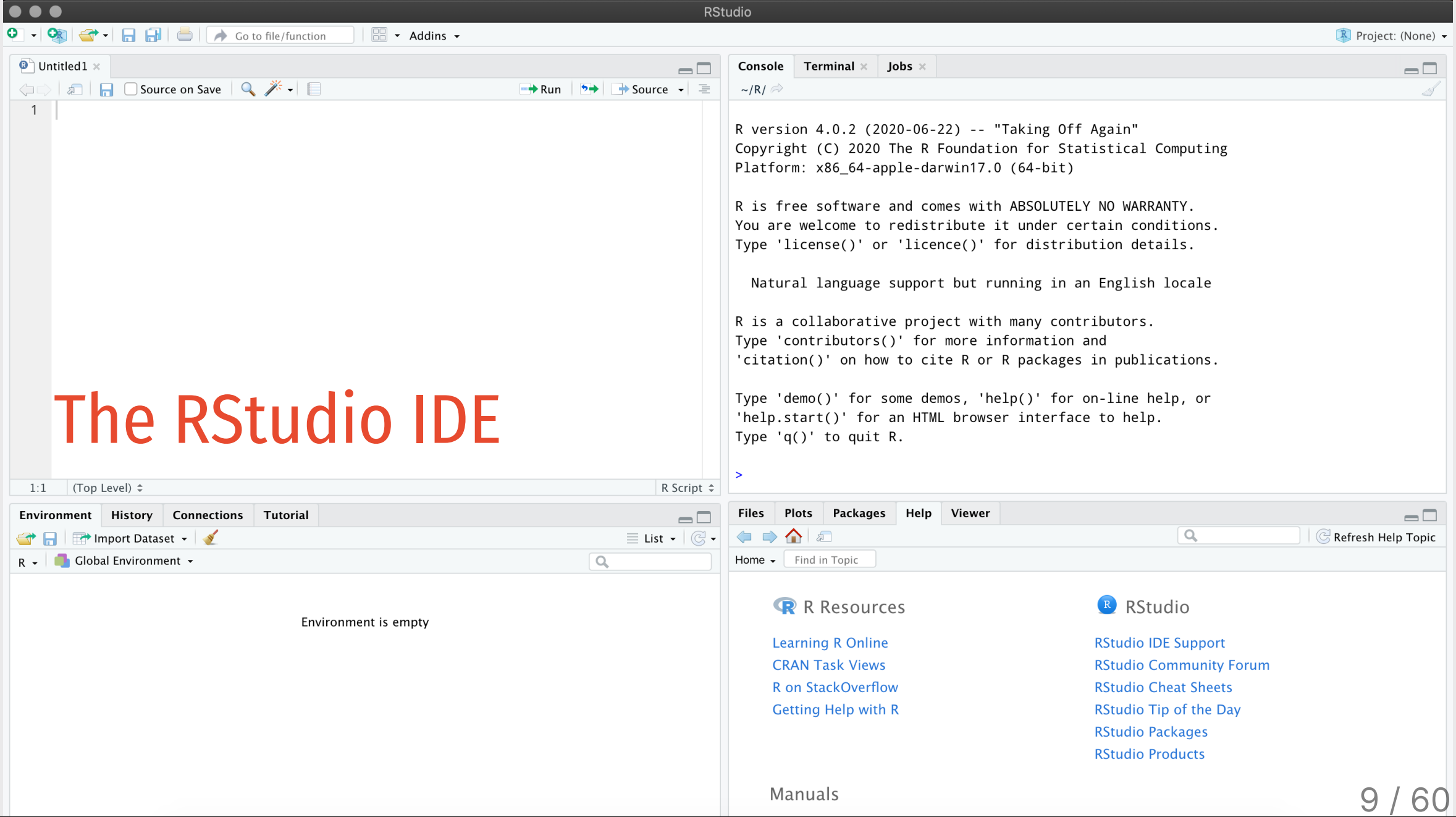
# Or use RStudio.Cloud

https://rstudio.cloud/






# The R Console


RStudio
Go to file/function
Addins
Project: (None)
Untitled1
Source on Save
Run
Source
1
The RStudio IDE
1:1
(Top Level)
R Script
Console
Terminal
Jobs
~/R/
R version 4.0.2 (2020-06-22) -- "Taking Off Again"
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Platform: x86_64-apple-darwin17.0 (64-bit)
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Natural language support but running in an English locale
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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.
>
Environment
History
Connections
Tutorial
Import Dataset
List
R
Global Environment
Environment is empty
Files
Plots
Packages
Help
Viewer
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# Running R Commands

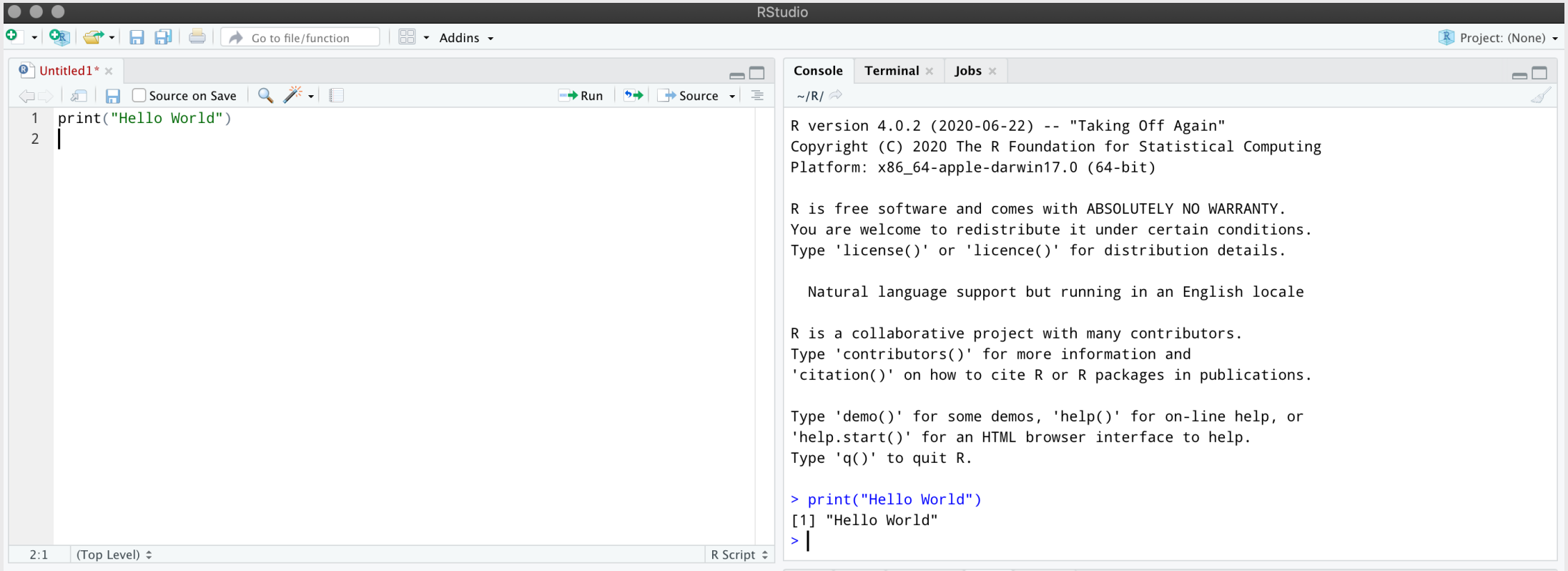
You can run R commands in the Console by entering them after the > operator (see example in R below)

```
print("Hello World")
```

```
  [1] "Hello World"
```

# Running R Commands

You can also run them in R scripts (see example in RStudio below)



# R Syntax

The R syntax is comprised of two major elements:

## Functions

***Functions perform operations: calculate a mean, build a table, create a graph, etc.***

## Objects

***Objects hold information: a collection of numbers, dates, words, models results, etc.***

We use functions to perform operations on objects

# Example: create a vector of numbers

The standard assignment operator in R is `<-`. We can use this in combination with `c()` to create an object `x`, which contains five numbers (`1`, `3`, `5`, `7`, `9`).

```
x <- c(1, 3, 5, 7, 9)
```

Place `x` inside `print()` to print `x` to the console

```
x <- c(1, 3, 5, 7, 9)
print(x)
```

NOTE: We can also use the `=` and move `->` to the end of the expression, but this is not recommended

# R Syntax: functions

```
x <- c(1, 3, 5, 7, 9)
print(x)
```

```
  [1] 1 3 5 7 9
```

In the example above, we've created object `x`, but what are `<-` and `c()`?

We can check this by passing them both in backticks to the `class()` function below.

```
class(`<-`)
```

```
  [1] "function"
```

```
class(`c`)
```

```
  [1] "function"
```

# Functions in R

***Functions*** perform operations (calculate, model, graph, etc.) on various ***objects*** that contain information (blood pressures, sales, political party affiliation, etc.)

Objects are similar to nouns: they hold information

```
object_1 <- "Sally"
object_2 <- "dog"
object_3 <- "road"
```

Functions are similar to verbs: they do things to nouns

```
work()
run()
implement()
```

# Functions and objects

Functions perform operations on objects.

```
sally_object <- "Sally"
work(sally_object)
```

*Sally works.*

```
dog_object <- "dog"
run(dog_object)
```

*The dog runs.*

```
idea_object <- "idea"
implement(idea_object)
```

*Implement the idea.*

# Packages and functions in R

Functions are stored in R packages.

Fortunately, R comes 'out-of-the-box' with a set of functions for basic data management and statistical calculations.

To access the functions in a package, use the following syntax:

```
package::function(object)
```

The `median()` function comes from the `stats` package.

```
stats::median(x)
```

```
[1] 5
```

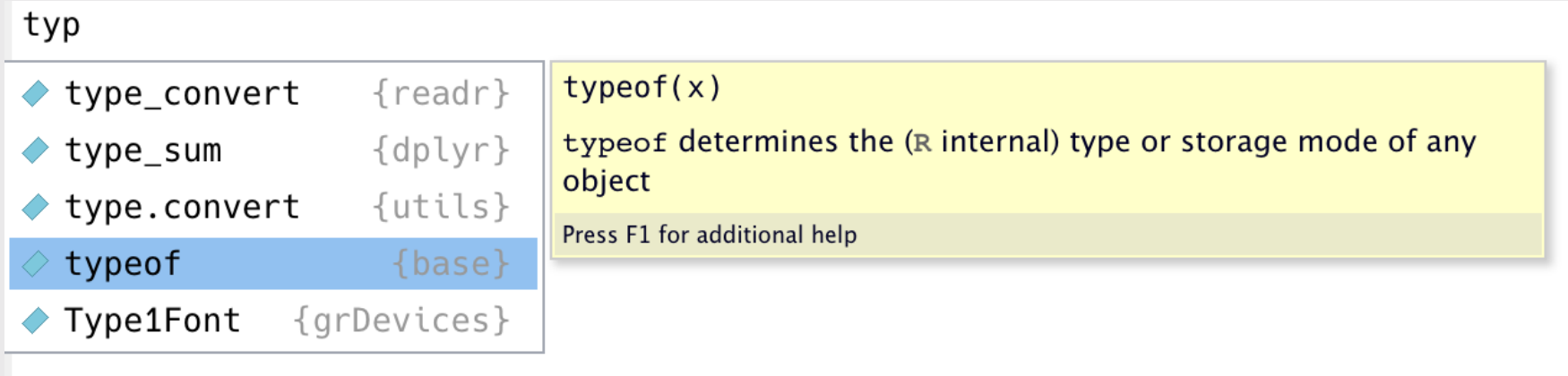
The `typeof()` function comes from the `base` package.

```
base::typeof(x)
```

```
[1] "double"
```

# Packages and functions

Use tab-completion and the arrow keys in RStudio to explore a packages functions.




We can take advantage of tab-completion by using names that allow us to look up common objects. For example, naming plot objects with a `plot_` prefix will allow us to use tab-completion to scroll through each object without having to remember the specific name.

# Installing packages from CRAN

To install packages from CRAN, we can use the `install.packages()` function.

```
install.packages("package name")
```

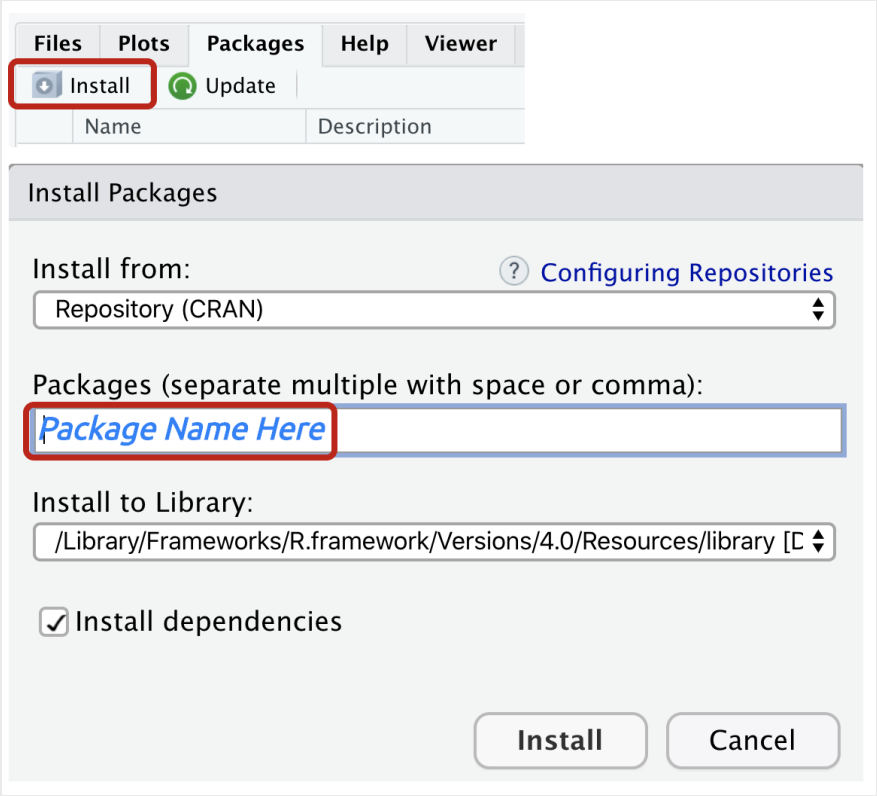
NOTE: *if this is the first time installing packages, you'll probably be presented with a list of CRAN "mirrors" to use--choose the mirror closest to you.*

To load the package into your environment, use `library(package name)`

```
library(package name)
```

# Installing packages from CRAN in RStudio

You can also use the **Packages** pane in RStudio



# Installing user packages

The code for user-written packages are typically stored in code repository, like Github.

To access user-written packages, you'll need to install the `devtools` or `remotes` packages.

```
install.packages("devtools")
install.packages("remotes")
```

Use `devtools::install_github()` or `remotes::install_github()` (with the author's username and package repository name)

```
devtools::install_github(<username>/<package>)
remotes::install_github(<username>/<package>)
```

# Objects

*R is typically referred to as an "object-oriented programming" language*

*We've covered functions, so now we'll dive into the aspects of some common R objects*

# Types of objects in R

- **Vectors**
  - atomic (logical, integer, double, and character)
  - S3 (factors, dates, date-times, durations)
- **Matrices**
  - two dimensional objects
- **Arrays**
  - multidimensional objects
- **Data frames & tibbles**
  - rectangular objects
- **Lists**
  - recursive objects

# Atomic vectors

Vectors are the fundamental data type in R.

Many of R's functions are *vectorised*, which means they're designed for performing operations on vectors.

The "atomic" in atomic vectors means, "*of or forming a single irreducible unit or component in a larger system.*"

Atomic vectors can be logical, integer, double, or character (strings).

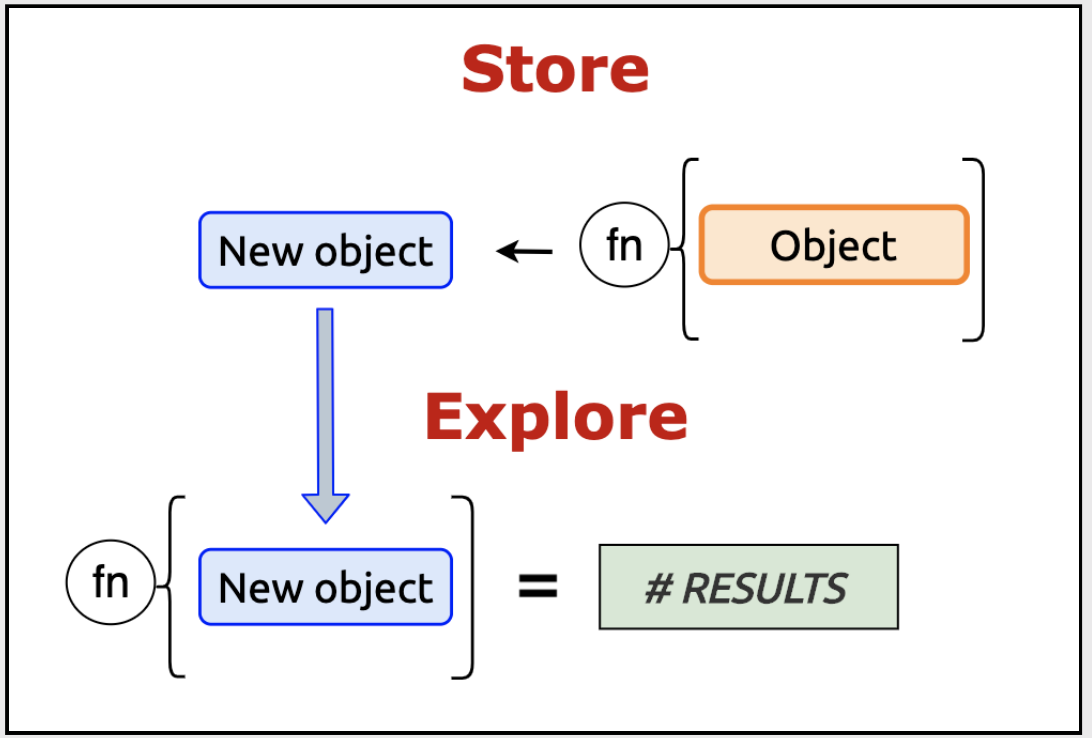
We will build each of these vectors using the previously covered assignment operator (`<-`) and `c()` function (*which stands for 'combine'*).

# Store and explore

A common practice in R is to create an object, perform an operation on that object with a function, and store the results in new object.

We then explore the contents of the new object with another function.

Many of the functions in R are written with this *store and explore* process in mind.



# Atomic vectors: numeric

The two atomic numeric vectors are integer and double.

Integer vectors are created with a number and capital letter `L` (i.e. `1L`, `10L`)

```
vec_integer <- c(1L, 10L, 100L)
```

Double vectors can be entered as decimals, but they can also be created in scientific notation (`2.46e8`), or values determined by the floating point standard (`Inf`, `-Inf` and `NaN`).

```
vec_double <- c(0.1, 1.0, 10.01)
```

# Atomic vectors: numeric

We will use the `typeof()` and `is.numeric()` functions to explore the contents of `vec_integer` and `vec_double`.

```
typeof(vec_integer)
```

```
[1] "integer"
```

```
is.numeric(vec_integer)
```

```
[1] TRUE
```

`typeof()` tells us that this is an `"integer"` vector, and `is.numeric()` tests to see if it is numeric (which is `TRUE`).

# Atomic vectors: logical vectors

Logical vectors can be `TRUE` or `FALSE` (or `T` or `F` for short). Below we use `typeof()` and `is.logical()` to explore the contents of `vec_logical`.

```
vec_logical <- c(TRUE, FALSE)
typeof(vec_logical)
```

```
[1] "logical"
```

```
is.logical(vec_logical)
```

```
[1] TRUE
```

# Atomic vectors: logical vectors

Logical vectors are handy because when we add them together, and the total number tells us how many TRUE values there are.

```
TRUE + TRUE + FALSE + TRUE
```

```
[1] 3
```

Logical vectors can be useful for subsetting (a way of extracting certain elements from a particular object) based on a set of conditions.

*How many elements in `vec_integer` are greater than `5`?*

```
vec_integer > 5
```

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

# Atomic vectors: character vectors

Character vectors store text data (note the double quotes). We'll *store and explore* again.

```
vec_character <- c("A", "B", "C")
typeof(vec_character)
```

```
[1] "character"
```

```
is.character(vec_character)
```

```
[1] TRUE
```

Character vectors typically store text information that we need to include in a calculation, visualization, or model. In these cases, we'll need to convert them into `factor`s. We'll cover those next.

# S3 vectors

*S3 vectors can be factors, dates, date-times, and difftimes.*

# S3 vectors: factors

Factors are categorical vectors with a given set of responses. Below we create a factor with three levels: `low`, `medium`, and `high`

```
vec_factor <- factor(x = c("low", "medium", "high"))
class(vec_factor)
```

```
[1] "factor"
```

Factors are not character variables, though. They get stored with an integer indicator for each character level.

```
typeof(vec_factor)
```

```
[1] "integer"
```

# S3 vectors: factor attributes

Factors are integer vectors with two additional attributes: `class` is set to `factor`, and `levels` for each unique response.

We can check this with `unique()` and `attributes()` functions.

```
unique(vec_factor)
```

```
[1] low    medium high
Levels: high low medium
```

```
attributes(vec_factor)
```

```
$levels
[1] "high"   "low"    "medium"

$class
[1] "factor"
```

# S3 vectors: factor attributes

Levels are assigned alphabetically, but we can manually assign the order of factor levels with the `levels` argument in `factor()`.

```
vec_factor <- factor(
      x = c("medium", "high", "low"),
      levels = c("low", "medium", "high"))
```

We can check the levels with `levels()` or `unclass()`

```
levels(vec_factor)
```

```
  [1] "low"    "medium" "high"
```

```
unclass(vec_factor)
```

```
  [1] 2 3 1
  attr(,"levels")
  [1] "low"    "medium" "high"
```

# S3 vectors: date

Dates are stored as `double` vectors with a `class` attribute set to `Date`.

R has a function for getting today's date, `Sys.Date()`. We'll create a `vec_date` using `Sys.Date()` and adding `1` and `2` to this value.

```
vec_date <- c(Sys.Date(),
              Sys.Date() + 1,
              Sys.Date() + 2)
vec_date
```

```
[1] "2021-11-30" "2021-12-01" "2021-12-02"
```

We can see adding units to the `Sys.Date()` added days to today's date. The `attributes()` function tells us this vector has it's own class.

```
attributes(vec_date)
```

```
$class
[1] "Date"
```

# S3 vectors: date calculations

Dates are stored as a number because they represent the amount of days since January 1, 1970, which is referred to as the UNIX Epoch.

`unclass()` tells us what the actual number is.

```
unclass(vec_date)
```

```
  [1] 18961 18962 18963
```

# S3 vectors: date-time

Date-times contain a bit more information than dates. The function to create a datetime vector is `as.POSIXct()`.

We'll convert `vec_date` to a date-time and store it in `vec_datetime_ct`. View the results below.

```
vec_date
```

```
[1] "2021-11-30" "2021-12-01" "2021-12-02"
```

```
vec_datetime_ct <- as.POSIXct(x = vec_date)
vec_datetime_ct
```

```
[1] "2021-11-29 17:00:00 MST" "2021-11-30 17:00:00 MST"
[3] "2021-12-01 17:00:00 MST"
```

We can see `vec_datetime_ct` stores some additional information.

# S3 vectors: date-time attributes

`vec_datetime_ct` is a `double` vector with an additional attribute of `class` set to `"POSIXct" "POSIXt"`.

```
typeof(vec_datetime_ct)
```

```
[1] "double"
```

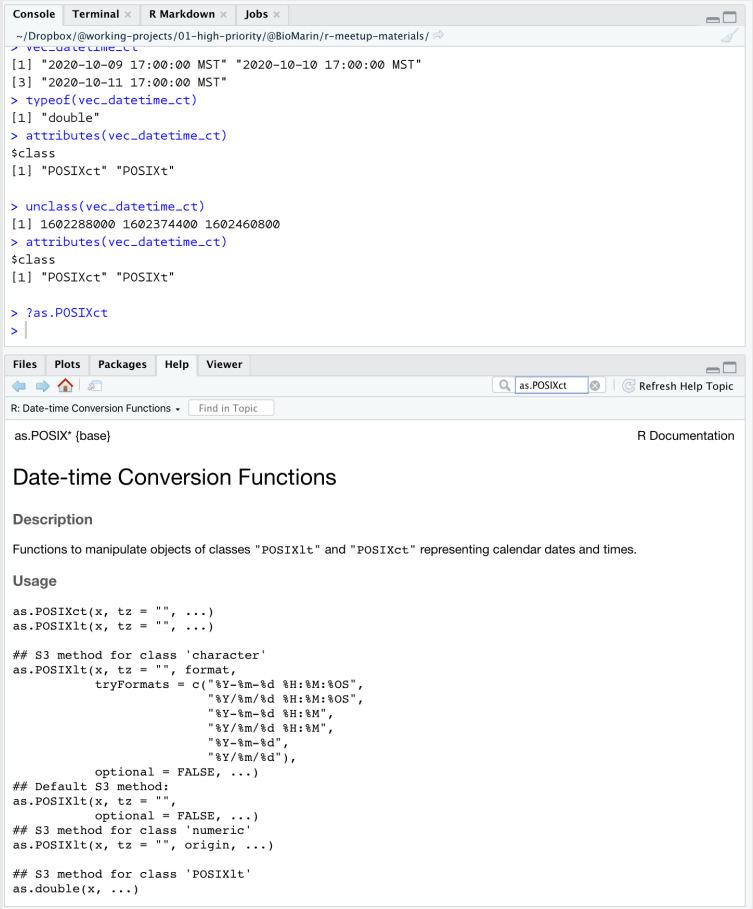
```
attributes(vec_datetime_ct)
```

```
$class
[1] "POSIXct" "POSIXt"
```

# S3 vectors: date-time help

Read more about date-times by entering the `as.POSIXct` function into the console preceded by a question mark.

```
?as.POSIXct
```



# S3 vectors: difftime

Difftimes are durations, so we to create them with `time_01` and `time_02`:

```
time_01 <- Sys.Date()
time_02 <- Sys.Date() + 10
time_01
```

```
[1] "2021-11-30"
```

```
time_02
```

```
[1] "2021-12-10"
```

Difftimes are stored as a `double` vector.

```
vec_difftime <- difftime(time_01,
                         time_02,
                         units = "days")
vec_difftime
```

```
Time difference of -10 days
```

```
typeof(vec_difftime)
```

```
[1] "double"
```

# S3 vectors: difftime attributes

Difftimes are their own `class` and have a `units` attribute set to whatever we've specified in the `units` argument.

```
attributes(vec_difftime)
```

```
$class
[1] "difftime"

$units
[1] "days"
```

We can see the actual number stored in the vector with `unclass()`

```
unclass(vec_difftime)
```

```
[1] -10
attr(,"units")
[1] "days"
```

# Matrices

A matrix is several vectors stored together into two a two-dimensional object.

```
mat_data <- matrix(
               data = c(vec_double,
vec_integer),
                    nrow = 3, ncol = 2,
                    byrow = FALSE)
mat_data
```

```
      [,1] [,2]
[1,]  0.10    1
[2,]  1.00   10
[3,] 10.01  100
```

We can check the dimensions of `mat_data` with `dim()`.

```
dim(mat_data)
```

```
[1] 3 2
```

This is a three-column, two-row matrix.

# Matrix positions

The output in the console tells us where each element is located in `mat_data`.

For example, if I want to get the `10` that's stored in `vec_integer`, I can use look at the output and use the indexes.

```
mat_data
```

```
      [,1] [,2]
[1,]  0.10    1
[2,]  1.00   10
[3,] 10.01  100
```

By placing the index (`[2, 2]`) next to the object, I am telling R, "*only return the value in this position*".

```
mat_data[2, 2]
```

```
[1] 10
```

# Arrays

Arrays are like matrices, but they can have more dimensions.

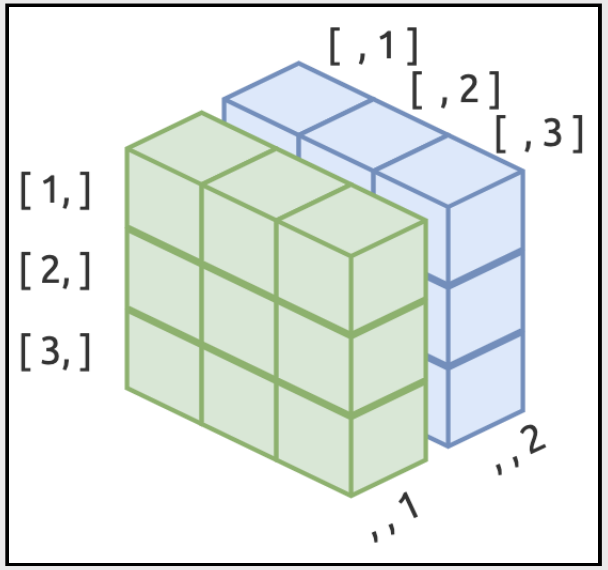
```
dat_array <- array(
                 data = c(1, 2, 3, 4, 5,
                          6, 7, 8, 9, 10,
                          11, 12, 13, 14,
                          15, 16, 17, 18),
                    dim = c(3, 3, 2))
```

```
dat_array
```

```
, , 1

     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    2    5    8
[3,]    3    6    9

, , 2

     [,1] [,2] [,3]
[1,]   10   13   16
[2,]   11   14   17
[3,]   12   15   18
```

# Array layers

`dat_array` contains numbers 1 through 18 in three columns and three rows, stacked in two *layers*.




```
class(dat_array)
```

```
[1] "array"
```

```
class(mat_data)
```

```
[1] "matrix" "array"
```

Matrices are arrays, but arrays are not matrices

# Data Frames

Data frames are rectangular data with rows and columns (or observations and variables).

```
DataFrame <- data.frame(
                character = c("A", "B",
"C"),
                integer = c(0.1, 1.0,
10.01),
                logical = c(TRUE, FALSE,
TRUE))
```

```
DataFrame
```

```
  character integer logical
1         A    0.10    TRUE
2         B    1.00   FALSE
3         C   10.01    TRUE
```

NOTE: `stringsAsFactors = FALSE` is not required as of R version 4.0.0.

# Data Frames

Check the structure of the `data.frame` with `str()`

```
str(DataFrame)
```

```
'data.frame':    3 obs. of  3 variables:
 $ character: chr  "A" "B" "C"
 $ integer  : num  0.1 1 10
 $ logical  : logi  TRUE FALSE TRUE
```

`str()` gives us a transposed view of the `DataFrame` object, and tells us the dimensions of the object.

# Tibbles

Tibbles are a special kind of `data.frame` (*they print better to the console and character vectors are never coerced into factors*).

```
Tibble <- tibble::tribble(
       ~character, ~integer,  ~logical,
              "A",      0.1,      TRUE,
              "B",        1,     FALSE,
              "C",    10.01,      TRUE)
```

The syntax to build them is slightly different, too.

```
Tibble
```

```
# A tibble: 3 × 3
  character integer logical
  <chr>       <dbl> <lgl>
1 A             0.1 TRUE
2 B             1   FALSE
3 C            10.0 TRUE
```

# Tibbles

Check the structure of `Tibble`.

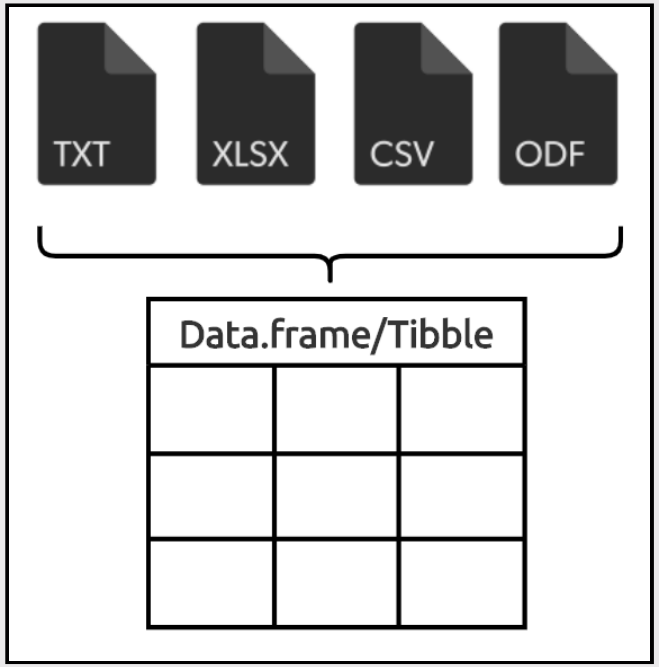
```
str(Tibble)
```

```
  tibble [3 × 3] (S3:
tbl_df/tbl/data.frame)
   $ character: chr [1:3] "A" "B" "C"
   $ integer  : num [1:3] 0.1 1 10
   $ logical  : logi [1:3] TRUE FALSE TRUE
```

`str()` tells us `tibbles` are `S3` objects, with types `tbl_df`, `tbl`, and `data.frame`.

# Data frames and tibbles

If you're importing spreadsheets, most of the work you'll do in R will be with rectangular data objects (i.e. `data.frame`s and `tibble`s).




*These are the common rectangular data storage object for tabular data in R*

# Data frames & tibbles

DataFrame

```
  character integer logical
1         A    0.10    TRUE
2         B    1.00   FALSE
3         C   10.01    TRUE
```

the `data.frame` prints the column names and contents

Tibble

```
# A tibble: 3 × 3
  character integer logical
  <chr>       <dbl> <lgl>
1 A             0.1 TRUE
2 B             1   FALSE
3 C            10.0 TRUE
```

the `tibble` prints the column names, dimensions, formats, and contents

# Data frames & tibbles

If we check the `type` of the `DataFrame` and `Tibble`...

```
typeof(DataFrame)
```

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

```
typeof(Tibble)
```

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

...we see they are `lists`

# Data Frames & Tibbles

Both `data.frame`s and `tibble`s are their own class,

```
class(DataFrame)
```

```
[1] "data.frame"
```

```
class(Tibble)
```

```
[1] "tbl_df"     "tbl"        "data.frame"
```

So we can think of `data.frame`s and `tibble`s as special kinds of *rectangular* lists, made with different types of vectors, with each vector being of equal length.

# Lists

Lists are special objects because they can contain all other objects (including other lists).

```
dat_list <- list(
             "integer" = vec_integer,
             "array" = dat_array,
             "matrix data" = mat_data,
             "data frame" = DataFrame,
             "tibble" = Tibble)
```

Lists have a `names` attribute, which we've defined above in double quotes.

```
attributes(dat_list)
```

```
  $names
  [1] "integer"     "array"
"matrix data" "data frame"  "tibble"
```

# List structure

If we check the structure of the `dat_list`, we see the structure of list, and the structure of the elements in the list.

```
str(dat_list)
```

```
List of 5
 $ integer    : int [1:3] 1 10 100
 $ array      : num [1:3, 1:3, 1:2] 1 2 3 4 5 6 7 8 9 10 ...
 $ matrix data: num [1:3, 1:2] 0.1 1 10 1 10 ...
 $ data frame :'data.frame':    3 obs. of  3 variables:
  ..$ character: chr [1:3] "A" "B" "C"
  ..$ integer  : num [1:3] 0.1 1 10
  ..$ logical  : logi [1:3] TRUE FALSE TRUE
 $ tibble     : tibble [3 × 3] (S3: tbl_df/tbl/data.frame)
  ..$ character: chr [1:3] "A" "B" "C"
  ..$ integer  : num [1:3] 0.1 1 10
  ..$ logical  : logi [1:3] TRUE FALSE TRUE
```

# Recap

**In R, two major elements: functions and objects.**

- *functions are verbs, objects are nouns*

**Packages: use `install.packages()` and `library()` to load functions from packages**

- *or `devtools::install_github(<username>/<package>)` or `remotes::install_github(<username>/<package>)`*

**The most common R object is a vector**

- Atomic vectors: *logical, integer, double, or character (strings)*
- S3 vectors: *factors, dates, date-times, and difftimes*

# Recap, cont.

**More complicated data structures: matrices and arrays**

- Matrix: *two-dimensional object*
- Array: *multidimensional object*

**Rectangular data structures:**

- `data.frame`*s &* `tibble`*s are special kinds of rectangular lists, which can hold different types of vectors, with each vector being of equal length*

**Catch-all data structures:**

- *lists can contain all other objects (including other lists)*

# More resources

Learn more about R objects in the help files or the following online texts:

1. R for Data Science
2. Advanced R
3. Hands on Programming with R
4. R Language Definition

# THANK YOU!

## Feedback

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