Finding your way in R

Data Wrangling, Session 2

Kieran Healy

Code Horizons

July 22, 2024

Writing documents

Using Quarto to produce and reproduce your work

Where we want to end up

Covid Cases

Kieran Healy

4/18/2021

Lorem Ipsum

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Table 1: Total cases in three countries.

country	cases
United States	30706129
France	4822470
United Kingdom	4359388

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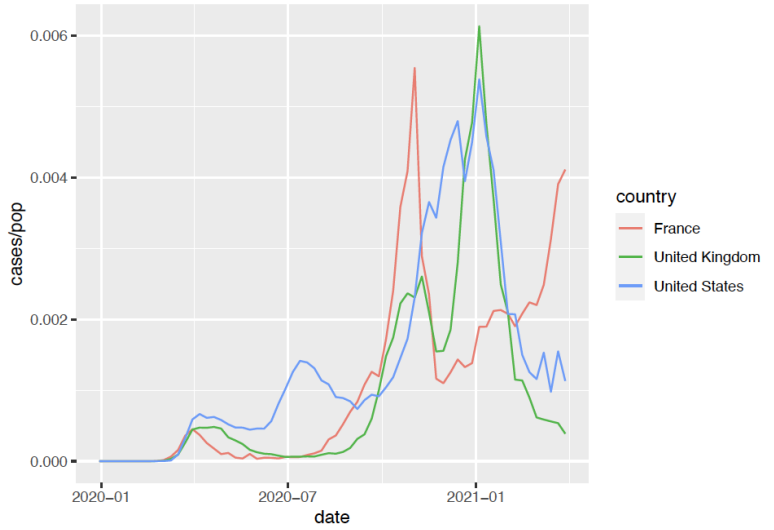

PDF out

Where we want to end up

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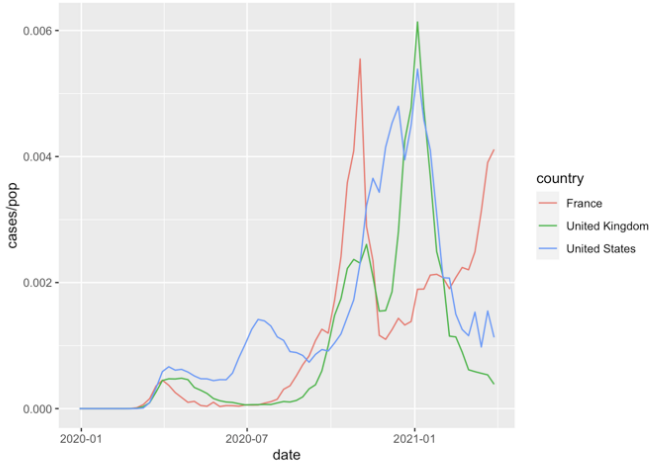

HTML out

Where we want to end up

Covid Cases

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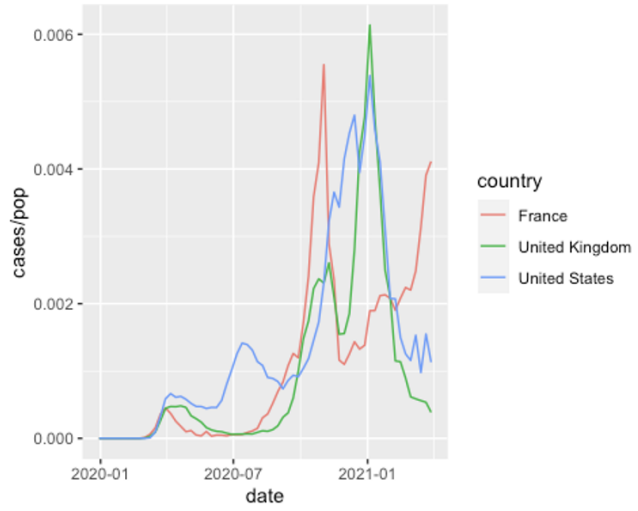

Word out

How to get there?

covidcases.R

```
# COVID
# Get data from ECDC
# FIXME Write a fn to
# do this
data_raw <- read_csv[url]

# Clean it
# Notes on the cleaning
# process.

covid <- data_raw %>%
         mutate[…] %>%
         select[…]


# Make some plots
covid %>%
     ggpplot[…] +
     geom_line[…]
```

Write an R script with some notes inside. Create some figures and tables, paste them into our document.

This will work, but we can do better.

We can make this ...

1. Lorem Ipsum

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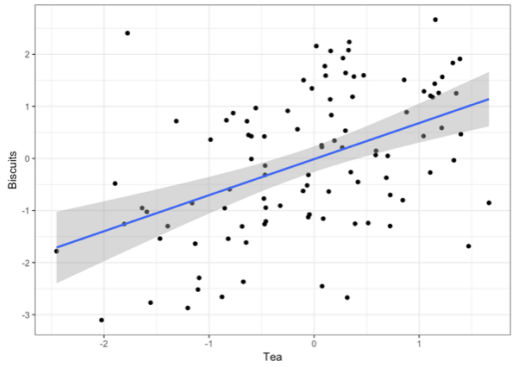

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… by writing this

1. Lorem Ipsum

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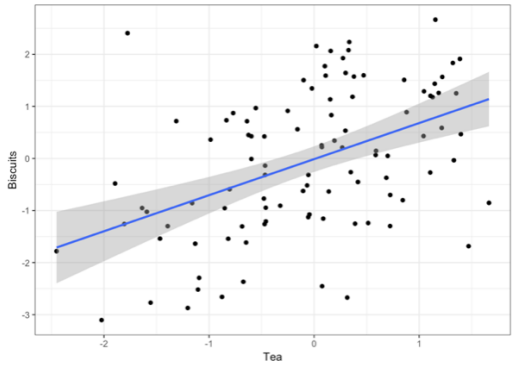

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```
# Lorem Ipsum

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aliqua. Ut enimad minim veniam, quis nostrud exercitation
ullamco laboris nisi ut aliquip ex ea commodo consequat.
```

```
library(ggplot2)
tea <- rnorm(100)
biscuits <- tea + rnorm(100, 0, 1.3)
data <- data.frame(tea, biscuits)
p <- ggplot(data, aes(x = tea, y = biscuits)) +
    geom_point() +
    geom_smooth(method = "lm") +
    labs(x = "Tea", y = "Biscuits") + theme_bw()
print(p)
```

```
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cillum dolore eu fugiat nulla pariatur. Excepteur sint
occaecat cupidatat non proident, sunt in culpa qui officia
deserunt mollit anim id est laborum.
```

The code gets replaced by its output

```
# Lorem Ipsum

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sed do *eiusmod tempor* incididunt ut labore et dolore magna
aliqua. Ut enimad minim veniam, quis nostrud exercitation
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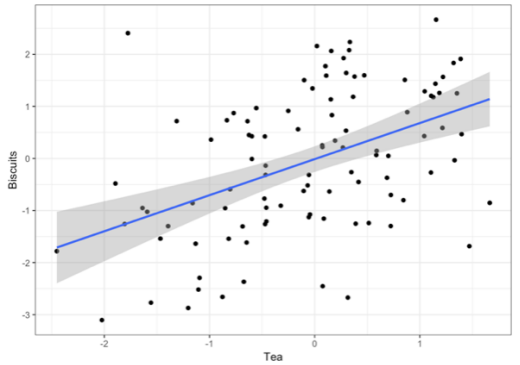

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```
---
title: "Covid Cases"
author: "Kieran Healy"
date: "4/18/2021"
output: html_document
---
```

```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = FALSE)
```

Introduction

We'll be looking at some COVID case data.

```{r libraries, message = FALSE}

library(tidyverse)
library(here)
library(janitor)
library(socviz)

```

```{r load-the-data, message = FALSE}
covid_cases <- read_csv("data/national_cases.csv")
```

Lorem Ipsum

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```{r case-table}
covid_cases %>%
  filter(country %in% c("United States", "United Kingdom", "France")) %>%
  group_by(country) %>%
  summarize(cases = sum(cases)) %>%
  arrange(desc(cases)) %>%
  kable(caption = "Total cases in three countries.")
```

```
---
title: "Covid Cases"
author: "Kieran Healy"
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---
```

Header section with metadata

```
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  kable(caption = "Total cases in three countries.")
```
```

Code chunk

In RStudio, code chunks can be "played" one at a time

Code chunks can have their own labels and options

Text with Markdown formatting

Chunks are replaced by their output when the document is knitted

Covid Cases

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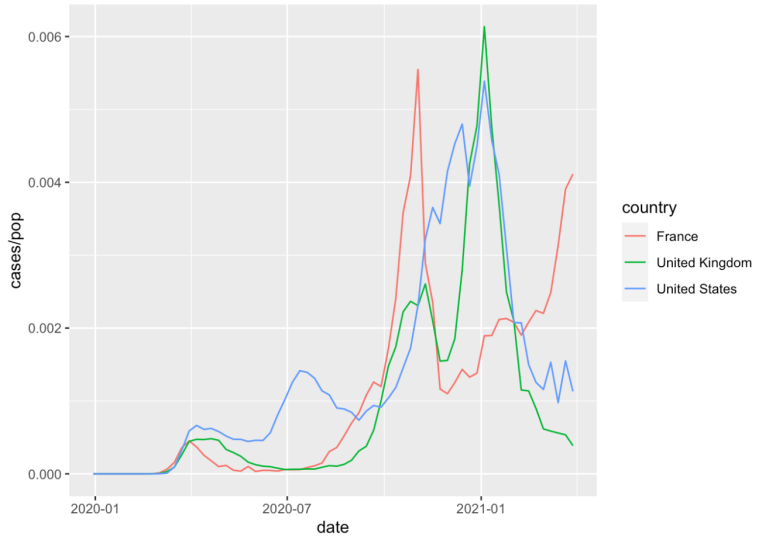
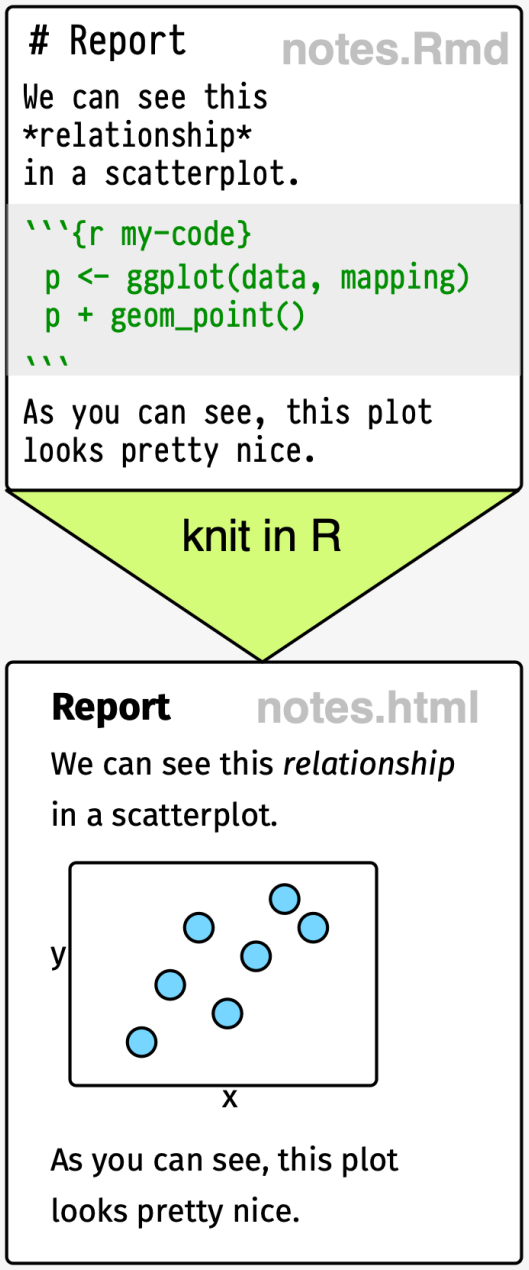


This approach has its limitations, but it's *very* useful.



When learning these workflows, stick with the defaults at the beginning. Later, you can customize the look of the output in all kinds of ways.

The right frame of mind

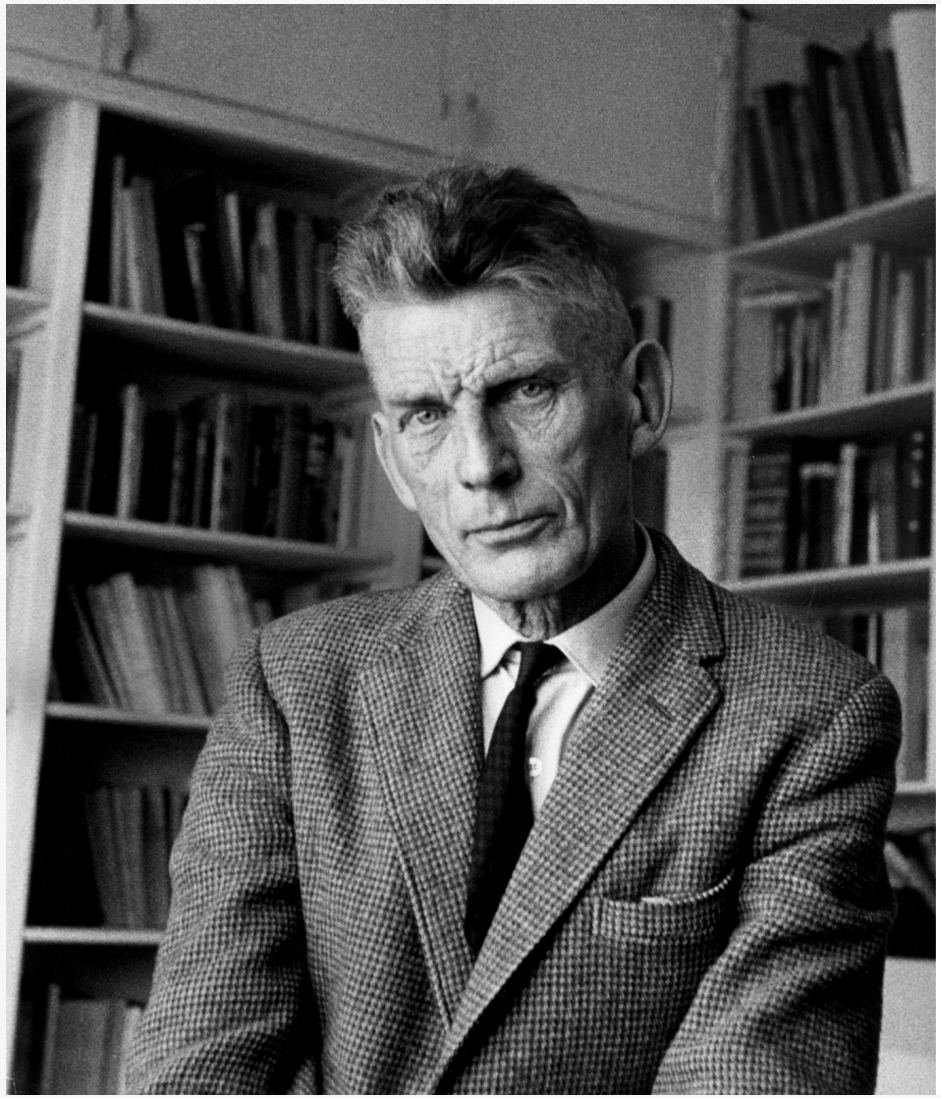
This is like learning how to drive a car, or how to cook in a kitchen … or learning to speak a language.

After some orientation to what's where, you will learn best by *doing*.

Software is a pain, but you won't crash the car or burn your house down.

TYPE OUT YOUR CODE BY HAND

By far the best way to get a feel for how R works, and to get comfortable with the cycle of try-fail-cry-fix-wail-retry that is a permanent part of writing any code.



Ever tried.
Ever failed.
No matter.
Try again.
Fail again.
Fail better.

Samuel Beckett,
early data analyst

Samuel Beckett

Getting Oriented

Loading the tidyverse libraries

```
library(tidyverse)
```

```
── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
✔ dplyr     1.1.3     ✔ readr     2.1.4
✔ forcats   1.0.0     ✔ stringr   1.5.0
✔ ggplot2   3.4.4     ✔ tibble    3.2.1
✔ lubridate 1.9.3     ✔ tidyr     1.3.0
✔ purrr     1.0.2
── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag()    masks stats::lag()
ℹ Use the conflicted package to force all conflicts to become errors
```

The tidyverse has several components.

We'll return to this message about Conflicts later.

Tidyverse components

```
library(tidyverse)
Loading tidyverse: ggplot2
Loading tidyverse: tibble
Loading tidyverse: tidyr
Loading tidyverse: readr
Loading tidyverse: purrr
Loading tidyverse: dplyr
```

Call the package and ...

- ◁ **Draw graphs**
- ◁ **Nicer data tables**
- ◁ **Tidy your data**
- ◁ **Get data into R**
- ◁ **Fancy Iteration**
- ◁ **Action verbs for tables**

What R looks like

Code you can type and run:

```
## Inside code chunks, lines beginning with a # character are comments
## Comments are ignored by R

my_numbers ← c(1, 1, 2, 4, 1, 3, 1, 5) # Anything after a # character is ignored as well
```

Output:

```
my_numbers
```

```
[1] 1 1 2 4 1 3 1 5
```

This is equivalent to running the code above, typing `my_numbers` at the console, and hitting enter.

What R looks like

By convention, code output in documents is prefixed by ##

Also by convention, outputting vectors, etc, gets a counter keeping track of the number of elements. For example,

```
letters
```

```
 [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s"
[20] "t" "u" "v" "w" "x" "y" "z"
```

SOME THINGS TO KNOW ABOUT R

0. It’s a calculator

Arithmetic

```
(31 * 12) / 2^4
```

```
[1] 23.25
```

```
sqrt(25)
```

```
[1] 5
```

```
log(100)
```

```
[1] 4.60517
```

```
log10(100)
```

```
[1] 2
```

0. It's a calculator

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```
sqrt(25)
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```
[1] 5
```

```
log(100)
```

```
[1] 4.60517
```

```
log10(100)
```

```
[1] 2
```

Logic

```
4 < 10
```

```
[1] TRUE
```

```
4 > 2 & 1 > 0.5 # The "&" means "and"
```

```
[1] TRUE
```

```
4 < 2 | 1 > 0.5 # The "|" means "or"
```

```
[1] TRUE
```

```
4 < 2 | 1 < 0.5
```

```
[1] FALSE
```

Boolean and Logical operators

Logical equality and inequality (yielding a `TRUE` or `FALSE` result) is done with `==` and `!=`. Other logical operators include `<`, `>`, `<=`, `>=`, and `!` for negation.

```
## A logical test
2 == 2 # Write `=` twice
```

```
[1] TRUE
```

```
## This will cause an error, because R will think you are trying to assign a value
2 = 2

## Error in 2 = 2 : invalid (do_set) left-hand side to assignment
```

```
3 != 7 # Write `!` and then `=` to make `!=`
```

```
[1] TRUE
```

Watch out!

Here's a gotcha. You might think you could write `3 < 5 & 7` and have it be interpreted as "Three is less than five and also less than seven [True or False?]":

```
3 < 5 & 7
```

```
[1] TRUE
```

It seems to work!

Watch out!

But now try `3 < 5 & 1`, where your intention is “Three is less than five and also less than one [True or False?]”

```
3 < 5 & 1
```

```
[1] TRUE
```

What’s happening is that `3 < 5` is evaluated first, and resolves to `TRUE`, leaving us with the expression `TRUE & 1`.

R interprets this as `TRUE & as.logical(1)`.

In Boolean algebra, `1` resolves to `TRUE`. Any other number is `FALSE`. So,

Watch out!

```
TRUE & as.logical(1)
```

```
[1] TRUE
```

```
3 < 5 & 3 < 1
```

```
[1] FALSE
```

You have to make your comparisons explicit.

Logic and floating point arithmetic

Let's evaluate `0.6 + 0.2 == 0.8`

Logic and floating point arithmetic

Let's evaluate `0.6 + 0.2 == 0.8`

```
0.6 + 0.2 == 0.8
```

```
[1] TRUE
```

Logic and floating point arithmetic

Let's evaluate `0.6 + 0.2 == 0.8`

```
0.6 + 0.2 == 0.8
```

```
[1] TRUE
```

Now let's try `0.6 + 0.3 == 0.9`

Logic and floating point arithmetic

Let's evaluate `0.6 + 0.2 == 0.8`

```
0.6 + 0.2 == 0.8
```

```
[1] TRUE
```

Now let's try `0.6 + 0.3 == 0.9`

```
0.6 + 0.3 == 0.9
```

```
[1] FALSE
```

Er. That's not right.

Welcome to floating point math!

In Base 10, you can't precisely express fractions like $\frac{1}{3}$ and $\frac{1}{9}$. They come out as repeating decimals: 0.3333… or 0.1111… You *can* cleanly represent fractions that use a prime factor of the base, which in the case of Base 10 are 2 and 5.

Welcome to floating point math!

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Computers represent numbers as binary (i.e. Base 2) floating-points. In Base 2, the only prime factor is 2. So $\frac{1}{5}$ or $\frac{1}{10}$ in binary would be repeating.

Logic and floating point arithmetic

When you do binary math on repeating numbers and convert back to decimals you get tiny leftovers, and this can mess up *logical* comparisons of equality. The `all.equal()` function exists for this purpose.

```
print(.1 + .2)
```

```
[1] 0.3
```

```
print(.1 + .2, digits=18)
```

```
[1] 0.300000000000000044
```

```
all.equal(.1 + .2, 0.3)
```

```
[1] TRUE
```

See e.g. https://0.30000000000000004.com

More later on why this might bite you, and how to deal with it

For now, “Be very careful about doing logical comparisons on floating-point numbers” is not a bad rule.

1. Everything in R has a name

```
my_numbers # We created this a few minutes ago
```

```
[1] 1 1 2 4 1 3 1 5
```

```
letters  # This one is built-in
```

```
 [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s"
[20] "t" "u" "v" "w" "x" "y" "z"
```

```
pi  # Also built-in
```

```
[1] 3.141593
```

Some names are forbidden

Or it's a *really* bad idea to try to use them

```
TRUE
FALSE
Inf
NaN
NA
NULL

for
if
while
break
function
```

2. Everything is an object

There are a few built-in objects:

```
letters
```

```
 [1] "a" "b" "c" "d" "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s"
[20] "t" "u" "v" "w" "x" "y" "z"
```

```
pi
```

```
[1] 3.141593
```

```
LETTERS
```

```
 [1] "A" "B" "C" "D" "E" "F" "G" "H" "I" "J" "K" "L" "M" "N" "O" "P" "Q" "R" "S"
[20] "T" "U" "V" "W" "X" "Y" "Z"
```

3. You can create objects

In fact, this is mostly what we will be doing.

Objects are created by assigning a thing to a name:

```
## name ... gets ... this stuff
my_numbers ← c(1, 2, 3, 1, 3, 5, 25, 10)

## name ... gets ... the output of the function `c()`
your_numbers ← c(5, 31, 71, 1, 3, 21, 6, 52)
```

The `c()` function *combines* or *concatenates* things

The assignment operator

The assignment operator performs the action of creating objects

Use a keyboard shortcut to write it:

Press `option` *and* `-` on a Mac

Press `alt` *and* `-` on Windows

Assignment with =

You can use = as well as ← for assignment.

```
my_numbers = c(1, 2, 3, 1, 3, 5, 25)

my_numbers
```

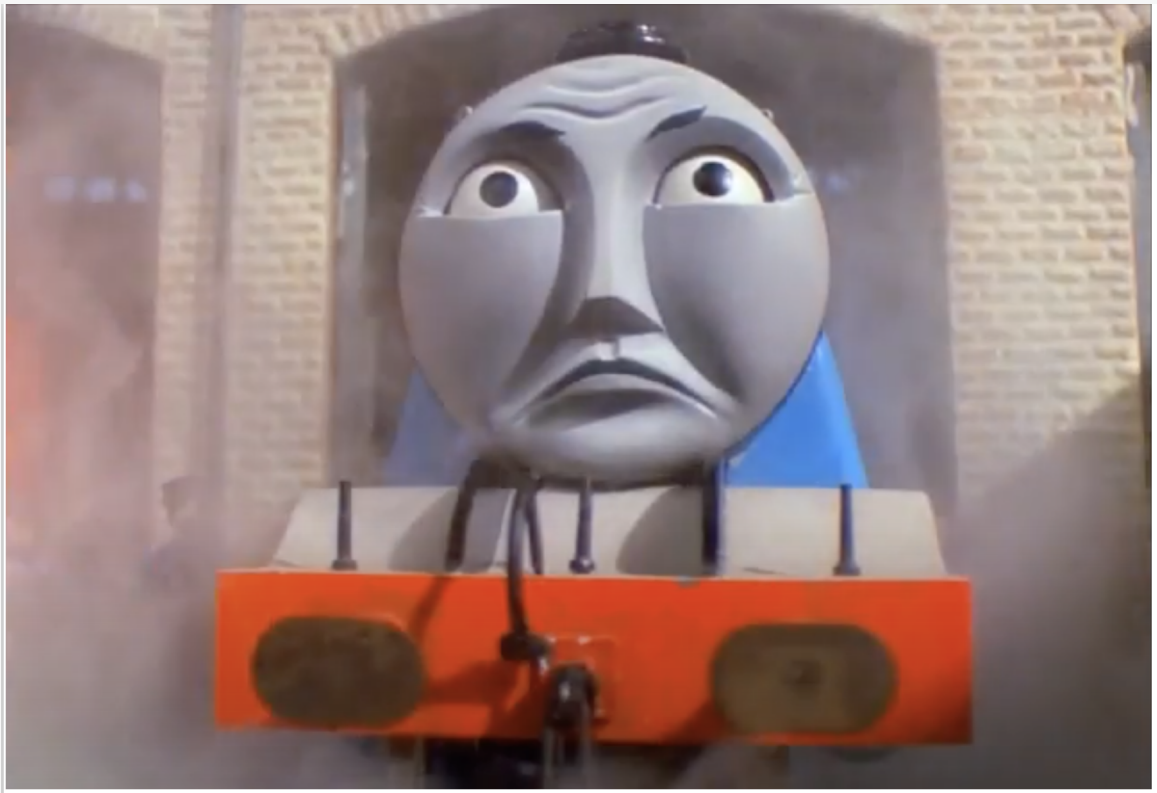
```
[1]  1  2  3  1  3  5 25
```

On the other hand, = has a different meaning when used in functions.

I'm going to use ← for assignment throughout.

Be consistent either way.

Assignment with =



It isn't *wrong*, but we just *don't do it*.

4. Do things to objects with functions

```
## this object ... gets ... the output of this function
my_numbers ← c(1, 2, 3, 1, 3, 5, 25, 10)

your_numbers ← c(5, 31, 71, 1, 3, 21, 6, 52)
```

```
my_numbers
```

```
[1]  1  2  3  1  3  5 25 10
```

4. Do things to objects with functions

Functions can be identified by the parentheses after their names.

```
my_numbers
```

```
[1]  1  2  3  1  3  5 25 10
```

```
## If you run this you'll get an error
mean()
```

What functions usually do

They take **inputs** to **arguments**

They perform **actions**

They produce, or return, **outputs**

```
mean(x = my_numbers)
```

What functions usually do

They take **inputs** to **arguments**

They perform **actions**

They produce, or return, **outputs**

```
mean(x = my_numbers)
[1] 6.25
```

What functions usually do

```
## Get the mean of what? Of x.
## You need to tell the function what x is
mean(x = my_numbers)
```

```
[1] 6.25
```

```
mean(x = your_numbers)
```

```
[1] 23.75
```

What functions usually do

If you don't *name* the arguments, R assumes you are providing them in the order the function expects.

```
mean(your_numbers)
```

```
[1] 23.75
```

What functions usually do

What arguments? Which order? Read the function's help page

```
help(mean)
```

```
## quicker
?mean
```

How to read an R help page?

What functions usually do

Arguments often tell the function what to do in specific circumstances

```
missing_numbers ← c(1:10, NA, 20, 32, 50, 104, 32, 147, 99, NA, 45)

mean(missing_numbers)
```

```
[1] NA
```

```
mean(missing_numbers, na.rm = TRUE)
```

```
[1] 32.44444
```

Or select from one of several options

```
## Look at ?mean to see what `trim` does
mean(missing_numbers, na.rm = TRUE, trim = 0.1)
```

```
[1] 27.25
```

What functions usually do

There are all kinds of functions. They return different things.

```
summary(my_numbers)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    1.75    3.00    6.25    6.25   25.00 
```

What functions usually do

You can assign the output of a function to a name, which turns it into an object. (Otherwise it'll send its output to the console.)

```
my_summary ← summary(my_numbers)

my_summary
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    1.75    3.00    6.25    6.25   25.00 
```

What functions usually do

Objects hang around in your work environment until they are overwritten by you, or are deleted.

```
## rm() function removes objects
rm(my_summary)

my_summary

## Error: object 'my_summary' not found
```

Functions can be nested

```
c(1:20)
```

```
 [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

```
mean(c(1:20))
```

```
[1] 10.5
```

```
summary(mean(c(1:20)))
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   10.5    10.5    10.5    10.5    10.5    10.5 
```

```
names(summary(mean(c(1:20))))
```

```
[1] "Min."    "1st Qu." "Median"  "Mean"    "3rd Qu." "Max."
```

```
length(names(summary(mean(c(1:20)))))
```

```
[1] 6
```

Nested functions are evaluated from the inside out.

Use the pipe operator: |>

Instead of deeply nesting functions in parentheses, we can use the *pipe operator*:

```
c(1:20) |> mean() |> summary() |> names() |>  length()
```

```
[1] 6
```

Read this operator as "***and then***"

Use the pipe operator: |>

Better, vertical space is free in R:

```
c(1:20) ▷
  mean() ▷
  summary() ▷
  names() ▷
  length()
```

```
[1] 6
```

Pipelines make code more readable

Not great, Bob:

```
serve(stir(pour_in_pan(whisk(crack_eggs(get_from_fridge(eggs), into = "bowl"), len = 40), temp = "med-high")))
```

Notice how the first thing you read is the last operation performed.

Pipelines make code more readable

We can use vertical space and indents, but it's really not much better:

```
serve(
  stir(
    pour_in_pan(
      whisk(
        crack_eggs(
          get_from_fridge(eggs),
        into = "bowl"),
      len = 40),
    temp = "med-high")
  )
)
```

Pipelines make code more readable

Much nicer:

```
eggs ▷
  get_from_fridge() ▷
  crack_eggs(into = "bowl") ▷
  whisk(len = 40) ▷
  pour_in_pan(temp = "med-high") ▷
  stir() ▷
  serve()
```

We'll still use nested parentheses quite a bit, often in the context of a function working inside a pipeline. But it's good not to have too many levels of nesting.

The other pipe: %>%

The Base R pipe operator, |> is a relatively recent addition to R.

Piping operations were originally introduced in a package called called `magrittr`, where it took the form %>%

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The other pipe: %>%

The Base R pipe operator, `|>` is a relatively recent addition to R.

Piping operations were originally introduced in a package called called `magrittr`, where it took the form `%>%`

It's been so successful, a version of it has been incorporated into Base R. It *mostly* but does not *quite* work the same way as `%>%` in every case. We'll use the Base R pipe in this course, but you'll see the Magrittr pipe a lot out in the world.

With the Base R pipe, you can only pass an object to the *first* argument in a function. This is fine for most tidyverse pipelines, where the first argument is usually (implicitly) the data. But it does mean that most Base R functions will continue not to be easily piped, as most of them do not follow the convention of passing the current data as the first argument

Functions are bundled into packages

Packages are loaded into your working environment using the `library()` function:

```
## A package containing a dataset rather than functions
library(gapminder)

gapminder
```

```
# A tibble: 1,704 × 6
   country     continent  year lifeExp      pop gdpPercap
   <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
 1 Afghanistan Asia       1952    28.8  8425333      779.
 2 Afghanistan Asia       1957    30.3  9240934      821.
 3 Afghanistan Asia       1962    32.0 10267083      853.
 4 Afghanistan Asia       1967    34.0 11537966      836.
 5 Afghanistan Asia       1972    36.1 13079460      740.
 6 Afghanistan Asia       1977    38.4 14880372      786.
 7 Afghanistan Asia       1982    39.9 12881816      978.
 8 Afghanistan Asia       1987    40.8 13867957      852.
 9 Afghanistan Asia       1992    41.7 16317921      649.
10 Afghanistan Asia       1997    41.8 22227415      635.
# ℹ 1,694 more rows
```

Functions are bundled into packages

You need only *install* a package once (and occasionally update it):

```
## Do at least once for each package. Once done, not needed each time.
install.packages("palmerpenguins", repos = "http://cran.rstudio.com")

## Needed sometimes, especially after an R major version upgrade.
update.packages(repos = "http://cran.rstudio.com")
```

Functions are bundled into packages

But you must *load* the package in each R session before you can access its contents:

```
## To load a package, usually at the start of your RMarkdown document or script file
library(palmerpenguins)
penguins
```

```
# A tibble: 344 × 8
   species island    bill_length_mm bill_depth_mm flipper_length_mm body_mass_g
   <fct>   <fct>              <dbl>         <dbl>             <int>       <int>
 1 Adelie  Torgersen           39.1          18.7               181        3750
 2 Adelie  Torgersen           39.5          17.4               186        3800
 3 Adelie  Torgersen           40.3          18                 195        3250
 4 Adelie  Torgersen           NA            NA                  NA          NA
 5 Adelie  Torgersen           36.7          19.3               193        3450
 6 Adelie  Torgersen           39.3          20.6               190        3650
 7 Adelie  Torgersen           38.9          17.8               181        3625
 8 Adelie  Torgersen           39.2          19.6               195        4675
 9 Adelie  Torgersen           34.1          18.1               193        3475
10 Adelie  Torgersen           42            20.2               190        4250
# ℹ 334 more rows
# ℹ 2 more variables: sex <fct>, year <int>
```

Grabbing a single function with ::

“Reach in” to an unloaded package and grab a function directly, using `<package>::<function>`

Grabbing a single function with ::

```
## A little glimpse of what we'll do soon
penguins |>
  select(species, body_mass_g, sex) |>
  gtsummary::tbl_summary(by = species)
```

Characteristic	**Adelie**, N = 152	**Chinstrap**, N = 68	**Gentoo**, N = 124
body_mass_g, Median (IQR)	3,700 (3,350 – 4,000)	3,700 (3,488 – 3,950)	5,000 (4,700 – 5,500)
Unknown	1	0	1
sex, n (%)			
female	73 (50)	34 (50)	58 (49)
male	73 (50)	34 (50)	61 (51)
Unknown	6	0	5

Remember those conflicts?

```
library(tidyverse)
```

```
## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.3     ✓ purrr   0.3.4
## ✓ tibble  3.1.0     ✓ dplyr   1.0.5
## ✓ tidyr   1.1.3     ✓ stringr 1.4.0
## ✓ readr   1.4.0     ✓ forcats 0.5.1

## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## x dplyr::filter()  masks stats::filter()
## x purrr::is_null() masks testthat::is_null()
## x dplyr::lag()     masks stats::lag()
## x dplyr::matches() masks tidyr::matches(), testthat::matches()
```

Notice how some functions in different packages have the same names.

Related concepts of *namespaces* and *environments*.

The scope of names

```
x ← c(1:10)
y ← c(90:100)

x
```

```
 [1]  1  2  3  4  5  6  7  8  9 10
```

```
y
```

```
 [1]  90  91  92  93  94  95  96  97  98  99 100
```

```
mean()

## Error in mean.default() : argument "x" is missing, with no default
```

The scope of names

```
mean(x) # argument names are internal to functions
```

```
[1] 5.5
```

```
mean(x = x)
```

```
[1] 5.5
```

```
mean(x = y)
```

```
[1] 95
```

```
x
```

```
 [1]  1  2  3  4  5  6  7  8  9 10
```

```
y
```

```
 [1]  90  91  92  93  94  95  96  97  98  99 100
```

5. Objects come in types and classes

I’m going to speak somewhat loosely here for now, and gloss over some distinctions between object classes and data structures, as well as kinds of objects and their attributes.

5. Objects come in types and classes

I'm going to speak somewhat loosely here for now, and gloss over some distinctions between object classes and data structures, as well as kinds of objects and their attributes.

The object inspector in RStudio is your friend.

You can ask an object what it is at the console, too:

```
class(my_numbers)
```

```
[1] "numeric"
```

```
typeof(my_numbers)
```

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

5. Objects come in types and classes

Objects can have more than one (nested) class:

```
summary(my_numbers)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    1.75    3.00    6.25    6.25   25.00 
```

```
my_smry ← summary(my_numbers) # remember, outputs can be assigned to a name, creating an object

class(summary(my_numbers)) # functions can be nested, and are evaluated from the inside out
```

```
[1] "summaryDefault" "table"
```

```
class(my_smry) # equivalent to the previous line
```

```
[1] "summaryDefault" "table"
```

5. Objects come in types and classes

```
typeof(my_smry)
```

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

```
attributes(my_smry)
```

```
$names
[1] "Min."    "1st Qu." "Median"  "Mean"    "3rd Qu." "Max."

$class
[1] "summaryDefault" "table"
```

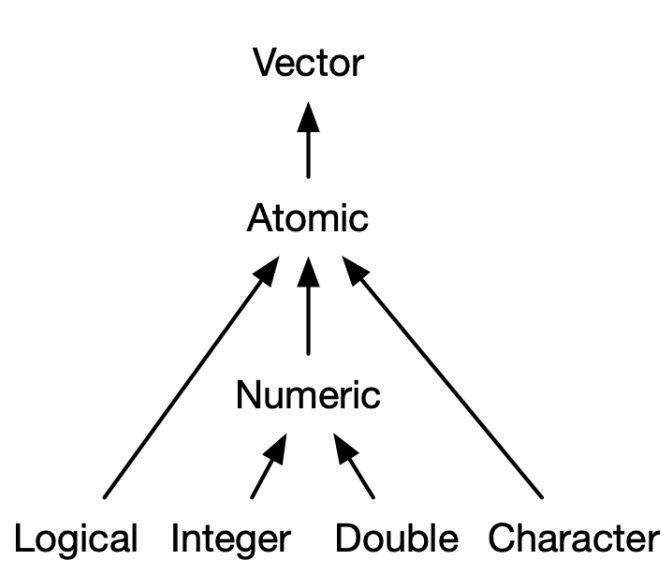
```
## In this case, the functions extract the corresponding attribute
class(my_smry)
```

```
[1] "summaryDefault" "table"
```

```
names(my_smry)
```

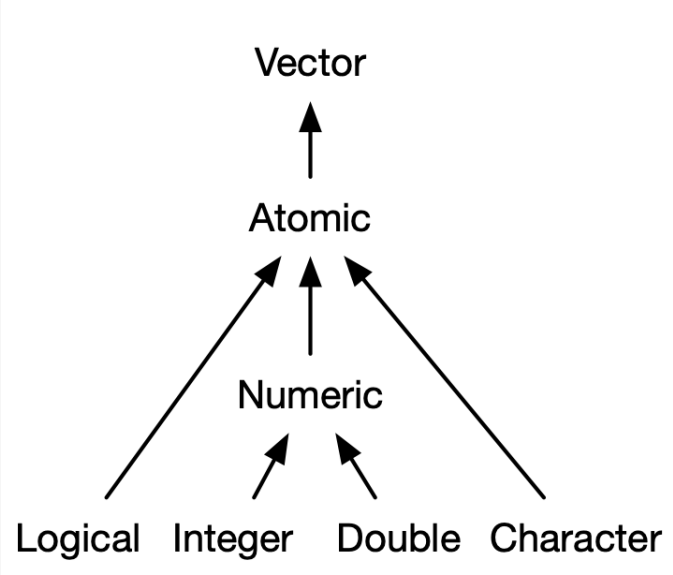
```
[1] "Min."    "1st Qu." "Median"  "Mean"    "3rd Qu." "Max."
```

Kinds of vector



Hadley Wickham, *Advanced R*

Kinds of vector



Hadley Wickham, *Advanced R*

```
my_int ← c(1, 3, 5, 6, 10)
is.integer(my_int)
```

```
[1] FALSE
```

```
is.double(my_int)
```

```
[1] TRUE
```

```
my_int ← as.integer(my_int)
is.integer(my_int)
```

```
[1] TRUE
```

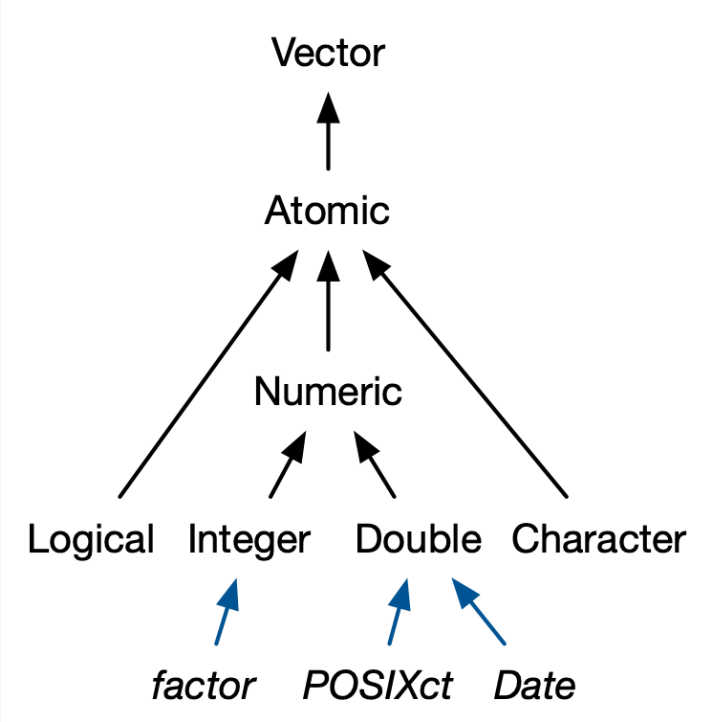
```
my_chr ← c("Mary", "had", "a", "little", "lamb")
is.character(my_chr)
```

```
[1] TRUE
```

```
my_lgl ← c(TRUE, FALSE, TRUE)
is.logical(my_lgl)
```

```
[1] TRUE
```

Kinds of vector




```
## Factors are for storing undordered or ordered categorical variables
x ← factor(c("Yes", "No", "No", "Maybe", "Yes", "Yes", "Yes", "No"))
x
```

```
[1] Yes   No    No    Maybe Yes   Yes   Yes   No
Levels: Maybe No Yes
```

```
summary(x) # Alphabetical order by default
```

```
Maybe    No   Yes
    1     3     4
```

```
typeof(x)       # Underneath, a factor is a type of integer ...
```

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

```
attributes(x)   # ... with labels for its numbers, or "levels"
```

```
$levels
[1] "Maybe" "No"    "Yes"

$class
[1] "factor"
```

```
levels(x)
```

```
[1] "Maybe" "No"    "Yes"
```

```
is.ordered(x)
```

Vector types can’t be heterogenous

Objects can be manually or automatically coerced from one class to another. Take care.

```
class(my_numbers)
```

```
[1] "numeric"
```

```
my_new_vector ← c(my_numbers, "Apple")

my_new_vector # vectors are homogeneous/atomic
```

```
[1] "1"     "2"     "3"     "1"     "3"     "5"     "25"    "10"    "Apple"
```

```
class(my_new_vector)
```

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

Vector types can't be heterogenous

Objects can be manually or automatically coerced from one class to another. Take care.

```
my_dbl ← c(2.1, 4.77, 30.111, 3.14519)
is.double(my_dbl)
```

```
[1] TRUE
```

```
my_dbl ← as.integer(my_dbl)

my_dbl
```

```
[1]  2  4 30  3
```

A table of data is a kind of list

```
gapminder # tibbles and data frames can contain vectors of different types
```

```
# A tibble: 1,704 × 6
   country     continent  year lifeExp      pop gdpPercap
   <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
 1 Afghanistan Asia       1952    28.8  8425333      779.
 2 Afghanistan Asia       1957    30.3  9240934      821.
 3 Afghanistan Asia       1962    32.0 10267083      853.
 4 Afghanistan Asia       1967    34.0 11537966      836.
 5 Afghanistan Asia       1972    36.1 13079460      740.
 6 Afghanistan Asia       1977    38.4 14880372      786.
 7 Afghanistan Asia       1982    39.9 12881816      978.
 8 Afghanistan Asia       1987    40.8 13867957      852.
 9 Afghanistan Asia       1992    41.7 16317921      649.
10 Afghanistan Asia       1997    41.8 22227415      635.
# ℹ 1,694 more rows
```

```
class(gapminder)
```

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

```
typeof(gapminder) # hmm
```

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

A table of data is a kind of list

Lists *can* be heterogenous. Underneath, most complex R objects are some kind of list with different components.

A *data frame* is a list of vectors of the same length, where the vectors can be of different types (e.g. numeric, character, logical, etc)

A *tibble* is an enhanced data frame

Some classes are versions of others

Base R's trusty `data.frame`

```
library(socviz)
titanic
```

```
      fate    sex    n percent
1 perished   male 1364    62.0
2 perished female  126     5.7
3 survived   male  367    16.7
4 survived female  344    15.6
```

```
class(titanic)
```

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

```
## The `$` idiom picks out a named column here;
## more generally, the named element of a list
titanic$percent
```

```
[1] 62.0  5.7 16.7 15.6
```

Some classes are versions of others

Base R's trusty `data.frame`

```
library(socviz)
titanic
```

```
      fate    sex    n percent
1 perished   male 1364    62.0
2 perished female  126     5.7
3 survived   male  367    16.7
4 survived female  344    15.6
```

```
class(titanic)
```

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

```
## The `$` idiom picks out a named column here;
## more generally, the named element of a list
titanic$percent
```

```
[1] 62.0  5.7 16.7 15.6
```

The Tidyverse's enhanced `tibble`

```
## tibbles are build on data frames
titanic_tb <- as_tibble(titanic)
titanic_tb
```

```
# A tibble: 4 × 4
  fate     sex        n percent
  <fct>    <fct>  <dbl>   <dbl>
1 perished male    1364    62
2 perished female   126     5.7
3 survived male     367    16.7
4 survived female   344    15.6
```

```
class(titanic_tb)
```

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

A data frame and a tibble are both fundamentally a list of vectors of the same length, where the vectors can be of different types (e.g. numeric, character, logical, etc)

All of this will be clearer in use

```
gss_sm
```

```
# A tibble: 2,867 × 32
    year    id ballot       age childs sibs   degree race  sex   region income16
   <dbl> <dbl> <labelled> <dbl>  <dbl> <labe> <fct>  <fct> <fct> <fct>  <fct>
 1  2016     1 1             47      3 2      Bache… White Male  New E… $170000…
 2  2016     2 2             61      0 3      High … White Male  New E… $50000 …
 3  2016     3 3             72      2 3      Bache… White Male  New E… $75000 …
 4  2016     4 1             43      4 3      High … White Fema… New E… $170000…
 5  2016     5 3             55      2 2      Gradu… White Fema… New E… $170000…
 6  2016     6 2             53      2 2      Junio… White Fema… New E… $60000 …
 7  2016     7 1             50      2 2      High … White Male  New E… $170000…
 8  2016     8 3             23      3 6      High … Other Fema… Middl… $30000 …
 9  2016     9 1             45      3 5      High … Black Male  Middl… $60000 …
10  2016    10 3             71      4 1      Junio… White Male  Middl… $60000 …
# ℹ 2,857 more rows
# ℹ 21 more variables: relig <fct>, marital <fct>, padeg <fct>, madeg <fct>,
#   partyid <fct>, polviews <fct>, happy <fct>, partners <fct>, grass <fct>,
#   zodiac <fct>, pres12 <labelled>, wtssall <dbl>, income_rc <fct>,
#   agegrp <fct>, ageq <fct>, siblings <fct>, kids <fct>, religion <fct>,
#   bigregion <fct>, partners_rc <fct>, obama <dbl>
```

Tidyverse tools are generally *type safe*, meaning their functions return the same type of thing every time, or fail if they cannot do this. So it's good to know about the various data types

6. Arithmetic on vectors

In R, all numbers are vectors of different sorts. Even single numbers ("scalars") are conceptually vectors of length 1.

Arithmetic on vectors (and arrays generally) follows a series of *recycling rules* that favor ease of expression of vectorized, "elementwise" operations.

See if you can predict what the following operations do:

6. Arithmetic on vectors

```
my_numbers
```

```
[1]  1  2  3  1  3  5 25 10
```

```
result1 ← my_numbers + 1
```

6. Arithmetic on vectors

```
my_numbers
```

```
[1]  1  2  3  1  3  5 25 10
```

```
result1 ← my_numbers + 1
```

```
result1
```

```
[1]  2  3  4  2  4  6 26 11
```

6. Arithmetic on vectors

```
result2 ← my_numbers + my_numbers
```

6. Arithmetic on vectors

```
result2 ← my_numbers + my_numbers
```

```
result2
```

```
[1]  2  4  6  2  6 10 50 20
```

6. Arithmetic on vectors

```
two_nums ← c(5, 10)

result3 ← my_numbers + two_nums
```

6. Arithmetic on vectors

```
two_nums ← c(5, 10)

result3 ← my_numbers + two_nums
```

```
result3
```

```
[1]  6 12  8 11  8 15 30 20
```

6. Arithmetic on vectors

```
three_nums ← c(1, 5, 10)

result4 ← my_numbers + three_nums
```

```
Warning in my_numbers + three_nums: longer object length is not a multiple of
shorter object length
```

6. Arithmetic on vectors

```
three_nums ← c(1, 5, 10)

result4 ← my_numbers + three_nums
```

```
Warning in my_numbers + three_nums: longer object length is not a multiple of
shorter object length
```

```
result4
```

```
[1]  2  7 13  2  8 15 26 15
```

Note that you get a *warning* here. It'll still do it, though! Don't ignore warnings until you understand what they mean.

7. R will be frustrating

The IDE tries its best to help you. Learn to attend to what it is trying to say.

```
Warning message:
In my_numbers + two_nums :
  longer object length is not a multiple of shorter object length
```

```
39 p <- ggplot(data = gapminder
expected ',' after expression
41                             y = lifeExp))
42
```

```
39 p <- ggplot(data = gapminder,
40              mapping = aes(x = gdpPercap,
41                            y = lifeExp)))
unexpected token ')'
43 ```
```