

Finding your way in R

Session 2

Kieran Healy
Statistical Horizons, September 2021

Using RMarkdown to produce and reproduce your work

Where we want to end up

Covid Cases

Kieran Healy

4/18/2021

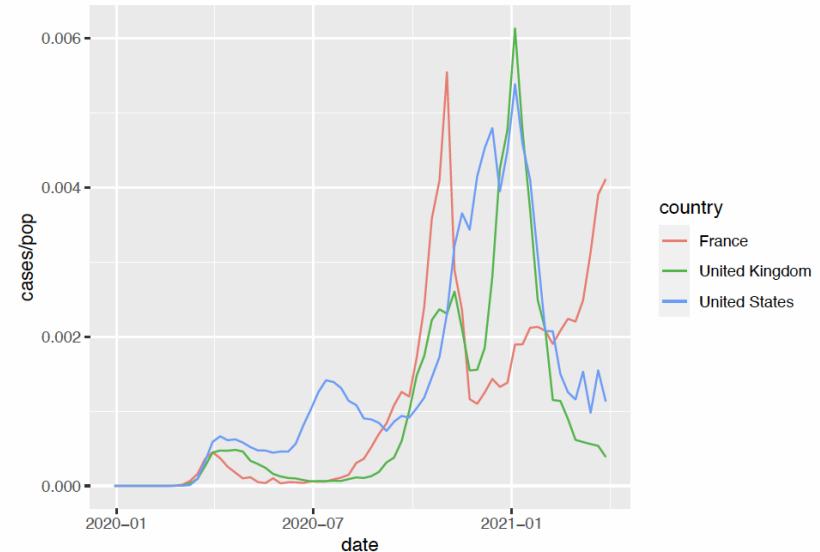
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Table 1: Total cases in three countries.

country	cases
United States	30706129
France	4822470
United Kingdom	4359388

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Where we want to end up

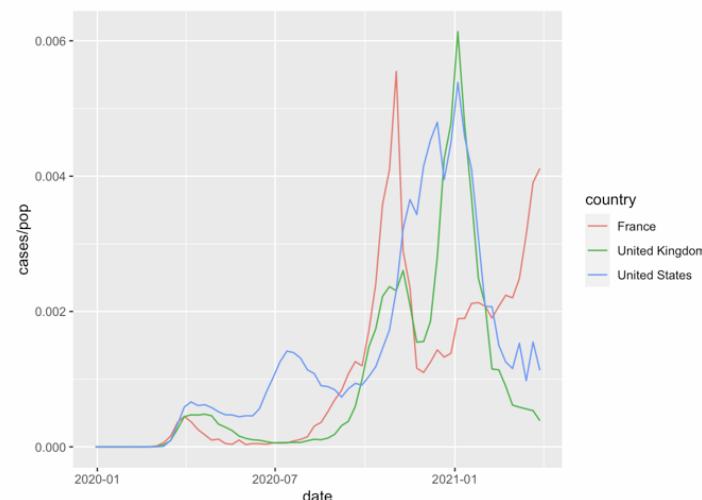
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Where we want to end up

Covid Cases

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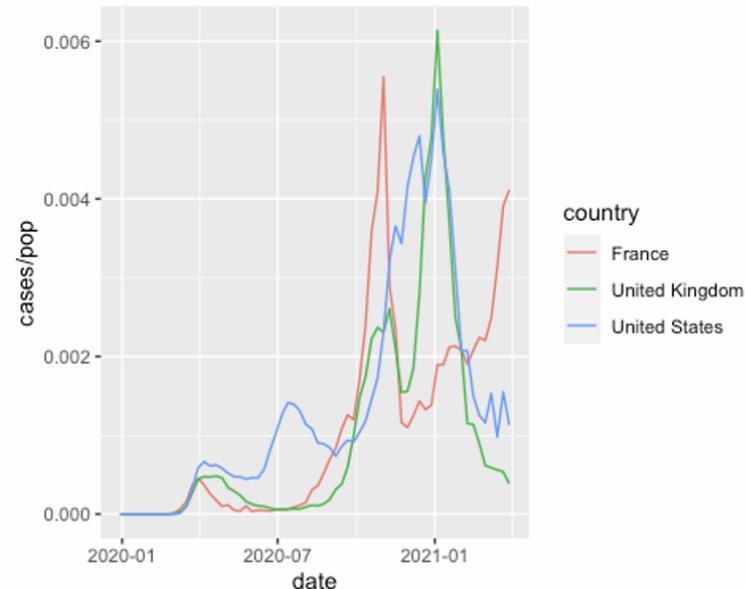
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How to get there?

```
# COVID      covidcases.R  
# 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 %>%  
  ggplot(...) +  
  geom_line(...)
```

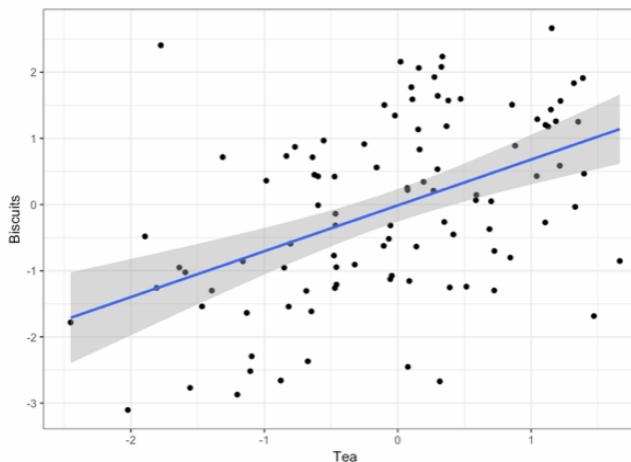
Write an R script with some notes inside. Create some figures and tables, paste them into our document.

This will work, but we can do better.

We can make this ...

1. Lorem Ipsum

Lore*m* ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enimad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.



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... by writing this

Lorem Ipsum

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 sed do *eiusmod tempor* incididunt ut labore et dolore magna
 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
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 deserunt mollit anim id est laborum.

The code gets replaced by its output

Lorem Ipsum

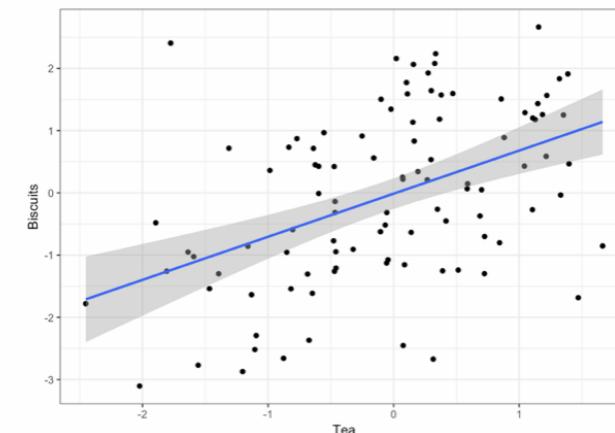
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proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

```
--  
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  
  
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.  
  
```{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"  
date: "4/18/2021"  
output: html_document  
---
```

```
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Introduction

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```
```{r libraries, message = FALSE}
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library(tidyverse)
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```
```

## ## 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.")  
```
```

# Header section with metadata



## 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

Kieran Healy

4/18/2021

## Introduction

We'll be looking at some COVID case data.

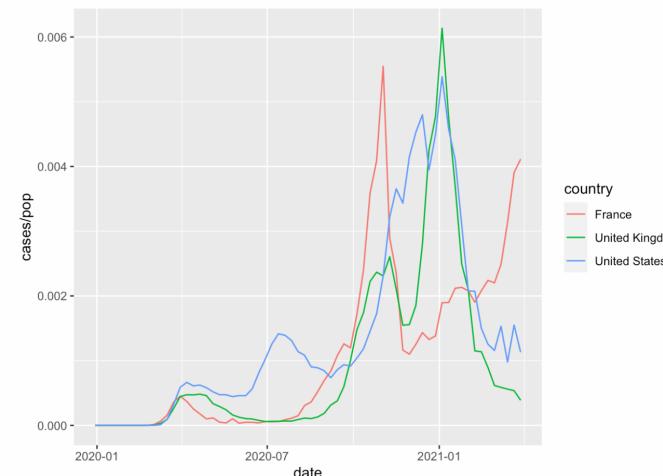
## Lorem Ipsum

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Total cases in three countries.

| country        | cases    |
|----------------|----------|
| United States  | 30706129 |
| France         | 4822470  |
| United Kingdom | 4359388  |

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# Covid Cases

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We'll be looking at some COVID case data.

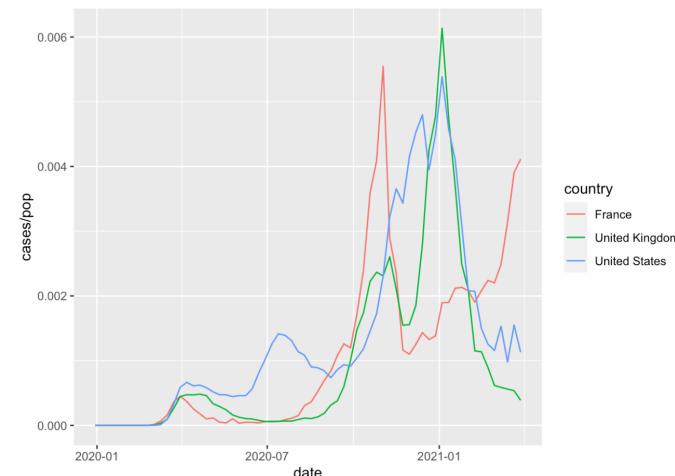
### Lorem Ipsum

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

## # Report notes.Rmd

We can see this \*relationship\* in a scatterplot.

```
```{r my-code}
p <- ggplot(data, mapping)
p + geom_point()
````
```

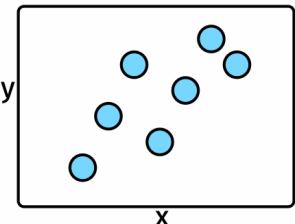
As you can see, this plot looks pretty nice.

knit in R

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.

## Report notes.html

We can see this *relationship* in a scatterplot.



As you can see, this plot looks pretty nice.

# 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.

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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*.

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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

# 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

# GETTING ORIENTED

# Loading the tidyverse libraries

```
library(tidyverse)

— Attaching packages ————— tidyverse 1.3.1 —

✓ ggplot2 3.3.5 ✓ purrr 0.3.4
✓ tibble 3.1.4 ✓ dplyr 1.0.7
✓ tidyr 1.1.3 ✓ stringr 1.4.0
✓ readr 2.0.1 ✓forcats 0.5.1

— Conflicts ————— tidyverse_conflicts() —

x readr::edition_get() masks testthat::edition_get()
x dplyr::filter() masks stats::filter()
x purrr::is_null() masks testthat::is_null()
x dplyr::lag() masks stats::lag()
x readr::local_edition() masks testthat::local_edition()
x dplyr::matches() masks tidyverse::matches(), testthat::matches()
```

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
```

# Tidyverse components

```
library(tidyverse)
```

Loading tidyverse:: ggplot2 ◀ Draw graphs

Loading tidyverse:: tibble ◀ Nicer data tables

Loading tidyverse:: tidyr ◀ Tidy your data

Loading tidyverse:: readr ◀ Get data into R

Loading tidyverse:: purrr ◀ Cool functional programming stuff

Loading tidyverse:: dplyr ◀ Action verbs for manipulating data

# 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:

Equivalent to running the code above, typing `my_numbers` at the console, and hitting enter.

```
my_numbers

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

# What R looks like

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

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

# What R looks like

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

```
my_numbers
```

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

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

## Arithmetic

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

```
[1] 23.25
```

```
sqrt(25)
```

```
[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
```

```
[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
```

```
[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
```

# 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,

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

```
[1] TRUE
```

# 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,

```
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  $0.6 + 0.2 == 0.8$

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```
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
```

# 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.

# 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!

# Logic and floating point arithmetic

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.

# Logic and floating point arithmetic

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.

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.

# 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
```

# 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

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"
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# 2. Everything is an object

There are a few built-in objects

```
letters
```

```
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```

```
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```
[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

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In fact, this is mostly what we will be doing

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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)
```

# 3. You can create objects

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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

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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
```

# 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.

# Assignment with =

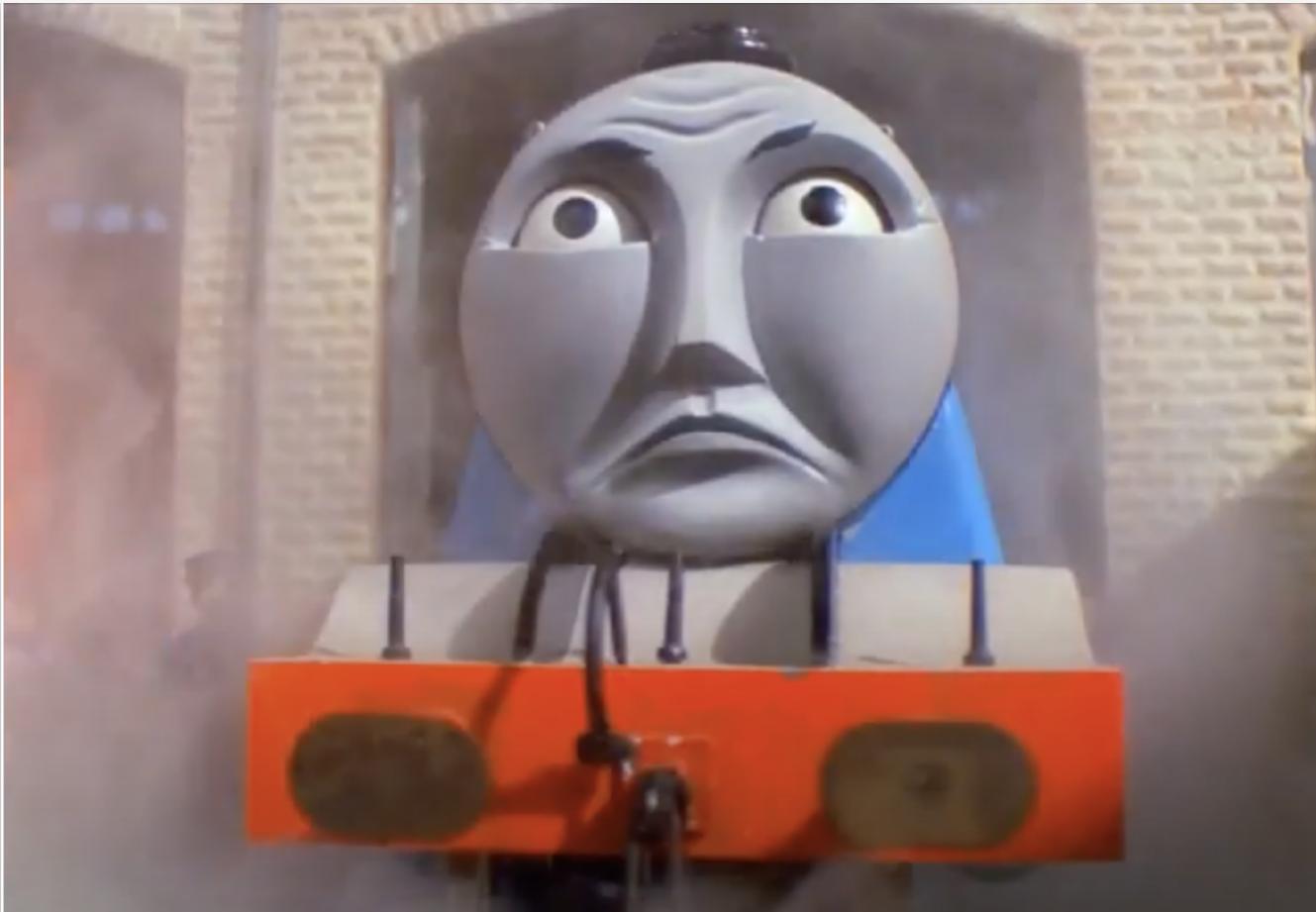
You can use "=" as well as "<- " for assignment

```
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. Just 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
```

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

```
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
```

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
```

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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
```

# 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

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
```

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
```

# 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
```

# 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."
```

# 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
```

# 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 nesting functions in parentheses, we can use the *pipe operator*:

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

```
[1] 6
```

# Use the pipe operator: %>%

Instead of 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: %>%

Instead of 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**"

Better, vertical space is free in R:

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

[1] 6
```

# Piped operations 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")))
```

# Piped operations 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.

# Piped operations 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.

Really not much better:

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

# Piped operations 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()
```

# Piped operations 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.

# Now showing at an R near you: |>

The pipe operator `%>%` is not part of Base R. It was introduced in a package called `magrittr`.

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It's been so successful, a version of it has been incorporated into Base R.

# Now showing at an R near you: |>

The pipe operator `%>%` is not part of Base R. It was introduced in a package called `magrittr`.

It's been so successful, a version of it has been incorporated into Base R.

It is denoted by `|>`. But! It does not *quite* replace `%>%` in every case.\*

The `magrittr` pipe will continue to work as shown in these slides.

\*With the new 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

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

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```
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.
... with 1,694 more rows
```

# Functions are bundled into packages

# Functions are bundled into packages

You need only *install* a package once (and occasionally update it). But you must *load* the package in each R session before you can access its contents.

```
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")

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
... with 334 more rows, and 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>

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```
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 this warning about 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.

# Remember this warning about conflicts?

```
library(tidyverse)

━━ Attaching packages ━━━━━━━━━━━━━━━━ tidyverse 1.3.0 ━━

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━━ Conflicts ━━━━━━━━━━━━━━━━ tidyverse_conflicts() ━━

x dplyr::filter() masks stats::filter()
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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*.

# 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
```

# 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
```

# 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

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.

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The object inspector in RStudio is your friend.

# 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.

```
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:

# 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"

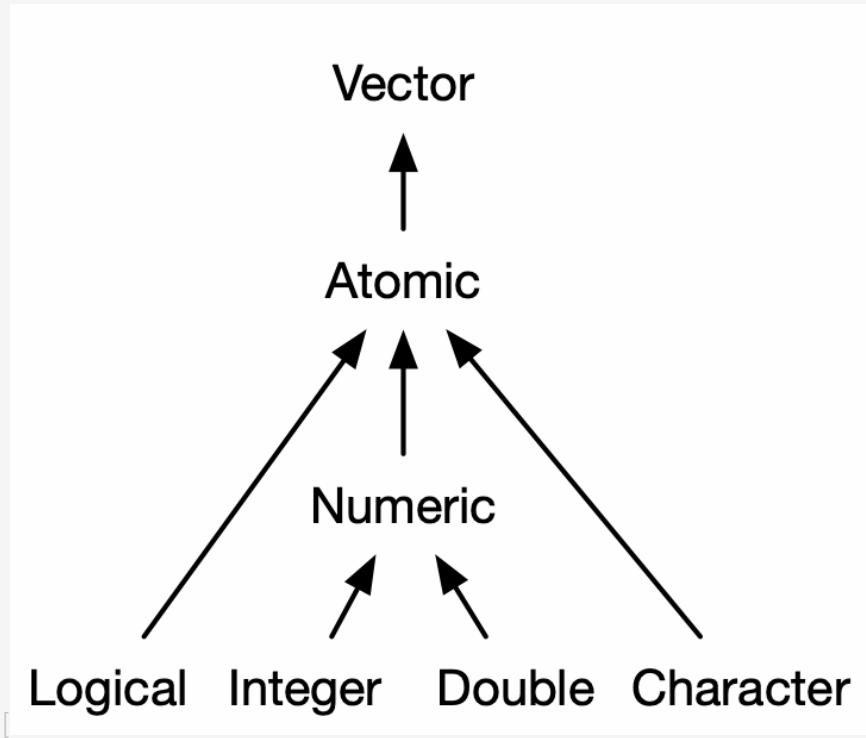
In this case, the functions extract the corresponding attribute
class(my_smry)

[1] "summaryDefault" "table"

names(my_smry)

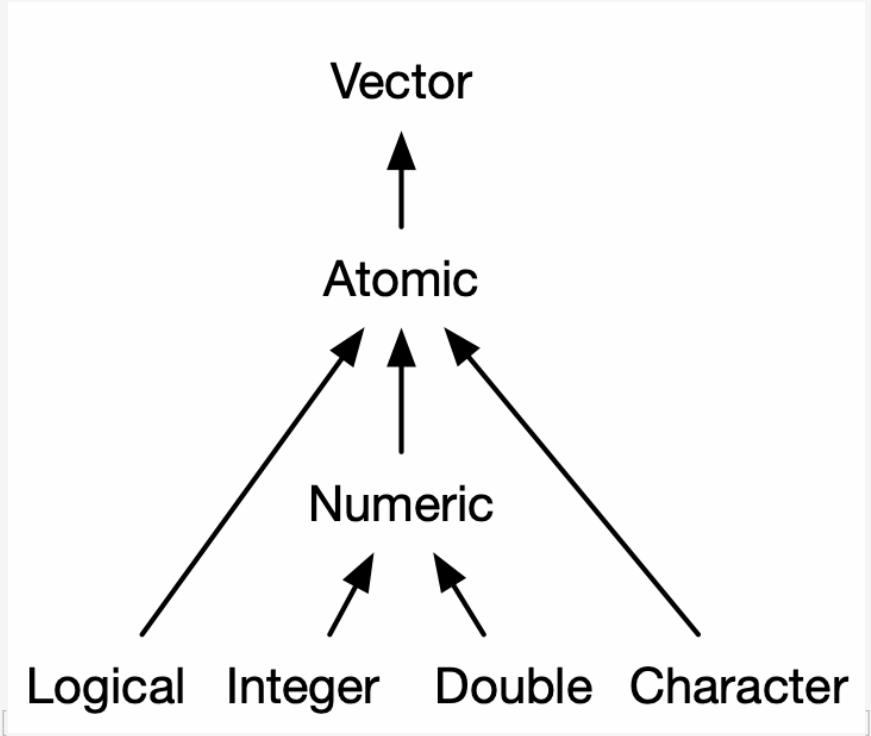
[1] "Min." "1st Qu." "Median" "Mean" "3rd Qu." "Max."
```

# The most common types of **vector**



From Hadley Wickham, *Advanced R*

# The most common types of **vector**



From Hadley Wickham, *Advanced R*

```
my_int <- c(1, 3, 5, 6, 10)
is.integer(my_int)
[1] FALSE

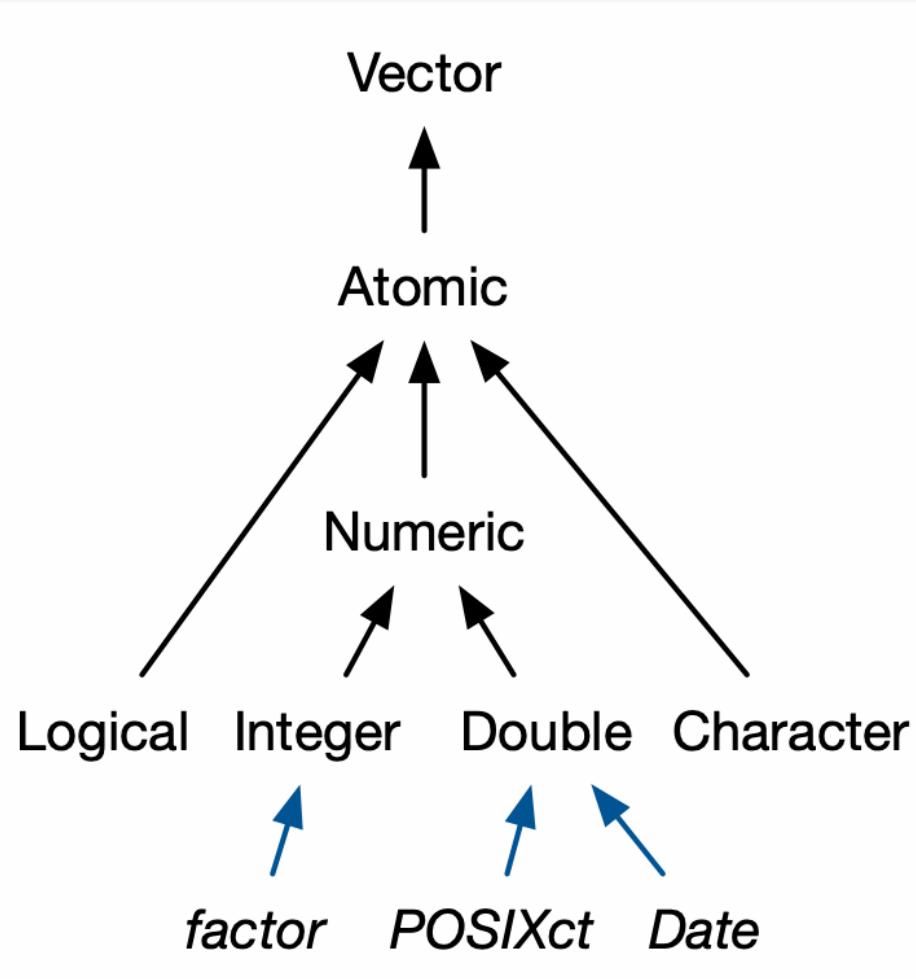
is.double(my_int)
[1] TRUE

my_int <- as.integer(my_int)
is.integer(my_int)
[1] TRUE

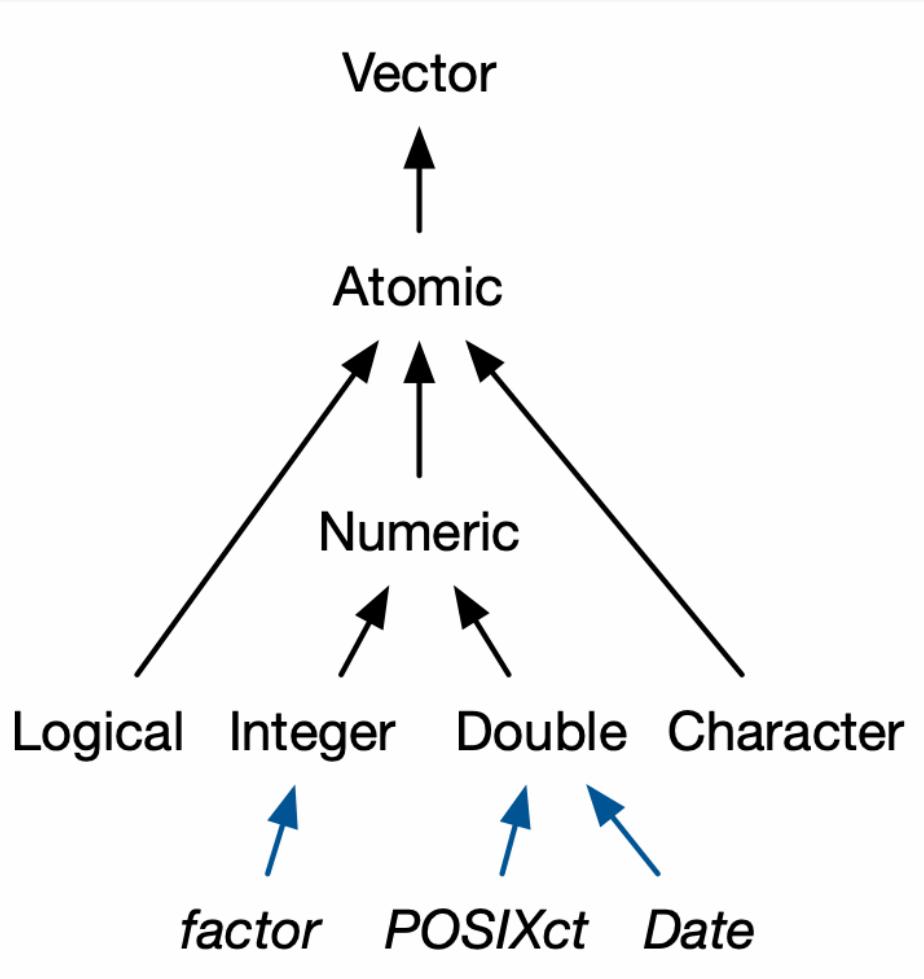
my_chr <- c("Mary", "had", "a", "little", "lamb")
is.character(my_chr)
[1] TRUE

my_lgl <- c(TRUE, FALSE, TRUE)
is.logical(my_lgl)
[1] TRUE
```

# The most common types of **vector**



# The most common types of **vector**



```
Factors are for storing unordered 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"

class(x)

[1] "factor"

levels(x)

[1] "Maybe" "No" "Yes"
is.ordered(x)

[1] FALSE
```

# Vector types can't be heterogenous

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

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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.

```
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"

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.
... with 1,694 more rows
```

```
class(gapminder)
```

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

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

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

Underneath, most complex R objects are some kind of list with different components.

# Some classes are nested

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 nested

## 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)
class(titanic)

[1] "data.frame"

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"
```

# All of this will matter later on

```
gss_sm
```

```
A tibble: 2,867 × 32
year id ballot age child� 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 ...
... with 2,857 more rows, and 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>
```

# All of this will matter later on

```
gss_sm
```

```
A tibble: 2,867 × 32
year id ballot age child� 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 ...
... with 2,857 more rows, and 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.

# 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\* 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:

\*And arrays, too.

# 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

```
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
```

```
result2 <- my_numbers + my_numbers
```

# 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

result2 <- my_numbers + my_numbers
```

```
result2
[1] 2 4 6 2 6 10 50 20
```

# 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

result2 <- my_numbers + my_numbers
```

```
result2
[1] 2 4 6 2 6 10 50 20

two_nums <- c(5, 10)

result3 <- my_numbers + two_nums
```

# 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

result2 <- my_numbers + my_numbers
```

```
result2
[1] 2 4 6 2 6 10 50 20

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

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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
```

# 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
```

```
38 #> #> make a plot +>
✖ 39 p <- ggplot(data = gapminder
 expected ',' after expression| x = gdpPercap,
 41 y = lifeExp))
42 |
```

# 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
```

```
38 #> c, <- make_a_plot()
✖ 39 p <- ggplot(data = gapminder
 expected ',', after expression | x = gdpPercap,
41 y = lifeExp))
42 |
```

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