Finding your way in R and RStudio

Data Visualization: Session 2

Kieran Healy

Code Horizons, May 2022

We want to draw graphs reproducibly


RStudio®

Abstraction in software

Less

Easy things are awkward

Hard things are straightforward

Really hard things are possible

More

Easy things are trivial

Hard things are very awkward

Really hard things are impossible

Compare: D3, Grid, ggplot, Stata, Excel

Two ways to use R and ggplot

1. Do everything in R from start to finish

```
Raw data |> Read, Clean, Analyse |> Tidy table |> Make figures
```

Two ways to use R and ggplot

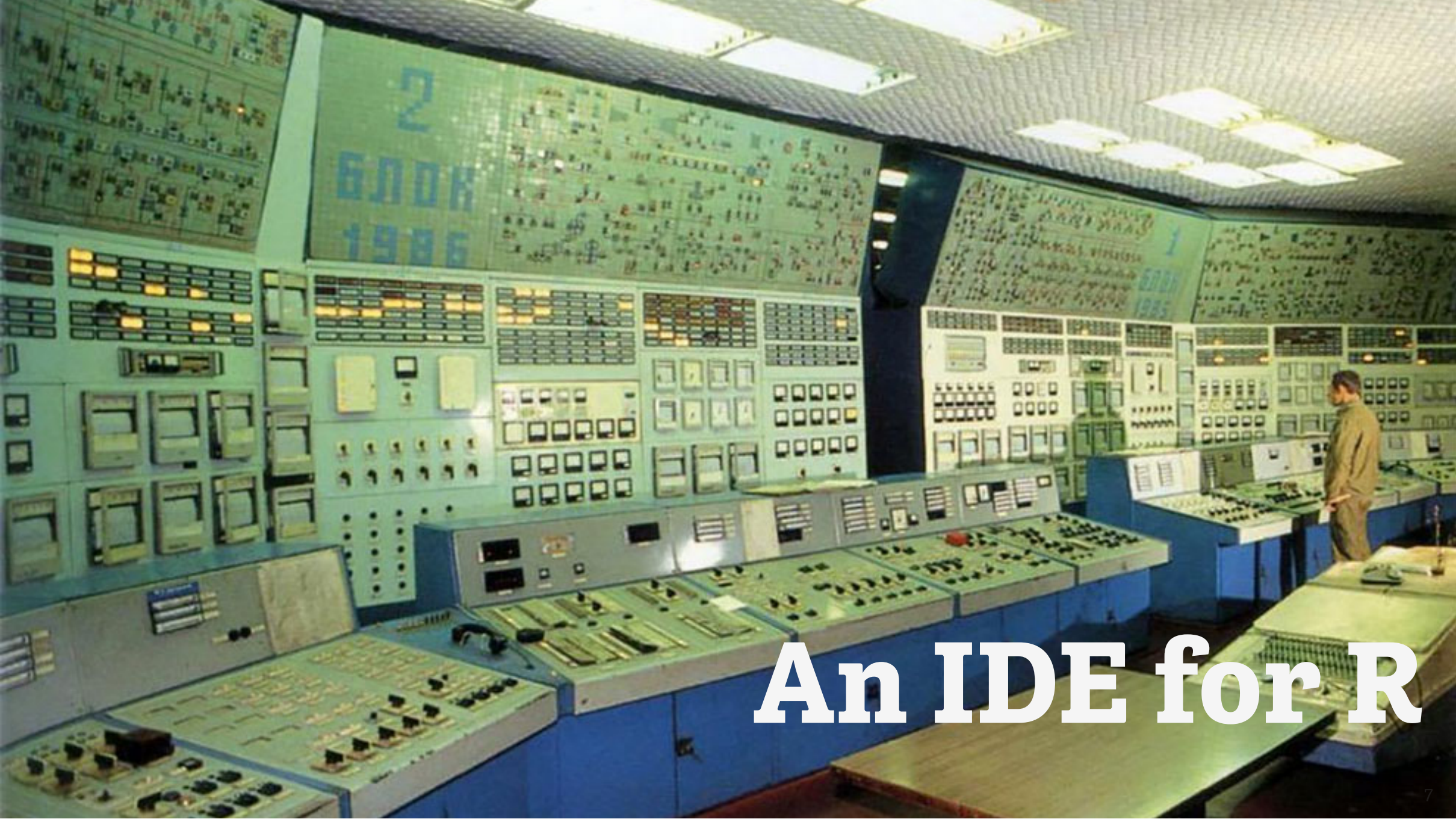
1. Do everything in R from start to finish

```
Raw data |> Read, Clean, Analyse |> Tidy table |> Make figures
```

2. Just hand ggplot a table of results

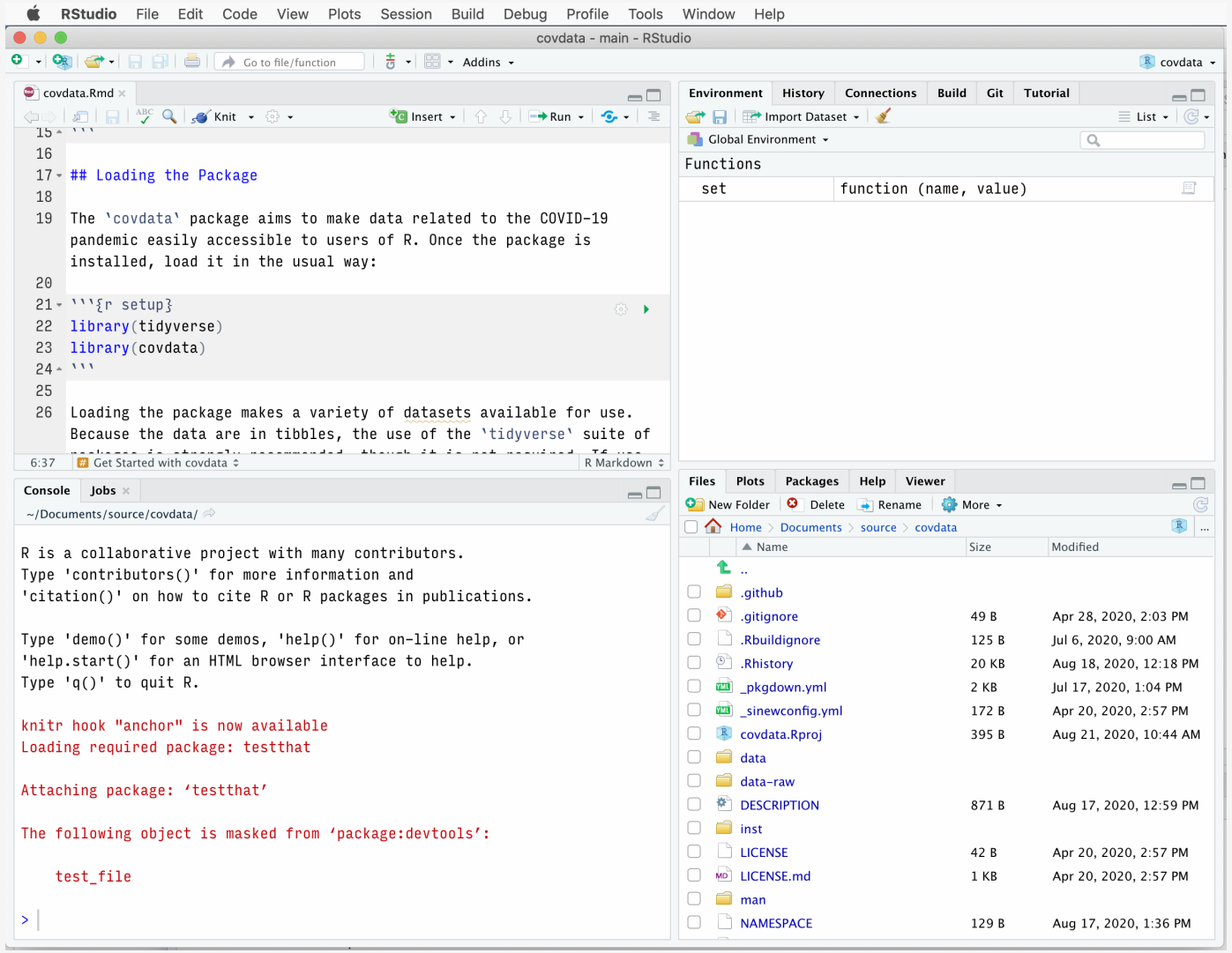
```
Stata/SAS/etc |> Tidy table |> Read in to R |> Make figures
```

The RStudio IDE

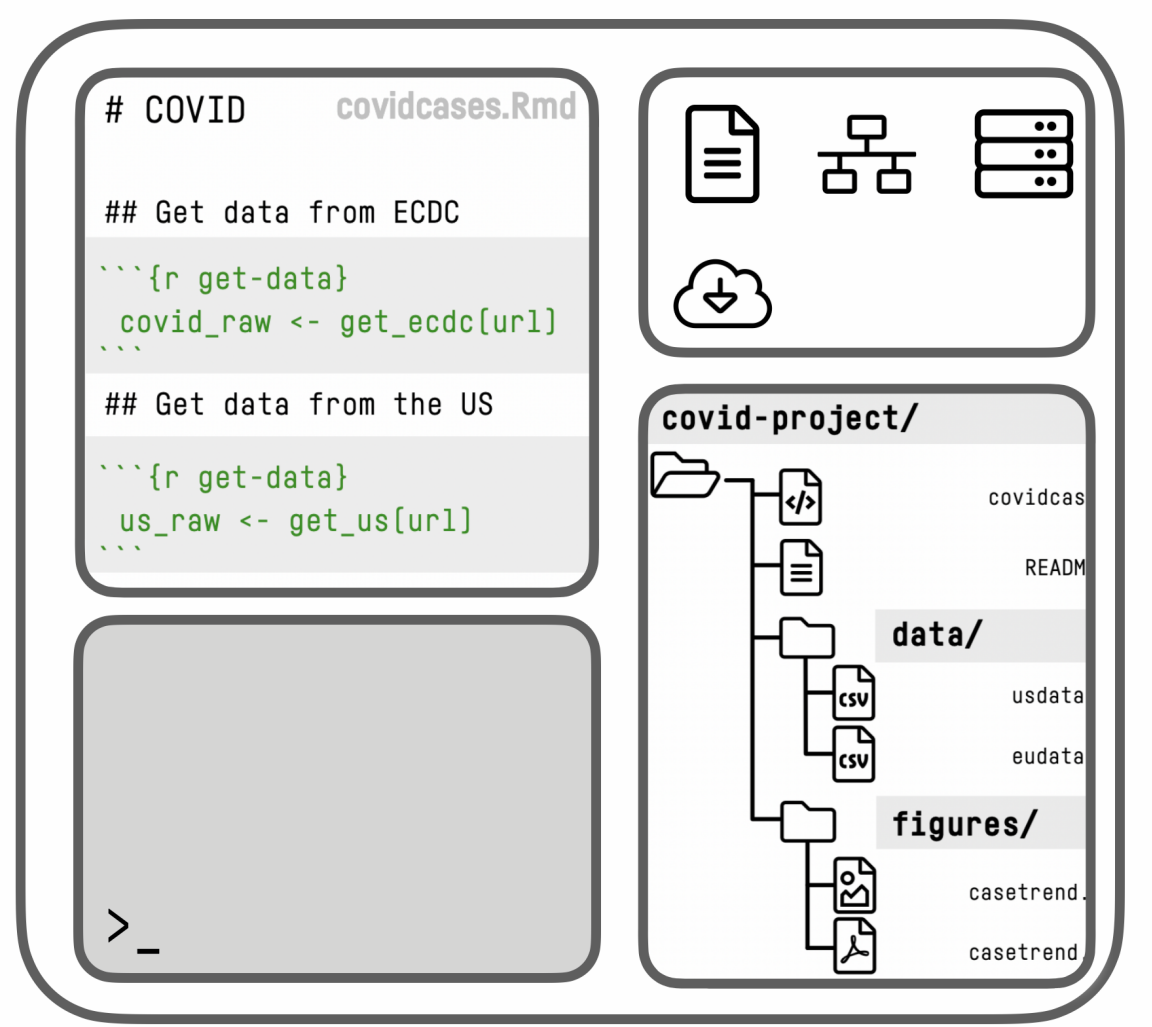


An IDE for R

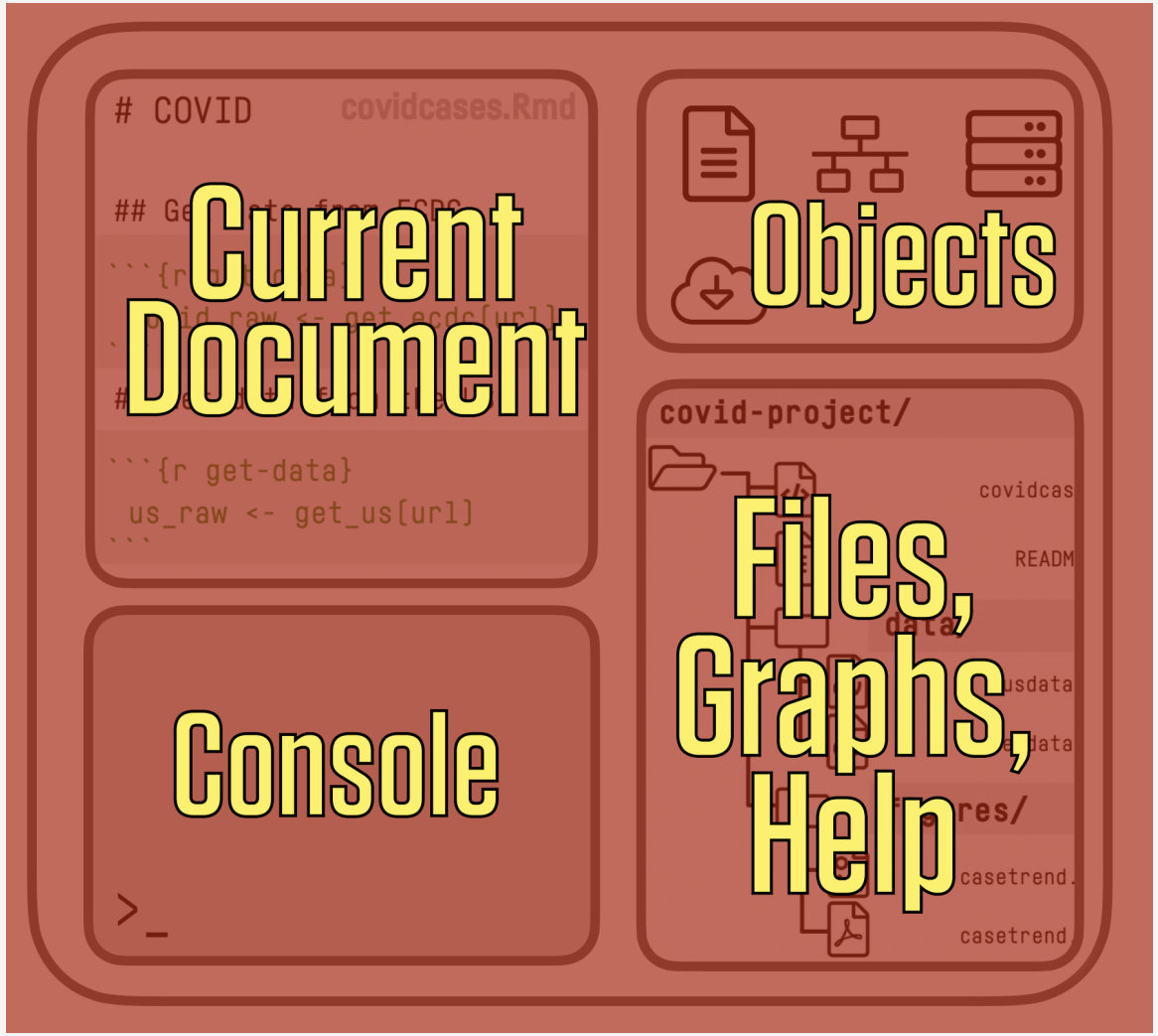
An IDE for Meals



RStudio at startup



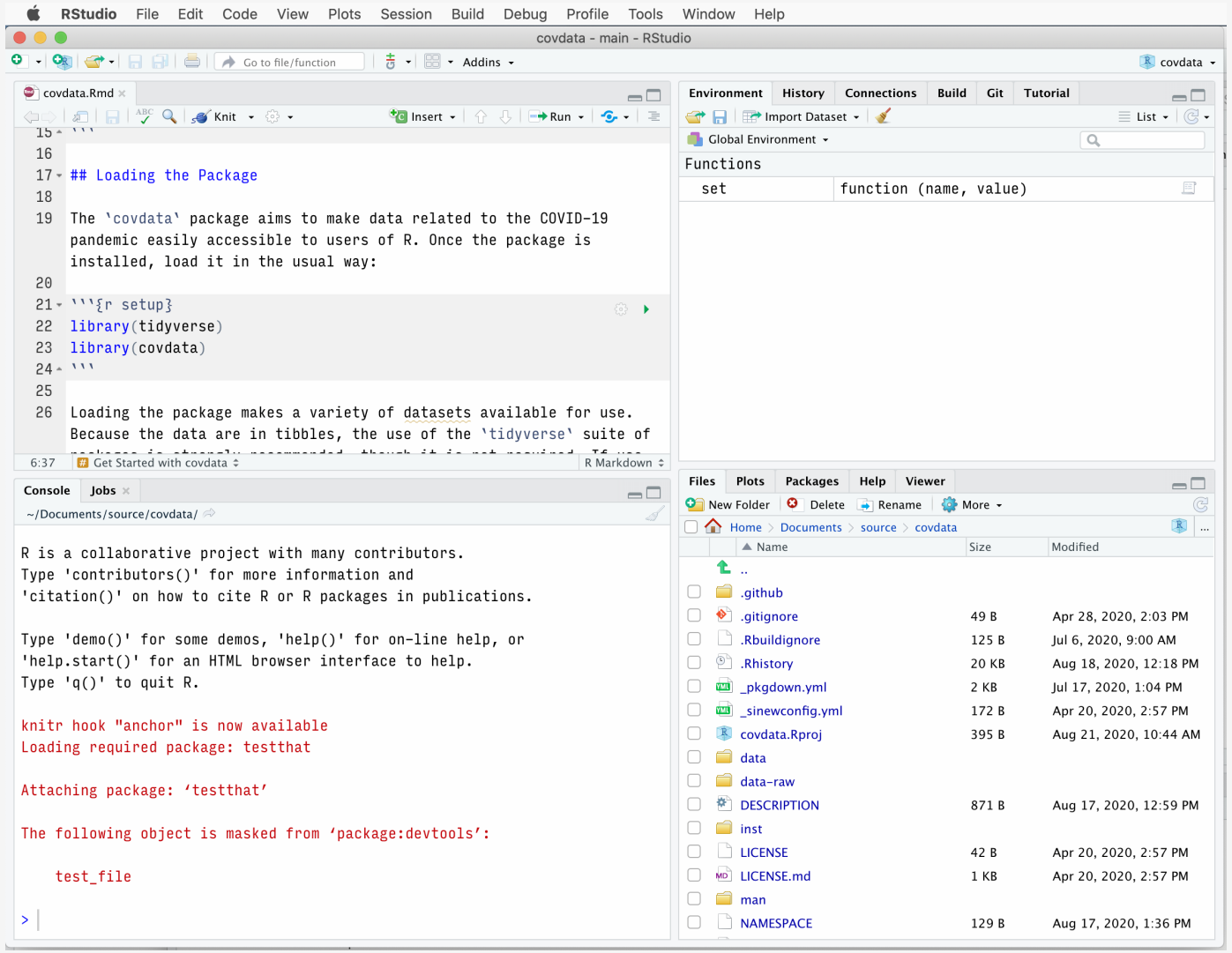
RStudio schematic overview



RStudio schematic overview

Think in terms of Data + Transformations, written out as code, rather than a series of point-and-click steps

Our starting data + our code is what's "real" in our projects, not the final output or any intermediate objects



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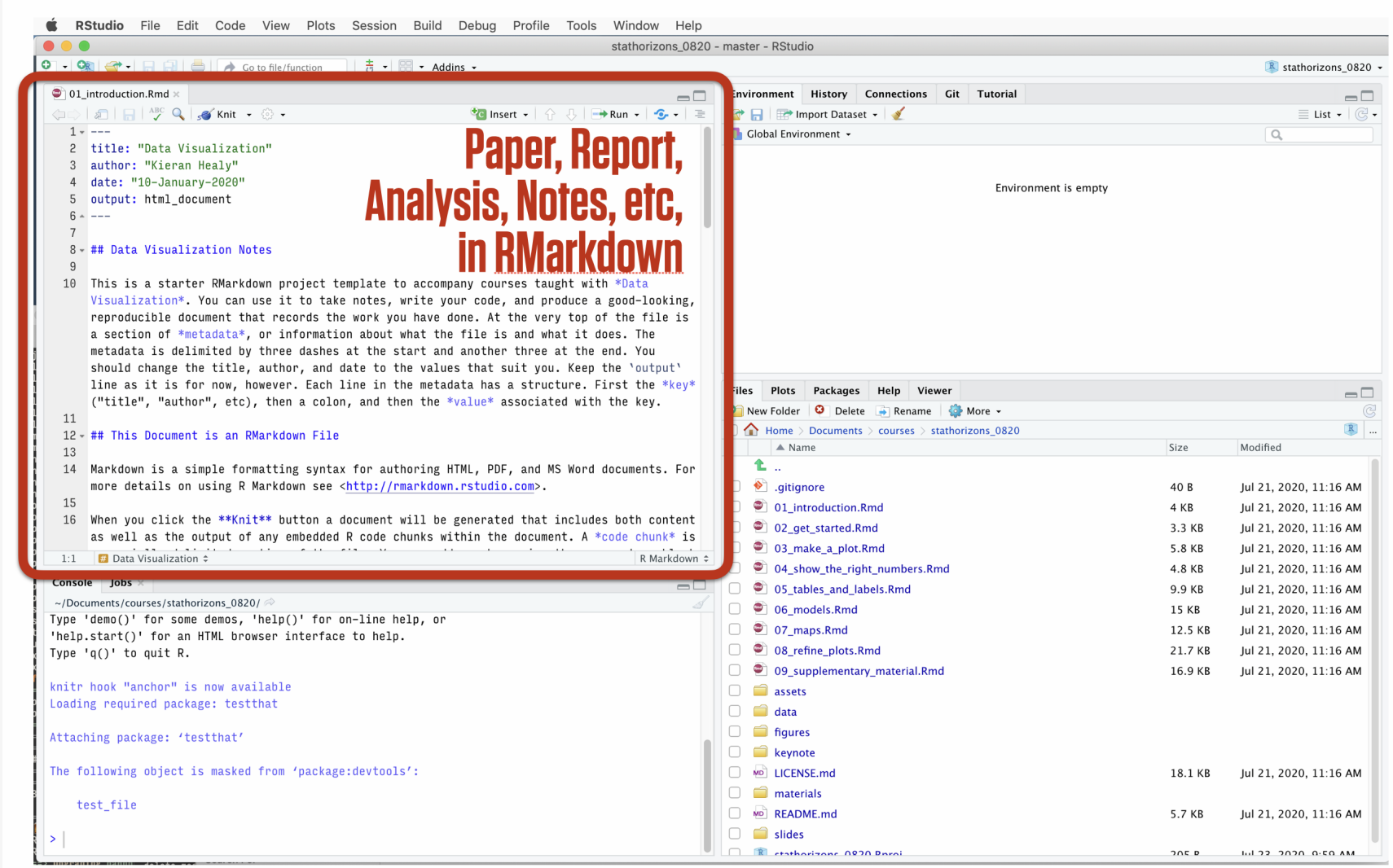
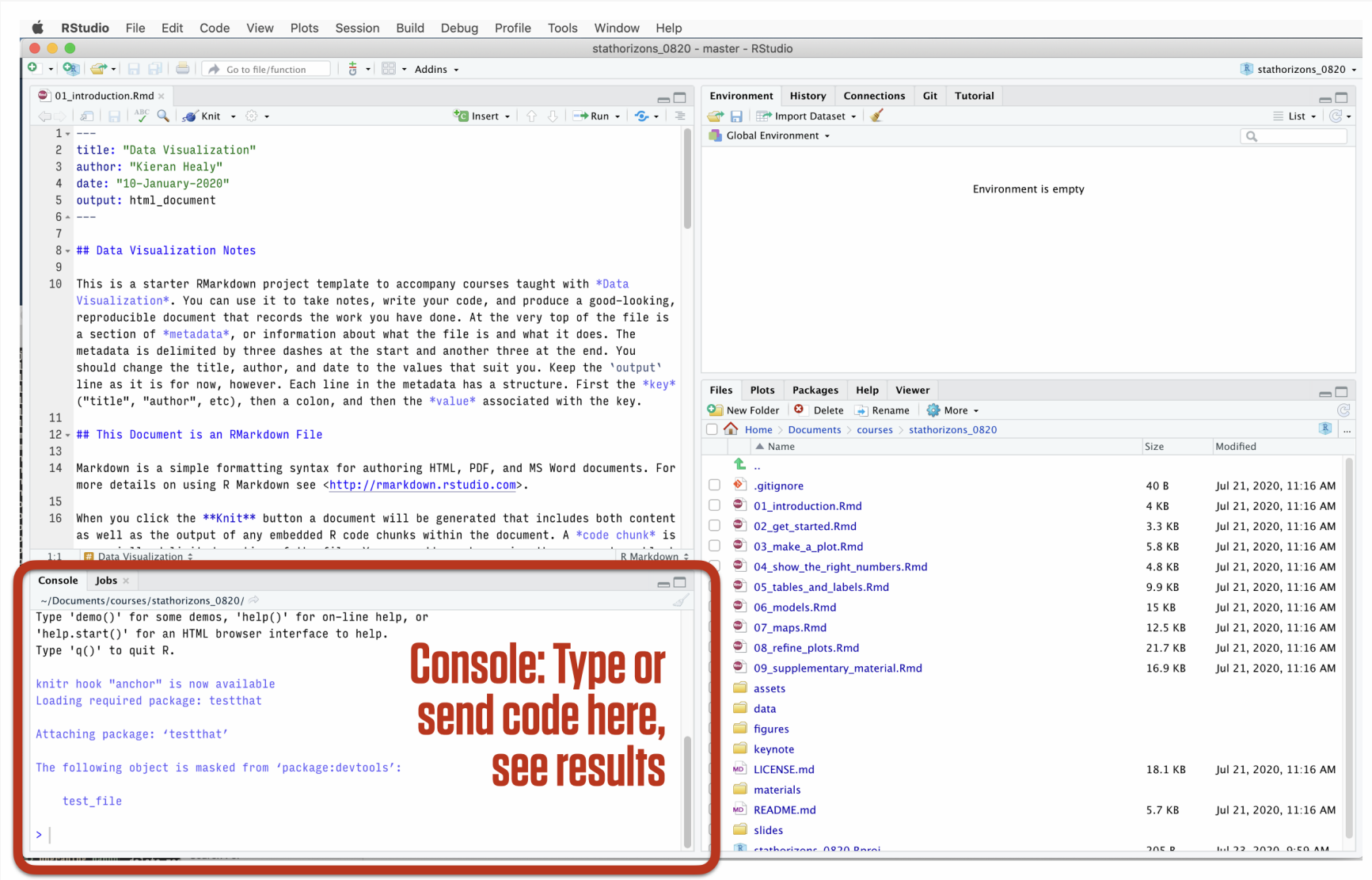
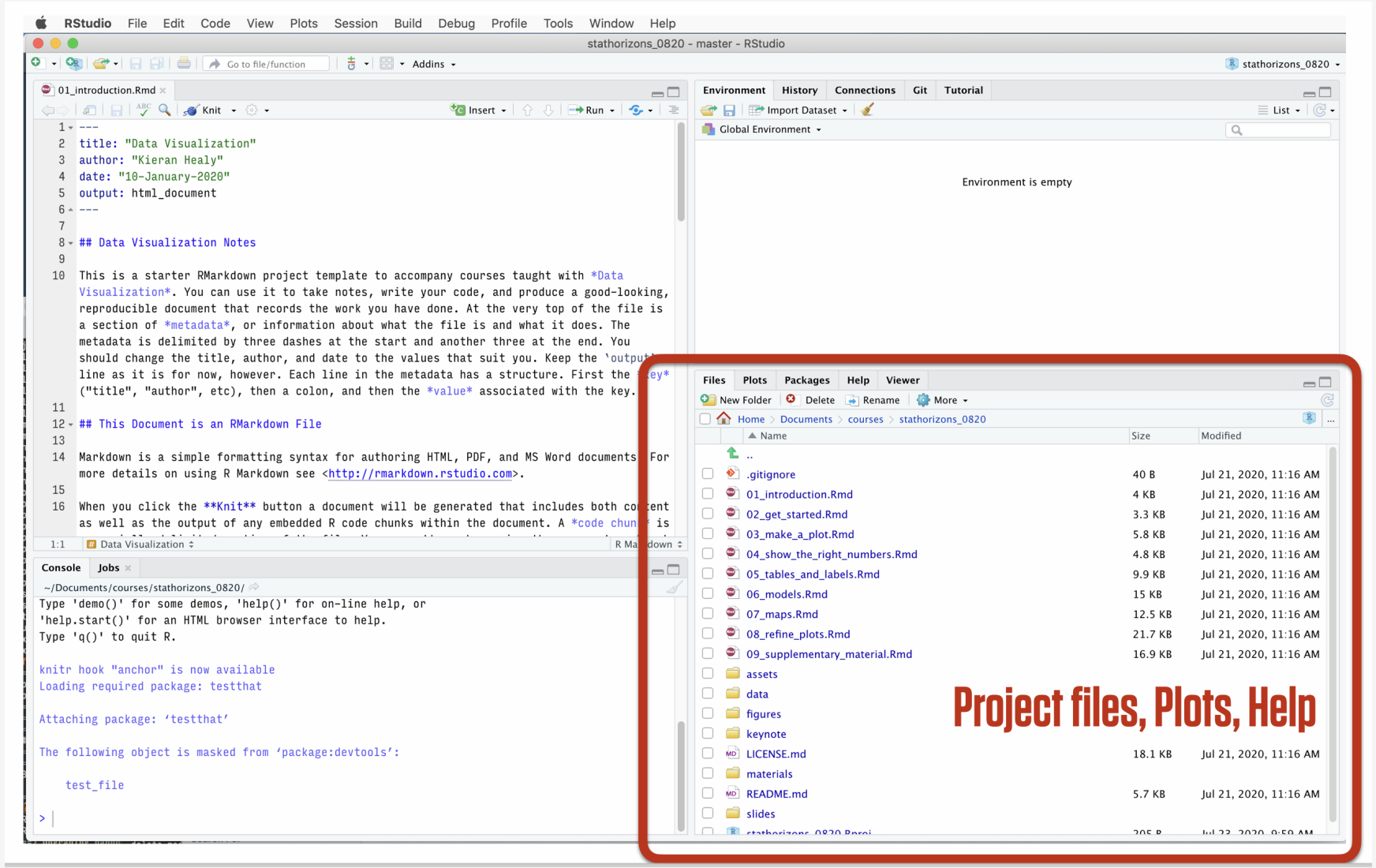


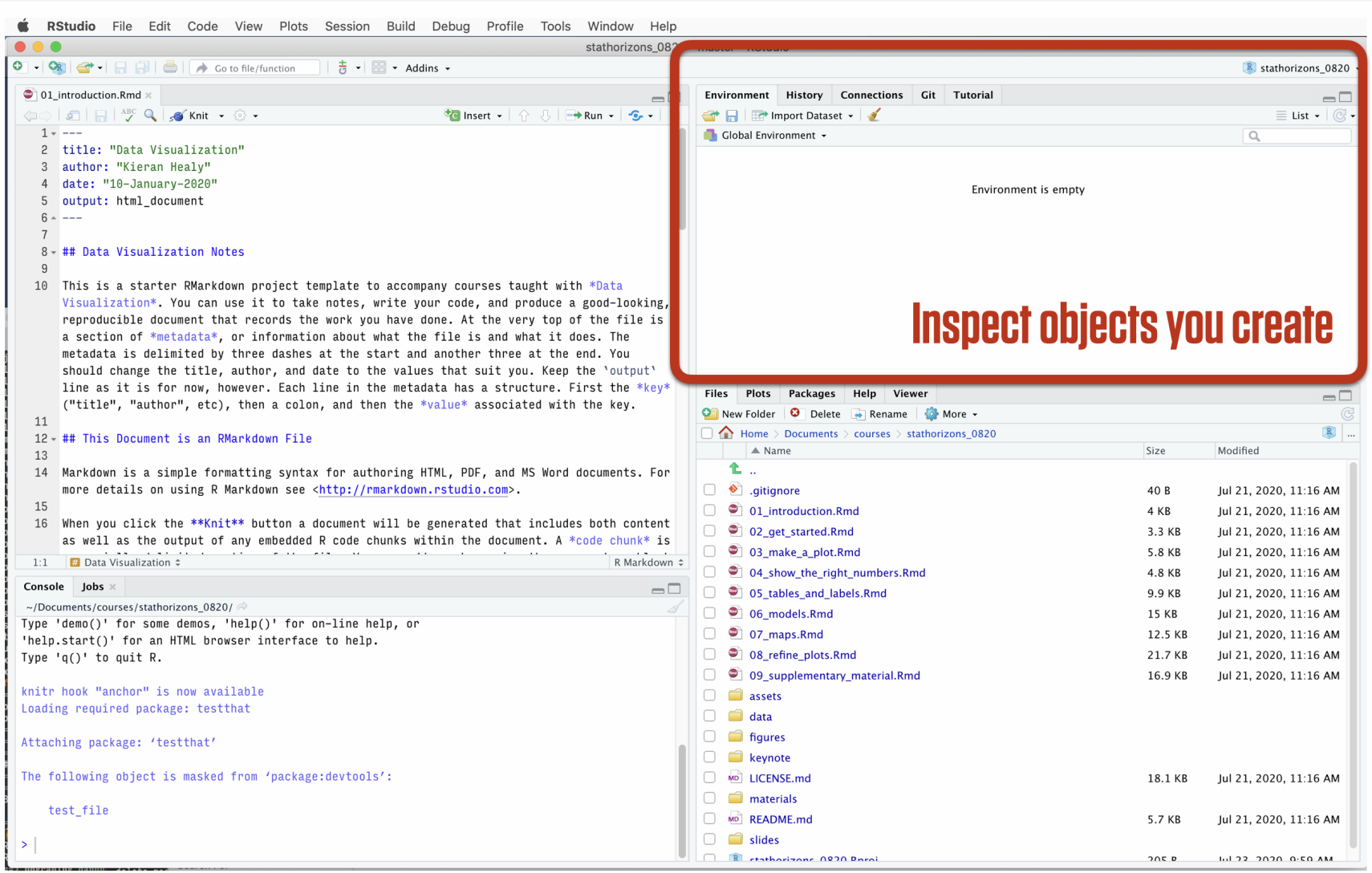
RStudio at startup



RStudio at startup



RStudio at startup



RStudio at startup

Use RMarkdown to produce and reproduce 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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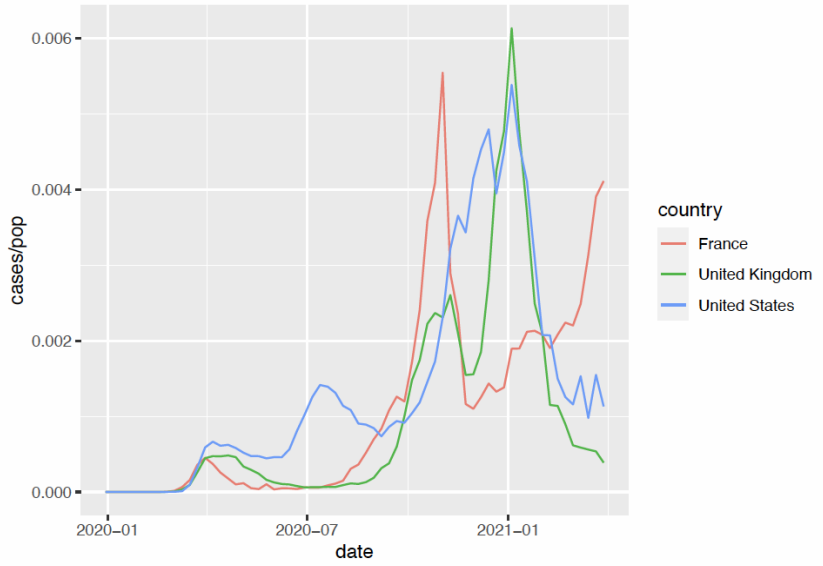

Where we want to end up

Lorem Ipsum

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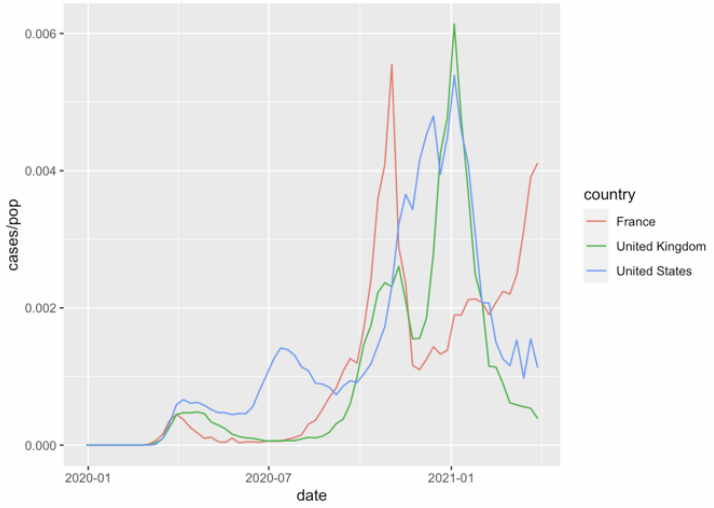

Where we want to end up

Covid Cases

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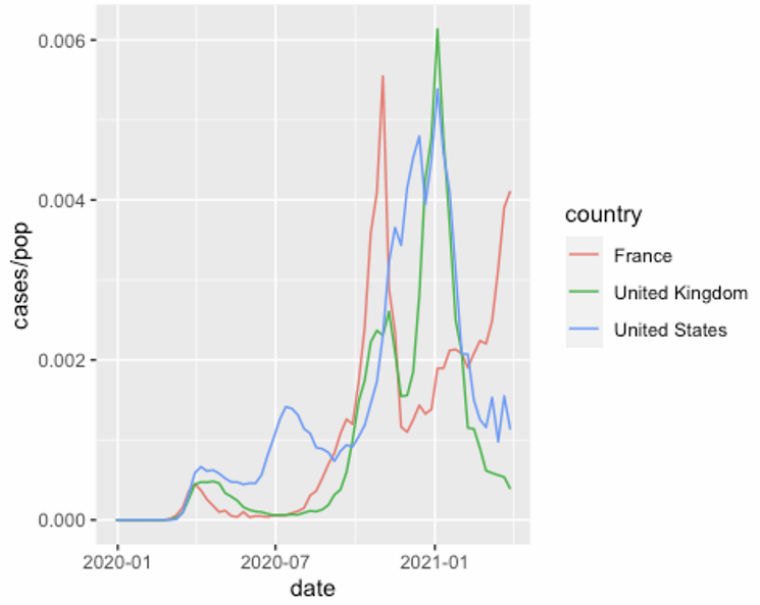

How to get there?

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[…]
```

We could write an **R script** with some notes inside, using it to 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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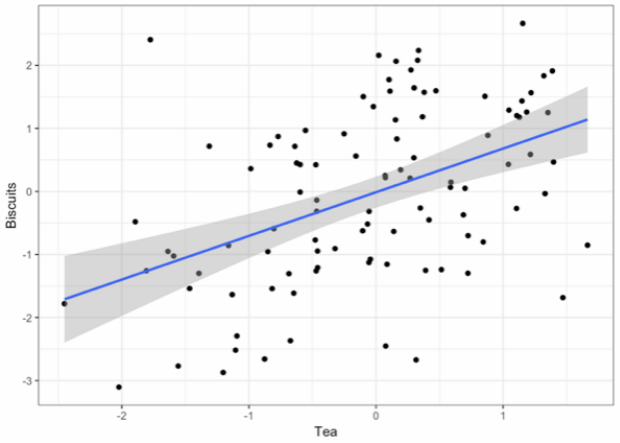

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This is what we want to end up with. Nicely-formatted text, plots, and tables. In an "Office" approach we write the document and paste in the figures and tables.

… by writing this

```
# Lorem Ipsum

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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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deserunt mollit anim id est laborum.
```

In a literate programming approach, chunks of code contained in documents are processed and then replaced with their output when the output document is produced.

The code gets replaced by its output

```
# Lorem Ipsum

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    geom_point() +
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print(p)

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```

1. Lorem Ipsum

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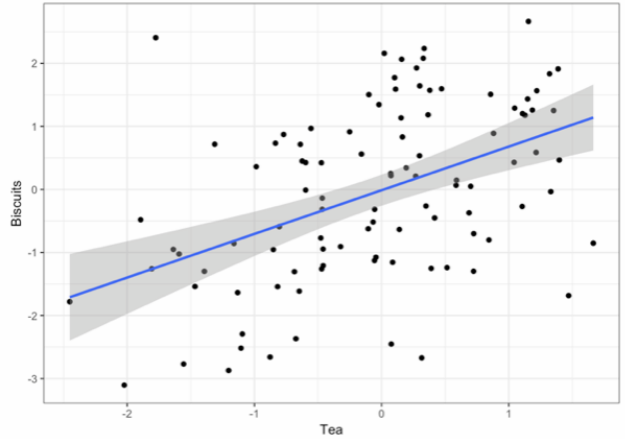

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```
---
title: "Covid Cases"
author: "Kieran Healy"
date: "4/18/2021"
output: html_document
---
```

```
```{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"
date: "4/18/2021"
output: html_document
---
```

Header section with metadata

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

We'll be looking at some COVID case data.

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  summarize(cases = sum(cases)) %>%
  arrange(desc(cases)) %>%
  kable(caption = "Total cases in three countries.")
```
```

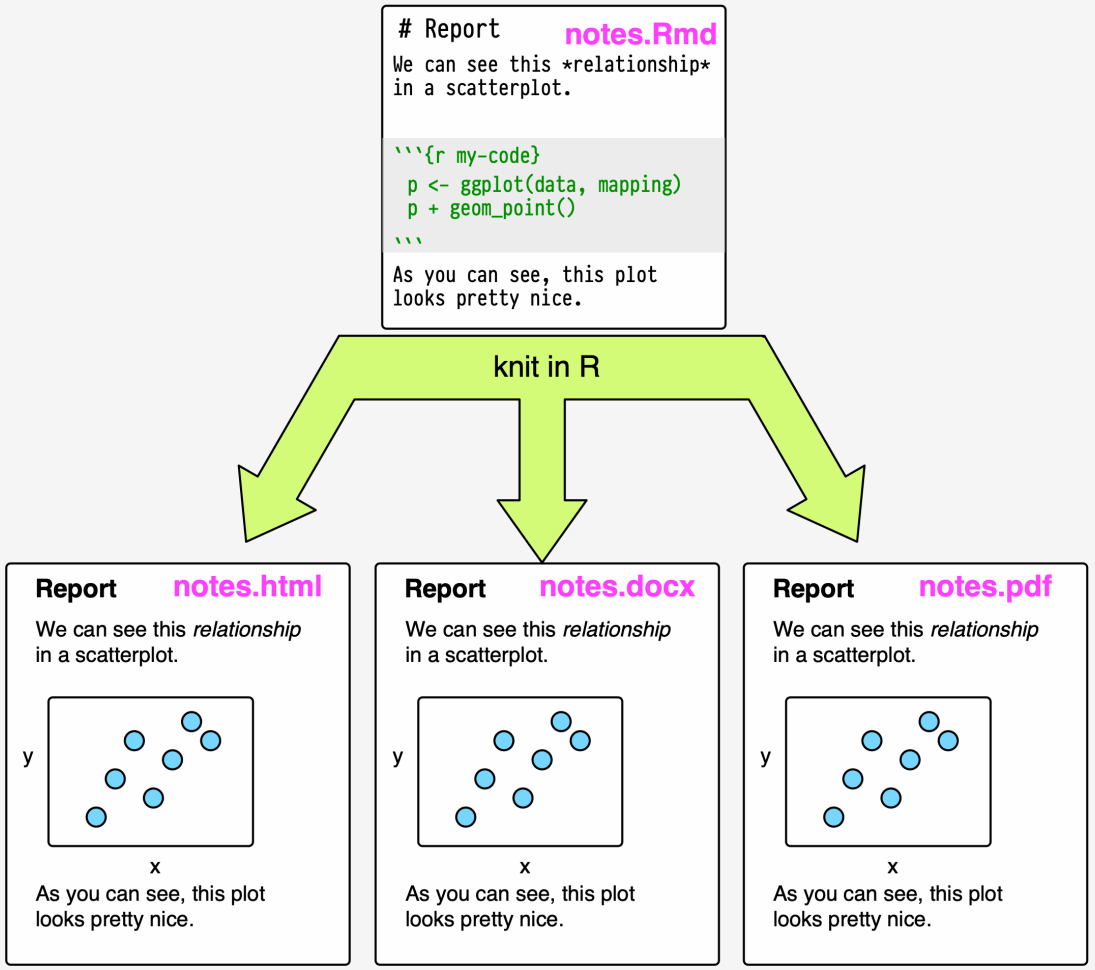
Code chunk

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


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
Report
notes.html
We can see this relationship
in a scatterplot.
y
x
As you can see, this plot
looks pretty nice.
Report
notes.docx
We can see this relationship
in a scatterplot.
y
x
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Report
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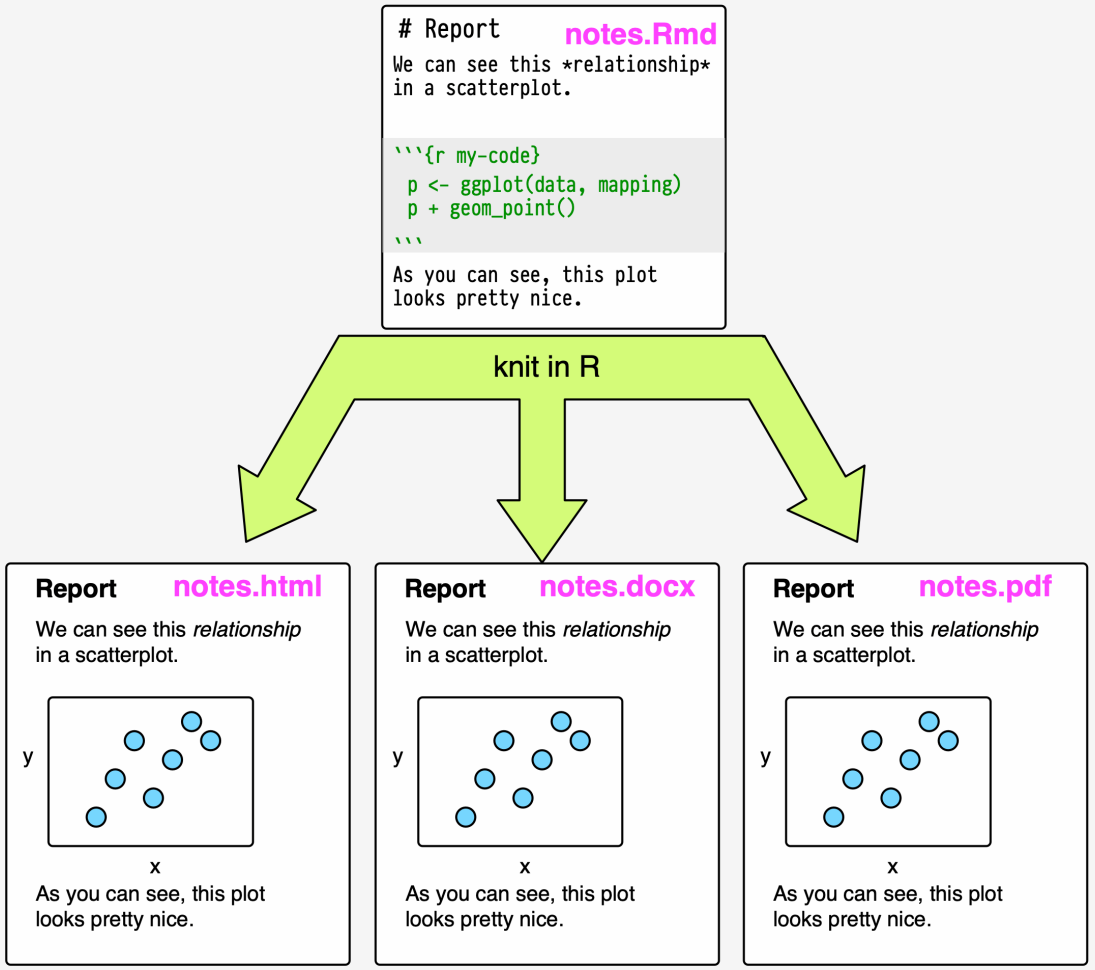
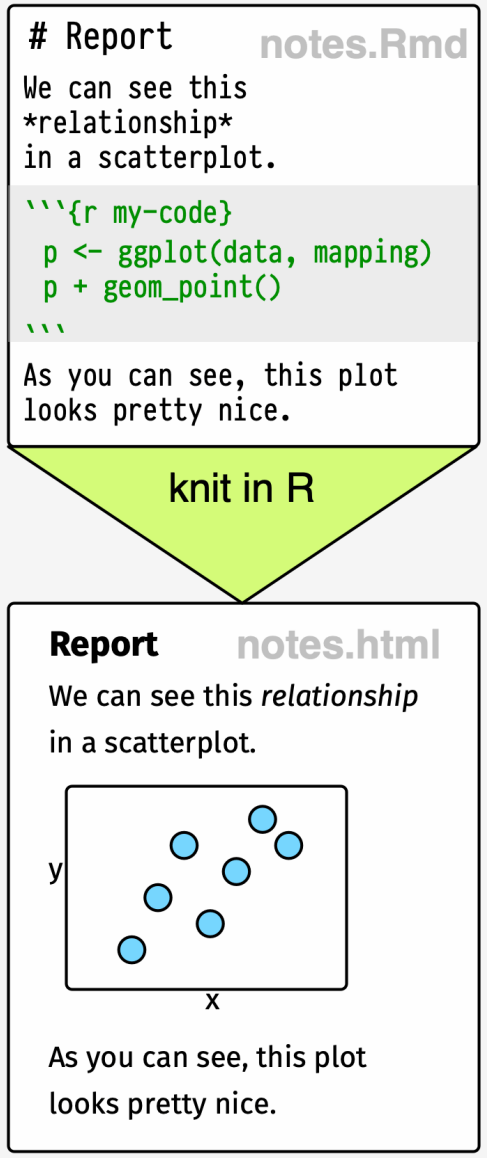


This approach has its limitations, but it's *very* useful and has many benefits.



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 slides for this course were written in RMarkdown. Many of the resources for R that you'll find online (including websites and full-length books) were as well.

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.

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*.

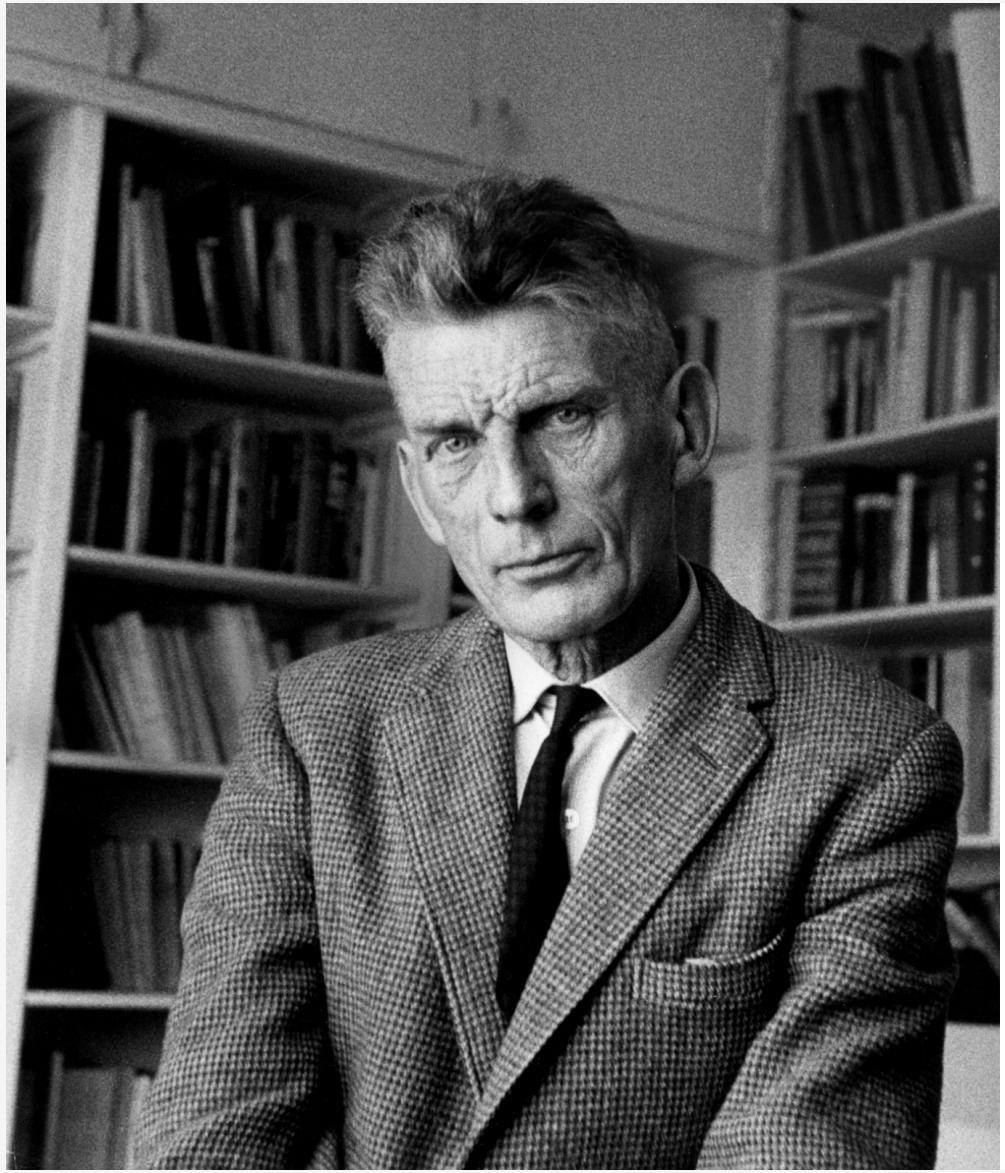
The right frame of mind

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



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)
```

The tidyverse has several components.

We'll return to this message about Conflicts later.

Again, the code and messages you see here is actual R output, produced at the same time as the slide.

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
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Loading tidyverse: tidyr
Loading tidyverse: readr
Loading tidyverse: purrr
Loading tidyverse: dplyr
```

Load 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:

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
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```

```
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
```

0. It's a calculator

Logical equality and inequality (yielding a `TRUE` or `FALSE` result) is done with == and !=. Other logical operators include <, >, <=, >=, and ! for negation. We'll use these in plots to filter data, test conditions, and so on.

```
## 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
```

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

```
## Don't name objects with terms fo logical values,
## or missing and null-value indicators

TRUE
FALSE
Inf
NaN
NA
NULL

## Don't name objects with terms that are also
## built-in functions for programming and flow-control

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"
```

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
```

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

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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

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**, `<-`, performs the action of creating objects.

The assignment operator

The assignment operator performs the action of creating objects:

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
```

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)

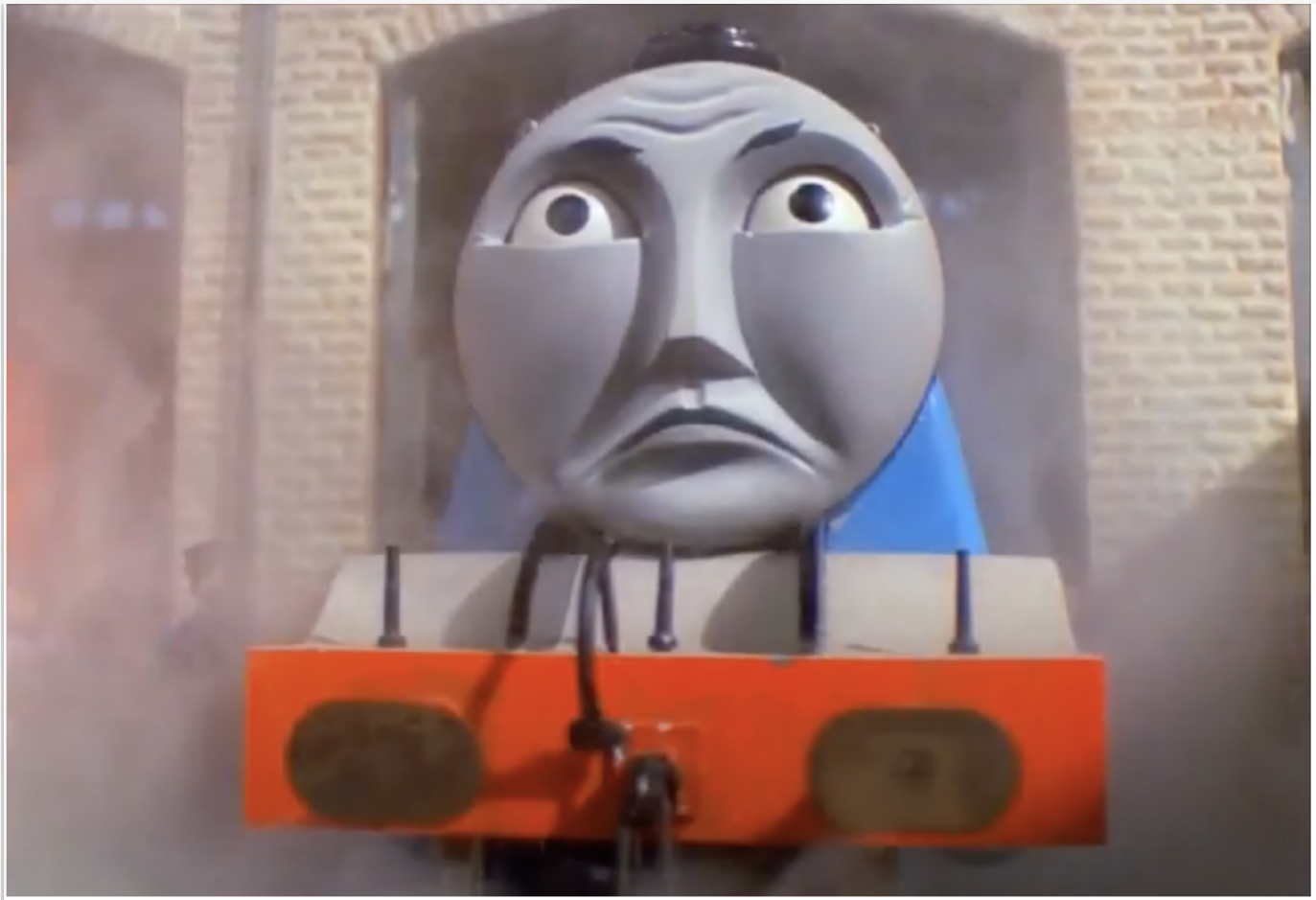
my_numbers
```

```
## [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 assigment 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

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They perform actions

They produce, or return, outputs

```
x <- c(1, 2, 3, 1, 3, 5, 25, 10)

x
```

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

What functions usually do

They take inputs to arguments

They perform actions

They produce, or return, outputs

```
x <- c(1, 2, 3, 1, 3, 5, 25, 10)
```

```
x
```

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

```
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)
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```
## 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
```

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

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    5.75   10.50   10.50   15.25   20.00
```

```
names(summary(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
```

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

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    5.75   10.50   10.50   15.25   20.00
```

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

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

```
length(names(summary(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
```

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

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    5.75   10.50   10.50   15.25   20.00
```

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

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

```
length(names(summary(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* to join them together:

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

```
## [1] 6
```

Use the pipe operator: |>

Instead of nesting functions in parentheses, we can use the *pipe operator* to join them together:

```
c(1:20) |> 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* to join them together:

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

```
## [1] 6
```

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

Better, vertical space is free in R:

```
c(1:20) |>
  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")))
```

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

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")
  )
)
```

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()
```

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 magrittr pipe: %>%

The pipe operator `|>` was not part of Base R until very recently. Pipling was originally introduced in a package called `magrittr`, where it was written `%>%` and behaved in very nearly* the same way as the base pipe now does.

The magrittr pipe: %>%

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The magrittr pipe continues to work. A lot of existing code uses it (e.g., my book!).

The magrittr pipe: %>%

The pipe operator `|>` was not part of Base R until very recently. Pipling was originally introduced in a package called `magrittr`, where it was written **`%>%`** and behaved in very nearly* the same way as the base pipe now does.

The magrittr pipe continues to work. A lot of existing code uses it (e.g., my book!).

Sidenote: There are bunch of special operators in R that have the naming convention **`%something%`**. For example **`%*%`** means "matrix multiply". We'll see more of them as we go. In this context the **`% %`** is sometimes pronounced "grapes".

*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

Functions are bundled into packages

All programming languages gain power and convenience by having libraries or packages of functions that extend the core abilities of the language. In R, packages are loaded into your working environment using the `library()` function.

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All programming languages gain power and convenience by having libraries or packages of functions that extend the core abilities of the language. In R, 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.
## # … 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 ──

## ✓ 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*.

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
```

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.

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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:

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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"
```

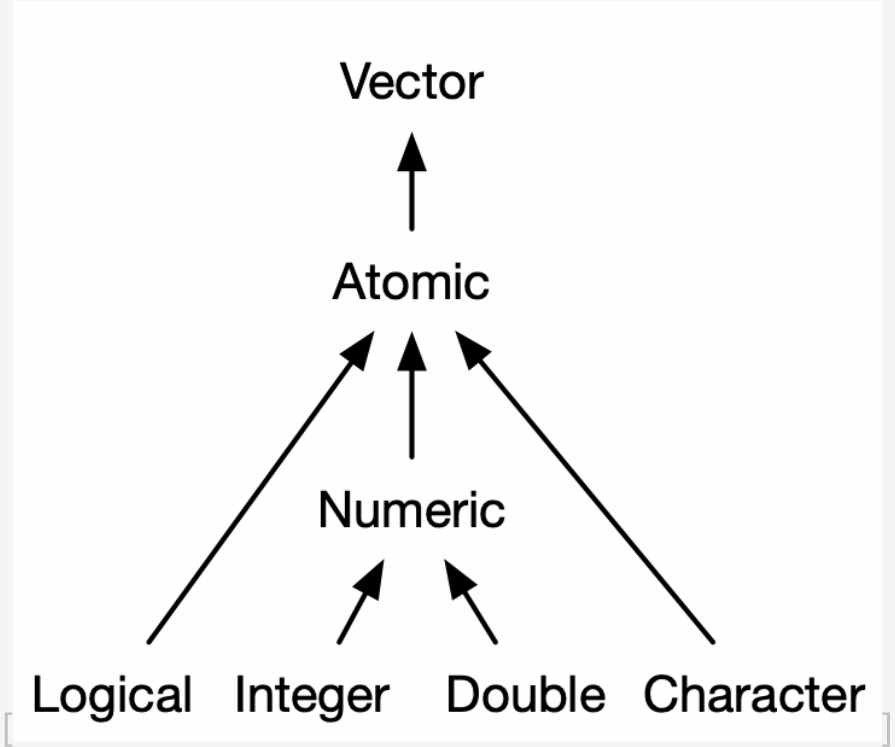
```
## In this case, the functions extract the corresponding attribute
class(my_smry)
```

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

```
names(my_smry)
```

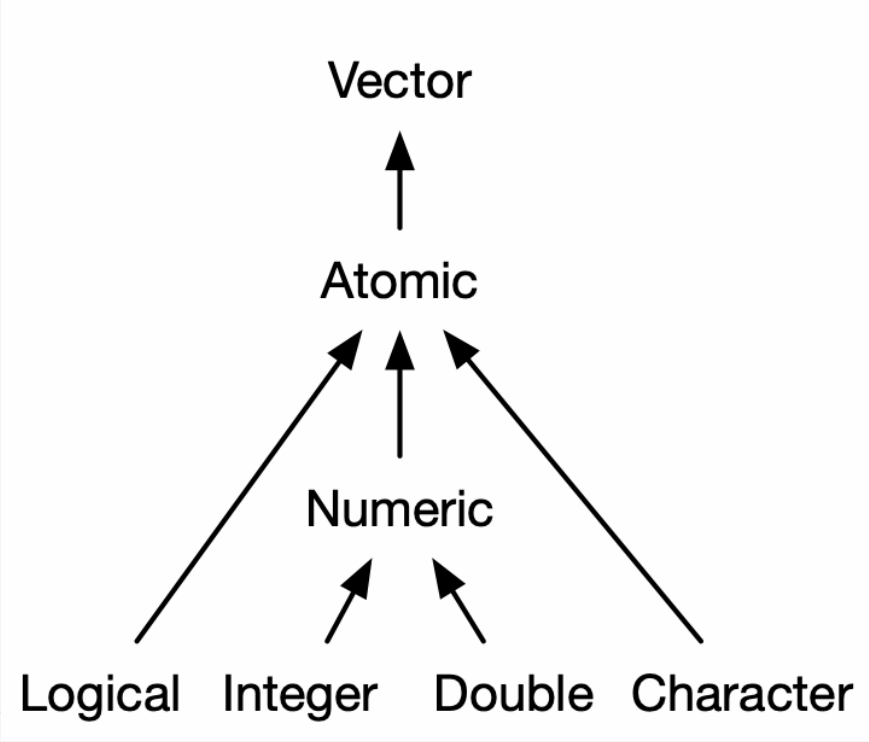
```
## [1] "Min."    "1st Qu." "Median"  "Mean"    "3rd Qu." "Max."
```

A vector is a fundamental kind of object



From Hadley Wickham, *Advanced R*

A vector is a fundamental kind of object



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
```

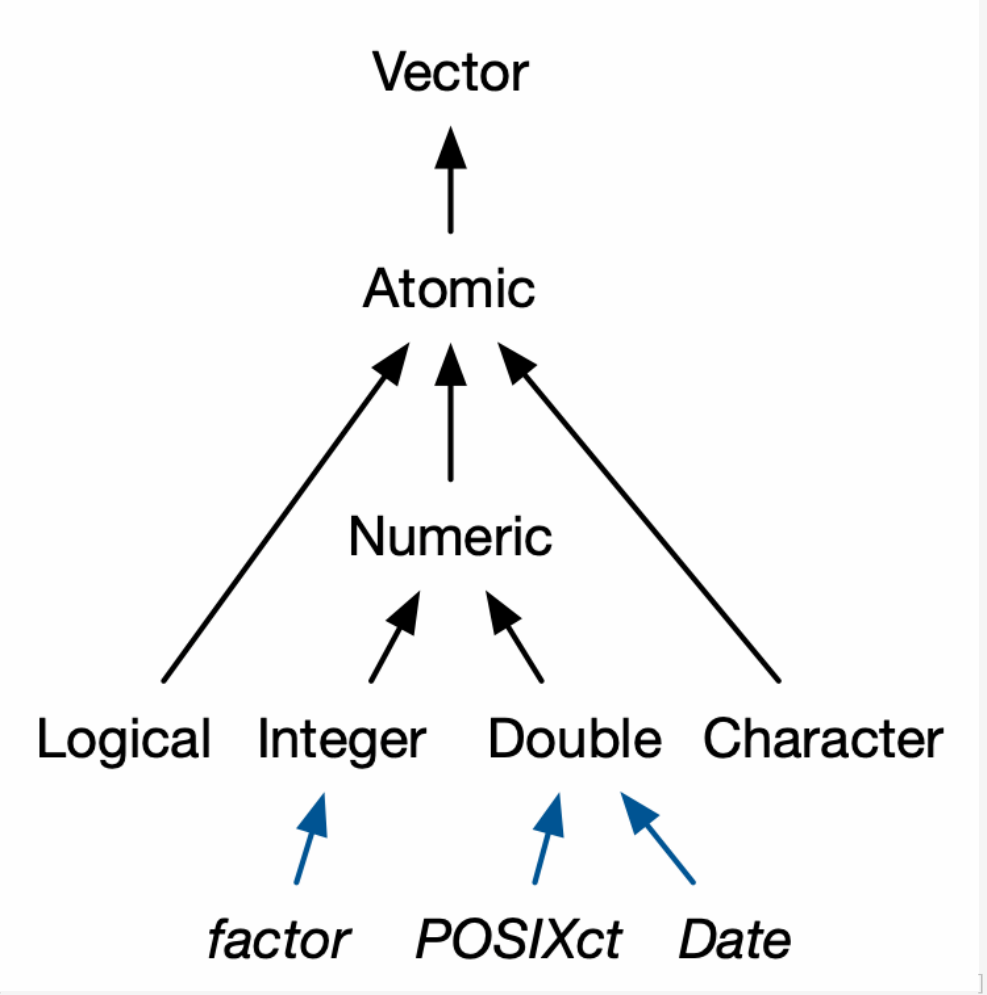
```
my_chr <- c("Mary", "had", "a", "little", "lamb")
is.character(my_chr)
```

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

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

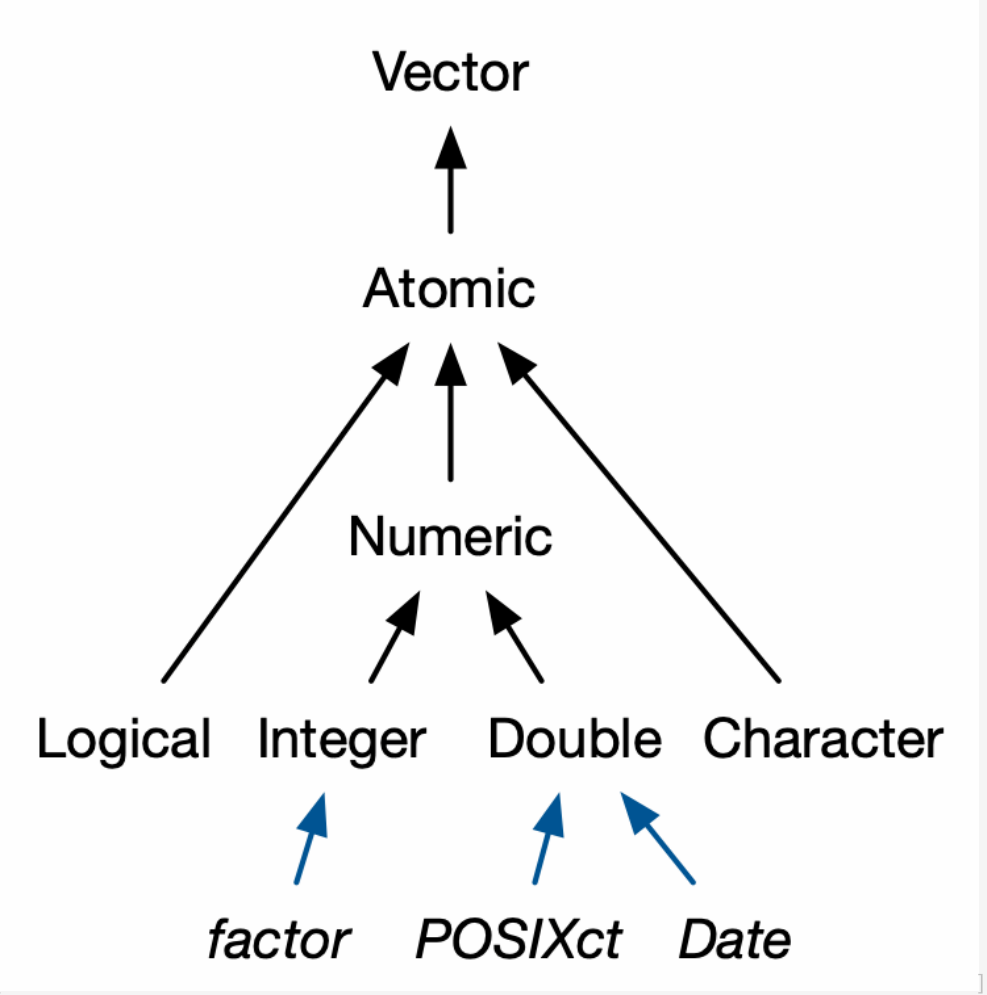
```
## [1] TRUE
```

The most common types of vector



From Hadley Wickham, *Advanced R*

The most common types of vector



From Hadley Wickham, *Advanced R*

```
## Factors are for storing categorical variables
x <- factor(c("Yes", "No", "No", "Maybe", "Yes", "Yes"))
x
```

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

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

```
## Maybe    No   Yes
##     1     2     3
```

```
typeof(x)       # A factor is a vector of integers
```

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

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

```
## $levels
## [1] "Maybe" "No"    "Yes"
##
## $class
## [1] "factor"
```

```
levels(x)
```

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

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

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

Individual vectors can't be heterogenous

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

Individual vectors 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"
```

Individual vectors can't be heterogenous

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

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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
```

Tibbles are a list of vectors of various types

```
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.

Classes can be nested

Some classes build on and enhance the properties of simpler classes.

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
```

Classes can be nested

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## 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
class(titanic)
```

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

```
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"
```

All of this will matter later on

```
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 …
## # … 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 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…
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##  7  2016     7 1             50      2 2      High … White Male  New E… $170000…
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##  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>,
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## #   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.

*And arrays, too.

6. Arithmetic on vectors

See if you can predict what the following operations do:

```
my_numbers
```

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

```
result1 <- my_numbers + 1
```

6. Arithmetic on vectors

See if you can predict what the following operations do:

```
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
```

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See if you can predict what the following operations do:

```
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

See if you can predict what the following operations do:

```
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

See if you can predict what the following operations do:

```
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

See if you can predict what the following operations do:

```
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 got a **warning** here. R will still do what you told it do, 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.

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Warning message:
In my_numbers + two_nums :
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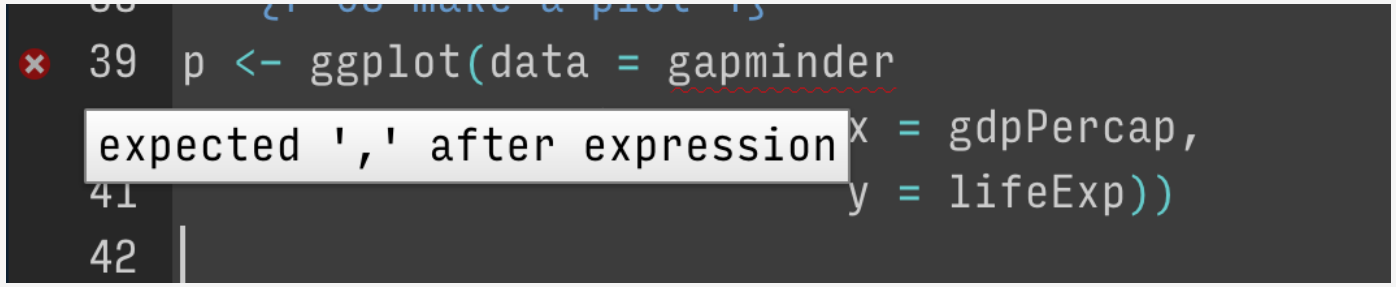

7. R will be frustrating

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 ```
```

Let's Go!

Time to make a plot

Like before:

```
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.
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## # … with 1,694 more rows
```

Like before

```
library(tidyverse)
library(gapminder)

p <- ggplot(data = gapminder,
            mapping = aes(x = gdpPercap,
                          y = lifeExp))

p + geom_point()
```

Like before

```
library(tidyverse)
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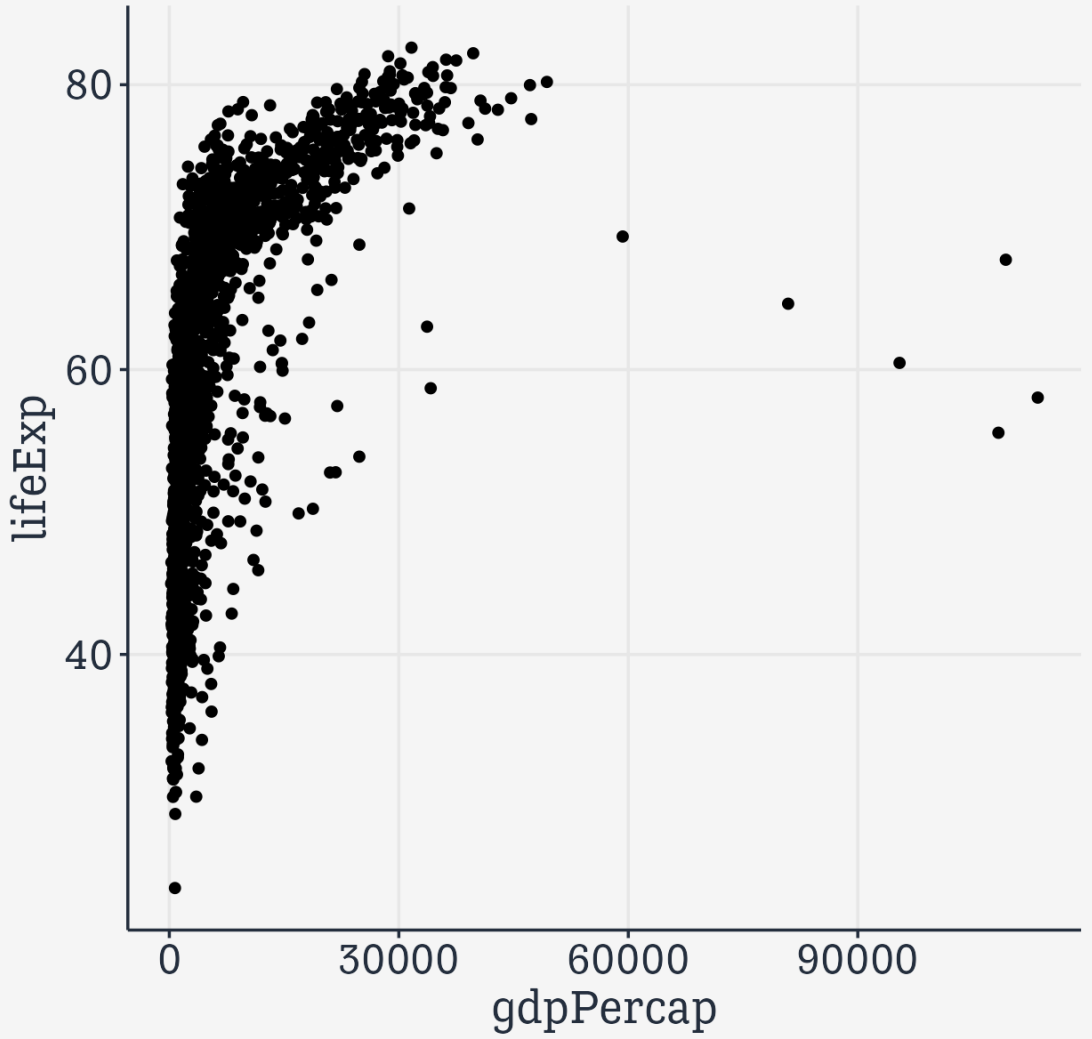

What we did

```
library(tidyverse)
library(gapminder)
```

Load the packages we need: `tidyverse` and `gapminder`

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library(tidyverse)

library(gapminder)
```

Load the packages we need: `tidyverse` and `gapminder`

```
p <- ggplot(data = gapminder,
            mapping = aes(x = gdpPercap,
                          y = lifeExp))
```

New object named `p` `gets` the output of the `ggplot()` *function*, given these *arguments*
Notice how one of the arguments, `mapping`, is itself taking the output of a function named `aes()`

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```
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library(gapminder)
```

Load the packages we need: `tidyverse` and `gapminder`

```
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            mapping = aes(x = gdpPercap,
                          y = lifeExp))
```

New object named `p` `gets` the output of the `ggplot()` *function*, given these *arguments*
Notice how one of the arguments, `mapping`, is itself taking the output of a function named `aes()`

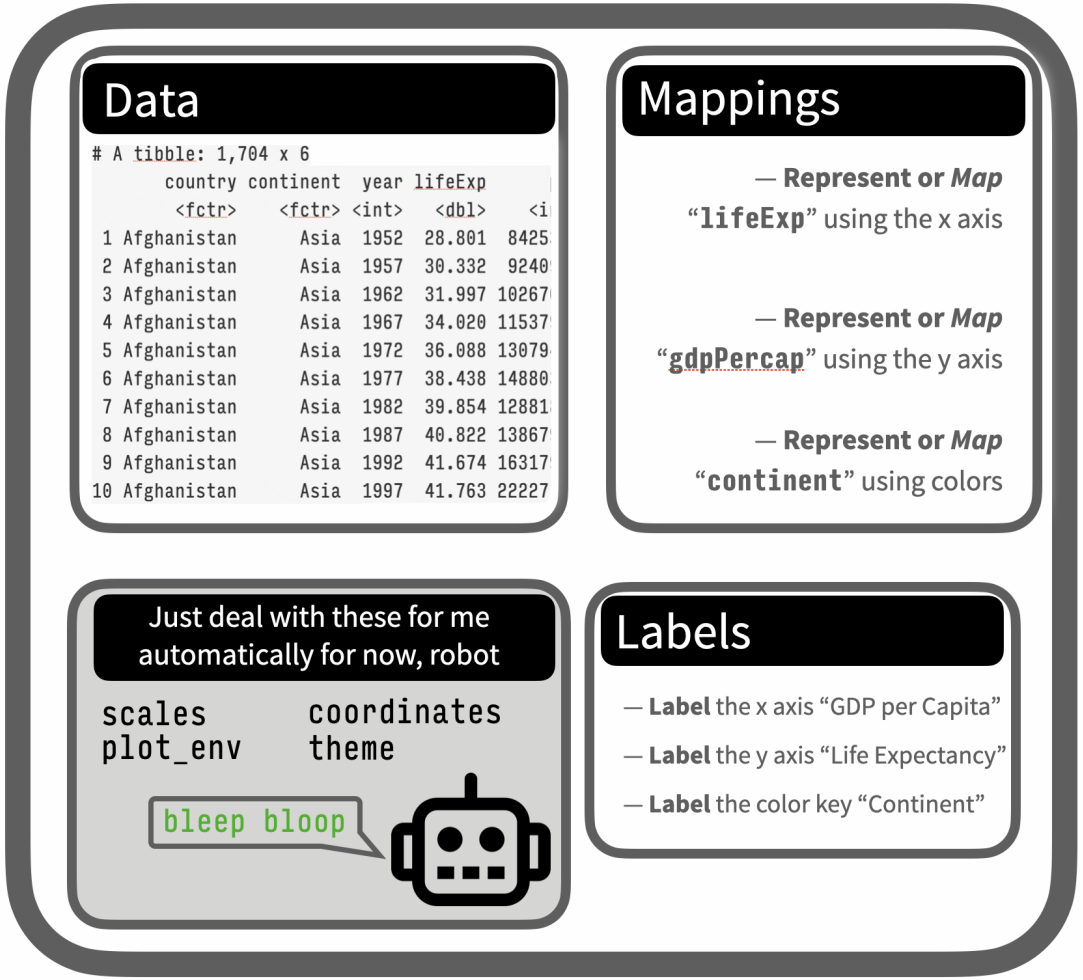
```
p + geom_point()
```

Show me the output of the `p` object and the `geom_point()` function.
The `+` here acts just like the `|>` pipe, but for ggplot functions only. (This is an accident of history.)

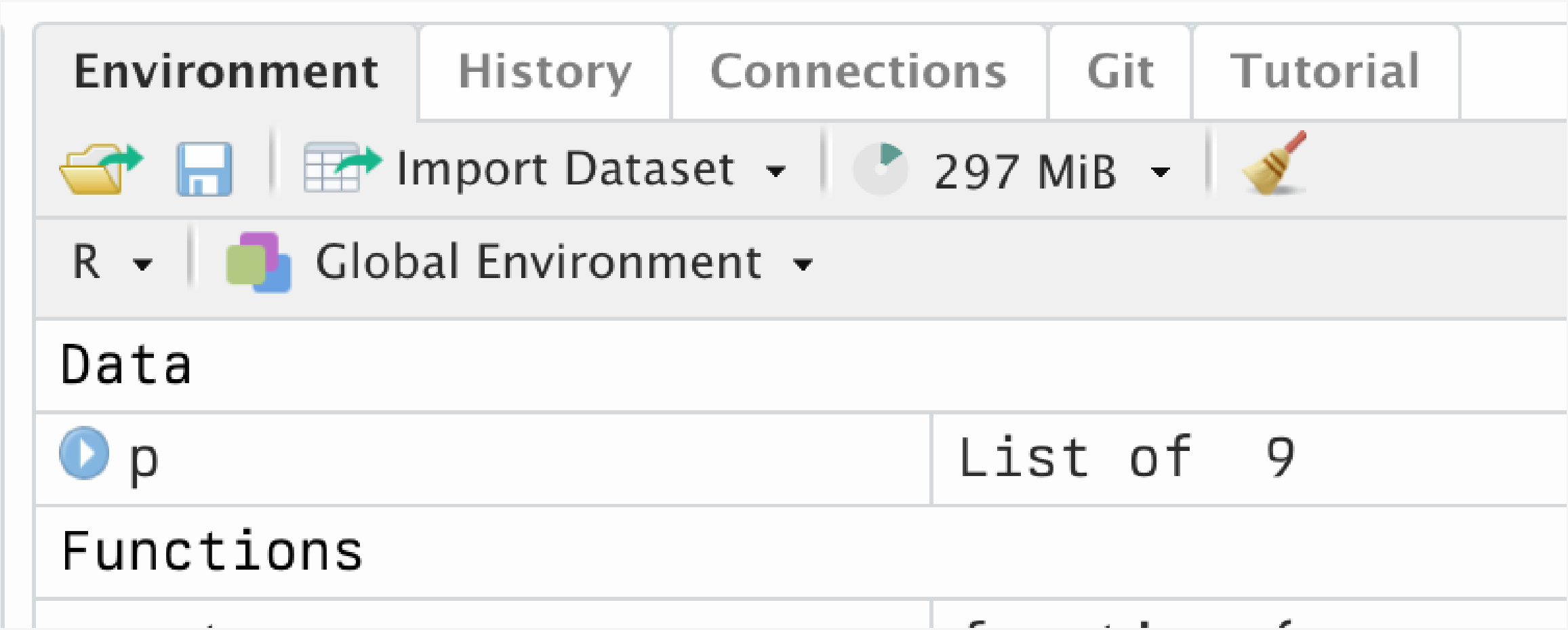
And what is R doing?

R objects are just lists of stuff to use or things to do

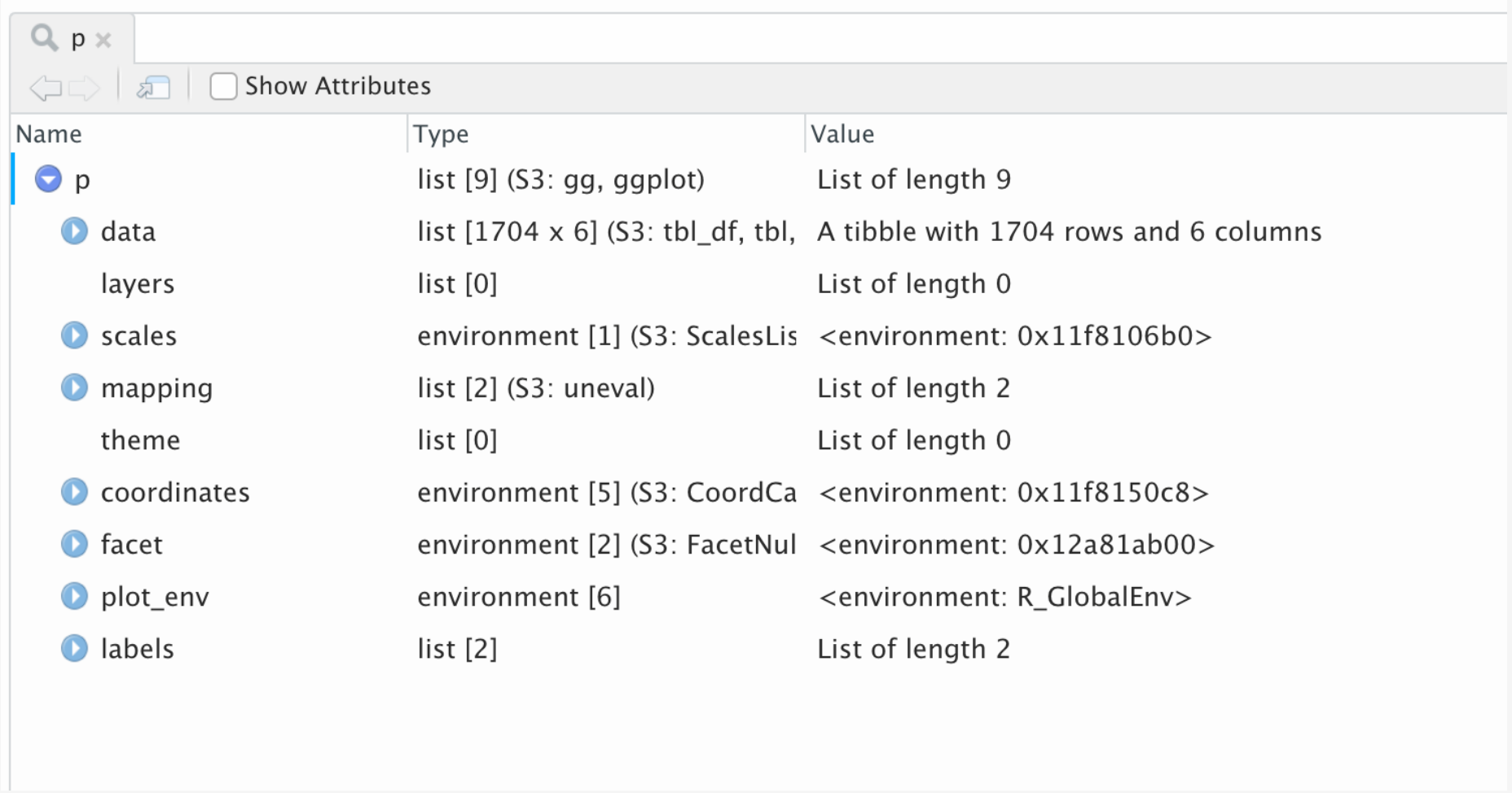

Objects are like Bento Boxes
総本山金剛峯寺御用達
高野山料理
花菱


Data
A tibble: 1,704 x 6
country continent year lifeExp
<fctr> <fctr> <int> <dbl> <i
1 Afghanistan Asia 1952 28.801 8425
2 Afghanistan Asia 1957 30.332 9240
3 Afghanistan Asia 1962 31.997 10267
4 Afghanistan Asia 1967 34.020 11537
5 Afghanistan Asia 1972 36.088 13079
6 Afghanistan Asia 1977 38.438 14880
7 Afghanistan Asia 1982 39.854 12881
8 Afghanistan Asia 1987 40.822 13867
9 Afghanistan Asia 1992 41.674 16317
10 Afghanistan Asia 1997 41.763 22227
Mappings
— Represent or Map
"lifeExp" using the x axis
— Represent or Map
"gdpPercap" using the y axis
— Represent or Map
"continent" using colors
Just deal with these for me automatically for now, robot
scales
plot_env
coordinates
theme
bleep bloop
Labels
— Label the x axis "GDP per Capita"
— Label the y axis "Life Expectancy"
— Label the color key "Continent"

The p object



Peek in with the object inspector



Peek in with the object inspector