

Module 1, Introduction to the **tidyverse**

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2-dimensional Data and the **tidyverse**

Learning Outcomes

- Students will be able to load packages.
- Students will be able to use some functions of the tidyverse: select, filter, the pipe, mutate, summarize, and group by.
- Students will compare and contrast base R and tidyverse methodology for sub-setting data frames.
- Students will be able to use tidyverse functions to summarize real-world data.

The **tidyverse**: What is it?

Different programming languages have different syntax (language structure). The **tidyverse** is a package (more accurately, a set of packages) offered in R that all have similar goals and a unified syntax designed to work particularly well with 2-dimensional data.

Until now, all of the coding we have done is in the original R language, which is often called “base R.” The syntax in the **tidyverse** is often pretty different from base R. Both are useful, and many people often combine them, which is why we start with base R.

That said, we will be primarily using the **tidyverse** for the rest of the semester.

Wait, what is a package??

Packages are one of the neatest things of working in an open-source environment like R! They contain bits of code (often in the form of functions) that can be reused, making them a core component of reproducible data science. Anyone can develop a package, and there are thousands of them doing all sorts of things.

Explore the **tidyverse**

If you want to learn more about the tidyverse, head over to www.tidyverse.org and browse the site. Below is a brief summary of *some* of the packages I think you might find the most useful.

- **tidyr**: creating data that is consistent in form/shape
- **dplyr**: creating data that is clean, easily wrangled, and summarized
- **ggplot2**: publication-worthy plots using The Grammar of Graphics
- **tibble**: data frames but better!
- **readr**: fast and friendly ways to read data into R
- **stringr**: easy manipulation of strings (character data)
- **lubridate**: easy manipulation of time and date values

Practice with the tidyverse

Download and install

In most scenarios, you will need to download a package from the internet onto your computer before you can use it in RStudio. However, with RStudio Cloud, I've already done this step for you!

For future reference, though:

- you usually only need to go through this process once until you update R
- we use the function `install.packages()` to download the package

```
# download and install the tidyverse package(s)
# to run the line of code, remove the # in front of the line below and run this chunk
# install.packages("tidyverse")
```

Load into R

Any time we open R/RStudio and want to use functions from the **tidyverse**, we need to “load” the package. We use the `library()` function to do this.

When you run this code, you'll see a message that says “Attaching packages” and “Conflicts.” Don't panic!

- The first bit tells us that the core packages have been brought into our R session.
- The “conflict” part is a little more complicated but we don't need to worry too much about it.
 - If you're curious, though, it is telling us that there are some functions in the **tidyverse** that have the same names as functions that are automatically installed with R and that the **tidyverse** versions of those functions will be the ones that get used by default unless we specify otherwise.

```
# load the tidyverse (tell RStudio we want to use this package in this session)
library(tidyverse)
```

Climate Data

To learn about the **tidyverse** syntax, we're going to use a real data set on climate change from Berkeley, CA, USA. It outlines temperatures in major cities across the world since 1750.

```
# read in the data file

# `read_csv()` is part of the `tidyverse` and gives us nice options when reading in data
# your file path should only be read_csv("global_temps.csv")
climate_df <- read_csv("../data/global_temps.csv")
```

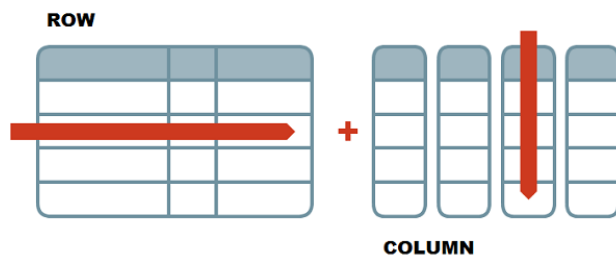
```
## Rows: 239177 Columns: 7
## -- Column specification -----
## Delimiter: ","
## chr  (4): City, Country, Latitude, Longitude
## dbl  (2): AverageTemperature, AverageTemperatureUncertainty
## date (1): dt
##
## i Use 'spec()' to retrieve the full column specification for this data.
## i Specify the column types or set 'show_col_types = FALSE' to quiet this message.
```

```
# Let's take a look at the climate data.
climate_df
```

```
## # A tibble: 239,177 x 7
##   dt                AverageTemperature AverageTemperatureUncer~1 City Country Latitude
##   <date>                <dbl>                <dbl> <chr> <chr> <chr>
## 1 1849-01-01                26.7                1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01                27.4                1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01                28.1                1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01                26.1                1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01                25.4                1.2  Abid~ Côte D~ 5.63N
## 6 1849-06-01                24.8                1.40 Abid~ Côte D~ 5.63N
## 7 1849-07-01                24.1                1.25 Abid~ Côte D~ 5.63N
## 8 1849-08-01                23.6                1.26 Abid~ Côte D~ 5.63N
## 9 1849-09-01                23.7                1.23 Abid~ Côte D~ 5.63N
## 10 1849-10-01                25.3                1.18 Abid~ Côte D~ 5.63N
## # i 239,167 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

The **tidyverse** converts 2D data into something called a tibble! For our intents and purposes, it is basically the same as a data frame (and I'll probably call it a data frame, in reality).

As a quick reminder, *columns* represent variables and are vertical. *Rows* represent observations and are horizontal.



Let's take a look at our tibble (AKA data frame).

```
# explore the data set
head(climate_df)
```

```
## # A tibble: 6 x 7
##   dt                AverageTemperature AverageTemperatureUncer~1 City Country Latitude
##   <date>                <dbl>                <dbl> <chr> <chr> <chr>
## 1 1849-01-01                26.7                1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01                27.4                1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01                28.1                1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01                26.1                1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01                25.4                1.2  Abid~ Côte D~ 5.63N
## 6 1849-06-01                24.8                1.40 Abid~ Côte D~ 5.63N
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

```
str(climate_df)
```

```
## spc_tbl_ [239,177 x 7] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
## $ dt : Date[1:239177], format: "1849-01-01" "1849-02-01" ...
## $ AverageTemperature : num [1:239177] 26.7 27.4 28.1 26.1 25.4 ...
## $ AverageTemperatureUncertainty: num [1:239177] 1.44 1.36 1.61 1.39 1.2 ...
## $ City : chr [1:239177] "Abidjan" "Abidjan" "Abidjan" "Abidjan" ...
## $ Country : chr [1:239177] "Côte D'Ivoire" "Côte D'Ivoire" "Côte D'Ivoire" "Côte
## $ Latitude : chr [1:239177] "5.63N" "5.63N" "5.63N" "5.63N" ...
## $ Longitude : chr [1:239177] "3.23W" "3.23W" "3.23W" "3.23W" ...
## - attr(*, "spec")=
## .. cols(
## .. dt = col_date(format = ""),
## .. AverageTemperature = col_double(),
## .. AverageTemperatureUncertainty = col_double(),
## .. City = col_character(),
## .. Country = col_character(),
## .. Latitude = col_character(),
## .. Longitude = col_character()
## .. )
## - attr(*, "problems")=<externalptr>
```

select()ing columns

Let's use our first function, `select()`. `Select` allows us to pick out specific columns from our data. You can use names or their position in the data frame.

First, let's remind ourselves how we would accomplish this in base R.

```
# column selection in base R
# climate_df$dt
climate_df[,1:2]
```

```
## # A tibble: 239,177 x 2
## dt AverageTemperature
## <date> <dbl>
## 1 1849-01-01 26.7
## 2 1849-02-01 27.4
## 3 1849-03-01 28.1
## 4 1849-04-01 26.1
## 5 1849-05-01 25.4
## 6 1849-06-01 24.8
## 7 1849-07-01 24.1
## 8 1849-08-01 23.6
## 9 1849-09-01 23.7
## 10 1849-10-01 25.3
## # i 239,167 more rows
```

The `select()` function does the same thing but with more power (and, in my opinion, more easily). The first argument in the function is the data frame. Any following arguments are the columns we want to select.

```
# first argument is the data frame, then the columns
select(climate_df, dt)
```

```
## # A tibble: 239,177 x 1
##   dt
##   <date>
## 1 1849-01-01
## 2 1849-02-01
## 3 1849-03-01
## 4 1849-04-01
## 5 1849-05-01
## 6 1849-06-01
## 7 1849-07-01
## 8 1849-08-01
## 9 1849-09-01
## 10 1849-10-01
## # i 239,167 more rows
```

```
# multiple columns
select(climate_df, dt, City, Country)
```

```
## # A tibble: 239,177 x 3
##   dt      City      Country
##   <date>   <chr>   <chr>
## 1 1849-01-01 Abidjan Côte D'Ivoire
## 2 1849-02-01 Abidjan Côte D'Ivoire
## 3 1849-03-01 Abidjan Côte D'Ivoire
## 4 1849-04-01 Abidjan Côte D'Ivoire
## 5 1849-05-01 Abidjan Côte D'Ivoire
## 6 1849-06-01 Abidjan Côte D'Ivoire
## 7 1849-07-01 Abidjan Côte D'Ivoire
## 8 1849-08-01 Abidjan Côte D'Ivoire
## 9 1849-09-01 Abidjan Côte D'Ivoire
## 10 1849-10-01 Abidjan Côte D'Ivoire
## # i 239,167 more rows
```

```
select(climate_df, dt:Country)
```

```
## # A tibble: 239,177 x 5
##   dt      AverageTemperature AverageTemperatureUncertainty City      Country
##   <date>                <dbl>                <dbl> <chr>   <chr>
## 1 1849-01-01             26.7                1.44 Abidjan Côte D'I-
## 2 1849-02-01             27.4                1.36 Abidjan Côte D'I-
## 3 1849-03-01             28.1                1.61 Abidjan Côte D'I-
## 4 1849-04-01             26.1                1.39 Abidjan Côte D'I-
## 5 1849-05-01             25.4                1.2  Abidjan Côte D'I-
## 6 1849-06-01             24.8                1.40 Abidjan Côte D'I-
## 7 1849-07-01             24.1                1.25 Abidjan Côte D'I-
## 8 1849-08-01             23.6                1.26 Abidjan Côte D'I-
## 9 1849-09-01             23.7                1.23 Abidjan Côte D'I-
## 10 1849-10-01            25.3                1.18 Abidjan Côte D'I-
## # i 239,167 more rows
```

```
select(climate_df, -City)
```

```
## # A tibble: 239,177 x 6
##   dt      AverageTemperature AverageTemperatureUncertainty Country Latitude
##   <date>          <dbl>          <dbl> <chr>    <chr>
## 1 1849-01-01          26.7          1.44 Côte D'~ 5.63N
## 2 1849-02-01          27.4          1.36 Côte D'~ 5.63N
## 3 1849-03-01          28.1          1.61 Côte D'~ 5.63N
## 4 1849-04-01          26.1          1.39 Côte D'~ 5.63N
## 5 1849-05-01          25.4          1.2  Côte D'~ 5.63N
## 6 1849-06-01          24.8          1.40 Côte D'~ 5.63N
## 7 1849-07-01          24.1          1.25 Côte D'~ 5.63N
## 8 1849-08-01          23.6          1.26 Côte D'~ 5.63N
## 9 1849-09-01          23.7          1.23 Côte D'~ 5.63N
## 10 1849-10-01          25.3          1.18 Côte D'~ 5.63N
## # i 239,167 more rows
## # i 1 more variable: Longitude <chr>
```

Note that we haven't put any column names in quotations. Using the `tidyverse`, we will rarely (if ever, in this class) put column names in quotation marks.

Let's practice!

Write a line of code to select the following data from the `climate_df`: average temperature, latitude and longitude

```
select(climate_df, AverageTemperature, Latitude, Longitude)
```

```
## # A tibble: 239,177 x 3
##   AverageTemperature Latitude Longitude
##   <dbl> <chr>    <chr>
## 1      26.7 5.63N    3.23W
## 2      27.4 5.63N    3.23W
## 3      28.1 5.63N    3.23W
## 4      26.1 5.63N    3.23W
## 5      25.4 5.63N    3.23W
## 6      24.8 5.63N    3.23W
## 7      24.1 5.63N    3.23W
## 8      23.6 5.63N    3.23W
## 9      23.7 5.63N    3.23W
## 10     25.3 5.63N    3.23W
## # i 239,167 more rows
```

It is important to remember that the computer interprets everything literally. We need to tell the function the **exact** names of the columns. R will interpret `latitude` and `Latitude` as different things; it doesn't know that they are probably the same!

`filter()`ing rows

`filter()` allows you filter rows by certain conditions. The code below is how we would do this in base R.

```
# base R
climate_df[climate_df$AverageTemperature > 25, ]
```

```
## # A tibble: 79,690 x 7
##   dt          AverageTemperature AverageTemperatureUnce~1 City Country Latitude
##   <date>          <dbl>          <dbl> <chr> <chr> <chr>
## 1 1849-01-01          26.7          1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01          27.4          1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01          28.1          1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01          26.1          1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01          25.4          1.2  Abid~ Côte D~ 5.63N
## 6 1849-10-01          25.3          1.18 Abid~ Côte D~ 5.63N
## 7 1849-11-01          26.3          1.51 Abid~ Côte D~ 5.63N
## 8 1849-12-01          25.4          1.84 Abid~ Côte D~ 5.63N
## 9 1850-01-01          25.8          1.94 Abid~ Côte D~ 5.63N
## 10 1850-02-01          27.9          1.43 Abid~ Côte D~ 5.63N
## # i 79,680 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

The code above is, in my opinion, a bit unwieldy. Filter feels more intuitive. We still need the double equal signs, though!

```
# filter
filter(climate_df, AverageTemperature > 25)
```

```
## # A tibble: 68,688 x 7
##   dt          AverageTemperature AverageTemperatureUnce~1 City Country Latitude
##   <date>          <dbl>          <dbl> <chr> <chr> <chr>
## 1 1849-01-01          26.7          1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01          27.4          1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01          28.1          1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01          26.1          1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01          25.4          1.2  Abid~ Côte D~ 5.63N
## 6 1849-10-01          25.3          1.18 Abid~ Côte D~ 5.63N
## 7 1849-11-01          26.3          1.51 Abid~ Côte D~ 5.63N
## 8 1849-12-01          25.4          1.84 Abid~ Côte D~ 5.63N
## 9 1850-01-01          25.8          1.94 Abid~ Côte D~ 5.63N
## 10 1850-02-01          27.9          1.43 Abid~ Côte D~ 5.63N
## # i 68,678 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

```
# easy to write multiple conditions and to chain stuff together
# only rows that meet both conditions; could also use & instead of ,
filter(climate_df, AverageTemperature > 25, Country == "United States")
```

```
## # A tibble: 61 x 7
##   dt          AverageTemperature AverageTemperatureUnce~1 City Country Latitude
##   <date>          <dbl>          <dbl> <chr> <chr> <chr>
## 1 1761-07-01          27.8          2.39 Chic~ United~ 42.59N
## 2 1868-07-01          25.1          0.699 Chic~ United~ 42.59N
```

```
## 3 1900-08-01      25.2      0.49 Chic~ United~ 42.59N
## 4 1921-07-01      25.6      0.264 Chic~ United~ 42.59N
## 5 1947-08-01      26.4      0.199 Chic~ United~ 42.59N
## 6 1955-08-01      25.3      0.153 Chic~ United~ 42.59N
## 7 1959-08-01      25.1      0.205 Chic~ United~ 42.59N
## 8 1988-08-01      25.4      0.305 Chic~ United~ 42.59N
## 9 1995-08-01      25.9      0.283 Chic~ United~ 42.59N
## 10 2012-07-01     25.9      0.516 Chic~ United~ 42.59N
## # i 51 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

```
# rows that meet one or the other condition; the | symbol means `or`
filter(climate_df, AverageTemperature > 25 | Country == "United States" )
```

```
## # A tibble: 77,082 x 7
##   dt      AverageTemperature AverageTemperatureUnce-1 City Country Latitude
##   <date>          <dbl>          <dbl> <chr> <chr> <chr>
## 1 1849-01-01      26.7          1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01      27.4          1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01      28.1          1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01      26.1          1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01      25.4          1.2  Abid~ Côte D~ 5.63N
## 6 1849-10-01      25.3          1.18 Abid~ Côte D~ 5.63N
## 7 1849-11-01      26.3          1.51 Abid~ Côte D~ 5.63N
## 8 1849-12-01      25.4          1.84 Abid~ Côte D~ 5.63N
## 9 1850-01-01      25.8          1.94 Abid~ Côte D~ 5.63N
## 10 1850-02-01     27.9          1.43 Abid~ Côte D~ 5.63N
## # i 77,072 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```

```
# pulls rows in which the Country column has either "United States" OR "Mexico"
filter(climate_df, Country == "United States" | Country == "Mexico")
```

```
## # A tibble: 10,600 x 7
##   dt      AverageTemperature AverageTemperatureUnce-1 City Country Latitude
##   <date>          <dbl>          <dbl> <chr> <chr> <chr>
## 1 1743-11-01      5.44          2.20 Chic~ United~ 42.59N
## 2 1743-12-01      NA          NA    Chic~ United~ 42.59N
## 3 1744-01-01      NA          NA    Chic~ United~ 42.59N
## 4 1744-02-01      NA          NA    Chic~ United~ 42.59N
## 5 1744-03-01      NA          NA    Chic~ United~ 42.59N
## 6 1744-04-01      8.77          2.36 Chic~ United~ 42.59N
## 7 1744-05-01     11.6          2.10 Chic~ United~ 42.59N
## 8 1744-06-01     18.0          1.99 Chic~ United~ 42.59N
## 9 1744-07-01     21.7          1.79 Chic~ United~ 42.59N
## 10 1744-08-01      NA          NA    Chic~ United~ 42.59N
## # i 10,590 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 1 more variable: Longitude <chr>
```



```
# worth noting here that we haven't saved any of this. We need to write to a new object.
us_df <- filter(climate_df, AverageTemperature > 25)
```

Let's practice using `select()` and `filter()`

Work with the climate data we've been using this class period. Construct a small set of code that does the following:

1. Slims down the full data frame to one that contains the columns `dt`, `AverageTemperature` and `City`. Assign this to an object called `slim`.
2. Filters the data for Paris with an average temperature less than 22.
3. Name this new data frame "cold_paris"

```
# not piped
slim <- select(climate_df, dt, AverageTemperature, City)
filtered <- filter(slim, City == "Paris", AverageTemperature < 22)
cold_paris <- filtered
```

The pipe `%>%`

You can use the pipe operator to chain tidyverse functions together. You can think of the pipe as automatically sending the output from the first line into the next line as the input.

This is helpful for a lot of reasons, including:

1. removing the clutter of creating a lot of intermediate objects in your work space, which reduces the chance of errors caused by using the wrong input object
2. makes things more human-readable (in addition to computer-readable)

The shortcut for typing a pipe is `Ctrl + Shift + M` (or `Cmd + Shift + M` on a Mac)

```
climate_df %>%
  select(dt, City)
```

```
## # A tibble: 239,177 x 2
##   dt      City
##   <date>   <chr>
## 1 1849-01-01 Abidjan
## 2 1849-02-01 Abidjan
## 3 1849-03-01 Abidjan
## 4 1849-04-01 Abidjan
## 5 1849-05-01 Abidjan
## 6 1849-06-01 Abidjan
## 7 1849-07-01 Abidjan
## 8 1849-08-01 Abidjan
## 9 1849-09-01 Abidjan
## 10 1849-10-01 Abidjan
## # i 239,167 more rows
```

```
cold_paris <- climate_df %>%
  select(dt, AverageTemperature, City) %>%
  filter(City == "Paris", AverageTemperature < 22)
```

Let's practice!

In small groups, use pipes to create a new data frame called `warm_nigeria` that includes the following:

- the columns `AverageTemperature`, `City`, `Country`
- only rows for the country `Nigeria` and temperatures that are greater than 30 degrees

```
warm_nigeria <- climate_df %>%
  select(AverageTemperature, City, Country) %>%
  filter(Country == "Nigeria", AverageTemperature > 30)
```

Creating new variables with `mutate()`

Sometimes our data doesn't have our data in exactly the format we want. For example, we might want our temperature data in Fahrenheit instead of Celsius.

The `tidyverse` has a function called `mutate()` that lets us create a new column. Often, we want to apply a function to the entire column or perform some type of calculation, such as converting temp from F to C.

To help us out, here is the equation for converting: $\text{Fahrenheit} = \text{Celcius} * (9/5) + 32$

```
# create a new column for temps in Fahrenheit
climate_df %>%
  select(dt, AverageTemperature) %>%
  mutate(AverageTemperature_F = AverageTemperature * (9/5) + 32)
```

```
## # A tibble: 239,177 x 3
##   dt          AverageTemperature AverageTemperature_F
##   <date>          <dbl>          <dbl>
## 1 1849-01-01          26.7          80.1
## 2 1849-02-01          27.4          81.4
## 3 1849-03-01          28.1          82.6
## 4 1849-04-01          26.1          79.1
## 5 1849-05-01          25.4          77.8
## 6 1849-06-01          24.8          76.7
## 7 1849-07-01          24.1          75.3
## 8 1849-08-01          23.6          74.4
## 9 1849-09-01          23.7          74.6
## 10 1849-10-01          25.3          77.5
## # i 239,167 more rows
```

The first part of the argument in the `mutate` function (before the `=`) is the name of the new column we want to create (or, sometime, the name of a column we want to overwrite). After the `=` is what we want the new column to contain.

Let's Practice

Write some code that uses the `round()` function to create a new column of average temperatures (Celsius) with only point value after the decimal point.

```
climate_df %>%
  mutate(AverageTemperatureRound = round(AverageTemperature, digits = 1))

## # A tibble: 239,177 x 8
##   dt                AverageTemperature AverageTemperatureUncertainty City Country Latitude
##   <date>                <dbl>                <dbl> <chr> <chr> <chr>
## 1 1849-01-01                26.7                1.44 Abid~ Côte D~ 5.63N
## 2 1849-02-01                27.4                1.36 Abid~ Côte D~ 5.63N
## 3 1849-03-01                28.1                1.61 Abid~ Côte D~ 5.63N
## 4 1849-04-01                26.1                1.39 Abid~ Côte D~ 5.63N
## 5 1849-05-01                25.4                1.2  Abid~ Côte D~ 5.63N
## 6 1849-06-01                24.8                1.40 Abid~ Côte D~ 5.63N
## 7 1849-07-01                24.1                1.25 Abid~ Côte D~ 5.63N
## 8 1849-08-01                23.6                1.26 Abid~ Côte D~ 5.63N
## 9 1849-09-01                23.7                1.23 Abid~ Côte D~ 5.63N
## 10 1849-10-01               25.3                1.18 Abid~ Côte D~ 5.63N
## # i 239,167 more rows
## # i abbreviated name: 1: AverageTemperatureUncertainty
## # i 2 more variables: Longitude <chr>, AverageTemperatureRound <dbl>
```

If we set the “new” column name in the `mutate()` function as the same name of a column that already exists, the code will replace that column with the new values.

Understanding data through `summarize()`

Like we have talked about in previous classes, some of the best ways for us to understand our data is through what we call summary statistics such as the mean, standard deviation, minimums, maximums, etc.

Fortunately, the `tidyverse` has a handy-dandy function to make this easy to do with data frames.

The `summarize()` function creates a new dataframe with columns and values we give it. Similar to `mutate()`, what is on the left of the `=` is the name of the new column, and what is on the right of the `=` is the value(s) to put in the new column.

```
# first attempt at mean and sd of average temperature
climate_df %>%
  summarise(mean_temp = mean(AverageTemperature),
            sd_temp = sd(AverageTemperature))
```

```
## # A tibble: 1 x 2
##   mean_temp sd_temp
##   <dbl>    <dbl>
## 1      NA      NA
```

Wait a second! Those are some weird values!

NA is used to represent missing data. So what is happening here? We know that there are numbers to calculate these values.

It is important to note that if any of the values in the column that you are trying to summarize are missing (NA), you might get some wonky values, like you did above.

Fortunately, `mean()` and `sd()` and some other functions have an argument to remove the missing values: `na.rm = TRUE`

```
climate_df %>%  
  summarise(mean_temp = mean(AverageTemperature, na.rm = TRUE),  
            sd_temp = sd(AverageTemperature, na.rm = TRUE))
```

```
## # A tibble: 1 x 2  
##   mean_temp sd_temp  
##   <dbl>    <dbl>  
## 1     18.1     10.0
```

Pay attention to where the `na.rm = TRUE` argument is placed. We are putting it inside the parentheses for the `mean()` and `sd()` function, not as an argument in the `summarize()` function.

Split, Apply, Combine with `group_by()`

One common way we analyze data is through something we call the “split, apply, combine” approach. This means that we:

- *split* data up into groups via some type of categorization
- *apply* some type of analysis to each group independently and
- *combine* the data back together

The `group_by()` function lets us do this. It is most often used in combination with `mutate()` or `summarize()`.

For example, we can use this method to calculate the mean temperatures of **each** country instead of the overall mean of the entire dataset. In order to do these, we create groups in the data based on the country.

```
climate_df %>%  
  group_by(Country) %>%  
  summarise(mean_temp = mean(AverageTemperature, na.rm = TRUE),  
            sd_temp = sd(AverageTemperature, na.rm = TRUE))
```

```
## # A tibble: 49 x 3  
##   Country      mean_temp sd_temp  
##   <chr>         <dbl>    <dbl>  
## 1 Afghanistan    14.3     8.65  
## 2 Angola          23.7     1.98  
## 3 Australia       15.2     3.70  
## 4 Bangladesh     25.5     3.88  
## 5 Brazil          22.8     2.95  
## 6 Burma           26.7     1.87  
## 7 Canada           5.11    10.7  
## 8 Chile            5.69     4.75  
## 9 China           11.8    11.4  
## 10 Colombia       20.9     1.15  
## # i 39 more rows
```

Let's practice!

Practice using the combination of `group_by()` and `summarize()` to calculate the minimum (`min()`) and maximum (`max()`) average temperatures for each city. Save this data frame as `city_min_max`

```
climate_df %>%
  group_by(City) %>%
  summarize(min_temp = min(AverageTemperature, na.rm = TRUE),
            max_temp = max(AverageTemperature, na.rm = TRUE))
```

```
## # A tibble: 100 x 3
##   City      min_temp max_temp
##   <chr>      <dbl>    <dbl>
## 1 Abidjan      22.4      29.9
## 2 Addis Abeba  14.5      21.2
## 3 Ahmadabad   16.8      35.4
## 4 Aleppo       0.67     32.6
## 5 Alexandria  10.2      28.8
## 6 Ankara      -6.28     26.0
## 7 Baghdad      4.24     38.3
## 8 Bangalore   20.3      29.7
## 9 Bangkok     21.9      31.1
## 10 Belo Horizonte 15.9      25.2
## # i 90 more rows
```

Already accomplished this task? Try to figure out how you can keep the “Country” column in the final data frame. This is trickier than you might think!

```
climate_df %>%
  group_by(Country, City) %>%
  summarize(min_temp = min(AverageTemperature, na.rm = TRUE),
            max_temp = max(AverageTemperature, na.rm = TRUE))
```

```
## 'summarise()' has grouped output by 'Country'. You can override using the
## '.groups' argument.
```

```
## # A tibble: 100 x 4
## # Groups:   Country [49]
##   Country City      min_temp max_temp
##   <chr>   <chr>      <dbl>    <dbl>
## 1 Afghanistan Kabul      -2.08     27.6
## 2 Angola    Luanda      18.7     27.2
## 3 Australia Melbourne    6.63     23.0
## 4 Australia Sydney      12.0     22.0
## 5 Bangladesh Dhaka       15.1     30.7
## 6 Brazil    Belo Horizonte 15.9     25.2
## 7 Brazil    Brasília     17.2     25.9
## 8 Brazil    Fortaleza    24.3     30.0
## 9 Brazil    Rio De Janeiro 18.5     28.8
## 10 Brazil    Salvador     21.0     28.3
## # i 90 more rows
```