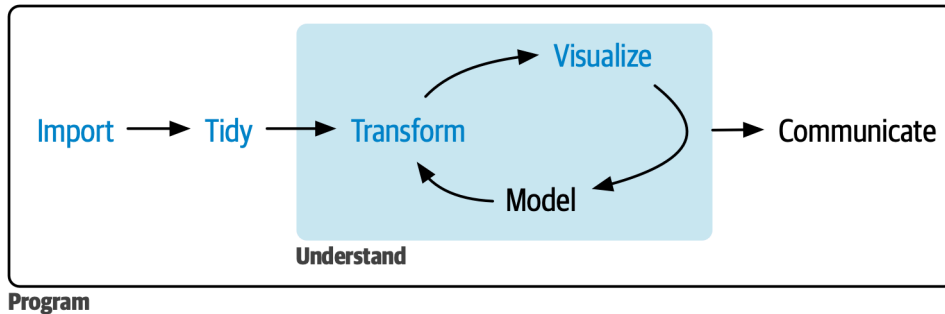


## The Data Analysis Workflow



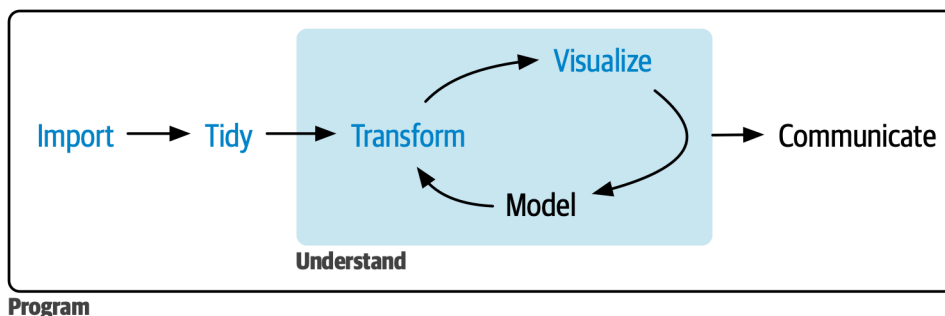
Source: H. Wickham, M. Cetinkaya-Rundel, and G. Grolemund [1], R. A. Poldrack [2]

### The process of statistical modeling

There is a set of steps that we generally go through when we want to use our statistical model to test a scientific hypothesis:

1. Specify your question of interest
2. Identify or collect the appropriate data
3. Prepare the data for analysis
4. Determine the appropriate model
5. Fit the model to the data
6. Criticize the model to make sure it fits properly
7. Test hypothesis and quantify effect size
8. Communicate your analysis

### Data Analysis Workflow



### Import

Throughout, we have been using the tidyverse library of packages for data analysis.

The tidyverse is an opinionated **collection of R packages** designed for data science. All packages share an underlying design philosophy, grammar, and data structures.

```
library(tidyverse)
```



## Import

- There are tools for reading data from almost any source:
  - `read_csv()`, `read_excel()`, `read_rds()`, ...
- When we load a dataset with a `tidyverse()` function, it will return a `tibble`

```
data <- read_csv("data/Apple_Emissions/greenhouse_gas_emissions.csv")
```

## Tidy

The same data can be represented in multiple ways. Here's the same data organized three different ways:

Each dataset shows the same values of four variables: country, year, population, and number of documented cases of TB (tuberculosis), but each dataset organizes the values in a different way.

table1

```
# A tibble: 6 × 4
  country    year cases population
  <chr>      <dbl> <dbl>      <dbl>
1 Afghanistan 1999    745   19987071
2 Afghanistan 2000   2666   20595360
3 Brazil       1999  37737  172006362
4 Brazil       2000  80488  174504898
5 China        1999 212258 1272915272
6 China        2000 213766 1280428583
```

table3

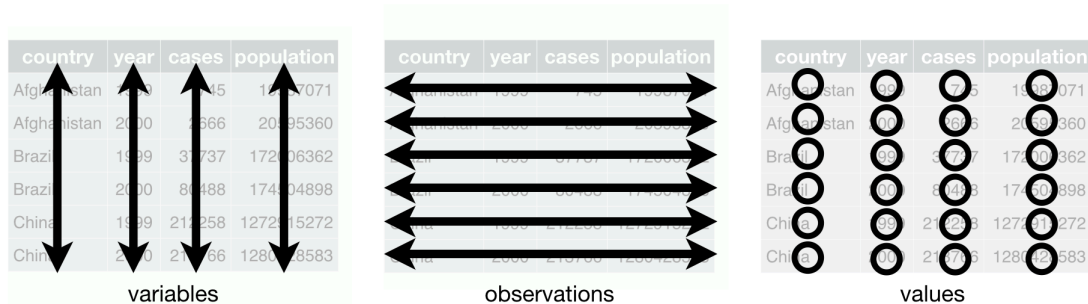
```
# A tibble: 6 × 3
  country    year rate
  <chr>      <dbl> <chr>
1 Afghanistan 1999 745/19987071
2 Afghanistan 2000 2666/20595360
3 Brazil       1999 37737/172006362
4 Brazil       2000 80488/174504898
5 China        1999 212258/1272915272
6 China        2000 213766/1280428583
```

table2

```
# A tibble: 12 × 4
  country    year type      count
  <chr>      <dbl> <chr>      <dbl>
1 Afghanistan 1999 cases         745
2 Afghanistan 1999 population 19987071
3 Afghanistan 2000 cases         2666
4 Afghanistan 2000 population 20595360
5 Brazil       1999 cases         37737
6 Brazil       1999 population 172006362
7 Brazil       2000 cases         80488
8 Brazil       2000 population 174504898
```

9	China	1999 cases	212258
10	China	1999 population	1272915272
11	China	2000 cases	213766
12	China	2000 population	1280428583

- There are three rules that make a dataset tidy:
  1. Each variable is a column; each column is a variable.
  2. Each observation is a row; each row is an observation.
  3. Each value is a cell; each cell is a single value.



### Why ensure your data is tidy?

1. There's a general advantage to picking one consistent way of storing data. If you have a consistent data structure, it's easier to learn the tools that work with it because they have an underlying uniformity.
2. There's a specific advantage to placing variables in columns because it allows R's vectorized nature to shine. That makes transforming tidy data feel particularly natural.

So, our first task after importing the data is to make sure it's tidy. In addition to the rules above, this can also include things like:

- ensure the data types are correct
- clean up the column names
- make sure we know what the variables represent

For the .csv data we loaded, our column names can be a bit difficult to work with since they have spaces in them. We can use a function from the `janitor` package to clean these:

```
data <- data |>
  janitor::clean_names()
data
```

```
# A tibble: 127 × 6
  fiscal_year category      type      scope description emissions
  <dbl> <chr>      <chr>      <chr>      <chr>      <dbl>
1    2022 Corporate emissions Gross emissions Scope 1 Natural ga... 39700
2    2022 Corporate emissions Gross emissions Scope 1 Fleet vehi... 12600
3    2022 Corporate emissions Gross emissions Scope 1 Other (R&D... 2900
4    2022 Corporate emissions Gross emissions Scope ... Electricity 0
5    2022 Corporate emissions Gross emissions Scope ... Steam, hea... 3000
6    2022 Corporate emissions Gross emissions Scope 3 Business t... 113500
7    2022 Corporate emissions Gross emissions Scope 3 Employee c... 134200
8    2022 Corporate emissions Gross emissions Scope 3 Upstream f... 10600
9    2022 Corporate emissions Gross emissions Scope 3 Work from ... 7500
10   2022 Corporate emissions Gross emissions Scope 3 Transmissi... 0
# i 117 more rows
```

## Transform

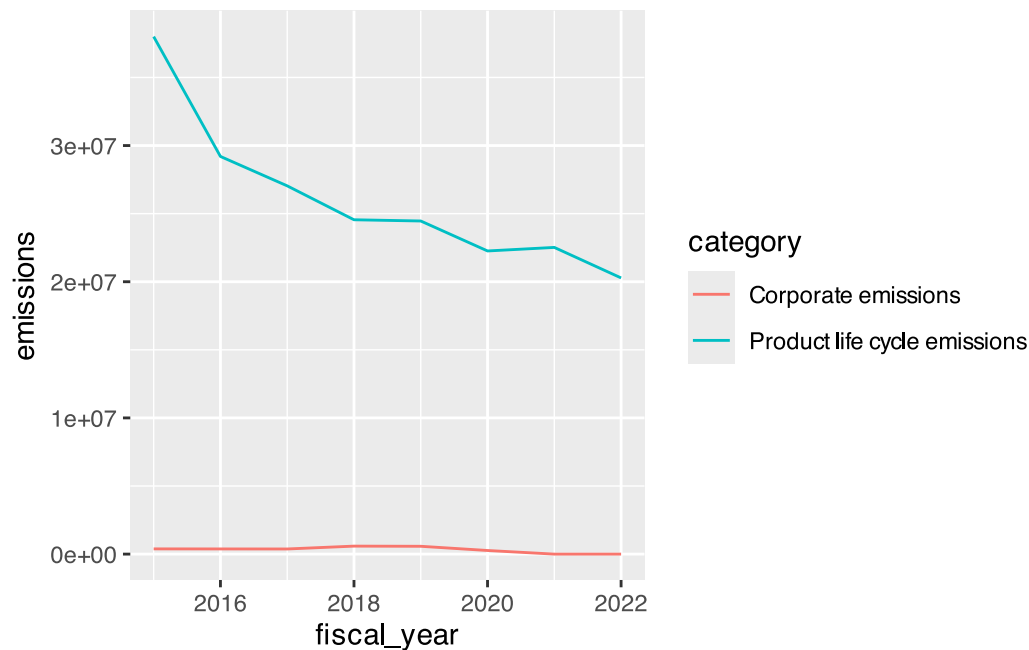
We've dealt with data transformations quite a bit already. This includes operations like calculating the mean for different groups, or for multiple groups:

```
data |>
  group_by(category) |>
  summarise(
    mean_emissions = mean(emissions, na.rm = TRUE),
  )
```

```
# A tibble: 2 × 2
  category      mean_emissions
  <chr>      <dbl>
1 Corporate emissions 35594.
2 Product life cycle emissions 5630000
```

## Visualize

```
data |>
  group_by(category, fiscal_year) |>
  summarise(emissions = sum(emissions, na.rm = TRUE)) |>
  ggplot(aes(x = fiscal_year, y = emissions, color = category)) +
  geom_line()
```



## Communicate

This is where we will dive into using Quarto. Start by downloading the Apple Emissions dataset from Moodle and open RStudio.

We'll go through how to create and write a full analysis in a .qmd file using this dataset.

Refer to our lecture notes specifically on using Quarto

## Assignment - Deceptive Visualisation

### References

### Bibliography

- [1] H. Wickham, M. Cetinkaya-Rundel, and G. Grolemund, *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data*, Second edition. Beijing ; Sebastopol, CA: O'Reilly, 2023.
- [2] R. A. Poldrack, *Statistical Thinking. Analyzing Data in an Uncertain World*. Princeton: Princeton University Press, 2023. [Online]. Available: <https://statstheinking21.github.io/statstheinking21-core-site/>