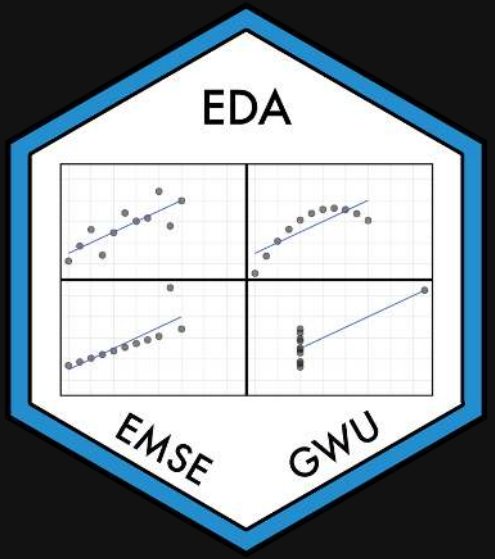

Week 2: *Tidy Data*

EMSE 4572/6572: Exploratory Data Analysis

John Paul Helveston

September 06, 2022

Week 2: *Tidy Data*

1. Tidy Data

2. Tidy Data Wrangling

BREAK

3. Tidy Data Visualization

4. Data Provenance & Curation

5. Writing a Research Question

Week 2: *Tidy Data*

1. Tidy Data
2. Tidy Data Wrangling

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3. Tidy Data Visualization
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5. Writing a Research Question

Federal R&D Spending by Department

```
#> # A tibble: 6 × 15
#>    year   DHS   DOC   DOD   DOE   DOT   EPA   HHS Interior  NASA   NIH   NSF Other  USD
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>    <dbl> <dbl> <dbl> <dbl> <dbl> <dbl
#> 1  1976     0   819 35696 10882  1142   968  9226     1152 12513  8025  2372  1191  183
#> 2  1977     0   837 37967 13741  1095   966  9507     1082 12553  8214  2395  1280  179
#> 3  1978     0   871 37022 15663  1156  1175 10533     1125 12516  8802  2446  1237  196
#> 4  1979     0   952 37174 15612  1004  1102 10127     1176 13079  9243  2404  2321  205
#> 5  1980     0   945 37005 15226  1048   903 10045     1082 13837  9093  2407  2468  188
#> 6  1981     0   829 41737 14798   978   901  9644      990 13276  8580  2300  1925  196
```

Federal R&D Spending by Department

"Wide" format

```
#> # A tibble: 6 × 15
#>    year   DHS   DOC   DOD   DOE   DOT   EPA   HHS Inte
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>    <
#> 1  1976     0   819 35696 10882  1142   968  9226
#> 2  1977     0   837 37967 13741  1095   966  9507
#> 3  1978     0   871 37022 15663  1156  1175 10533
#> 4  1979     0   952 37174 15612  1004  1102 10127
#> 5  1980     0   945 37005 15226  1048   903 10045
#> 6  1981     0   829 41737 14798   978   901  9644
```

"Long" format

```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>         <dbl>
#> 1 DOD         1976         35696
#> 2 NASA        1976         12513
#> 3 DOE         1976         10882
#> 4 HHS         1976          9226
#> 5 NIH         1976          8025
#> 6 NSF         1976          2372
```

Federal R&D Spending by Department

"Wide" format

```
#> # A tibble: 6 × 15
#>    year   DHS   DOC   DOD   DOE   DOT   EPA   HHS Inte
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>    <
#> 1  1976     0   819 35696 10882  1142   968  9226
#> 2  1977     0   837 37967 13741  1095   966  9507
#> 3  1978     0   871 37022 15663  1156  1175 10533
#> 4  1979     0   952 37174 15612  1004  1102 10127
#> 5  1980     0   945 37005 15226  1048   903 10045
#> 6  1981     0   829 41737 14798   978   901  9644
```

```
#> [1] 42 15
```

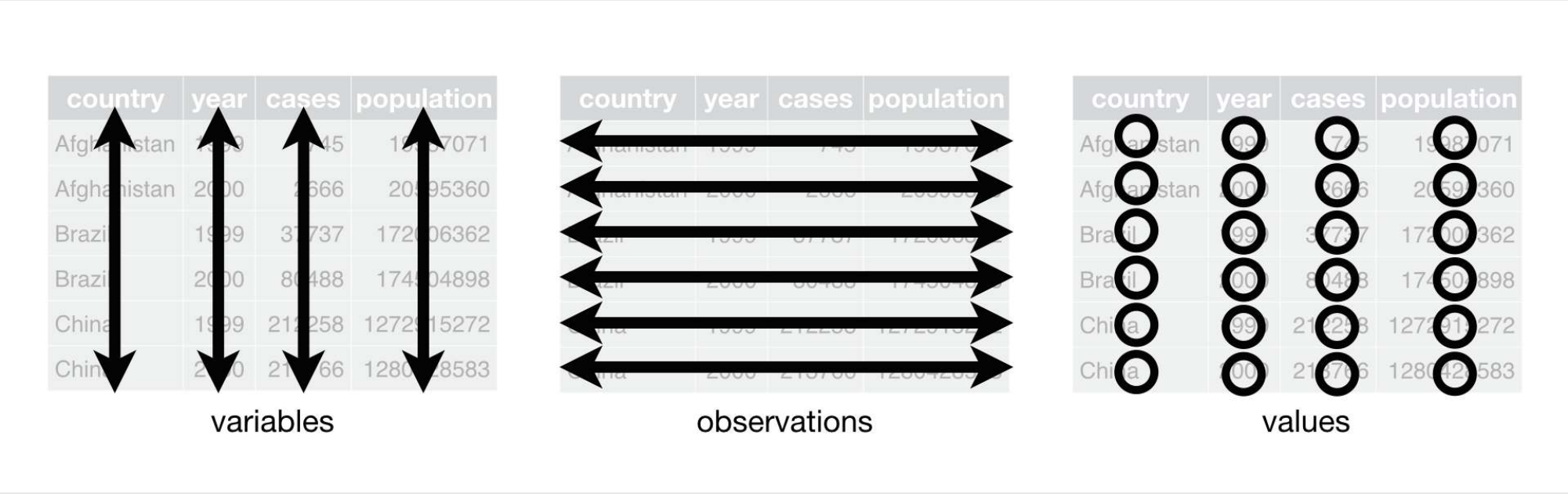
"Long" format

```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>         <dbl>
#> 1 DOD         1976         35696
#> 2 NASA        1976         12513
#> 3 DOE         1976         10882
#> 4 HHS         1976          9226
#> 5 NIH         1976          8025
#> 6 NSF         1976          2372
```

```
#> [1] 588   3
```

Tidy data = "Long" format

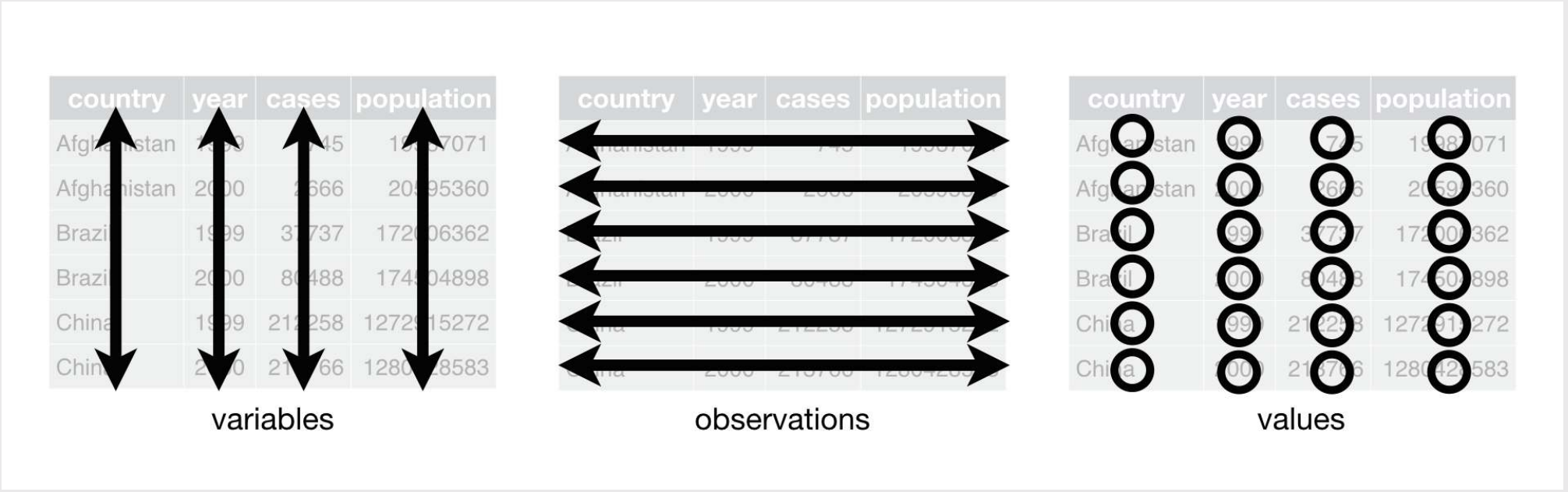
- Each **variable** has its own **column**
- Each **observation** has its own **row**



Tidy data

- Each **variable** has its own **column**
- Each **observation** has its own **row**

```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>          <dbl>
#> 1 DOD         1976          35696
#> 2 NASA        1976          12513
#> 3 DOE         1976          10882
#> 4 HHS         1976           9226
#> 5 NIH         1976           8025
#> 6 NSF         1976           2372
```



"Long" format

```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>          <dbl>
#> 1 DOD         1976          35696
#> 2 NASA        1976          12513
#> 3 DOE         1976          10882
#> 4 HHS         1976           9226
#> 5 NIH         1976           8025
#> 6 NSF         1976           2372
```

"Wide" format

```
#> # A tibble: 6 × 15
#>    year   DHS   DOC   DOD   DOE   DOT   EPA   HHS Inte
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>    <
#> 1  1976     0   819 35696 10882  1142   968  9226
#> 2  1977     0   837 37967 13741  1095   966  9507
#> 3  1978     0   871 37022 15663  1156  1175 10533
#> 4  1979     0   952 37174 15612  1004  1102 10127
#> 5  1980     0   945 37005 15226  1048   903 10045
#> 6  1981     0   829 41737 14798   978   901  9644
```

Do the names describe the values?

Yes: "Long" format

```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>          <dbl>
#> 1 DOD         1976          35696
#> 2 NASA        1976          12513
#> 3 DOE         1976          10882
#> 4 HHS         1976           9226
#> 5 NIH         1976           8025
#> 6 NSF         1976           2372
```

No: "Wide" format

```
#> # A tibble: 6 × 8
#>    year   DHS   DOC   DOD   DOE   DOT   EPA   HHS
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
#> 1  1976     0   819 35696 10882  1142   968  9226
#> 2  1977     0   837 37967 13741  1095   966  9507
#> 3  1978     0   871 37022 15663  1156  1175 10533
#> 4  1979     0   952 37174 15612  1004  1102 10127
#> 5  1980     0   945 37005 15226  1048   903 10045
#> 6  1981     0   829 41737 14798   978   901  9644
```

Quick practice 1: "long" or "wide" format?

Description: Tuberculosis cases in various countries

```
#> # 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
```

Quick practice 2: "long" or "wide" format?

Description: Word counts in LOTR trilogy

```
#> # A tibble: 9 × 4
#>   Film                      Race   Female  Male
#>   <chr>                     <chr>   <dbl> <dbl>
#> 1 The Fellowship Of The Ring Elf      1229   971
#> 2 The Fellowship Of The Ring Hobbit     14  3644
#> 3 The Fellowship Of The Ring Man         0  1995
#> 4 The Return Of The King     Elf       183   510
#> 5 The Return Of The King     Hobbit      2  2673
#> 6 The Return Of The King     Man       268  2459
#> 7 The Two Towers             Elf       331   513
#> 8 The Two Towers             Hobbit      0  2463
#> 9 The Two Towers             Man       401  3589
```

Quick practice 3: "long" or "wide" format?

Description: Word counts in LOTR trilogy

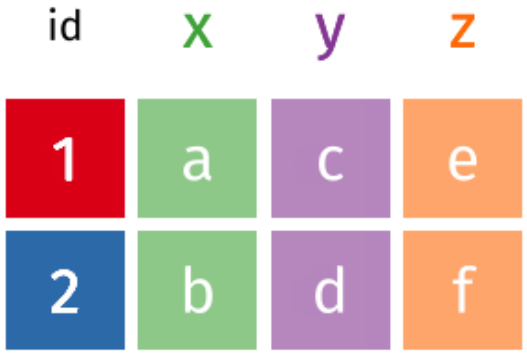
```
#> # A tibble: 15 × 4
#>    Film                      Race   Gender Word_Count
#>    <chr>                     <chr>  <chr>       <dbl>
#>  1 The Fellowship Of The Ring Elf    Female       1229
#>  2 The Fellowship Of The Ring Elf    Male          971
#>  3 The Fellowship Of The Ring Hobbit Female         14
#>  4 The Fellowship Of The Ring Hobbit Male         3644
#>  5 The Fellowship Of The Ring Man    Female          0
#>  6 The Fellowship Of The Ring Man    Male         1995
#>  7 The Return Of The King     Elf    Female        183
#>  8 The Return Of The King     Elf    Male          510
#>  9 The Return Of The King     Hobbit Female          2
#> 10 The Return Of The King     Hobbit Male         2673
#> 11 The Return Of The King     Man    Female        268
#> 12 The Return Of The King     Man    Male         2459
#> 13 The Two Towers             Elf    Female        331
#> 14 The Two Towers             Elf    Male          513
#> 15 The Two Towers             Hobbit Female          0
```

Reshaping data with `pivot_longer()` and `pivot_wider()`

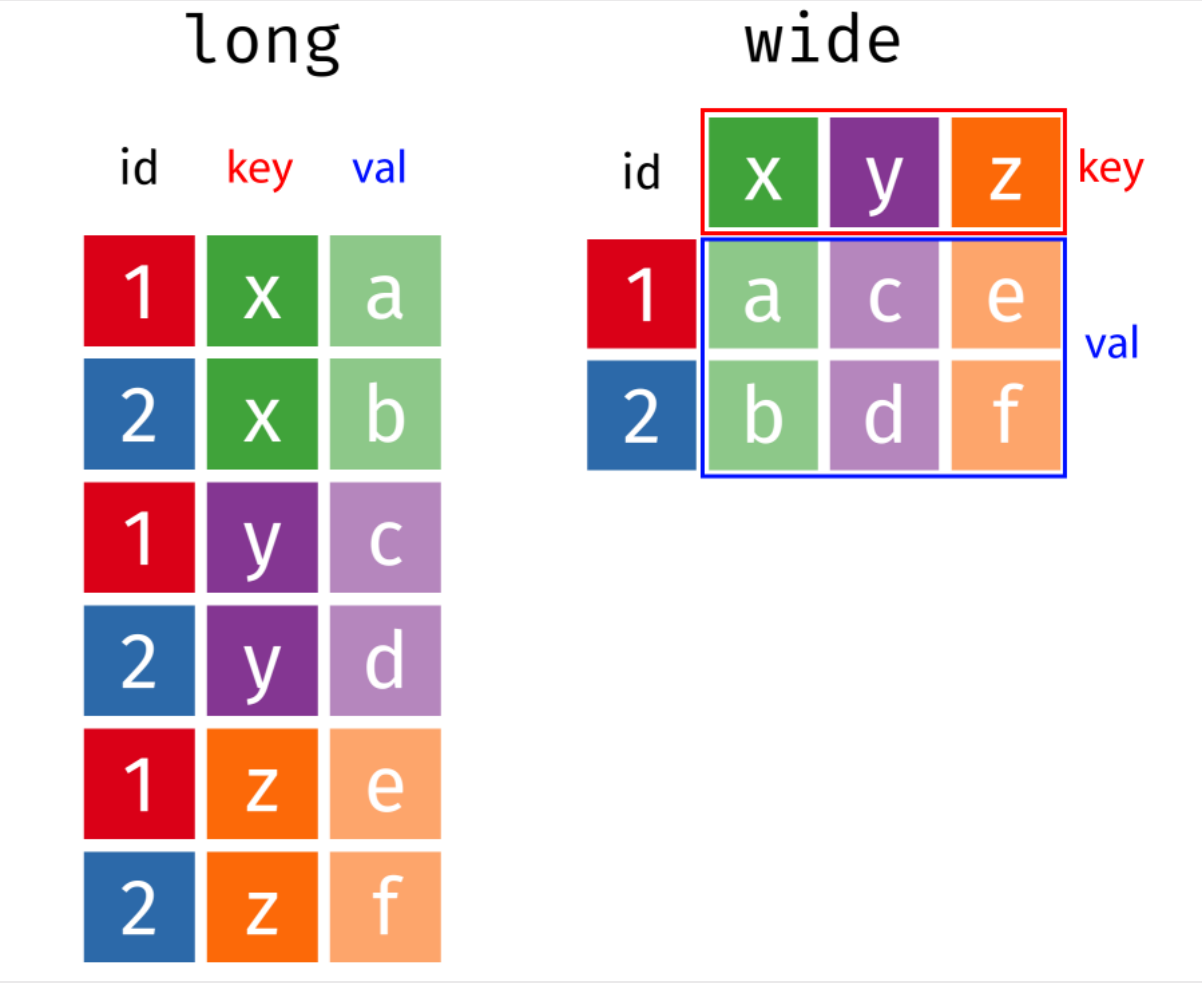
Reshaping data

`pivot_longer()`
`pivot_wider()`

wide



From "long" to "wide" with `pivot_wider()`



From "long" to "wide" with `pivot_wider()`

```
head(fed_spend_long)
```

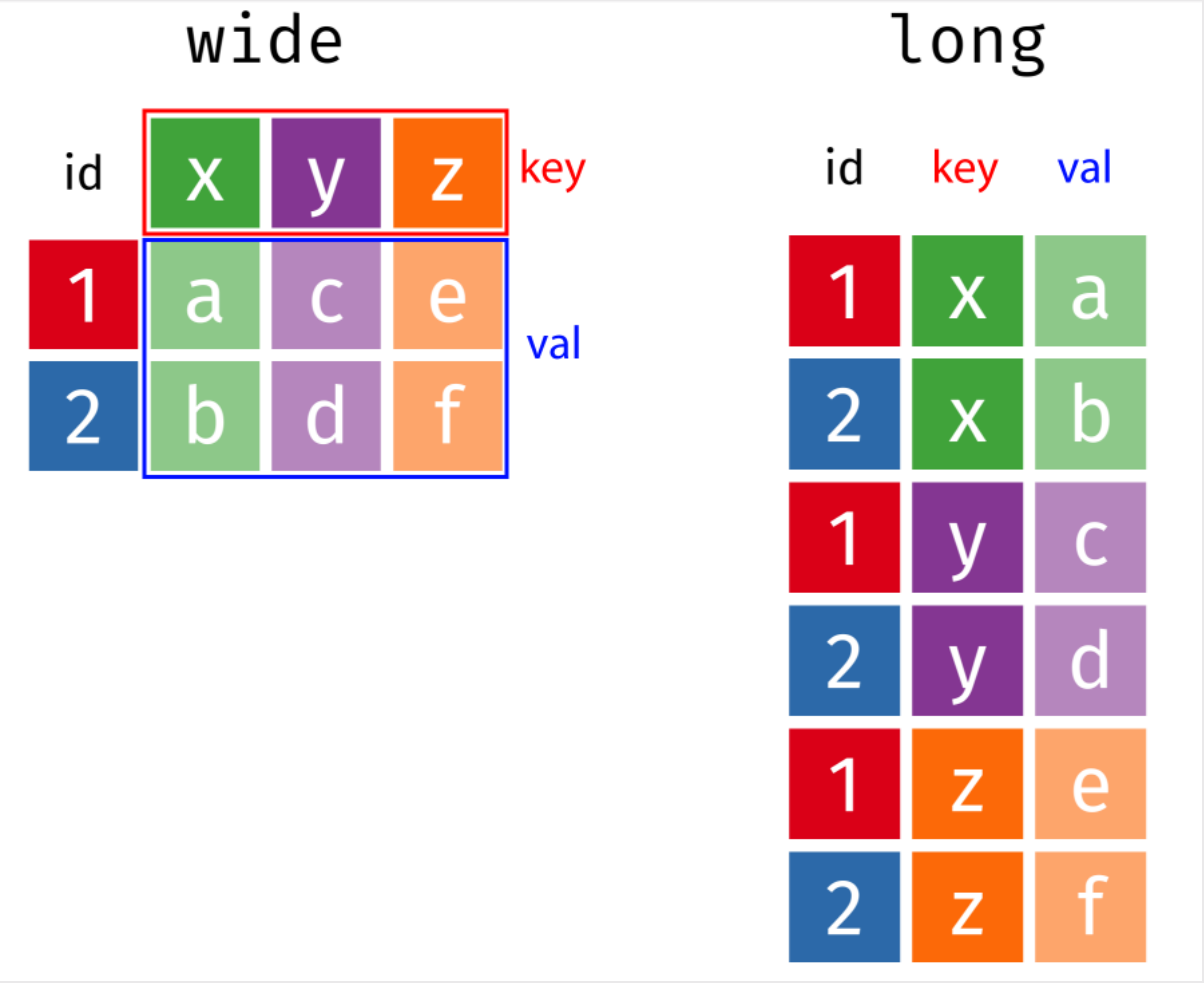
```
#> # A tibble: 6 × 3
#>   department  year rd_budget_mil
#>   <chr>      <dbl>          <dbl>
#> 1 DOD         1976          35696
#> 2 NASA        1976          12513
#> 3 DOE         1976          10882
#> 4 HHS         1976           9226
#> 5 NIH         1976           8025
#> 6 NSF         1976           2372
```

```
fed_spend_wide <- fed_spend_long %>%
    pivot_wider(
        names_from = department,
        values_from = rd_budget_mil)

head(fed_spend_wide)
```

```
#> # A tibble: 6 × 15
#>    year   DOD  NASA   DOE   HHS   NIH   NSF <
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <
#> 1  1976 35696 12513 10882  9226  8025  2372
#> 2  1977 37967 12553 13741  9507  8214  2395
#> 3  1978 37022 12516 15663 10533  8802  2446
#> 4  1979 37174 13079 15612 10127  9243  2404
#> 5  1980 37005 13837 15226 10045  9093  2407
#> 6  1981 41737 13276 14798  9644  8580  2300
```

From "wide" to "long" with `pivot_longer()`



From "wide" to "long" with `pivot_longer()`

```
head(fed_spend_wide)
```

```
#> # A tibble: 6 × 15
#>    year   DOD  NASA   DOE   HHS   NI
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl
#> 1  1976 35696 12513 10882  9226  802
#> 2  1977 37967 12553 13741  9507  821
#> 3  1978 37022 12516 15663 10533  880
#> 4  1979 37174 13079 15612 10127  924
#> 5  1980 37005 13837 15226 10045  909
#> 6  1981 41737 13276 14798  9644  858
```

```
fed_spend_long <- fed_spend_wide %>%
    pivot_longer(
        names_to = "department",
        values_to = "rd_budget_mil",
        cols = DOD:Other)

head(fed_spend_long)
```

```
#> # A tibble: 6 × 3
#>    year department rd_budget_mil
#>   <dbl> <chr>                <dbl>
#> 1  1976 DOD                  35696
#> 2  1976 NASA                 12513
#> 3  1976 DOE                  10882
#> 4  1976 HHS                   9226
#> 5  1976 NIH                   8025
#> 6  1976 NSF                   2372
```

Can also set `cols` by selecting which columns *not* to use

```
names(fed_spend_wide)
```

```
#>  [1] "year"     "DOD"      "NASA"
```

```
fed_spend_long <- fed_spend_wide %>%
    pivot_longer(
        names_to = "department",
        values_to = "rd_budget_mil",
        cols = -year)

head(fed_spend_long)
```

```
#> # A tibble: 6 × 3
#>    year department rd_budget_mil
#>   <dbl> <chr>                <dbl>
#> 1  1976 DOD                  35696
#> 2  1976 NASA                 12513
#> 3  1976 DOE                  10882
#> 4  1976 HHS                   9226
#> 5  1976 NIH                   8025
#> 6  1976 NSF                   2372
```

Your turn: Reshaping Data

15:00

Open the `practice.qmd` file.

Run the code chunk to read in the following two data files:

- `pv_cell_production.xlsx`: Data on solar photovoltaic cell production by country
- `milk_production.csv`: Data on milk production by state

Now modify the format of each:

- If the data are in "wide" format, convert it to "long" with `pivot_longer()`
- If the data are in "long" format, convert it to "wide" with `pivot_wider()`

Week 2: *Tidy Data*

1. Tidy Data
2. Tidy Data Wrangling

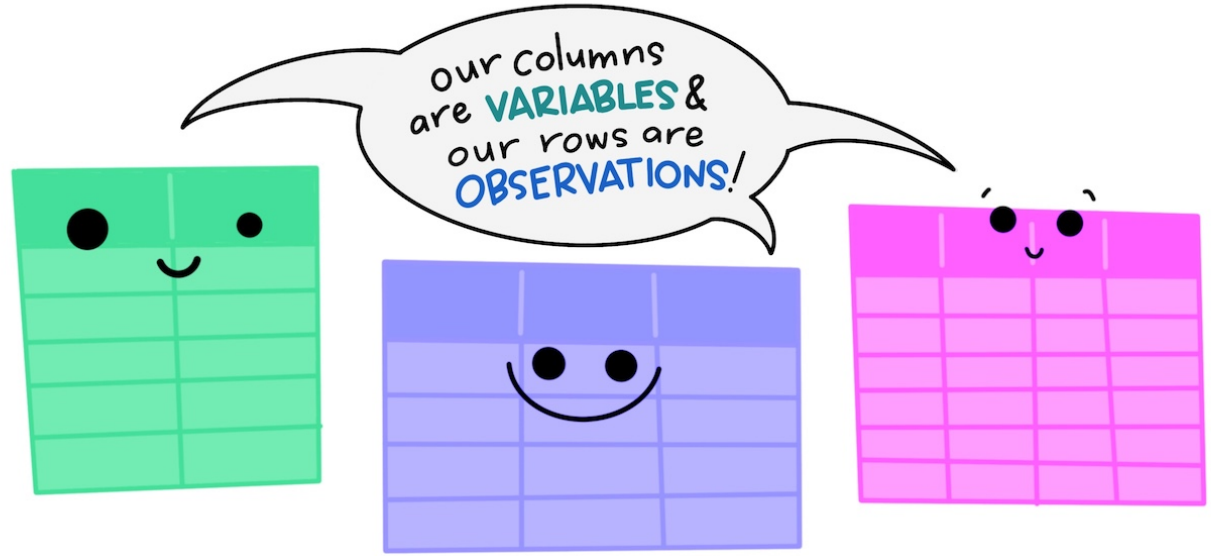
BREAK

3. Tidy Data Visualization
4. Data Provenance & Curation
5. Writing a Research Question

Why do we need tidy data?

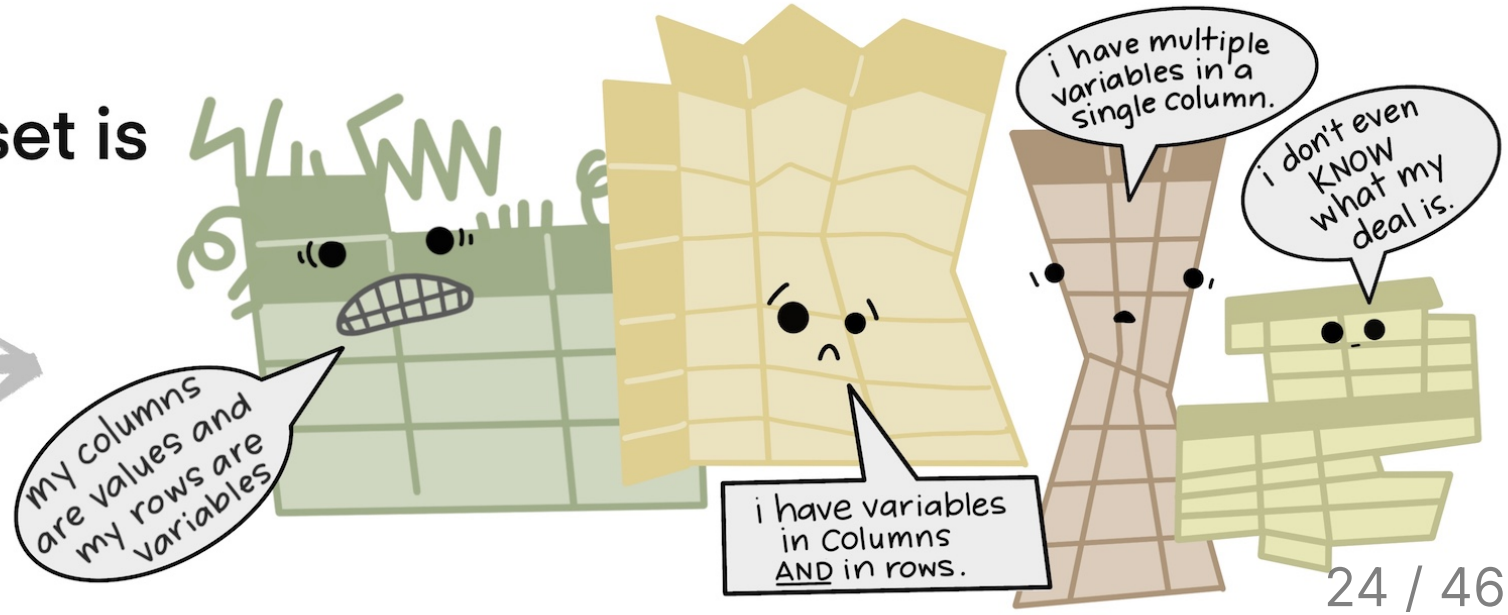
(a quick explanation with cute graphics, by Allison Horst)

The standard structure of tidy data means that "tidy datasets are all alike..."

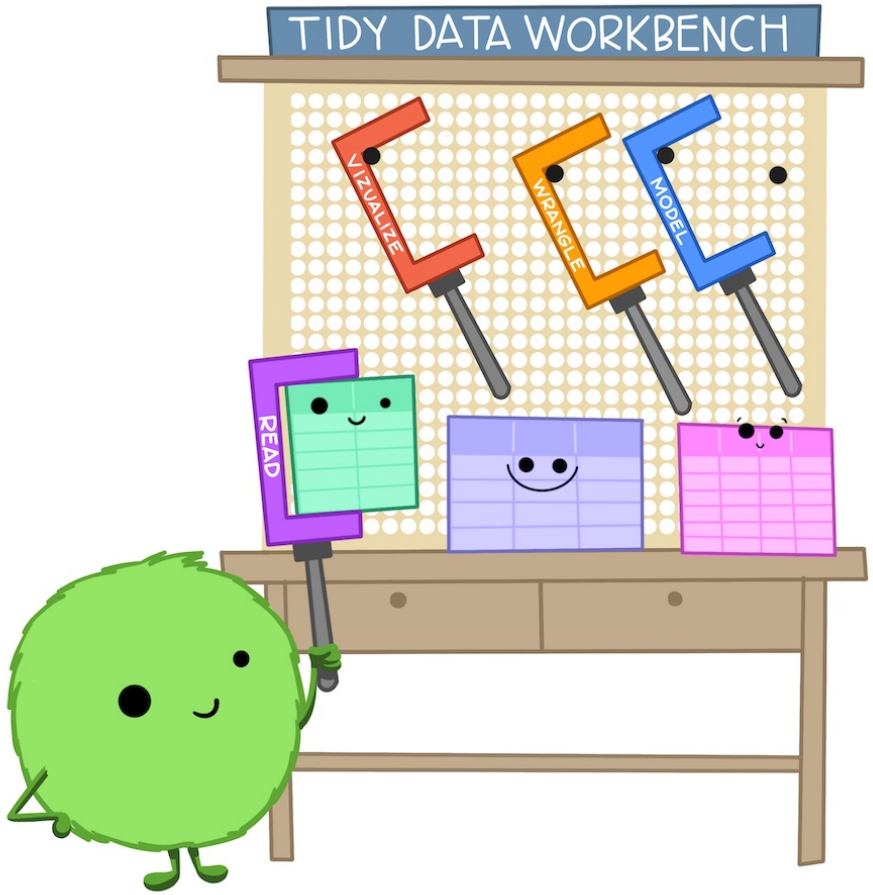


"...but every messy dataset is messy in its own way."

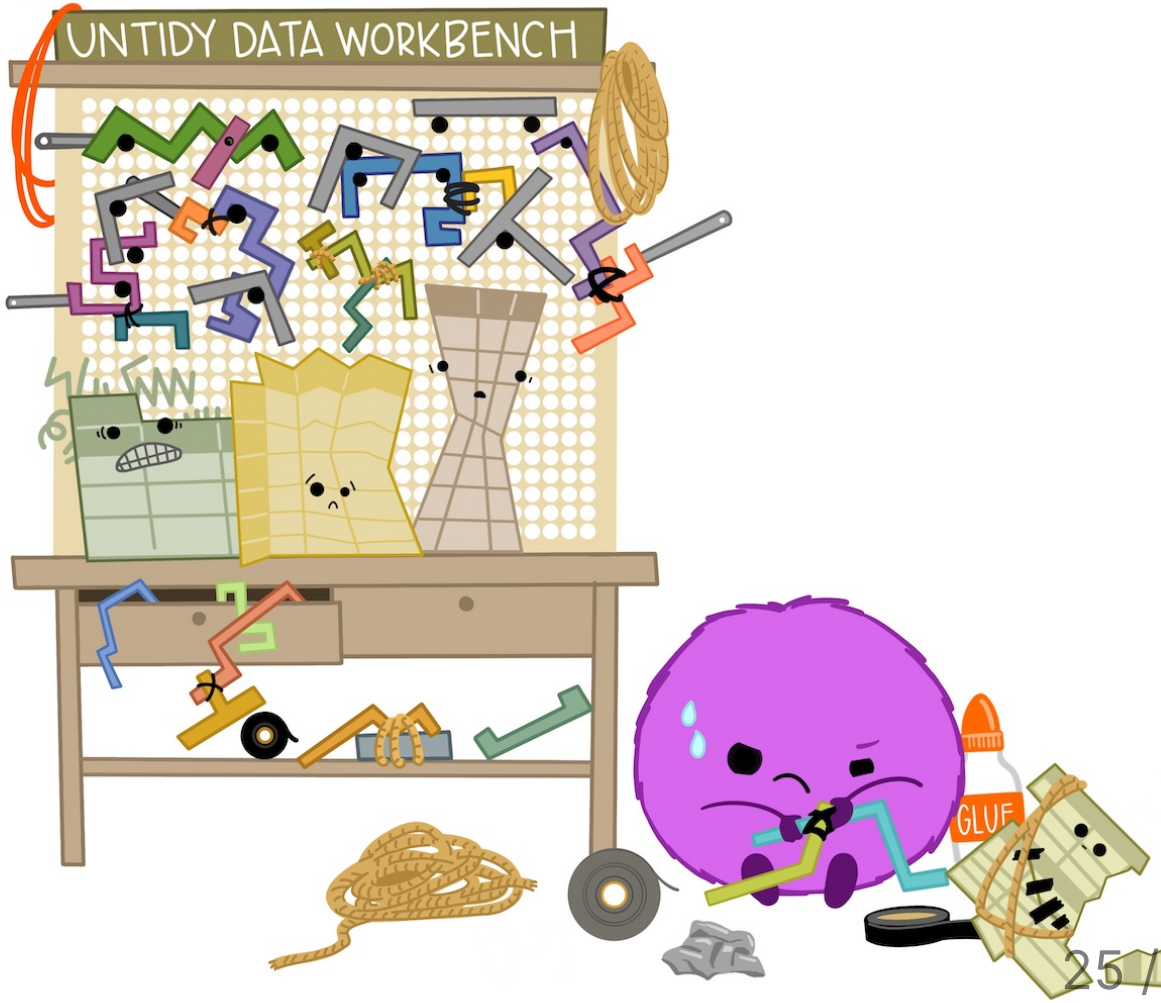
–HADLEY WICKHAM

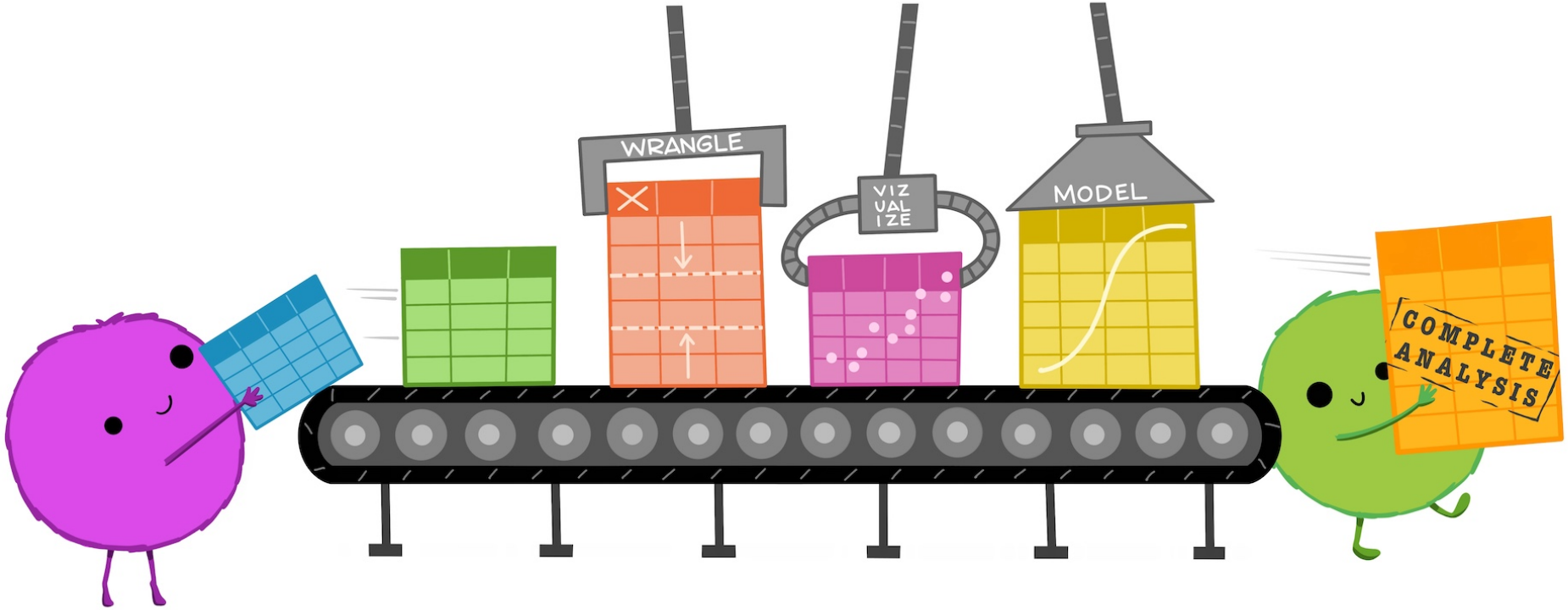


When working with tidy data, we can use the same tools in similar ways for different datasets...



...but working with untidy data often means reinventing the wheel with one-time approaches that are hard to iterate or reuse.




WRANGLE
VIZ
UAL
IZE
MODEL
COMPLETE
ANALYSIS

Tidy data wrangling

Compute the total R&D spending in each year

```
head(fed_spend_wide)
```

```
#> # A tibble: 6 × 15
#>    year   DOD  NASA   DOE   HHS   NIH   NSF  USDA Interior   DOT   EPA   DOC   DHS     V
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>    <dbl> <dbl> <dbl> <dbl> <dbl> <dbl
#> 1  1976 35696 12513 10882  9226  8025  2372  1837     1152  1142   968   819     0   40
#> 2  1977 37967 12553 13741  9507  8214  2395  1796     1082  1095   966   837     0   37
#> 3  1978 37022 12516 15663 10533  8802  2446  1962     1125  1156  1175   871     0   35
#> 4  1979 37174 13079 15612 10127  9243  2404  2054     1176  1004  1102   952     0   35
#> 5  1980 37005 13837 15226 10045  9093  2407  1887     1082  1048   903   945     0   35
#> 6  1981 41737 13276 14798  9644  8580  2300  1964      990   978   901   829     0   38
```

Tidy data wrangling

Compute the total R&D spending in each year

Approach 1: Create new `total` by adding each variable

```
fed_spend_wide %>%
  mutate(total = DHS + DOC + DOD + DOE + DOT + EPA + HHS + Interior + NASA + NIH + NSF + C
  select(year, total)
```

```
#> # A tibble: 42 × 2
#>     year  total
#>    <dbl>  <dbl>
#>  1  1976  86227
#>  2  1977  91807
#>  3  1978  94864
#>  4  1979  96601
#>  5  1980  96305
#>  6  1981  98304
#>  7  1982  95448
#>  8  1983  95010
#>  9  1984 105371
```

Tidy data wrangling

Compute the total R&D spending by department in each year

Approach 2: Reshape first, then summarise

```
fed_spend_long <- fed_spend_wide %>%
    pivot_longer(
        names_to = "department",
        values_to = "rd_budget_mil",
        cols = -year)

head(fed_spend_long)
```

```
#> # A tibble: 6 × 3
#>    year department rd_budget_mil
#>   <dbl> <chr>                <dbl>
#> 1  1976 DOD                  35696
#> 2  1976 NASA                 12513
#> 3  1976 DOE                  10882
#> 4  1976 HHS                   9226
#> 5  1976 NIH                   8025
```

```
fed_spend_long %>%
    group_by(year) %>%
    summarise(total = sum(rd_budget_mil))
```

```
#> # A tibble: 42 × 2
#>     year  total
#>    <dbl>  <dbl>
#>  1  1976  86227
#>  2  1977  91807
#>  3  1978  94864
#>  4  1979  96601
#>  5  1980  96305
#>  6  1981  98304
#>  7  1982  95448
#>  8  1983  95010
#>  9  1984 105371
```

Tidy data wrangling

Compute the total R&D spending by department in each year

Approach 2: Reshape first, then summarise

```
total <- fed_spend_wide %>%
    pivot_longer(
        names_to = "department",
        values_to = "rd_budget_mil",
        cols = -year) %>%
    group_by(year) %>%
    summarise(total = sum(rd_budget_mil))
```

```
head(total)
```

```
#> # A tibble: 6 × 2
#>    year total
#>   <dbl> <dbl>
#> 1  1976 86227
#> 2  1977 91807
#> 3  1978 94864
#> 4  1979 96601
#> 5  1980 96305
#> 6  1981 98304
```

Your turn: Tidy Data Wrangling

15:00

Open the `practice.qmd` file.

Run the code chunk to read in the following two data files:

- `gapminder.csv`: Life expectancy in different countries over time
- `gdp.csv`: GDP of different countries over time

Now convert the data into a tidy (long) structure, then create the following summary data frames:

- Mean life expectancy in each year.
- Mean GDP in each year.

Break

05:00

Week 2: *Tidy Data*

1. Tidy Data

2. Tidy Data Wrangling

BREAK

3. Tidy Data Visualization

4. Data Provenance & Curation

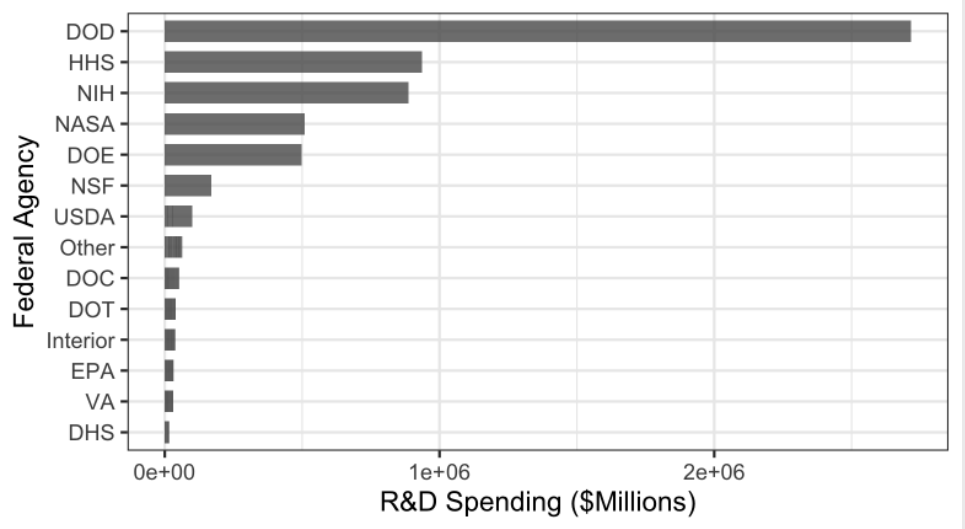
5. Writing a Research Question

Tidy data vizualization

Make a bar chart of total R&D spending by agency

```
head(fed_spend_wide)
```

```
#> # A tibble: 6 × 15
#>    year   DOD  NASA   DOE   HHS   NIH   NSF
#>   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <
#> 1  1976 35696 12513 10882  9226  8025  2372
#> 2  1977 37967 12553 13741  9507  8214  2395
#> 3  1978 37022 12516 15663 10533  8802  2446
#> 4  1979 37174 13079 15612 10127  9243  2404
#> 5  1980 37005 13837 15226 10045  9093  2407
#> 6  1981 41737 13276 14798  9644  8580  2300
```

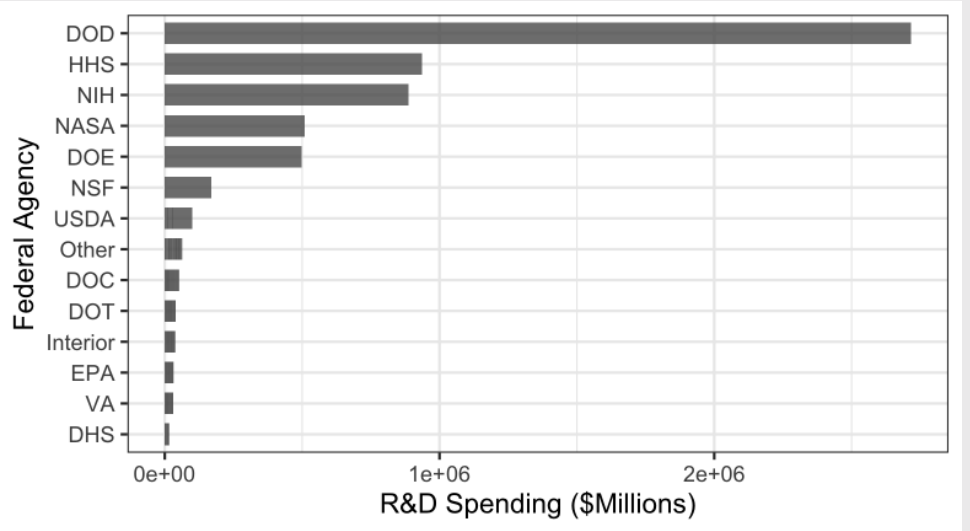


Tidy data vizualization

Make a bar chart of total R&D spending by agency

```
ggplot(fed_spend_wide) +
  geom_col(aes(x = rd_budget_mil, y = department
  theme_bw() +
  labs(
      x = "R&D Spending ($Millions)",
      y = "Federal Agency"
  )
```

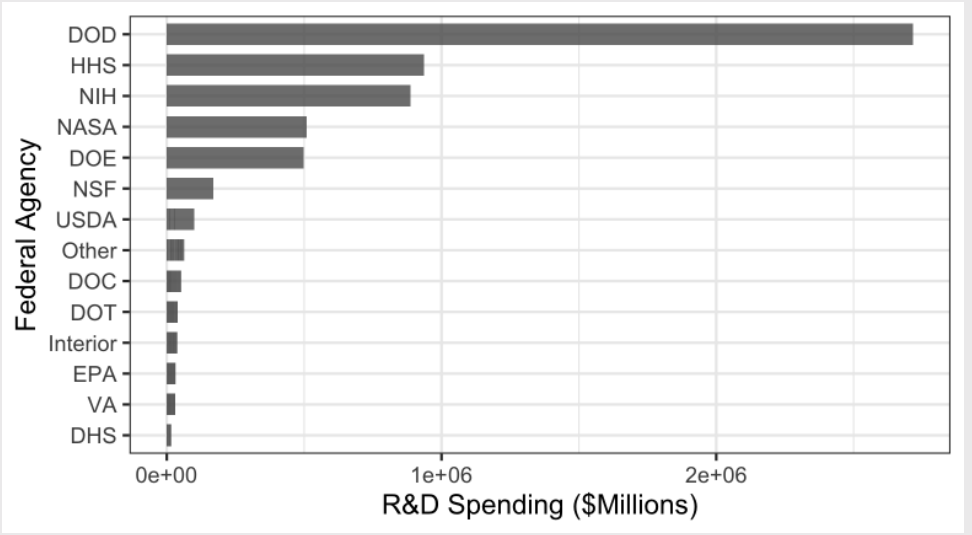
```
#> Error in `geom_col()`:
#> ! Problem while computing aesthetics.
#> ℹ Error occurred in the 1st layer.
#> Caused by error in `FUN()`:
#> ! object 'rd_budget_mil' not found
```



Tidy data vizualization

Make a bar chart of total R&D spending by agency

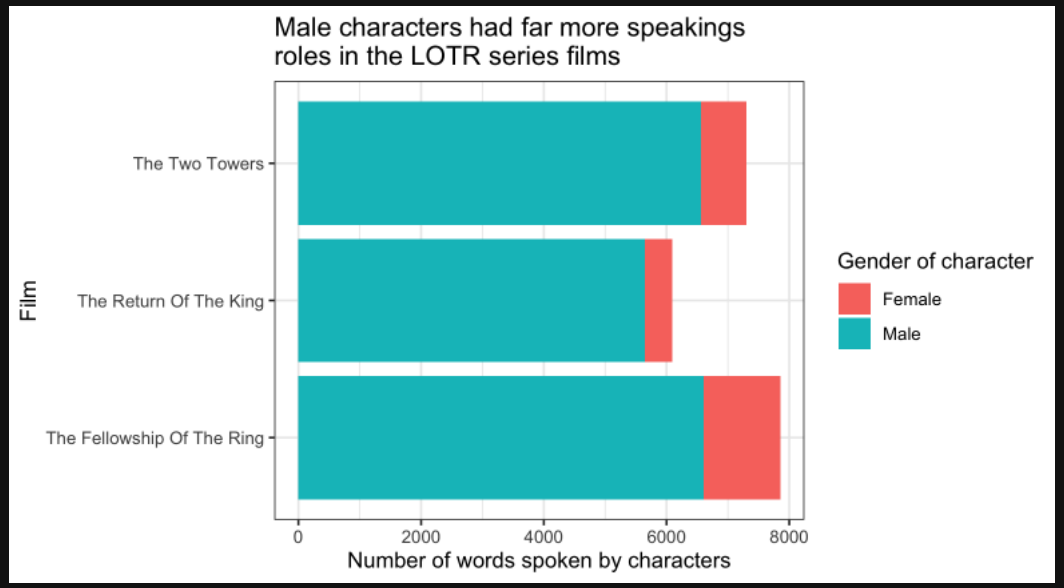
```
fed_spend_wide %>%
  pivot_longer(
    names_to = "department",
    values_to = "rd_budget_mil",
    cols = -year
  ) %>%
  ggplot() +
  geom_col(aes(x = rd_budget_mil, y = department
  theme_bw() +
  labs(
    x = "R&D Spending ($Millions)",
    y = "Federal Agency"
  )
```

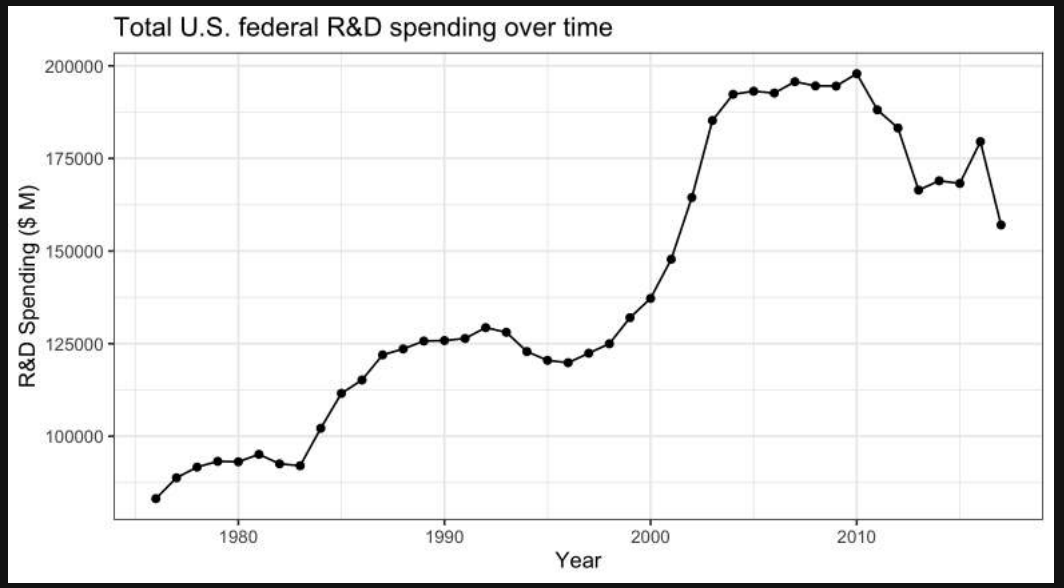


Your turn: Tidy Data Visualization

15:00

Run the code chunk to read in the two data files, then convert the data into a tidy (long) structure to create the following charts:





Week 2: *Tidy Data*

1. Tidy Data

2. Tidy Data Wrangling

BREAK

3. Tidy Data Visualization

4. Data Provenance & Curation

5. Writing a Research Question

Data provenance - It matters where you get your data

Validity:

- Is this data trustworthy? Is it authentic?
- Where did the data come from?
- How has the data been changed / managed over time?
- Is the data complete?

Comprehension:

- Is this data accurate?
- Can you explain your results?
- Is this the right data to answer your question?

Reproducibility:

- I should be able to fully replicate your results from your raw data and code.

🔍 Document your source like a museum curator

Example: View `README.md` file in the `data` folder

Whenever you download data, you should **at a minimum** record the following:

- The name of the file you are describing.
- The date you downloaded it.
- The original name of the downloaded file (in case you renamed it).
- The url to the site you downloaded it from.
- The source of the *original* data (sometimes different from the site you downloaded it from).
- A short description of the data, maybe how they were collected (if available).
- A dictionary for the data (e.g. a simple markdown table describing each variable).

Your turn

10:00

Documentation in the "data/README.md" file is missing for the following data sets:

- wildlife_impacts.csv: source
- north_america_bear_killings.txt: source
- uspto_clean_energy_patents.xlsx: source

Go to the above sites and add the following information to the "data/README.md" file:

- The name of the downloaded file.
- The web address to the site you downloaded the data from.
- The source of the *original* data (if different from the website).
- A short description of the data and how they were collected.
- A dictionary for the data (hint: the site might already have this!).

Week 2: *Tidy Data*

1. Tidy Data

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5. Writing a Research Question

Writing a research question

Follow these guidelines - your question should be:

- **Clear**: your audience can easily understand its purpose without additional explanation.
- **Focused**: it is narrow enough that it can be addressed thoroughly with the data available and within the limits of the final project report.
- **Concise**: it is expressed in the fewest possible words.
- **Complex**: it is not answerable with a simple "yes" or "no," but rather requires synthesis and analysis of data.
- **Arguable**: its potential answers are open to debate rather than accepted facts (do others care about it?)

Writing a research question

Bad question: Why are social networking sites harmful?

- Unclear: it does not specify *which* social networking sites or state what harm is being caused; assumes that "harm" exists.

Improved question: How are online users experiencing or addressing privacy issues on social networking sites such as Facebook and Twitter?

- Specifies the sites (Facebook and Twitter), type of harm (privacy issues), and who is harmed (online users).

Writing a research question

Example from previous classes:

- Genders in the Workforce: How has the US gender wage gap changed over time for different occupations and age groups?
- NFL Suspensions: What factors contribute to the severity of disciplinary actions towards NFL players from 2002-2014?

Other good examples: See the Example Projects page

Use this link to form teams