Week 3: Tidy Data and Data Wrangling

with `dplyr` (and a small mention of `tidyr`)

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^ Us / the plan 4 2-day

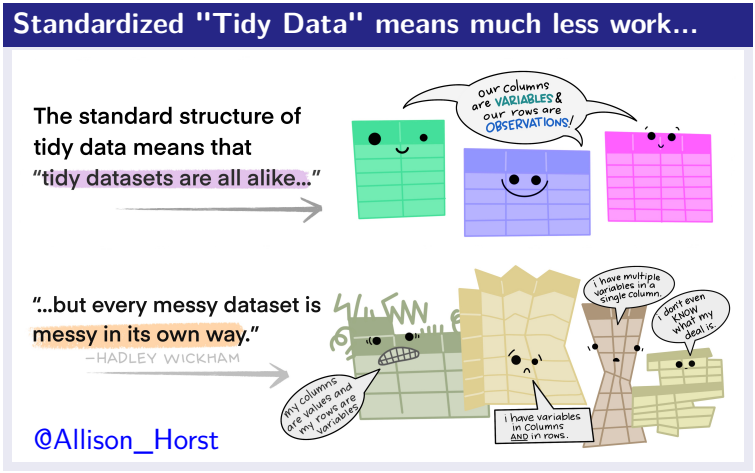
@Allison_Horst

Class Check Round 1

https://pollev.com/sta (3 questions)

Tidy Data

"Happy families are all alike; every unhappy family is unhappy in its own way." – Tolstoy

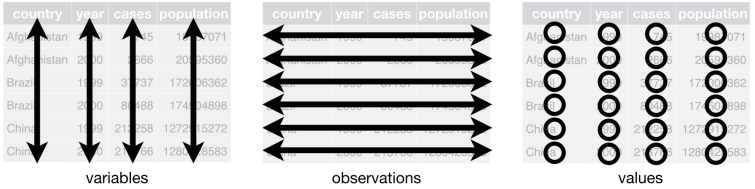


"Write code for humans, but data for computers"
– Vince Buffalo, author of Bioinformatics Data Skills

"It's often said that 80% of data analysis is spent on the process of cleaning and preparing the data"
– Hadley Wickham, author of the R4DS and `dplyr`

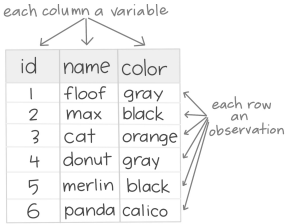
Tidy Data

"Tidy Data" really just means " 'Easy for a Computer to Use' Data"



In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement



@R4DS and @Allison_Horst

Wickham, H. (2014). Tidy Data. Journal of Statistical Software *59* (10). DOI: 10.18637/jss.v059.i10

Quiz 1 on Tidy Data

Which of these tables is organized in the "Tidy Data" format?

Which most easily plots the distribution of grades for all of the students?

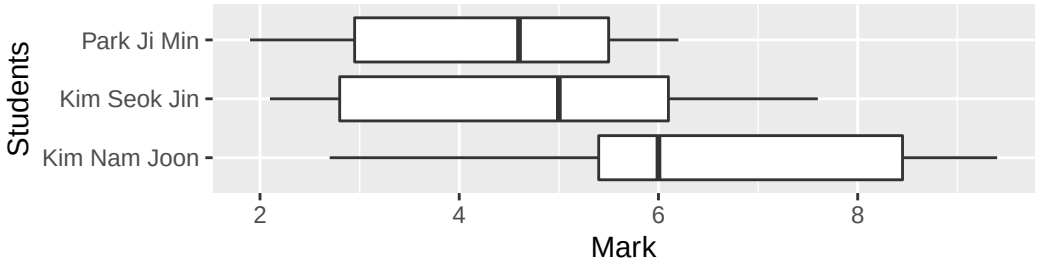
```
## # A tibble: 3 x 8
##   Students     Mark1 Mark2 Mark3 Mark4 Mark5 Mark6 Mark7
##   <chr>        <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 Kim Nam Joon   9.2   9.4   6     2.7   7.7   5.7   5.1
## 2 Kim Seok Jin   5.1   5     2.1   7.1   2.7   7.6   2.9
## 3 Park Ji Min    1.9   6     4.6   6.2   5     2.9   3
```

```
## # A tibble: 7 x 4
##   `Kim Nam Joon` `Kim Seok Jin` `Park Ji Min` Marks
##            <dbl>          <dbl>          <dbl> <chr>
## 1            9.2            5.1            1.9 Mark1
## 2            9.4            5              6   Mark2
## 3            6              2.1            4.6 Mark3
## 4            2.7            7.1            6.2 Mark4
## 5            7.7            2.7            5   Mark5
## 6            5.7            7.6            2.9 Mark6
## 7            5.1            2.9            3   Mark7
```

```
## # A tibble: 21 x 3
##    Marks Students      Mark
##    <chr> <chr>        <dbl>
##  1 Mark1 Kim Nam Joon   9.2
##  2 Mark1 Kim Seok Jin   5.1
##  3 Mark1 Park Ji Min    1.9
##  4 Mark2 Kim Nam Joon   9.4
##  5 Mark2 Kim Seok Jin   5
##  6 Mark2 Park Ji Min    6
##  7 Mark3 Kim Nam Joon   6
##  8 Mark3 Kim Seok Jin   2.1
##  9 Mark3 Park Ji Min    4.6
## 10 Mark4 Kim Nam Joon   2.7
## # ... with 11 more rows
```

This should be easy with Tidy Data

```
# {r, fig.height=1.5, fig.width=5.5}
tidy_marks %>% ggplot(aes(x=Mark,y=Students)) + geom_boxplot()
```

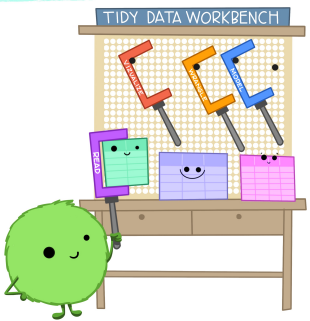


- Comparisons within columns should always be sensible
- Comparisons across columns should be less meaningful

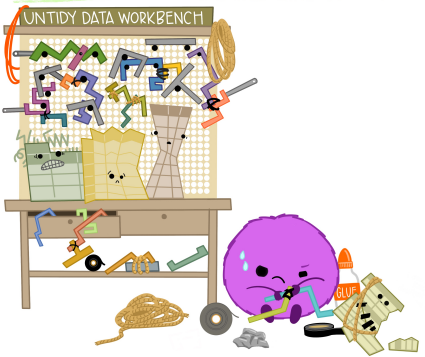
“One Size Fits All” when you have Tidy Data

Efficiency Increases when you have a Standard Reliabile Tool Set

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.



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Quiz 2 on Tidy Data

Which of these is "Tidy"?

```
## # A tibble: 12 x 4
##    country      year type            count
##    <chr>       <int> <chr>           <int>
##  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
```

```
## # A tibble: 6 x 4
##   country      year  cases population
##   <chr>       <int>  <int>      <int>
## 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
```

```
## # A tibble: 6 x 3
##   country      year rate
## * <chr>       <int> <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
```

Tidying and making data useful by Data Wrangling

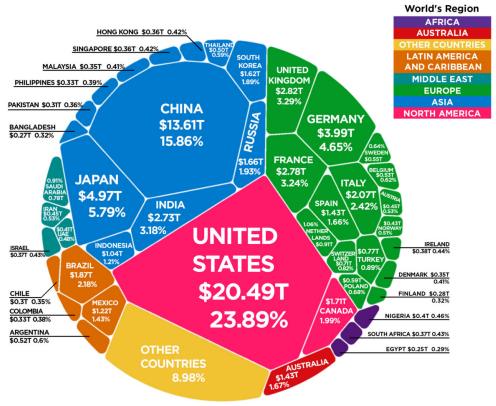
- "80% of data analysis is spent on the process of cleaning and preparing data"
- "Write code for humans, but data for computers"

- `dplyr` is designed on a structured and very general grammar (like `ggplot2`)

The dplyr and tidyr libraries are part of the tidyverse. Introductions to these libraries are respectively given in the Transformation and Tidy Data chapters of the R4DS textbook, in the official `dplyr` and `tidyr` cheat sheets, and in the UofT DoSS Toolkit.

Some Data for Data Wrangling

+



Article & Sources:
https://howmuch.net/articles/the-world-economy-2018
https://databank.worldbank.org

howmuch.net

Some Data for Data Wrangling

Created by previous STA130 profs. based on VGAMdata

```
#install.packages("VGAMdata")
library(VGAMdata)
help(oly12)
```

Variable	Description
Country	Name of the country
athletes_f	# of female athletes
athletes_m	# of male athletes
athletes_total	# of athletes
G/S/B	# of G/S/B medals won

G=gold; S=silver; B=bronze

by adding in `ISO`, `GDP`, and `pop`

Variable	Description
ISO	International Standard Code of 2 or 3 characters uniquely identifying each country
GDP.2011	Gross domestic product in 2011
pop.2010	Population in 2010

- A similar data set exists on kaggle

Some Data for Data Wrangling

```
#install.packages("tidyverse") # preinstalled on jupyterhub so not required
library(tidyverse) # autoloads `readr`, `dplyr`, `ggplot2`, `tidyr`, etc.
olympics <- read_csv("oly12countries.csv")
glimpse(olympics)
```

```
## Rows: 204
## Columns: 10
## $ Country        <chr> "Afghanistan", "Albania", "Algeria", "American Samoa", ~
## $ ISO            <chr> "AFG", "ALB", "DZA", "ASM", "AND", "AGO", "ATG", "ARG",~
## $ GDP.2011       <dbl> 2.034346e+10, 1.295956e+10, 1.886810e+11, 5.370000e+08,~
## $ pop.2010       <dbl> 34385000, 3205000, 35468000, 68420, 84864, 19082000, 88~
## $ athletes_f     <dbl> 1, 4, 18, 1, 2, 30, 2, 43, 4, 1, 188, 31, 14, 11, 8, 1,~
## $ athletes_m     <dbl> 5, 7, 21, 4, 4, 5, 3, 99, 21, 3, 225, 39, 39, 15, 4, 4,~
## $ athletes_total <dbl> 6, 11, 39, 5, 6, 35, 5, 142, 25, 4, 413, 70, 53, 26, 12~
## $ gold           <dbl> 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 7, 0, 2, 1, 0, 0, 0, 2, 0~
## $ silver         <dbl> 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 16, 0, 2, 0, 0, 0, 0, 5, ~
## $ bronze         <dbl> 1, 0, 0, 0, 0, 0, 0, 2, 2, 0, 12, 0, 6, 0, 1, 0, 0, 5, ~
```

`select()` Data Wrangling

`dplyr::select()`

Extract a subset of VARIABLES

```
olympics %>% select(Country, athletes_total, gold, silver, bronze) %>%
  print(n=6) # What is `print(n=6)` compared to `head()`?
```

```
## # A tibble: 204 x 5
##   Country        athletes_total  gold silver bronze
##   <chr>                   <dbl> <dbl>  <dbl>  <dbl>
## 1 Afghanistan                 6     0      0      1
## 2 Albania                    11     0      0      0
## 3 Algeria                    39     1      0      0
## 4 American Samoa              5     0      0      0
## 5 Andorra                     6     0      0      0
## 6 Angola                     35     0      0      0
## # ... with 198 more rows
```

select() Data Wrangling

dplyr::select()

Extract a subset of VARIABLES / Remove specific VARIABLES

```
olympics %>% select(-ISO,-GDP.2011,-pop.2010,-athletes_f,-athletes_m) %>%
  print(n=6) # https://tibble.tidyverse.org/reference/formatting.html
```

```
## # A tibble: 204 x 5
##   Country        athletes_total  gold silver bronze
##   <chr>                   <dbl> <dbl>  <dbl>  <dbl>
## 1 Afghanistan                 6     0      0      1
## 2 Albania                    11     0      0      0
## 3 Algeria                    39     1      0      0
## 4 American Samoa              5     0      0      0
## 5 Andorra                     6     0      0      0
## 6 Angola                     35     0      0      0
## # ... with 198 more rows
```

select() Data Wrangling

dplyr::select() [and see also dplyr::rename()]

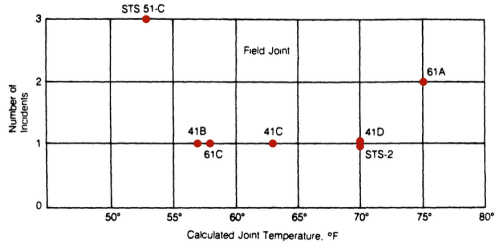
Extract a subset of VARIABLES / Remove specific VARIABLES / Rename VARIABLES

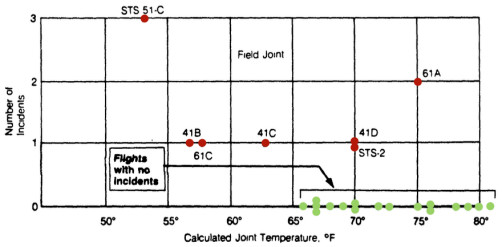
```
olympics %>% select(Country, `# of athletes`=athletes_total,
                    `#G`=gold, Num_S=silver, NumB=bronze) %>% print(n=6)
```

```
## # A tibble: 204 x 5
##   Country        `# of athletes`  `#G` Num_S  NumB
##   <chr>                    <dbl> <dbl> <dbl> <dbl>
## 1 Afghanistan                  6     0     0     1
## 2 Albania                     11     0     0     0
## 3 Algeria                     39     1     0     0
## 4 American Samoa               5     0     0     0
## 5 Andorra                      6     0     0     0
## 6 Angola                      35     0     0     0
## # ... with 198 more rows
```

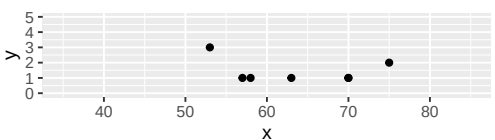
With great power comes great responsibility

The Challenger Disaster was caused by a bad `filter()` command...

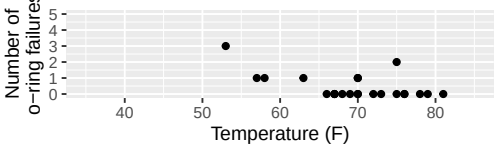




filter(nfailed > 0)



All Challenger O−Ring Data



filter() Data Wrangling

dplyr::filter()

Extract OBSERVATION subsets based on conditions on values in one or more columns

```
olympics %>% filter(athletes_total > 300 | gold > 5) %>% print(n=7)
```

```
## # A tibble: 15 x 10
##   Country   ISO     GDP.2011 pop.2010 athletes_f athletes_m athletes_total  gold
##   <chr>     <chr>      <dbl>    <dbl>      <dbl>      <dbl>          <dbl> <dbl>
## 1 Australia AUS      1.37e12   2.23e7        188        225            413     7
## 2 China     CHN      7.30e12   1.34e9        208        163            371    38
## 3 France    FRA      2.77e12   6.49e7        148        187            335    11
## 4 Germany   DEU      3.57e12   8.18e7        176        219            395    11
## 5 Hungary   HUN      1.40e11   1   e7         63         95            158     8
## 6 Italy     ITA      2.19e12   6.05e7        122        159            281     8
## 7 Japan     JPN      5.87e12   1.27e8        162        141            303     7
## # ... with 8 more rows, and 2 more variables: silver <dbl>, bronze <dbl>
```

select() + filter() Data Wrangling

dplyr::filter() and dplyr::select()

Extract DATA subsets of interest / Remove DATA of no interest

```
olympics %>% filter(athletes_total > 200 & gold < 10) %>%
  select(Country, athletes_total, gold, silver, bronze) %>% print(n=6)
```

```
## # A tibble: 8 x 5
##   Country   athletes_total  gold silver bronze
##   <chr>              <dbl> <dbl>  <dbl>  <dbl>
## 1 Australia            413     7     16     12
## 2 Brazil               266     3      5      9
## 3 Canada               279     1      5     12
## 4 Italy                281     8      9     11
## 5 Japan                303     7     14     17
## 6 Poland               217     2      2      6
## # ... with 2 more rows
```

Quiz on `select()` + `filter()` Data Wrangling

```
olympics %>% filter(athletes_total < 100 & gold > 1) %>%
  select(Country, athletes_total, gold, silver, bronze)
```

Options

A. All countries in the original tibble with fewer than 100 athletes and all variables from the original tibble

B. All countries in the original tibble and five variables: Country, # of athletes, and # of gold/silver/bronze medals

C. All countries in the original tibble which won more than one gold medal and had fewer than 100 athletes and five variables: Country, # of athletes, and # of gold/silver/bronze medals

D. All countries in the original tibble with fewer than 100 athletes or who won more than one gold medal and five variables: Country, # of athletes, and # of gold/silver/bronze medals

arrange() + select() + filter() Data Wrangling

dplyr::arrange() and dplyr::arrange(dplyr::desc())

Sort rows/observations based on the values in one or more columns/variables

```
olympics %>%
  arrange(desc(athletes_total), gold) %>%
  filter(athletes_total<100 & gold>1) %>%
  select(Country, athletes_total, gold)
```

```
## # A tibble: 8 x 3
##   Country     athletes_total  gold
##   <chr>                <dbl> <dbl>
## 1 Norway                  65     2
## 2 Lithuania               62     2
## 3 North Korea             55     4
## 4 Azerbaijan              53     2
## 5 Iran                    53     4
## 6 Kenya                   50     2
## 7 Jamaica                 50     4
## 8 Ethiopia                35     3
```

- What does 'desc()' do?
- Is the following "*order of operations*" more efficient?
  1. select()
  2. filter()
  3. arrange()

```
olympics %>%
  select(Country,athletes_total,gold) %>%
  filter(athletes_total<100 & gold>1) %>%
  arrange(desc(athletes_total), gold)
```

Review Quiz on Data Wrangling

Do the outputs match the code?

Check the `select()`, `arrange()`, `desc()`, and `head()`/`print()` functions & input

```
olympics %>% arrange(tot_medals) %>%
  select(tot_medals, avg_medals,
         Country, ISO) %>% head()
```

```
## # A tibble: 204 x 3
##   tot_medals avg_medals Country
##        <dbl>      <dbl> <chr>
## 1        104      0.196 US
## 2         88      0.237 China
## 3         82      0.189 Russia
## 4         65      0.117 UK
## 5         44      0.111 Germany
## # ... with 199 more rows
```

```
olynew %>% arrange(desc(avg_medals)) %>%
  select(tot_medals, avg_medals,
         Country, ISO) %>% head()
```

```
## # A tibble: 6 x 4
##   tot_medals avg_medals Country  ISO
##        <dbl>      <dbl> <chr>    <chr>
## 1          1      0.25  Botswana BWA
## 2         12      0.24  Jamaica  JAM
## 3         88      0.237 China    CHN
## 4         12      0.226 Iran     IRN
## 5         11      0.22  Kenya    KEN
## 6          7      0.2   Ethiopia ETH
```

Some errors during Data Wrangling

```
olympics %>% filter(tot_medals > 1 & avg_medals > 0.1)
```

```
## Error in `filter()`:
## ! Problem while computing `..1 = tot_medals > 1 & avg_medals > 0.1`.
## Caused by error:
## ! object 'tot_medals' not found
```

Errors messages in RStudio are often (but not always) informative about what's gone wrong; *but, you have to read error output text to find the explanation.*

```
olympics %>% select(tot_medals, avg_medals)
```

```
## Error in `select()`:
## ! Can't subset columns that don't exist.
## x Column `tot_medals` doesn't exist.
```

mutate() Data Wrangling

dplyr::mutate()

Defining and creating new useful and interesting variables

```
olympics %>% select(Country, athletes_total, gold, silver, bronze) %>%
  mutate(tot_medals = gold+silver+bronze,
         avg_medals = tot_medals/athletes_total) -> olynew
olynew %>% print(n=4)
```

```
## # A tibble: 204 x 8
##   Country        ISO   athletes_total  gold silver bronze tot_medals avg_medals
##   <chr>          <chr>          <dbl> <dbl>  <dbl>  <dbl>      <dbl>      <dbl>
## 1 Afghanistan    AFG                6     0      0      1          1     0.167
## 2 Albania        ALB               11     0      0      0          0     0
## 3 Algeria        DZA               39     1      0      0          1     0.0256
## 4 American Samoa ASM                5     0      0      0          0     0
## # ... with 200 more rows
```

case_when() + mutate() Data Wrangling

dplyr::mutate() and dplyr::case_when()

```
olympics %>% mutate(majority = case_when(
                      athletes_f > athletes_m ~ "Female",
                      athletes_f < athletes_m ~ "Male",
                      athletes_f == athletes_m ~ "Balanced"),
                    total_medals = gold+silver+bronze) -> olynew
olynew %>% select(Country, athletes_total, athletes_f,
                  athletes_m, majority, total_medals) %>% print(n=4)
```

```
## # A tibble: 204 x 6
##   Country        athletes_total athletes_f athletes_m majority total_medals
##   <chr>                   <dbl>      <dbl>      <dbl> <chr>           <dbl>
## 1 Afghanistan                 6          1          5 Male                1
## 2 Albania                    11          4          7 Male                0
## 3 Algeria                    39         18         21 Male                1
## 4 American Samoa              5          1          4 Male                0
## # ... with 200 more rows
```

summarise() for Summary Tables

dplyr::summarise() and Aggregation Functions

```
olympics %>% summarise(n=n(), sum_gold=sum(gold), median_gold=median(gold),
                       mean_gold=mean(gold), var_gold=var(gold), sd_gold=sd(gold))
```

```
## # A tibble: 1 x 6
##       n sum_gold median_gold mean_gold var_gold sd_gold
##   <int>    <dbl>       <dbl>     <dbl>    <dbl>   <dbl>
## 1   204      302           0      1.48     27.2    5.21
```

```
olympics %>% summarize(n=n(), sumGold=sum(gold), minGold=min(gold), maxGold=max(gold),
                       `25th%tile`=quantile(gold,0.25), IQRgold=IQR(gold),
                       `75th%tile`=quantile(gold,0.75), `90th%tile`=quantile(gold,0.90))
```

```
## # A tibble: 1 x 8
##       n sumGold minGold maxGold `25th%tile` IQRgold `75th%tile` `90th%tile`
##   <int>   <dbl>   <dbl>   <dbl>       <dbl>   <dbl>       <dbl>       <dbl>
## 1   204     302       0      46           0       1           1           3
```

group_by() + summarise() for Summary Tables

dplyr::summarise() and Aggregation Functions and dplyr::group_by()

Creating more complex summary tables with multiple rows

```
olympics %>% mutate(teamsize = case_when(
                        athletes_total >= 100 ~ "big",
                       (athletes_total < 100) & (athletes_total >= 20) ~ "medium",
                        athletes_total < 20 ~ "small")) %>%
  group_by(teamsize) %>%
  summarize(n=n(), `Total Gold`=sum(gold), Average_Gold=mean(gold),
            MedianGold=median(gold), maxGold=max(gold))
```

```
## # A tibble: 3 x 6
##   teamsize     n `Total Gold` Average_Gold MedianGold maxGold
##   <chr>    <int>        <dbl>        <dbl>      <dbl>   <dbl>
## 1 big         36          266       7.39            3      46
## 2 medium      51           34       0.667           0       4
## 3 small      117            2       0.0171          0       1
```

group_by() + summarise() for Summary Tables

dplyr::summarise() and Aggregation Functions and dplyr::group_by()

Creating more complex Aggregation Functions for multiple row summary tables

```
olynew %>% group_by(majority) %>%
  summarize(n=n(), `Average Medals`=mean(gold+silver+bronze),
            minMedals=min(gold+silver+bronze), max_Medals=max(gold+silver+bronze))
```

```
## # A tibble: 4 x 5
##   majority     n `Average Medals` minMedals max_Medals
##   <chr>    <int>            <dbl>     <dbl>      <dbl>
## 1 Balanced    25             0.6          0         12
## 2 Female      34            10.8          0        104
## 3 Male       144             4.02         0         65
## 4 <NA>         1             0            0          0
```

Question: Why are there 4 groups above? What's going on with the <NA> thing?

is.na() for Handling NA Missing Data in R

```
vector <- c(1,2,NA,4,NA); is.na(vector)
```

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

```
olynew %>% filter(is.na(majority))
```

```
## # A tibble: 1 x 8
##   Country  athletes_f athletes_m athletes_total majority  gold silver bronze
##   <chr>         <dbl>      <dbl>          <dbl> <chr>    <dbl>  <dbl>  <dbl>
## 1 Barbados         NA          6              6 <NA>         0      0      0
```

```
olynew %>% filter(!is.na(majority)) %>% group_by(majority) %>%
  summarize(n=n(), `Average Medals`=mean(gold+silver+bronze),
            minMedals=min(gold+silver+bronze), max_Medals=max(gold+silver+bronze))
```

```
## # A tibble: 3 x 5
##   majority     n `Average Medals` minMedals max_Medals
##   <chr>    <int>            <dbl>     <dbl>      <dbl>
## 1 Balanced    25             0.6          0         12
## 2 Female      34            10.8          0        104
## 3 Male       144             4.02         0         65
```

na.rm() for Handling NA Missing Data in R

You can't calculate with NA *but you can remove and ignore NA with* na.rm()

```
vector <- c(1,2,NA,4,NA); mean(vector)
```

```
## [1] NA
```

```
mean(vector, na.rm=TRUE)
```

```
## [1] 2.333333
```

Be careful with the n() function

- It doesn't know about missing data NA so it can misrepresent data...

```
olynew %>% summarize(n_NumberOfRows=n(), n_NumberOfMeasurements=sum(!is.na(majority)),
                     mean=mean(athletes_f), mean_na_rm=mean(athletes_f, na.rm=TRUE))
```

```
## # A tibble: 1 x 4
##   n_NumberOfRows n_NumberOfMeasurements  mean mean_na_rm
##            <int>                  <int> <dbl>      <dbl>
## 1            204                    203    NA       23.7
```

Class Check Round 2

https://pollev.com/sta (8 questions)

Self Quiz

- Can you explain the benefit of having tidy data?
- Can you explain why a data set is not tidy?
- Can you describe the new `tibble` produced from a sequence of `dplyr` functions applied to a given `tibble`?
- Can you use `dplyr` `filter()` and `select()` functions to extract a subset of a larger data set?
- Can you list 10 *aggregation functions* that are used with `dplyr` `summarise()` and `group_by` functions?
- Can you use `dplyr` `summarise()` and `group_by` along with *aggregation functions* to answer questions with summary tables?

Class Check Round 3

https://pollev.com/sta (2 questions)

Rstudio Demo

1. Click this jupyterhub repo launcher link