Using R Markdown & the Tidyverse to Create Reproducible Research

Justin Post

Overview & R Markdown

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What is this course about?

Basic use of R for reading, manipulating, and summarizing data. With a focus on reproducibility!

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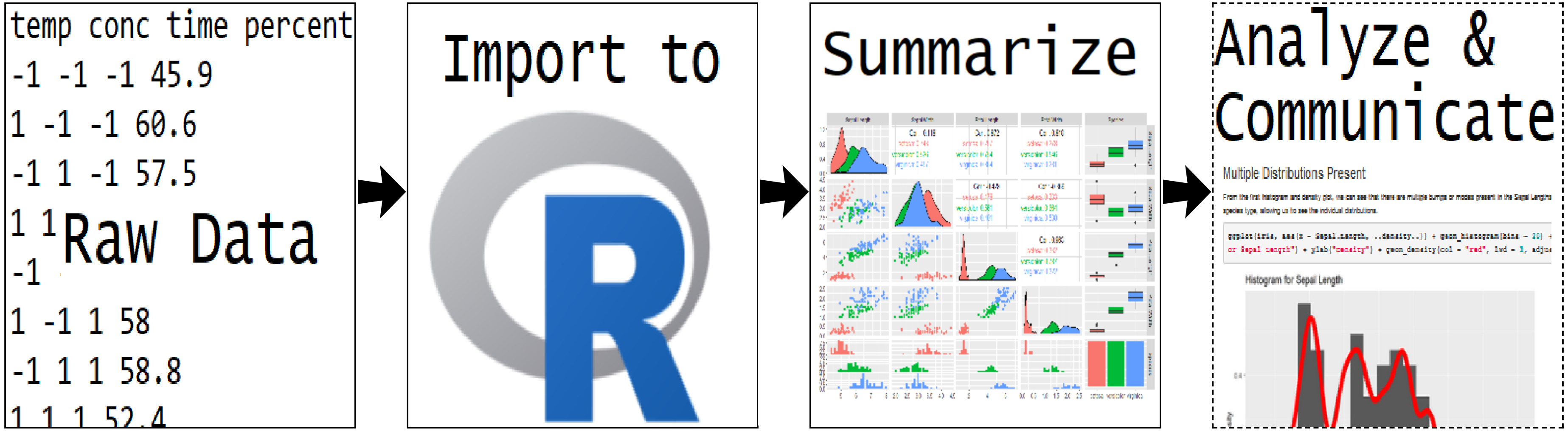

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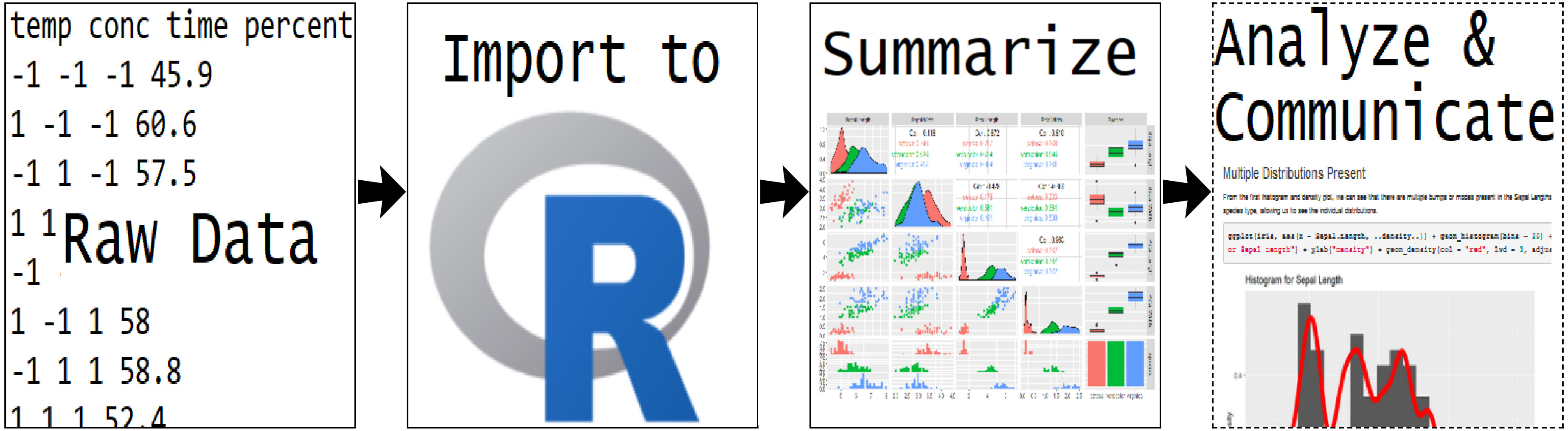
Basic use of R for reading, manipulating, and summarizing data. With a focus on reproducibility!



Start with an example!

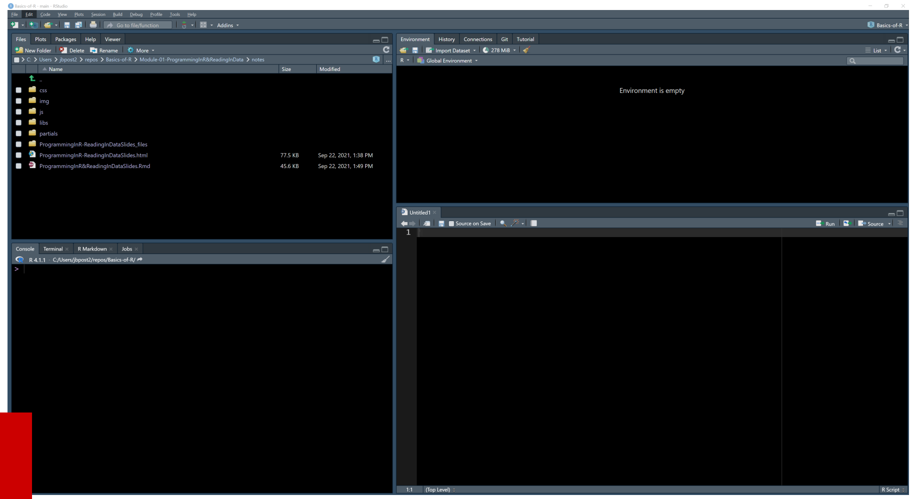
First Part of Course

- Learn basics of R Markdown for literate programming
- Understand how R stores data
- Read external data into R

RStudio IDE

In RStudio, four main locations (easy to customize!)

- Console (& Terminal)
- Files/Plots/Packages/Help
- Environment (& Connections/Git)
- Scripting and Viewing Window



Console

- Type code directly into the **console** for evaluation

```r
#simple math operations
# <-- is a comment - code not evaluated
3 + 7
```

```
## [1] 10
```

```r
10 * exp(3) #exp is exponential function
```

```
## [1] 200.8554
```

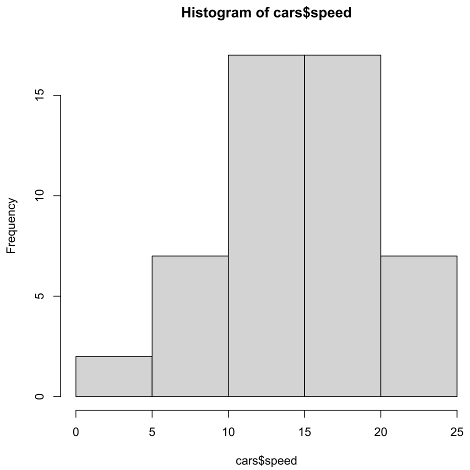
```r
log(pi^2) #log is natural log by default
```

```
## [1] 2.28946
```

```r
mean(cars$speed)
```

```
## [1] 15.4
```

```r
hist(cars$speed)
```



Files/Plots/Packages/Help

- Files (navigate through files)
- Created plots stored in `Plots` tab
  - Cycle through past plots
  - Easily save
- Packages (update and install)
- Documentation within RStudio via `help(...)`
  - Ex: `help(seq)`

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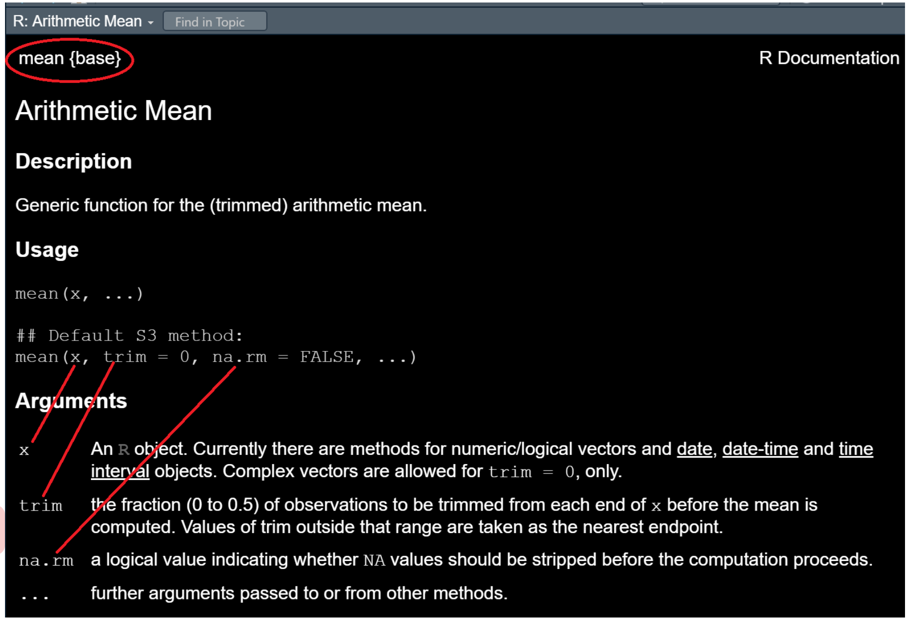

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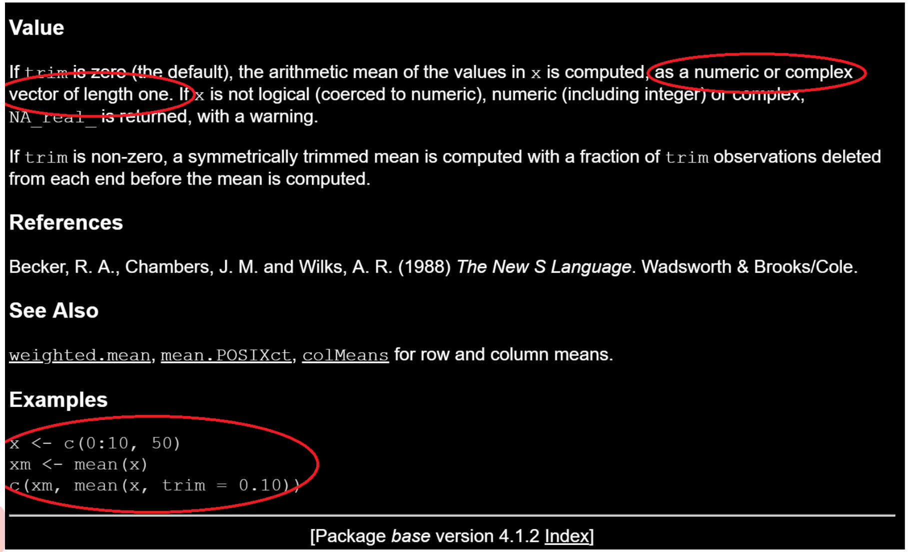


Value

If `trim` is zero (the default), the arithmetic mean of the values in `x` is computed, as a numeric or complex vector of length one. If `x` is not logical (coerced to numeric), numeric (including integer) or complex, `NA_real_` is returned, with a warning.

If `trim` is non-zero, a symmetrically trimmed mean is computed with a fraction of `trim` observations deleted from each end before the mean is computed.

References

Becker, R. A., Chambers, J. M. and Wilks, A. R. (1988) *The New S Language*. Wadsworth & Brooks/Cole.

See Also

`weighted.mean`, `mean.POSIXct`, `colMeans` for row and column means.

Examples

```
x <- c(0:10, 50)
xm <- mean(x)
c(xm, mean(x, trim = 0.10))
```

[Package *base* version 4.1.2 Index]

Environment

- We store **data/info/function/etc.** in R objects
- Create an R object via `<-` (recommended) or `=`

```
#save for later
avg <- (5 + 7 + 6) / 3
#call avg object
avg
```

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

```
#strings (text) can be saved as well
words <- c("Hello there!", "How are you?")
words
```

```
## [1] "Hello there!" "How are you?"
```

Environment

- Built-in objects exist like `letters` and `cars` don't show automatically

```
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"
```

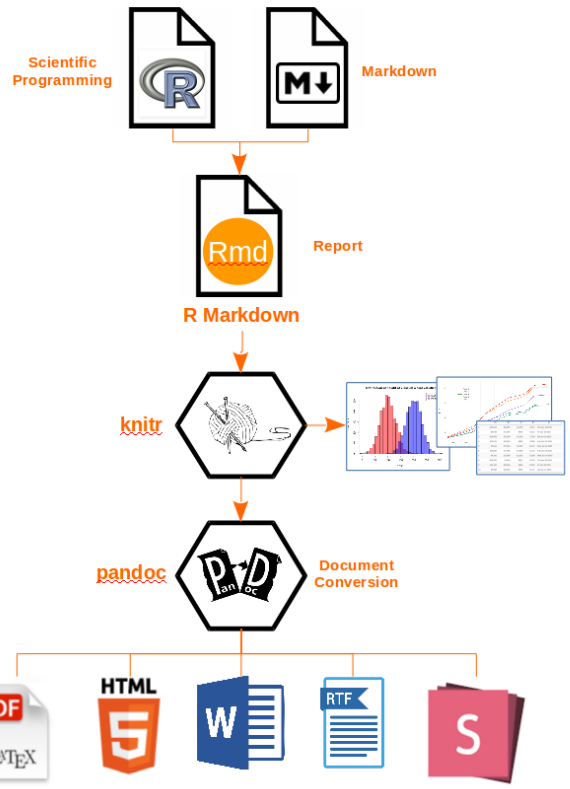
```
head(cars, n = 3)
```

```
##   speed dist
## 1     4    2
## 2     4   10
## 3     7    4
```

- `data()` shows available built-in data sets

Scripting and Viewing Window

- Usually want to keep code for later use!
- Traditionally code in a 'script' and save script
    - Instead we'll use R Markdown
    - A file with extension `.Rmd`
- Let's start with R Markdown!



http://applied-r.com/

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Documenting with Markdown

Designed to be used in three ways (R for Data Science)

- Communicating to decision makers (focus on conclusions not code)
- Collaborating with other data scientists (including future you!)
- As environment to do data science (documents what you did and what you were thinking)

Markdown Languages

- May have heard of HTML (HyperText Mark-up Language)
  - Write plain text with *tags* that the browser interprets and renders

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- R Markdown is a specific markup language
  - Easier syntax
  - Not as powerful
- Any plain text file can be used (`.Rmd` extension associates it with R Studio)

Markdown Languages

- May have heard of HTML (HyperText Mark-up Language)
    - Write plain text with *tags* that the browser interprets and renders
- R Markdown is a specific markup language
    - Easier syntax
    - Not as powerful
- Any plain text file can be used (`.Rmd` extension associates it with R Studio)
- Easy to create many types of documents in R Markdown!

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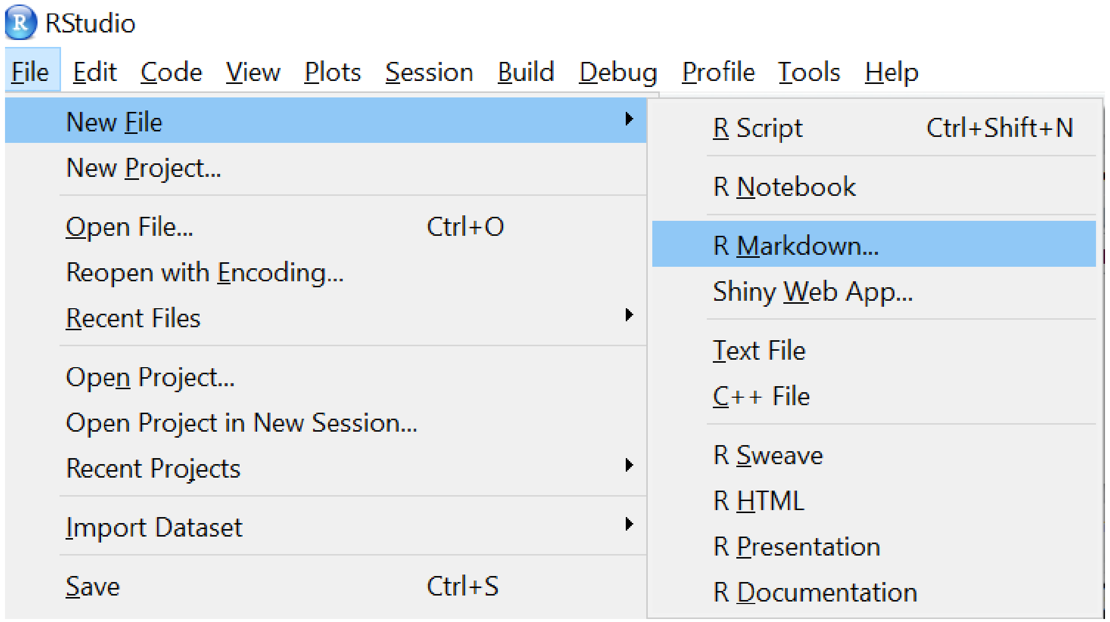
Creating an R Markdown Document

- R Studio makes it easy!



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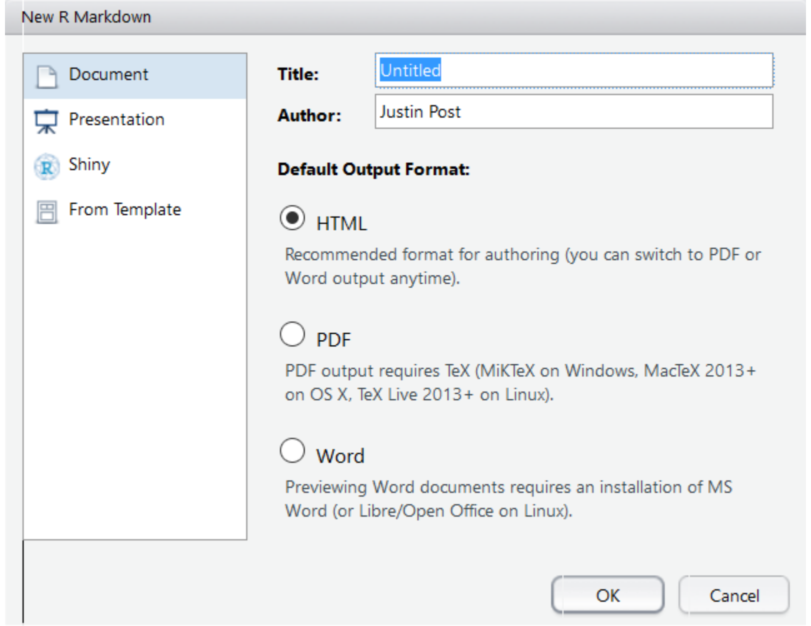
Choosing the Output Type

- Many commonly used document types can be created



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`.Rmd` Files

R Markdown files (`.Rmd`) contain three important types of content:

1. (Optional) YAML header surrounded by `---`s
    - Defines meta data about the document
2. Chunks of R code
    - Code that may evaluate and produce output when *knitting* the document
3. Text mixed with simple text formatting instructions (R Markdown syntax)

YAML Header

- Defines settings for the creation process

```
---
title: "Untitled"
author: "First Last"
date: "xxxx"
output: html_document
---
```

- CTRL/CMD + Shift + k or the **Knit** button creates a document via this info
- Great examples of options here

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Creating PDF Output

Change the `output` to `pdf_document`

- If you have a `Tex` engine on their computer (such as `MikTex`), good to go
- If not, easiest to do the following first:
  1. Install the `tinytex` package
  2. Run `library(tinytex)`
  3. Run `install_tinytex()`
  4. Restart R

Markdown Syntax

- `# R Markdown` $\longrightarrow$ First level header
- `## Next` $\longrightarrow$ Second level header

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- `# R Markdown` $\longrightarrow$ First level header
- `## Next` $\longrightarrow$ Second level header
- `<http://rmarkdown.rstudio.com>` $\longrightarrow$ A hyperlink: http://rmarkdown.rstudio.com
- `[Cheat Sheet link](https://www.rstudio.com/wp-content/uploads/2015/03/rmarkdown-reference.pdf)` $\longrightarrow$ Cheat Sheet link

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Markdown Syntax

- `# R Markdown` → First level header
- `## Next` → Second level header
- `<http://rmarkdown.rstudio.com>` → A hyperlink: http://rmarkdown.rstudio.com
- `[Cheat Sheet link](https://www.rstudio.com/wp-content/uploads/2015/03/rmarkdown-reference.pdf)` → Cheat Sheet link
- `**Knit**` or `__Knit__` → Bold font (**Knit**)
- `*italic*` or `_italic_` → Italic font (*italic*)
- `*__both__*` → Bold and italic (***both***)

Markdown Syntax

- Can do lists (be careful with spaces & returns)
    - Indent sub lists four spaces

```
- unordered list
- item 2
    + sub-item 1
    + sub-item 2

1. ordered list
2. item 2
    a. sub-item 1
    b. sub-item 2
```

- unordered list
- item 2
    - sub-item 1
    - sub-item 2

1. ordered list
2. item 2
    a. sub-item 1
    b. sub-item 2

- See the cheatsheet here or here

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Code Chunks

```
```{r ggplot,eval=FALSE}
select(iris, Sepal.Width)
ggplot(iris, aes(x = Sepal.Width, y = Sepal.Length)) +
geom_point()
```
```

Code Chunks

```
```{r ggplot,eval=FALSE}
select(iris, Sepal.Width)
ggplot(iris, aes(x = Sepal.Width, y = Sepal.Length)) +
geom_point()
```
```

- Start code chunk by typing out the syntax or with CTRL/CMD + Alt/Option + I
- Can execute code in RStudio as you are writing
- Code is executed sequentially when document is created

Code Chunks

```
```{r ggplot,eval=FALSE}
select(iris, Sepal.Width)
ggplot(iris, aes(x = Sepal.Width, y = Sepal.Length)) +
geom_point()
```
```

Can specify behavior of each code chunks via **global** or **local** chunk options:

- Hide/show code: `echo = FALSE/TRUE`
- `eval = TRUE/FALSE`
- Eval, not show code or output: `include = TRUE/FALSE`
- `message = TRUE/FALSE` and `warning = TRUE/FALSE`

Code Chunks

```
```{r ggplot,eval=FALSE}
select(iris, Sepal.Width)
ggplot(iris, aes(x = Sepal.Width, y = Sepal.Length)) +
geom_point()
```
```

Global chunk options:

- Usually have a **setup** code chunk (with `include = FALSE`)
- Defines global behavior for all chunks

Ex: `opts_chunk$set(echo = FALSE, eval = TRUE, warning = FALSE)`

Code Chunks

```
knitr::include_graphics("img/chunk.png")
```

Using chunks is generally the best way to include an image.

Code chunk options often used

- `fig.align = 'center'`
- `out.width = "500px"`
- `echo = FALSE`

Inline R Code

R code can be evaluated inline!

- Begin with a single back-tick followed by `r`
- End with another back-tick

Ex: Iris has `r` `length(iris[ ,1])` observations $\rightarrow$ Iris has 150 observations

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Recap!

- R Markdown allows for easily reproducible analyses and documenting of thought processes
    - YAML header
    - Plain text with R Markdown syntax
    - Code chunks
- Cheat Sheet link great for getting started
- Everything you could want to know about R Markdown in R Markdown: The Definitive Guide

Let's Practice

- Take the raw text here
- Create the HTML output here

Guidance:

- Create a new .Rmd file and replace its test with the raw text (copy/paste)
- Knit the document as is to start
- Add headers (the `dplyr`, `ggplot2`, `readr`, and `tidyr` sections are second level headers), reknit
- Update YAML header to add code folding, reknit
- Update the global chunk options (`echo`, `eval` should be `TRUE`, `message` should be `FALSE`), reknit
- Modify local chunk options on the images to suppress code, reknit
- Add in markdown syntax (links, code font, etc.), reknit
- Add tabsets, reknit

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Data Storage in R

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R Objects and Classes

- Create an R object via `<-` (recommended) or `=`
    - allocates memory to object

```
vec <- c(1, 4, 10)
vec
```

```
## [1]  1  4 10
```

R Objects and Classes

- Create an R object via `<-` (recommended) or `=`
    - allocates memory to object

```
vec <- c(1, 4, 10)
vec
```

```
## [1]  1  4 10
```

```
fit <- lm(dist ~ speed, data = cars)
fit
```

```
##
## Call:
## lm(formula = dist ~ speed, data = cars)
##
## Coefficients:
## (Intercept)        speed
##     -17.579        3.932
```

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Investigating Objects

Many functions to help understand an R Object

- `str()`
- compactly displays the internal structure of an R object

```
str(cars)
```

```
## 'data.frame':	50 obs. of  2 variables:
##  $ speed: num  4 4 7 7 8 9 10 10 10 11 ...
##  $ dist : num  2 10 4 22 16 10 18 26 34 17 ...
```

```
str(vec)
```

```
##  num [1:3] 1 4 10
```

Data Objects

- Understand data structures first: Five major types
    - **Atomic Vector (1d)**
    - Matrix (2d)
    - Array (nd)
    - **Data Frame (2d)**
    - List (1d)

Dimension	Homogeneous	Heterogeneous
1d	Atomic Vector	List
2d	Matrix	Data Frame
nd	Array	

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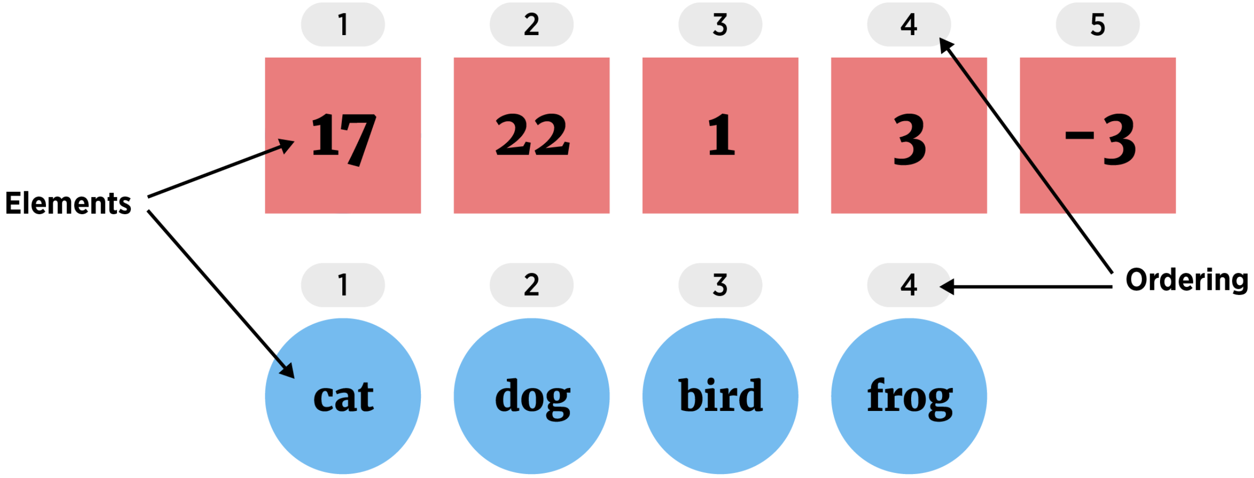
Vector

(Atomic) Vector (1D group of elements with an ordering)



- Elements must be same 'type'
  - numeric, character, or logical

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Vector

(Atomic) Vector (1D group of elements with an ordering)

- Create with `c()` function ('combine')

```
#vectors (1 dimensional) objects
x <- c(17, 22, 1, 3, -3)
y <- c("cat", "dog", "bird", "frog")
x
```

```
## [1] 17 22  1  3 -3
```

```
y
```

```
## [1] "cat"  "dog"  "bird" "frog"
```

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Vector

- Many **functions** output a numeric vector

```
v <- seq(from = 1, to = 5, length = 5)
#same result with different inputs:
v <- seq(from = 1, to = 5, by = 1)
v
```

```
## [1] 1 2 3 4 5
```

```
str(v)
```

```
##  num [1:5] 1 2 3 4 5
```

`:` to Create a Sequence

```r
1:20
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

- R does element-wise math on vectors

```r
1:20/20
```

```
##  [1] 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75
## [16] 0.80 0.85 0.90 0.95 1.00
```

```r
1:20 + 1
```

```
##  [1]  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21
```

Slicing Vectors

- Return elements using square brackets `[]`

```
letters #built-in vector
```

```
##  [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"
```

```
letters[1] #R starts counting at 1!
```

```
## [1] "a"
```

```
letters[26]
```

```
## [1] "z"
```

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Slicing Vectors

- Return elements using square brackets `[]`
- Can 'feed' in a vector of indices to `[]`

```
letters[1:4]
```

```
## [1] "a" "b" "c" "d"
```

```
letters[c(5, 10, 15, 20, 25)]
```

```
## [1] "e" "j" "o" "t" "y"
```

```
x <- c(1, 2, 5)
letters[x]
```

```
## [1] "a" "b" "e"
```

Slicing Vectors

- Return elements using square brackets `[]`
- Can 'feed' in a vector of indices to `[]`
- Use negative indices to return without

```
letters[-(1:4)]
```

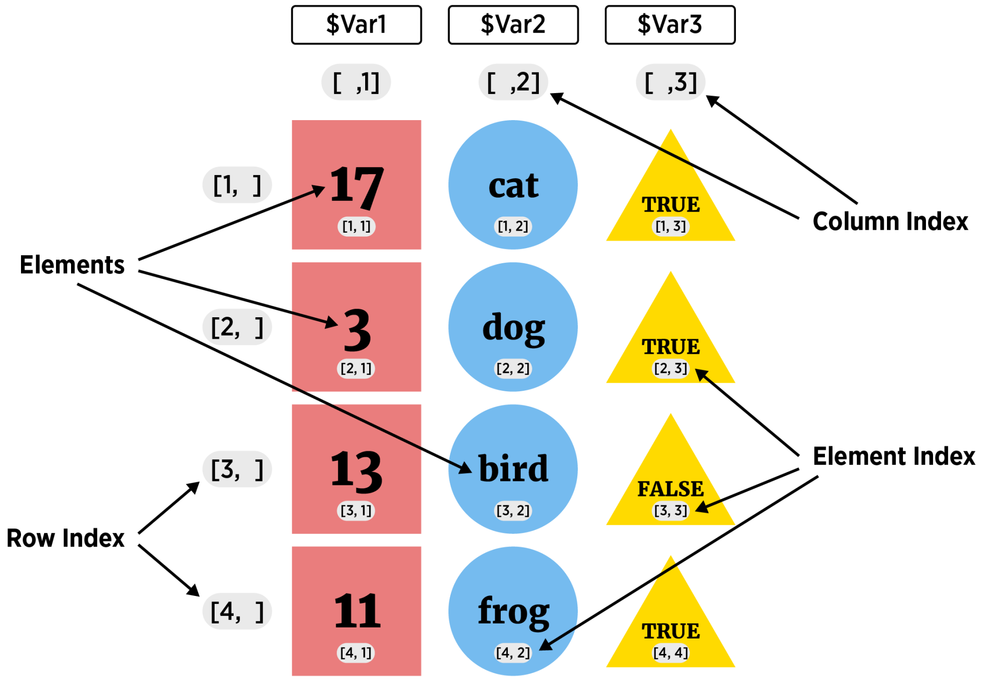
```
##  [1] "e" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s" "t" "u" "v" "w"
## [20] "x" "y" "z"
```

```
x <- c(1, 2, 5)
letters[-x]
```

```
##  [1] "c" "d" "f" "g" "h" "i" "j" "k" "l" "m" "n" "o" "p" "q" "r" "s" "t" "u" "v"
## [20] "w" "x" "y" "z"
```

Building Blocks for Data Frames

- Columns of a data frame are vectors



Data Frame

Data Frame (2D data structure)

- Collection (list) of **vectors** of the same *length*
- Create with `data.frame()` function

```
x <- c("a", "b", "c", "d", "e", "f")
y <- c(1, 3, 4, -1, 5, 6)
z <- 10:15
myDF <- data.frame(x, y, z)
myDF
```

```
##   x  y  z
## 1 a  1 10
## 2 b  3 11
## 3 c  4 12
## 4 d -1 13
## 5 e  5 14
## 6 f  6 15
```

Data Frame

Data Frame (2D data structure)

- Collection (list) of **vectors** of the same *length*
- Create with `data.frame()` function

```
myDF <- data.frame(char = x, data1 = y, data2 = z)
myDF
```

```
##   char data1 data2
## 1    a     1    10
## 2    b     3    11
## 3    c     4    12
## 4    d    -1    13
## 5    e     5    14
## 6    f     6    15
```

- char, data1, and data2 become the variable names for the data frame

Slicing a Data Frame

- Use square brackets with a comma `[ , ]`
  - Index rows (prior to the comma) then columns (after the comma)

```r
myDF
```

```
##   char data1 data2
## 1    a     1    10
## 2    b     3    11
## 3    c     4    12
## 4    d    -1    13
## 5    e     5    14
## 6    f     6    15
```

```r
myDF[c(2, 4), ]
```

```
##   char data1 data2
## 2    b     3    11
## 4    d    -1    13
```

```r
myDF[, 1]
```

```
## [1] "a" "b" "c" "d" "e" "f"
```

```r
myDF[2, ]
```

```
##   char data1 data2
## 2    b     3    11
```

```r
myDF[2, 1]
```

```
## [1] "b"
```

Slicing a Data Frame

- Can use columns names to subset

```
myDF[ , c("char", "data1")]
```

```
##   char data1
## 1    a     1
## 2    b     3
## 3    c     4
## 4    d    -1
## 5    e     5
## 6    f     6
```

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Slicing a Data Frame

- Dollar sign allows easy access to a single column!

```
myDF$char
```

```
## [1] "a" "b" "c" "d" "e" "f"
```

```
myDF$data1
```

```
## [1]  1  3  4 -1  5  6
```

Slicing a Data Frame

- Dollar sign allows easy access to a single column!
- Most used method for accessing a single variable
- RStudio fills in options.
    - Type `mydf$`
    - If no choices - hit tab
    - Hit tab again to choose

Recap!

Data Frame (2D data structure)

- Collection (list) of **vectors** of the same *length*
- Create with `data.frame()` function
- Access with `[ , ]` or `$`
- Perfect for most data sets!
- Most functions that read 2D data store it as a `data frame` (or `tibble` - a special data frame covered shortly)

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Let's Practice

We'll add to our `.Rmd` file from the previous activity

- Download the prompts to add to our markdown document here

Guidance:

- Copy and paste the text from above into the bottom of the document, reknit
- Add to the code chunks, evaluating in the notebook
- Reknit occasionally to check the output

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The `tidyverse`

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Where Do Our Objects & Functions Come From?

Dimension	Homogeneous	Heterogeneous
1d	Atomic Vector	List
2d	Matrix	Data Frame
nd	Array	

Basic access via

- Atomic vectors - `x[ ]`
- Data Frames - `x[ , ]` or `x$name`
- Lists - `x[ ]`, `x[[ ]]`, or `x$name`

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Where Do Our Objects & Functions Come From?

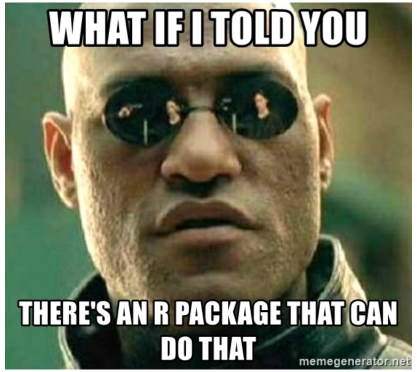
When you open R a few `packages` are loaded

- R package:
  - Collection of functions/objects/datasets/etc.

Where Do Our Objects & Functions Come From?

When you open R a few `packages` are loaded

- R package:
  - Collection of functions/objects/datasets/etc.
- Packages exist to do almost anything
  - List of CRAN approved packages
  - Plenty of other packages on places like GitHub



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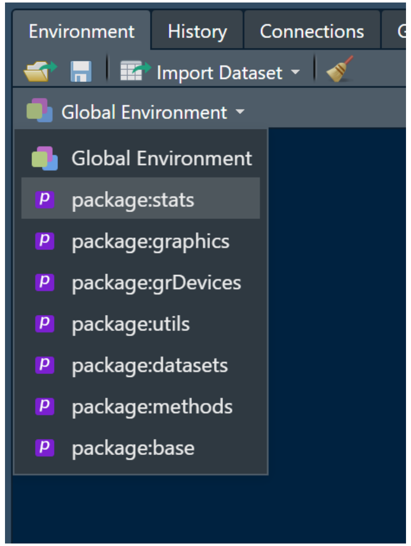
Where Do Our Objects & Functions Come From?

- Packages loaded automatically



- `base` package has `c()`, `data.frame()`, `list()`, …

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Base R vs Tidyverse

- Everything done so far uses `Base R`

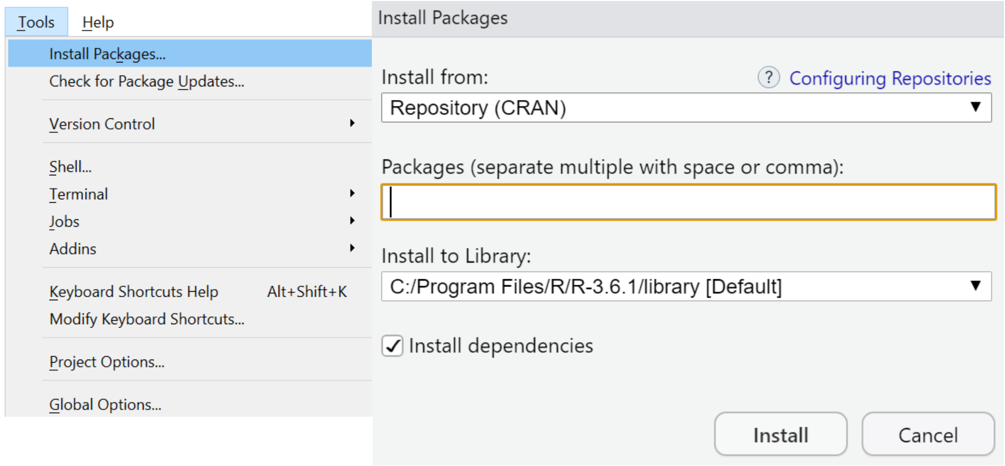
Coherent and opinionated framework for common data tasks:

- `TidyVerse`
    - data importing (`readr`, `readxl`, `haven`, `DBI`)
    - data manipulation (`dplyr`, `tidyr`)
    - plotting (sort of) (`ggplot2`)
    - …

Installing an R Package

- First time using a package
  - Must **install package** (download files to your computer)
  - Can use code, menus, or Packages tab

```
install.packages("dplyr")
```



Accessing a Package in Your R Session

- Only install once!
- **Each session**: read in package using `library()` or `require()`

```
library("dplyr")
```

Accessing a Package in Your R Session

- Only install once!
- **Each session**: read in package using `library()` or `require()`

```r
library("dplyr")
```

- See everything from that package:

```r
ls("package:dplyr")
```

```
##   [1] "%>%"                  "across"               "add_count"
##   [4] "add_count_"           "add_row"              "add_rownames"
##   [7] "add_tally"            "add_tally_"           "all_equal"
##  [10] "all_of"               "all_vars"             "anti_join"
##  [13] "any_of"               "any_vars"             "arrange"
##  [16] "arrange_"             "arrange_all"          "arrange_at"
##  [19] "arrange_if"           "as.tbl"               "as_data_frame"
##  [22] "as_label"             "as_tibble"            "auto_copy"
##  [25] "band_instruments"     "band_instruments2"    "band_members"
##  [28] "bench_tbls"           "between"              "bind_cols"
##  [31] "bind_rows"            "c_across"             "case_when"
##  [34] [illegible]            "check_dbplyr"         "coalesce"
##  [37] [illegible]            "collect"              "combine"
##  [40] [illegible]            "compare_tbls"         "compare_tbls2"
##  [43] "compute"              "contains"             "copy_to"
```

Calling From a Library

- Call functions without loading full library with `::`
- If not specified, most recently loaded package takes precedent

```r
#stats::filter(...) calls time-series function from stats package
dplyr::filter(iris, Species == "virginica")
```

```
##    Sepal.Length Sepal.Width Petal.Length Petal.Width   Species
## 1           6.3         3.3          6.0         2.5 virginica
## 2           5.8         2.7          5.1         1.9 virginica
## 3           7.1         3.0          5.9         2.1 virginica
## 4           6.3         2.9          5.6         1.8 virginica
## 5           6.5         3.0          5.8         2.2 virginica
## 6           7.6         3.0          6.6         2.1 virginica
## 7           4.9         2.5          4.5         1.7 virginica
## 8           7.3         2.9          6.3         1.8 virginica
## 9           6.7         2.5          5.8         1.8 virginica
## 10          7.2         3.6          6.1         2.5 virginica
## 11          6.5         3.2          5.1         2.0 virginica
## 12          6.4         2.7          5.3         1.9 virginica
## 13          6.8         3.0          5.5         2.1 virginica
## 14          5.7         2.5          5.0         2.0 virginica
## 15          5.8         2.8          5.1         2.4 virginica
                                         5.3         2.3 virginica
                                         5.5         1.8 virginica
                                         6.7         2.2 virginica
                                         6.9         2.3 virginica
```

Reading Raw Data Into R

- Read in **raw** data using the `tidyverse` via `readr`, `readxl`, `haven`, and `DBI`

Reading Raw Data Into R

- Read in **raw** data using the `tidyverse` via `readr`, `readxl`, `haven`, and `DBI`

Plan:

- Read 'clean' delimited data
- Read Excel data
- See an example of connecting to a database

Reading Delimited Data

- Delimited data
  - Delimiter - Character (such as a `,`) that separates data entries

```
Treatment,Sex,Age,Duration,Pain
P,F,68,1,No
B,M,74,16,No
P,F,67,30,No
P,M,66,26,Yes
B,F,67,28,No
B,F,77,16,No
A,F,71,12,No
B,F,72,50,No
B,F,76,9,Yes
A,M,71,17,Yes
```

Comma: usually .csv

```
temp conc time percent
-1 -1 -1 45.9
1 -1 -1 60.6
-1 1 -1 57.5
1 1 -1 58.6
-1 -1 1 53.3
1 -1 1 58
-1 1 1 58.8
```

Space: usually .txt or .dat

```
"color"	"spine"	"width"	"satell"	"weight"	"y"
3	3	28.3	8	3050	1
4	3	22.5	0	1550	0
2	1	26	9	2300	1
4	3	24.8	0	2100	0
4	3	26	4	2600	1
3	3	23.8	0	2100	0
2	1	26.5	0	2350	0
4	2	24.7	0	1900	0
3	1	23.7	0	1950	0
4	3	25.6	0	2150	0
4	3	24.3	0	2150	0
3	3	25.8	0	2650	0
3	3	28.2	11	3050	1
5	2	21	0	1850	0
3	1	26	14	2300	1
2	1	27.1	8	2950	1
3	3	25.2	1	2000	1
3	3	29	1	3000	1
5	3	24.7	0	2200	0
```

Tab: usually .tsv or .txt

```
2012>4>12>MIN>LAA>D.J. Reyburn
2012>4>12>SD>ARI>Marty Foster
2012>4>12>WSH>CIN>Mike Everitt
2012>4>12>PHI>MIA>Jeff Nelson
2012>4>12>CHC>MIL>Fieldin Culbreth
2012>4>12>LAD>PIT>Wally Bell
2012>4>12>TEX>SEA>Doug Eddings
2012>4>12>COL>SF>Ron Kulpa
2012>4>12>DET>TB>Mark Carlson
2012>4>13>NYY>LAA>Mike DiMuro
2012>4>13>COL>ARI>Mark Wegner
```

General: usually .txt or .dat

Reading Delimited Data

`baseR` `utils` package and `tidyverse` `readr` package function and purpose:

Type of Delimeter	`utils` Function	`readr` Function
Comma	`read.csv()`	`read_csv()`
Semicolon (`,` for decimal)	`read.csv2()`	`read_csv2()`
Tab	`read.delim()`	`read_tsv()`
General	`read.table(sep = "")`	`read_delim()`
White Space	`read.table(sep = "")`	`read_table()`

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Working Directory

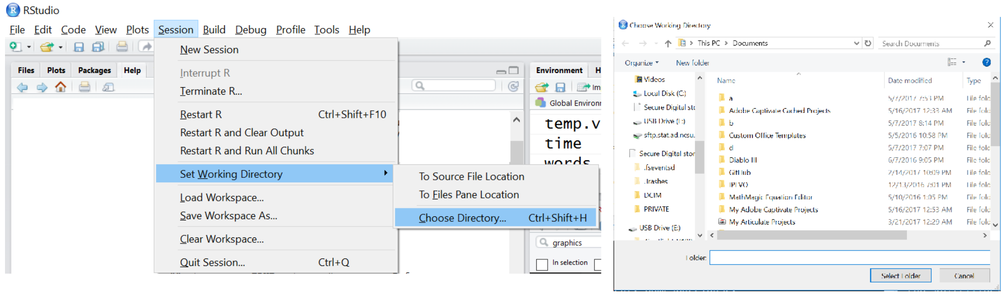
- Let's read in the 'neuralgia.csv' file
  - *csv* implies comma separated value (sometimes semi-colon)
- By default, R looks in the `working directory` for the file

```
getwd()
```

```
## [1] "C:/Users/jbpost2/repos/R4Reproducibility/slides"
```

Working Directory

- Can change *working directory* via code or menus




```r
setwd("C:/Users/jbpost2/repos/R4Reproducibility/datasets")
#or
setwd("C:\\Users\\jbpost2\\repos\\R4Reproducibility\\datasets")
```

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Reading a .csv File

Common arguments to `read_csv()`:

```
read_csv(
  file,
  col_names = TRUE,
  na = c("", "NA"),
  skip = 0,
  col_types = NULL,
  guess_max = min(1000, n_max),
)
```

Reading a .csv File

With `neuralgia.csv` file in the working directory:

```
neuralgiaData <- read_csv("neuralgia.csv")
```

```
neuralgiaData
```

```
## # A tibble: 60 x 5
##   Treatment Sex     Age Duration Pain
##   <chr>     <chr> <dbl>    <dbl> <chr>
## 1 P         F        68        1 No
## 2 B         M        74       16 No
## 3 P         F        67       30 No
## 4 P         M        66       26 Yes
## 5 B         F        67       28 No
## # ... with 55 more rows
```

Reading a .csv File

- Use full local path

```
neuralgiaData <- read_csv("C:/Users/jbpost2/repos/R4Reproducibility/slides/data/neuralgia.csv")
```

Reading a .csv File

- Use full local path

```
neuralgiaData <- read_csv("C:/Users/jbpost2/repos/R4Reproducibility/slides/data/neuralgia.csv")
```

- R can pull from URLs as well!

```
neuralgiaData <- read_csv("https://www4.stat.ncsu.edu/~online/datasets/neuralgia.csv")
neuralgiaData
```

```
## # A tibble: 60 x 5
##   Treatment Sex     Age Duration Pain
##   <chr>     <chr> <dbl>    <dbl> <chr>
## 1 P         F        68        1 No
## 2 B         M        74       16 No
## 3 P         F        67       30 No
## 4 P         M        66       26 Yes
## 5 B         F        67       28 No
## # ... with 55 more rows
```

tibbles

What kind of object does `read_csv()` create?

```
class(neuralgiaData)
```

```
## [1] "spec_tbl_df" "tbl_df"      "tbl"         "data.frame"
```

```
str(neuralgiaData)
```

```
## spec_tbl_df [60 x 5] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
##  $ Treatment: chr [1:60] "P" "B" "P" "P" ...
##  $ Sex      : chr [1:60] "F" "M" "F" "M" ...
##  $ Age      : num [1:60] 68 74 67 66 67 77 71 72 76 71 ...
##  $ Duration : num [1:60] 1 16 30 26 28 16 12 50 9 17 ...
##  $ Pain     : chr [1:60] "No" "No" "No" "Yes" ...
##  - attr(*, "spec")=
##   .. cols(
##   ..   Treatment = col_character(),
##   ..   Sex = col_character(),
##   ..   Age = col_double(),
##   ..   Duration = col_double(),
##   ..   Pain = col_character()
##   .. )
##  - attr(*, "problems")=<externalptr>
```

`tibbles`

- `tibbles` are the main object the tidyverse works with

`tibbles`

- `tibbles` are the main object the tidyverse works with
  - Fancy printing!
    - Checking column type is a basic data validation step

```
neuralgiaData
```

```
## # A tibble: 60 x 5
##   Treatment Sex     Age Duration Pain 
##   <chr>     <chr> <dbl>    <dbl> <chr>
## 1 P         F        68        1 No   
## 2 B         M        74       16 No   
## 3 P         F        67       30 No   
## 4 P         M        66       26 Yes  
## 5 B         F        67       28 No   
## # ... with 55 more rows
```

  - Behavior slightly different than a standard data frame. No simplification!

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tibbles

- `tibbles` do not simplify

```r
neuralgiaData[ ,1]
```

```
## # A tibble: 60 x 1
##   Treatment
##   <chr>
## 1 P
## 2 B
## 3 P
## 4 P
## 5 B
## # ... with 55 more rows
```

```r
neuralgiaData2 <- as.data.frame(neuralgiaData)
neuralgiaData2[ ,1]
```

```
##  [1] "P" "B" "P" "P" "B" "B" "A" "B" "B" "A" "A" "A" "B" "A" "P" "A" "P" "A
## [20] "B" "B" "A" "A" "A" "B" "P" "B" "B" "P" "P" "A" "A" "B" "B" "B" "A" "P
## [39] "B" "P" "P" "P" "A" "B" "A" "P" "P" "A" "B" "P" "P" "P" "B" "A" "P" "A
## [58] "A" "B" "A"
```

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tibbles

- Use either `dplyr::pull()` or `$` to return a vector

```
pull(neuralgiaData, Treatment) #or pull(neuralgiaData, 1)
```

```
##  [1] "P" "B" "P" "P" "B" "B" "A" "B" "B" "A" "A" "A" "B" "A" "P" "A" "P" "A" "P"
## [20] "B" "B" "A" "A" "A" "B" "P" "B" "B" "P" "P" "A" "A" "B" "B" "B" "A" "P" "B"
## [39] "B" "P" "P" "P" "A" "B" "A" "P" "P" "A" "B" "P" "P" "P" "B" "A" "P" "A" "P"
## [58] "A" "B" "A"
```

```
neuralgiaData$Treatment
```

```
##  [1] "P" "B" "P" "P" "B" "B" "A" "B" "B" "A" "A" "A" "B" "A" "P" "A" "P" "A" "P"
## [20] "B" "B" "A" "A" "A" "B" "P" "B" "B" "P" "P" "A" "A" "B" "B" "B" "A" "P" "B"
## [39] "B" "P" "P" "P" "A" "B" "A" "P" "P" "A" "B" "P" "P" "P" "B" "A" "P" "A" "P"
## [58] "A" "B" "A"
```

Reading Delimited Data with `readr`

- Reading *clean* delimited data pretty easy with the tidyverse!

Type of Delimeter	`readr` Function
Comma	`read_csv()`
Semicolon (`,` for decimal)	`read_csv2()`
Tab	`read_tsv()`
General	`read_delim()`
White Space	`read_table()`

- Let's read in the 'chemical.txt' file (space delimited) with `read_table()`
- Common arguments to `read_table()` are the same as `read_csv()`

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Reading Space Delimited Dtaa

- Let's read in the 'chemical.txt' file (space delimited) with `read_table()`

```
read_table("https://www4.stat.ncsu.edu/~online/datasets/chemical.txt")
```

```
## # A tibble: 19 x 4
##     temp  conc  time percent
##    <dbl> <dbl> <dbl>   <dbl>
##  1   -1    -1    -1     45.9
##  2    1    -1    -1     60.6
##  3   -1     1    -1     57.5
##  4    1     1    -1     58.6
##  5   -1    -1     1     53.3
##  6    1    -1     1     58
##  7   -1     1     1     58.8
##  8    1     1     1     52.4
##  9   -2     0     0     46.9
## 10    2     0     0     55.4
## 11    0    -2     0     55
## 12    0     2     0     57.5
## 13    0     0    -2     56.3
## 14    0     0     2     58.9
## 15    0     0     0     56.9
## 16    2    -3     0     61.1
## 17    2    -3     0     62.9
```

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Reading Tab Delimited Data

- Let's read in the 'crabs.txt' file (tab delimited) with `read_tsv()`

```
read_tsv("https://www4.stat.ncsu.edu/~online/datasets/crabs.txt")
```

```
## # A tibble: 173 x 6
##   color spine width satell weight     y
##   <dbl> <dbl> <dbl>  <dbl>  <dbl> <dbl>
## 1     3     3  28.3      8   3050     1
## 2     4     3  22.5      0   1550     0
## 3     2     1  26        9   2300     1
## 4     4     3  24.8      0   2100     0
## 5     4     3  26        4   2600     1
## # ... with 168 more rows
```

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Reading Generic Delimted Data

- Let's read in the 'umps2012.txt' file ('>' delimited) with `read_delim()`
    - `read_delim()` requires a `delim` argument

Reading Generic Delimted Data

- Let's read in the 'umps2012.txt' file ('>' delimited) with `read_delim()`
    - `read_delim()` requires a `delim` argument
- In umps20212.txt data file, no column names provided!
    - Use `col_names` argument: Either TRUE, FALSE or a character vector of column names.
    - When specifying a character vector, `read_delim()` automatically starts reading first row of data

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Reading Generic Delimted Data

- Let's read in the 'umps2012.txt' file ('>' delimited) with `read_delim()`

```
read_delim("https://www4.stat.ncsu.edu/~online/datasets/umps2012.txt",
           delim = ">",
           col_names = c("Year", "Month", "Day", "Home", "Away", "HPUmpire"))
```

```
## # A tibble: 2,359 x 6
##    Year Month   Day Home  Away  HPUmpire
##   <dbl> <dbl> <dbl> <chr> <chr> <chr>
## 1  2012     4    12 MIN   LAA   D.J. Reyburn
## 2  2012     4    12 SD    ARI   Marty Foster
## 3  2012     4    12 WSH   CIN   Mike Everitt
## 4  2012     4    12 PHI   MIA   Jeff Nelson
## 5  2012     4    12 CHC   MIL   Fieldin Culbreth
## # ... with 2,354 more rows
```

Reading Fixed Field & Tricky Non-Standard Data

- read_fwf()
  - reads in raw data where entries are very structured
- read_file()
  - reads an entire file into a single string
- read_lines()
  - reads a file into a character vector with one element per line
- Usually parse the last two with `regular expressions` :(

Recap!

Type of Delimeter	`readr` Function
Comma	`read_csv()`
Semicolon (`,` for decimal)	`read_csv2()`
Tab	`read_tsv()`
General	`read_delim()`
White Space	`read_table()`

Common arguments: `file,`
`col_names = TRUE,`
`na = c("", "NA"),`
`skip = 0,`
`col_types = NULL,`
`guess_max = min(1000, n_max),`

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Excel Data

Excel data refers to a `.xls` or `.xlsx` file

- `readxl` package does not load with `tidyverse` but is part of it!

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Excel Data

Excel data refers to a `.xls` or `.xlsx` file

- `readxl` package does not load with `tidyverse` but is part of it!
- `read_excel()` function can read both types of excel data files
  - Can't pull from web though!
- Read in censusEd.xlsx

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`read_excel()`

```r
#install package if necessary
library(readxl)
```

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read_excel()

```r
#install package if necessary
library(readxl)
#reads first sheet by default
edData <- read_excel("censusEd.xlsx")
```

```r
edData
```

```
## # A tibble: 3,198 x 42
##   Area_name     STCOU EDU010187F EDU010187D EDU010187N1 EDU010187N2 EDU010188F
##   <chr>         <chr>      <dbl>      <dbl> <chr>       <chr>            <dbl>
## 1 UNITED STATES 00000          0   40024299 0000        0000                 0
## 2 ALABAMA       01000          0     733735 0000        0000                 0
## 3 Autauga, AL   01001          0       6829 0000        0000                 0
## 4 Baldwin, AL   01003          0      16417 0000        0000                 0
## 5 Barbour, AL   01005          0       5071 0000        0000                 0
## # ... with 3,193 more rows, and 35 more variables: EDU010188D <dbl>,
## #   EDU010188N1 <chr>, EDU010188N2 <chr>, EDU010189F <dbl>, EDU010189D <dbl>,
## #   EDU010189N1 <chr>, EDU010189N2 <chr>, EDU010190F <dbl>, EDU010190D <dbl>,
## #   EDU010190N1 <chr>, EDU010190N2 <chr>, EDU010191F <dbl>, EDU010191D <dbl>,
## #   EDU010191N1 <chr>, EDU010191N2 <chr>, EDU010192F <dbl>, EDU010192D <dbl>,
## #   EDU010192N1 <chr>, EDU010192N2 <chr>, EDU010193F <dbl>, EDU010193D <dbl>,
## #   EDU010193N1 <chr>, EDU010193N2 <chr>, EDU010194F <dbl>, ...
```

Dealing with Excel Sheets

- Can look at sheets available with `excel_sheets()`

```r
excel_sheets("censusEd.xlsx")
```

```
##  [1] "EDU01A" "EDU01B" "EDU01C" "EDU01D" "EDU01E" "EDU01F" "EDU01G" "EDU01H"
##  [9] "EDU01I" "EDU01J"
```

- Specify sheet with name or integers (or `NULL` for 1st) using `sheet =`

```r
read_excel("censusEd.xlsx", sheet = "EDU01D")
```

```
## # A tibble: 3,198 x 42
##   Area_name     STCOU EDU264190F EDU264190D EDU264190N1 EDU264190N2 EDU280190F
##   <chr>         <chr>      <dbl>      <dbl> <chr>       <chr>            <dbl>
## 1 UNITED STATES 00000          0    4187099 0000        0000                 0
## 2 ALABAMA       01000          0      57284 0000        0000                 0
## 3 Autauga, AL   01001          0        604 0000        0000                 0
## 4 Baldwin, AL   01003          0       1761 0000        0000                 0
## 5 Barbour, AL   01005          0        466 0000        0000                 0
## # ... with 3,193 more rows, and 35 more variables: EDU280190D <dbl>,
## #   EDU280190N1 <chr>, EDU280190N2 <chr>, EDU282190F <dbl>, EDU282190D <dbl>,
## #   EDU282190N1 <chr>, EDU282190N2 <chr>, EDU284190F <dbl>, EDU284190D <dbl>,
## #   EDU284190N1 <chr>, EDU284190N2 <chr>, EDU299190F <dbl>, EDU299190D <dbl>,
                                     90N2 <chr>, EDU300200F <dbl>, EDU300200D <dbl>,
                                     00N2 <chr>, EDU310200F <dbl>, EDU310200D <dbl>,
                                     00N2 <chr>, EDU312200F <dbl>, ...
```

SAS Data

SAS data refers to a `.sas7bdat` file

- `haven` package does not load with `tidyverse` but is part of it!

SAS Data

SAS data refers to a `.sas7bdat` file

- `haven` package does not load with `tidyverse` but is part of it!
- `read_sas()` basically just needs the path to the SAS data set
- Read in smoke2003.sas7bdat

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read_sas()

```r
#install if necessary
library(haven)
```

read_sas()

```r
#install if necessary
library(haven)
smokeData <- read_sas("https://www4.stat.ncsu.edu/~online/datasets/smoke2003.sas7bdat")
smokeData
```

```
## # A tibble: 443 x 54
##    SEQN SDDSRVYR RIDSTATR RIDEXMON RIAGENDR RIDAGEYR RIDAGEMN RIDAGEEX RIDRETH1
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1 21010        3        2        2        2       52      633      634        3
## 2 21012        3        2        2        1       63      765      766        4
## 3 21048        3        2        1        2       42      504      504        1
## 4 21084        3        2        1        2       57      692      693        3
## 5 21093        3        2        1        2       64      778      778        2
## # ... with 438 more rows, and 45 more variables: RIDRETH2 <dbl>,
## #   DMQMILIT <dbl>, DMDBORN <dbl>, DMDCITZN <dbl>, DMDYRSUS <dbl>,
## #   DMDEDUC3 <dbl>, DMDEDUC2 <dbl>, DMDEDUC <dbl>, DMDSCHOL <dbl>,
## #   DMDMARTL <dbl>, DMDHHSIZ <dbl>, INDHHINC <dbl>, INDFMINC <dbl>,
## #   INDFMPIR <dbl>, RIDEXPRG <dbl>, DMDHRGND <dbl>, DMDHRAGE <dbl>,
## #   DMDHRBRN <dbl>, DMDHREDU <dbl>, DMDHRMAR <dbl>, DMDHSEDU <dbl>,
## #   SIALANG <dbl>, SIAPROXY <dbl>, SIAINTRP <dbl>, FIALANG <dbl>, ...
```

- haven can also read SPSS data and others

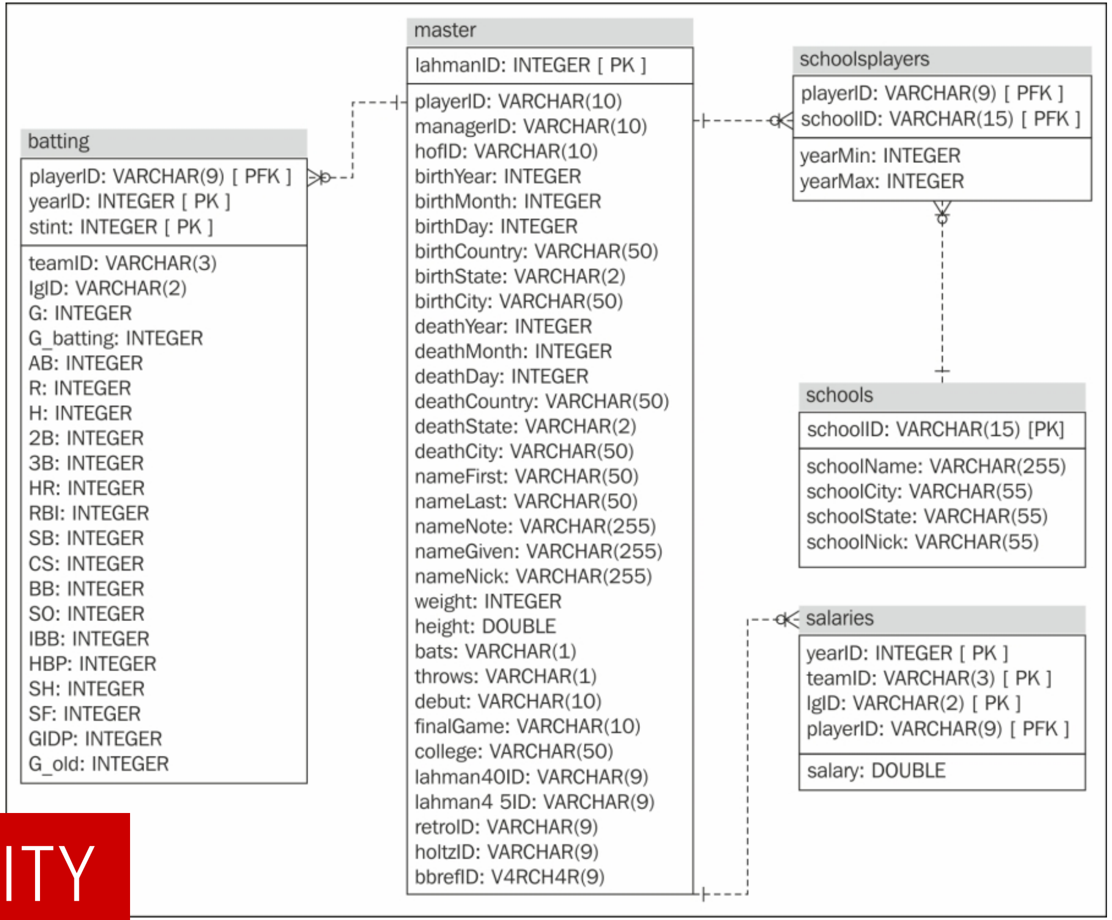
Other Data Sources

JSON - JavaScript Object Notation

- Used widely across the internet and databases
- Can represent usual 2D data or heirarchical data
- `tidyjson` package

Other Data Sources

Databases - Collection of data, often many related 2D tables



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Databases - Common flow in R

1. Connect to the database with `DBI::dbConnect()`
    - Need appropriate R package for database backend. Ex:
        - `RSQLite::SQLite()` for RSQLite
        - `RMySQL::MySQL()` for RMySQL

```
con <- DBI::dbConnect(
  RMySQL::MySQL(),
  host = "hostname.website",
  user = "username",
  password = rstudioapi::askForPassword("DB password")
)
```

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Databases - Common flow in R

1. Connect to the database with `DBI::dbConnect()`
    - Need appropriate R package for database backend
2. Use `tbl()` to reference a table in the database

```
tbl(con, "name_of_table")
```

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Databases - Common flow in R

1. Connect to the database with `DBI::dbConnect()`
    - Need appropriate R package for database backend
2. Use `tbl()` to reference a table in the database
3. Query the database with `SQL` or `dplyr/dbplyr`

Databases - Common flow in R

1. Connect to the database with `DBI::dbConnect()`
    - Need appropriate R package for database backend
2. Use `tbl()` to reference a table in the database
3. Query the database with `SQL` or `dplyr/dbplyr`
4. Disconnect from database with `dbDisconnect()`

More about R Studio and Databases

Connect to `chinook` Database

- `chinook` database is a commonly used intro database
  - `sqlite` backend

```r
library(DBI)
con <- dbConnect(
  RSQLite::SQLite(),
  "data/chinook.db"
)
dbListTables(con)
```

```
##  [1] "albums"          "artists"         "customers"       "employees"
##  [5] "genres"          "invoice_items"   "invoices"        "media_types"
##  [9] "playlist_track"  "playlists"       "sqlite_sequence" "sqlite_stat1"
## [13] "tracks"
```

Connect to `chinook` Database

- `chinook` database is a commonly used intro database

```
dbGetQuery(con, "SELECT * FROM invoices") %>%
  collect() %>%
  as_tibble()
```

```
## # A tibble: 412 x 9
##   InvoiceId CustomerId InvoiceDate       BillingAddress BillingCity BillingState
##       <int>      <int> <chr>             <chr>          <chr>       <chr>
## 1         1          2 2009-01-01 00:00~ Theodor-Heuss~ Stuttgart   <NA>
## 2         2          4 2009-01-02 00:00~ Ullevålsveien~ Oslo        <NA>
## 3         3          8 2009-01-03 00:00~ Grétrystraat ~ Brussels    <NA>
## 4         4         14 2009-01-06 00:00~ 8210 111 ST NW Edmonton    AB
## 5         5         23 2009-01-11 00:00~ 69 Salem Stre~ Boston      MA
## # ... with 407 more rows, and 3 more variables: BillingCountry <chr>,
## #   BillingPostalCode <chr>, Total <dbl>
```

Big Recap!

Dimension	Homogeneous	Heterogeneous
1d	Atomic Vector	List
2d	Matrix	Data Frame
nd	Array	

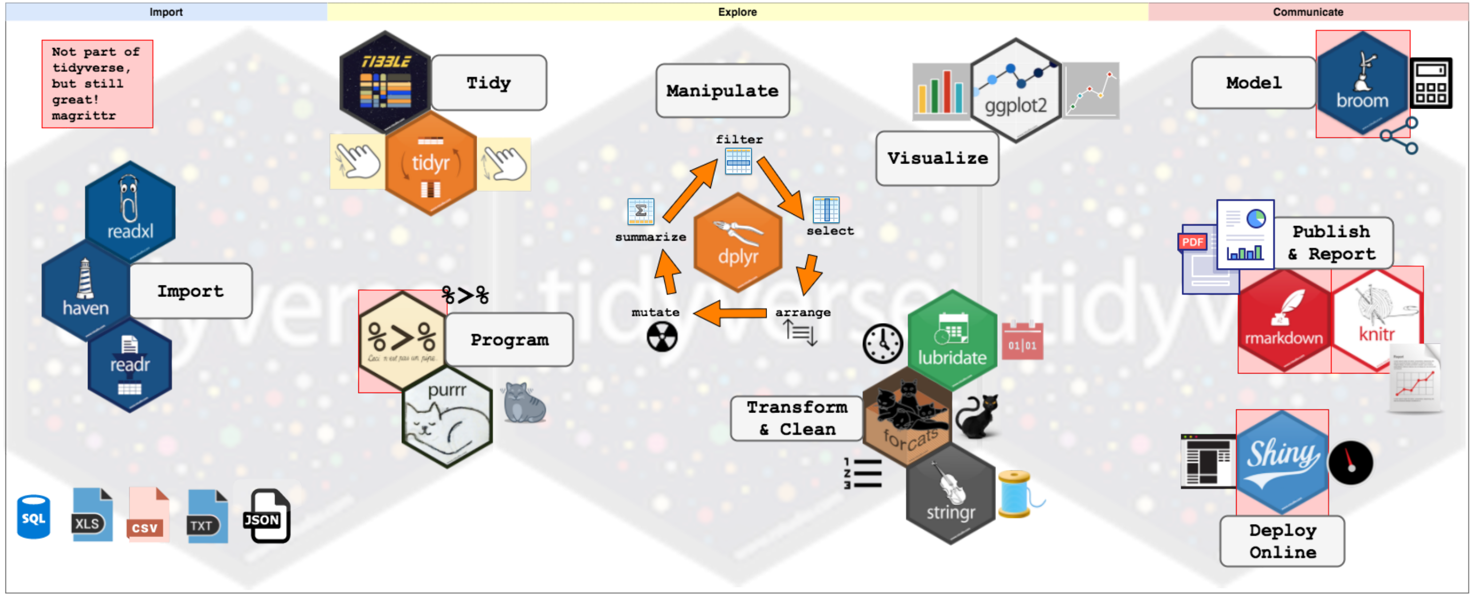
Basic access via

- Atomic vectors - `x[ ]`
- Data Frames - `x[ , ]` or `x$name`
- Lists - `x[ ]`, `x[[ ]]`, or `x$name`

Big Recap!

`tidyverse` - nice ecosystem of packages with similar behavior and syntax

- `readr`, `haven`, `readxl` all read the data into a tibble
- Good defaults that do the work for you



Let's Practice

We'll add to our `.Rmd` file from the previous activity

- Download the prompts to add to our markdown document here

Guidance:

- Copy and paste the text from above into the bottom of the document, reknit
- Add to the code chunks, evaluating in the notebook
- Reknit occasionally to check the output

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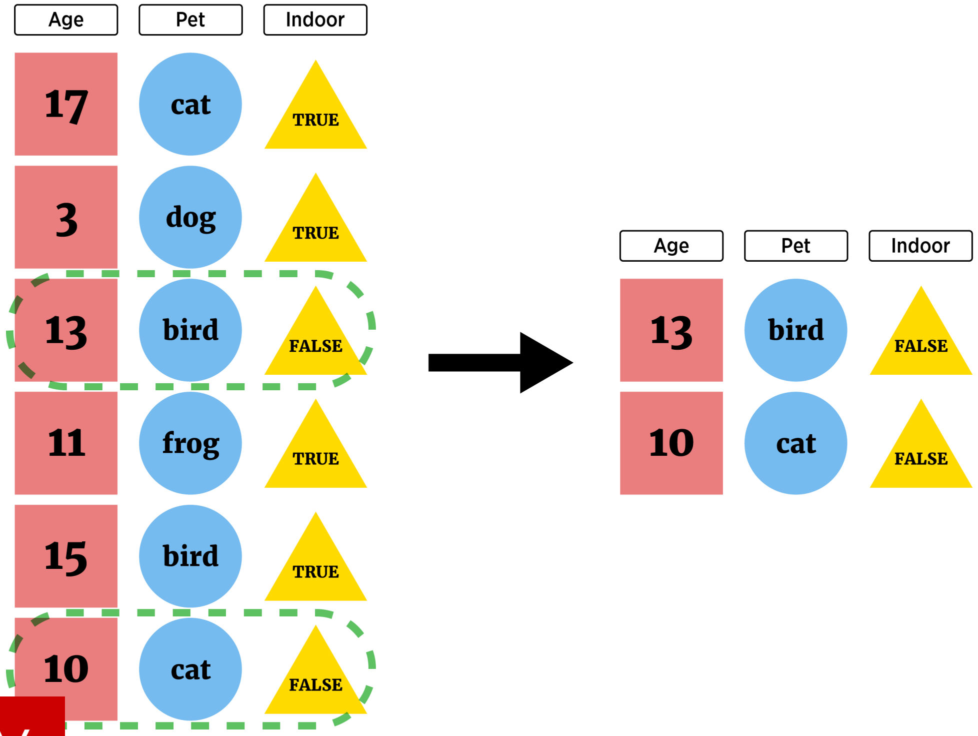
Data Manipulations with `dplyr`

Justin Post

Data Manipulation Ideas

We may want to subset our full data set or create new variables (columns)

- Grab only certain types of observations (**filter** rows)



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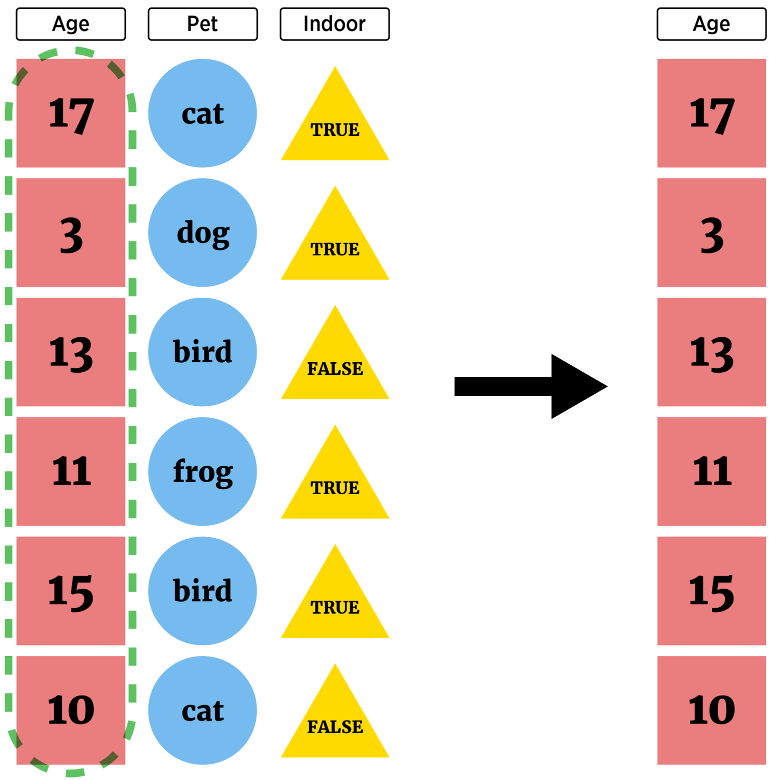
Data Manipulation Ideas

We may want to subset our full data set or create new variables (columns)

- Look at only certain variables (**select** columns)



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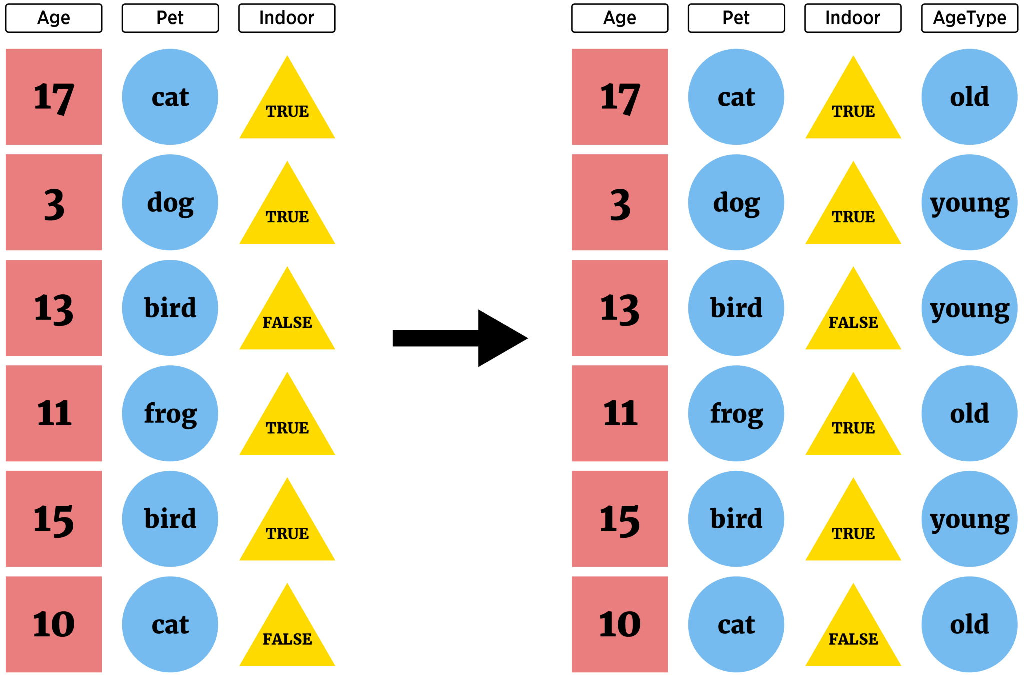
Data Manipulation Ideas

We may want to subset our full data set or create new variables (columns)

- Create new variables (**mutate** columns)



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`tidyverse`

`tidyverse` provides a coherent ecosystem for these tasks via the `dplyr` package! Cheat Sheet

- Functions take in a `tibble` (special data frames)
- Functions output a `tibble`
- All functions have similar syntax!
  `function(tibble, actions, ...)`
- Chaining makes for readable code: `tibble %>% function(actions)`

`dplyr`

- Commonly used functions:
  - `as_tibble()` - convert data frame to one with better printing

`dplyr`

- Commonly used functions:
  - `as_tibble()` - convert data frame to one with better printing
  - `filter()` - subset **rows**
  - `arrange()` - reorder **rows**

`dplyr`

- Commonly used functions:
    - `as_tibble()` - convert data frame to one with better printing
    - `filter()` - subset **rows**
    - `arrange()` - reorder **rows**
    - `select()` - subset **columns**
    - `rename()` - rename **columns**
    - `mutate()` - add newly created **column**

`dplyr`

- Commonly used functions:
    - `as_tibble()` - convert data frame to one with better printing
    - `filter()` - subset **rows**
    - `arrange()` - reorder **rows**
    - `select()` - subset **columns**
    - `rename()` - rename **columns**
    - `mutate()` - add newly created **column**
    - `group_by()` - group **rows** by a variable or variables
    - `if_else()` - conditional execution of code

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`as_tibble()` - A Tidy Data Frame

Want to work on `tibbles`, not just `data frames`

- `as_tibble()` - converts a data frame to one with better printing and no simplification

```
#install.packages("Lahman")
library(Lahman)
head(Batting, n = 4) #look at just first 4 observations
```

```
##    playerID yearID stint teamID lgID  G  AB  R  H X2B X3B HR RBI SB CS BB SO
## 1 abercda01   1871     1    TRO   NA  1   4  0  0   0   0  0   0  0  0  0  0
## 2  addybo01   1871     1    RC1   NA 25 118 30 32   6   0  0  13  8  1  4  0
## 3 allisar01   1871     1    CL1   NA 29 137 28 40   4   5  0  19  3  1  2  5
## 4 allisdo01   1871     1    WS3   NA 27 133 28 44  10   2  2  27  1  1  0  2
##   IBB HBP SH SF GIDP
## 1  NA  NA NA NA    0
## 2  NA  NA NA NA    0
## 3  NA  NA NA NA    1
## 4  NA  NA NA NA    0
```

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`as_tibble()` - A Tidy Data Frame

- Can 'wrap' a standard R data frame to convert it to a `tibble`

```
myBatting <- as_tibble(Batting)
myBatting
```

```
## # A tibble: 108,789 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 abercda01   1871     1 TRO    NA        1     4     0     0     0     0     0
## 2 addybo01    1871     1 RC1    NA       25   118    30    32     6     0     0
## 3 allisar01   1871     1 CL1    NA       29   137    28    40     4     5     0
## 4 allisdo01   1871     1 WS3    NA       27   133    28    44    10     2     2
## 5 ansonca01   1871     1 RC1    NA       25   120    29    39    11     3     0
## # ... with 108,784 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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Filtering Rows Requires Logical Conditions

- **logical statement** - comparison that resolves as `TRUE` or `FALSE`

```r
"hi" == " hi" #== is comparison
```

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

```r
"hi" == "hi"
```

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

```r
4 >= 1
```

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

```r
4 != 1
```

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

```r
sqrt(3)^2  == 3
```

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

```r
dplyr::near(sqrt(3)^2, 3)
```

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

Filtering Rows Requires Logical Conditions

- **logical statement** - comparison that resolves as `TRUE` or `FALSE`

```r
#use of is. functions
is.numeric("Word")
```

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

```r
is.numeric(10)
```

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

```r
is.character("10")
```

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

```r
is.na(c(1:2, NA, 3))
```

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

```r
is.matrix(c("hello", "world"))
```

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

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Filtering Rows

- Concept:
  - Feed an *indexing* vector of `TRUE`/`FALSE` values
  - R returns elements where `TRUE`

```r
myBatting$G > 20 #vector indicating Games > 20
```

```
##     [1] FALSE  TRUE  TRUE  TRUE  TRUE FALSE FALSE  TRUE FALSE FALSE  TRUE FALSE
##    [13] FALSE FALSE FALSE  TRUE FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE FALSE
##    [25] FALSE FALSE  TRUE FALSE FALSE  TRUE  TRUE FALSE FALSE  TRUE  TRUE FALSE
##    [37]  TRUE  TRUE  TRUE FALSE  TRUE  TRUE FALSE FALSE  TRUE FALSE  TRUE FALSE
##    [49]  TRUE  TRUE FALSE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE FALSE FALSE FALSE
##    [61]  TRUE FALSE  TRUE FALSE FALSE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE FALSE
##    [73]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE FALSE  TRUE  TRUE  TRUE FALSE
##    [85]  TRUE  TRUE  TRUE FALSE FALSE FALSE  TRUE  TRUE FALSE  TRUE FALSE  TRUE
##    [97]  TRUE FALSE  TRUE  TRUE FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE FALSE
##   [109] FALSE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE FALSE  TRUE FALSE FALSE  TRUE
##   [121] FALSE  TRUE FALSE  TRUE  TRUE FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE
##   [133]  TRUE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE  TRUE FALSE  TRUE
##   [145] FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE
##   [157] FALSE FALSE  TRUE  TRUE FALSE  TRUE  TRUE FALSE FALSE FALSE FALSE  TRUE
##   [169] FALSE  TRUE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE FALSE  TRUE
##   [181] FALSE  TRUE FALSE  TRUE FALSE  TRUE FALSE FALSE  TRUE FALSE FALSE FALSE
##   [193] FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE  TRUE
                                   E FALSE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE
                                   E  TRUE FALSE FALSE  TRUE FALSE FALSE  TRUE FALSE
                                   E FALSE  TRUE  TRUE FALSE  TRUE  TRUE FALSE  TRUE
##   [241] FALSE  TRUE  TRUE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE  TRUE FALSE
```

`filter()` - Subset Rows

- Return observations where myBatting$G is greater than 20

```
filter(myBatting, G > 20)
```

```
## # A tibble: 70,926 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 addybo01    1871     1 RC1    NA       25   118    30    32     6     0     0
## 2 allisar01   1871     1 CL1    NA       29   137    28    40     4     5     0
## 3 allisdo01   1871     1 WS3    NA       27   133    28    44    10     2     2
## 4 ansonca01   1871     1 RC1    NA       25   120    29    39    11     3     0
## 5 barnero01   1871     1 BS1    NA       31   157    66    63    10     9     0
## # ... with 70,921 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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Compound Logical Operators

- `&` 'and'
- `|` 'or'

Operator	A,B both true	A true, B false	A,B both false
`and`	TRUE	FALSE	FALSE
`or`	TRUE	TRUE	FALSE

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Logical statements

- Condition on those that played more than 20 games and played in 2015

```
(myBatting$G > 20) & (myBatting$yearID == 2015)
```

```
##     [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [85] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##    [97] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [109] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [121] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [133] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [145] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [157] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [169] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [181] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [193] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [205] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [217] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [229] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
                                E FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
                                E FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
                                E FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [277] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

`filter()` - Subset Rows

- Pull out those that played more than 20 games and played in 2015

```
filter(myBatting, (G > 20) & (yearID == 2015))
```

```
## # A tibble: 949 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 aardsda01   2015     1 ATL    NL       33     1     0     0     0     0     0
## 2 abadfe01    2015     1 OAK    AL       62     0     0     0     0     0     0
## 3 abreujo02   2015     1 CHA    AL      154   613    88   178    34     3    30
## 4 ackledu01   2015     1 SEA    AL       85   186    22    40     8     1     6
## 5 ackledu01   2015     2 NYA    AL       23    52     6    15     3     2     4
## # ... with 944 more rows, and 10 more variables: RBI <int>, SB <int>, CS <int>,
## #   BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>, GIDP <int>
```

`filter()` - Subset Rows

- `%in%` to choose any observations matching a vector

```
filter(myBatting, teamID %in% c("ATL", "PIT", "WSH"))
```

```
## # A tibble: 7,236 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 barklsa01   1887     1 PIT    NL       89   340    44    76    10     4     1
## 2 beeched01   1887     1 PIT    NL       41   169    15    41     8     0     2
## 3 bishobi01   1887     1 PIT    NL        3     9     0     0     0     0     0
## 4 brownto01   1887     1 PIT    NL       47   192    30    47     3     4     0
## 5 carrofr01   1887     1 PIT    NL      102   421    71   138    24    15     6
## # ... with 7,231 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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`arrange()` - Reorder Rows

- Other major observation (row) manipulation is to reorder the observations (rows)

```
arrange(myBatting, teamID)
```

```
## # A tibble: 108,789 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 berrych01   1884     1 ALT    UA        7    25     2     6     0     0     0
## 2 brownji01   1884     1 ALT    UA       21    88    12    22     2     2     1
## 3 carropa01   1884     1 ALT    UA       11    49     4    13     1     0     0
## 4 connojo01   1884     1 ALT    UA        3    11     0     1     0     0     0
## 5 crosscl01   1884     1 ALT    UA        2     7     1     4     1     0     0
## # ... with 108,784 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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`arrange()` - Reorder Rows

- Can obtain a secondary arrangement

```
arrange(myBatting, teamID, G)
```

```
## # A tibble: 108,789 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 daisege01   1884     1 ALT    UA        1     4     0     0     0     0     0
## 2 crosscl01   1884     1 ALT    UA        2     7     1     4     1     0     0
## 3 manloch01   1884     1 ALT    UA        2     7     1     3     0     0     0
## 4 connojo01   1884     1 ALT    UA        3    11     0     1     0     0     0
## 5 shafff01    1884     1 ALT    UA        6    19     1     3     0     0     0
## # ... with 108,784 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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`arrange()` - Reorder Rows

- Can reorder descending on a variable

```
arrange(myBatting, teamID, desc(G))
```

```
## # A tibble: 108,789 x 22
##   playerID  yearID stint teamID lgID      G    AB     R     H   X2B   X3B    HR
##   <chr>      <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int> <int>
## 1 smithge01   1884     1 ALT    UA       25   108     9    34     8     1     0
## 2 harrifr01   1884     1 ALT    UA       24    95    10    25     2     1     0
## 3 doughch01   1884     1 ALT    UA       23    85     6    22     5     0     0
## 4 murphjo01   1884     1 ALT    UA       23    94    10    14     1     0     0
## 5 brownji01   1884     1 ALT    UA       21    88    12    22     2     2     1
## # ... with 108,784 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

Recap!

- `dplyr` allows for easy row manipulations
    - `as_tibble()`
    - `filter()`
    - `arrange()`
- `dplyr` and `tidyr` Cheat Sheet

`select()` - Subset Columns

- To return a single (probably simplified) column:
  - `dplyr::pull()`
  - `$`
  - `[ , ]`

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`select()` - Subset Columns

- To return a single (probably simplified) column:
    - `dplyr::pull()`
    - `$`
    - `[ , ]`

```r
library(Lahman)
library(dplyr)
myBatting <- as_tibble(Batting)
pull(Batting, X2B)
```

```
##     [1]  0  6  4 10 11  2  0 10  1  2  1  0  0  0  9  3  0  0  1  0  2  3  4  0
##    [25]  2  2  8  3  0  8  7  0  1  5  7  0  6  3  8  0  5  6  3  1  9  1  3  1
##    [49]  9  3  0  4  6  3  4  3  4  5  1  1  1  1 10  1  3  8  7  7  3  8  3  0
##    [73]  4  0  9  9  4  6  0  0  2  2  5  0 10  5  6  0  1  0  7  7  0  7  3  5
##    [97]  6  2 10  5  0  4  3  1  7  7  6  2  0  6 10  7  5  5  3  3  2  4  0  4
##   [121]  2 10  0  1 28  1  0  1  1  2 11  4  3  0  0  3  5  4  6  3  0  7  0  3
##   [145]  0  0  7  1  7  0  4  1  3  9 10  4  0  1 20  3  3 10 13  1  0  0  1 11
##   [169]  2  1  0  3  1  0  0  2  9 17  0  4  3 15  0 12  0 10  1  3  5  1  1  1
##   [193]  0  0  0  1  0  0  8  1  7  0  0  9  5  0  0  2  1  2  3  6  5  3  0  0
##   [217]  3  9  6 10 10  0  0 14  0  0  1  0  5  0  5  0  1  2 15  0 13  0  0  3
##   [241]  0  7 10  2  0  5  2  2 12  0  5  1  0  6  1  0  2  4  7  1  2  0  1 11
                                       0  1  6  2  6  0  9  0  3  0 31  0  0  9 12  2  3
                                       0  2 18 10  2  0  9  5  5  5  4  2  0 13  0  1  3
                                       3  9  0  0  6  4  5  1  5  6  4  2  1  0  0  0  0
##   [337]  0  0  0 13  0  5 11  4  1  3  7  0  8  7  5 14 20  2  4  1 21  9  6  0
```

`select()` - Subset Columns

- `select()` function has same syntax as other `dplyr` functions:

`function(tibble, actions, ...)`

`select()` - Subset Columns

- `select()` function has same syntax as other `dplyr` functions:

`function(tibble, actions, ...)`

```
select(myBatting, X2B)
```

```
## # A tibble: 108,789 x 1
##      X2B
##    <int>
## 1      0
## 2      6
## 3      4
## 4     10
## 5     11
## # ... with 108,784 more rows
```

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`select()` - Subset Columns

- `select()` function has same syntax as other `dplyr` functions:

`function(tibble, actions, ...)`

```
select(myBatting, playerID, X2B)
```

```
## # A tibble: 108,789 x 2
##   playerID    X2B
##   <chr>     <int>
## 1 abercda01     0
## 2 addybo01      6
## 3 allisar01     4
## 4 allisdo01    10
## 5 ansonca01    11
## # ... with 108,784 more rows
```

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Piping or Chaining

- When applying multiple functions, reading the code can be difficult!

```
arrange(select(filter(myBatting, teamID == "PIT"), playerID, G, X2B), desc(X2B))
```

```
## # A tibble: 4,920 x 3
##   playerID      G   X2B
##   <chr>     <int> <int>
## 1 wanerpa01   154    62
## 2 wanerpa01   148    53
## 3 sanchfr01   157    53
## 4 wanerpa01   152    50
## 5 comorad01   152    47
## # ... with 4,915 more rows
```

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Piping or Chaining

- Piping or Chaining with `%>%` operator helps make code more readable

```
myBatting %>%
  filter(teamID == "PIT") %>%
  select(playerID, G, X2B) %>%
  arrange(desc(X2B))
```

```
## # A tibble: 4,920 x 3
##   playerID      G   X2B
##   <chr>     <int> <int>
## 1 wanerpa01   154    62
## 2 wanerpa01   148    53
## 3 sanchfr01   157    53
## 4 wanerpa01   152    50
## 5 comorad01   152    47
## # ... with 4,915 more rows
```

- Read `%>%` as 'then'

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Piping or Chaining

- Generically, `%>%` does the following

`x %>% f(y)` turns into `f(x,y)`

`x %>% f(y) %>% g(z)` turns into `g(f(x, y), z)`

Piping or Chaining

- Generically, `%>%` does the following

`x %>% f(y)` turns into `f(x,y)`

`x %>% f(y) %>% g(z)` turns into `g(f(x, y), z)`

- As `tidyverse` function generally have the same syntax:

`function(tibble, actions, ...)`

and they usually return a tibble, they all work great together!

- Can be used with functions outside the tidyverse if this structure works!

`select()` - Subset Columns

- Great functionality for choosing variables
    - All columns between

```
#all columns between
myBatting %>%
  select(X2B:HR)
```

```
## # A tibble: 108,789 x 3
##     X2B   X3B    HR
##   <int> <int> <int>
## 1     0     0     0
## 2     6     0     0
## 3     4     5     0
## 4    10     2     2
## 5    11     3     0
## # ... with 108,784 more rows
```

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`select()` - Subset Columns

- Great functionality for choosing variables
    - All columns containing

```
myBatting %>%
  select(contains("X"))
```

```
## # A tibble: 108,789 x 2
##      X2B   X3B
##    <int> <int>
## 1      0     0
## 2      6     0
## 3      4     5
## 4     10     2
## 5     11     3
## # ... with 108,784 more rows
```

`select()` - Subset Columns

- Great functionality for choosing variables
    - All columns starting with

```
myBatting %>%
  select(starts_with("X"))
```

```
## # A tibble: 108,789 x 2
##      X2B   X3B
##    <int> <int>
## 1      0     0
## 2      6     0
## 3      4     5
## 4     10     2
## 5     11     3
## # ... with 108,784 more rows
```

`select()` - Subset Columns

- Great functionality for choosing variables
    - Combinations of operators

```
myBatting %>%
  select(starts_with("X"), ends_with("ID"), G)
```

```
## # A tibble: 108,789 x 7
##      X2B   X3B playerID  yearID teamID lgID      G
##    <int> <int> <chr>      <int> <fct>  <fct> <int>
## 1      0     0 abercda01   1871 TRO    NA        1
## 2      6     0 addybo01    1871 RC1    NA       25
## 3      4     5 allisar01   1871 CL1    NA       29
## 4     10     2 allisdo01   1871 WS3    NA       27
## 5     11     3 ansonca01   1871 RC1    NA       25
## # ... with 108,784 more rows
```

`select()` - Subset Columns

- Can reorder variables with `everything()`

```
myBatting %>%
  select(playerID, HR, everything())
```

```
## # A tibble: 108,789 x 22
##   playerID     HR yearID stint teamID lgID      G    AB     R     H   X2B   X3B
##   <chr>     <int>  <int> <int> <fct>  <fct> <int> <int> <int> <int> <int> <int>
## 1 abercda01     0   1871     1 TRO    NA        1     4     0     0     0     0
## 2 addybo01      0   1871     1 RC1    NA       25   118    30    32     6     0
## 3 allisar01     0   1871     1 CL1    NA       29   137    28    40     4     5
## 4 allisdo01     2   1871     1 WS3    NA       27   133    28    44    10     2
## 5 ansonca01     0   1871     1 RC1    NA       25   120    29    39    11     3
## # ... with 108,784 more rows, and 10 more variables: RBI <int>, SB <int>,
## #   CS <int>, BB <int>, SO <int>, IBB <int>, HBP <int>, SH <int>, SF <int>,
## #   GIDP <int>
```

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`rename()` - Rename Columns

- Easy to rename multple columns (variables) at once

```
myBatting %>%
  select(starts_with("X"), ends_with("ID"), G) %>%
  rename("Doubles" = X2B, "Triples" = X3B)
```

```
## # A tibble: 108,789 x 7
##   Doubles Triples playerID  yearID teamID lgID      G
##     <int>   <int> <chr>      <int> <fct>  <fct> <int>
## 1       0       0 abercda01   1871 TRO    NA        1
## 2       6       0 addybo01    1871 RC1    NA       25
## 3       4       5 allisar01   1871 CL1    NA       29
## 4      10       2 allisdo01   1871 WS3    NA       27
## 5      11       3 ansonca01   1871 RC1    NA       25
## # ... with 108,784 more rows
```

Recap!

- `dplyr` allows for easy column manipulations
  - `select()`
  - `rename()`
- Pipe or Chain with `%>%`

Creating New Variables

- Consider a data set on movie ratings

```r
library(fivethirtyeight)
fandango
```

```
## # A tibble: 146 x 23
##   film      year rottentomatoes rottentomatoes_~ metacritic metacritic_user  imdb
##   <chr>    <dbl>          <int>            <int>      <int>           <dbl> <dbl>
## 1 Avenge~   2015             74               86         66             7.1   7.8
## 2 Cinder~   2015             85               80         67             7.5   7.1
## 3 Ant-Man   2015             80               90         64             8.1   7.8
## 4 Do You~   2015             18               84         22             4.7   5.4
## 5 Hot Tu~   2015             14               28         29             3.4   5.1
## # ... with 141 more rows, and 16 more variables: fandango_stars <dbl>,
## #   fandango_ratingvalue <dbl>, rt_norm <dbl>, rt_user_norm <dbl>,
## #   metacritic_norm <dbl>, metacritic_user_nom <dbl>, imdb_norm <dbl>,
## #   rt_norm_round <dbl>, rt_user_norm_round <dbl>, metacritic_norm_round <dbl>,
## #   metacritic_user_norm_round <dbl>, imdb_norm_round <dbl>,
## #   metacritic_user_vote_count <int>, imdb_user_vote_count <int>,
## #   fandango_votes <int>, fandango_difference <dbl>
```

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`mutate()` - Create New Column(s)

- Add newly created column(s) to current data frame (doesn't overwrite the data frame)

`mutate(data, newVarName = functionOfData, newVarName2 = functionOfData, ...)`

```
fandango %>%
  mutate(avgRotten = (rottentomatoes + rottentomatoes_user)/2)
```

```
## # A tibble: 146 x 24
##   film     year rottentomatoes rottentomatoes_~ metacritic metacritic_user  imdb
##   <chr>   <dbl>          <int>            <int>      <int>           <dbl> <dbl>
## 1 Avenge~  2015             74               86         66             7.1   7.8
## 2 Cinder~  2015             85               80         67             7.5   7.1
## 3 Ant-Man  2015             80               90         64             8.1   7.8
## 4 Do You~  2015             18               84         22             4.7   5.4
## 5 Hot Tu~  2015             14               28         29             3.4   5.1
## # ... with 141 more rows, and 17 more variables: fandango_stars <dbl>,
## #   fandango_ratingvalue <dbl>, rt_norm <dbl>, rt_user_norm <dbl>,
## #   metacritic_norm <dbl>, metacritic_user_nom <dbl>, imdb_norm <dbl>,
## #   rt_norm_round <dbl>, rt_user_norm_round <dbl>, metacritic_norm_round <dbl>,
## #   metacritic_user_norm_round <dbl>, imdb_norm_round <dbl>,
## #   metacritic_user_vote_count <int>, imdb_user_vote_count <int>,
## #   fandango_votes <int>, fandango_difference <dbl>, avgRotten <dbl>
```

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`mutate()` - Create New Column(s)

- Reorder columns so we can see it!

```
fandango %>%
  mutate(avgRotten = (rottentomatoes + rottentomatoes_user)/2) %>%
  select(film, year, avgRotten, everything())
```

```
## # A tibble: 146 x 24
##   film                year avgRotten rottentomatoes rottentomatoes_~ metacritic
##   <chr>              <dbl>     <dbl>          <int>            <int>      <int>
## 1 Avengers: Age of U~  2015      80               74               86         66
## 2 Cinderella          2015      82.5             85               80         67
## 3 Ant-Man             2015      85               80               90         64
## 4 Do You Believe?     2015      51               18               84         22
## 5 Hot Tub Time Machi~  2015      21               14               28         29
## # ... with 141 more rows, and 18 more variables: metacritic_user <dbl>,
## #   imdb <dbl>, fandango_stars <dbl>, fandango_ratingvalue <dbl>,
## #   rt_norm <dbl>, rt_user_norm <dbl>, metacritic_norm <dbl>,
## #   metacritic_user_nom <dbl>, imdb_norm <dbl>, rt_norm_round <dbl>,
## #   rt_user_norm_round <dbl>, metacritic_norm_round <dbl>,
## #   metacritic_user_norm_round <dbl>, imdb_norm_round <dbl>,
## #   metacritic_user_vote_count <int>, imdb_user_vote_count <int>, ...
```

`mutate()` - Create New Column(s)

- Add more than one variable

```
fandango %>%
  mutate(avgRotten = (rottentomatoes + rottentomatoes_user)/2,
         avgMeta = (metacritic_norm + metacritic_user_nom)/2) %>%
  select(film, year, avgRotten, avgMeta, everything())
```

```
## # A tibble: 146 x 25
##   film          year avgRotten avgMeta rottentomatoes rottentomatoes_~ metacritic
##   <chr>        <dbl>     <dbl>   <dbl>          <int>            <int>      <int>
## 1 Avengers: ~   2015      80      3.42             74               86         66
## 2 Cinderella    2015      82.5    3.55             85               80         67
## 3 Ant-Man       2015      85      3.62             80               90         64
## 4 Do You Bel~   2015      51      1.72             18               84         22
## 5 Hot Tub Ti~   2015      21      1.58             14               28         29
## # ... with 141 more rows, and 18 more variables: metacritic_user <dbl>,
## #   imdb <dbl>, fandango_stars <dbl>, fandango_ratingvalue <dbl>,
## #   rt_norm <dbl>, rt_user_norm <dbl>, metacritic_norm <dbl>,
## #   metacritic_user_nom <dbl>, imdb_norm <dbl>, rt_norm_round <dbl>,
## #   rt_user_norm_round <dbl>, metacritic_norm_round <dbl>,
## #   metacritic_user_norm_round <dbl>, imdb_norm_round <dbl>,
## #   metacritic_user_vote_count <int>, imdb_user_vote_count <int>, ...
```

`mutate()` - Create New Column(s)

`mutate()` can use some statistical functions

```
fandango %>%
  select(rottentomatoes) %>%
  mutate(avg = mean(rottentomatoes), sd = sd(rottentomatoes))
```

```
## # A tibble: 146 x 3
##   rottentomatoes   avg    sd
##            <int> <dbl> <dbl>
## 1             74  60.8  30.2
## 2             85  60.8  30.2
## 3             80  60.8  30.2
## 4             18  60.8  30.2
## 5             14  60.8  30.2
## # ... with 141 more rows
```

`mutate()` & `group_by()` - Create New Column(s)

`mutate()` can use some statistical functions

- `group_by()` to create summaries for groups

```
fandango %>%
  select(year, rottentomatoes) %>%
  group_by(year) %>%
  mutate(avg = mean(rottentomatoes), sd = sd(rottentomatoes))
```

```
## # A tibble: 146 x 4
## # Groups:   year [2]
##    year rottentomatoes   avg    sd
##   <dbl>          <int> <dbl> <dbl>
## 1  2015             74  58.4  30.3
## 2  2015             85  58.4  30.3
## 3  2015             80  58.4  30.3
## 4  2015             18  58.4  30.3
## 5  2015             14  58.4  30.3
## # ... with 141 more rows
```

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`mutate()` & `group_by()` - Create New Column(s)

- `across(.cols, .funs)` for multiple columns/summaries at once

```
fandango %>%
  select(year, rottentomatoes, metacritic) %>%
  group_by(year) %>%
  mutate(across(c(rottentomatoes, metacritic), list(avg = mean, SD = sd)))
```

```
## # A tibble: 146 x 7
## # Groups:   year [2]
##    year rottentomatoes metacritic rottentomatoes_avg rottentomatoes_SD
##   <dbl>          <int>      <int>              <dbl>             <dbl>
## 1  2015             74         66               58.4              30.3
## 2  2015             85         67               58.4              30.3
## 3  2015             80         64               58.4              30.3
## 4  2015             18         22               58.4              30.3
## 5  2015             14         29               58.4              30.3
## # ... with 141 more rows, and 2 more variables: metacritic_avg <dbl>,
## #   metacritic_SD <dbl>
```

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`mutate()` & `group_by()` - Create New Column(s)

- `across(.cols, .funs)` for multiple columns/summaries at once

```
fandango %>%
  select(year, ends_with("user")) %>%
  group_by(year) %>%
  mutate(across(ends_with("user"), list(trim_mean = mean), trim = 0.2))
```

```
## # A tibble: 146 x 5
## # Groups:   year [2]
##    year rottentomatoes_user metacritic_user rottentomatoes_use~ metacritic_user~
##   <dbl>               <int>           <dbl>               <dbl>            <dbl>
## 1  2015                  86             7.1                64.9             6.63
## 2  2015                  80             7.5                64.9             6.63
## 3  2015                  90             8.1                64.9             6.63
## 4  2015                  84             4.7                64.9             6.63
## 5  2015                  28             3.4                64.9             6.63
## # ... with 141 more rows
```

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Conditional Execution

- Often want to execute statements conditionally to create a variable

`dplyr::if_else()` - *vectorized* conditional execution. Syntax:

- `if_else(condition, true, false)`
- `condition` is a vector of TRUE/FALSE
- `true` is what to do when TRUE occurs
- `false` is what to do when FALSE occurs

Returns a vector

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Conditional Execution

- Consider built-in data set `airquality`
    - daily air quality measurements in New York
    - from May (Day 1) to September (Day 153) in 1973

```
myAirquality <- as_tibble(airquality)
myAirquality
```

```
## # A tibble: 153 x 6
##   Ozone Solar.R  Wind  Temp Month   Day
##   <int>   <int> <dbl> <int> <int> <int>
## 1    41     190   7.4    67     5     1
## 2    36     118   8      72     5     2
## 3    12     149  12.6    74     5     3
## 4    18     313  11.5    62     5     4
## 5    NA      NA  14.3    56     5     5
## # ... with 148 more rows
```

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Conditional Execution

Want to code a wind category variable

- high wind days (15mph $\leq$ `wind`)
- windy days (10mph $\leq$ `wind` < 15mph)
- lightwind days (6mph $\leq$ `wind` < 10mph)
- calm days (`wind` $\leq$ 6mph)

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if_else()

```r
if_else(myAirquality$Wind >= 15, "HighWind",
        if_else(myAirquality$Wind >= 10, "Windy",
                if_else(myAirquality$Wind >= 6, "LightWind", "Calm")))
```

```
##   [1] "LightWind" "LightWind" "Windy"     "Windy"     "Windy"     "Windy"
##   [7] "LightWind" "Windy"     "HighWind"  "LightWind" "LightWind" "LightWind"
##  [13] "LightWind" "Windy"     "Windy"     "Windy"     "Windy"     "HighWind"
##  [19] "Windy"     "LightWind" "LightWind" "HighWind"  "LightWind" "Windy"
##  [25] "HighWind"  "Windy"     "LightWind" "Windy"     "Windy"     "Calm"
##  [31] "LightWind" "LightWind" "LightWind" "HighWind"  "LightWind" "LightWind"
##  [37] "Windy"     "LightWind" "LightWind" "Windy"     "Windy"     "Windy"
##  [43] "LightWind" "LightWind" "Windy"     "Windy"     "Windy"     "HighWind"
##  [49] "LightWind" "Windy"     "Windy"     "LightWind" "Calm"      "Calm"
##  [55] "LightWind" "LightWind" "LightWind" "Windy"     "Windy"     "Windy"
##  [61] "LightWind" "Calm"      "LightWind" "LightWind" "Windy"     "Calm"
##  [67] "Windy"     "Calm"      "LightWind" "Calm"      "LightWind" "LightWind"
##  [73] "Windy"     "Windy"     "Windy"     "Windy"     "LightWind" "Windy"
##  [79] "LightWind" "Calm"      "Windy"     "LightWind" "LightWind" "Windy"
##  [85] "LightWind" "LightWind" "LightWind" "Windy"     "LightWind" "LightWind"
##  [91] "LightWind" "LightWind" "LightWind" "Windy"     "LightWind" "LightWind"
##  [97] "LightWind" "Calm"      "Calm"      "Windy"     "LightWind" "LightWind"
## [103] "Windy"     "Windy"     "Windy"     "LightWind" "Windy"     "Windy"
## [109] "LightWind" "LightWind" "Windy"     "Windy"     "HighWind"  "Windy"
## [115] "Windy"     "LightWind" "Calm"      "LightWind" "Calm"      "LightWind"
## [121] "Calm"      "LightWind" "LightWind" "LightWind" "Calm"      "Calm"
[illegible] "HighWind"  "Windy"     "Windy"     "Windy"
[illegible] "HighWind"  "LightWind" "Windy"     "Windy"
[illegible] "Windy"     "Windy"     "LightWind" "Windy"
```

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if_else() with mutate()

```
myAirquality <- myAirquality %>%
                mutate(Status = if_else(Wind >= 15, "HighWind",
                                        if_else(Wind >= 10, "Windy",
                                                if_else(Wind >= 6, "LightWind", "Calm"))))
myAirquality
```

```
## # A tibble: 153 x 7
##   Ozone Solar.R  Wind  Temp Month   Day Status
##   <int>   <int> <dbl> <int> <int> <int> <chr>
## 1    41     190   7.4    67     5     1 LightWind
## 2    36     118   8      72     5     2 LightWind
## 3    12     149  12.6    74     5     3 Windy
## 4    18     313  11.5    62     5     4 Windy
## 5    NA      NA  14.3    56     5     5 Windy
## # ... with 148 more rows
```

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Recap!

- `mutate()` - add newly created **column(s)** to current data frame
- Can use `group_by()` with `mutate()` to add common summary statistics
- Use `if_else()` to do conditional creation
- `dplyr` and `tidyr` Cheat Sheet

Let's Practice

We'll add to our `.Rmd` file from the previous activity

- Download the prompts to add to our markdown document here

Guidance:

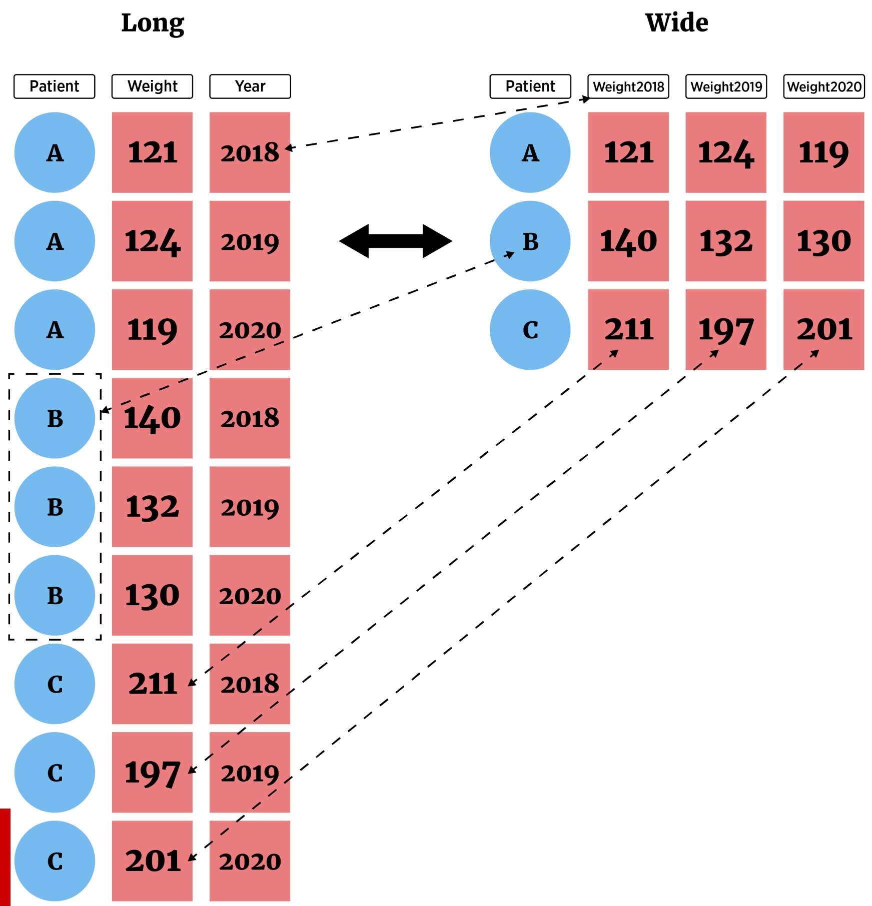
- Copy and paste the text from above into the bottom of the document, reknit
- Add to the code chunks, evaluating in the notebook
- Reknit occasionally to check the output

Reshaping Data with `tidyr`

Justin Post

Reshaping Data

Long vs Wide format data



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`tidyr` Package

Easily allows for two very important actions

- `pivot_longer()` - lengthens data by increasing the number of rows and decreasing the number of columns
  - Most important as analysis methods often prefer this form
- `pivot_wider()` - widens data by increasing the number of columns and decreasing the number of rows

tidyr Package

- Data in 'Wide' form

```r
tempsData <- read_table(file = "https://www4.stat.ncsu.edu/~online/datasets/cityTemps.txt")
tempsData
```

```
## # A tibble: 6 x 8
##   city        sun   mon   tue   wed   thr   fri   sat
##   <chr>     <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 atlanta      81    87    83    79    88    91    94
## 2 baltimore    73    75    70    78    73    75    79
## 3 charlotte    82    80    75    82    83    88    93
## 4 denver       72    71    67    68    72    71    58
## 5 ellington    51    42    47    52    55    56    59
## 6 frankfort    70    70    72    70    74    74    79
```

Reshaping Data

```
## # A tibble: 6 x 8
##   city        sun   mon   tue   wed   thr   fri   sat
##   <chr>     <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 atlanta      81    87    83    79    88    91    94
## 2 baltimore    73    75    70    78    73    75    79
## 3 charlotte    82    80    75    82    83    88    93
## 4 denver       72    71    67    68    72    71    58
## 5 ellington    51    42    47    52    55    56    59
## 6 frankfort    70    70    72    70    74    74    79
```

- Switch to 'Long' form with `pivot_longer()`
  - `cols` = columns to pivot to longer format (`cols = 2:8`)
  - `names_to` = new name(s) for columns created (`names_to = "day"`)
  - `values_to` = new name(s) for data values (`values_to = "temp"`)

Reshaping Data

- Switch to 'Long' form with `pivot_longer()`
    - `cols` = columns to pivot to longer format (`cols = 2:8`)
    - `names_to` = new name(s) for columns created (`names_to = "day"`)
    - `values_to` = new name(s) for data values (`values_to = "temp"`)

```
tempsData %>% pivot_longer(cols = 2:8, names_to = "day", values_to = "temp")
```

```
## # A tibble: 42 x 3
##   city    day    temp
##   <chr>   <chr> <dbl>
## 1 atlanta sun      81
## 2 atlanta mon      87
## 3 atlanta tue      83
## 4 atlanta wed      79
## 5 atlanta thr      88
## # ... with 37 more rows
```

Reshaping Data

- Switch to 'Long' form with `pivot_longer()`
- Can provide columns in many ways!

```
newTempsData <- tempsData %>%
  pivot_longer(cols = sun:sat, names_to = "day", values_to = "temp")
newTempsData
```

```
## # A tibble: 42 x 3
##   city    day    temp
##   <chr>   <chr> <dbl>
## 1 atlanta sun      81
## 2 atlanta mon      87
## 3 atlanta tue      83
## 4 atlanta wed      79
## 5 atlanta thr      88
## # ... with 37 more rows
```

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Reshaping Data

- Switch to 'Wide' form with `pivot_wider()`
  - `names_from` = column(s) to get the names used in the output columns (`names_from = "day"`)
  - `values_from` = column(s) to get the cell values from (`values_from = "temp"`)

```
newTempsData %>%
  pivot_wider(names_from = "day", values_from = "temp")
```

```
## # A tibble: 6 x 8
##   city        sun   mon   tue   wed   thr   fri   sat
##   <chr>     <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 atlanta      81    87    83    79    88    91    94
## 2 baltimore    73    75    70    78    73    75    79
## 3 charlotte    82    80    75    82    83    88    93
## 4 denver       72    71    67    68    72    71    58
## 5 ellington    51    42    47    52    55    56    59
## 6 frankfort    70    70    72    70    74    74    79
```

Big Recap!

- `dplyr` and `tidyr` packages
    - Convert to tibble: `as_tibble()`
    - Row manipulations: `arrange()`, `filter()`
    - Column manipulations: `select()`, `rename()`, `mutate()`, `group_by()`, `if_else()`
    - Reshape data: `pivot_wider()`, `pivot_longer()`

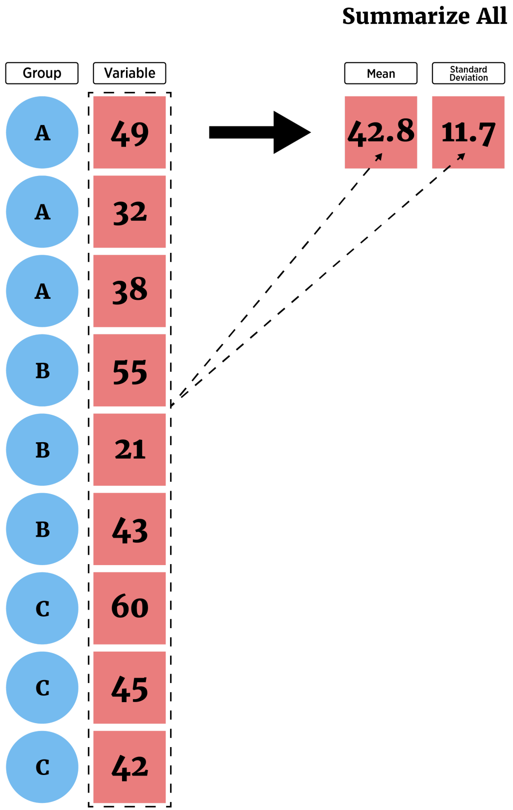
EDA: Numeric Summaries

Justin Post

Making Sense of Data

Goal: Understand types of data and their distributions

- Numerical summaries



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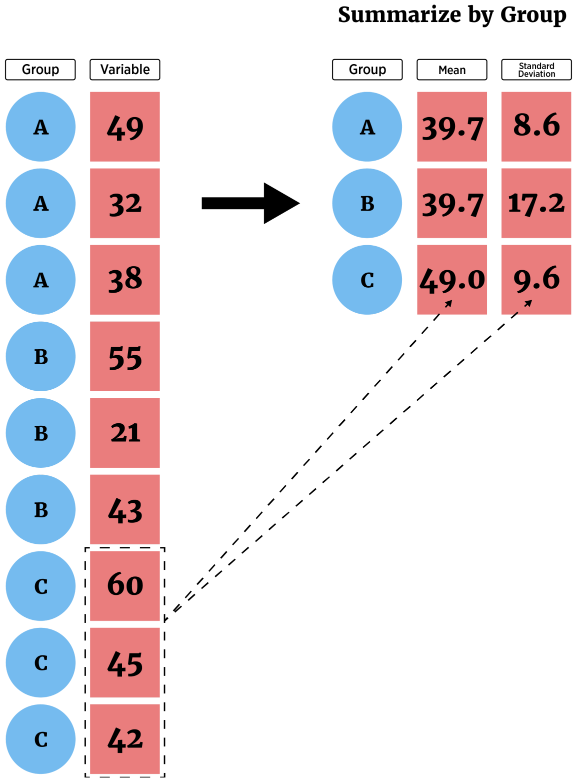
Making Sense of Data

Goal: Understand types of data and their distributions

- Numerical summaries (across subgroups)



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Making Sense of Data

Goal: Understand types of data and their distributions

- Numerical summaries (across subgroups)
    - Contingency Tables
    - Mean/Median
    - Standard Deviation/Variance/IQR
    - Quantiles/Percentiles

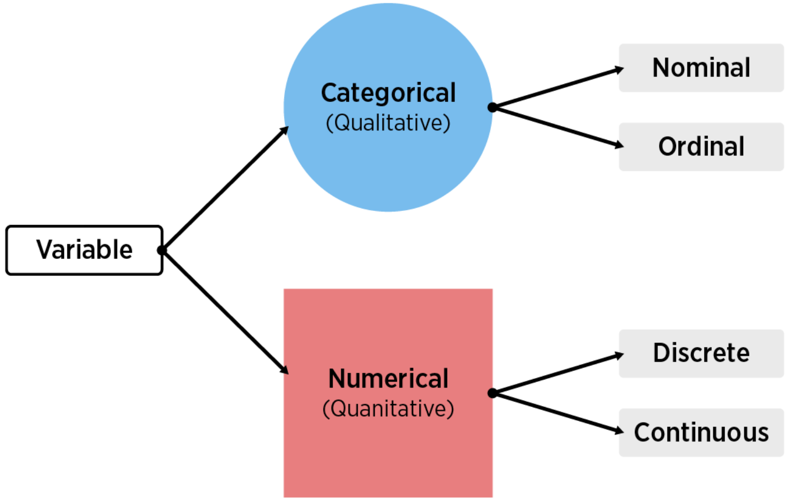
Making Sense of Data

Goal: Understand types of data and their distributions

- Numerical summaries (across subgroups)
    - Contingency Tables
    - Mean/Median
    - Standard Deviation/Variance/IQR
    - Quantiles/Percentiles
- Graphical summaries (across subgroups)
    - Bar plots
    - Histograms
    - Box plots
    - Scatter plots

Types of Data

- How to summarize data depends on the type of data
  - Categorical (Qualitative) variable - entries are a label or attribute
  - Numeric (Quantitative) variable - entries are a numerical value where math can be performed



Categorical Data

Goal: Describe the **distribution** of the variable

- Distribution = pattern and frequency with which you observe a variable
- Categorical variable - entries are a label or attribute

Categorical Data

Goal: Describe the **distribution** of the variable

- Distribution = pattern and frequency with which you observe a variable
- Categorical variable - entries are a label or attribute
    - Describe the relative frequency (or count) for each category
    - Can be done with `group_by()` and `summarize()` from `dplyr` (easier with base R `table()`)

Contingency tables

- Consider data on titanic passengers in `titanic.csv`

```
titanicData <- read_csv("https://www4.stat.ncsu.edu/~online/datasets/titanic.csv")
titanicData
```

```
## # A tibble: 1,310 x 14
##   pclass survived name      sex      age sibsp parch ticket  fare cabin embarked
##    <dbl>    <dbl> <chr>     <chr>  <dbl> <dbl> <dbl> <chr>  <dbl> <chr> <chr>
## 1      1        1 Allen, M~ fema~ 29         0     0 24160   211. B5    S
## 2      1        1 Allison,~ male   0.917     1     2 113781  152. C22 ~ S
## 3      1        0 Allison,~ fema~  2         1     2 113781  152. C22 ~ S
## 4      1        0 Allison,~ male  30         1     2 113781  152. C22 ~ S
## 5      1        0 Allison,~ fema~ 25         1     2 113781  152. C22 ~ S
## # ... with 1,305 more rows, and 3 more variables: boat <chr>, body <dbl>,
## #   home.dest <chr>
```

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Contingency tables

- Create a **one-way contingency table** for the `embarked` variable and for the `survived` variable

```
titanicData %>%
  group_by(embarked) %>%
  summarize(counts = n())
```

```
## # A tibble: 4 x 2
##   embarked counts
##   <chr>     <int>
## 1 C           270
## 2 Q           123
## 3 S           914
## 4 <NA>          3
```

```
titanicData %>%
  group_by(survived) %>%
  summarize(counts = n())
```

```
## # A tibble: 3 x 2
##   survived counts
##      <dbl>  <int>
## 1        0    809
## 2        1    500
## 3       NA      1
```

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Two-way contingency tables

- Create **two-way contingency tables** for pairs of categorical variables

```r
titanicData %>%
  group_by(embarked, survived) %>%
  summarize(counts = n())
```

```
## # A tibble: 8 x 3
## # Groups:   embarked [4]
##   embarked survived counts
##   <chr>       <dbl>  <int>
## 1 C               0    120
## 2 C               1    150
## 3 Q               0     79
## 4 Q               1     44
## 5 S               0    610
## 6 S               1    304
## 7 <NA>            1      2
## 8 <NA>           NA      1
```

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Two-way contingency tables

- Create **two-way contingency tables** for pairs of categorical variables

```
titanicData %>%
  group_by(embarked, survived) %>%
  summarize(counts = n())
```

```
## # A tibble: 8 x 3
## # Groups:   embarked [4]
##   embarked survived counts
##   <chr>       <dbl>  <int>
## 1 C               0    120
## 2 C               1    150
## 3 Q               0     79
## 4 Q               1     44
## 5 S               0    610
## 6 S               1    304
## 7 <NA>            1      2
## 8 <NA>           NA      1
```

```
titanicData %>%
  group_by(embarked, survived) %>%
  summarize(counts = n()) %>%
  pivot_wider(values_from = counts, names_from = embarked)
```

```
## # A tibble: 3 x 5
##   survived     C     Q     S  `NA`
##      <dbl> <int> <int> <int> <int>
## 1        0   120    79   610    NA
## 2        1   150    44   304     2
## 3       NA    NA    NA    NA     1
```

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Two-way contingency tables

- Let's drop the `NA` values first

```
titanicData %>%
  drop_na(embarked, survived) %>%
  group_by(embarked, survived) %>%
  summarize(counts = n())
```

```
## # A tibble: 6 x 3
## # Groups:   embarked [3]
##   embarked survived counts
##   <chr>       <dbl>  <int>
## 1 C               0    120
## 2 C               1    150
## 3 Q               0     79
## 4 Q               1     44
## 5 S               0    610
## 6 S               1    304
```

```
titanicData %>%
  drop_na(embarked, survived) %>%
  group_by(embarked, survived) %>%
  summarize(counts = n()) %>%
  pivot_wider(values_from = counts, names_from = embarked)
```

```
## # A tibble: 2 x 4
##   survived     C     Q     S
##      <dbl> <int> <int> <int>
## 1        0   120    79   610
## 2        1   150    44   304
```

Numeric Data

Goal: Describe the **distribution** of the variable

- Distribution = pattern and frequency with which you observe a variable
- Numeric variable - entries are a numerical value where math can be performed

Numeric Data

Goal: Describe the **distribution** of the variable

- Distribution = pattern and frequency with which you observe a variable
- Numeric variable - entries are a numerical value where math can be performed

For a single numeric variable, describe the distribution via

- Shape: Histogram, Density plot, …
- Measures of center: Mean, Median, …
- Measures of spread: Variance, Standard Deviation, Quartiles, IQR, …

Measures of Center

Mean & Median

```r
mean(titanicData$fare, na.rm = TRUE)
```

```
## [1] 33.29548
```

```r
median(titanicData$fare, na.rm = TRUE)
```

```
## [1] 14.4542
```

```r
titanicData %>%
  summarize(fareMean = mean(fare, na.rm = TRUE),
            fareMedian = median(fare, na.rm = TRUE))
```

```
## # A tibble: 1 x 2
##   fareMean fareMedian
##      <dbl>      <dbl>
## 1     33.3       14.5
```

```r
mean(titanicData$age, na.rm = TRUE)
```

```
## [1] 29.88113
```

```r
median(titanicData$age, na.rm = TRUE)
```

```
## [1] 28
```

```r
titanicData %>%
  summarize(ageMean = mean(age, na.rm = TRUE),
            ageMedian = median(age, na.rm = TRUE))
```

```
## # A tibble: 1 x 2
##   ageMean ageMedian
##     <dbl>     <dbl>
## 1    29.9        28
```

Measures of Spread

Standard Deviation, Quantiles, & IQR

```
titanicData %>%
  summarize(fareMean = mean(fare, na.rm = TRUE),
            fareMedian = median(fare, na.rm = TRUE),
            fareSD = sd(fare, na.rm = TRUE),
            fareIQR = IQR(fare, na.rm = TRUE),
            fareQ1 = quantile(fare, probs = c(0.25), na.rm = TRUE))
```

```
## # A tibble: 1 x 5
##   fareMean fareMedian fareSD fareIQR fareQ1
##      <dbl>      <dbl>  <dbl>   <dbl>  <dbl>
## 1     33.3       14.5   51.8    23.4   7.90
```

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Measures of Spread

Standard Deviation, Quantiles, & IQR

```
titanicData %>%
  summarize(fareQuantiles = quantile(fare, probs = c(0.1, 0.25, 0.5, 0.75, 0.9), na.rm = TRUE),
            q = c(0.1, 0.25, 0.5, 0.75, 0.9))
```

```
## # A tibble: 5 x 2
##   fareQuantiles     q
##           <dbl> <dbl>
## 1          7.57  0.1
## 2          7.90  0.25
## 3         14.5   0.5
## 4         31.3   0.75
## 5         78.1   0.9
```

Measures of Linear Relationship

For two numeric variables we can find Covariance & Correlation

```
titanicData %>%
  summarize(covar = cov(fare, age, use = "complete.obs"),
            corr = cor(fare, age, use = "complete.obs"))
```

```
## # A tibble: 1 x 2
##   covar  corr
##   <dbl> <dbl>
## 1  143. 0.179
```

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Summaries Across Groups

Usually want summaries for different **subgroups of data**

- Ex: Get similar fare summaries for each *survival status*

Idea:

- Use `dplyr::group_by()` to associate groups with the tibble
- Use `dplyr::summarize()` to create basic summaries for each subgroup

Summaries Across Groups

- Ex: Get similar fare summaries for each *survival status*

```
titanicData %>%
  group_by(survived) %>%
    summarise(avg = mean(fare, na.rm = TRUE),
              med = median(fare, na.rm = TRUE),
              var = var(fare, na.rm = TRUE))
```

```
## # A tibble: 3 x 4
##   survived   avg   med   var
##      <dbl> <dbl> <dbl> <dbl>
## 1        0  23.4  10.5 1166.
## 2        1  49.4  26   4713.
## 3       NA NaN    NA     NA
```

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Summaries Across Groups

- Remove `NA` class for `survived`

```
titanicData %>%
  drop_na(survived) %>%
  group_by(survived) %>%
    summarise(avg = mean(fare, na.rm = TRUE),
              med = median(fare, na.rm = TRUE),
              var = var(fare, na.rm = TRUE))
```

```
## # A tibble: 2 x 4
##   survived   avg   med   var
##      <dbl> <dbl> <dbl> <dbl>
## 1        0  23.4  10.5 1166.
## 2        1  49.4  26   4713.
```

Summaries Across Groups

- Ex: Get similar fare summaries for each *survival status* and *embarked value*

```
titanicData %>%
  drop_na(survived, embarked) %>%
  group_by(survived, embarked) %>%
    summarise(avg = mean(fare, na.rm = TRUE),
              med = median(fare, na.rm = TRUE),
              var = var(fare, na.rm = TRUE))
```

```
## # A tibble: 6 x 5
## # Groups:   survived [2]
##   survived embarked   avg   med   var
##      <dbl> <chr>    <dbl> <dbl> <dbl>
## 1        0 C         40.3 15.0  3198.
## 2        0 Q         11.6  7.75  119.
## 3        0 S         21.5 11.5   829.
## 4        1 C         80.0 55.4  9534.
## 5        1 Q         13.8  7.75  306.
## 6        1 S         39.2 25.9  2271.
```

Summarizing across groups

`dplyr::across()` allows for applying a summarization to multiple columns easily!

```
titanicData %>%
  drop_na(survived) %>%
  group_by(survived) %>%
    summarise(across(.fns = mean, .cols = c(age, fare), na.rm = TRUE))
```

```
## # A tibble: 2 x 3
##   survived   age  fare
##      <dbl> <dbl> <dbl>
## 1        0  30.5  23.4
## 2        1  28.9  49.4
```

Summarizing across groups

`dplyr::across()` allows for applying a summarization to multiple columns easily!

```
titanicData %>%
  drop_na(survived) %>%
  group_by(survived) %>%
    summarise(across(.fns = mean, .cols = where(is.double), na.rm = TRUE))
```

```
## # A tibble: 2 x 7
##   survived pclass   age sibsp parch  fare  body
##      <dbl>  <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1        0   2.50  30.5 0.522 0.329  23.4  161.
## 2        1   1.96  28.9 0.462 0.476  49.4  NaN
```

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Recap!

- Must understand the type of data you have
- Goal: Describe the distribution
- Numerical summaries: use `summarize()`
  - Contingency Tables: `n()`
  - Mean/Median: `mean()`, `median()`
  - Standard Deviation/Variance/IQR: `sd()`, `var()`, `IQR()`
  - Quantiles/Percentiles: `quantile()`
- Across subgroups with `dplyr::group_by()`,
- Multiple columns/functions with `dplyr::across()`

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Let's Practice

We'll add to our `.Rmd` file from the previous activity

- Download the prompts to add to our markdown document here

Guidance:

- Copy and paste the text from above into the bottom of the document, reknit
- Add to the code chunks, evaluating in the notebook
- Reknit occasionally to check the output

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`ggplot2`

Justin Post

Graphical Summaries in `R`

Three major systems for plotting:

- Base R (built-in functions)
- `lattice`
- `ggplot2` (sort of part of the tidyverse)

Great ggplot2 reference book here!

`ggplot2` Plotting

ggplot2 basics (Cheat Sheet)

- `ggplot(data = data_frame)` creates a plot instance
- Add "layers" to the plot (`geom` or `stat` layers)
  - Creates a visualization of the data

`ggplot2` Plotting

ggplot2 basics (Cheat Sheet)

- `ggplot(data = data_frame)` creates a plot instance
- Add "layers" to the plot (`geom` or `stat` layers)
  - Creates a visualization of the data
- Modify layer "mapping" args (usually with `aes()`)
  - Map variables to attributes of the plot
  - Ex: size, color, x variable, y variable
- Improve by adding title layers, faceting, etc.

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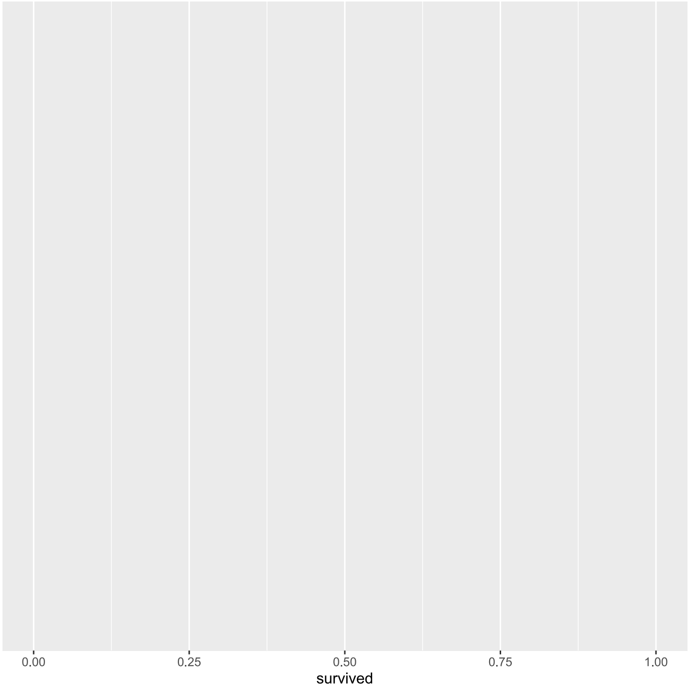
`ggplot2` Barplots

- Barplots via `ggplot() + geom_bar()`
- Across x-axis we want our categories - specify with `aes(x = ...)`

```
ggplot(data = titanicData, aes(x = survived))
```



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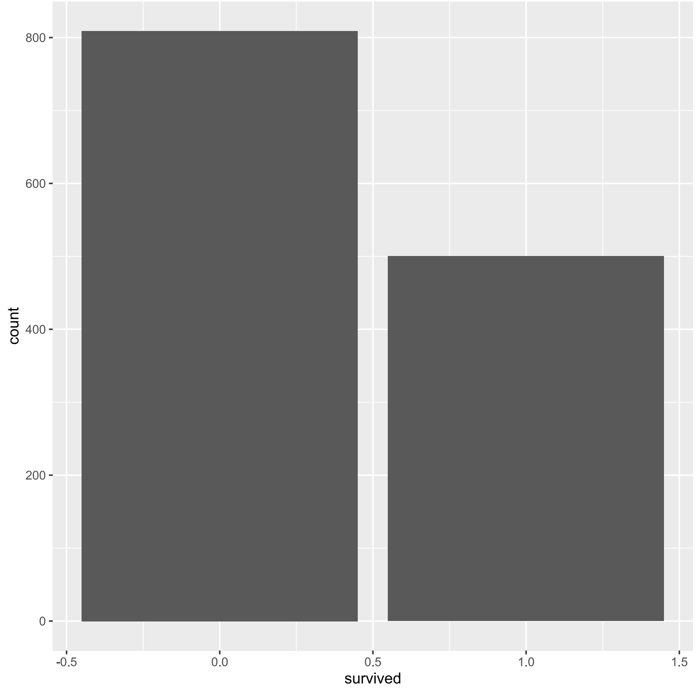
`ggplot2` Barplots

- Barplots via `ggplot() + geom_bar()`
- Must add geom (or stat) layer!

```
ggplot(data = titanicData, aes(x = survived)) + geom_bar()
```



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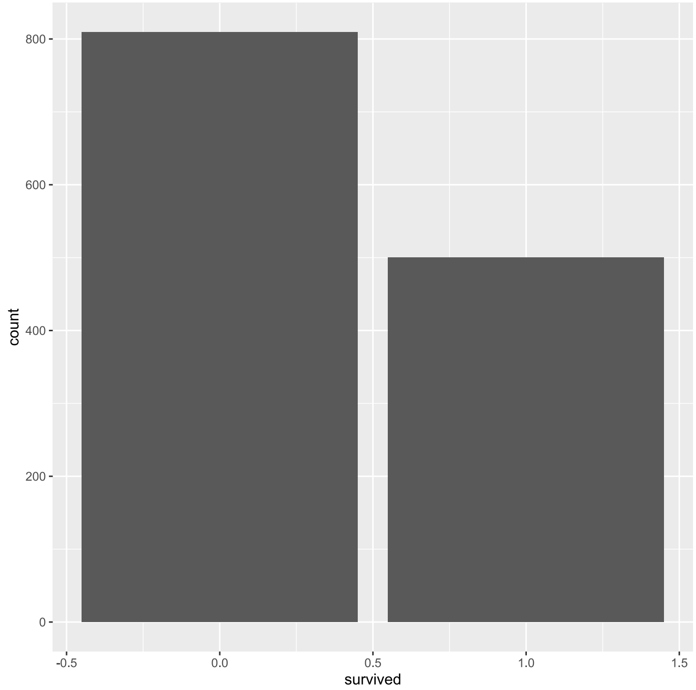
`ggplot2` Barplots

- Generally: Save base object with **global** `aes()` assignments, then add layers

```
g <- ggplot(data = titanicData, aes(x = survived))
g + geom_bar()
```



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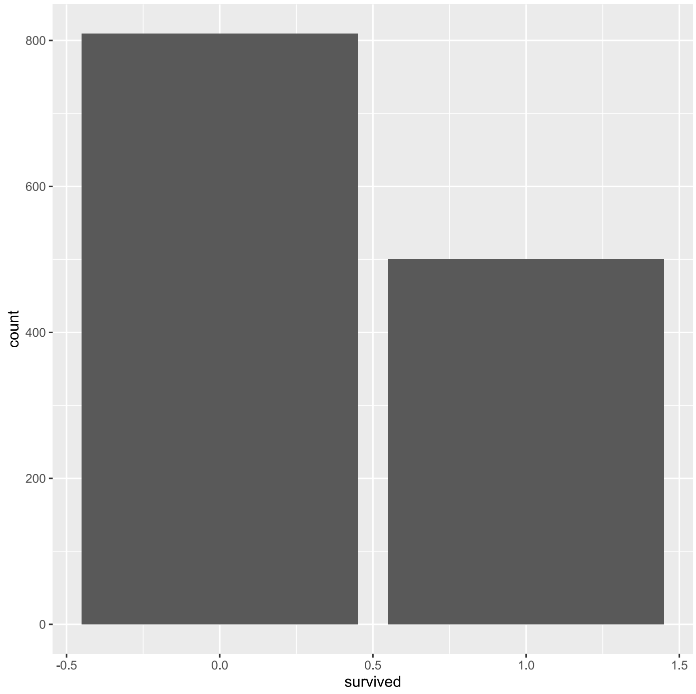
Better Labeling Needed

- `survived` data values create a sub-optimal plot!



- Can fix with additional layers but it is easier to change the variable used for plotting!

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Factors

- `survived` is read as a numeric variable (truly it is categorical)

```
titanicData
```

```
## # A tibble: 1,310 x 14
##   pclass survived name      sex      age sibsp parch ticket  fare cabin embarked
##    <dbl>    <dbl> <chr>     <chr>  <dbl> <dbl> <dbl> <chr>  <dbl> <chr> <chr>
## 1      1        1 Allen, M~ fema~ 29         0     0 24160   211. B5    S
## 2      1        1 Allison,~ male   0.917     1     2 113781  152. C22 ~ S
## 3      1        0 Allison,~ fema~  2         1     2 113781  152. C22 ~ S
## 4      1        0 Allison,~ male  30         1     2 113781  152. C22 ~ S
## 5      1        0 Allison,~ fema~ 25         1     2 113781  152. C22 ~ S
## # ... with 1,305 more rows, and 3 more variables: boat <chr>, body <dbl>,
## #   home.dest <chr>
```

- Can create a new version that is a `factor` - works well with `ggplot()`

Factors

Factor - special class of vector with a `levels` attribute

- Levels define all possible values for that variable
  - Great for variable like `Day` (Monday, Tuesday, …, Sunday)
  - Not great for variable like `Name` where new values may come up

Factors

- Create a new `factor` version of `survived`

```
titanicData <- titanicData %>% mutate(mySurvived = as.factor(survived))
str(titanicData$mySurvived)
```

```
##  Factor w/ 2 levels "0","1": 2 2 1 1 1 2 2 1 2 1 ...
```

```
levels(titanicData$mySurvived)
```

```
## [1] "0" "1"
```

- Useful if you want to create better labels (or change the ordering)

```
levels(titanicData$mySurvived) <- c("Died", "Survived")
levels(titanicData$mySurvived)
```

```
## [1] "Died"     "Survived"
```

Prepare our Data

- Let's convert another categorical variable to a factor for better plotting

```
titanicData <- titanicData %>% mutate(myEmbarked = as.factor(embarked))
levels(titanicData$myEmbarked) <- c("Cherbourg", "Queenstown", "Southampton")
```

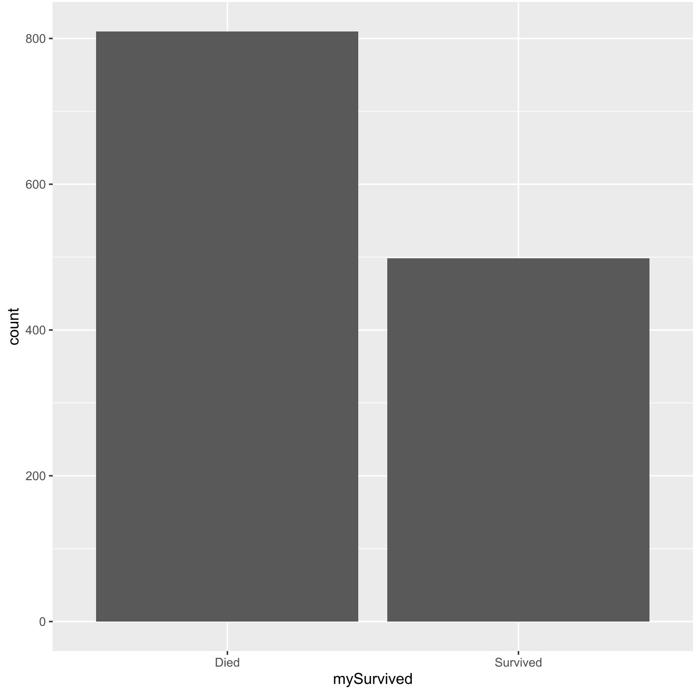
- Let's drop any rows with missing values for any of these variables

```
titanicData <- titanicData %>% drop_na(mySurvived, sex, myEmbarked)
```

Better Labels!

- Same barplot using the factor version of the variable: `mySurvived`

```
g <- ggplot(data = titanicData, aes(x = mySurvived))
g + geom_bar()
```



`aes()` Arguments

- `aes()` defines visual properties of objects in the plot
- Map variables in the data frame to plot elements

  `x = , y = , size = , shape = , color = , alpha = , ...`

- Cheat Sheet gives most common properties for a given `geom`

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`aes()` Arguments for Barplots

- `aes()` defines visual properties of objects in the plot
- Map variables in the data frame to plot elements

  `x = , y = , size = , shape = , color = , alpha = , ...`

- Cheat Sheet gives most common properties for a given `geom`

  `d + geom_bar()`

  `x, alpha, color, fill, linetype, size, weight`

`aes()` Arguments for Barplots

- **Stacked barplot** created by via `fill` aesthetic
- Automatic assignment of colors and creation of legends for `aes` elements (except group)

```
g <- ggplot(data = titanicData, aes(x = mySurvived, fill = myEmbarked))
g + geom_bar()
```

`ggplot2` Global vs Local Aesthetics

`data` and `aes` can be set in two ways;

- 'globally' (for all layers) via the `aes()` function in the `ggplot()` call
- 'locally' (for just that layer) via the `geom` or `stat` layer's `aes()`

`ggplot2` Global vs Local Aesthetics

`data` and `aes` can be set in two ways;

- 'globally' (for all layers) via the `aes()` function in the `ggplot()` call
- 'locally' (for just that layer) via the `geom` or `stat` layer's `aes()`

```
#global
ggplot(data = titanicData, aes(x = mySurvived, fill = myEmbarked)) + geom_bar()
```

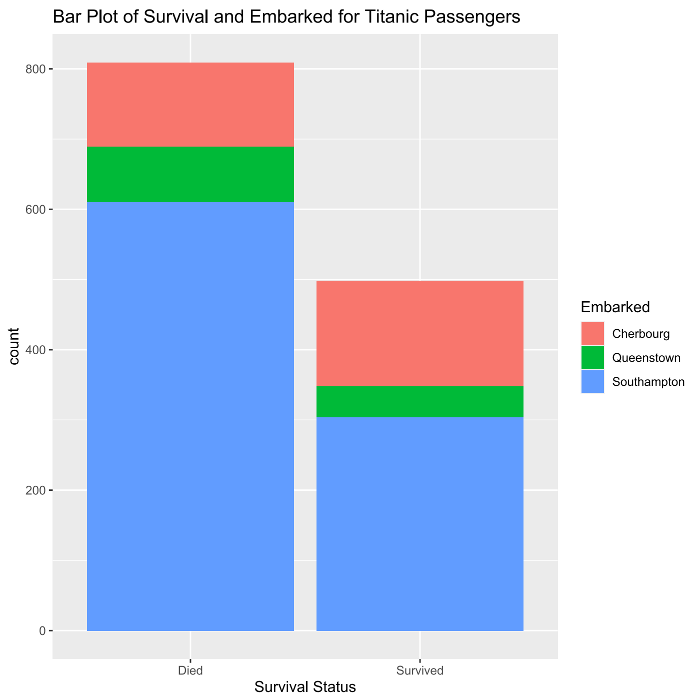
```
#some local, some global
ggplot(data = titanicData, aes(fill = myEmbarked)) + geom_bar(aes(x = mySurvived))
```

```
#all local
ggplot() + geom_bar(data = titanicData, aes(x = mySurvived, fill = myEmbarked))
```

`ggplot2` Barplots

- Improve our plot by adding a `labs` layer

```
g <- ggplot(titanicData)
g + geom_bar(aes(x = mySurvived, fill = myEmbarked)) +
  labs(x = "Survival Status", title = "Bar Plot of Survival and Embarked for Titanic Passengers",
       fill = "Embarked")
```



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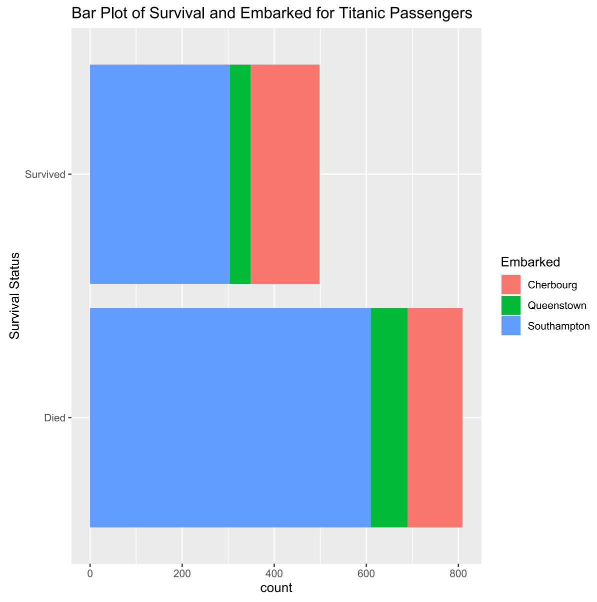
`ggplot2` Horizontal Barplots

- Easy to rotate a plot with `coord_flip()`

```
g <- ggplot(titanicData)
g + geom_bar(aes(x = mySurvived, fill = myEmbarked)) +
  labs(x = "Survival Status", title = "Bar Plot of Survival and Embarked for Titanic Passengers",
       fill = "Embarked") +
  coord_flip()
```



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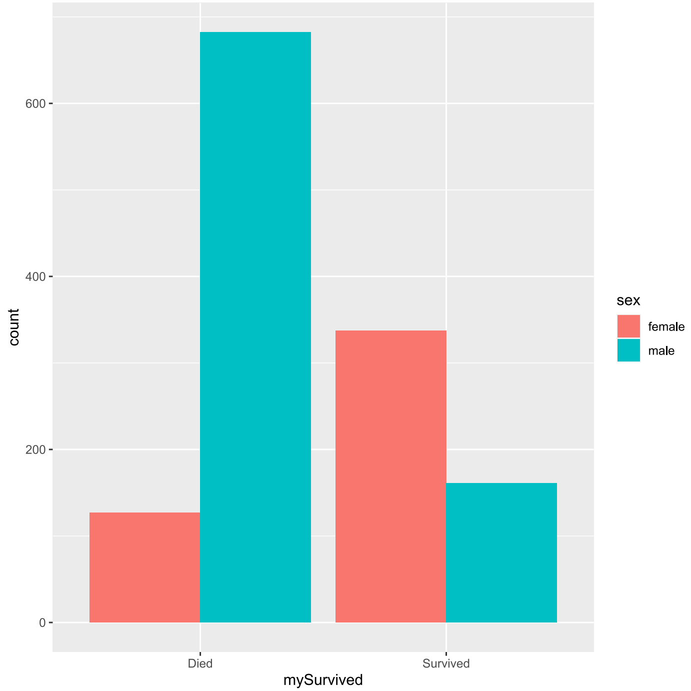
`ggplot2` Side-By-Side Barplots

- **Side-by-side barplot** created via the `position` aesthetic
    - `dodge` for side-by-side bar plot
    - `jitter` for continuous data with many points at same values
    - `fill` stacks bars and standardises each stack to have constant height
    - `stack` stacks bars on top of each other

`ggplot2` Side-By-Side Barplots

- **Side-by-side barplot** created by via `position` aesthetic

```
g <- ggplot(data = titanicData, aes(x = mySurvived, fill = sex))
g + geom_bar(position = "dodge")
```



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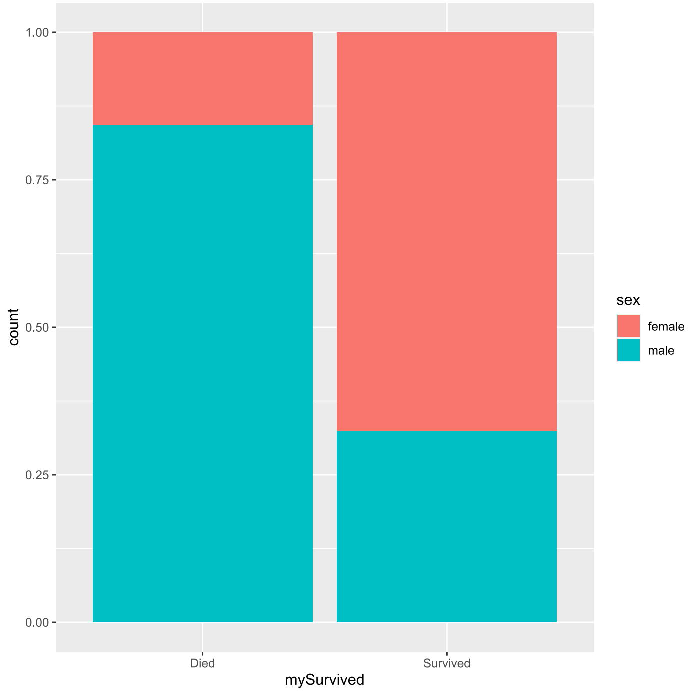
ggplot2 Filled Barplots

- `position = fill` stacks bars and standardizes each stack to have constant height (especially useful with equal group sizes)

```
g <- ggplot(data = titanicData, aes(x = mySurvived, fill = sex))
g + geom_bar(position = "fill")
```



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Recap!

General `ggplot2` things:

- Create base plot with `ggplot()`
- Add `geom` layer
- Can set local or global `aes()` (mappings of variables to attributes of the plot)
- Modify titles, labels, etc. by adding more layers
- `position` argument can change style of plot

`ggplot2` Smoothed Histogram

- **Kernel Smoother** - Smoothed version of a histogram
- Common `aes` values (from cheat sheet):

  `c + geom_density(kernel = "gaussian")`

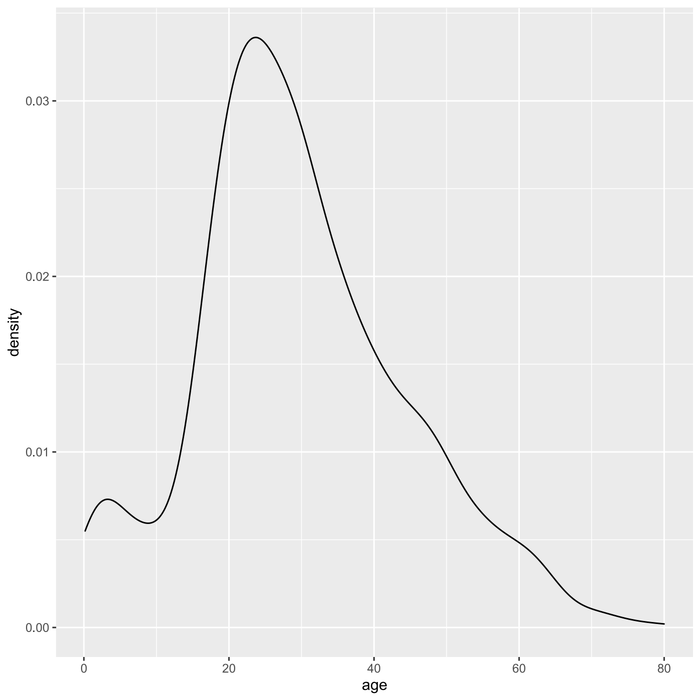
  `x, y, alpha, color, fill, group, linetype, size, weight`

- Only `x =` is really needed

`ggplot2` Smoothed Histogram

- **Kernel Smoother** - Smoothed version of a histogram

```
g <- ggplot(titanicData, aes(x = age))
g + geom_density()
```



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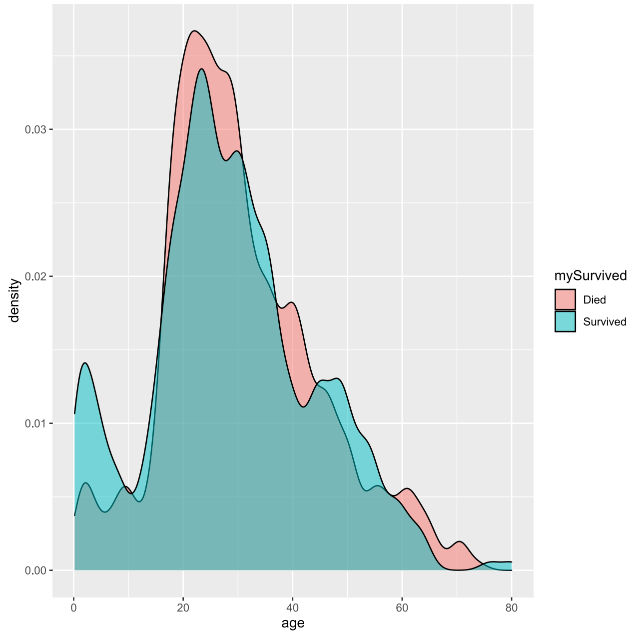
`ggplot2` Smoothed Histogram

- **Kernel Smoother** - Smoothed version of a histogram
- `fill` a useful aesthetic!

```
g <- ggplot(titanicData, aes(x = age))
g + geom_density(adjust = 0.5, alpha = 0.5, aes(fill = mySurvived))
```



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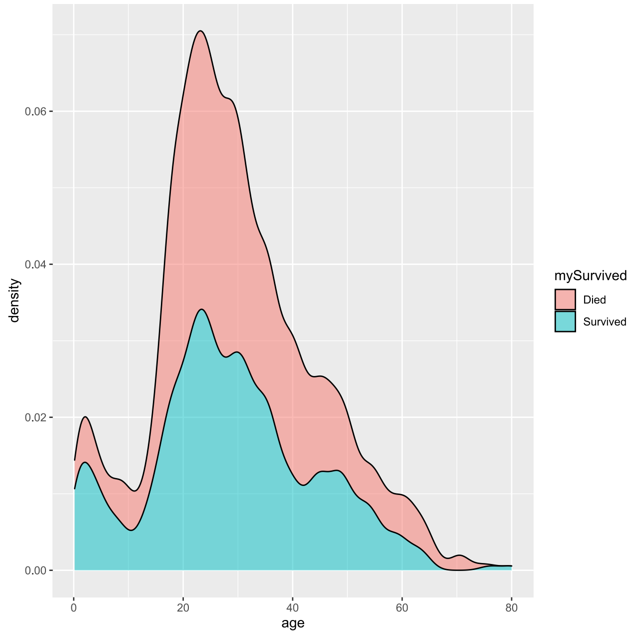
`ggplot2` Smoothed Histogram

- **Kernel Smoother** - Smoothed version of a histogram
- Recall `position` choices of `dodge`, `jitter`, `fill`, and `stack`

```
g <- ggplot(titanicData, aes(x = age))
g + geom_density(adjust = 0.5, alpha = 0.5, position = "stack", aes(fill = mySurvived))
```



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`ggplot2` Boxplots

- **Boxplot** - Provides the five number summary in a graph
- Common `aes` values (from cheat sheet):

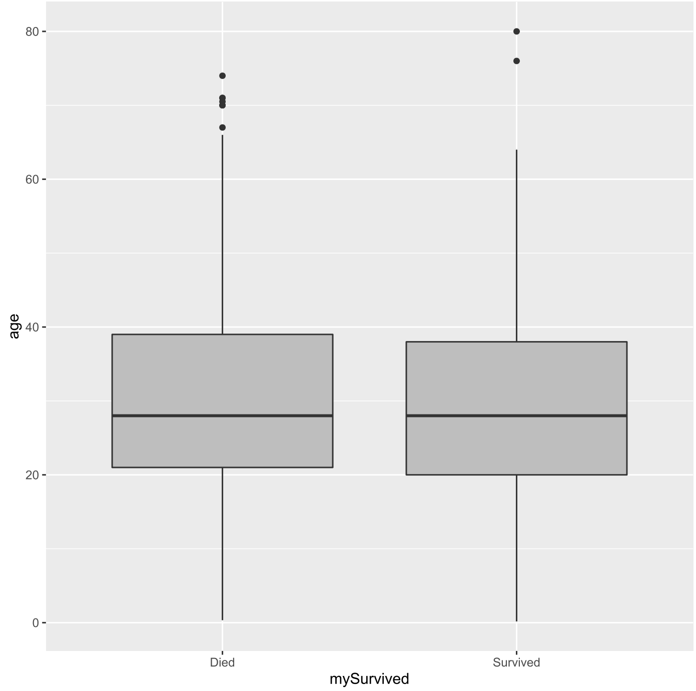
`f + geom_boxplot()`

`x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight`

- Only `x =, y =` are really needed

`ggplot2` Boxplots

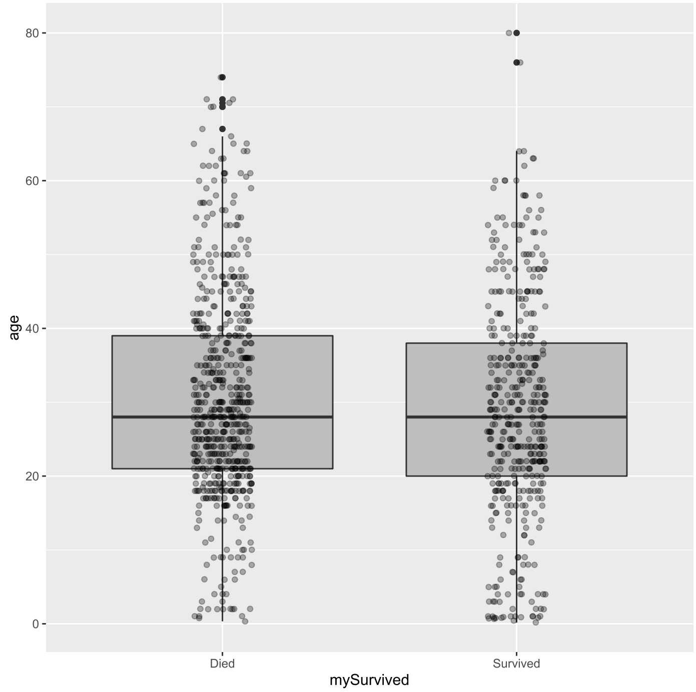
```r
g <- ggplot(titanicData, aes(x = mySurvived, y = age))
g + geom_boxplot(fill = "grey")
```



`ggplot2` Boxplots with Points

- Can add data points (jittered) to see shape of data better (or use violin plot)

```
g <- ggplot(titanicData, aes(x = mySurvived, y = age))
g + geom_boxplot(fill = "grey") +
    geom_jitter(width = 0.1, alpha = 0.3)
```



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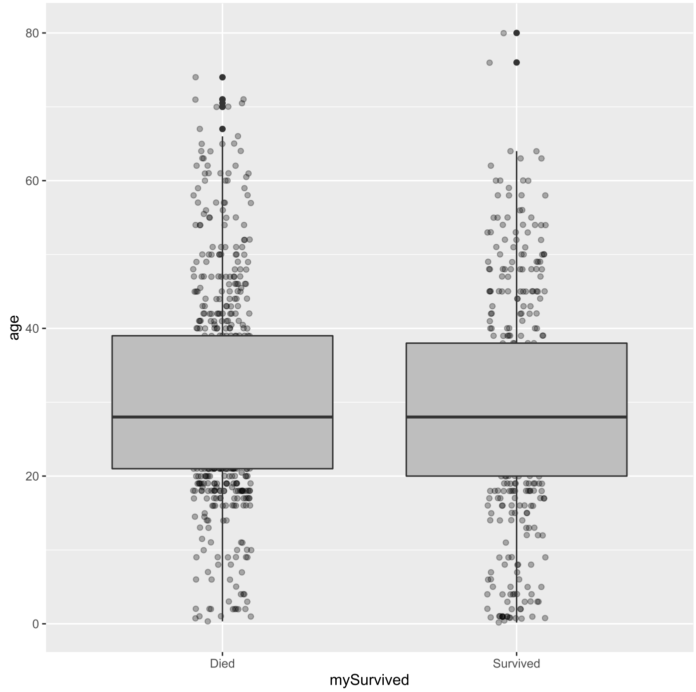
ggplot2 Boxplots with Points

- Order of layers important!

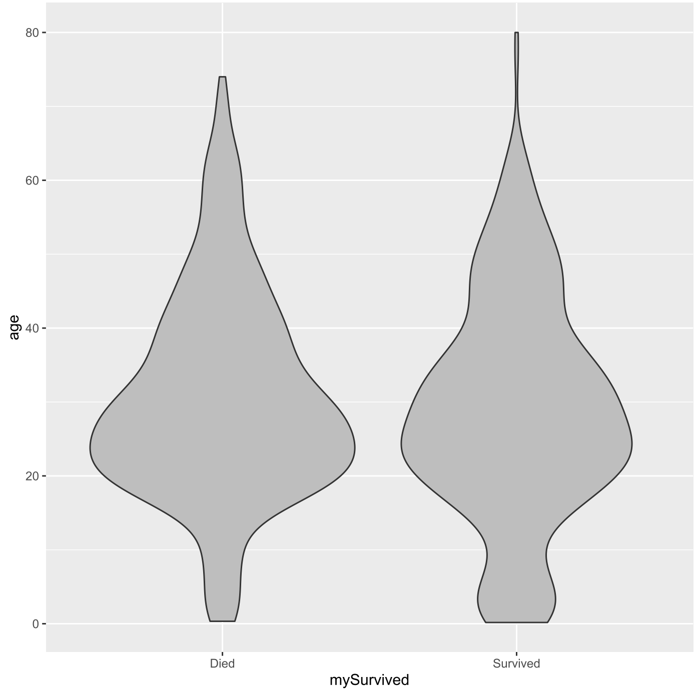
```
g <- ggplot(titanicData, aes(x = mySurvived, y = age))
g + geom_jitter(width = 0.1, alpha = 0.3) +
    geom_boxplot(fill = "grey")
```



ggplot2 Violin Plots

- Violin plot similar to boxplot

```
g <- ggplot(titanicData, aes(x = mySurvived, y = age))
g + geom_violin(fill = "grey")
```



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`ggplot2` Scatter Plots

Two numerical variables

- **Scatter Plot** - graphs points corresponding to each observation
- Common `aes` values (from cheat sheet):

  `e + geom_point()`

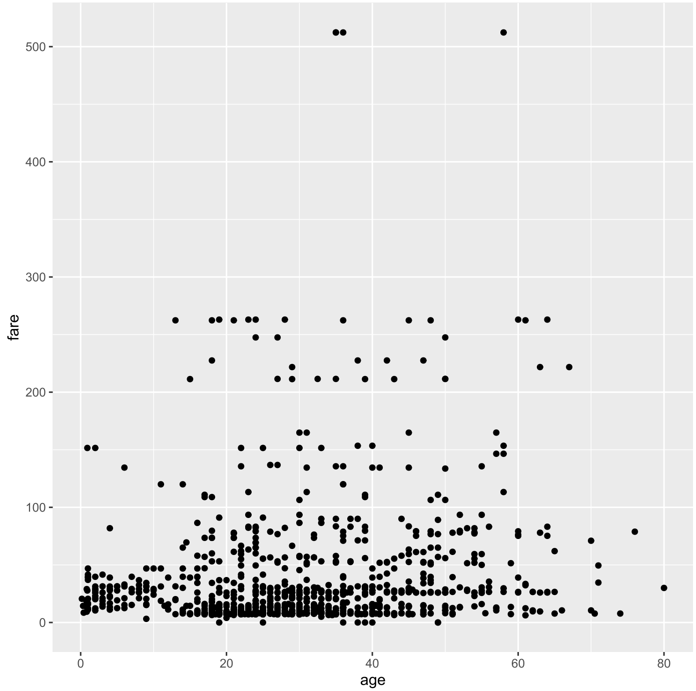
  `x, y, alpha, color, fill, shape, size, stroke`

- Only `x =, y =` are really needed

`ggplot2` Scatter Plots

- **Scatter Plot** - graphs points corresponding to each observation

```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_point()
```



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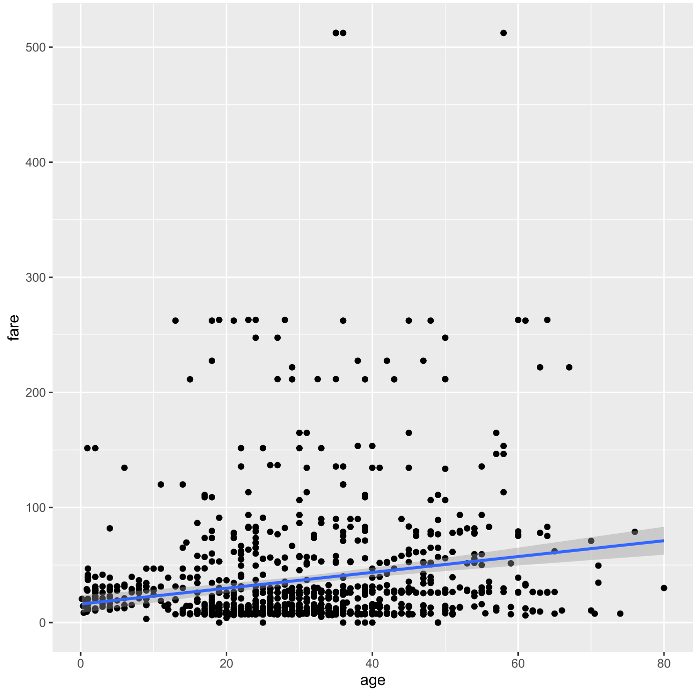
`ggplot2` Scatter Plots with Trend Line

- Add trend lines easily with `geom_smooth()`

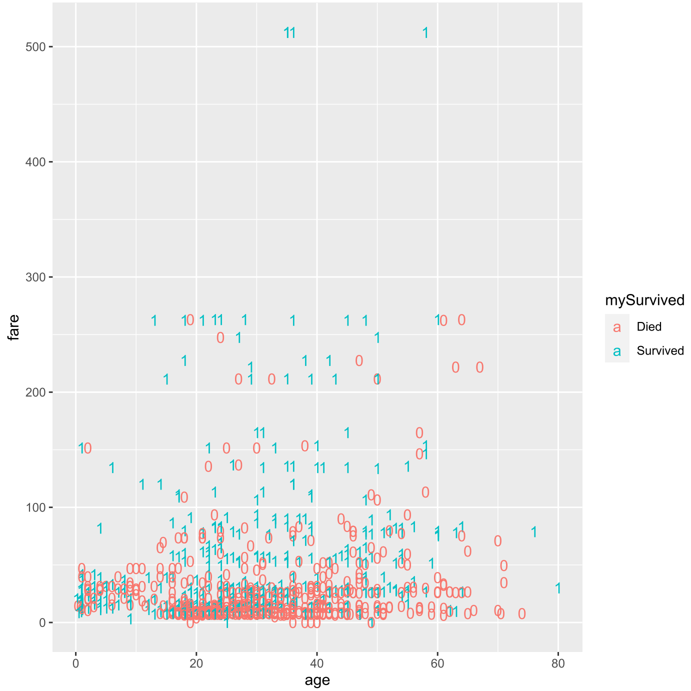
```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_point() +
    geom_smooth(method = lm)
```



`ggplot2` Scatter Plots with Text Points

- Text for points with `geom_text`

```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_text(aes(label = survived, color = mySurvived))
```



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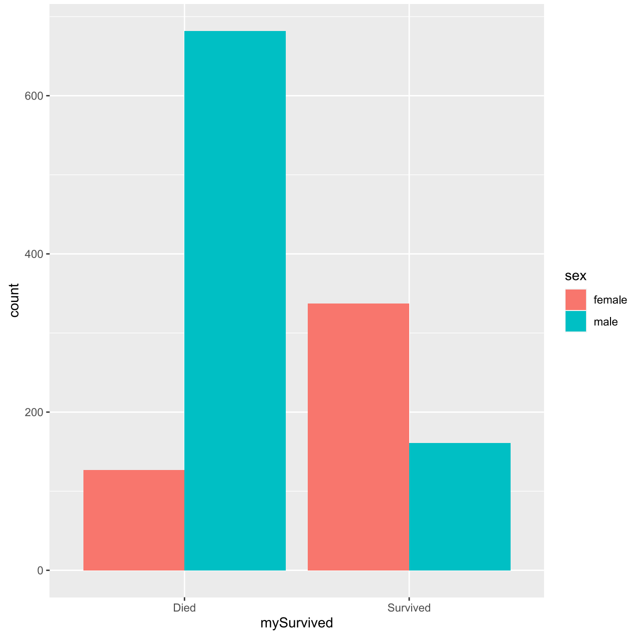
ggplot2 Faceting

Suppose we want to take one of our plots and produce similar plots across another variable!

How to create this plot across each `myEmbarked` category? Use **faceting**!

```
g <- ggplot(data = titanicData, aes(x = mySurvived, fill = sex))
g + geom_bar(position = "dodge")
```



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`ggplot2` Faceting

`facet_wrap(~ var)` - creates a plot for each setting of `var`

- Can specify `nrow` and `ncol` or let R figure it out

`ggplot2` Faceting

`facet_wrap(~ var)` - creates a plot for each setting of `var`

- Can specify `nrow` and `ncol` or let R figure it out

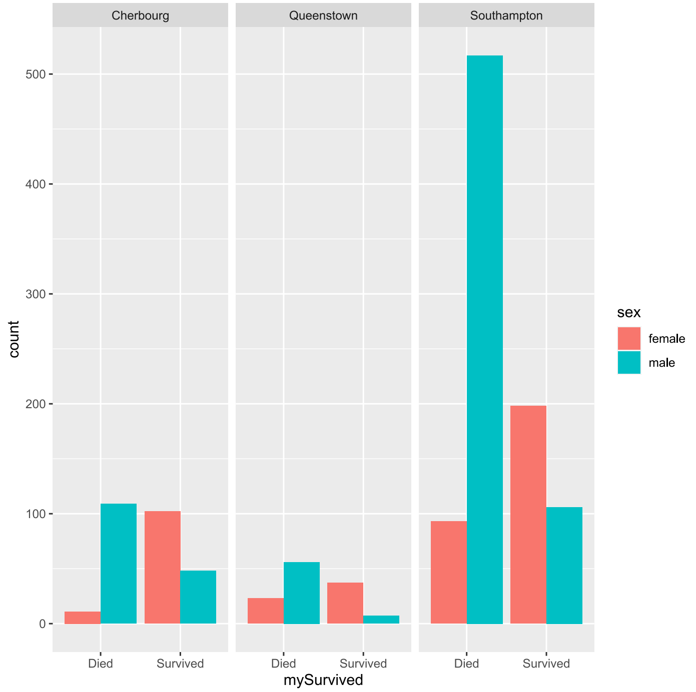
`facet_grid(var1 ~ var2)` - creats a plot for each combination of `var1` and `var2`

- `var1` values across rows
- `var2` values across columns
- Use `. ~ var2` or `var1 ~ .` to have only one row or column

`ggplot2` Faceting

- `facet_wrap(~ var)` - creates a plot for each setting of `var`

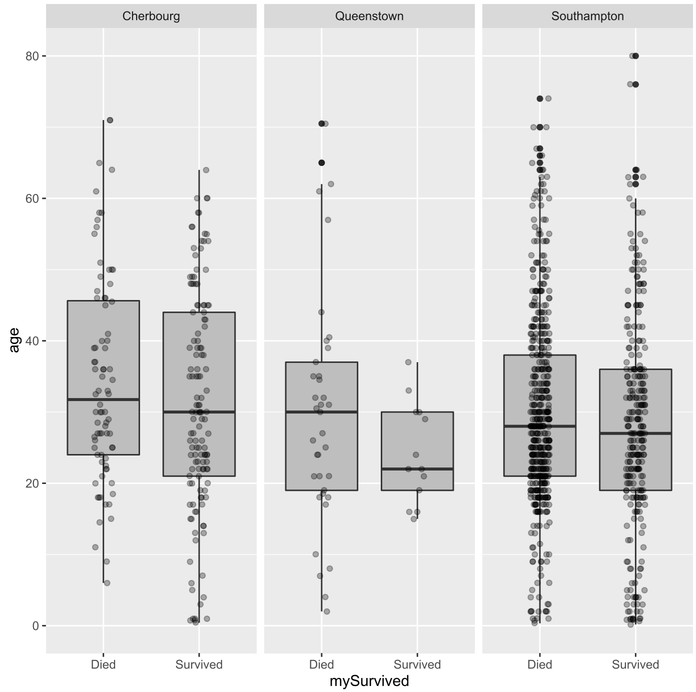
```
g <- ggplot(data = titanicData, aes(x = mySurvived, fill = sex))
g + geom_bar(position = "dodge") +
    facet_wrap(~ myEmbarked)
```



`ggplot2` Faceting

- Faceting can be used with any `ggplot`

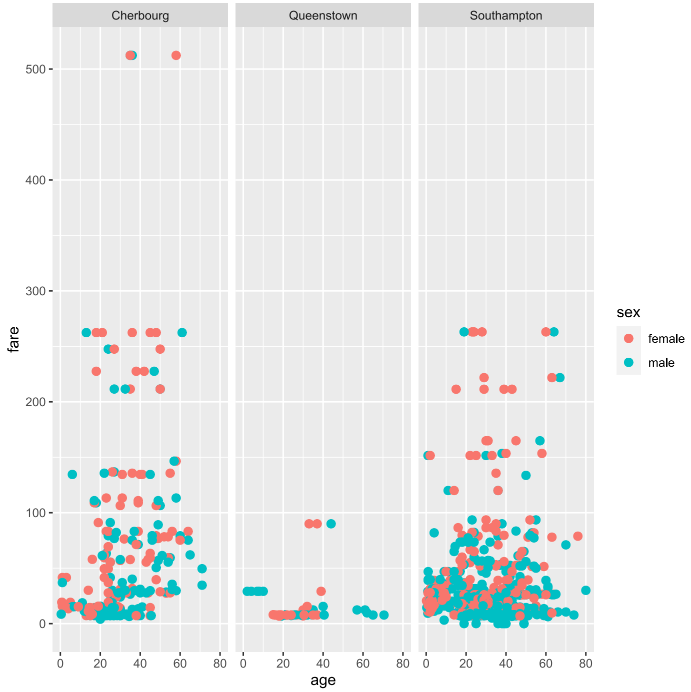
```
g <- ggplot(titanicData, aes(x = mySurvived, y = age))
g + geom_boxplot(fill = "grey") +
    geom_jitter(width = 0.1, alpha = 0.3) +
    facet_wrap(~ myEmbarked)
```



`ggplot2` Faceting

- Faceting can be used with any `ggplot`

```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_point(aes(color = sex), size = 2.5) +
    facet_wrap(~ myEmbarked)
```



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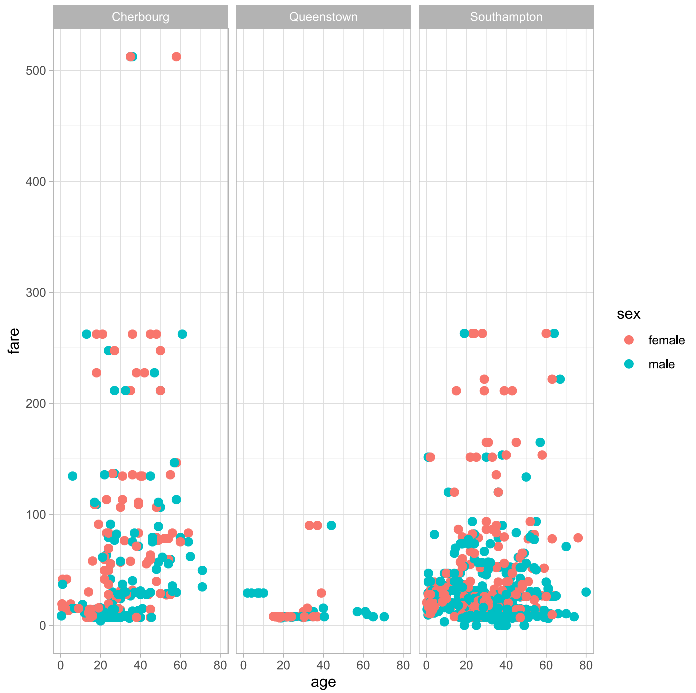
`ggplot2` Themes

- Can easily change the general look of plots using `themes`

```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_point(aes(color = sex), size = 2.5) +
    facet_wrap(~ myEmbarked) +
    theme_light()
```



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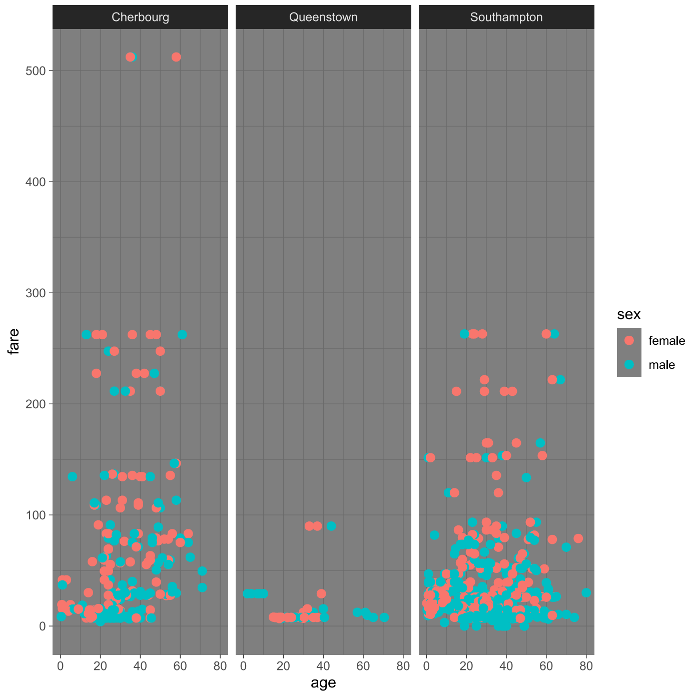
`ggplot2` Themes

- Can easily change the general look of plots using `themes`

```
g <- ggplot(titanicData, aes(x = age, y = fare))
g + geom_point(aes(color = sex), size = 2.5) +
    facet_wrap(~ myEmbarked) +
    theme_dark()
```

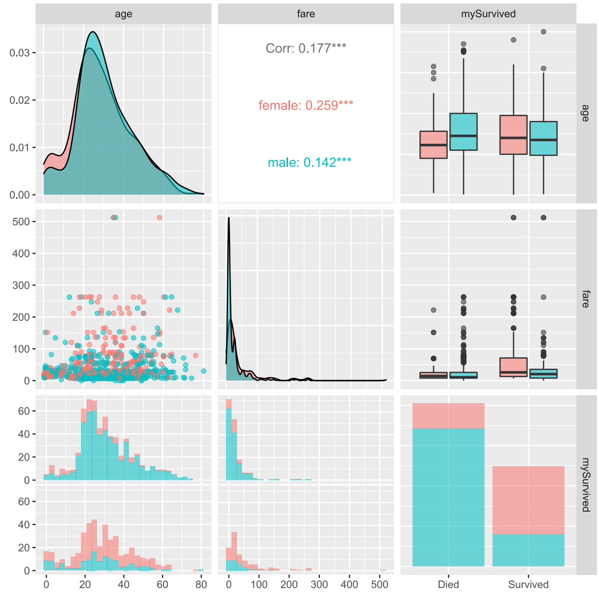


`ggplot2` Extensions

Many extension packages that do nice things!

- `GGally` package has the `ggpairs()` function

```
library(GGally) #install if needed
ggpairs(titanicData, aes(colour = sex, alpha = 0.4), columns = c("age", "fare", "mySurvived"))
```



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`ggplot2` Extensions

Over 100 registered extensions at https://exts.ggplot2.tidyverse.org/!

- `gganimate` package allows for the creation of gifs

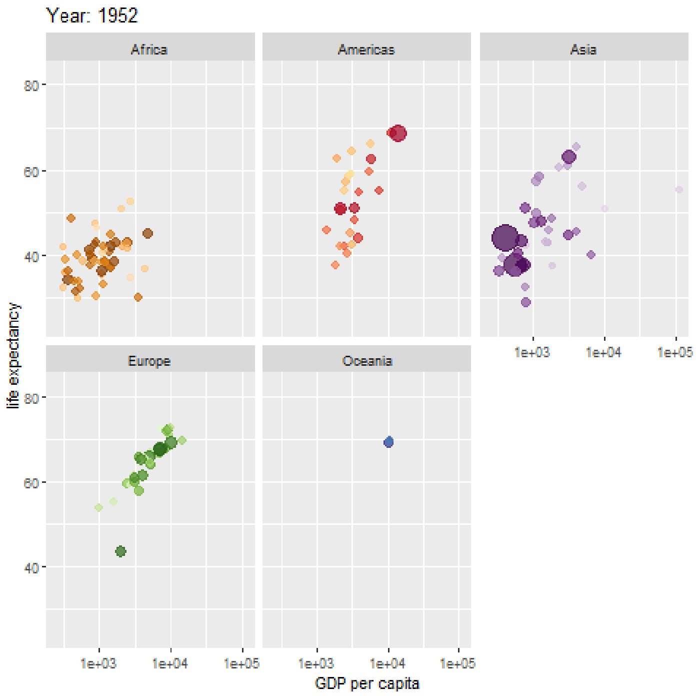
```
#install each if needed
library(gapminder)
library(gganimate)
library(gifski)

gif <- ggplot(gapminder, aes(gdpPercap, lifeExp, size = pop, colour = country)) +
          geom_point(alpha = 0.7, show.legend = FALSE) +
          scale_colour_manual(values = country_colors) +
          scale_size(range = c(2, 12)) +
          scale_x_log10() +
          facet_wrap(~continent) +
          # Here comes the gganimate specific bits
          labs(title = 'Year: {frame_time}', x = 'GDP per capita', y = 'life expectancy') +
          transition_time(year) +
          ease_aes('linear')
anim_save(filename = "img/myGif.gif", animation = gif, renderer = gifski_renderer())
```

`ggplot2` Extensions

Over 100 registered extensions at https://exts.ggplot2.tidyverse.org/!

- `gganimate` package allows for the creation of gifs



Recap!

General `ggplot2` things:

- Can set local or global `aes()`
    - Generally, only need `aes()` if setting a mapping value that is dependent on the data
- Modify titles/labels by adding more layers
- Use either `stat` or `geom` layer
- Faceting (multiple plots) via `facet_grid()` or `facet_wrap()`
- `esquisse` is a great package for exploring ggplot2!

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Let's Practice

We'll add to our `.Rmd` file from the previous activity

- Download the prompts to add to our markdown document here

Guidance:

- Copy and paste the text from above into the bottom of the document, reknit
- Add to the code chunks, evaluating in the notebook
- Reknit occasionally to check the output