Data Visualization with *ggplot2*

INFO 201

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https://slides.com/joelross/info201w17-ggplot2/live

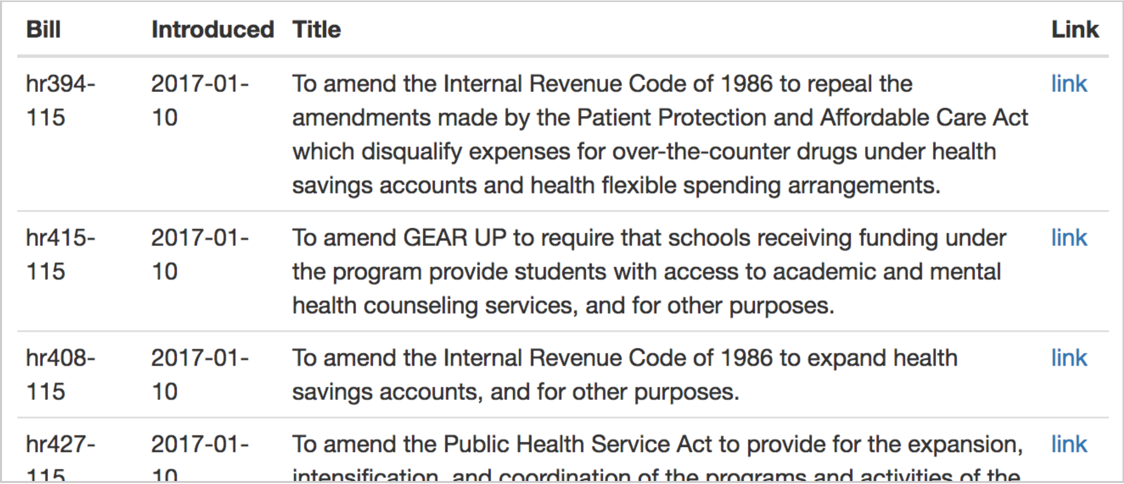
Today's Objectives

By the end of class, you should be able to

- Describe visualizations using the **Grammar of Graphics**
- Use **ggplot2** to draw beautiful data charts

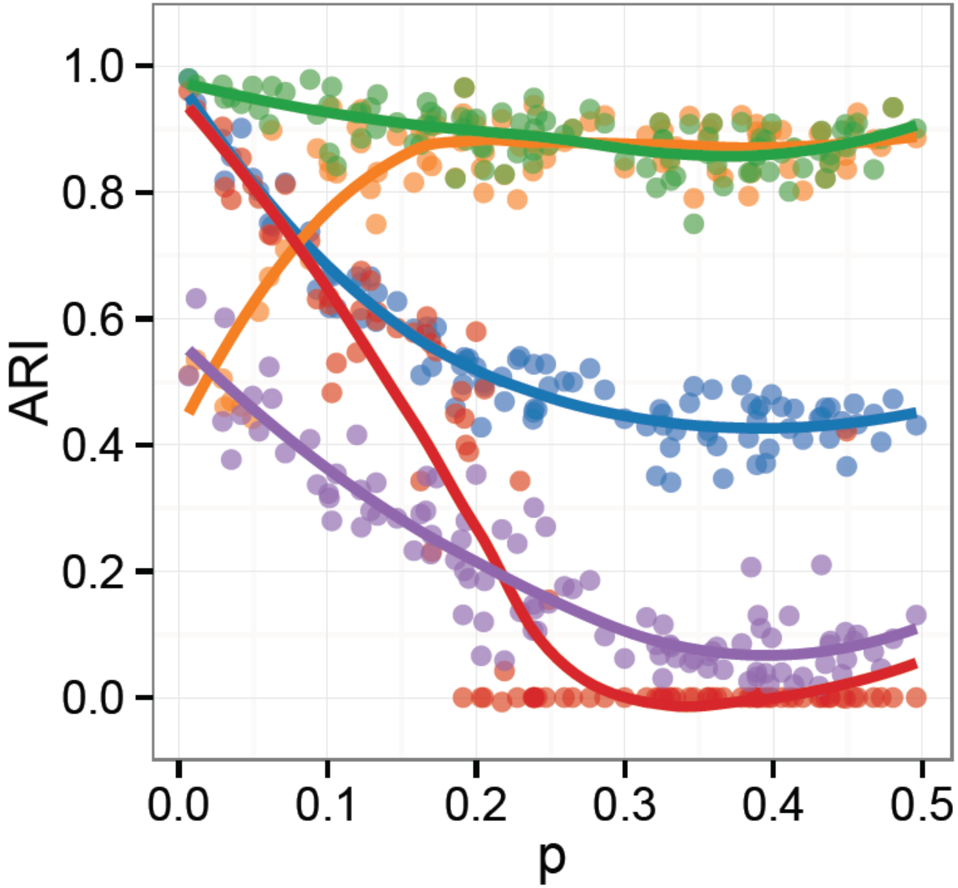
Why create graphical visualizations of data?

What's wrong with tables?



Bill	Introduced	Title	Link
hr394-115	2017-01-10	To amend the Internal Revenue Code of 1986 to repeal the amendments made by the Patient Protection and Affordable Care Act which disqualify expenses for over-the-counter drugs under health savings accounts and health flexible spending arrangements.	link
hr415-115	2017-01-10	To amend GEAR UP to require that schools receiving funding under the program provide students with access to academic and mental health counseling services, and for other purposes.	link
hr408-115	2017-01-10	To amend the Internal Revenue Code of 1986 to expand health savings accounts, and for other purposes.	link
hr427-115	2017-01-10	To amend the Public Health Service Act to provide for the expansion, intensification, and coordination of the programs and activities of the	link

How would you describe this chart?



RECALL

Grammar of Data Manipulation

Words (***verbs***) used to describe ways to manipulate data:

- **Select** the columns of interest
- **Filter** out irrelevant data to keep rows of interest
- **Mutate** a data set by adding more columns
- **Arrange** the rows in a data set
- **Summarize** the data (e.g., *mean*, *median*, *max*)
- **Group** the data by category
- **Join** multiple data sets together

Grammar of Graphics

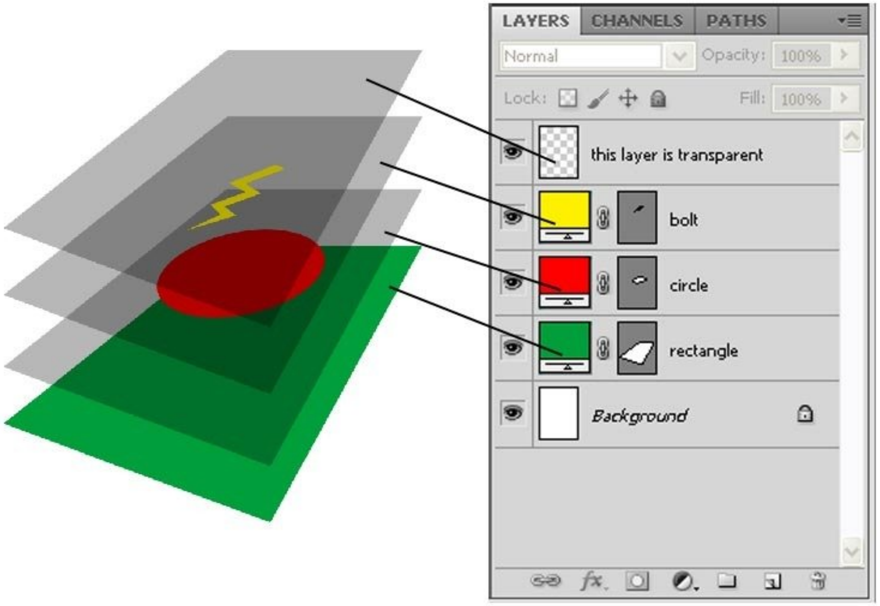
Words used to describe the visual components and aspects of a graphic.

- **Data** shown in the plot
- **Geometric objects (geoms)** that appear on the plot
- **Aesthetic mappings** from the data to the **geoms**
- **Statistical transformation** used to calculate the data
- **Scales** (range of values) for each **aesthetic**
- **Coordinate system** to organize the **geoms**
- **Facets** or groups of data shown in different plots

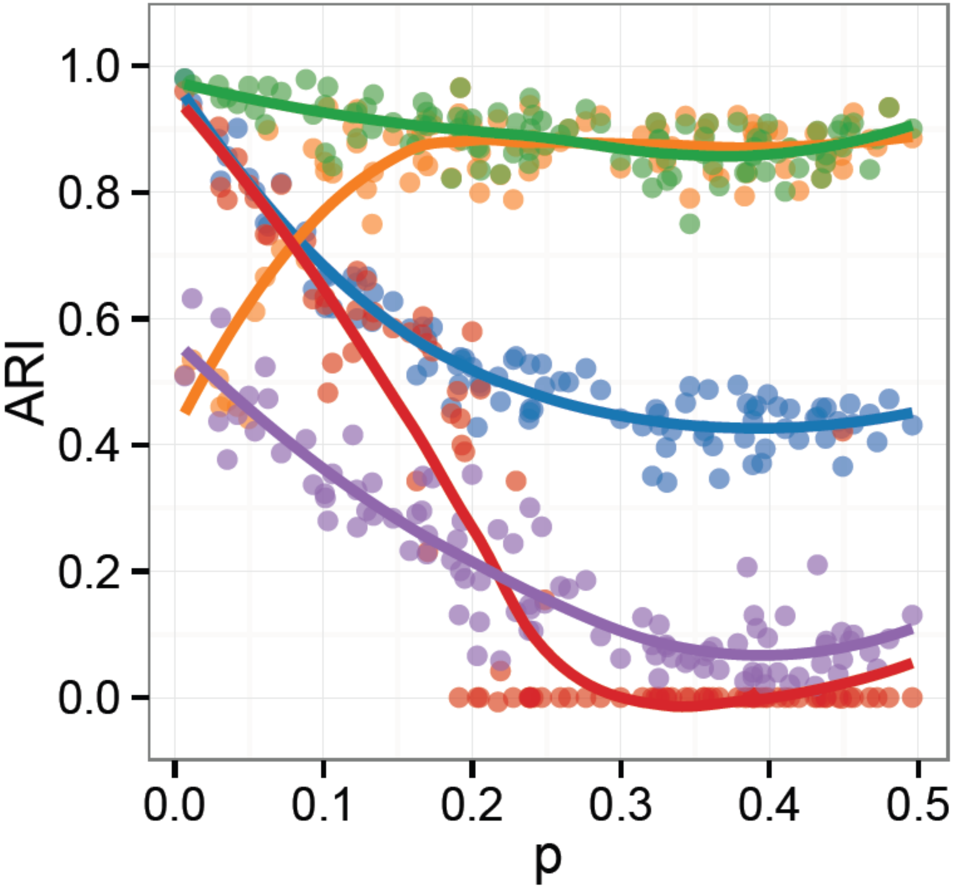
Layers

Organize plots into **layers**, where each layer has:

- A **geometric object**
- A set of **aesthetic mappings**
- A **statistical transformation**
- A **position adjustment**



How to describe with Grammar of Graphics?



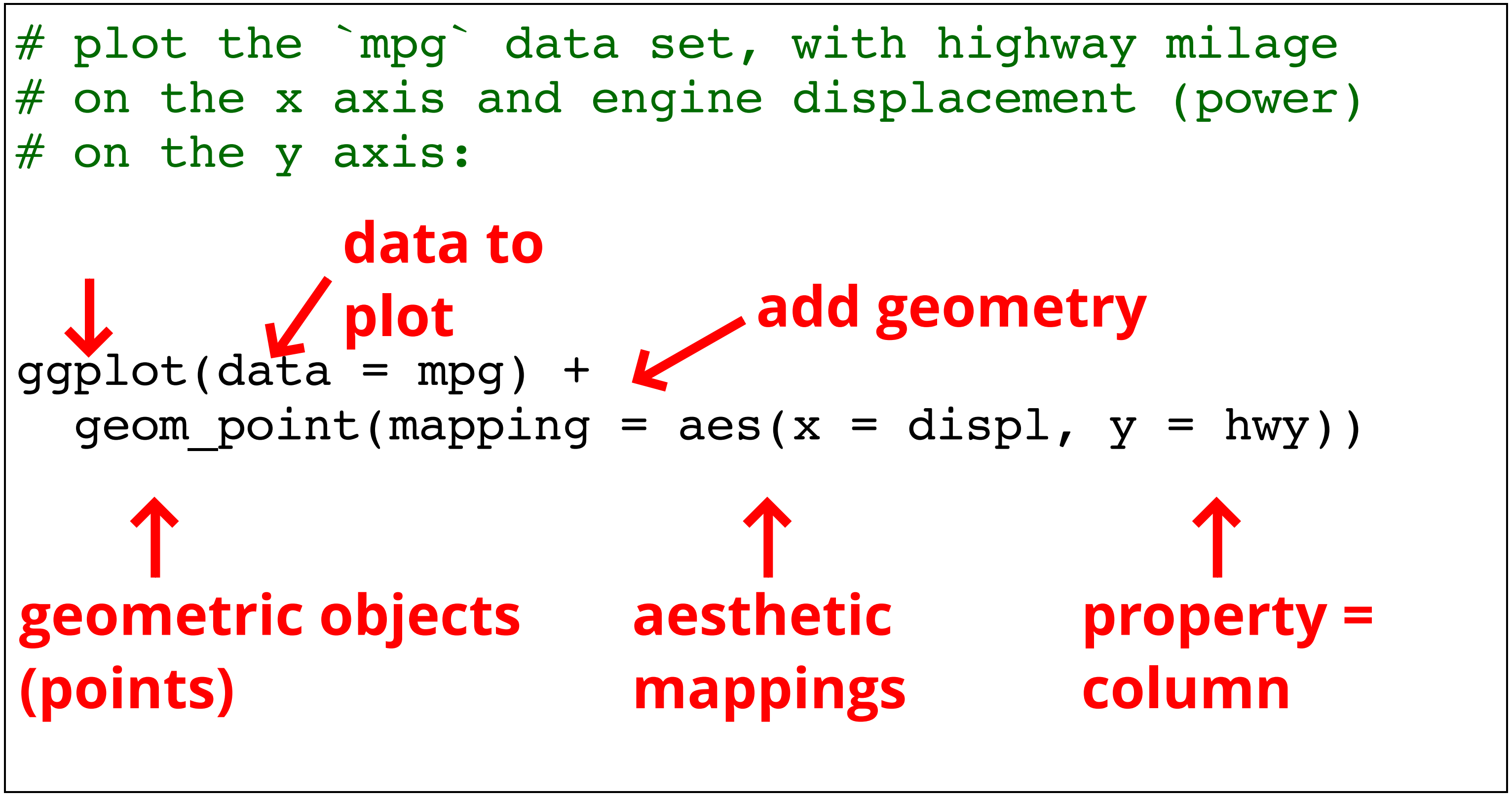
ggplot2

ggplot2 is an R package (library) that implements this Grammar of Graphics.
It provides ***declarative functions*** for specifying plots in terms of the grammar.

```r
install.packages("ggplot2")  # once per machine
library("ggplot")  # load the package
```

Plotting with ggplot2

Use the `ggplot()` function to draw a plot, specifying plot elements via the grammar.



```
# plot the `mpg` data set, with highway milage
# on the x axis and engine displacement (power)
# on the y axis:

ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

data to plot

add geometry

geometric objects (points)

aesthetic mappings

property = column

Aesthetics

The `aes()` function specifies *aesthetic* mappings from data values to **visual channels**.

```
# color the data by car type
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy, color = class))
```

x-location based on *displ* column (continuous)

color based on *class* column (discrete)

Can also **set** visual channels without mapping

```
# blue points!
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy), color = "blue")
```

Geoms

ggplot2 supports many different **geoms**, each created with a **function**. Each geom requires/supports different **aesthetics**.

```
# line chart of milage by engine power
ggplot(data = mpg) +
  geom_line(mapping = aes(x = displ, y = hwy))

# bar chart of car type
ggplot(data = mpg) +
  geom_bar(mapping = aes(x = class))
```

no y mapping, automatically aggregated

Each plot can include multiple **geoms**, which *inherit* data and aesthetics unless specified otherwise.

```
ggplot(data = mpg, mapping = aes(x = displ, y = hwy)) +
  geom_point() +
  geom_smooth(se=FALSE)
```

Module 13 exercise-1

FORK and clone the repo
to turn in for participation

Grammar of Graphics

RECALL

Words used to describe the visual components and aspects of a graphic.

- ✓ **Data** shown in the plot
- ✓ **Geometric objects (geoms)** that appear on the plot
- ✓ **Aesthetic mappings** from the data to the **geoms**
- **Statistical transformation** used to calculate the data
- **Scales** (range of values) for each **aesthetic**
- **Coordinate system** to organize the **geoms**
- **Facets** or groups of data shown in different plots

Statistical Transformation

Many **geoms** have a *default* **statistical transformation** used to calculate *new* data to plot (e.g., for bar graphs).

```
# bar chart of car type
ggplot(data = mpg) +
  geom_bar(mapping = aes(x = class), stat="count")
```

explicit "count" for y

Each **geom** is associated with a **stat_** function, and can be used interchangeably.

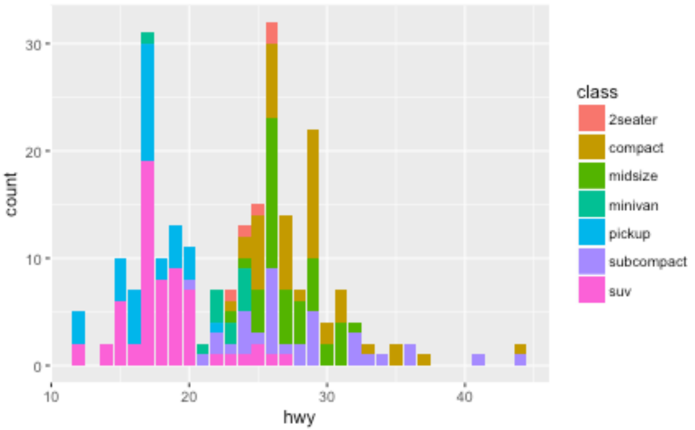
```
# these two charts are identical
ggplot(data = mpg) +
  geom_bar(mapping = aes(x = class))

ggplot(data = mpg) +
  stat_count(mapping = aes(x = class))
```

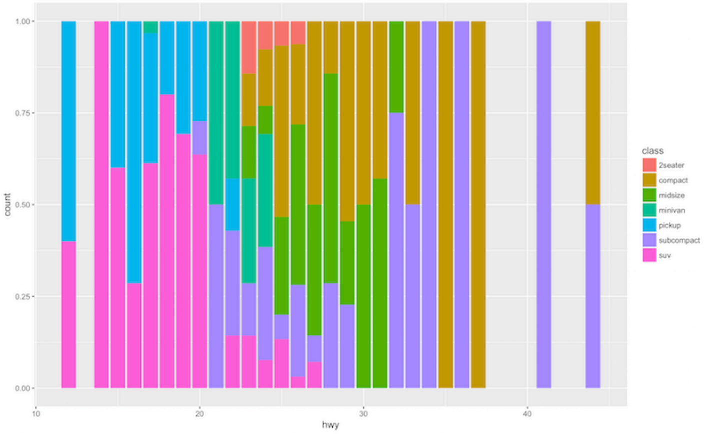
Position Adjustment

Many **geoms** have a *default* **position adjustment** use to lay out the plot separate from the aesthetic mappings

```
# bar chart of milage, colored by car type
ggplot(data = mpg) +
  geom_bar(mapping = aes(x = hwy, fill = class))
```



```
# bar chart of milage, colored by car type
ggplot(data = mpg) +
  geom_bar(aes(x=hwy, fill=class), position="fill")
```



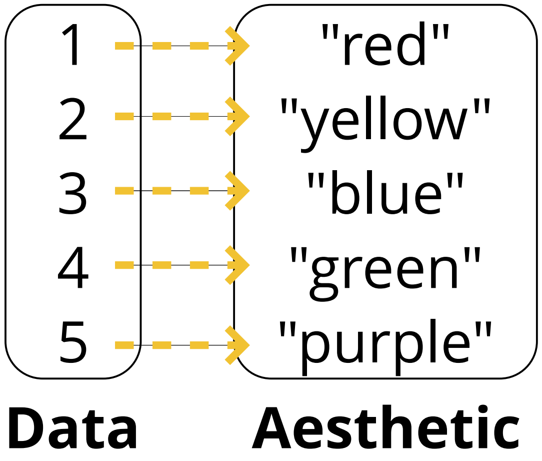
Scales

Add **scales** to a plot to determine the *range of (aesthetic) values* data should map to (replacing the default)

```
# city/highway milage relationship
ggplot(data = mpg) +
  geom_point(mapping = aes(x = cty, y = hwy, color = class)) +
  scale_x_reverse() +  # reverse x axis
  scale_color_hue(l = 70, c = 30)  # custom color scale
```

aesthetic to scale

scale to use



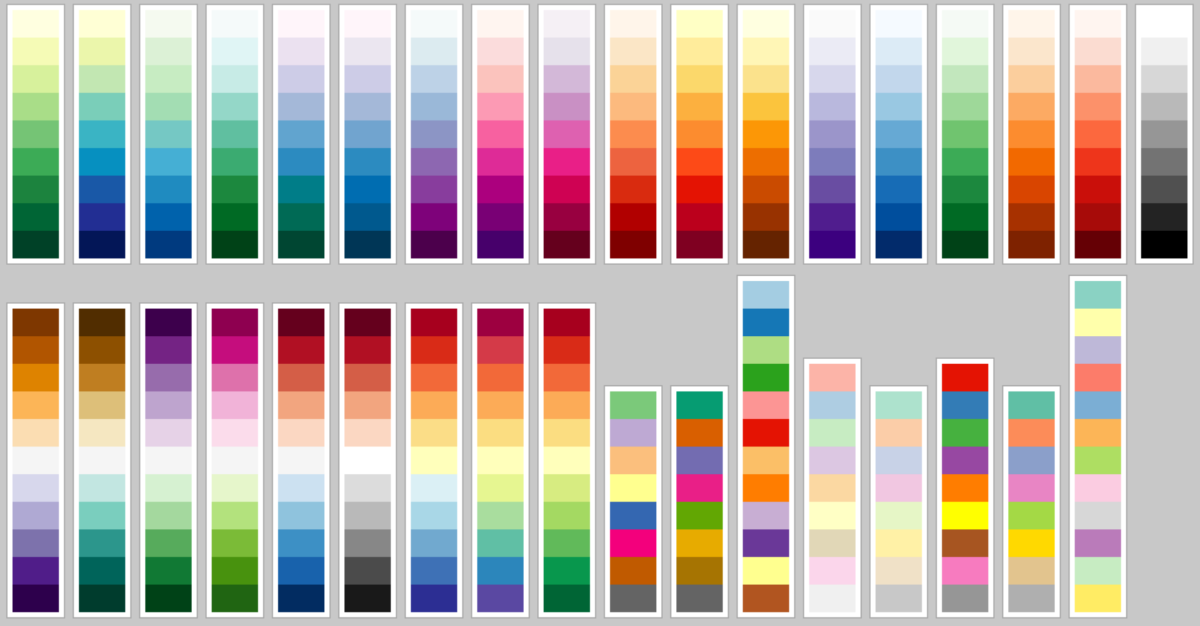
1 "red"
2 "yellow"
3 "blue"
4 "green"
5 "purple"

Data **Aesthetic**

ColorBrewer Scales

Use palettes from **colorbrewer.org** to specify color schemes that are ***color-bind safe***.

```
# efficiency by engine size, colored nicely
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy, color = class), size=4) +
  scale_color_brewer(palette = "Set3")
```



Coordinate System

You can also add a specific **coordinate system** to a plot.

```
# horizontal bar chart of milage, colored by car type
ggplot(data = mpg) +
  geom_bar(mapping = aes(x = hwy, fill = class)) +
  coord_flip()
```

```
# A pie chart = stacked bar chart + polar coordinates
ggplot(mpg, aes(x = factor(1), fill = factor(cyl))) +
  geom_bar(width = 1) +
  coord_polar(theta = "y")
```

make numeric vector into factor

angle based on (aggregate) "y"

Facets

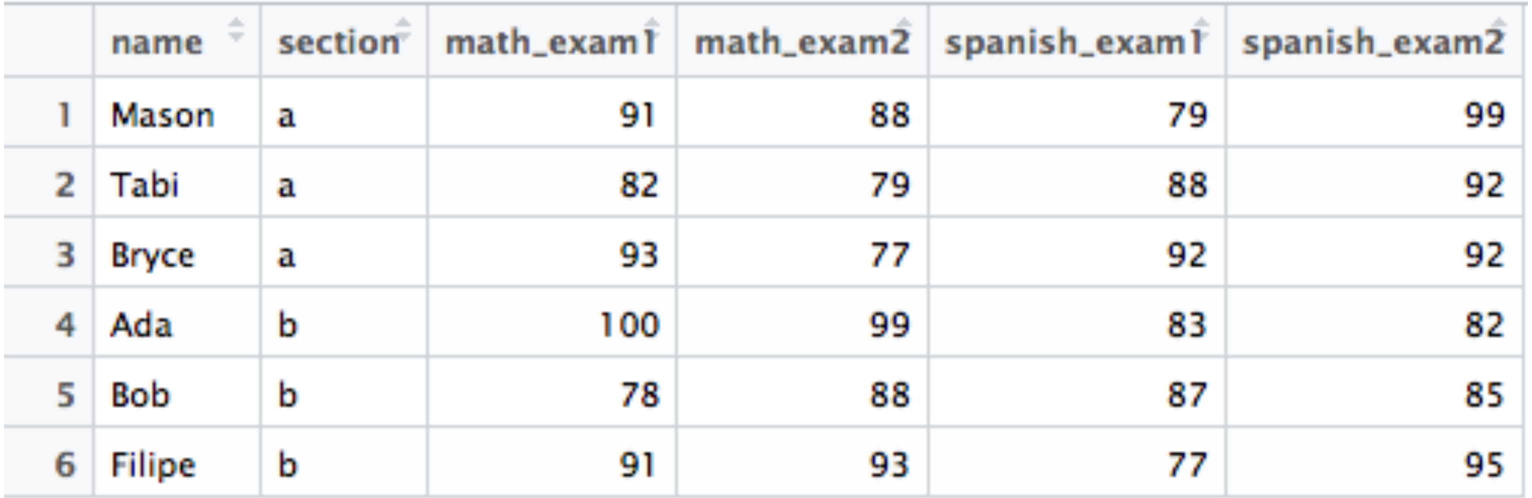
Break a plot into parts with **facets** (similar to `group_by()` in `dplyr`). Each facet acts like a "level" in a factor, with a plot for each level.

```
# a plot with facets based on vehicle type.
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy)) +
  facet_wrap(~class)
```

A **formula** , read as

"as a function of"

Module 13 exercise-2

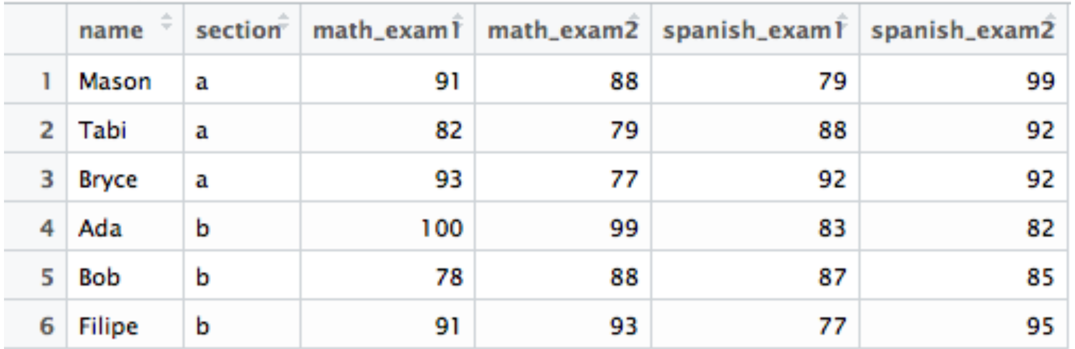


	name	section	math_exam1	math_exam2	spanish_exam1	spanish_exam2
1	Mason	a	91	88	79	99
2	Tabi	a	82	79	88	92
3	Bryce	a	93	77	92	92
4	Ada	b	100	99	83	82
5	Bob	b	78	88	87	85
6	Filipe	b	91	93	77	95

What if we want to **facet** by exam?

Data Shape

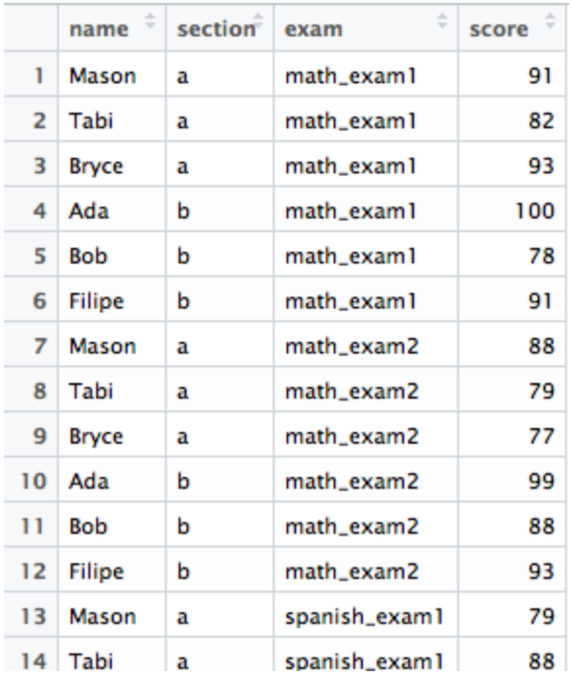
Wide Data



	name	section	math_exam1	math_exam2	spanish_exam1	spanish_exam2
1	Mason	a	91	88	79	99
2	Tabi	a	82	79	88	92
3	Bryce	a	93	77	92	92
4	Ada	b	100	99	83	82
5	Bob	b	78	88	87	85
6	Filipe	b	91	93	77	95

6 rows x 4 cols
= 24 scores

Long Data



	name	section	exam	score
1	Mason	a	math_exam1	91
2	Tabi	a	math_exam1	82
3	Bryce	a	math_exam1	93
4	Ada	b	math_exam1	100
5	Bob	b	math_exam1	78
6	Filipe	b	math_exam1	91
7	Mason	a	math_exam2	88
8	Tabi	a	math_exam2	79
9	Bryce	a	math_exam2	77
10	Ada	b	math_exam2	99
11	Bob	b	math_exam2	88
12	Filipe	b	math_exam2	93
13	Mason	a	spanish_exam1	79
14	Tabi	a	spanish_exam1	88

24 rows x 1 col
= 24 scores

Data Shape

We can convert between **wide** and **long** data (and vice versa) using the `tidyr` package.

```r
# Alternatively, install "tidyverse"
install.packages("tidyr")  # once per machine
library("tidyr")



# Make a data.frame (example)
students <- data.frame(
  name = c('Mason', 'Tabi', 'Bryce', 'Ada', 'Bob','Filipe'),
  section = c('a','a','a','b','b','b'),
  math_exam1 = c(91, 82, 93, 100, 78, 91),
  math_exam2 = c(88, 79, 77, 99, 88, 93),
  spanish_exam1 = c(79, 88, 92, 83, 87, 77),
  spanish_exam2 = c(99, 92, 92, 82, 85, 95)
)
```

http://tidyr.tidyverse.org/

http://tidyverse.org/

Data Shape

Convert from **wide** to **long** using `gather()`. The **key** is a new column containing *gathered colnames*, and **value** is a new column with their values.

```
students.long <- gather(students.wide,
                        key = exam,
                        value = score,
                        math_exam1, math_exam2,
                        spanish_exam1, spanish_exam2
                       )
```

names for new columns

col data to populate with

Convert from **long** to **wide** using `spread()`. The **key** is where to get the *new colnames*, and **value** is where to get the values

```
# spread by column "exam"
stu.wide <- spread(students.long, key = exam, value = score)

# spread by column "name"
stu.wide.name <-
        spread(students.long, key = name, value = score)
```

Questions on anything so far?

Action Items!

- Be comfortable with **module 13**
- Assignment 5 due ***Thursday before class***
    - (Assignment 6 online soon)

Thursday: What makes a good visualization?
Also maps.