1.3 — Data Visualization with ggplot2

ECON 480 • Econometrics • Fall 2020

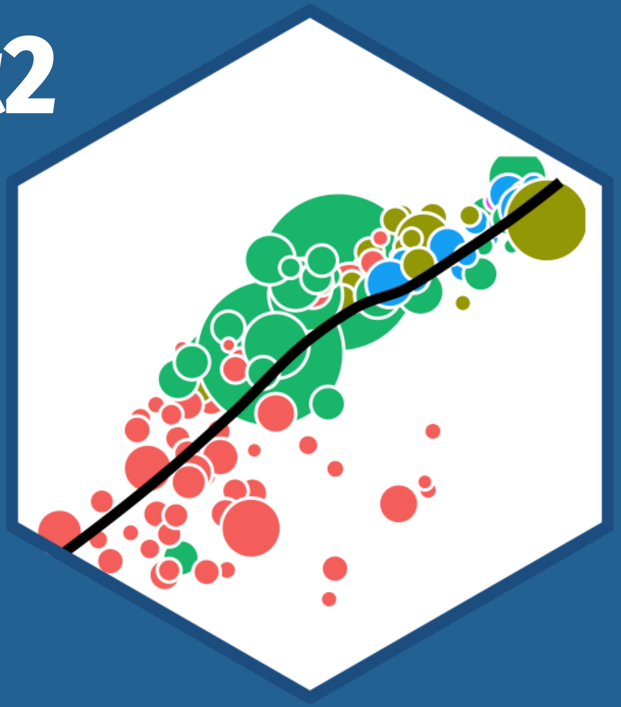
Ryan Safner

Assistant Professor of Economics

safner@hood.edu

[ryansafner/metricsF20](https://github.com/ryansafner/metricsF20)

metricsF20.classes.ryansafner.com



Outline

Graphics and Statistics

- Admittedly, we still need to cover basic descriptive statistics and data fundamentals
    - continuous, discrete, cross-sectional, time series, panel data
    - mean, median, variance, standard deviation
    - random variables, distributions, PDFs, Z-scores
    - bargraphs, boxplots, histograms, scatterplots
- All of this is coming in 2 weeks as we return to statistics and econometric theory
- But let's start with the fun stuff right away, even if you don't fully know the *reasons*: **data visualiation**

Plotting in Base R

Our Data Source

- For our examples, we'll use a dataset `mpg` from the `ggplot2` library

```r
library(ggplot2)

head(mpg)
```

```
## # A tibble: 6 x 11
##   manufacturer model displ  year   cyl trans      drv     cty   hwy fl    class
##   <chr>        <chr> <dbl> <int> <int> <chr>      <chr> <int> <int> <chr> <chr>
## 1 audi         a4      1.8  1999     4 auto(l5)   f        18    29 p     compa…
## 2 audi         a4      1.8  1999     4 manual(m5) f        21    29 p     compa…
## 3 audi         a4      2    2008     4 manual(m6) f        20    31 p     compa…
## 4 audi         a4      2    2008     4 auto(av)   f        21    30 p     compa…
## 5 audi         a4      2.8  1999     6 auto(l5)   f        16    26 p     compa…
## 6 audi         a4      2.8  1999     6 manual(m5) f        18    26 p     compa…
```

Plotting in Base R

- Base `R` is very powerful and intuitive to plot, but not very sexy
- Basic syntax for most types of plots:

```
plot_type(my_df$variable)
```

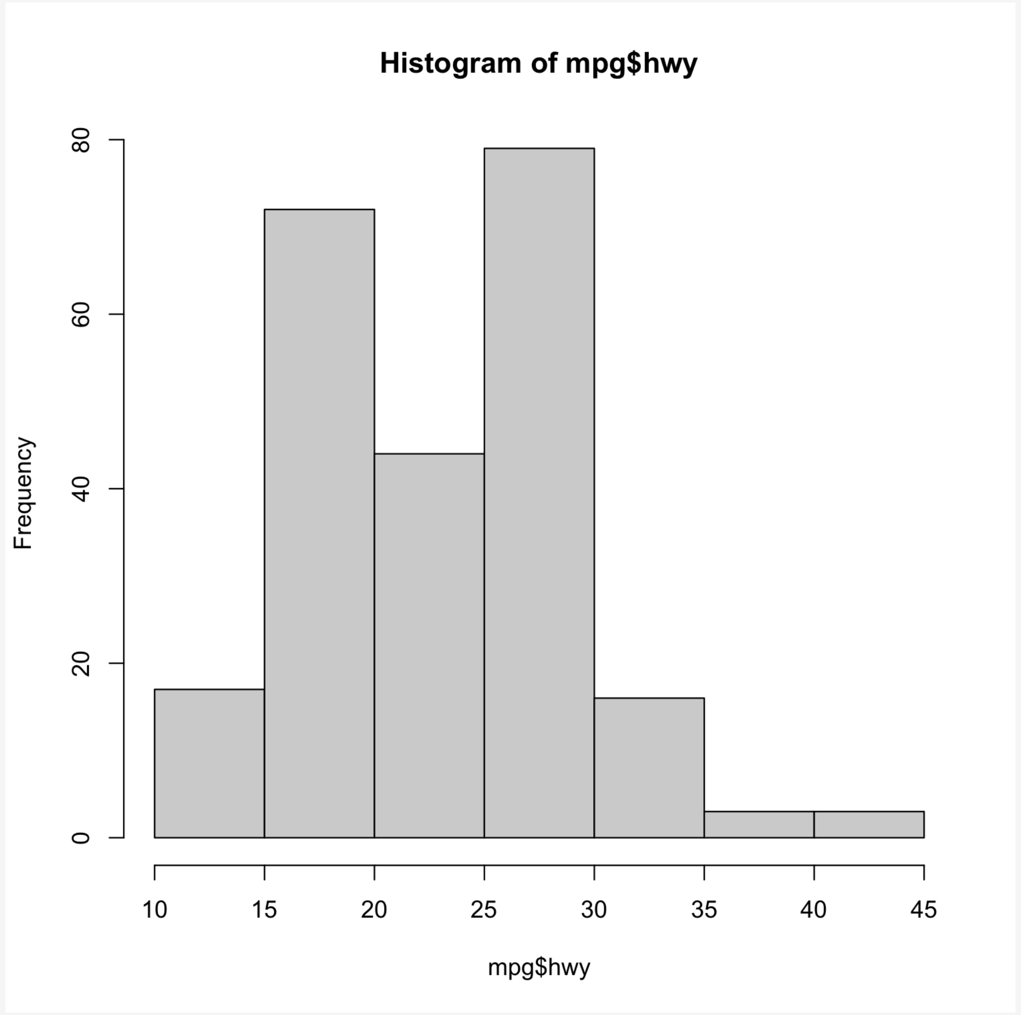
- If using multiple variables, you can avoid typing `$` by just typing the variable names and then in another argument to the plotting function, specify `data = my_df`

```
plot_type(my_df$variable1, my_df$variable2, data = my_df)
```

Plotting in Base R: Histogram

- Using the `mpg` data, plotting a **histogram** of `hwy`

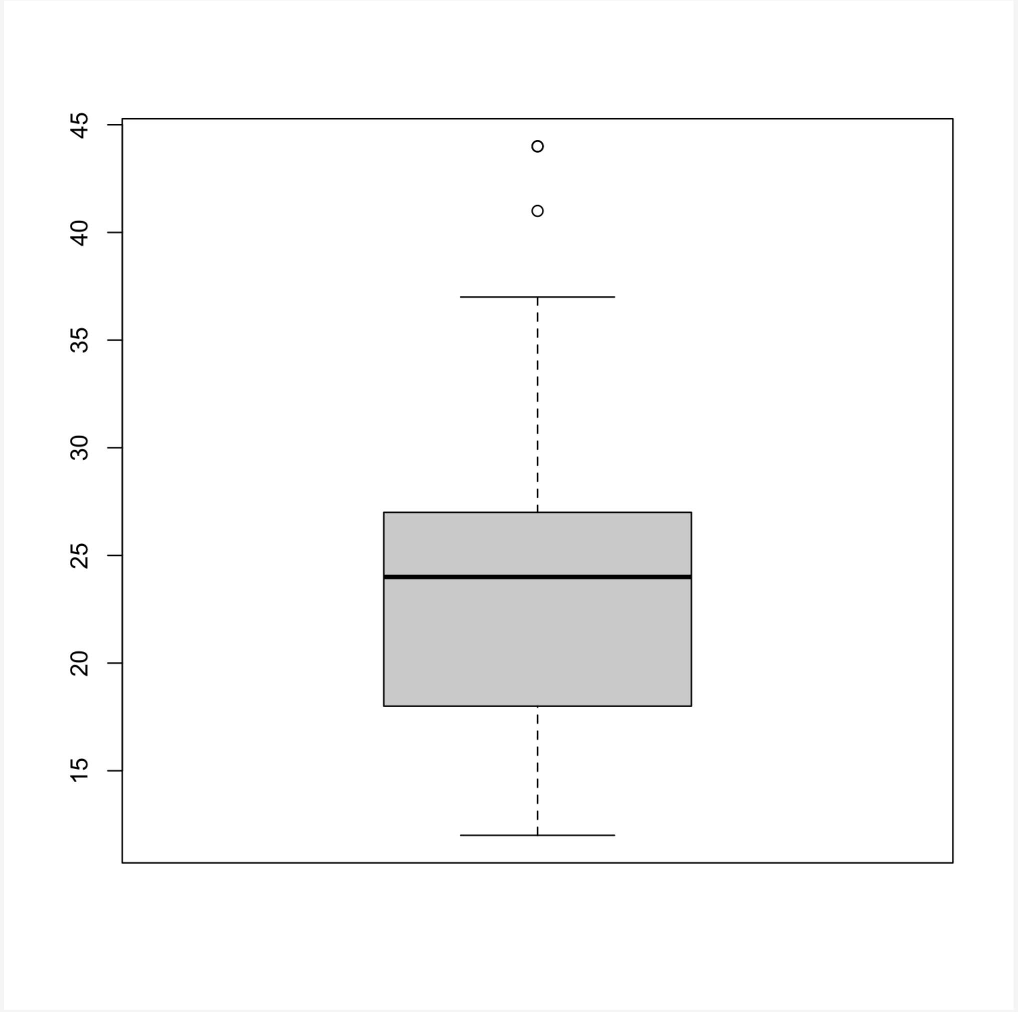
```
hist(mpg$hwy)
```



Plotting in Base R: Boxplot

- Using the `mpg` data, plotting a **boxplot** of `hwy`

```
boxplot(mpg$hwy)
```



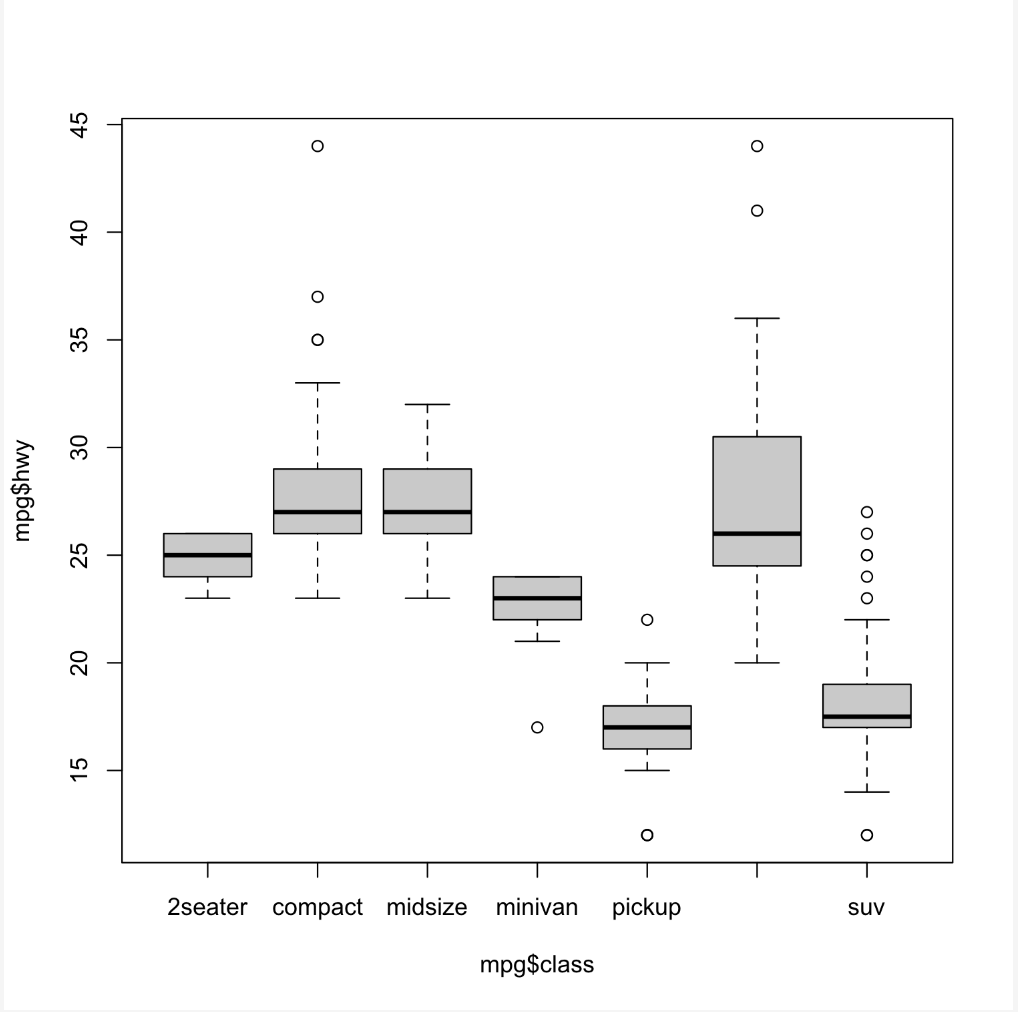
Plotting in Base R: Boxplot by Category

- Using the `mpg` data, plotting a **boxplot** of `hwy` **by** `class`

```
boxplot(mpg$hwy ~ mpg$class)
```

```
# second method
boxplot(mpg ~ class, data = mtcars)
```

- The `~` is part of `R`'s **"formula notation"**:
  - Dependent variable goes to left
  - Independent variable(s) to right, separated with `+`'s
  - Think `y~x+z` means "`y` is explained by `x` and `z`"

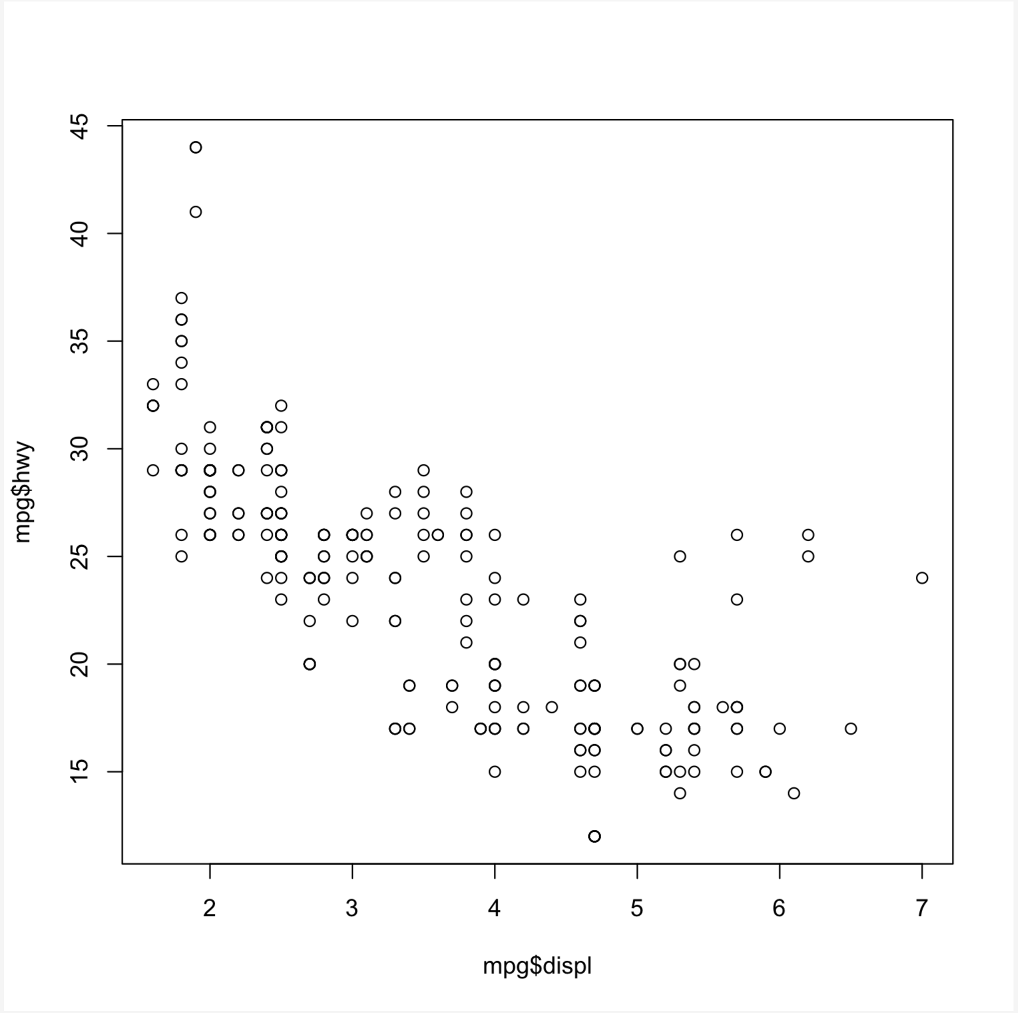


Plotting in Base R: Scatterplot

- Using the `mpg` data, plotting a **scatterplot** of `hwy` against `displ`

```r
plot(mpg$hwy ~ mpg$displ)
```

```r
# second method
plot(hwy ~ displ, data = mpg)
```



ggplot2 and the tidyverse

tidyverse

The tidyverse

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

- Largely (but not only) created by Hadley Wickham
- We will look at this much more extensively next week!
- This "flavor" of R will make your coding life *so much easier!*

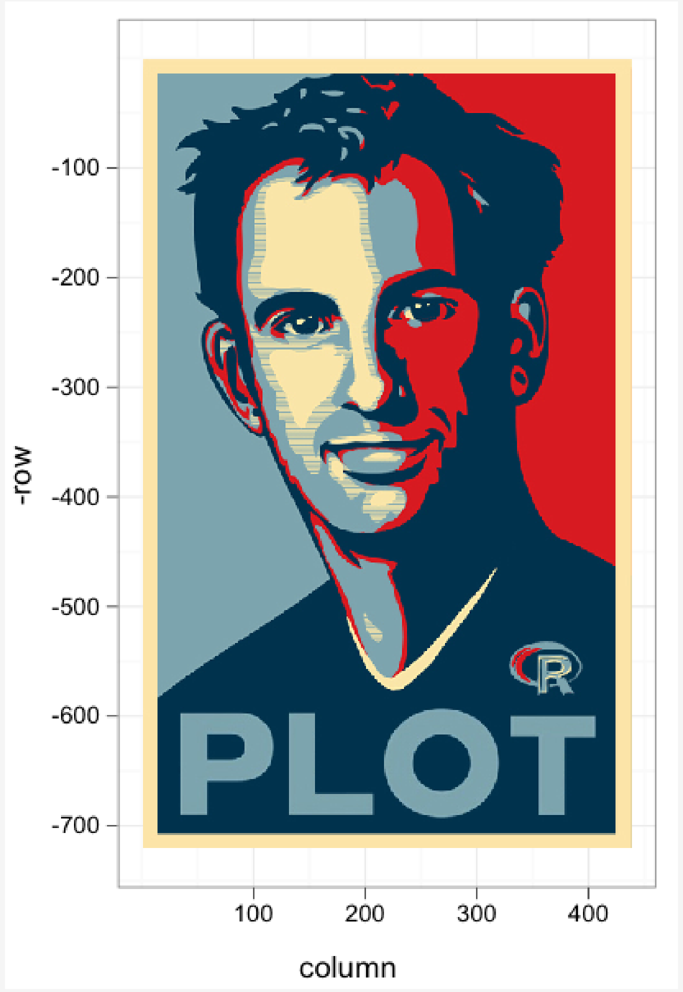
ggplot

- `ggplot2` is perhaps the most popular package in `R` and a core element of the `tidyverse`

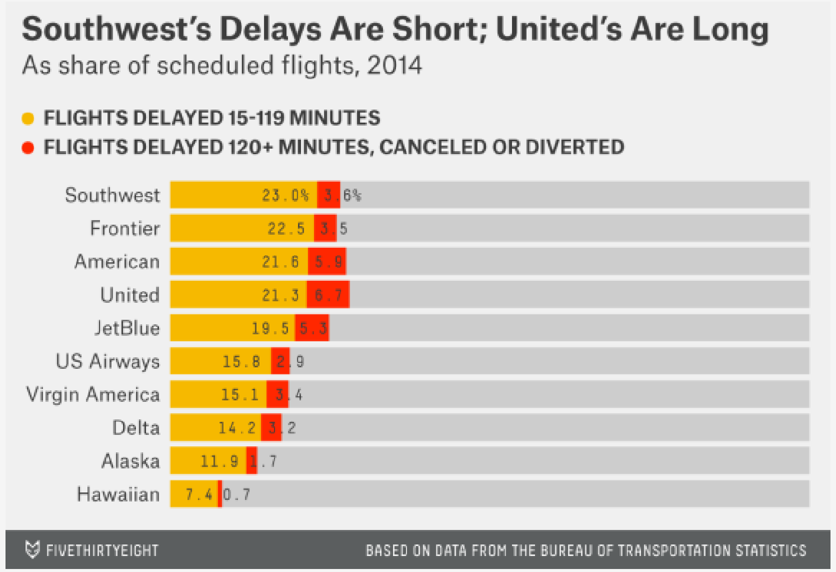
- `gg` stands for a **grammar of graphics**

- Very powerful and beautiful graphics, very customizable and reproducible, but requires a bit of a learning curve

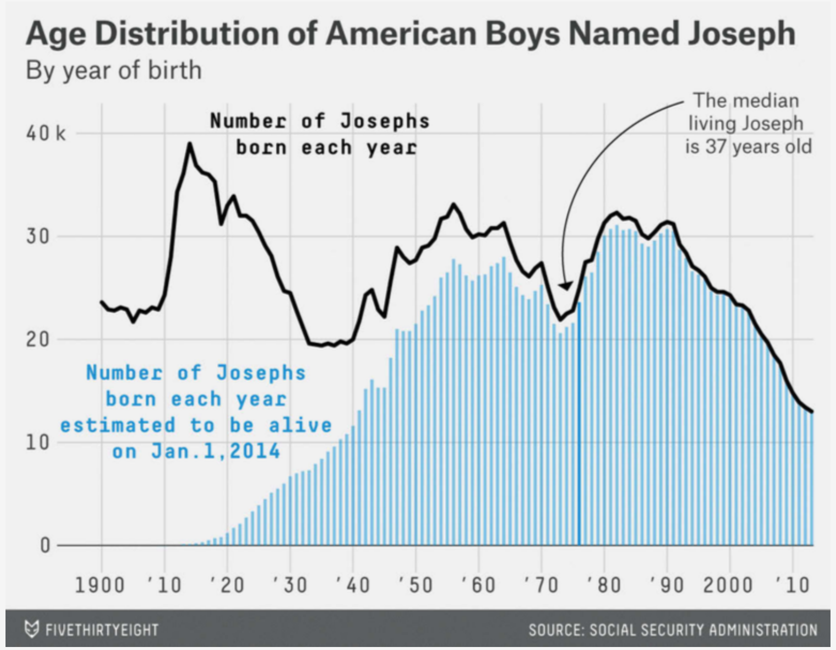
- All those "cool graphics" you've seen in the New York Times, fivethirtyeight, the Economist, Vox, etc use the grammar of graphics



ggplot: All Your Figure are Belong to Us

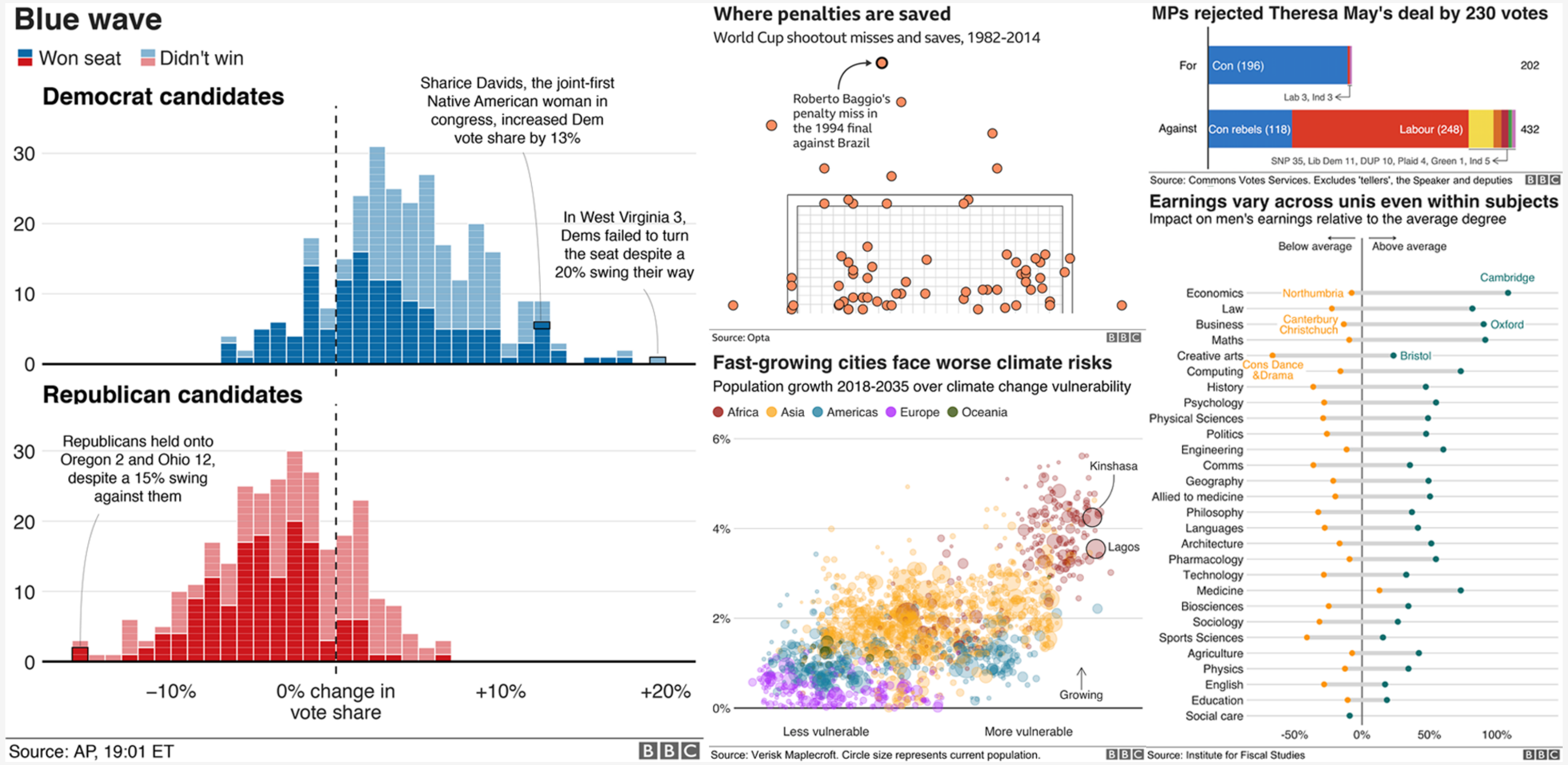


Source: fivethirtyeight



Source: fivethirtyeight

ggplot: All Your Figure are Belong to Us



Source: BBC's bbplot

Why Go gg?

Hadley Wickham

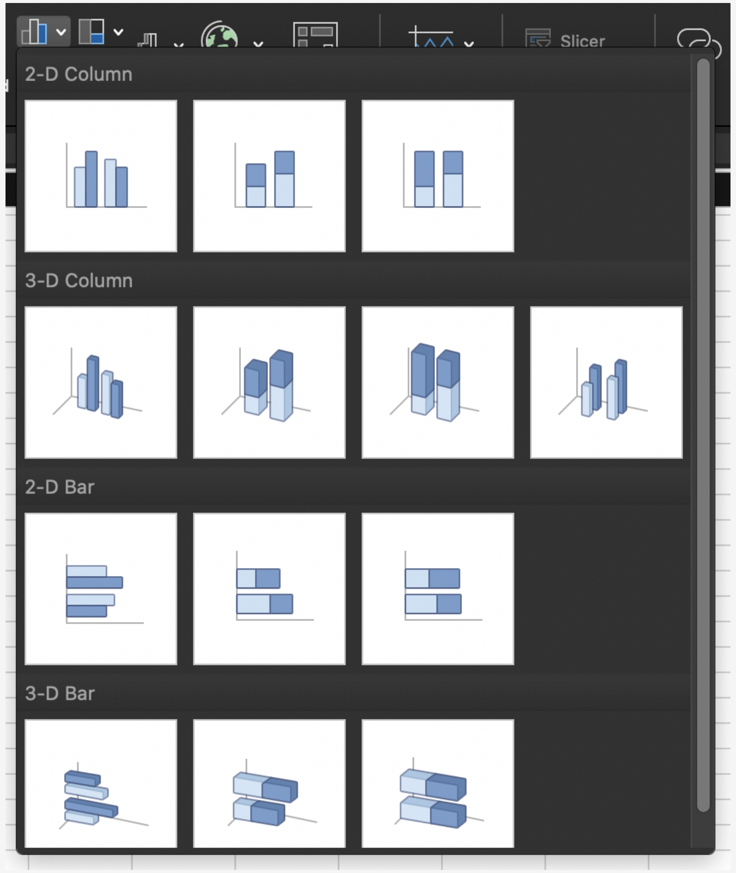
Chief Scientist, R Studio

> "The transferrable skills from ggplot2 are not the idiosyncracies of plotting syntax, but a powerful way of thinking about visualisation, as a way of **mapping between variables and the visual properties of geometric objects** that you can perceive."

http://disq.us/p/sv640d

The Grammar of Graphics (gg)

- This is a true *grammar*
- We *don't* talk about specific chart **types**
    - That you have to hunt through in Excel and reshape your data to fit it
- Instead we talk about specific chart **components**

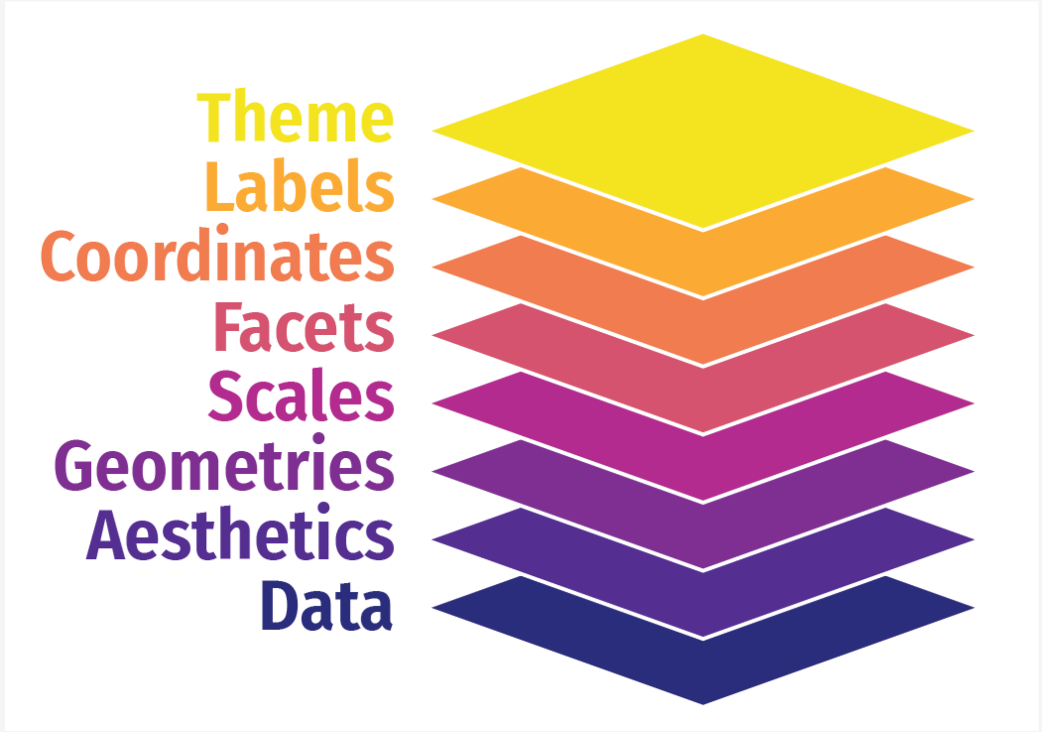


The Grammar of Graphics (gg) I

- Any graphic can be built from the same components:

  1. **Data** to be drawn from
  2. **Aesthetic mappings** from data to some visual marking
  3. **Geometric objects** on the plot
  4. **Scales** define the range of values
  5. **Coordinates** to organize location
  6. **Labels** describe the scale and markings
  7. **Facets** group into subplots
  8. **Themes** style the plot elements

- Not every plot needs *every* component, but all plots *must* have the first 3!

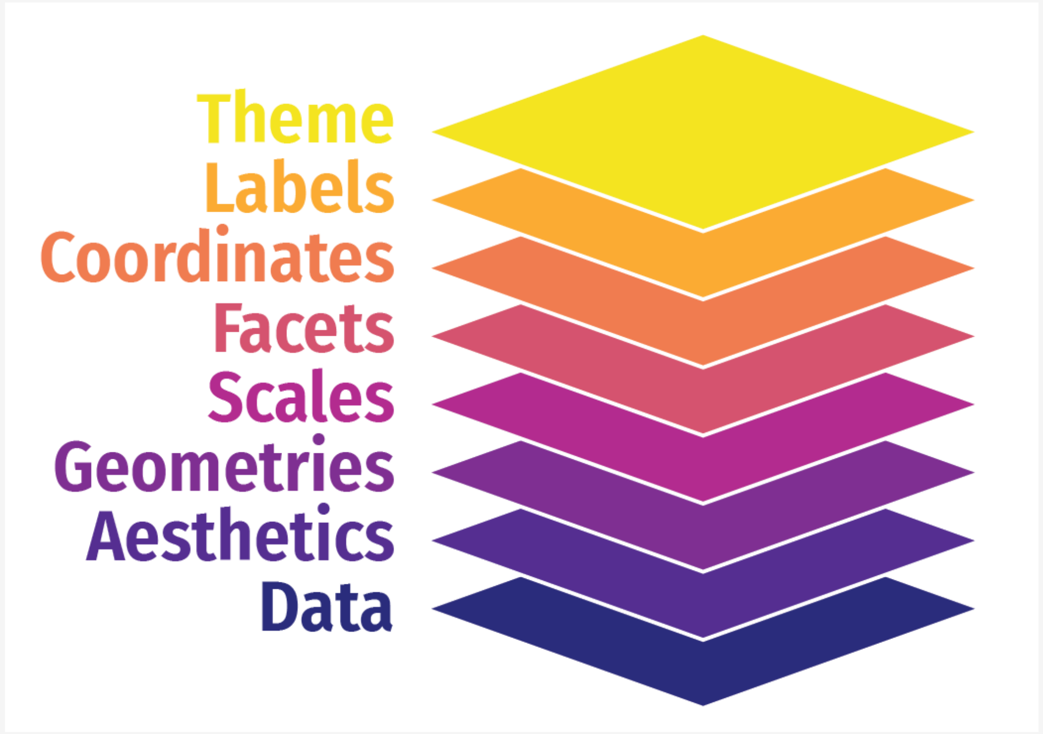


The Grammar of Graphics (gg) II

- Any graphic can be built from the same components:

  1. `data` to be drawn from
  2. `aes`**thetic mappings** from data to some visual marking
  3. `geom`**metric objects** on the plot
  4. `scale` define the range of values
  5. `coord`**inates** to organize location
  6. `labels` describe the scale and markings
  7. `facet` group into subplots
  8. `theme` style the plot elements

- Not every plot needs *every* component, but all plots *must* have the first 3!



The Grammar of Graphics (gg): All at Once

All in one command

- Produces plot output in viewer
- Does not save plot
    - Save with `Export` menu in viewer
- Adding layers requires whole code for new plot

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

The Grammar of Graphics (gg): As R Objects

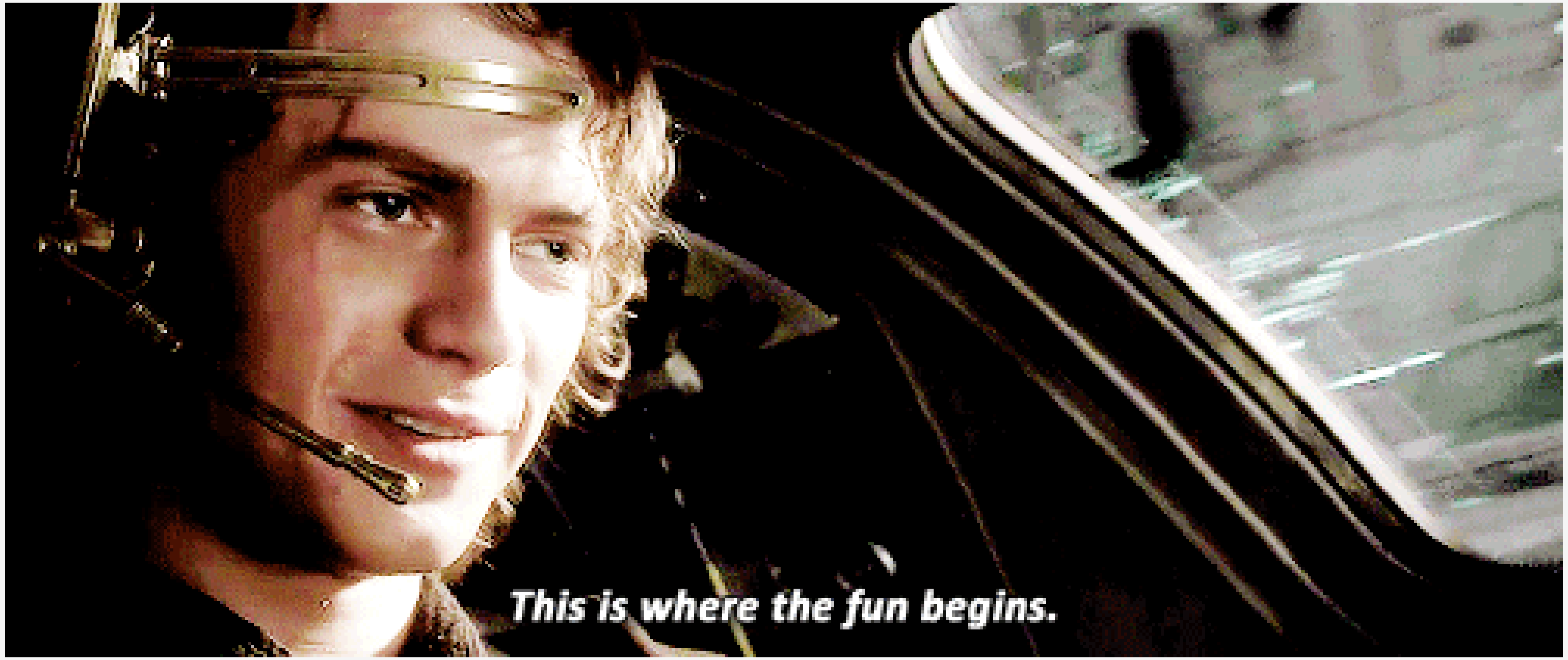
Saving as an object

- Saves your plot as an `R` object
- Does *not* show in viewer
  - Execute the name of your object to see it
- Can add layers by calling the original plot name

```r
# make and save plot
p <- ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point()

p # view plot

# add a layer

p + geom_smooth() # shows new plot

p <- p + geom_smooth() # saves and overwrites p
p2 <- p + geom_smooth() # saves as different ob
```

Plot Layers

The Grammar of Graphics



The Grammar of Graphics (gg): Data

Data

```
ggplot(data = mpg)
```

Data is the source of our data. As part of the `tidyverse`, `ggplot2` requires data to be **"tidy"**[1]:

1. Each variable forms a column
2. Each observation forms a row
3. Each observational unit forms a table

[1] Data "tidyness" is the core element of all `tidyverse` packages. Much more on all of this next class.

The Grammar of Graphics (gg): Adding Layers

Data

- Add a layer with `+` at the end of a line (never at the beginning!)
- Style recommendation: start a new line after each `+` to improve legibility!
- We will build a plot layer-by-layer

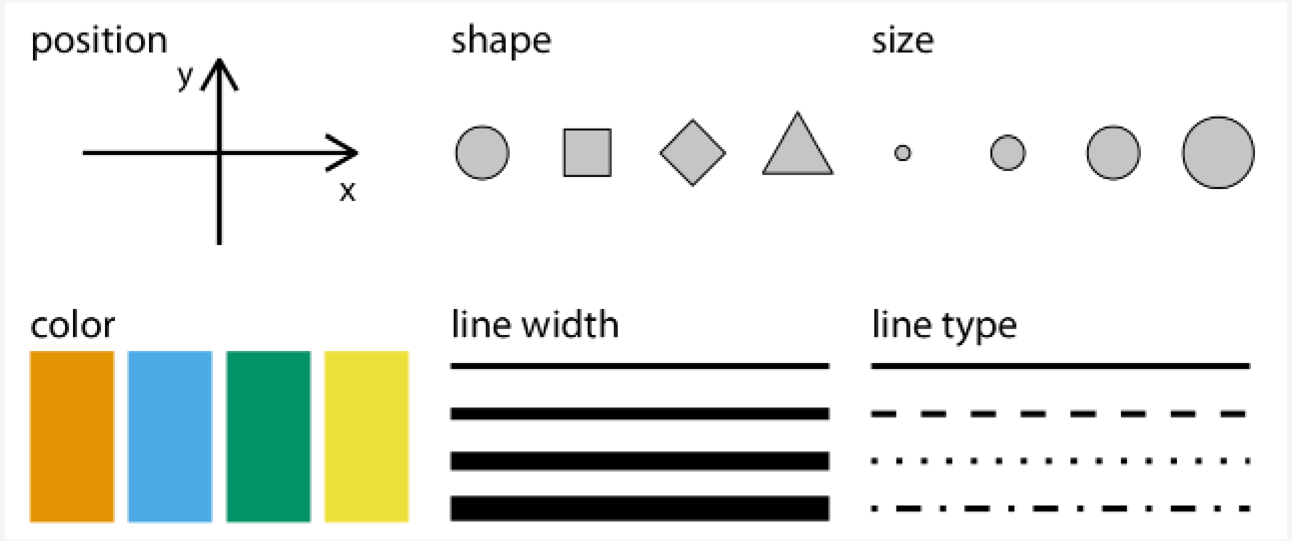
The Grammar of Graphics (gg): Aesthetics I

Data

Aesthetics

```
+ aes()
```

Aesthetics map data to visual elements or parameters



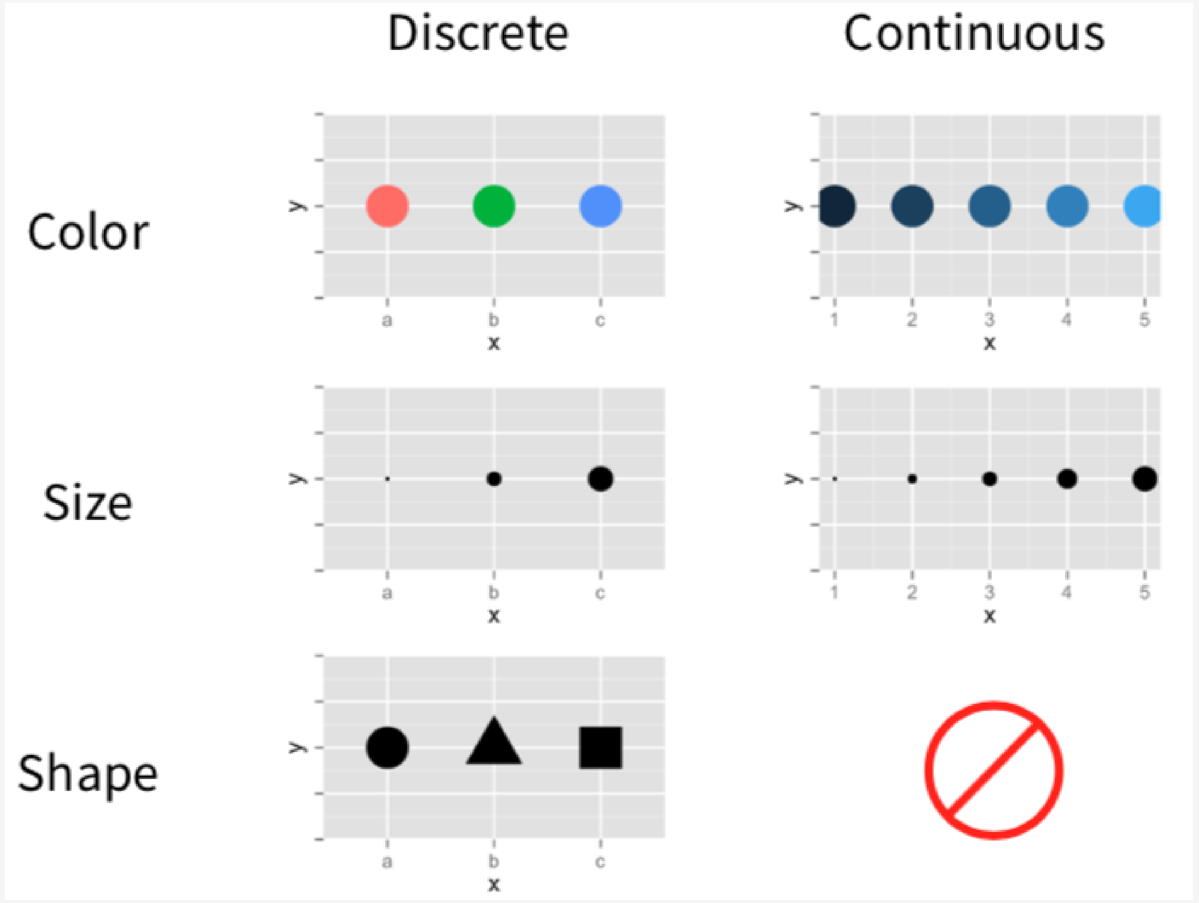
The Grammar of Graphics (gg): Aesthetics II

Data

Aesthetics

```
+ aes()
```

Aesthetics map data to visual elements or parameters



The Grammar of Graphics (gg): Aesthetics III

Data

Aesthetics

`+ aes()`

Aesthetics map data to visual elements or parameters

- `displ`
- `hwy`
- `class`

The Grammar of Graphics (gg): Aesthetics III

Data

Aesthetics

`+ aes()`

Aesthetics map data to visual elements or parameters

- `displ` $\longrightarrow$ **x**
- `hwy` $\longrightarrow$ **y**
- `class` $\longrightarrow$ *shape*, *size*, **color**, etc.

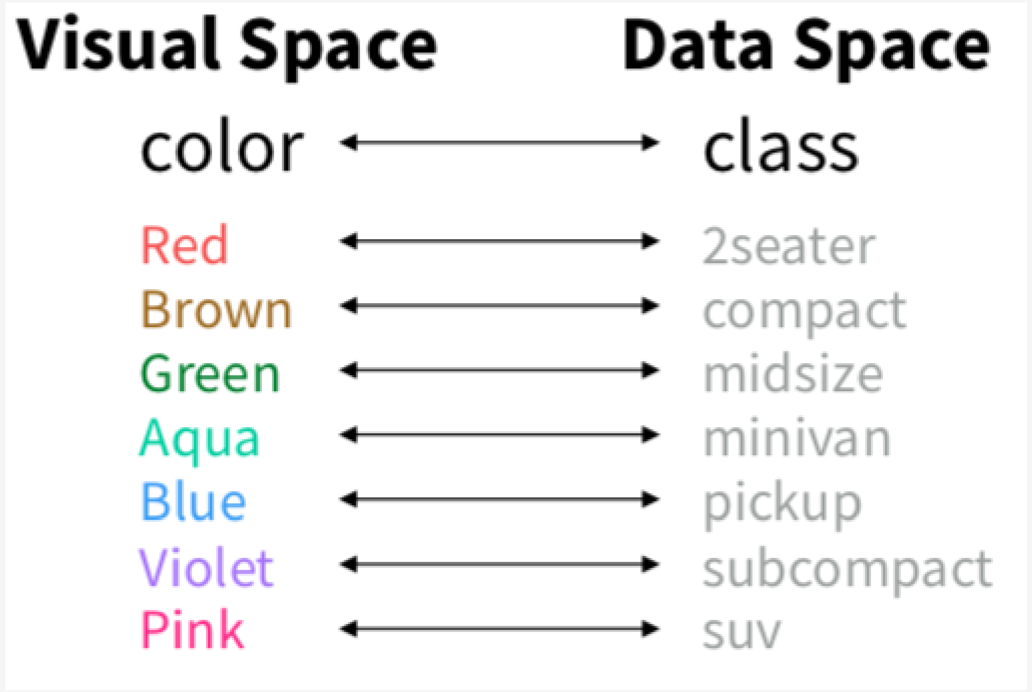
The Grammar of Graphics (gg): Aesthetics IV

Data

Aesthetics

```
+ aes()
```

Aesthetics map data to visual elements or parameters



Visual Space	Data Space
color	class
Red	2seater
Brown	compact
Green	midsize
Aqua	minivan
Blue	pickup
Violet	subcompact
Pink	suv

The Grammar of Graphics (gg): Aesthetics IV

Data

Aesthetics

`+ aes()`

Aesthetics map data to visual elements or parameters

```
aes(x = displ,
    y = hwy,
    color = class)
```

The Grammar of Graphics (gg): Geoms I

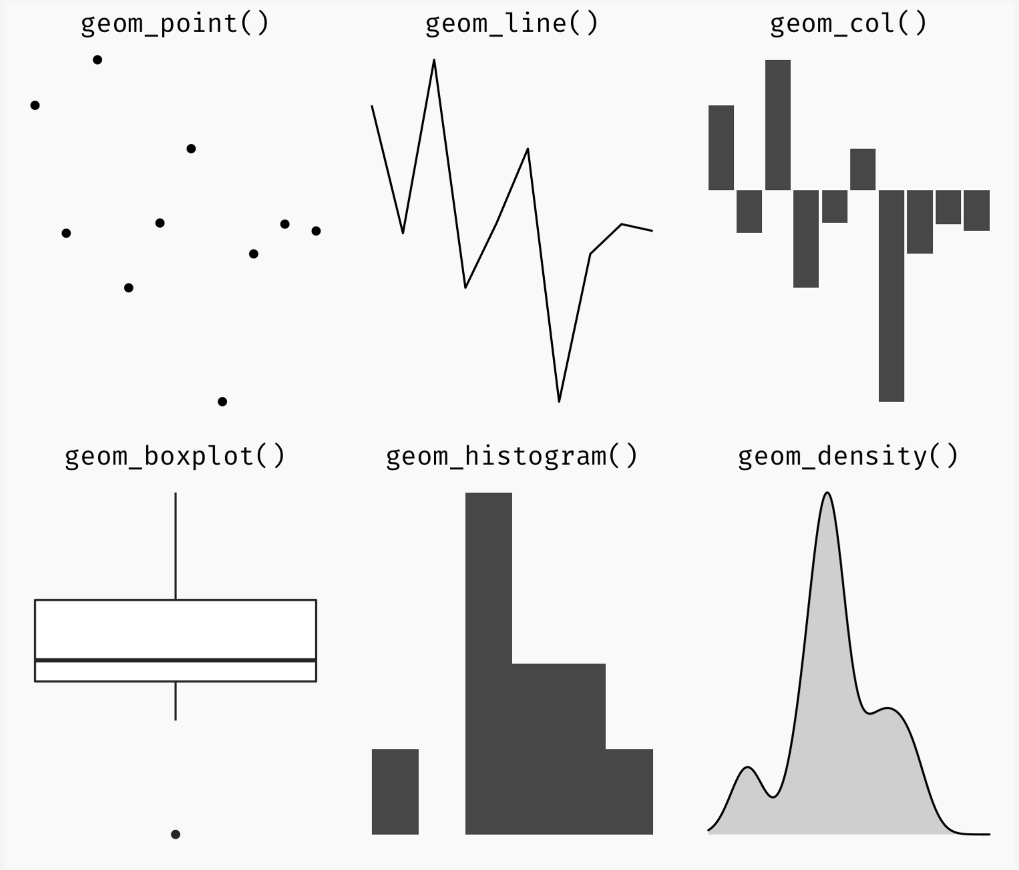
Data

Aesthetics

Geoms

```
+ geom_*()
```

Geometric objects displayed on the plot



The Grammar of Graphics (gg): Geoms II

Data

Aesthetics

Geoms

`+ geom_*()`

Geometric objects displayed on the plot

- What `geom`s you should use depends on what you want to show:

Type	`geom`
Point	`geom_point()`
Line	`geom_line()`, `geom_path()`
Bar	`geom_bar()`, `geom_col()`
Histogram	`geom_histogram()`
Regression	`geom_smooth()`
Boxplot	`geom_boxplot()`

The Grammar of Graphics (gg): Geoms III

Data

Aesthetics

Geoms

`+ geom_*()`

Geometric objects displayed on the plot

```
##  [1] "geom_abline"      "geom_area"        "geom_bar"
##  [5] "geom_blank"       "geom_boxplot"     "geom_col"
##  [9] "geom_count"       "geom_crossbar"    "geom_curve"
## [13] "geom_density_2d"  "geom_density2d"   "geom_dotplot"
## [17] "geom_errorbarh"   "geom_freqpoly"    "geom_hex"
## [21] "geom_hline"       "geom_jitter"      "geom_label"
## [25] "geom_linerange"   "geom_map"         "geom_path"
## [29] "geom_pointrange"  "geom_polygon"     "geom_qq"
## [33] "geom_quantile"    "geom_raster"      "geom_rect"
## [37] "geom_rug"         "geom_segment"     "geom_sf"
## [41] "geom_sf_text"     "geom_smooth"      "geom_spoke"
## [45] "geom_text"        "geom_tile"        "geom_violin"
```

See http://ggplot2.tidyverse.org/reference for many more options

The Grammar of Graphics (gg): Geoms IV

Data

Aesthetics

Geoms

```
+ geom_*()
```

Geometric objects displayed on the plot

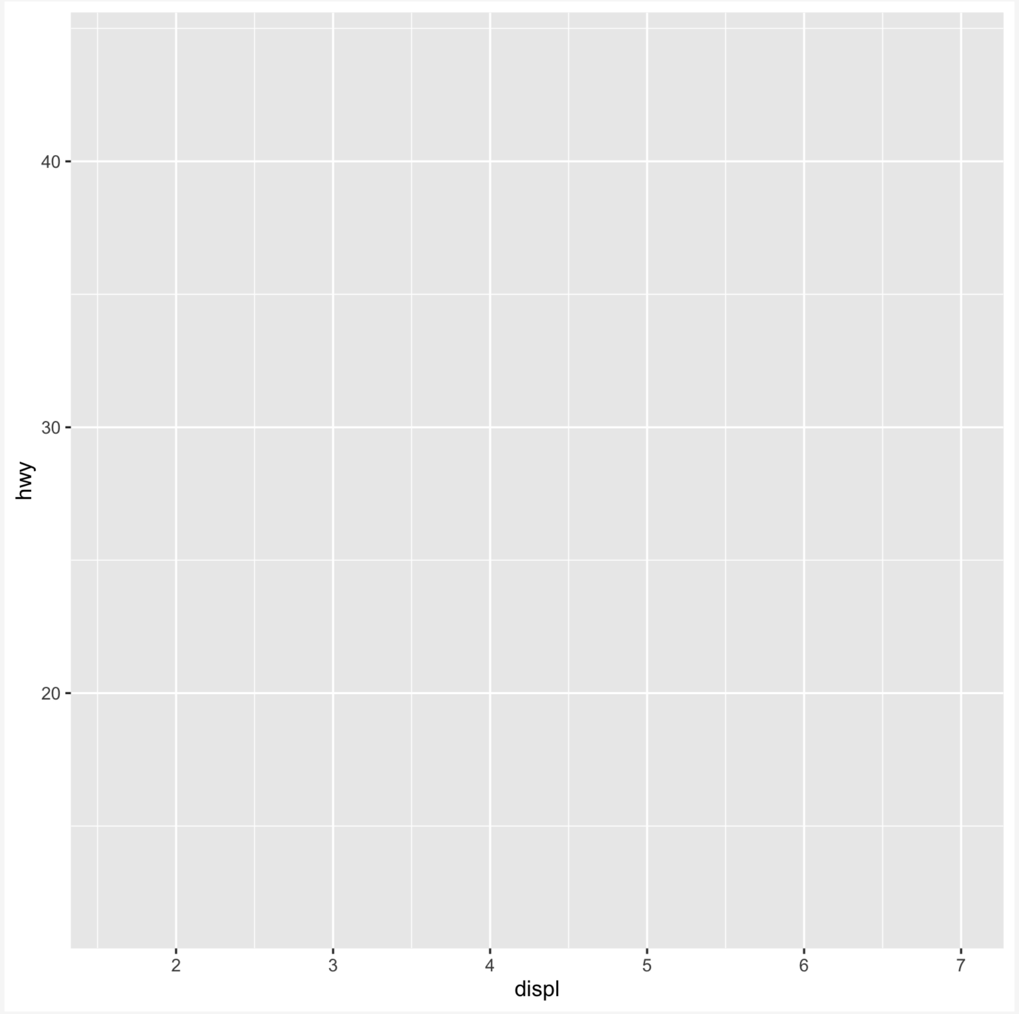
Or just start typing `geom_` in R Studio!

Let's Make a Plot!

```
ggplot(data = mpg)
```

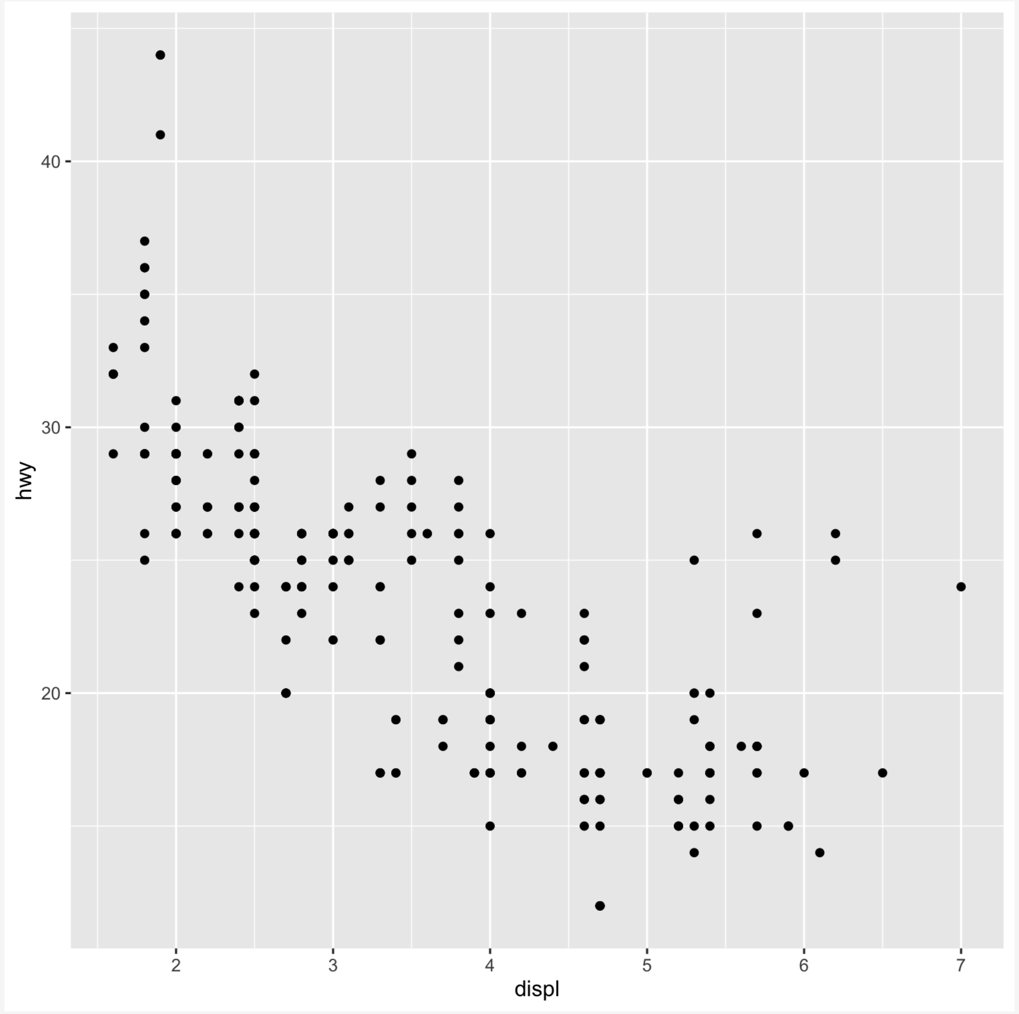
Let's Make a Plot!

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



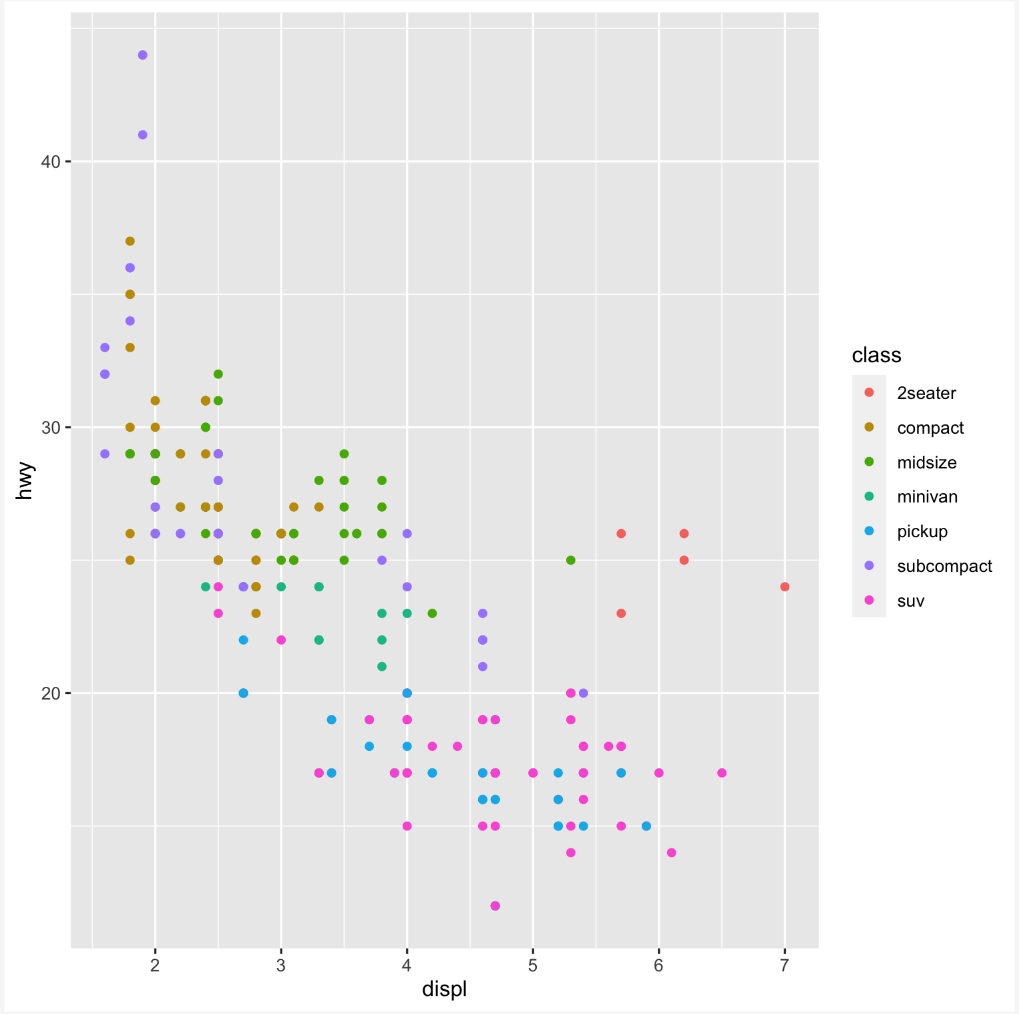
Let's Make a Plot!

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



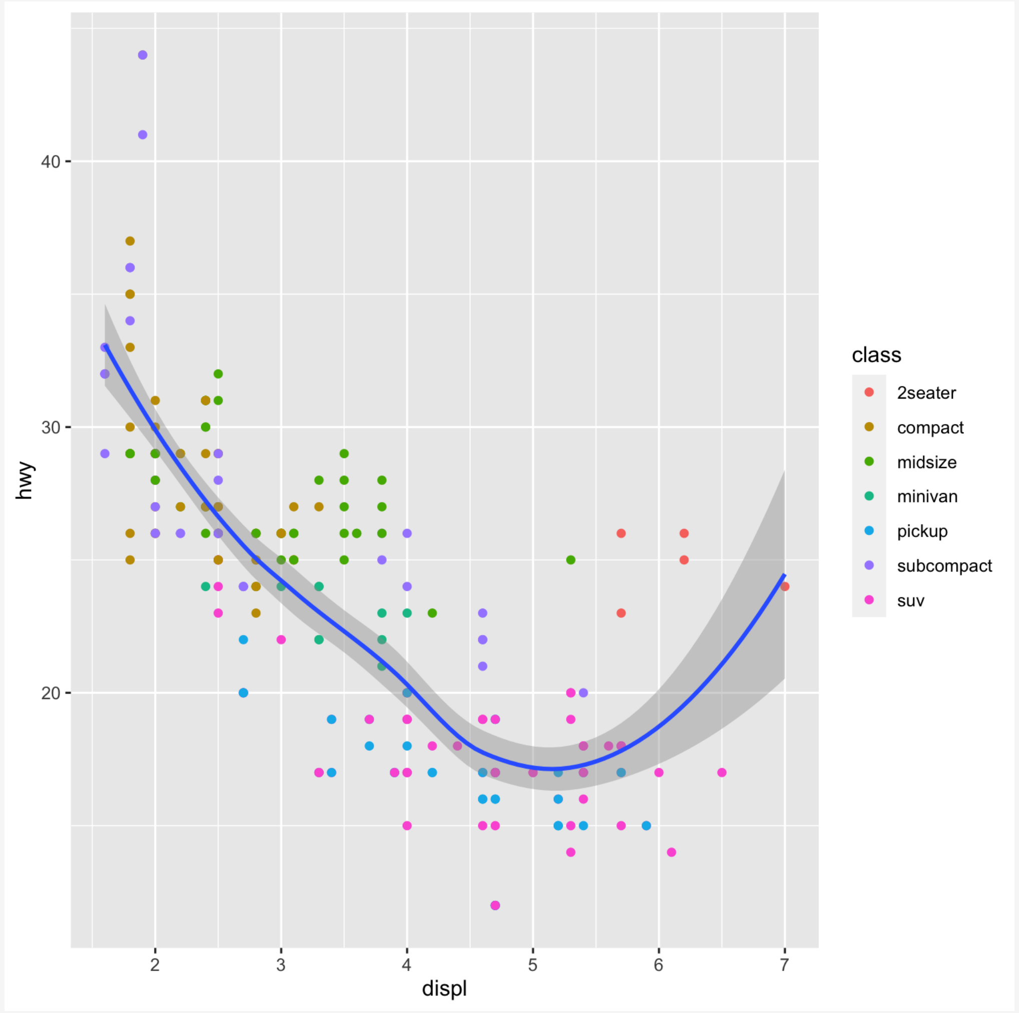
Let's Make a Plot!

```r
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))
```



Let's Make a Plot!

```r
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()
```



More Geoms

Data

Aesthetics

Geoms

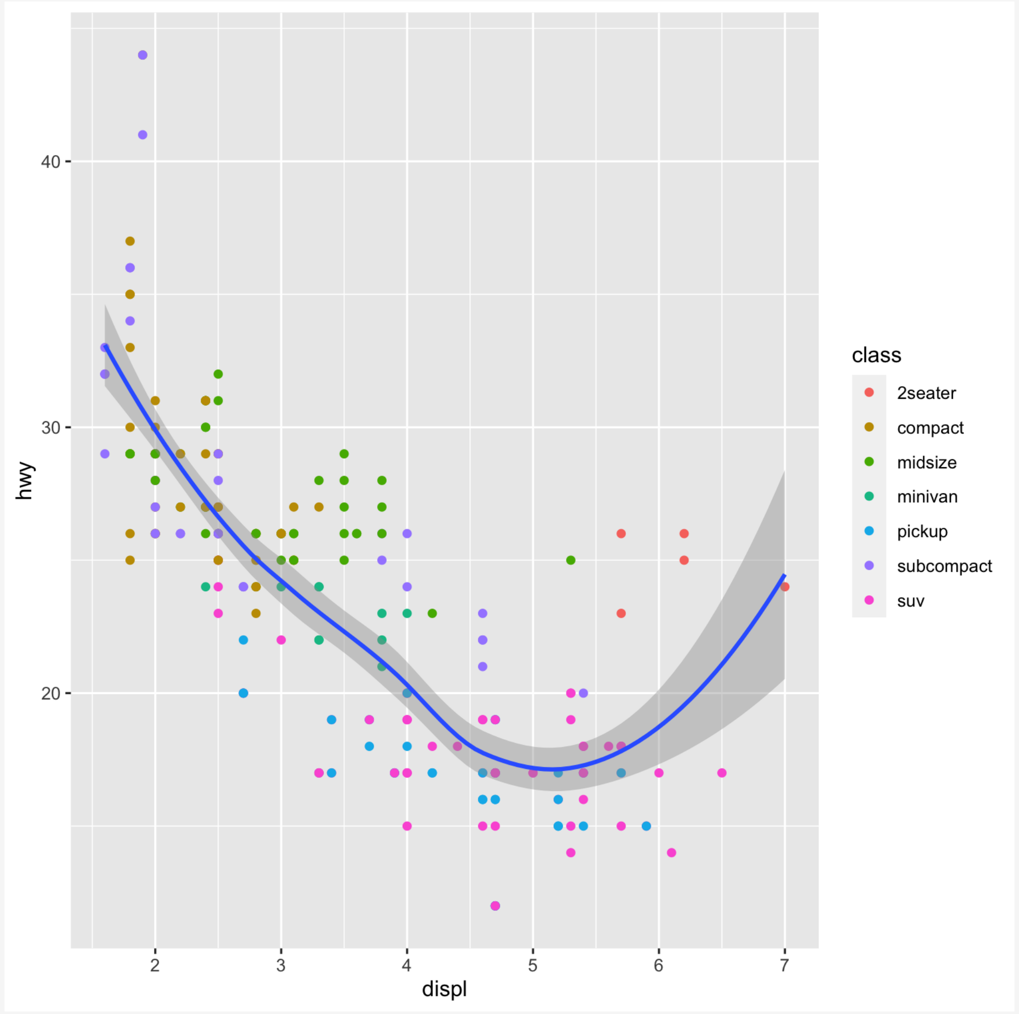
`+ geom_*()`

`geom_*(aes, data, stat, position)`

- `data`: geoms can have their own data
  - has to map onto global coordinates
- `aes`: geoms can have their own aesthetics
  - inherits global aesthetics by default
  - different geoms have different available aesthetics

Change Our Plot

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()
```



More Geoms II

Data

Aesthetics

Geoms

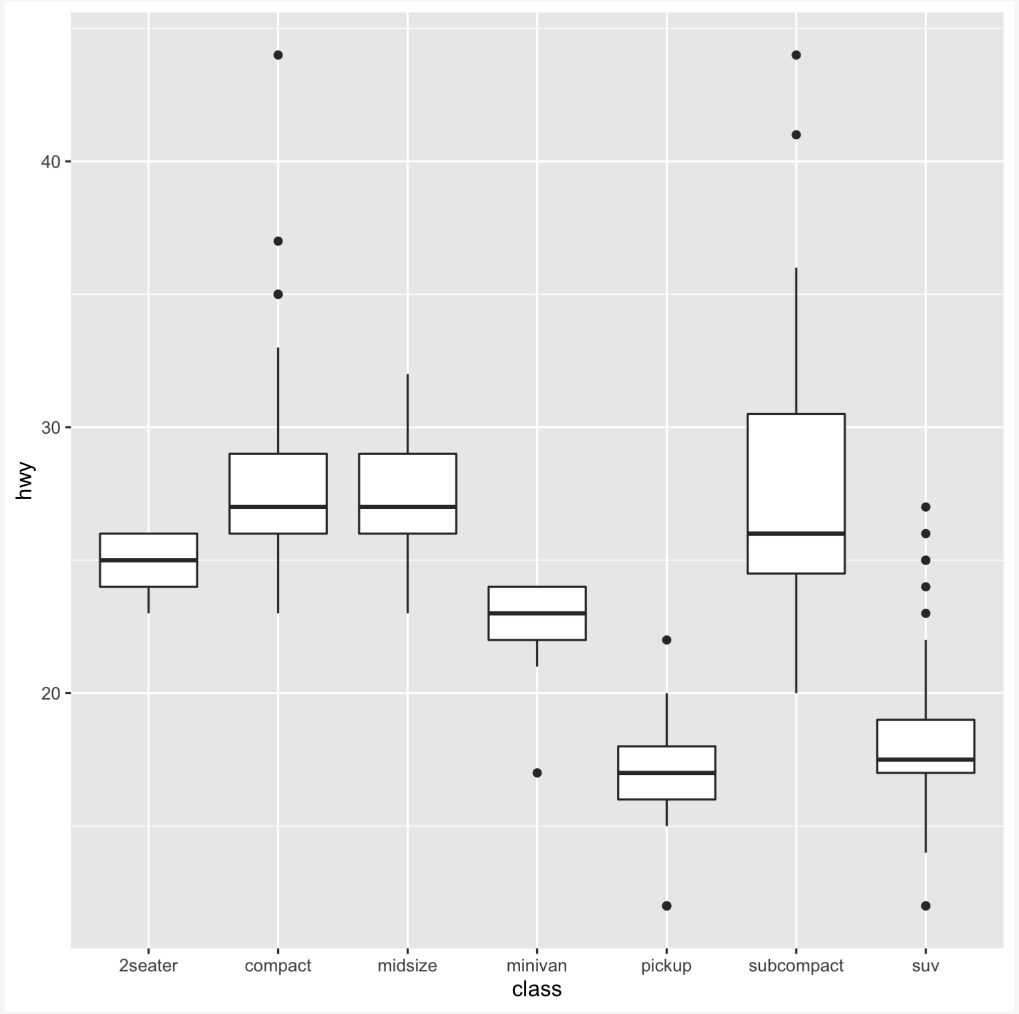
`+ geom_*()`

`geom_*(aes, data, stat, position)`

- `stat`: some geoms statistically transform data
  - `geom_histogram()` uses `stat_bin()` to group observations into bins
- `position`: some adjust location of objects
  - `dodge`, `stack`, `jitter`

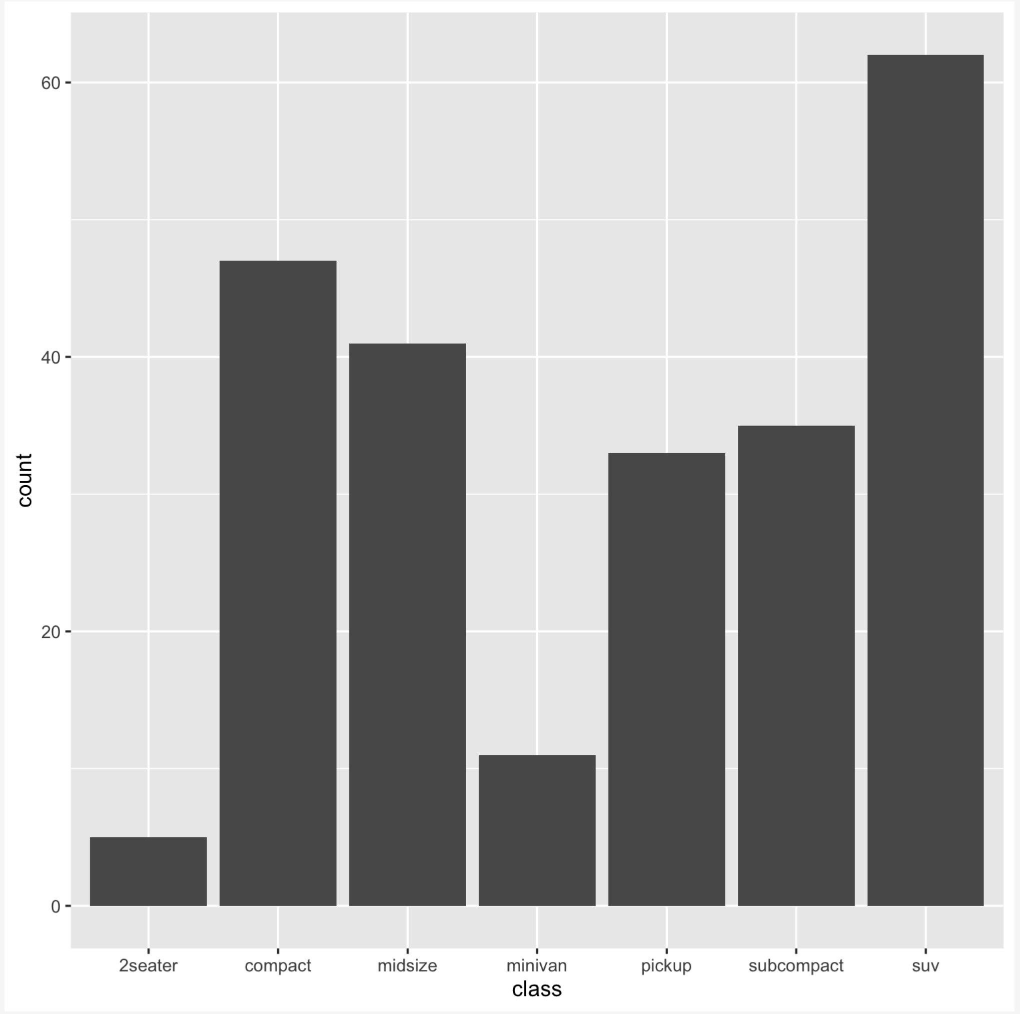
Let's Change Our Plot

```
ggplot(data = mpg)+
  aes(x = class,
      y = hwy)+
  geom_boxplot()
```



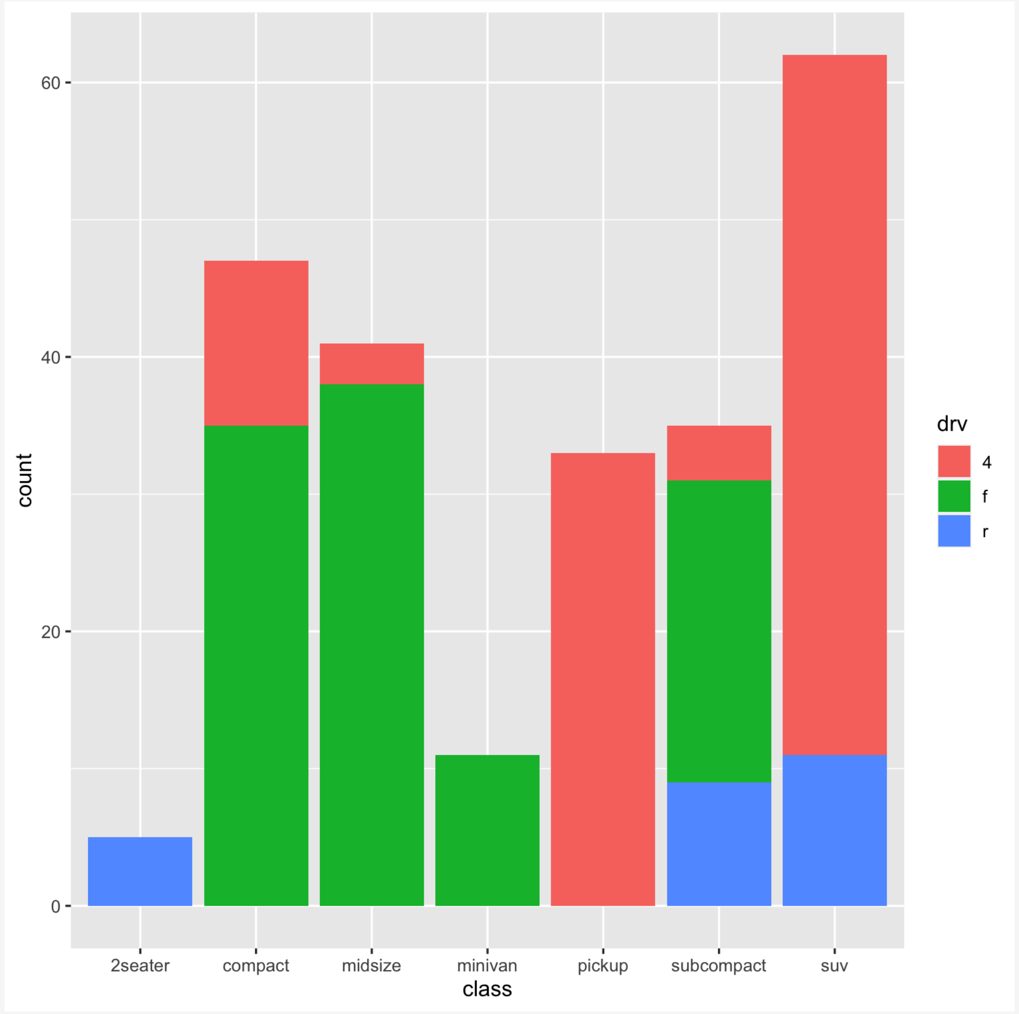
Let's Change Our Plot

```r
ggplot(data = mpg)+
  aes(x = class)+
  geom_bar()
```



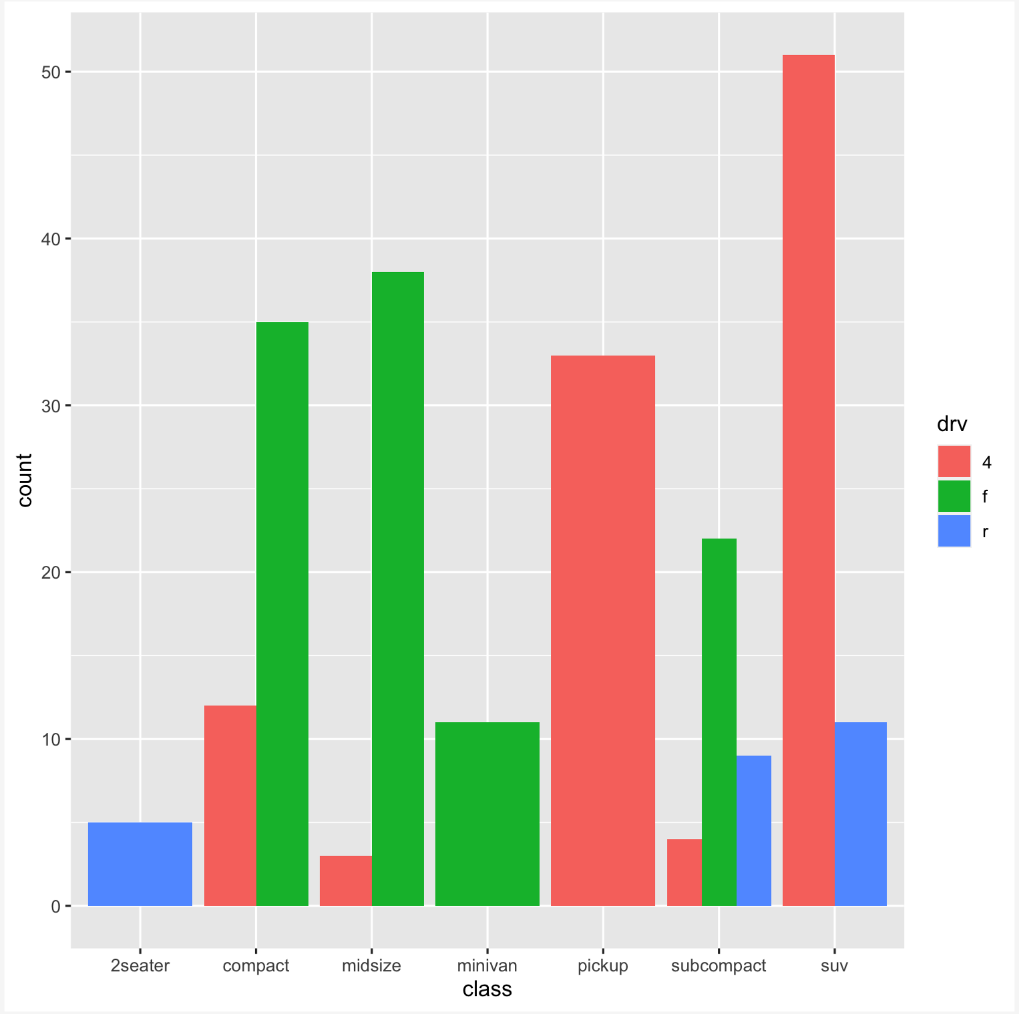
Let's Change Our Plot

```
ggplot(data = mpg)+
  aes(x = class,
      fill = drv)+
  geom_bar()
```



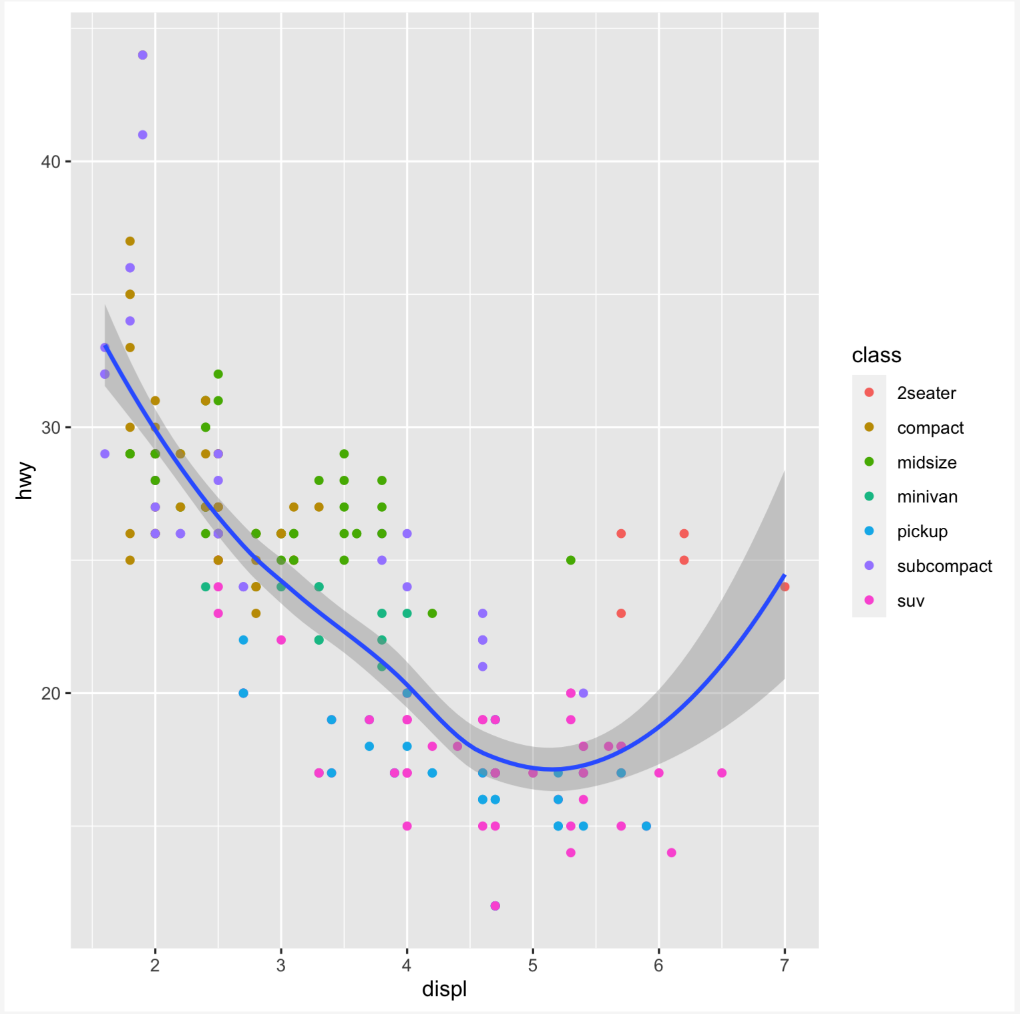
Let's Change Our Plot

```r
ggplot(data = mpg)+
  aes(x = class,
      fill = drv)+
  geom_bar(position = "dodge")
```



Back to the Original (and saving it)

```r
p <- ggplot(data = mpg)+
  aes(x = displ,
      y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()

p # show plot
```



The Grammar of Graphics (gg): Facets I

Data

Aesthetics

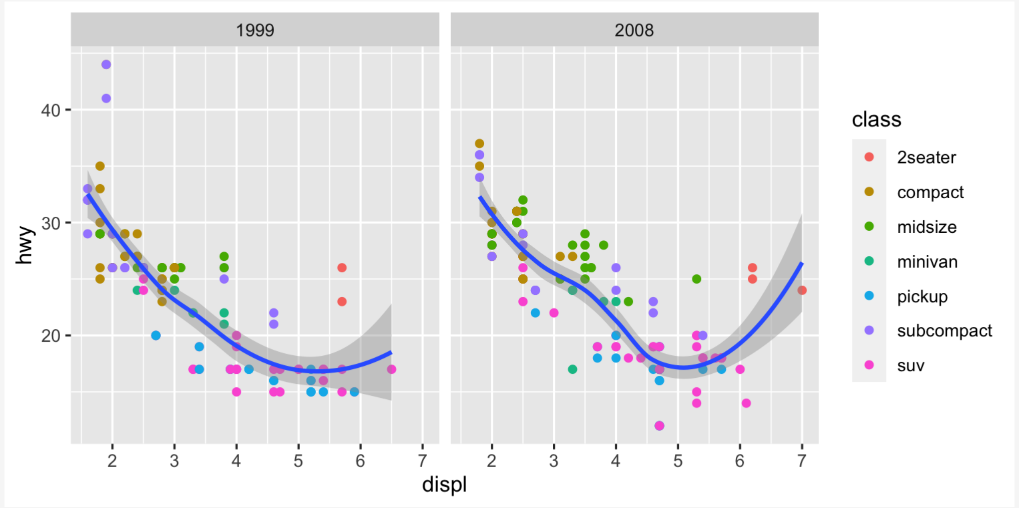
Geoms

Facets

`+ facet_wrap()`

`+ facet_grid()`

```r
p + facet_wrap(~year)
```



The Grammar of Graphics (gg): Facets II

Data

Aesthetics

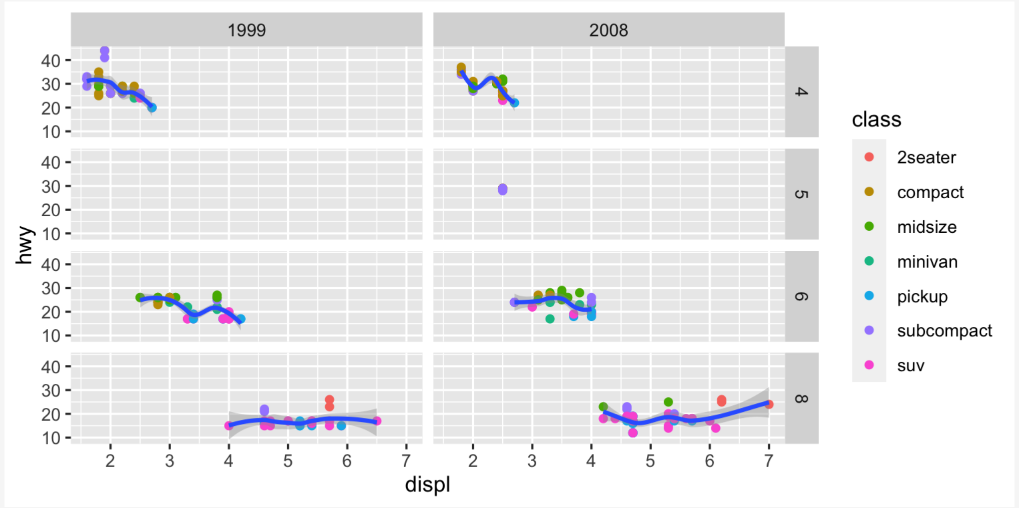
Geoms

Facets

`+ facet_wrap()`

`+ facet_grid()`

```
p + facet_grid(cyl~year)
```



The Grammar of Graphics (gg): Labels

Data

Aesthetics

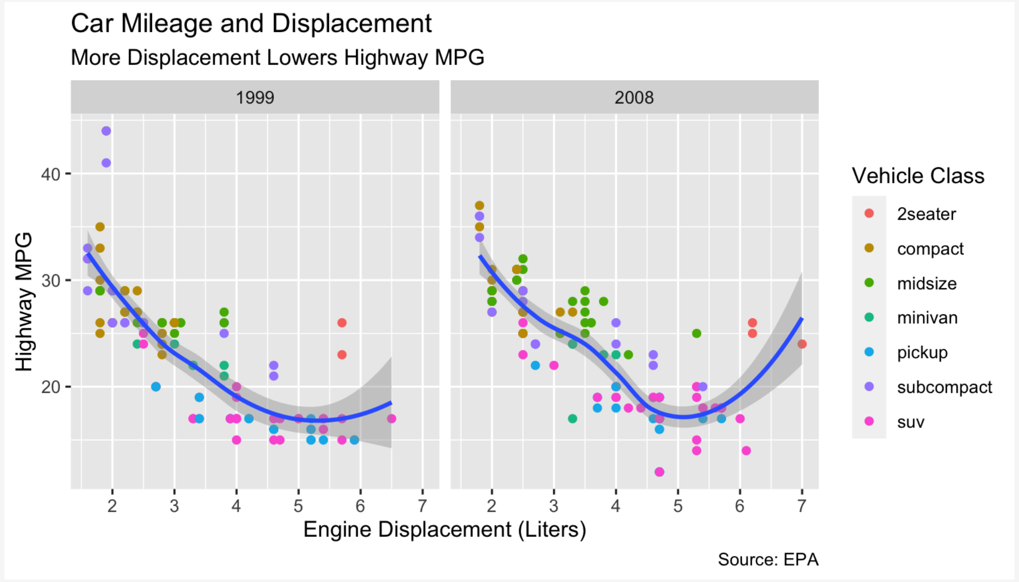
Geoms

Facets

Labels

`+ labs()`

```r
p + facet_wrap(~year)+
  labs(x = "Engine Displacement (Liters)",
       y = "Highway MPG",
       title = "Car Mileage and Displacement",
       subtitle = "More Displacement Lowers Highway MPG",
       caption = "Source: EPA",
       color = "Vehicle Class")
```



The Grammar of Graphics (gg): Scales

Data

Aesthetics

Geoms

Facets

Labels

Scales

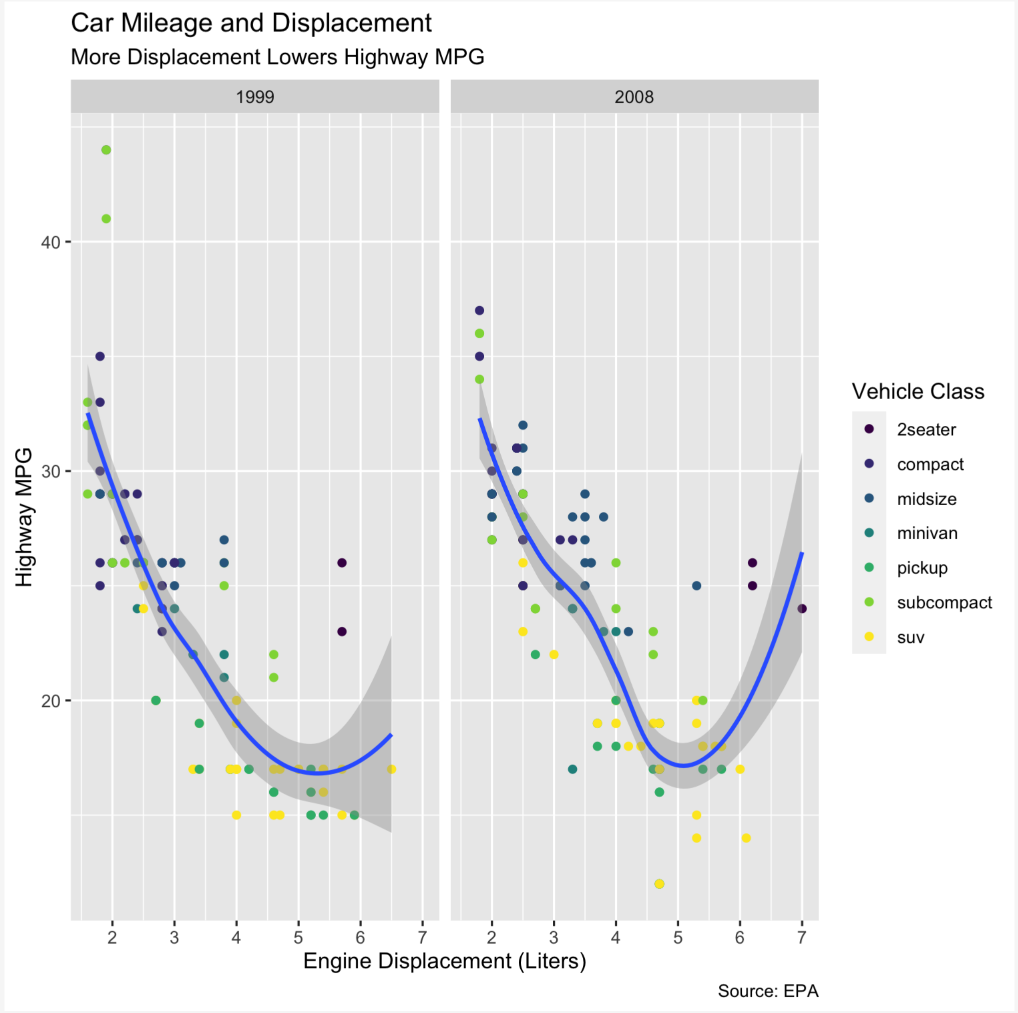
`+ scale_*_*()`

`scale` + `_` + `<aes>` + `_` + `<type>` + `()`

- `<aes>`: parameter you want to adjust
- `<type`: type of parameter
- I want to change my discrete x-axis: `scale_x_discrete()`
- I want to change my continuous y-axis: `scale_y_continuous()`
- I want to rescale x-axis to log: `scale_x_log10()`
- I want to use a different color palette: `scale_fill_discrete()`,

The Grammar of Graphics (gg): Scales

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()
```



The Grammar of Graphics (gg): Themes

Data

Aesthetics

Geoms

Facets

Labels

Scales

Theme

Theme changes appearance of plot decorations (things not mapped to data)

- Some themes that come with `ggplot2`:
- `+ theme_bw()`
- `+ theme_dark()`
- `+ theme_gray()`
- `+ theme_minimal()`
- `+ theme_light()`
- `+ theme_classic()`

The Grammar of Graphics (gg): Themes

Data

Aesthetics

Geoms

Facets

Labels

Scales

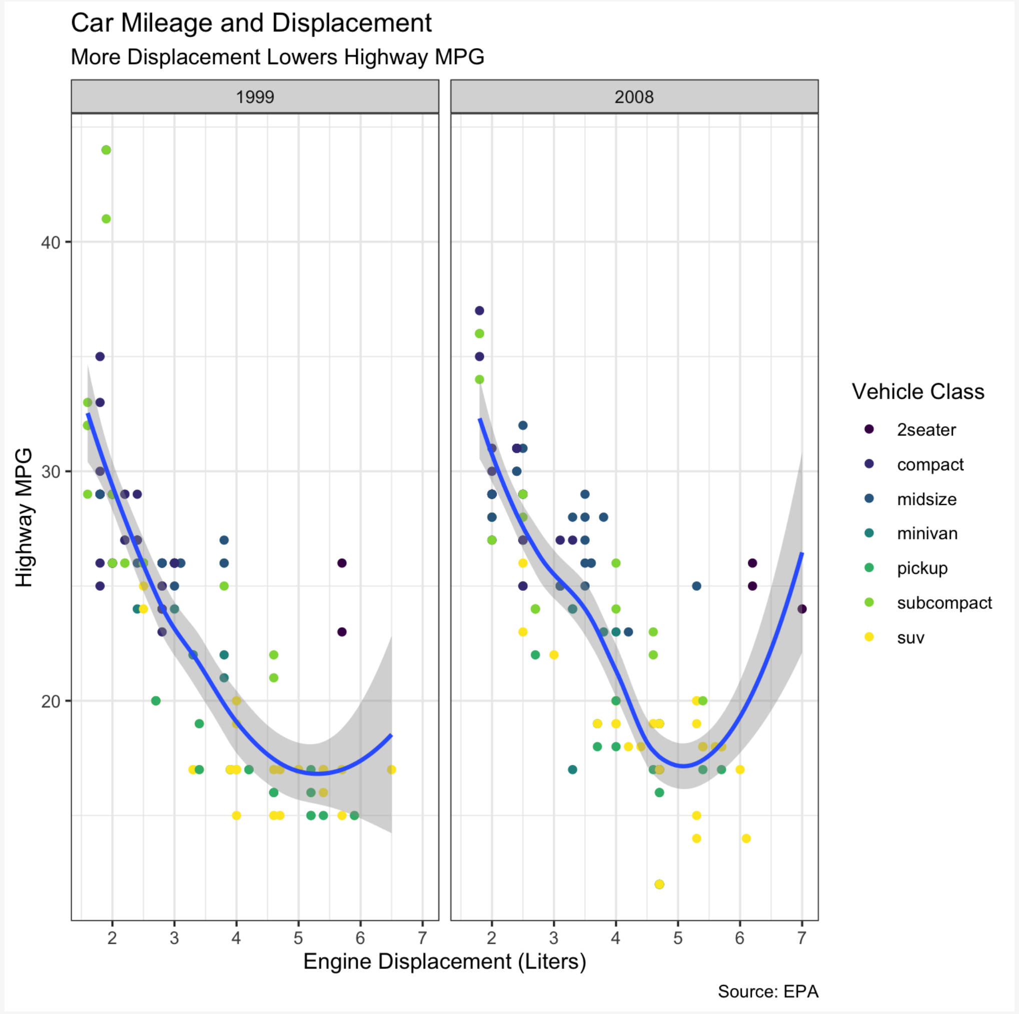
Theme

Theme changes appearance of plot decorations (things not mapped to data)

- Many parameters we could change
- Global options: `line`, `rect`, `text`, `title`
- `axis`: x-, y-, or other axis title, ticks, lines
- `legend`: plot legends for fill or color
- `panel`: actual plot area
- `plot`: whole image
- `strip`: facet labels

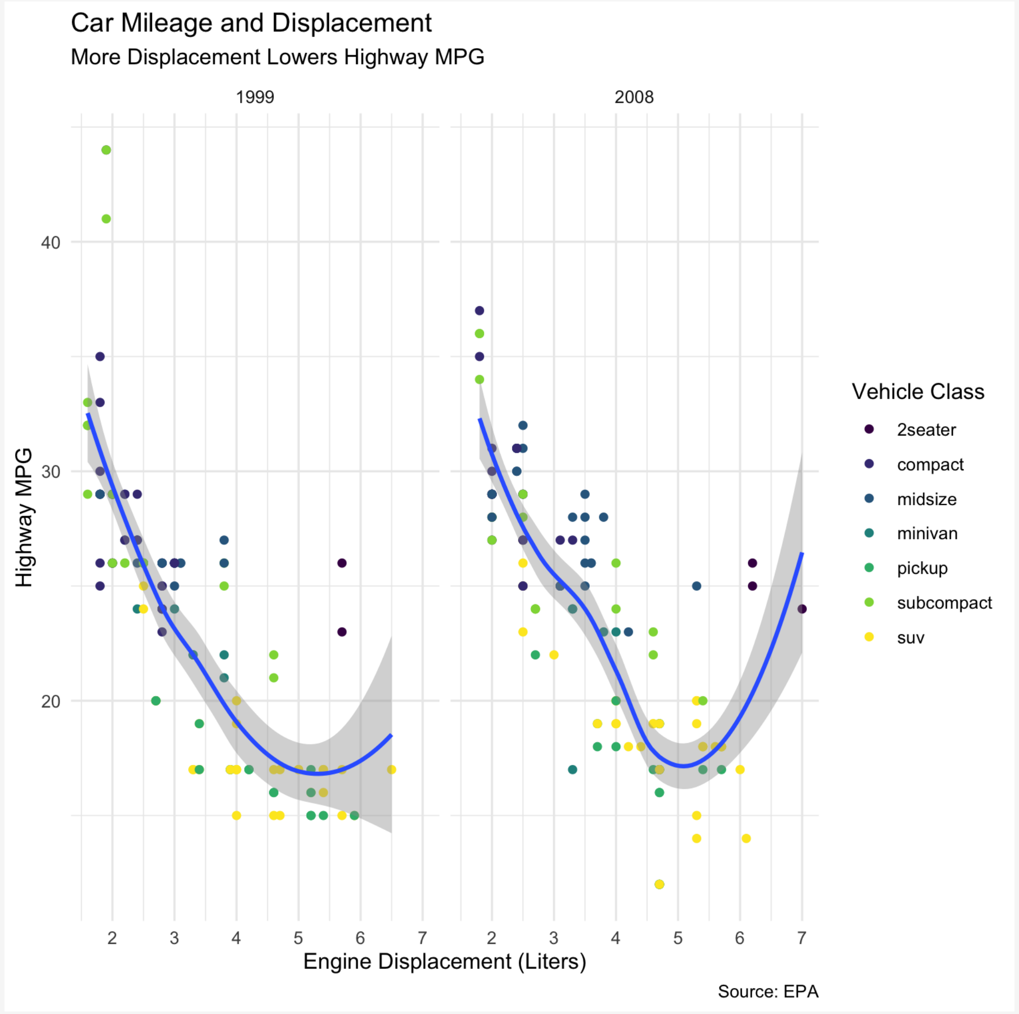
The Grammar of Graphics (gg): Themes

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_bw()
```



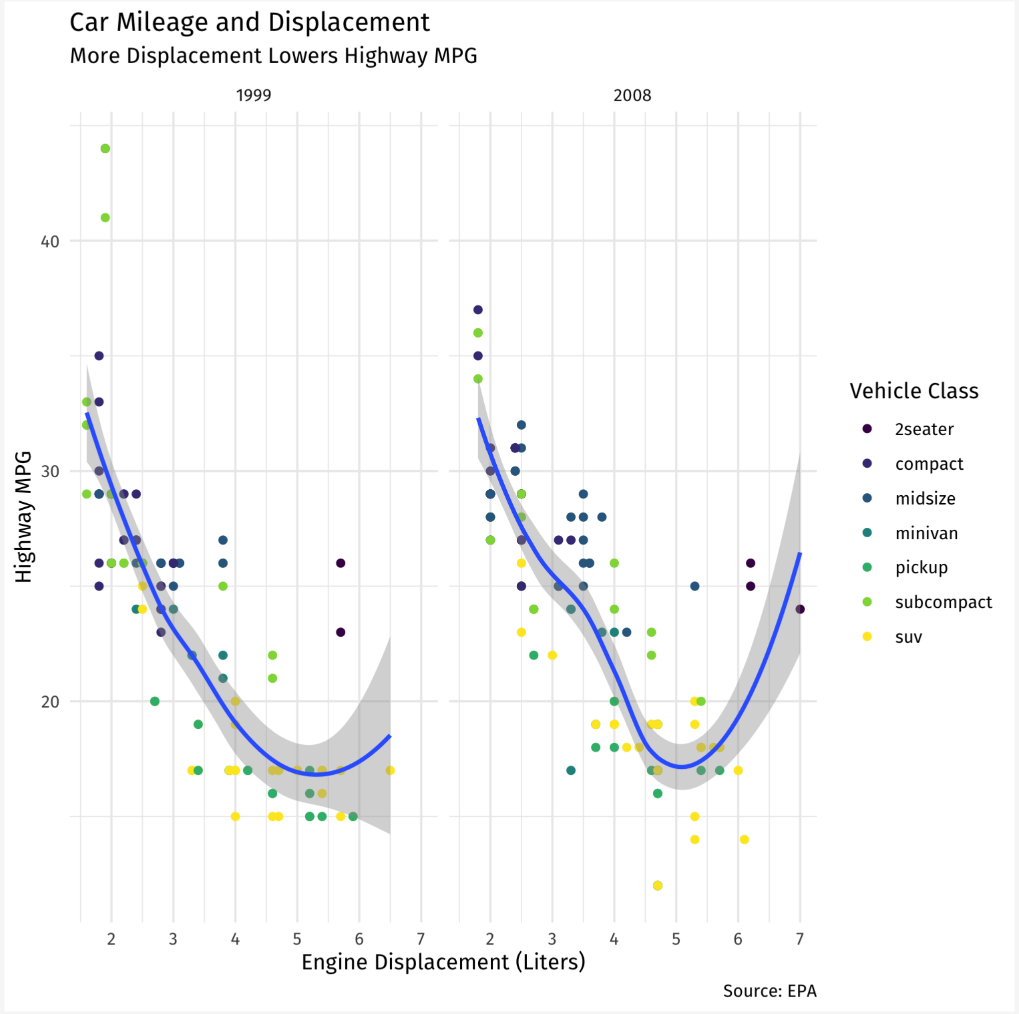
The Grammar of Graphics (gg): Themes II

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_minimal()
```



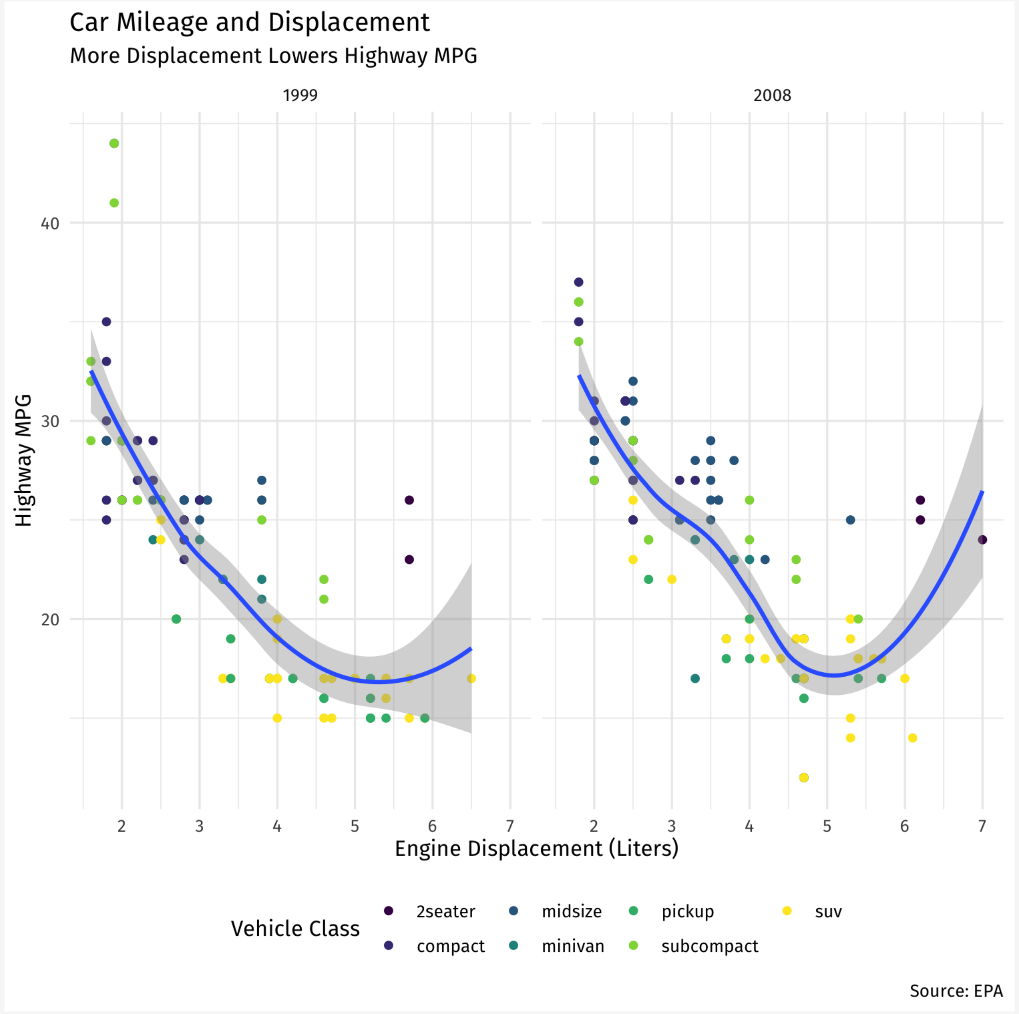
The Grammar of Graphics (gg): Themes III

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_minimal()+
  theme(text = element_text(family = "
```



The Grammar of Graphics (gg): Themes III

```
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_minimal()+
  theme(text = element_text(family = "
        legend.position="bottom")
```



The Grammar of Graphics (gg): Themes (ggthemes)

Data

Aesthetics

Geoms

Facets

Labels

Scales

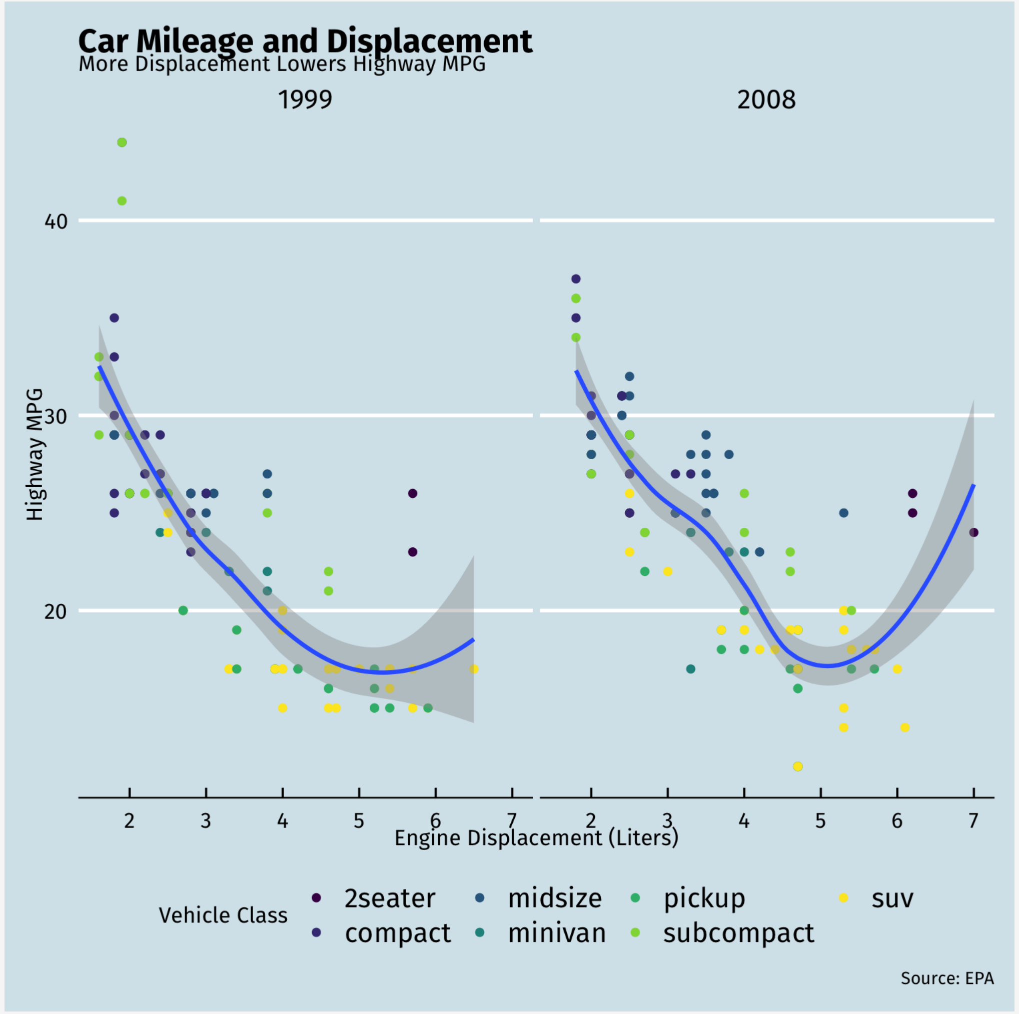
Theme

- `ggthemes` package adds some other nice themes

```r
# install if you don't have it
# install.packages("ggthemes")
library("ggthemes") # load package
```

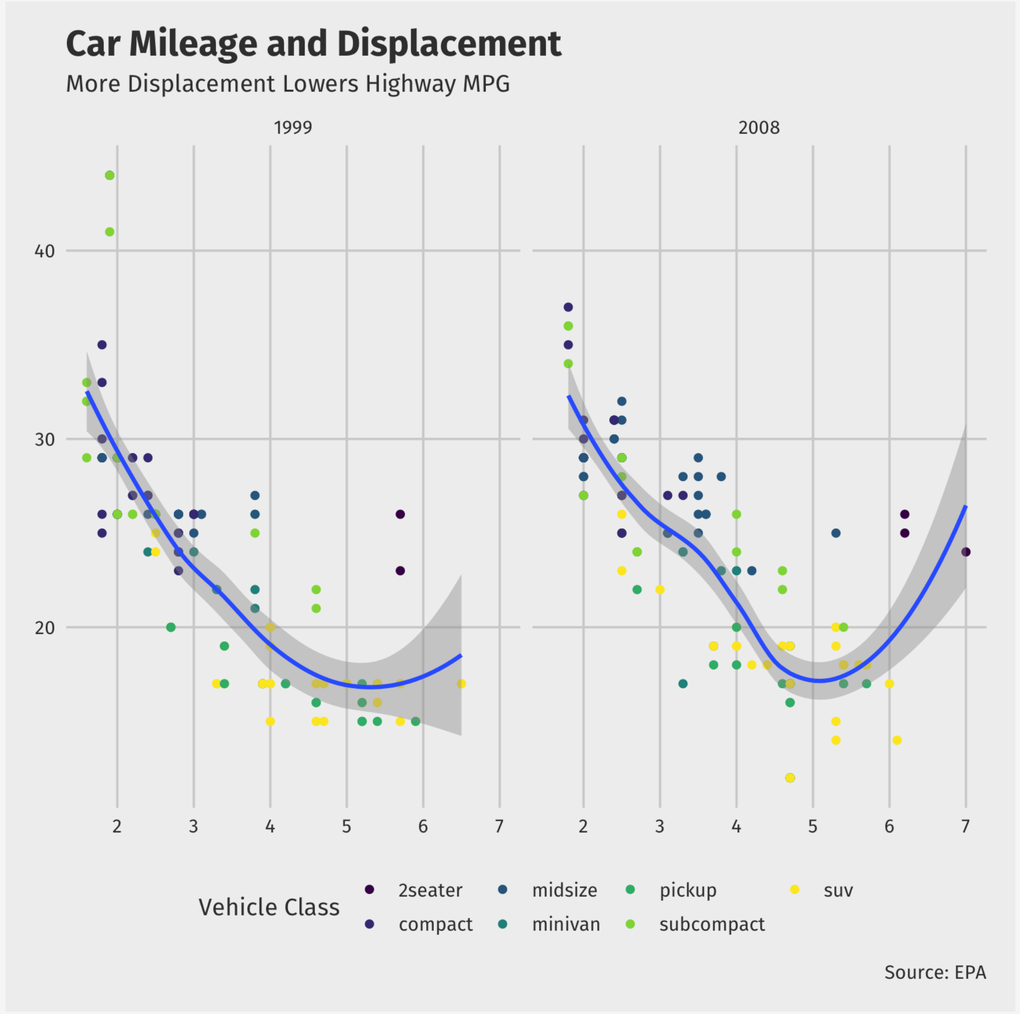
The Grammar of Graphics (gg): Themes IV

```r
library("ggthemes")
ggplot(data = mpg)+
  aes(x = displ,
        y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_economist()+
  theme(text = element_text(family = "
        legend.position="bottom")
```



The Grammar of Graphics (gg): Themes V

```r
library("ggthemes")
ggplot(data = mpg)+
  aes(x = displ,
      y = hwy)+
  geom_point(aes(color = class))+
  geom_smooth()+
  facet_wrap(~year)+
  labs(x = "Engine Displacement (Liter
       y = "Highway MPG",
       title = "Car Mileage and Displa
       subtitle = "More Displacement L
       caption = "Source: EPA",
       color = "Vehicle Class")+
  scale_color_viridis_d()+
  theme_fivethirtyeight()+
  theme(text = element_text(family = "
        legend.position="bottom")
```



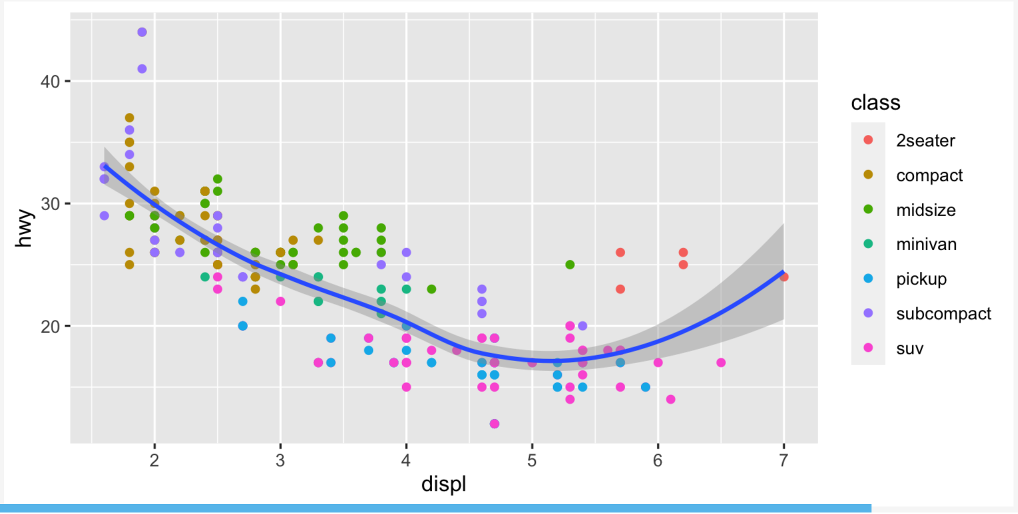
Some Troubleshooting

Global vs. Local Aesthetics

- `aes()` can go in base (`data`) layer and/or in individual `geom()` layers
- All `geoms` will inherit global `aes` from `data` layer unless overridden

```r
# ALL GEOMS will map data to colors
ggplot(data = mpg, aes(x = displ,
                       y = hwy,
                       color = class))+
  geom_point()+
  geom_smooth()
```

```r
# ONLY points will map data to colors
ggplot(data = mpg, aes(x = displ,
                       y = hwy))+
  geom_point(aes(color = class))+
  geom_smooth()
```

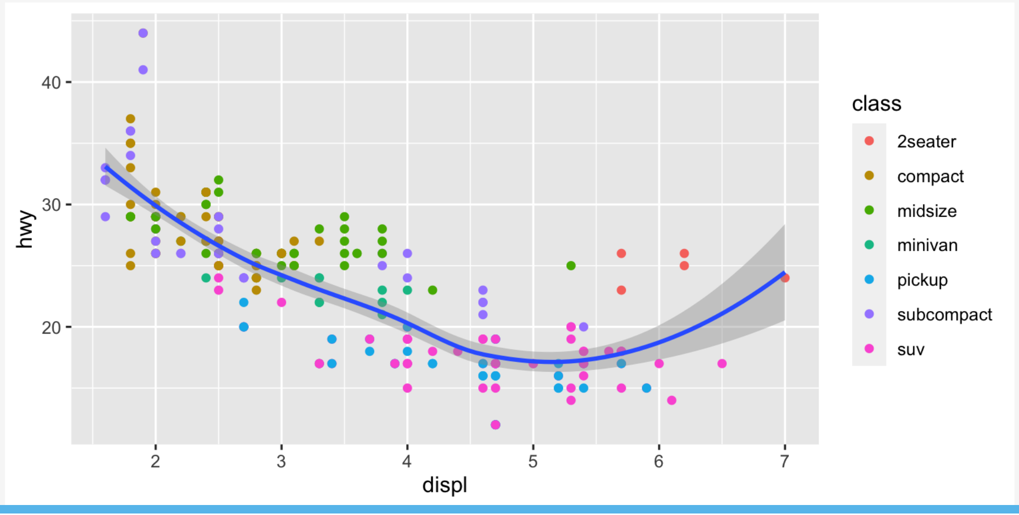


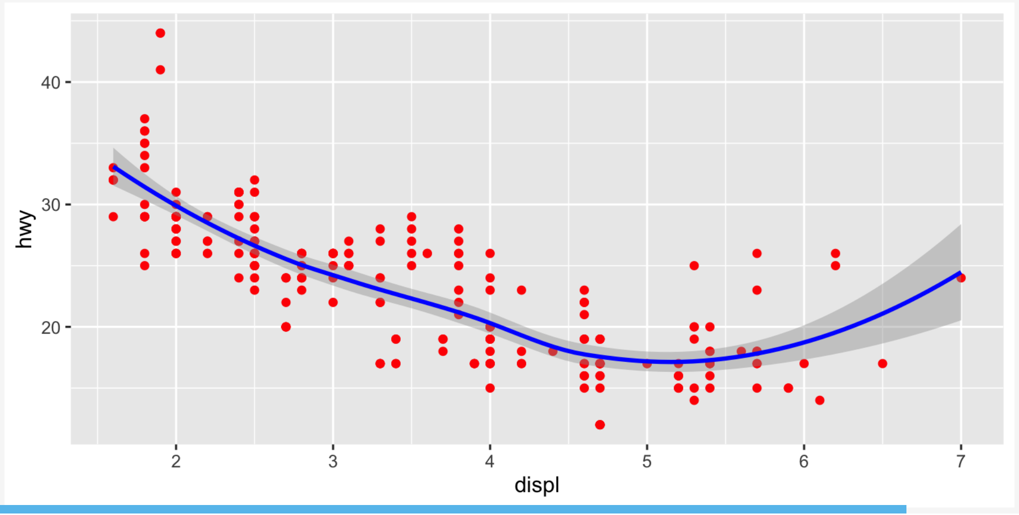
Mapped vs. Set Aesthetics

- `aes`thetics such as `size` and `color` can be mapped from data or set to a single value
- Map *inside* of `aes()`, set *outside* of `aes()`

```r
# Point colors are mapped from class data
ggplot(data = mpg, aes(x = displ,
                       y = hwy))+
  geom_point(aes(color = class))+
  geom_smooth()
```

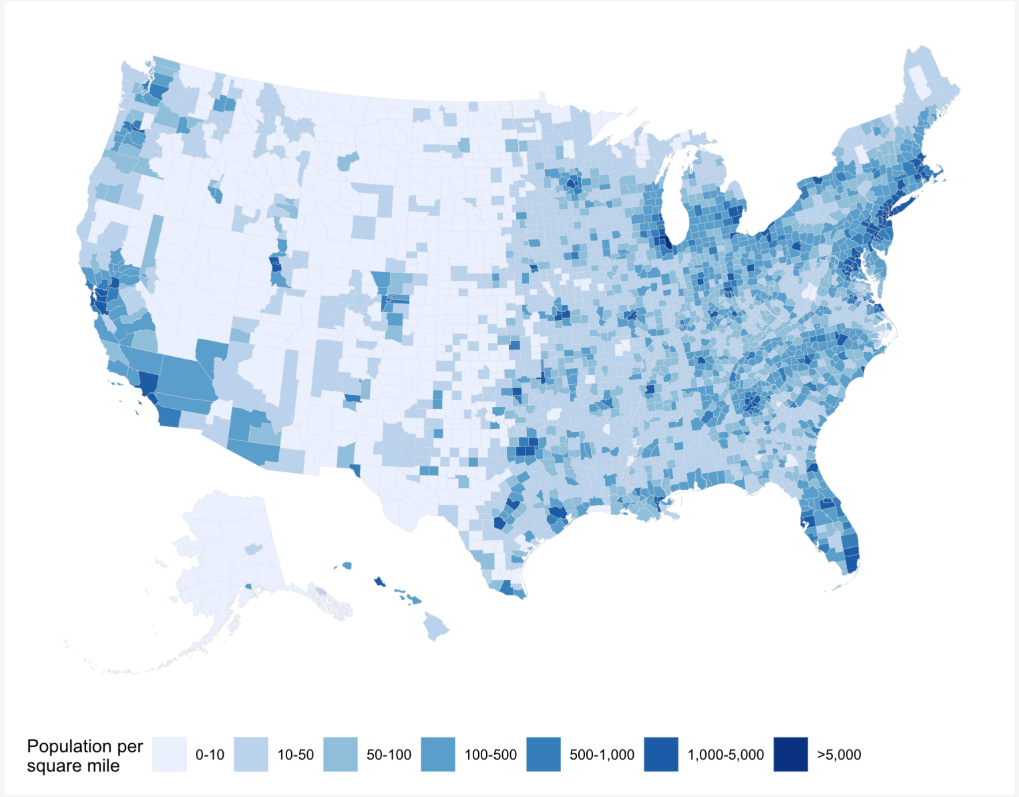
```r
# Point colors are all set to blue
ggplot(data = mpg, aes(x = displ,
                       y = hwy))+
  geom_point(aes(), color = "red")+
  geom_smooth(aes(), color = "blue")
```





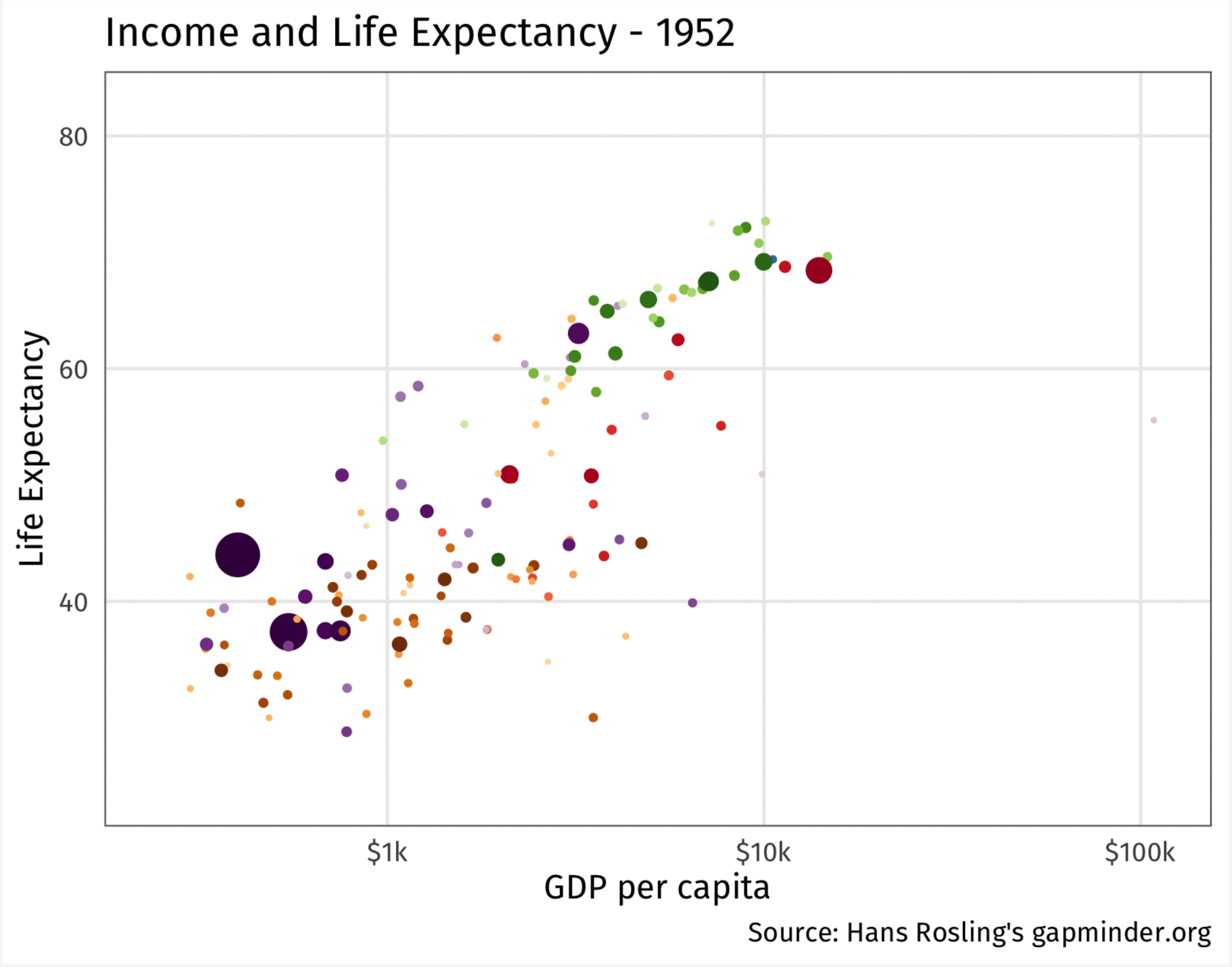
Go Crazy I

```r
# I did some (hidden) data work before
ggplot(data = county_full,
            mapping = aes(x = long, y
                          fill = pop_d
                          group = grou
  geom_polygon(color = "gray90", size
  coord_equal()+
  scale_fill_brewer(palette="Blues",
                             labels =

  labs(fill = "Population per\nsquare
    theme_map() +
    guides(fill = guide_legend(nrow =
    theme(legend.position = "bottom")
```



Go Crazy II

```r
library("gapminder")
library("gganimate")
ggplot(gapminder) +
  aes(x = gdpPercap, y = lifeExp, size
  geom_point() +
  guides(color = FALSE, size = FALSE)
  scale_x_log10(
    breaks = c(10^3, 10^4, 10^5),
    labels = c("$1k", "$10k", "$100k")
  scale_color_manual(values = gapminde
  scale_size(range = c(0.5, 12)) +
  labs(
    x = "GDP per capita",
    y = "Life Expectancy",
    caption = "Source: Hans Rosling's
  theme_minimal(14, base_family = "Fir
  theme(
    strip.text = element_text(size = 1
    panel.border = element_rect(fill =
```



Data Visualization and Graphic Design Principles

- We will return to various graphics as we cover descriptive statistics and regression

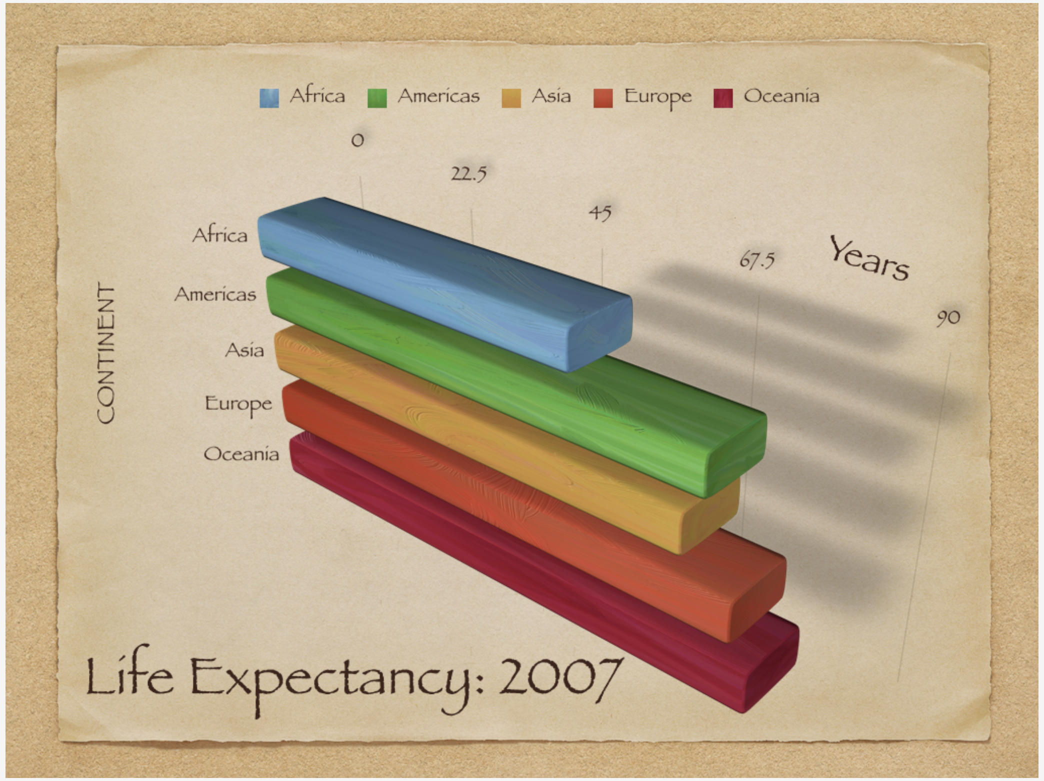
- I hope to cover some basic principles of good graphic design for figures and plots

    - If not in class, I will make a page on the website, and/or a video

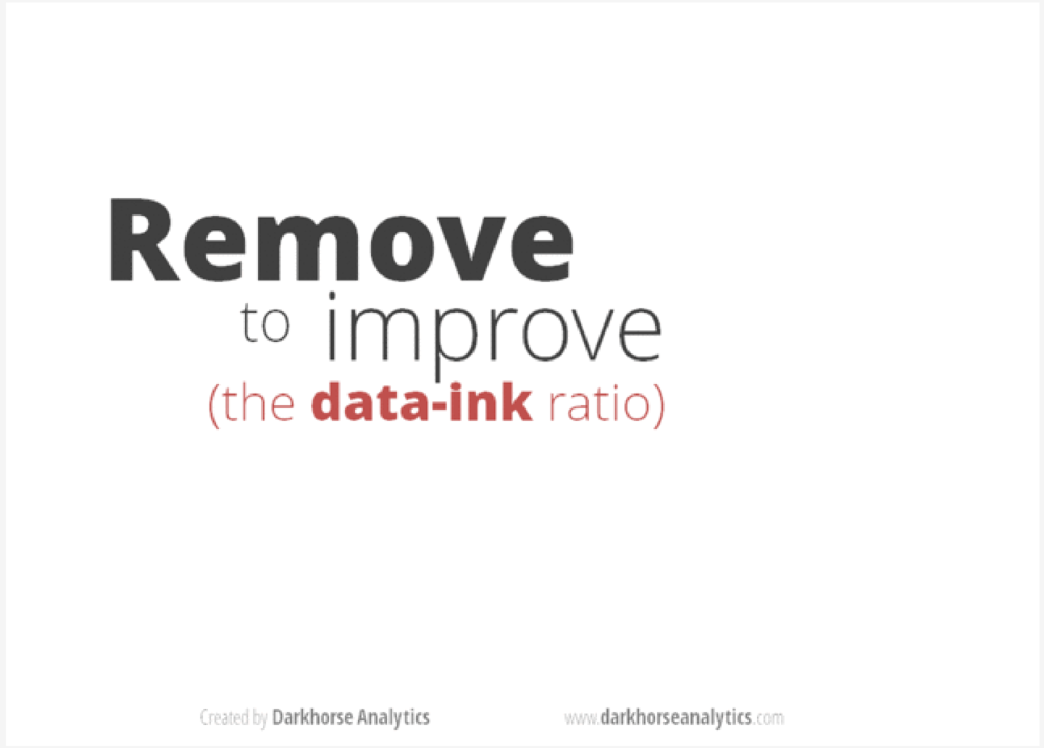
Remember:

Less is More

"Shoot me"

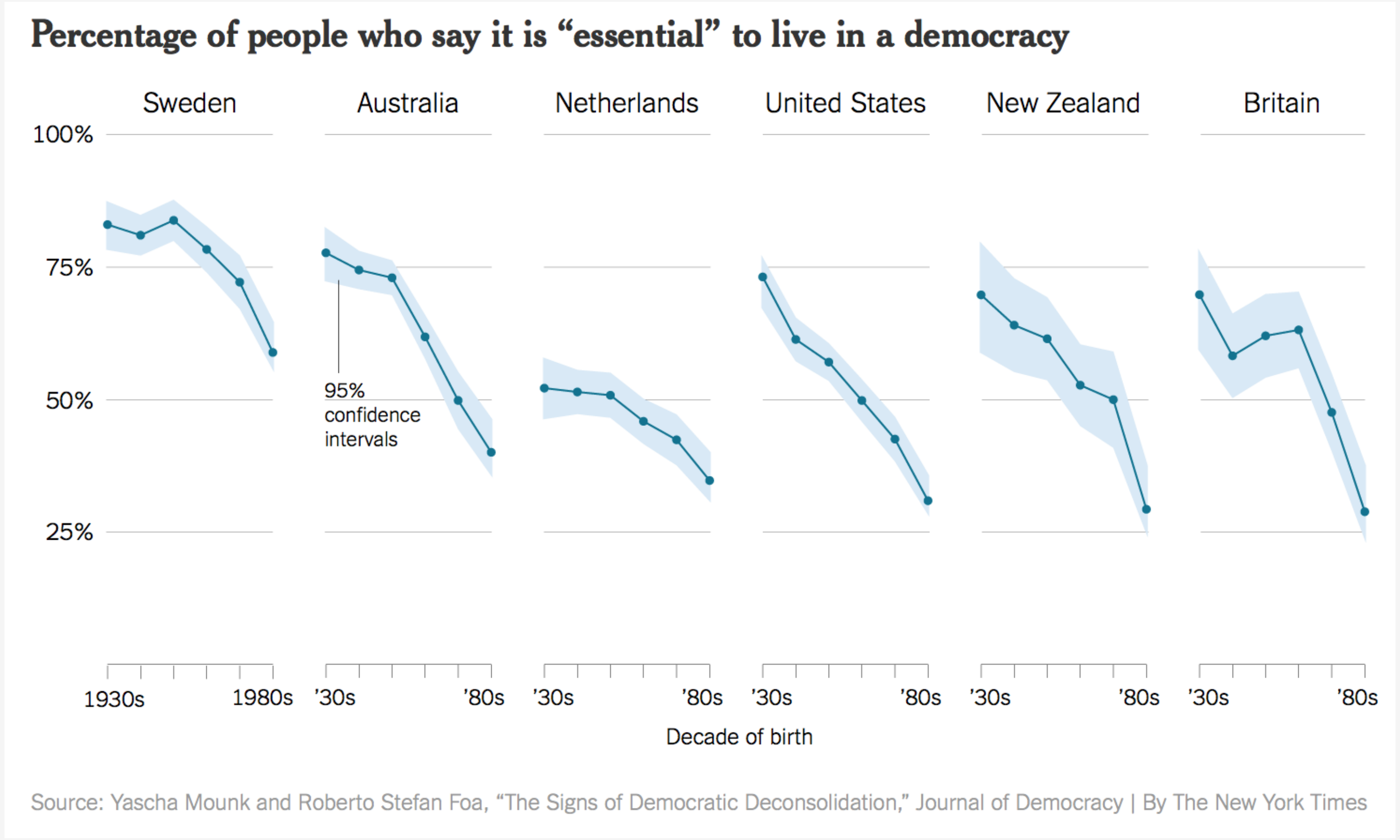


Less is More:


Remove
to improve
(the **data-ink** ratio)

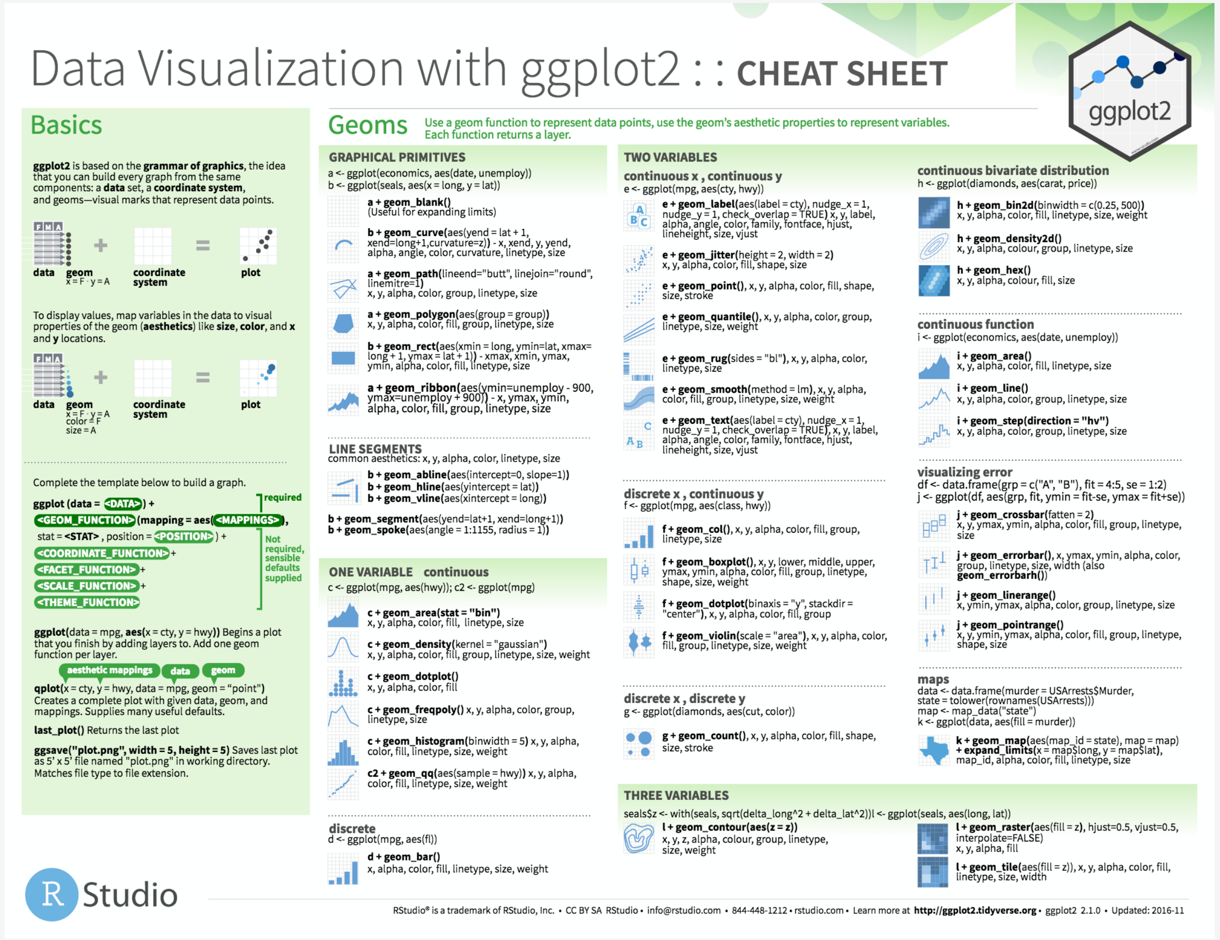
Created by **Darkhorse Analytics** www.**darkhorseanalytics**.com

Try to Show One Trend Really Clearly



New York Times: "How Stable Are Democracies? 'Warning Signs Are Flashing Red'", Nov 29, 2016

Reference: R Studio Makes Great "Cheat Sheet"s!



Data Visualization with ggplot2 : : CHEAT SHEET

ggplot2

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and geoms—visual marks that represent data points.

data **geom** x = F · y = A + **coordinate system** = **plot**

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

data **geom** x = F · y = A, color = F, size = A + **coordinate system** = **plot**

Complete the template below to build a graph.

ggplot (data = <DATA>) + required
<GEOM_FUNCTION>(mapping = aes(<MAPPINGS>),
stat = **<STAT>** , position = **<POSITION>**) + Not required, sensible defaults supplied
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>

ggplot(data = mpg, **aes**(x = cty, y = hwy)) Begins a plot that you finish by adding layers to. Add one geom function per layer.

aesthetic mappings · data · geom

qplot(x = cty, y = hwy, data = mpg, geom = “point”) Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

last_plot() Returns the last plot

ggsave("plot.png", width = 5, height = 5) Saves last plot as 5’ x 5’ file named "plot.png" in working directory. Matches file type to file extension.

Geoms

Use a geom function to represent data points, use the geom’s aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))

a + geom_blank()
(Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)**)** - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend="butt", linejoin="round", linemitre=1**)**
x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(group = group)**)**
x, y, alpha, color, fill, group, linetype, size

b + geom_rect(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)**)** - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin=unemploy - 900, ymax=unemploy + 900)**)** - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept=0, slope=1)**)**
b + geom_hline(aes(yintercept = lat)**)**
b + geom_vline(aes(xintercept = long)**)**

b + geom_segment(aes(yend=lat+1, xend=long+1)**)**
b + geom_spoke(aes(angle = 1:1155, radius = 1)**)**

ONE VARIABLE continuous

c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)

c + geom_area(stat = "bin")
x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian"**)**
x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot()
x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5**)** x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)**)** x, y, alpha, color, fill, linetype, size, weight

discrete

d <- ggplot(mpg, aes(fl))

d + geom_bar()
x, alpha, color, fill, linetype, size, weight

TWO VARIABLES

continuous x , continuous y

e <- ggplot(mpg, aes(cty, hwy))

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE**)** x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_jitter(height = 2, width = 2**)**
x, y, alpha, color, fill, shape, size

e + geom_point(), x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile(), x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"**)**, x, y, alpha, color, linetype, size

e + geom_smooth(method = lm**)**, x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE**)**, x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

f <- ggplot(mpg, aes(class, hwy))

f + geom_col(), x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot(), x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"**)**, x, y, alpha, color, fill, group

f + geom_violin(scale = "area"**)**, x, y, alpha, color, fill, group, linetype, size, weight

discrete x , discrete y

g <- ggplot(diamonds, aes(cut, color))

g + geom_count(), x, y, alpha, color, fill, shape, size, stroke

continuous bivariate distribution

h <- ggplot(diamonds, aes(carat, price))

h + geom_bin2d(binwidth = c(0.25, 500)**)**
x, y, alpha, color, fill, linetype, size, weight

h + geom_density2d()
x, y, alpha, colour, group, linetype, size

h + geom_hex()
x, y, alpha, colour, fill, size

continuous function

i <- ggplot(economics, aes(date, unemploy))

i + geom_area()
x, y, alpha, color, fill, linetype, size

i + geom_line()
x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv")
x, y, alpha, color, group, linetype, size

visualizing error

df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))

j + geom_crossbar(fatten = 2**)**
x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar(), x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + geom_linerange()
x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange()
x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

data <- data.frame(murder = USArrests$Murder,
state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + geom_map(aes(map_id = state), map = map)
+ expand_limits(x = map$long, y = map$lat**)**, map_id, alpha, color, fill, linetype, size

THREE VARIABLES

seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2))l <- ggplot(seals, aes(long, lat))

l + geom_contour(aes(z = z))
x, y, z, alpha, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z)**)**, hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

l + geom_tile(aes(fill = z)), x, y, alpha, color, fill, linetype, size, width

RStudio

RStudio: ggplot2 Cheat Sheet

Reference

On `ggplot2`

- **R Studio's ggplot2 Cheat Sheet**
- **`ggplot2` 's website reference section**
- Hadley Wickham's R for Data Science book chapter on ggplot2
- STHDA's be awesome in ggplot2
- r-statistic's top 50 ggplot2 visualizations

On data visualization

- **Kieran Healy's Data Visualization: A Practical Guide**
- **Claus Wilke's Fundamentals of Data Visualization**
- PolicyViz Better Presentations
- Karl Broman's How to Display Data Badly