BGGN 213

Hands-on Lab Session

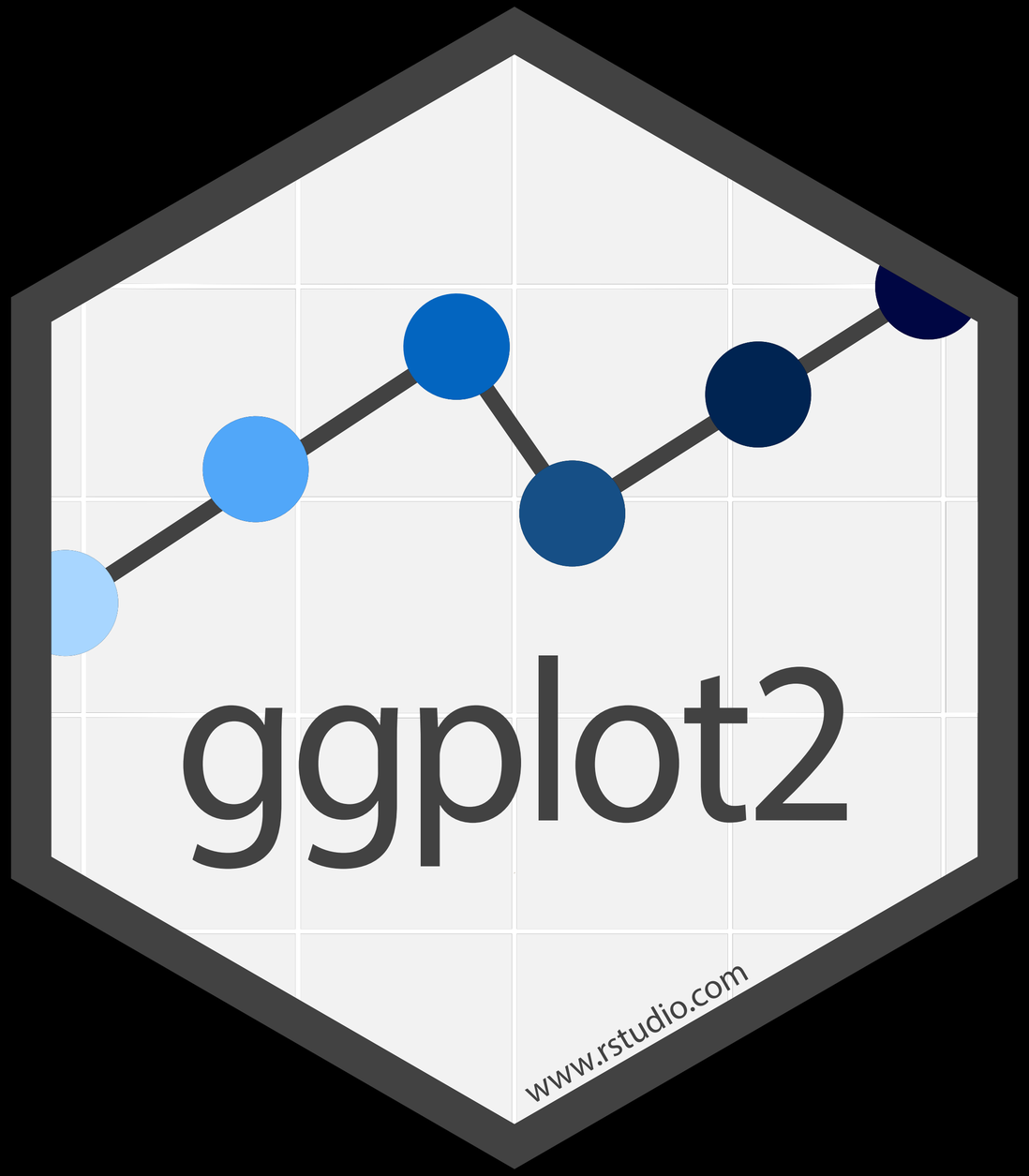
Class 05

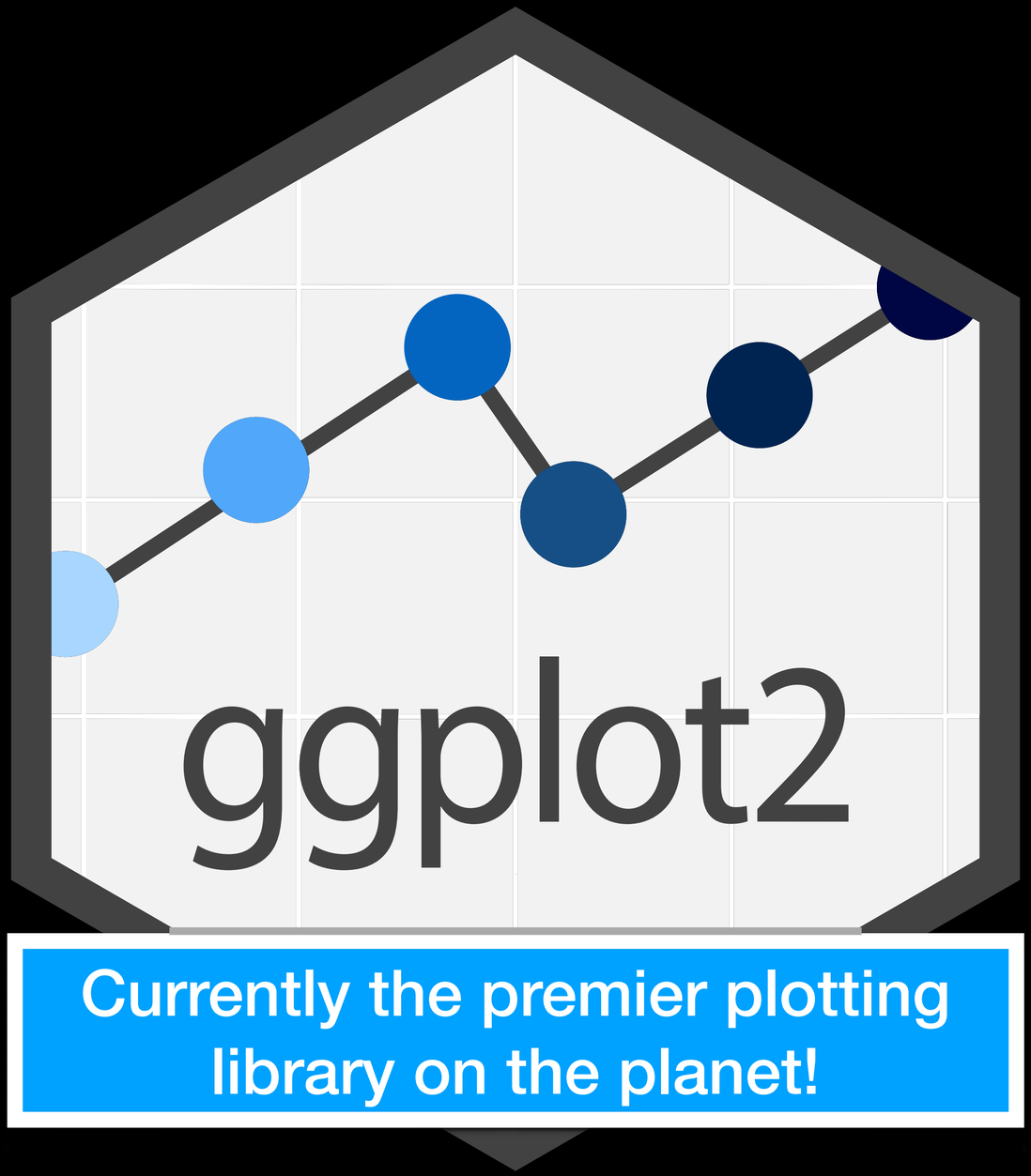
Barry Grant

UC San Diego

http://thegrantlab.org/bggn213

How do we make informative and compelling figures?


ggplot2
www.rstudio.com


ggplot2
Currently the premier plotting
library on the planet!

Key Insight: All visualizations map data into quantifiable aesthetic features of the resulting graphic

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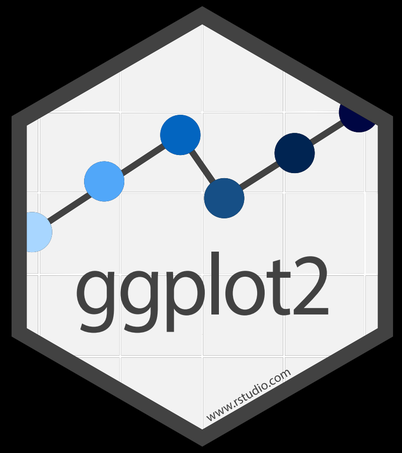
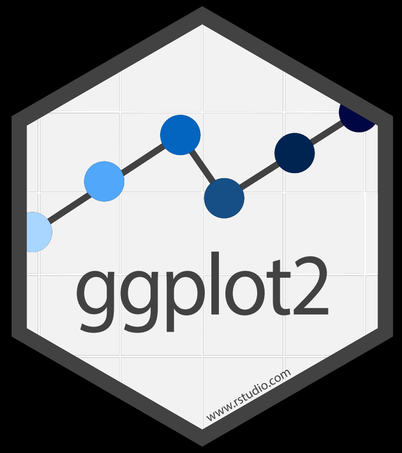
data ➡ aesthetics



data + aesthetics + geometrys

Three main "**layers**"
that are in every ggplot



data + aesthetics + geometrys

Three main "**layers**"
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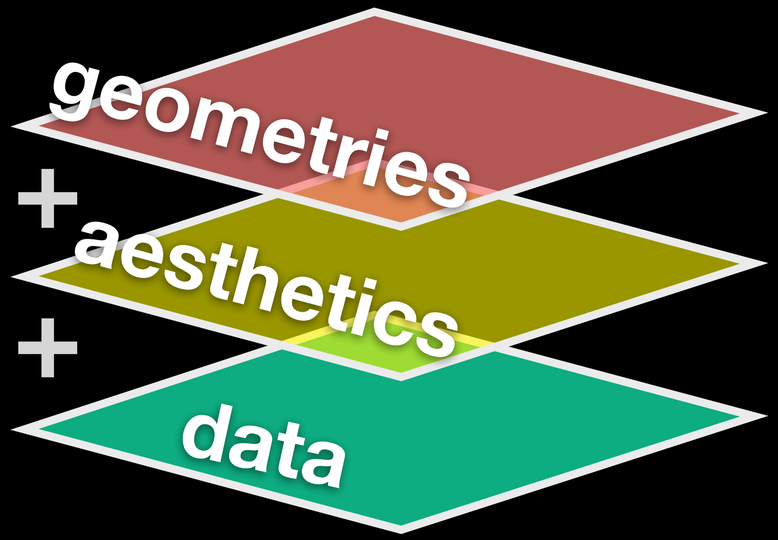
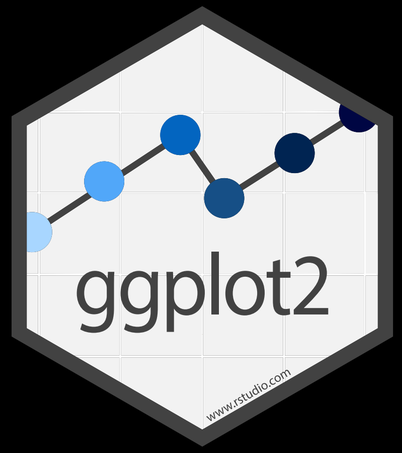
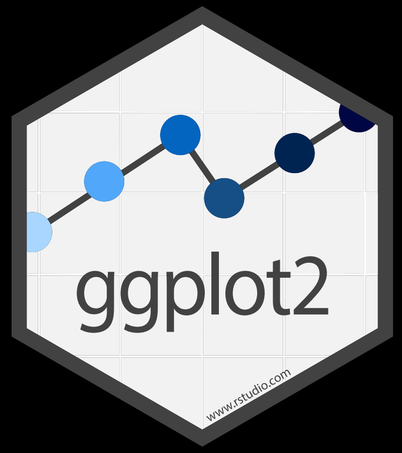




data + aesthetics + geometrys

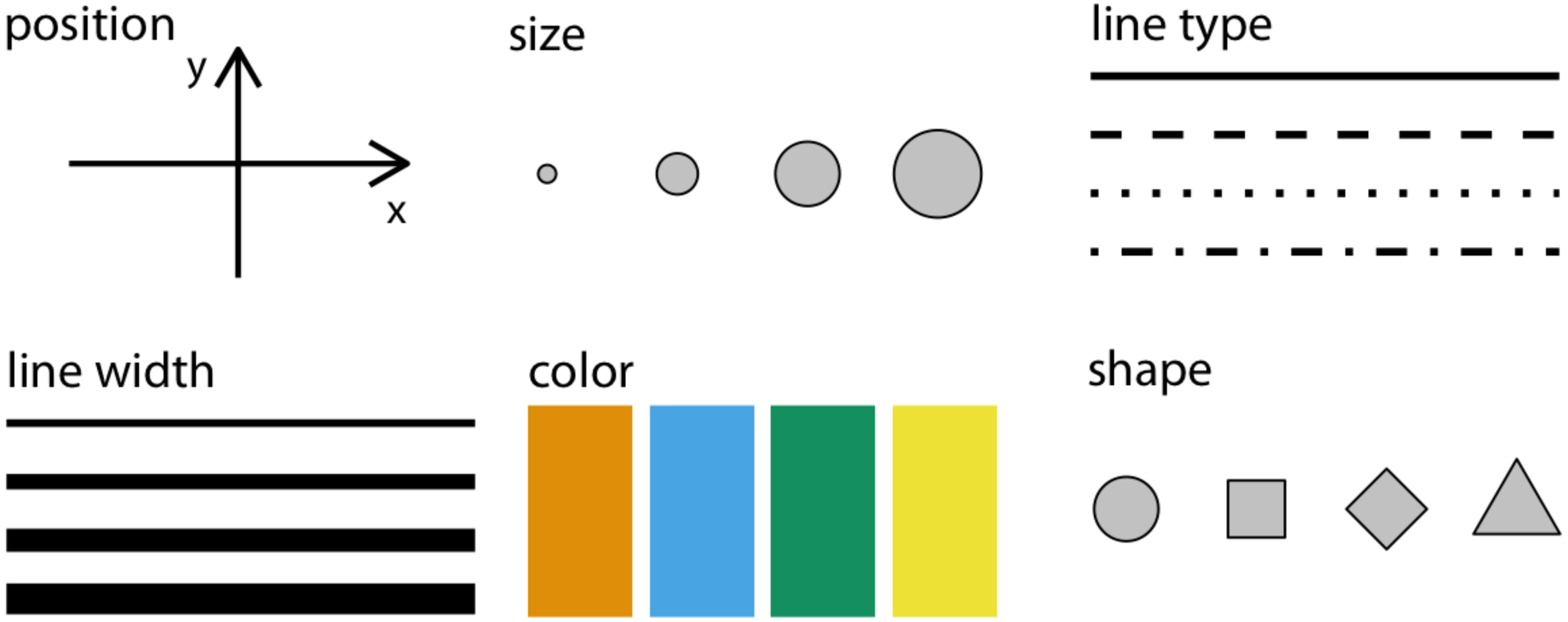
```
ggplot(data=mpg) +
  aes(x=displ, y=hwy, color=class) +
  geom_point()
```



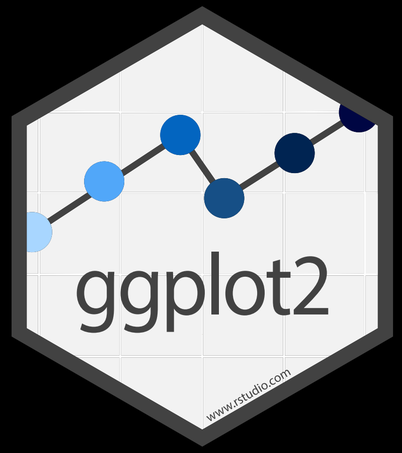
data + aesthetics + geometrys

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

Common aesthetics include



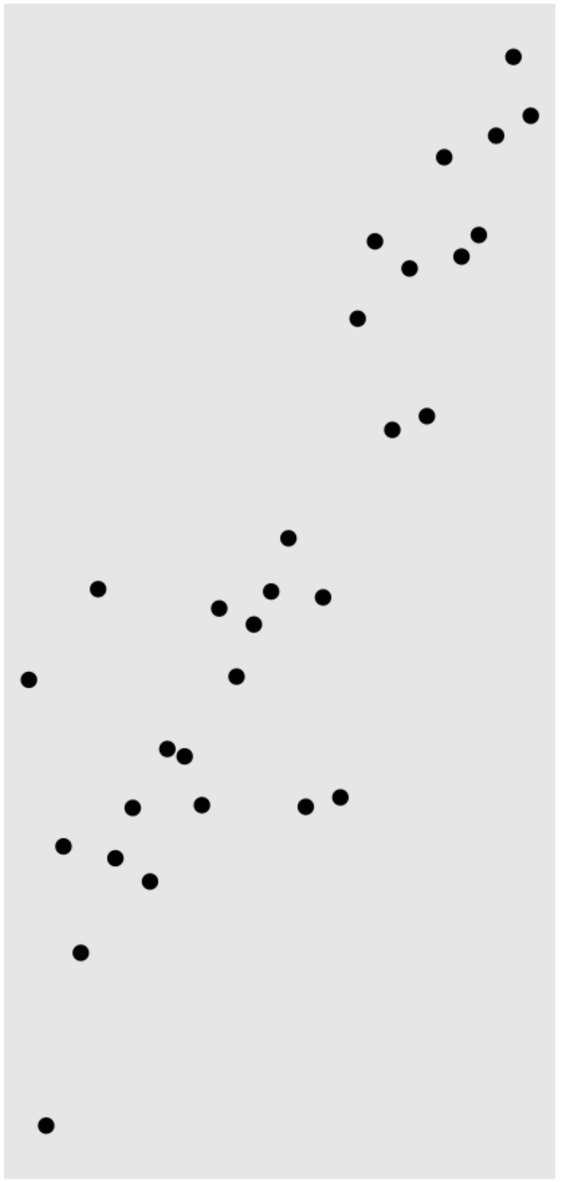
Modified from: Wilke (2019)



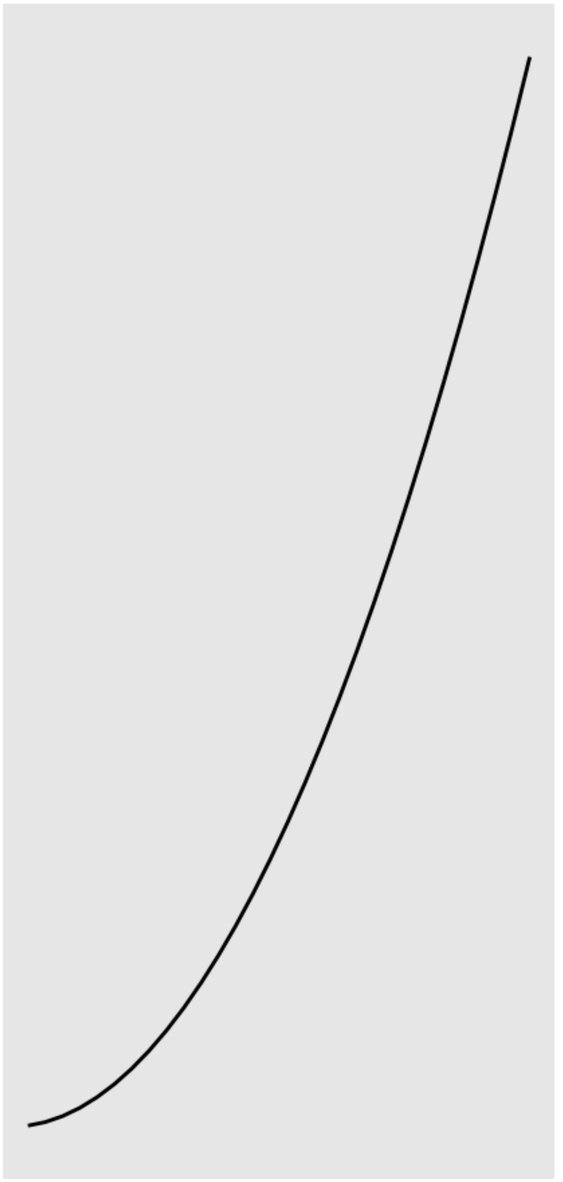
data + aesthetics + geometrys

Three main "**layers**"
that are in every ggplot

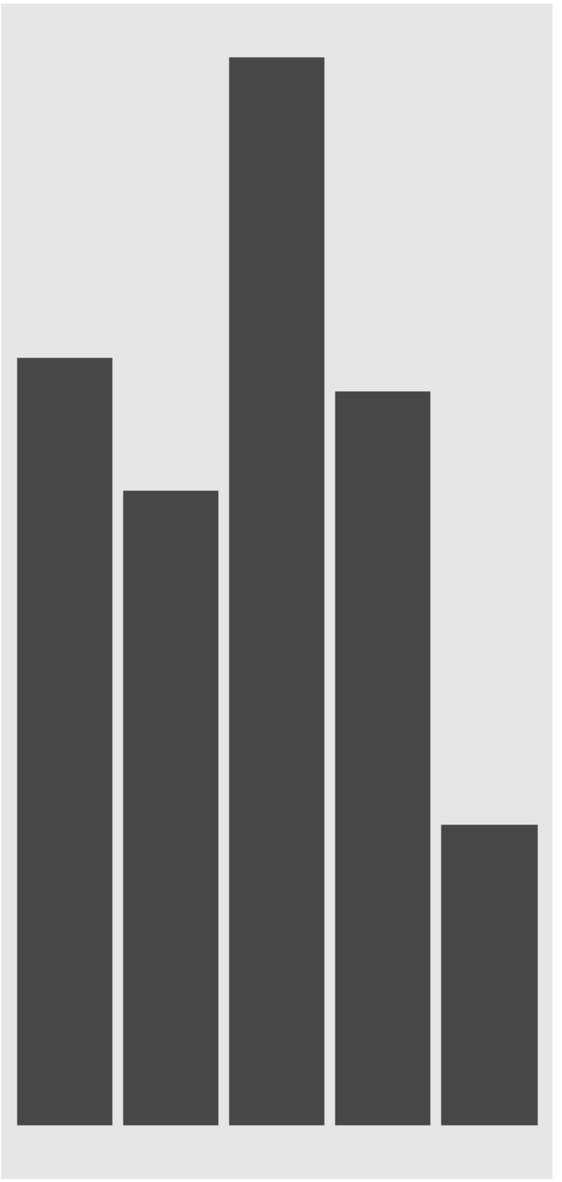
geom_point()



geom_line()



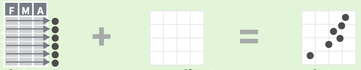
geom_col()



Data Visualization with ggplot2 : : CHEAT SHEET

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.



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

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=1**)** - 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

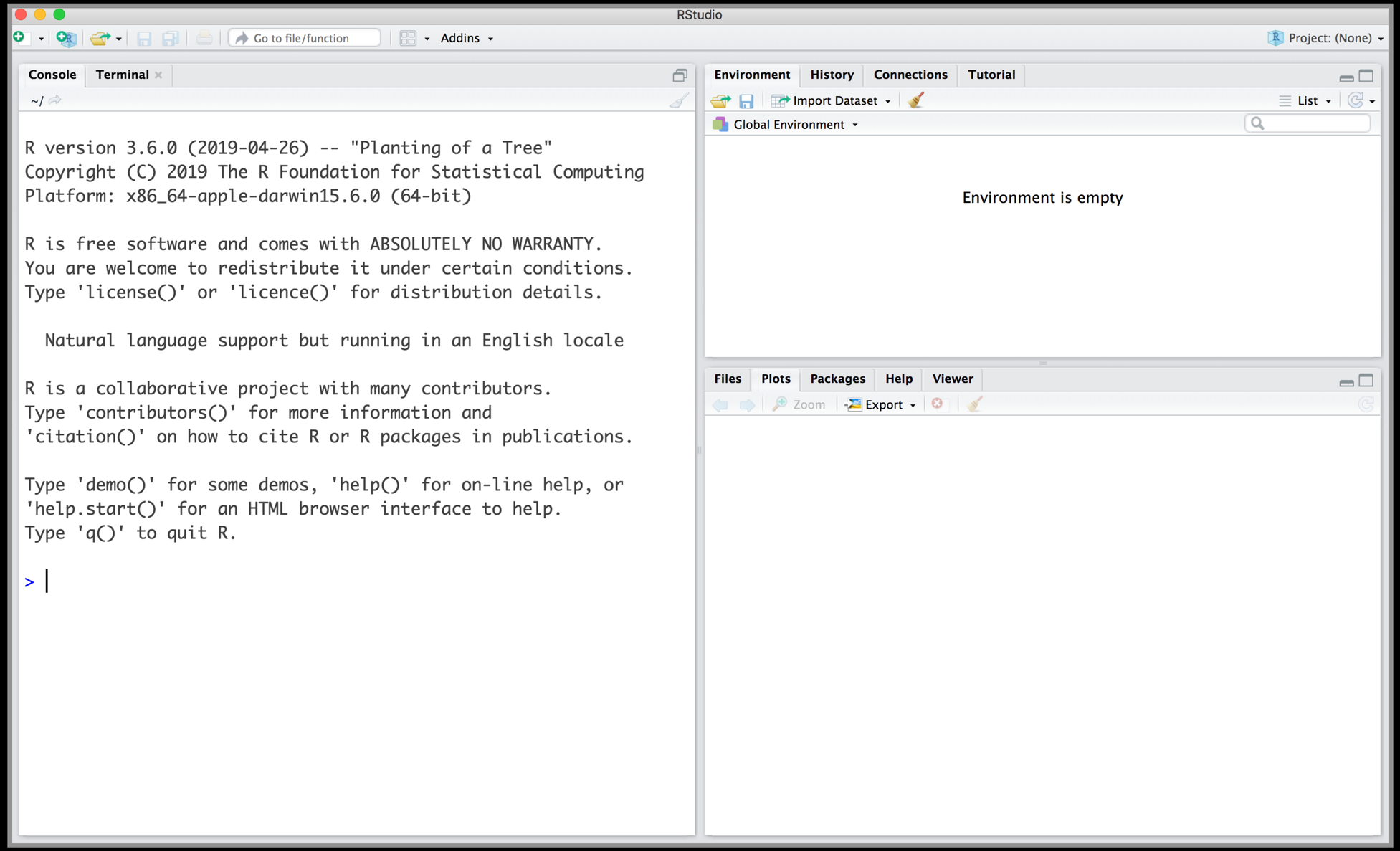
l + geom_tile(aes(fill = z)**)**, x, y, alpha, color, fill, linetype, size, width

Learn more about core `geom_FUNCTIONS()`

There are > 40 core "geom" functions. See cheat-sheet link on class website!

RStudio®

Follow Along!



RStudio

Follow Along!

RStudio

Go to file/function | Addins | Project: (None)

Source

Console | Terminal

~/

Input

```
R version 3.6.0 (2019-04-26) -- "Planting of a Tree"
Copyright (C) 2019 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin15.6.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> library(ggplot2)
> ggplot(mpg, aes(displ, hwy, color=class)) +
+ geom_point()
>
```

Environment | History | Connections | Tutorial

Import Dataset | List

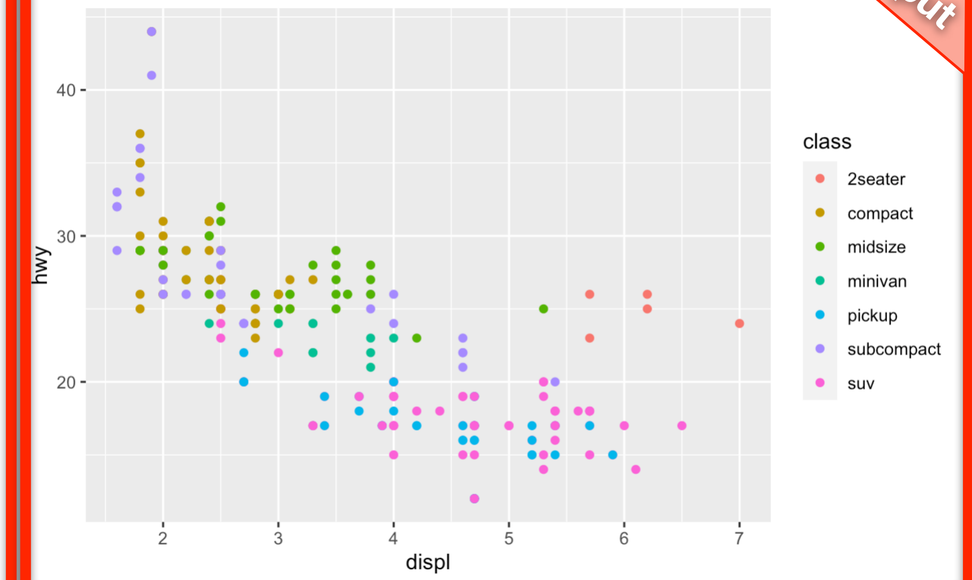
Global Environment

Environment is empty

Files | Plots | Packages | Help | Viewer

Zoom | Export

Output



RStudio >

Create a new Project and open a new R Script

(N.B. make a report with notes and plots)

In addition to your **PDF lab report** answer the **inbuilt questions**

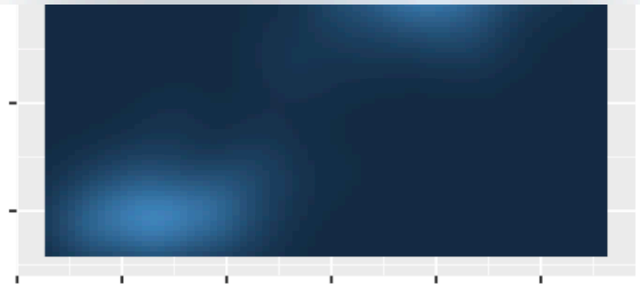
bioboot.github.io

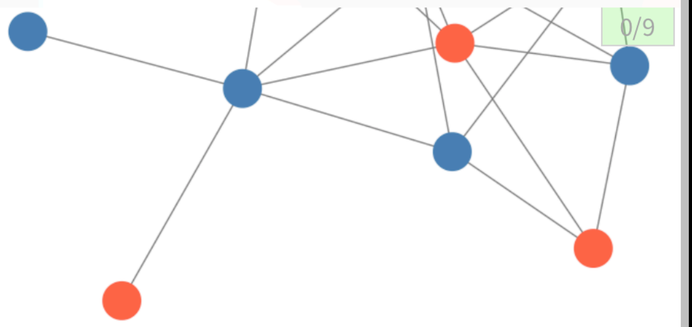
Week 4

Home Gmail Gcal GitHub BIMM143 BGGN213 GDrive Atmosphere CloudLaunch BIMM194 Blink News +

1. Overview
2. Background
3. Getting Organized
4. Common Plot Types
5. Creating Scatter Plots
   - Introduction to scatter plots
   - Specifing a dataset with `ggplot()`
   - Specifing aesthetic mappings with `aes()`
   - Specifing a geom layer with `geom_point()`
   - Adding more plot aesthetics through `aes()`
6. OPTIONAL: Going Further
7. OPTIONAL: Bar Charts

About this document





0/9

Question Counter

Q. Which plot types are typically NOT used to compare distributions of numeric variables?

✓
Density plots
Network graphs
Histograms
Violin plots
Box plots

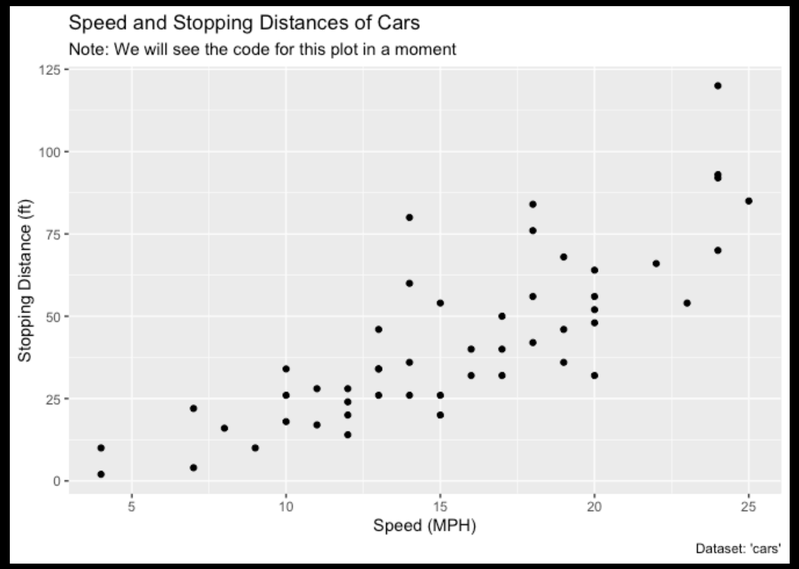
bout data visualization with ggplot2 is incorrect?

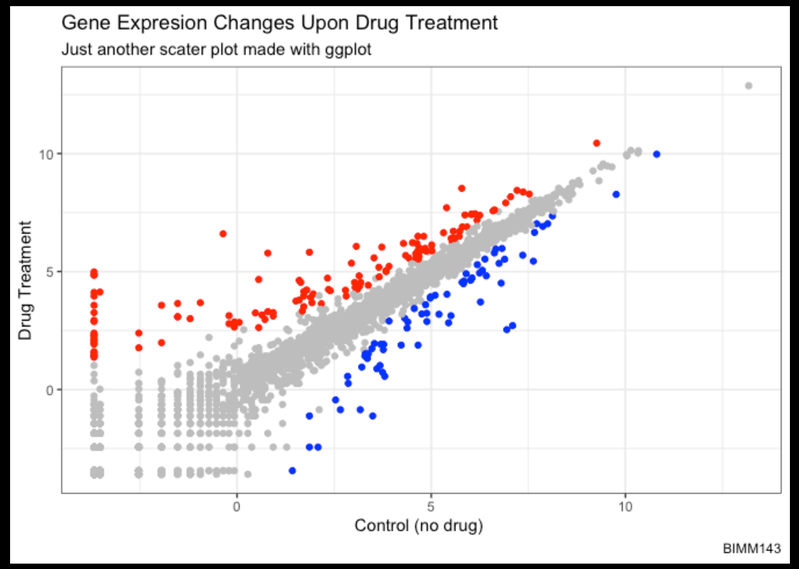
Questions

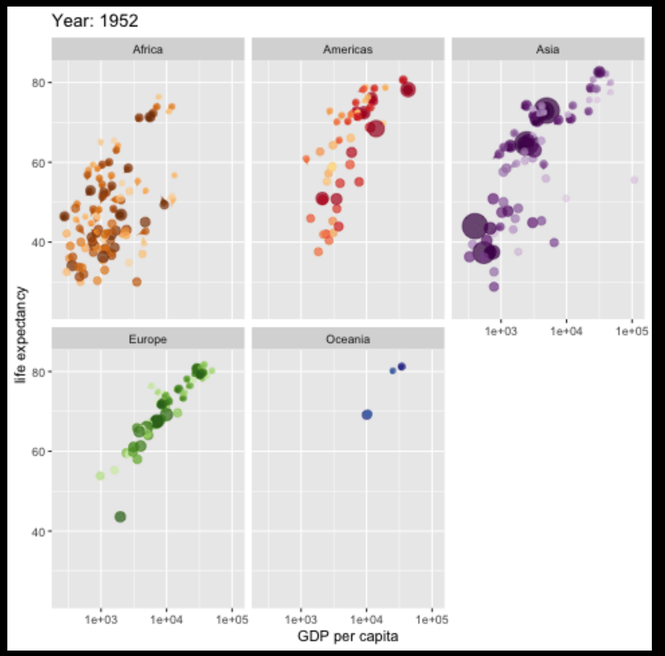
5. Creating Scatter Plots

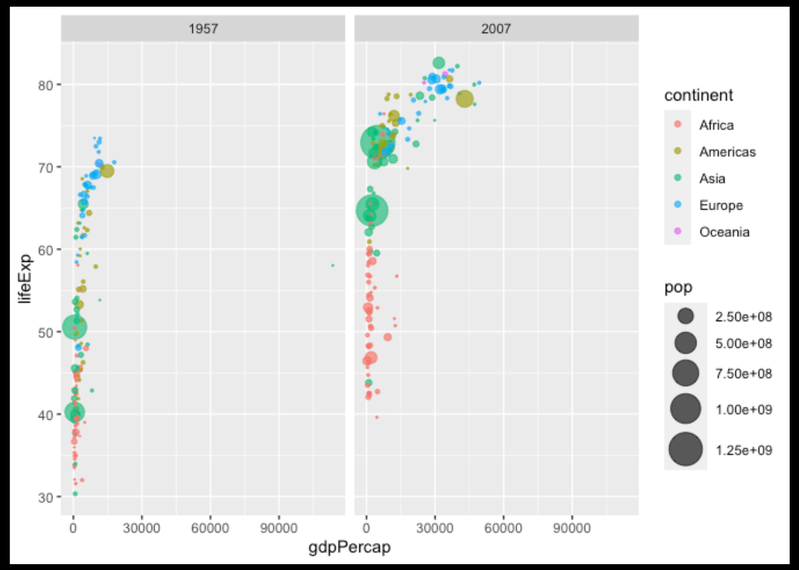
In this section we will focus on:

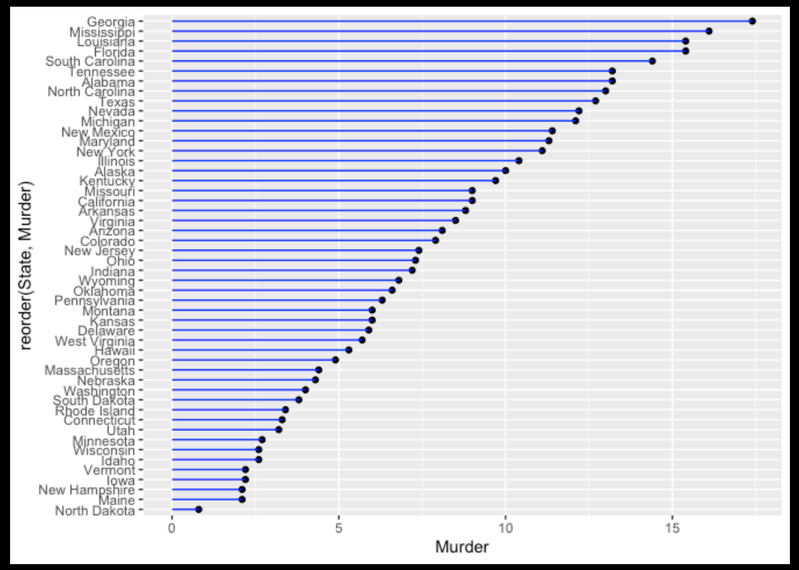
- Defining a dataset for your plot using the main `ggplot()` function.
- Specifying how your data maps to plot aesthetics with the `aes()` function.
- Adding geometric layers using the `geom_point()` function.

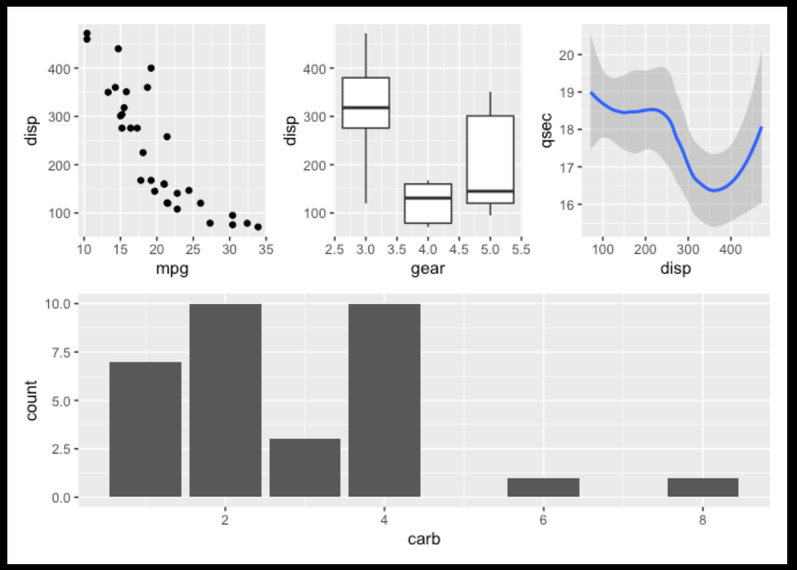

Speed and Stopping Distances of Cars
Note: We will see the code for this plot in a moment
Stopping Distance (ft)
Speed (MPH)
Dataset: 'cars'


Gene Expresion Changes Upon Drug Treatment
Just another scater plot made with ggplot
Drug Treatment
Control (no drug)
BIMM143


Year: 1952
Africa
Americas
Asia
Europe
Oceania
life expectancy
GDP per capita


1957
2007
lifeExp
gdpPercap
continent
Africa
Americas
Asia
Europe
Oceania
pop
2.50e+08
5.00e+08
7.50e+08
1.00e+09
1.25e+09

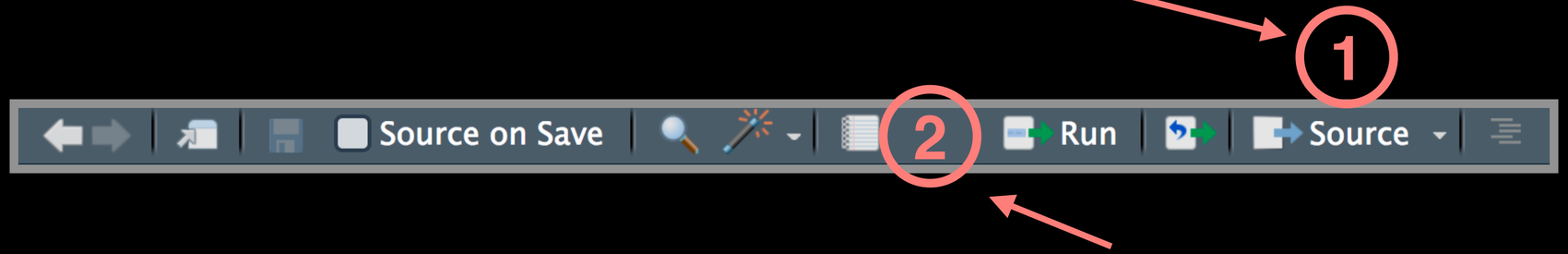

reorder(State, Murder)
Murder


disp
mpg
gear
qsec
count
carb

Making a HTML Lab Report

Lab Report

- Save your **R script** (make sure it has some plots and comments)
- Can you source this R script file to re-generate all your plots without error?



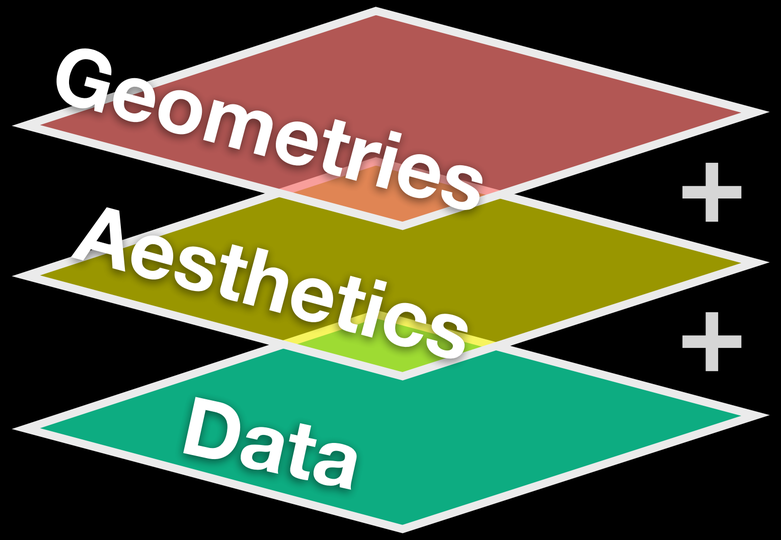
- If so you can now generate a nice PDF report of your work for upload to **GradeScope...**

[Optional Sections get you bonus points!]

data + aesthetics + geometrys

- **Summary:** ggplot takes an input *data.frame*, a mapping of columns to aesthetics and one or more geom *layers* (e.g. geom_point(), geom_line(), ...)

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



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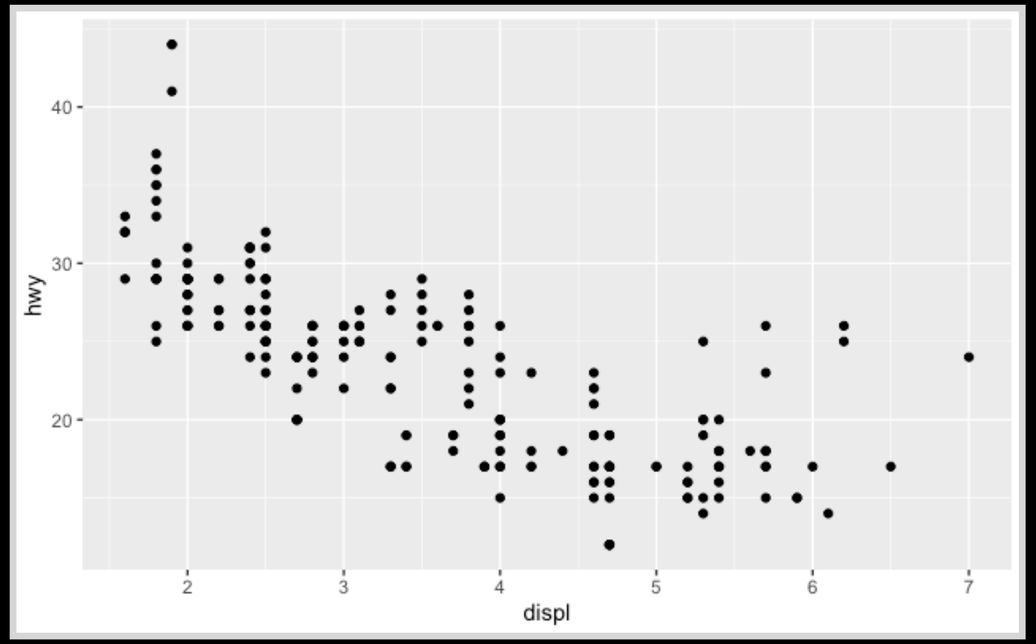

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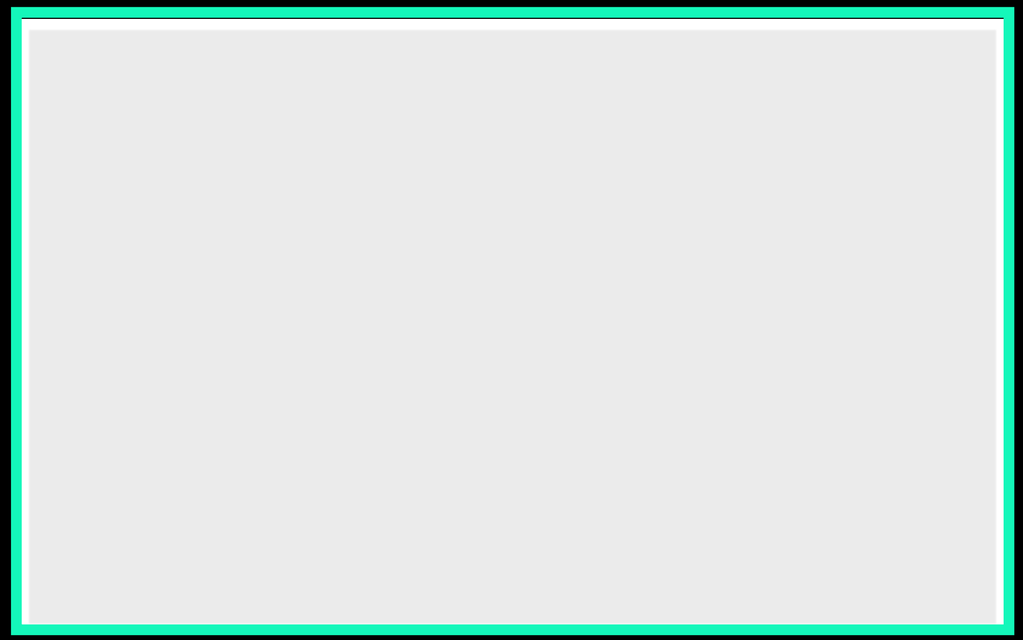

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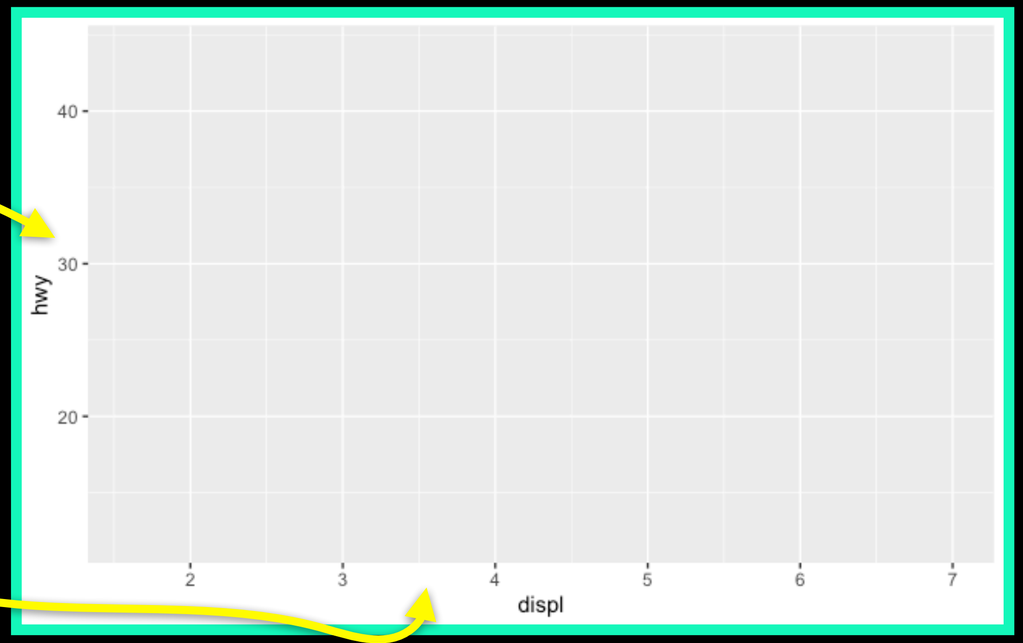
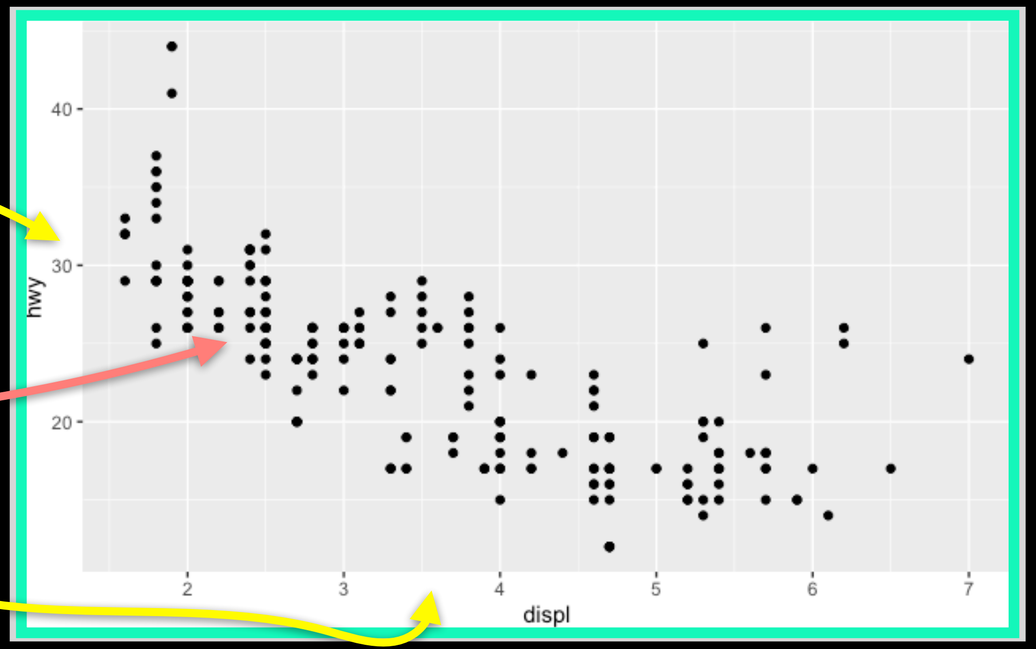
  aes(x=displ, y=hwy)
```



data + aesthetics + geometrys

- **Summary:** ggplot takes an input *data.frame*, a mapping of columns to aesthetics and one or more geom *layers* (e.g. geom_point(), geom_line(), ...)

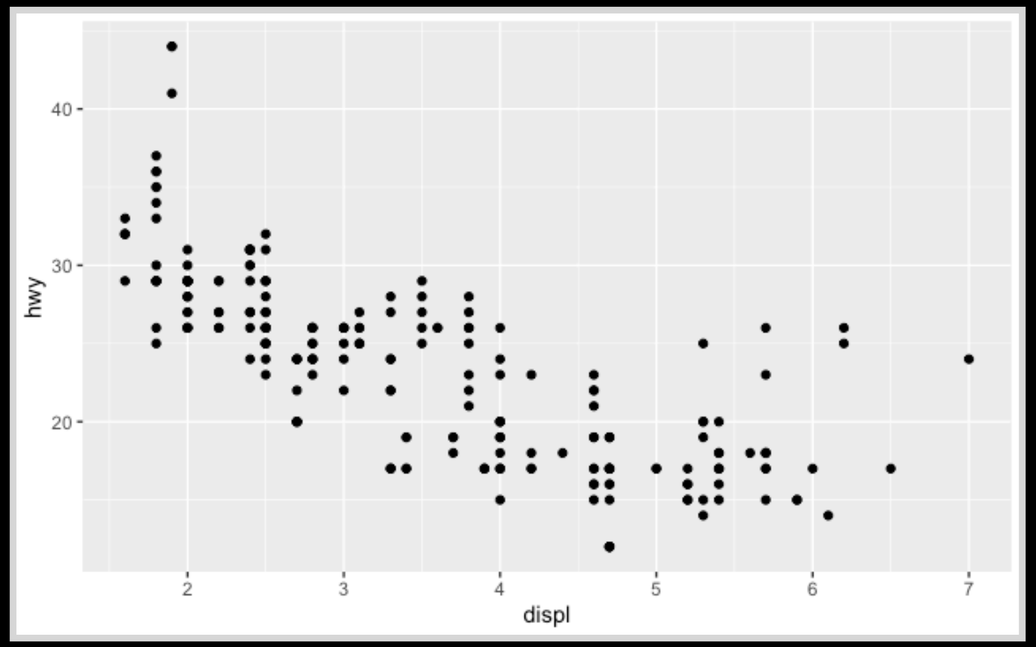
```
ggplot(data=mpg) +
  aes(x=displ, y=hwy) +
  geom_point()
```



data + aesthetics + geometrys

- We can keep building more complicated plots by adding more **layers**

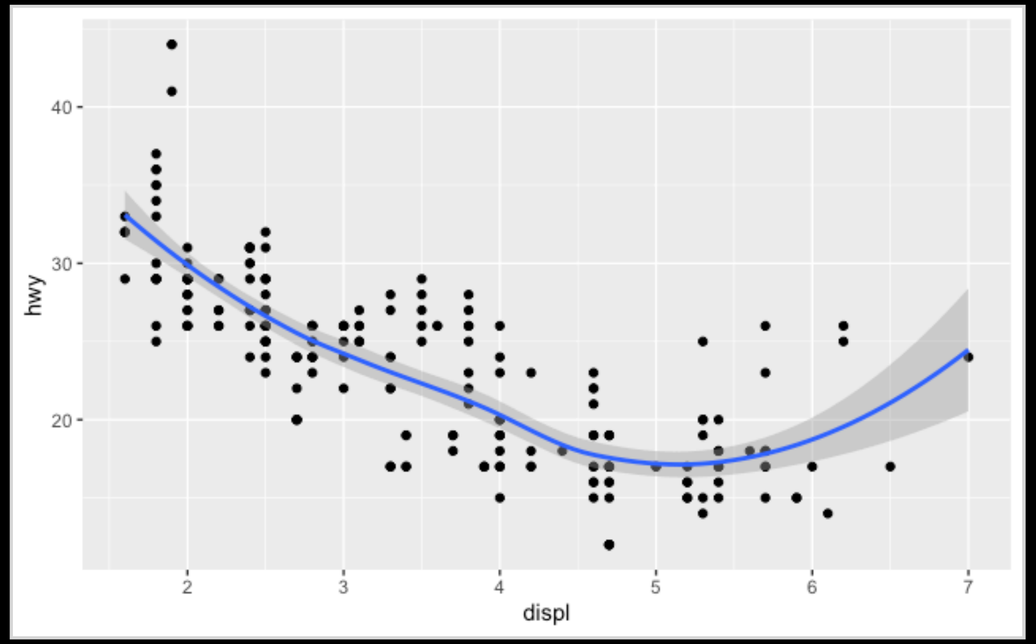
```
ggplot(data=mpg) +
  aes(x=displ, y=hwy) +
  geom_point()
```



data + aesthetics + geometrys

- We can keep building more complicated plots by adding more **layers**
- For example lets add another ***geom***, in this case a smooth line fitted to the data...

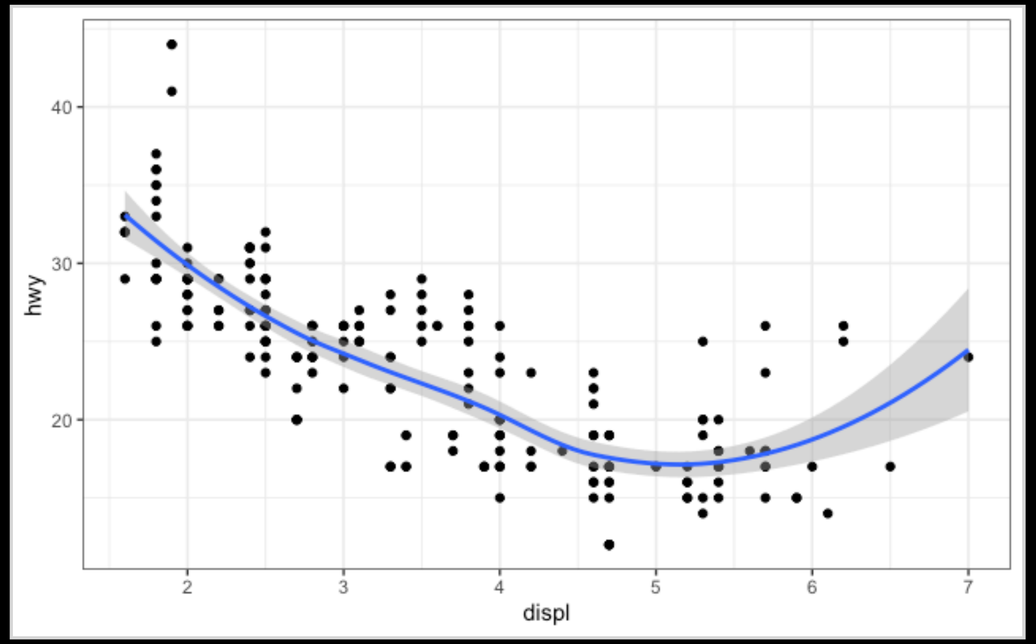
```
ggplot(data=mpg) +
  aes(x=displ, y=hwy) +
  geom_point() +
  geom_smooth()
```



data + aesthetics + geometrys

- We can also add other customizations like themes...

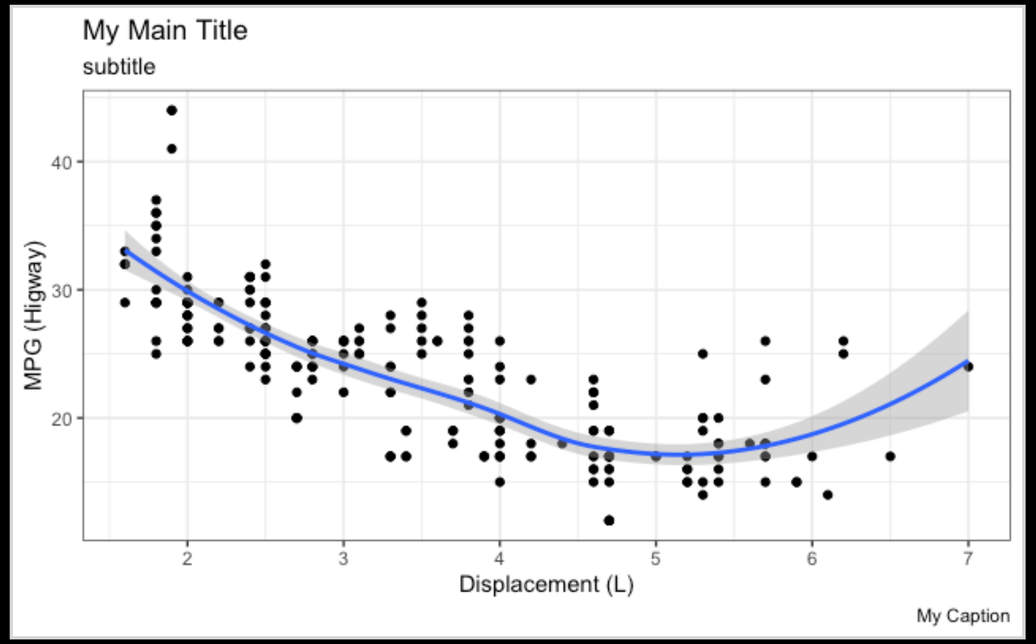
```
ggplot(data=mpg) +
  aes(x=displ, y=hwy) +
  geom_point() +
  geom_smooth() +
  theme_bw()
```



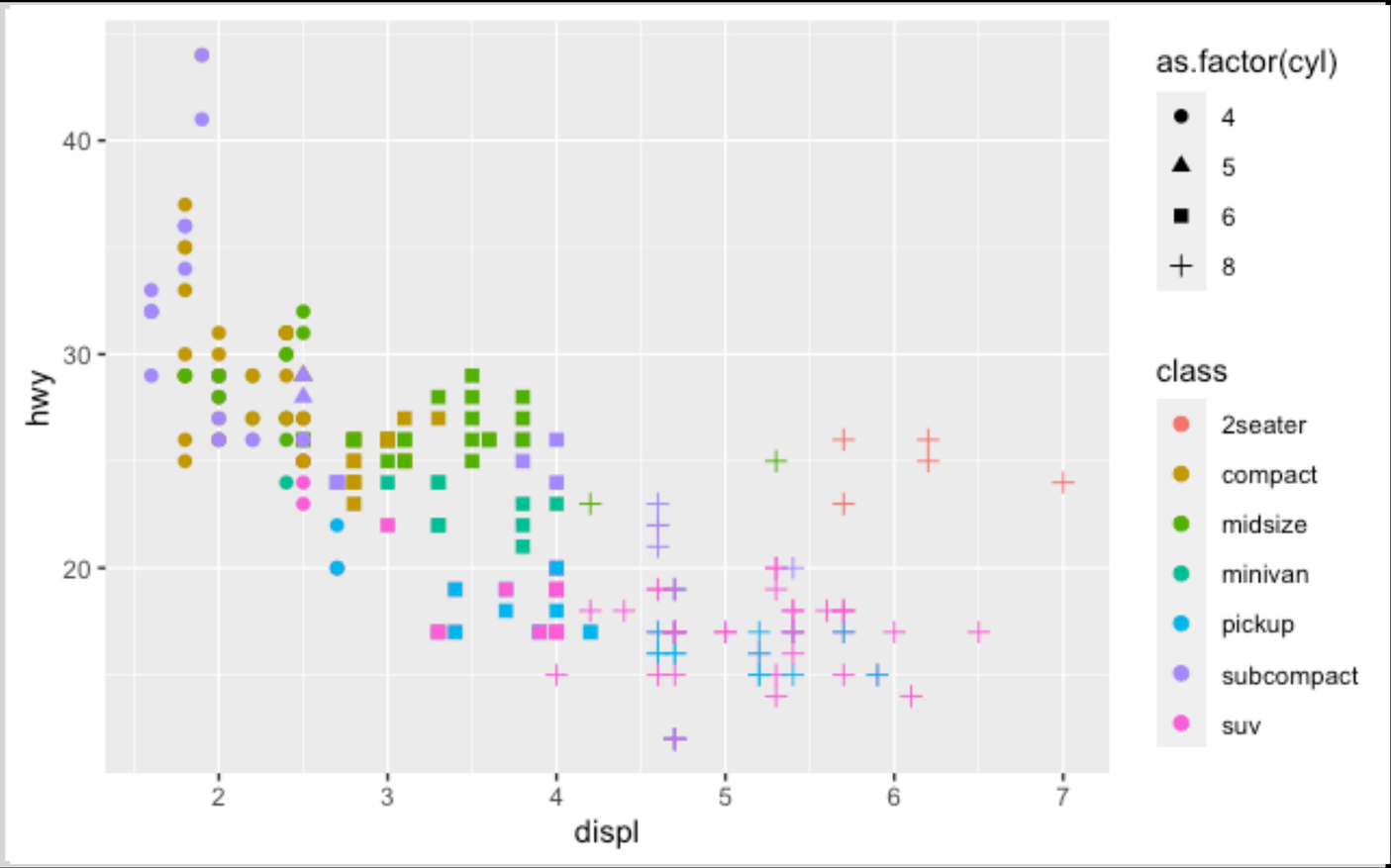
data + aesthetics + geometrys

- And various custom annotation labels...

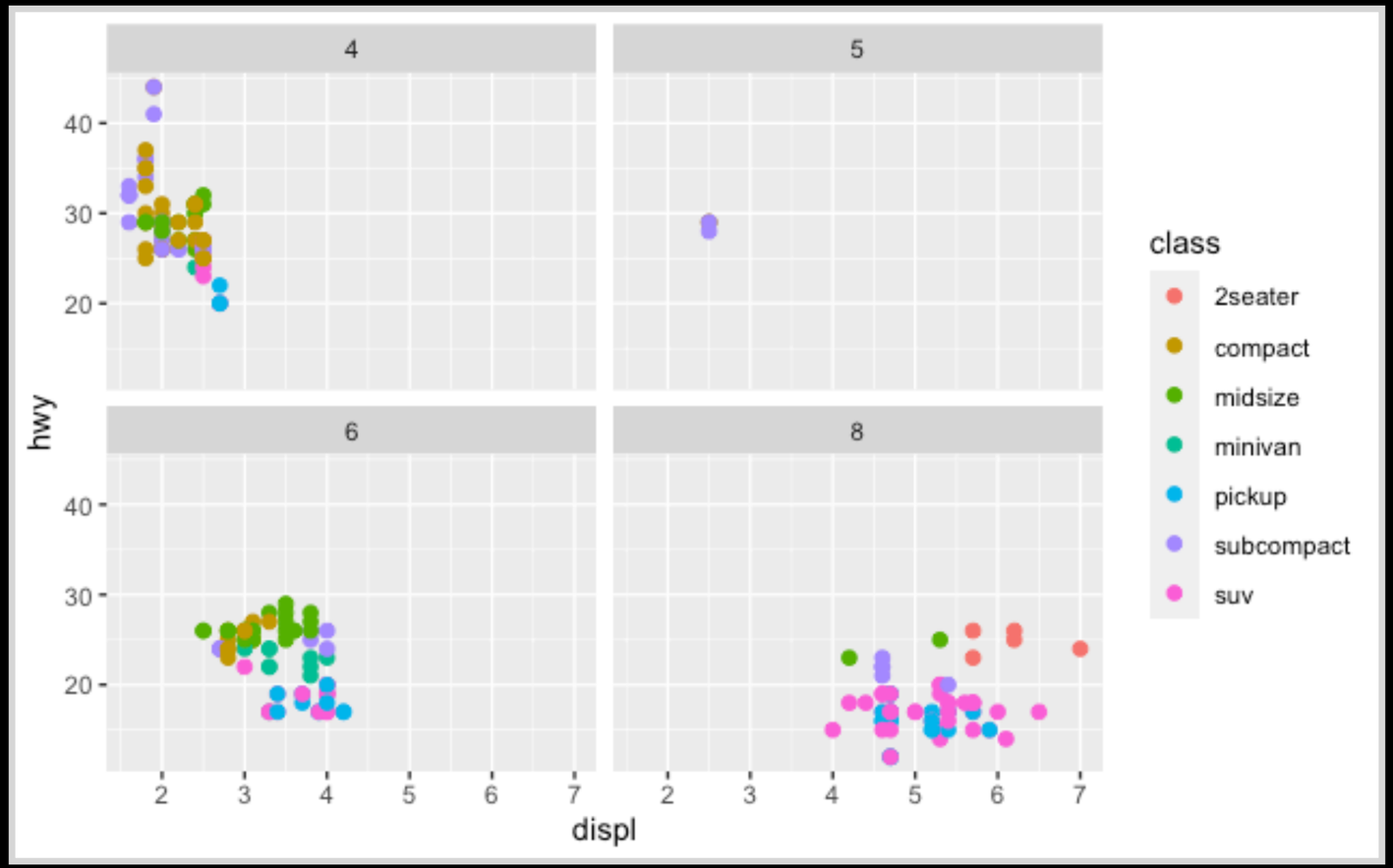
```
ggplot(data=mpg) +
 aes(x=displ, y=hwy) +
 geom_point() +
 geom_smooth() +
 theme_bw()+
 labs(title="My Main Title",
      subtitle = "subtitle",
      caption ="My Caption",
      x="Displacement (L)",
      y= "MPG (Higway)")
```



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



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



Data Visualization with ggplot2 : : CHEAT SHEET

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.

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

Complete the template below to build a graph.

```
ggplot (data = <DATA>) +                                   required
<GEOM_FUNCTION> (mapping = aes( <MAPPINGS> ),
 stat = <STAT> , position = <POSITION> ) +                 Not required,
<COORDINATE_FUNCTION> +                                    sensible
<FACET_FUNCTION> +                                         defaults
<SCALE_FUNCTION> +                                         supplied
<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=1**)** - 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

Learn more about core `geom_FUNCTIONS()`

DataCamp course!

BGGN 213

Hands-on Lab Session

Class 05

Barry Grant

UC San Diego

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