Mapping Data to Graphics

Session 3

PMAP 8921: Data Visualization with R
Andrew Young School of Policy Studies
May 2020

Plan for today

Data, aesthetics, & the grammar of graphics

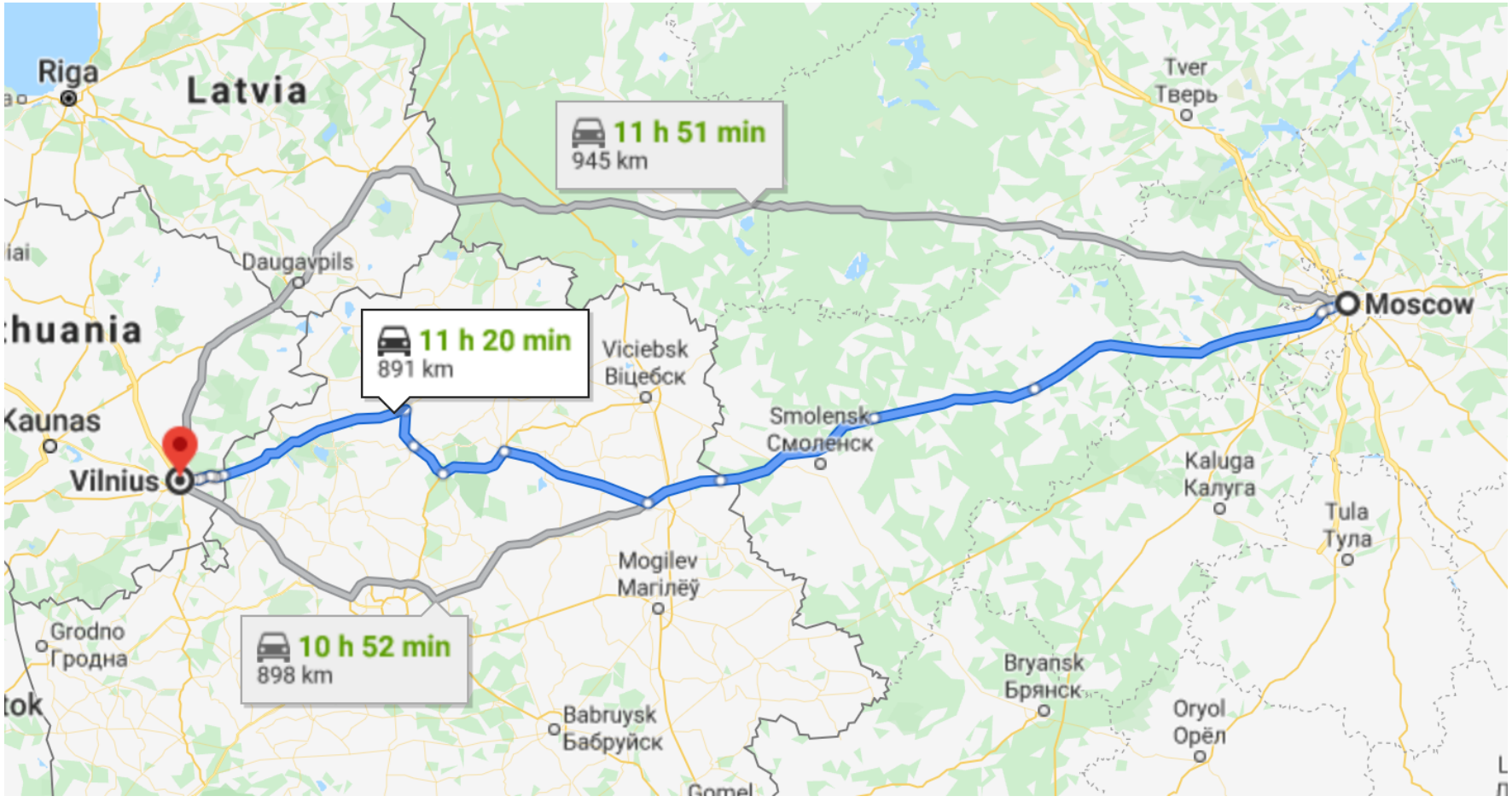
Grammatical layers

Aesthetics in extra dimensions

Tidy data

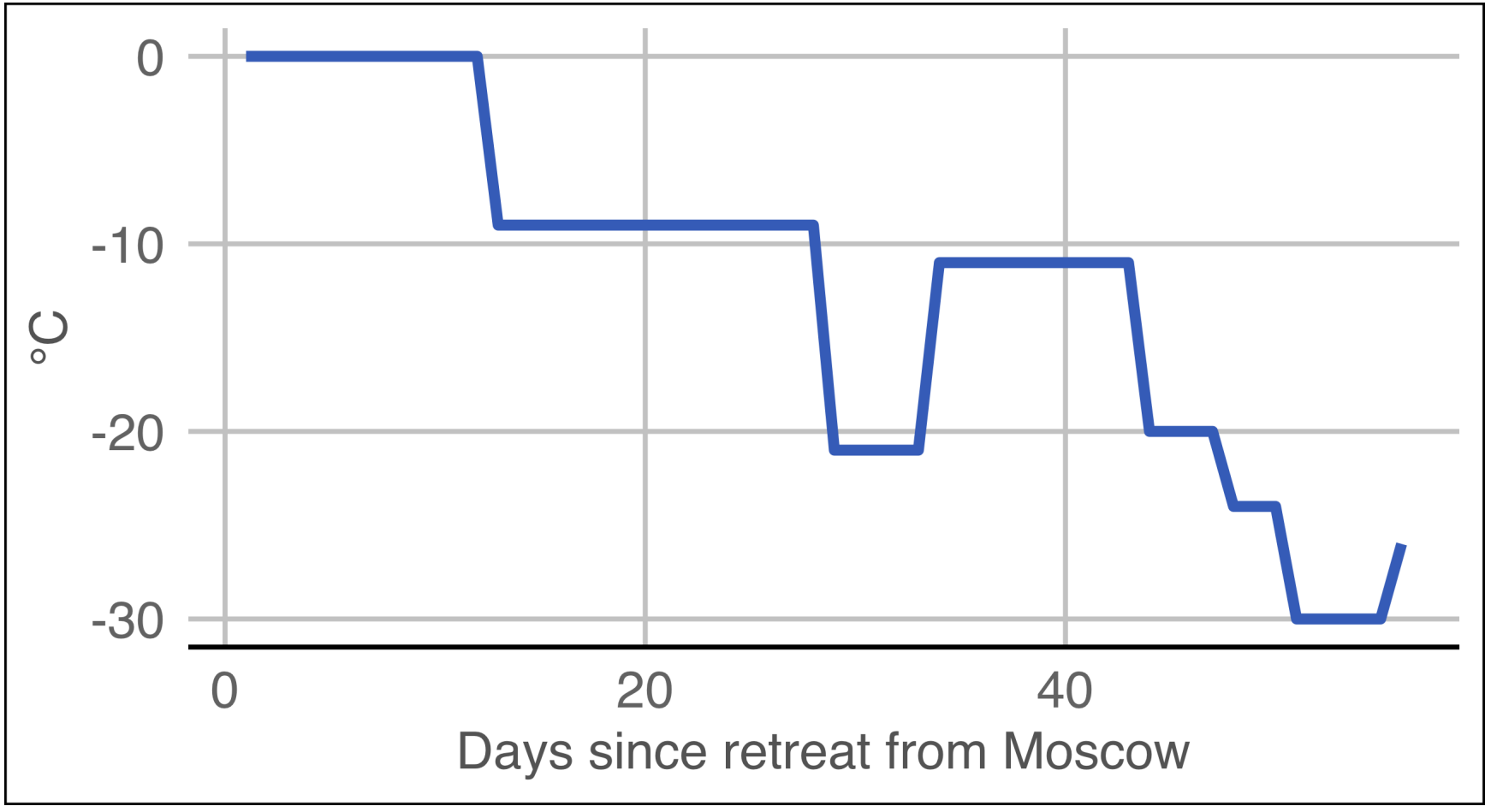
Data, aesthetics, & the grammar of graphics

Long distance!

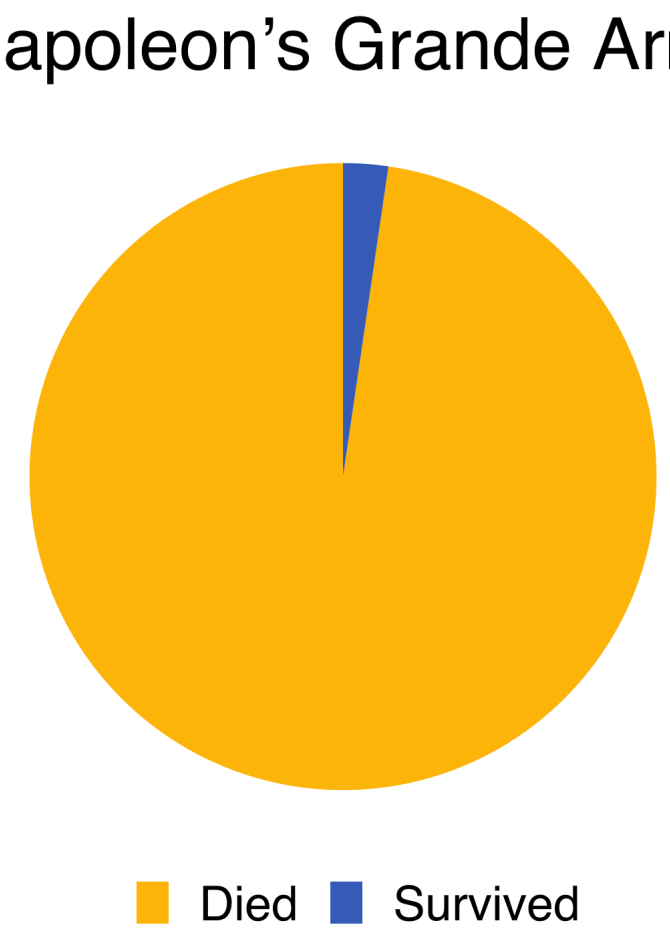


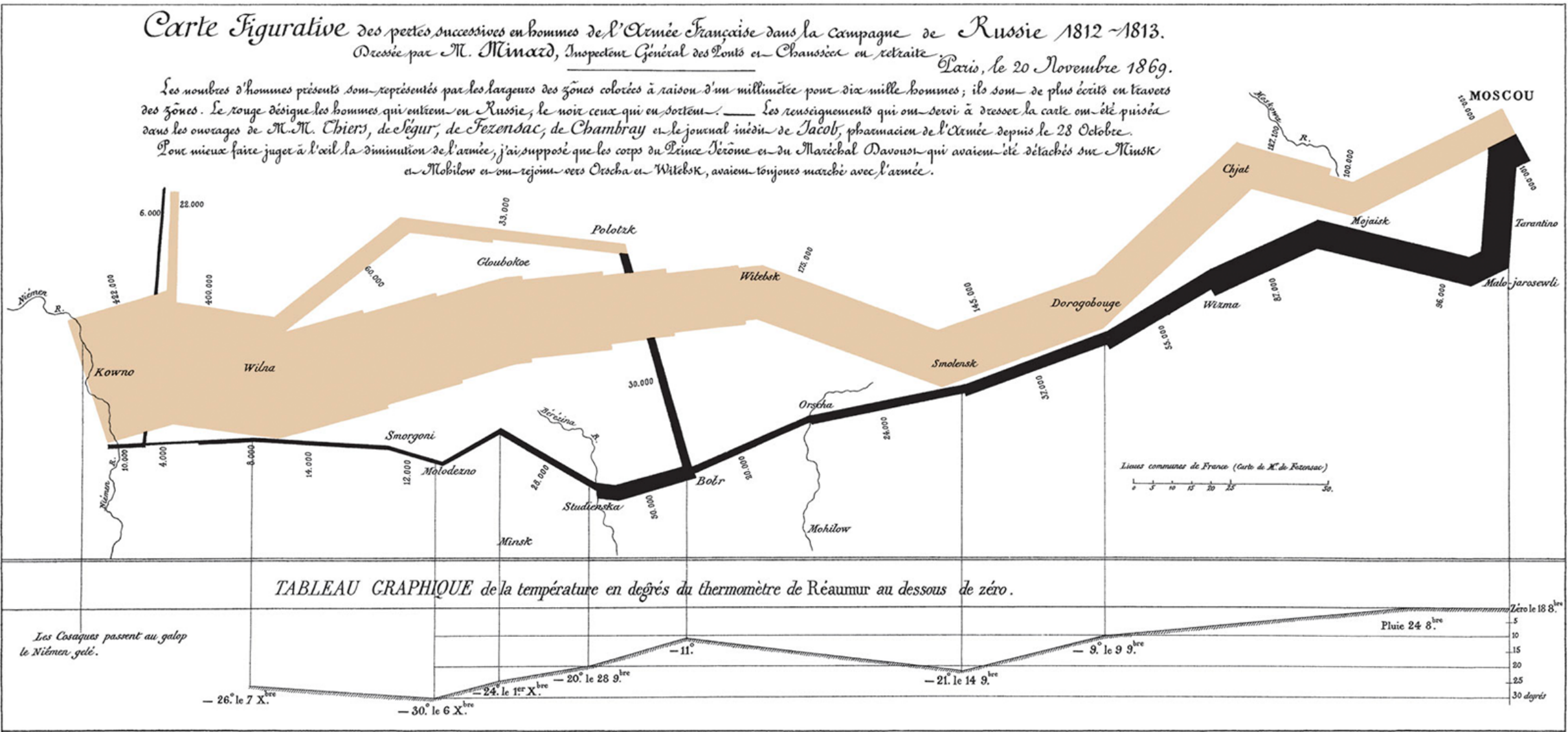
Moscow to Vilnius

Very cold!

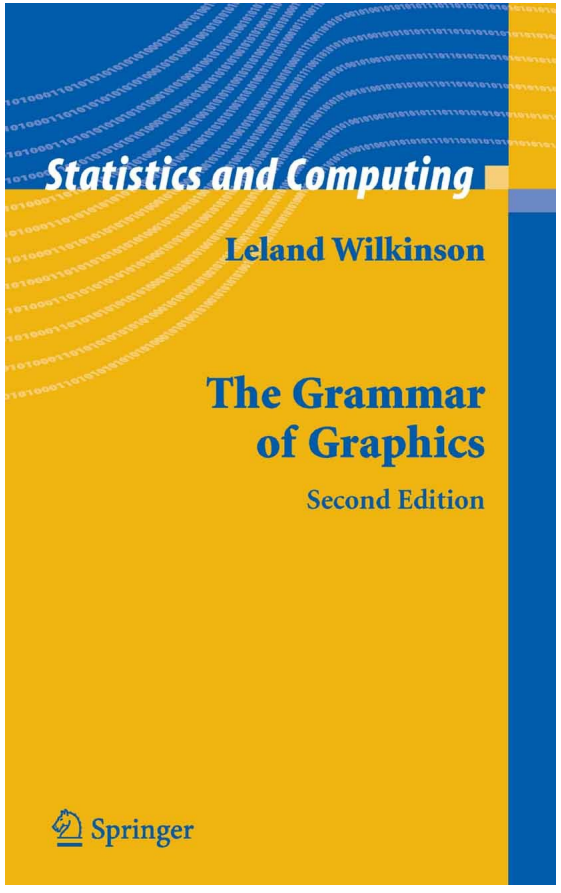


Lots of people died!




Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Paris, le 20 Novembre 1869.
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. ___ Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.
Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mobilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.
Niémen R.
Kowno
Wilna
Smorgoni
Molodezno
Minsk
Studienska
Bobr
Polotzk
Gloubokoe
Witebsk
Orscha
Mohilow
Smolensk
Dorogobouge
Wixma
Chjat
Mojaisk
MOSCOU
Tarrantino
Malo-jarosewli
Lieues communes de France (Carte de M. de Fezensac)
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
Les Cosaques passent au galop le Niémen gelé.
— 26.° le 7 X.bre
— 30.° le 6 X.bre
— 24.° le 1er X.bre
— 20.° le 28 9.bre
— 11.°
— 21.° le 14 9.bre
— 9.° le 9 9.bre
Pluie 24 8.bre
Zéro le 18 8.bre
5
10
15
20
25
30 degrés
Autog. par Regnier, 8. Pas. Ste Marie St Gdin à Paris.
Imp. Lith. Regnier et Dourdet.

Mapping data to aesthetics



Aesthetic

Visual property of a graph

Position, shape, color, etc.

Data

A column in a dataset

Mapping data to aesthetics

Data	Aesthetic	Graphic/Geometry
Longitude	Position (x-axis)	Point
Latitude	Position (y-axis)	Point
Army size	Size	Path
Army direction	Color	Path
Date	Position (x-axis)	Line + text
Temperature	Position (y-axis)	Line + text

Mapping data to aesthetics

Data	**`aes()`**	**`geom`**
Longitude	`x`	`geom_point()`
Latitude	`y`	`geom_point()`
Army size	`size`	`geom_path()`
Army direction	`color`	`geom_path()`
Date	`x`	`geom_line() + geom_text()`
Temperature	`y`	`geom_line() + geom_text()`

`ggplot()` template

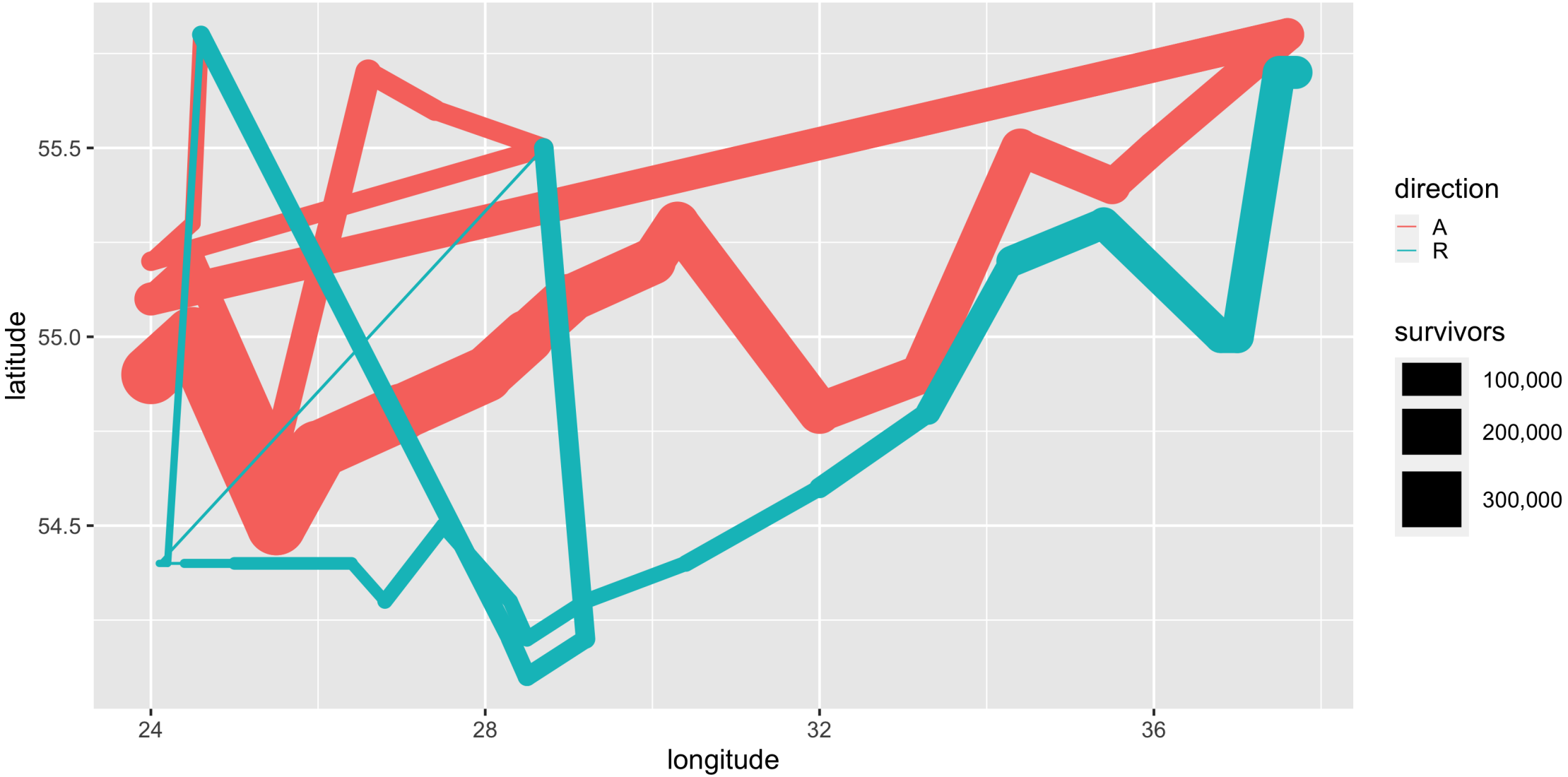
```
ggplot(data = DATA) +
  GEOM_FUNCTION(mapping = aes(AESTHETIC MAPPINGS))
```

```
ggplot(data = troops) +
  geom_path(mapping = aes(x = longitude,
                          y = latitude,
                          color = direction,
                          size = survivors))
```

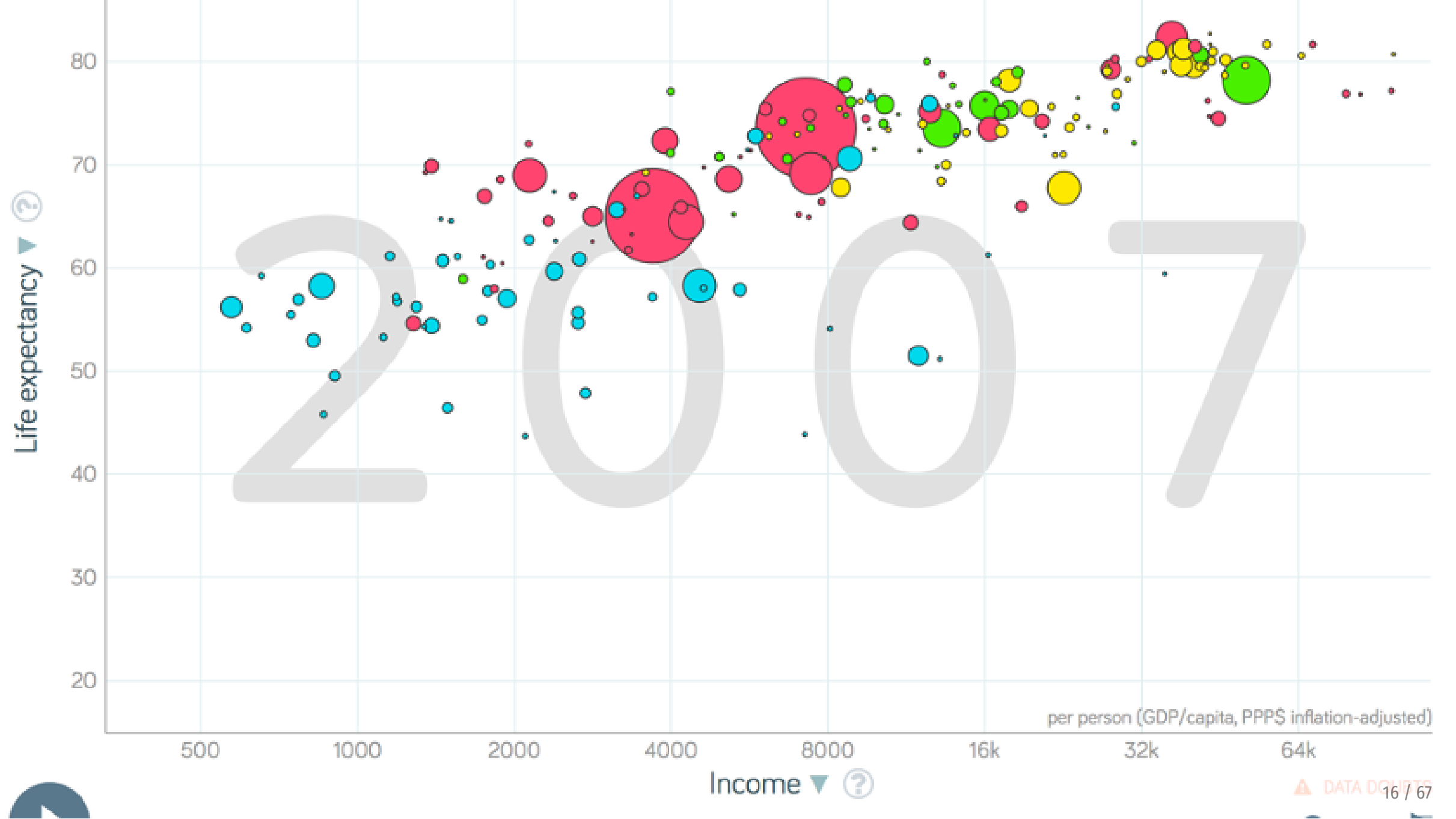
This is a dataset named `troops`:

longitude	latitude	direction	survivors
24	54.9	A	340000
24.5	55	A	340000
…	…	…	…

```
ggplot(data = troops) +
  geom_path(mapping = aes(x = longitude,
                          y = latitude,
                          color = direction,
                          size = survivors))
```


latitude
55.5
55.0
54.5
24
28
32
36
longitude
direction
A
R
survivors
100,000
200,000
300,000


0
1
2
3
4
5
6
7
8
Children per woman
TEDx
Chang
tly organized TED event


Life expectancy
80
70
60
50
40
30
20
2007
per person (GDP/capita, PPP$ inflation-adjusted)
500
1000
2000
4000
8000
16k
32k
64k
Income
DATA QUALITY

Mapping data to aesthetics

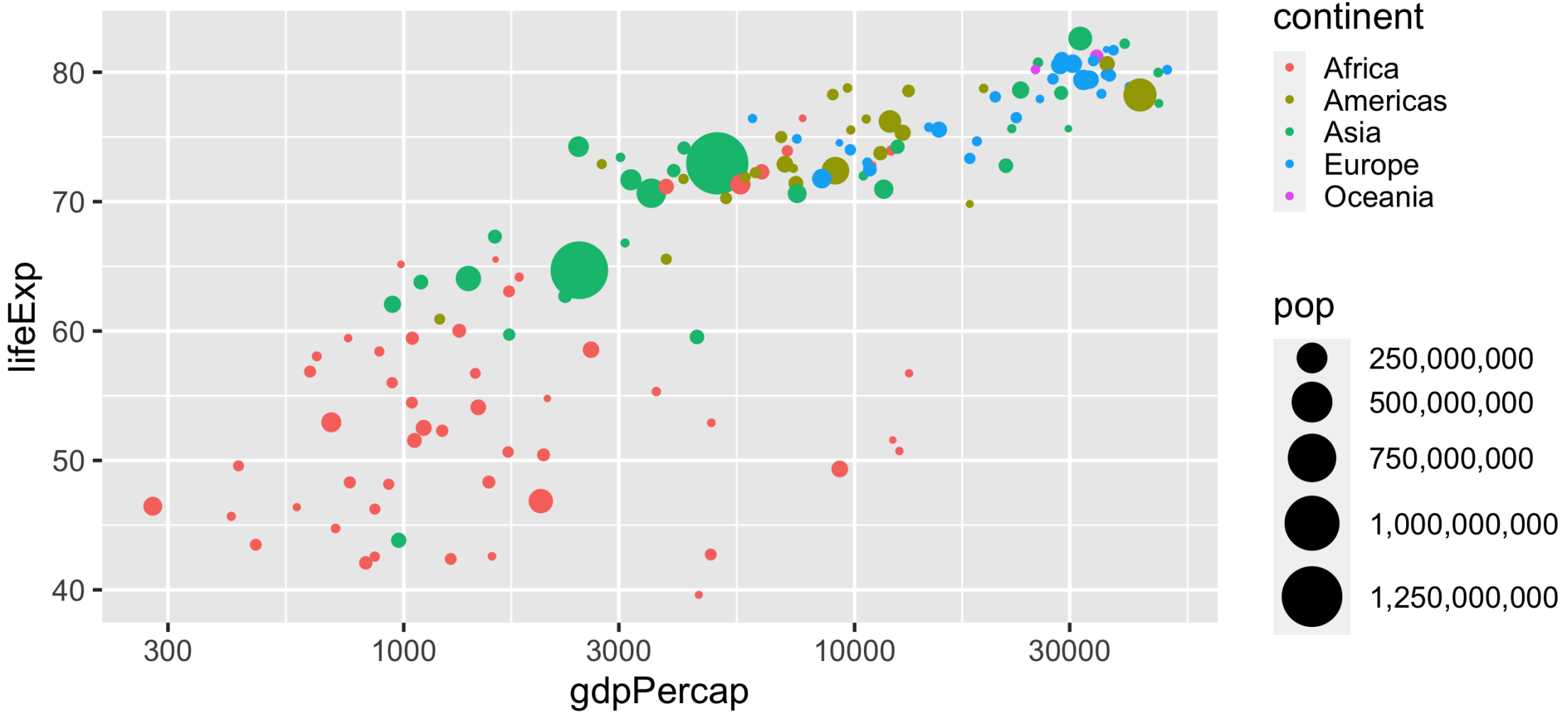
Data	**`aes()`**	**`geom`**
Wealth (GDP/capita)	`x`	`geom_point()`
Health (Life expectancy)	`y`	`geom_point()`
Continent	`color`	`geom_point()`
Population	`size`	`geom_point()`

This is a dataset named `gapminder_2007`:

country	continent	gdpPercap	lifeExp	pop
Afghanistan	Asia	974.5803384	43.828	31889923
Albania	Europe	5937.029526	76.423	3600523
...	...	...	...	...

```
ggplot(data = gapminder_2007,
       mapping = aes(x = gdpPercap,
                     y = lifeExp,
                     color = continent,
                     size = pop)) +
  geom_point() +
  scale_x_log10()
```

Health and wealth



Grammatical layers

Grammar components as layers

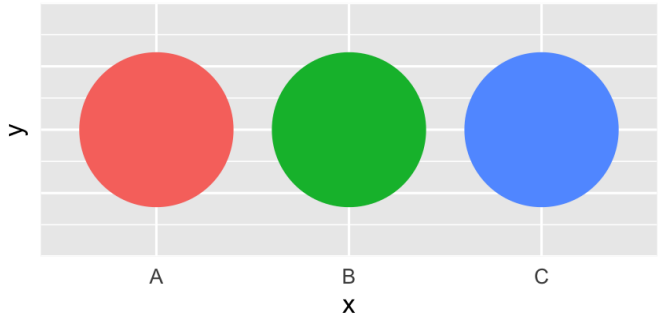
So far we know about data, aesthetics, and geometries

Think of these components as **layers**

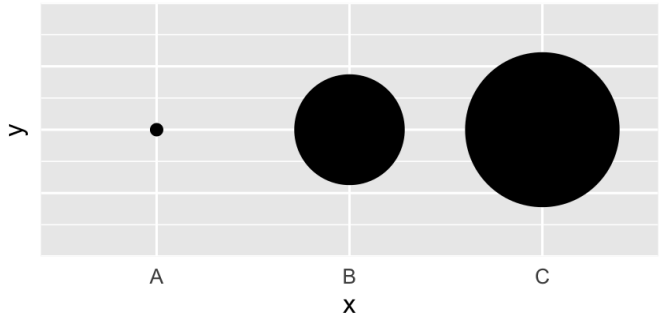
Add them to foundational `ggplot()` with `+`

Possible aesthetics

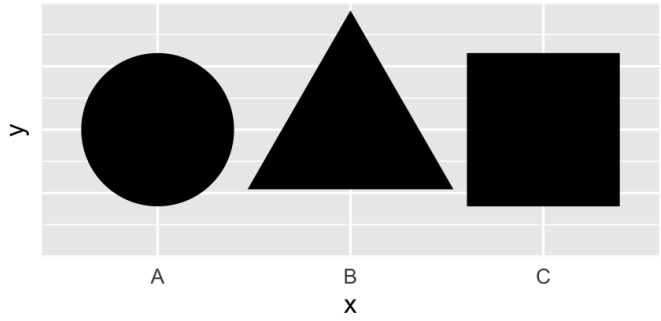
`color` (discrete)



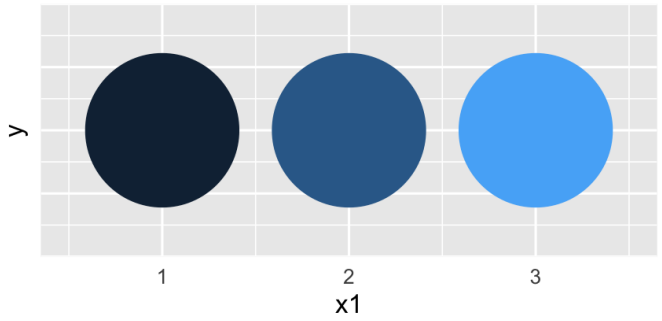
`size`



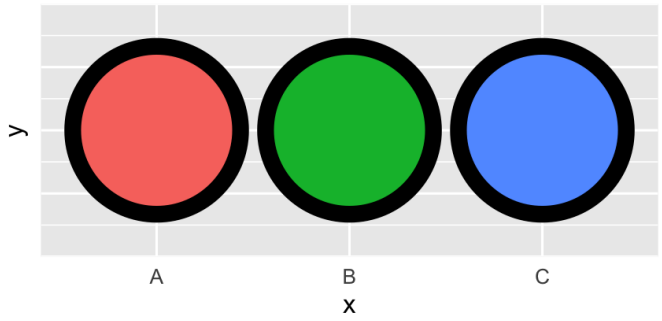
`shape`



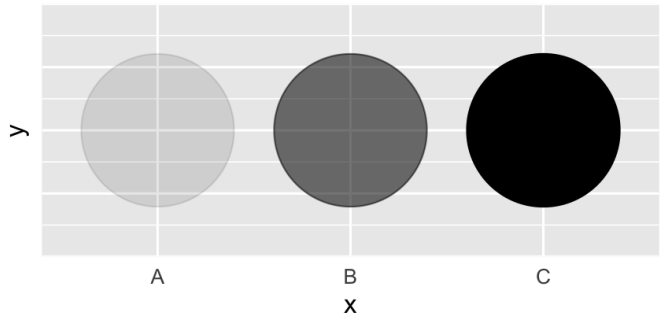
`color` (continuous)



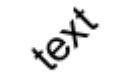
`fill`



`alpha`



Possible geoms

	Example geom	What it makes
	`geom_col()`	Bar charts
	`geom_text()`	Text
	`geom_point()`	Points
	`geom_boxplot()`	Boxplots
	`geom_sf()`	Maps

Possible geoms

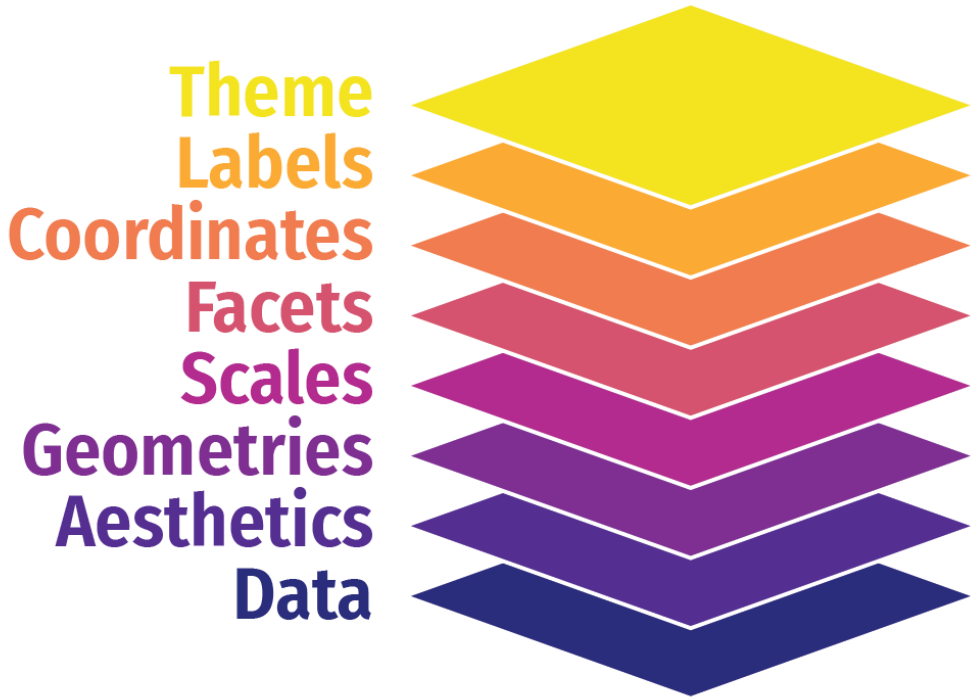
There are dozens of possible geoms and each class session will cover different ones.

See the ggplot2 documentation for complete examples of all the different geom layers

Additional layers

There are many of other grammatical layers we can use to describe graphs!

We sequentially add layers onto the foundational `ggplot()` plot to create complex figures



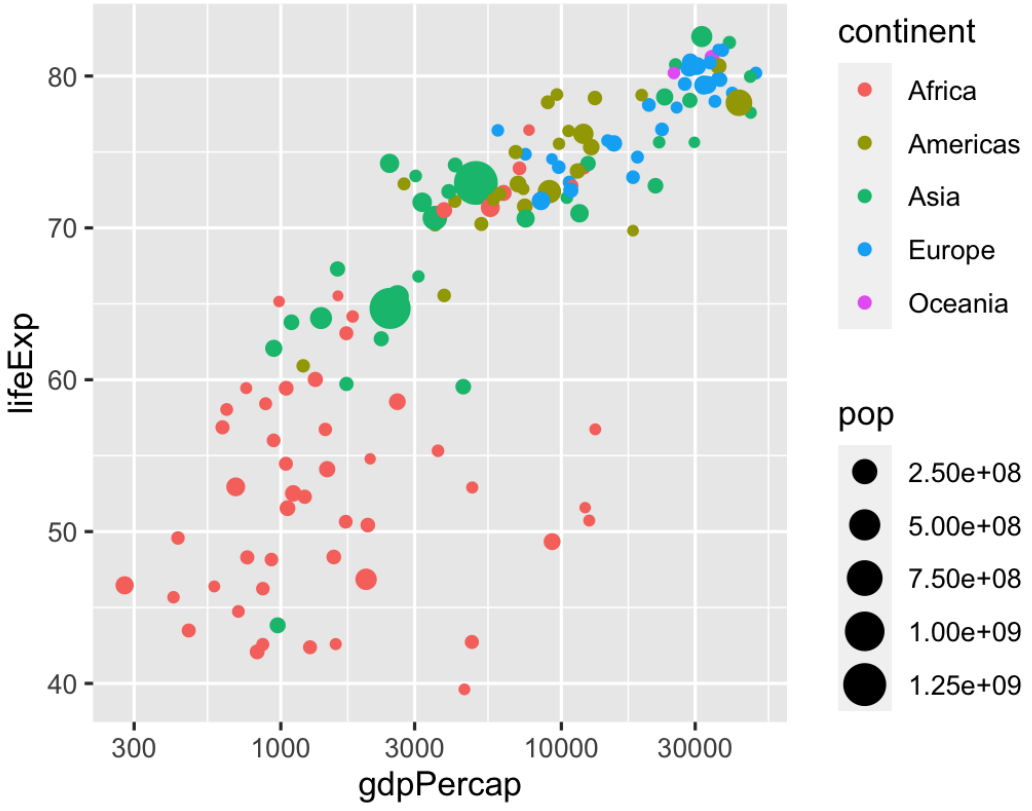
Scales

Scales change the properties of the variable mapping

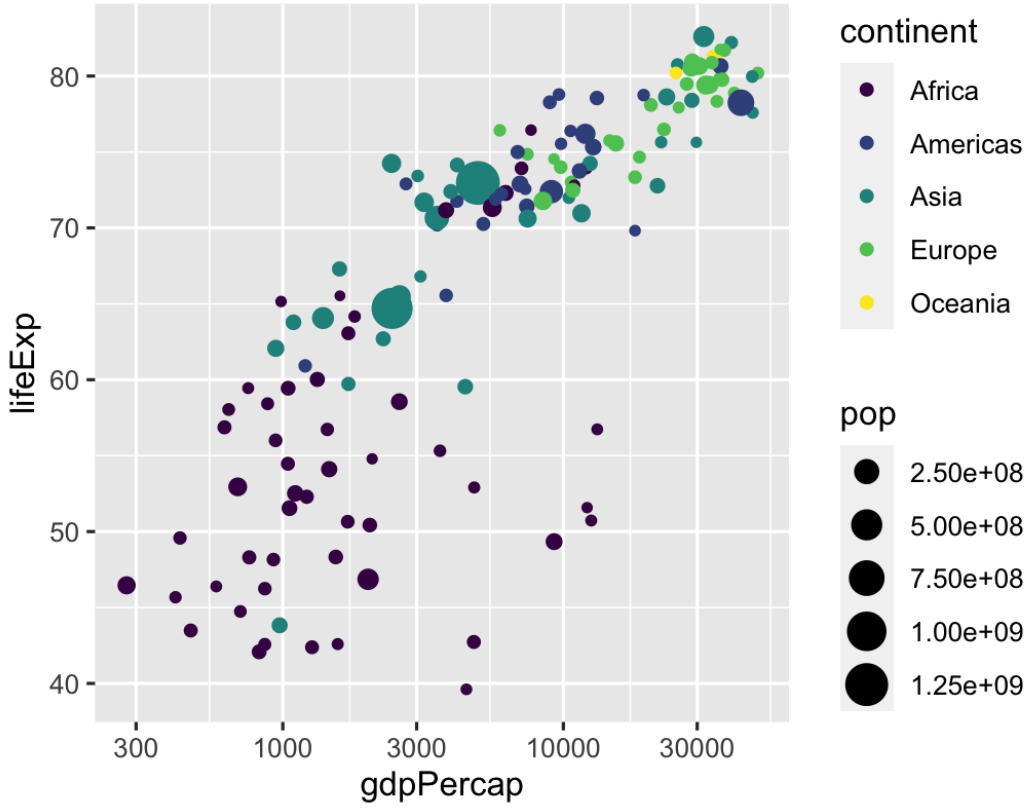
Example layer	What it does
`scale_x_continuous()`	Make the x-axis continuous
`scale_x_continuous(breaks = 1:5)`	Manually specify axis ticks
`scale_x_log10()`	Log the x-axis
`scale_color_gradient()`	Use a gradient
`scale_fill_viridis_d()`	Fill with discrete viridis colors

Scales

`scale_x_log10()`



`scale_color_viridis_d()`



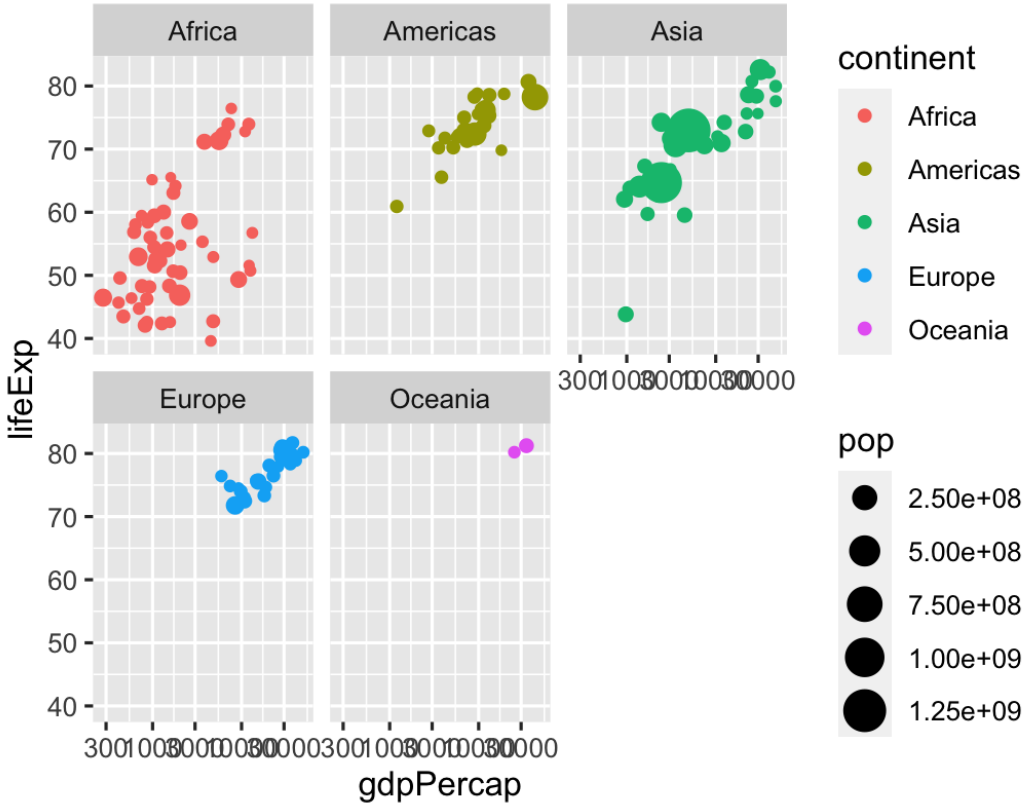
Facets

Facets show subplots for different subsets of data

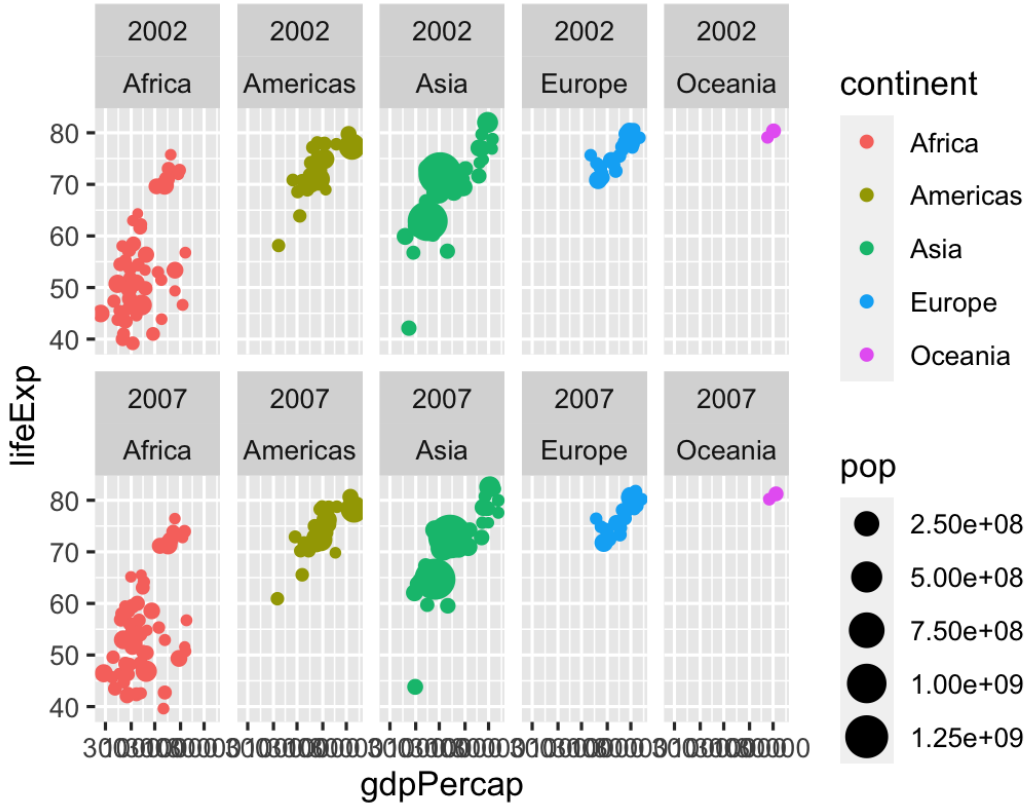
Example layer	What it does
`facet_wrap(vars(continent))`	Plot for each continent
`facet_wrap(vars(continent, year))`	Plot for each continent/year
`facet_wrap(..., ncol = 1)`	Put all facets in one column
`facet_wrap(..., nrow = 1)`	Put all facets in one row

Facets

`facet_wrap(vars(continent))`



`facet_wrap(vars(continent, year))`



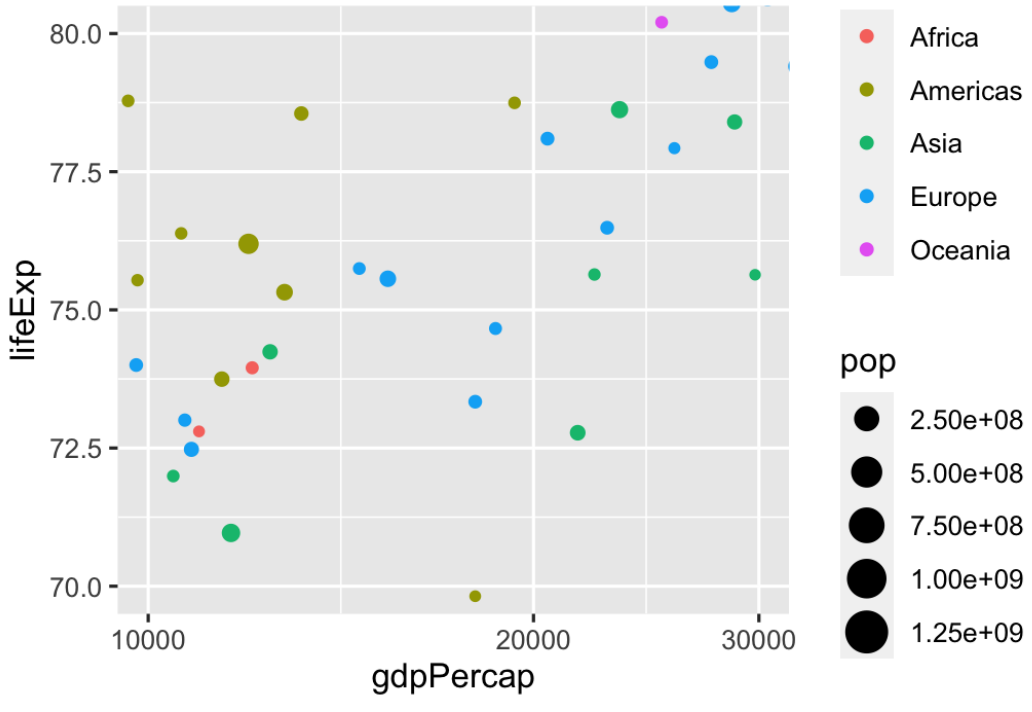
Coordinates

Change the coordinate system

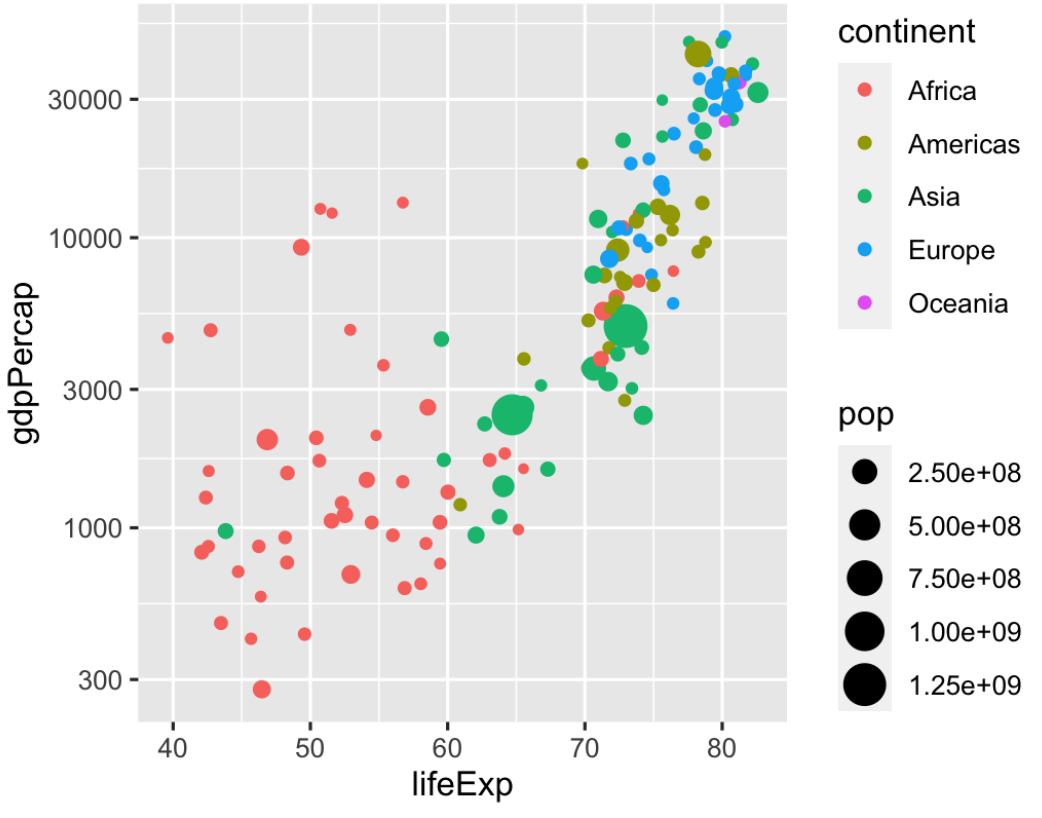
Example layer	What it does
`coord_cartesian()`	Plot for each continent
`coord_cartesian(ylim = c(1, 10))`	Zoom in where y is 1–10
`coord_flip()`	Switch x and y
`coord_polar()`	Use circular polar system

Coordinates

```
coord_cartesian(ylim = c(70, 80),
xlim = c(10000, 30000))
```




```
coord_flip()
```



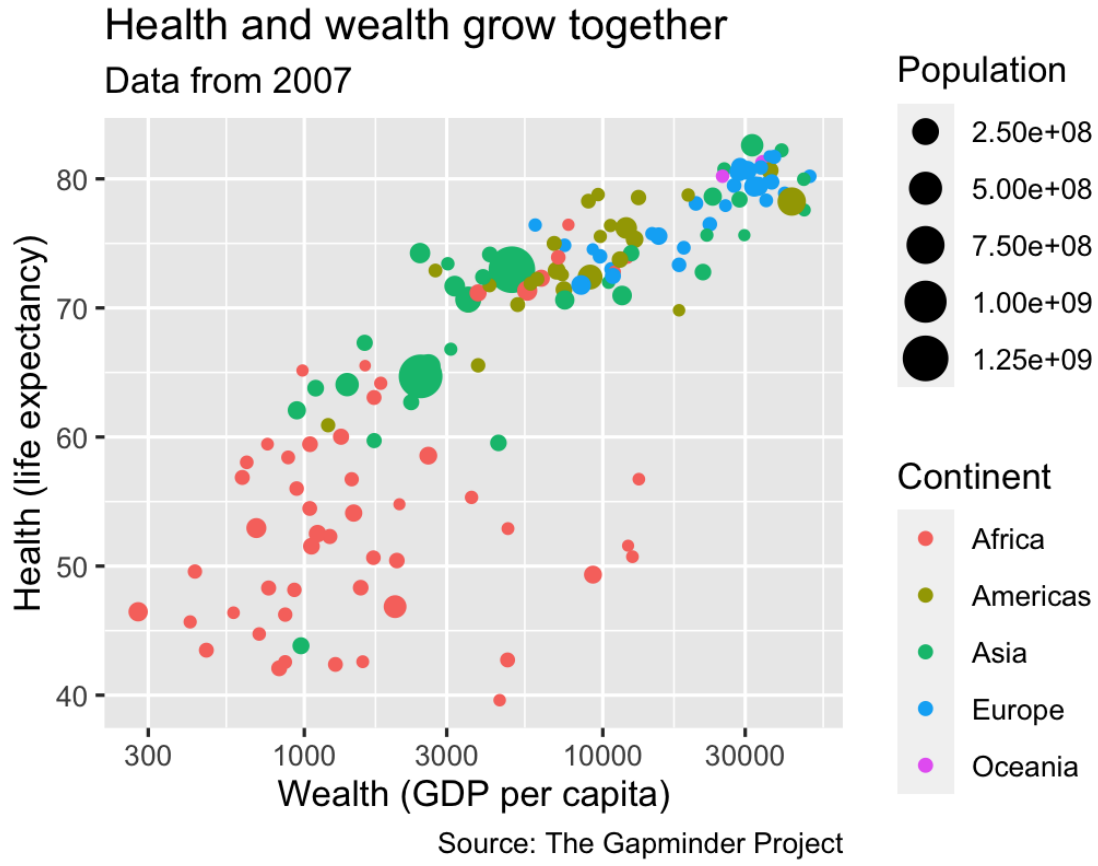
Labels

Add labels to the plot with a single `labs()` layer

Example layer	What it does
`labs(title = "Neat title")`	Title
`labs(caption = "Something")`	Caption
`labs(y = "Something")`	y-axis
`labs(size = "Population")`	Title of size legend

Labels

```
ggplot(gapminder_2007,
       aes(x = gdpPercap, y = lifeExp,
           color = continent, size = pop)) +
  geom_point() +
  scale_x_log10() +
  labels(title = "Health and wealth grow togeth
       subtitle = "Data from 2007",
       x = "Wealth (GDP per capita)",
       y = "Health (life expectancy)",
       color = "Continent",
       size = "Population",
       caption = "Source: The Gapminder Proje
```



Theme

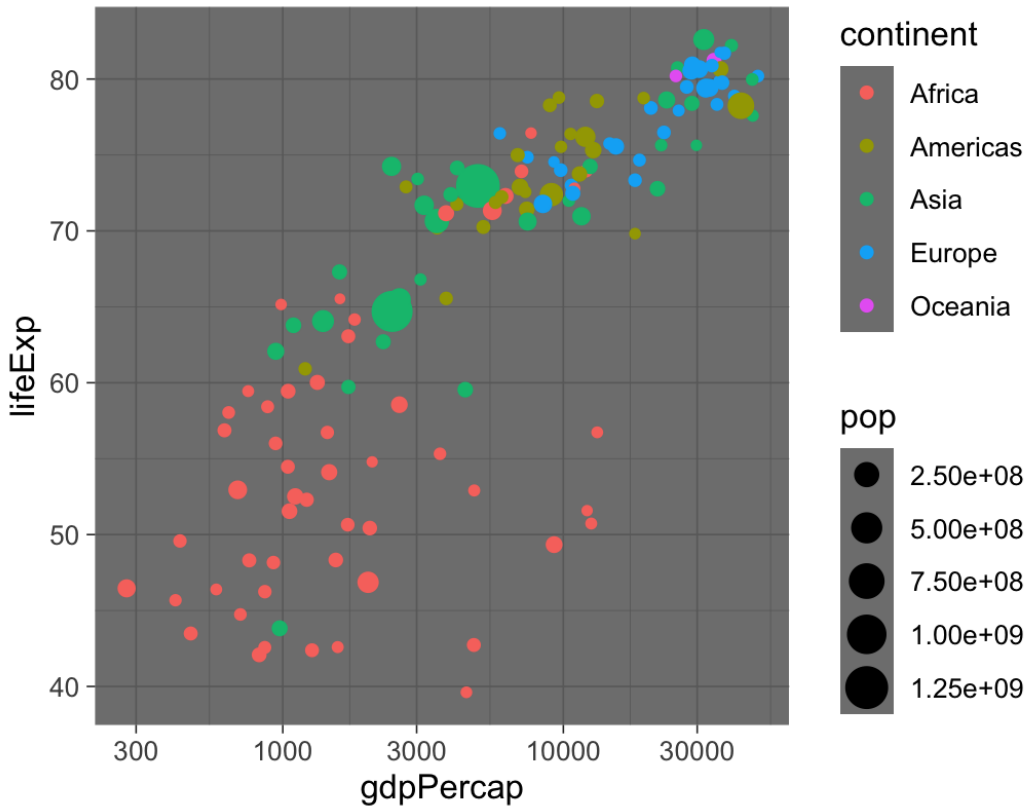
Change the appearance of anything in the plot

There are many built-in themes

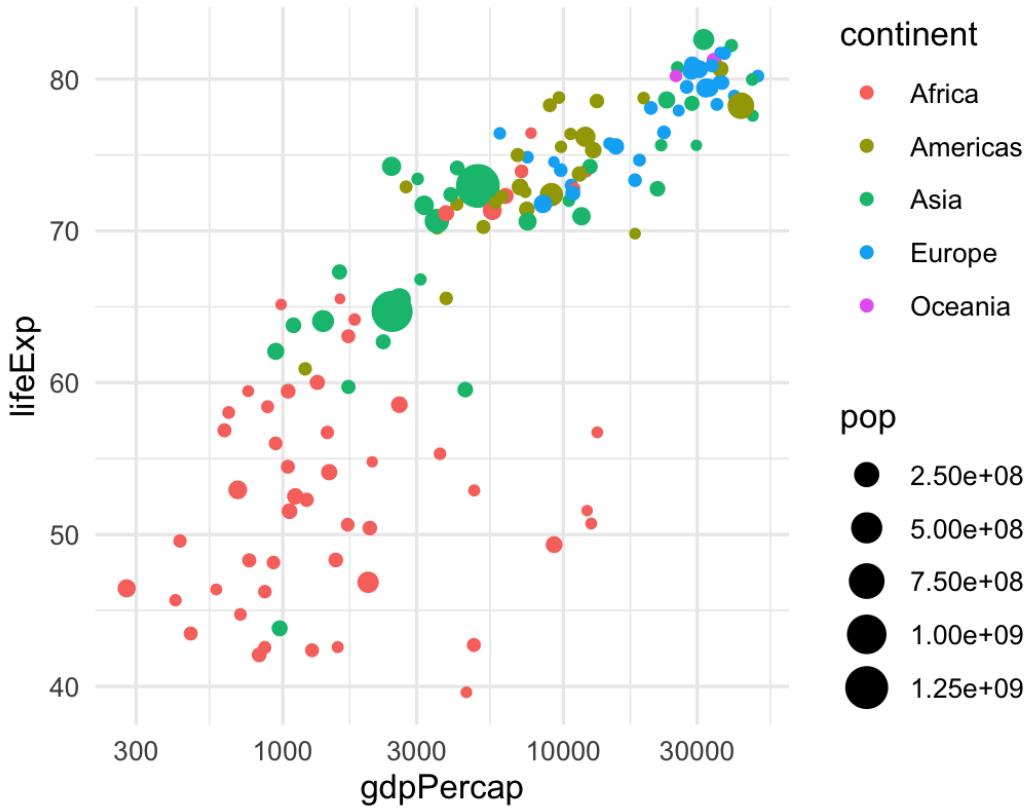
Example layer	What it does
`theme_grey()`	Default grey background
`theme_bw()`	Black and white
`theme_dark()`	Dark
`theme_minimal()`	Minimal

Theme

`theme_dark()`



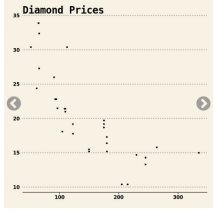
`theme_minimal()`



Theme

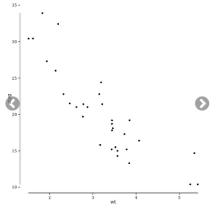
There are collections of pre-built themes online, like the ggthemes package

ggthemes



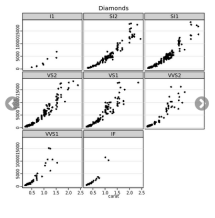
theme_wsj

Wall Street Journal theme



theme_tufte

Tufte Maximal Data, Minimal Ink Theme

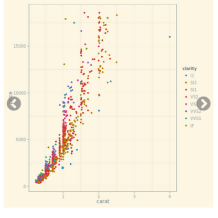


theme_stata

Themes based on Stata graph schemes

theme_solid

Theme with nothing other than a background color

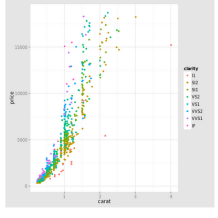


theme_solarized

ggplot color themes based on the Solarized palette

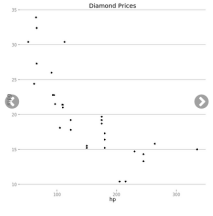
theme_map

Clean theme for maps



theme_igray

Inverse gray theme

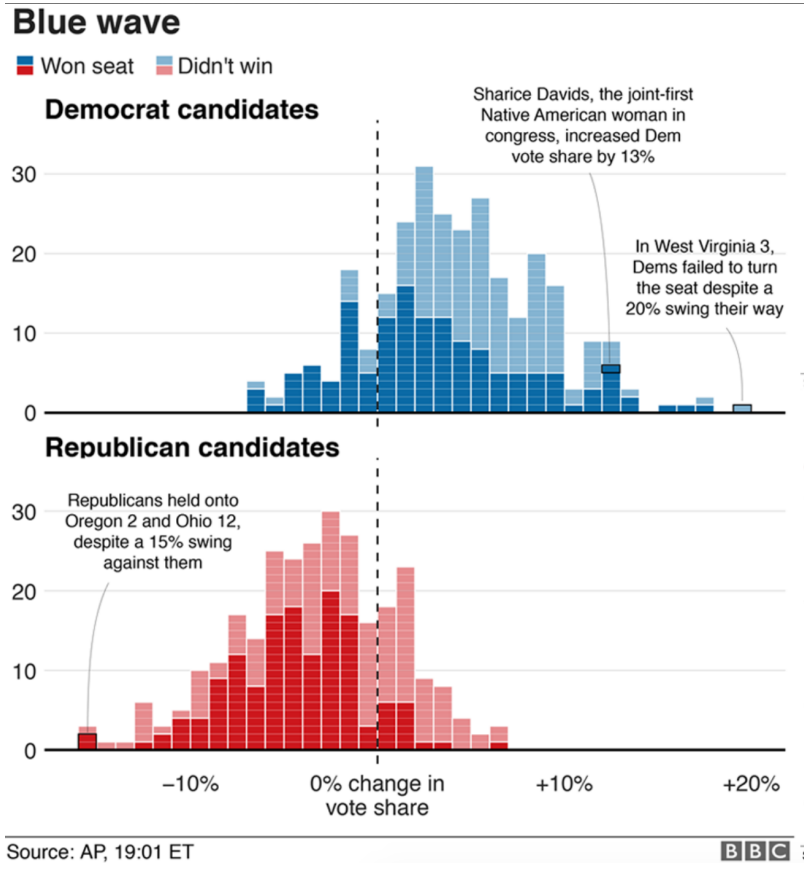


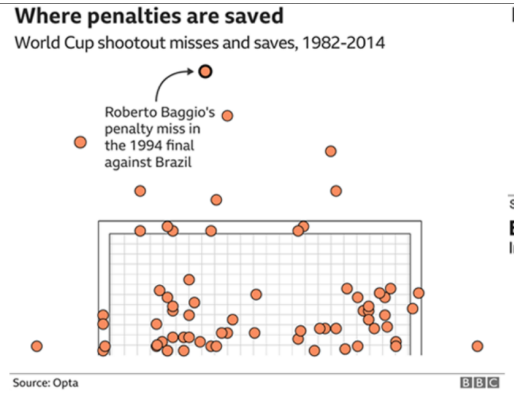
theme_hc

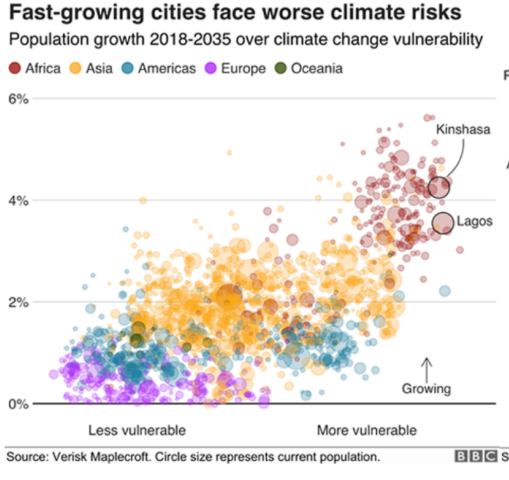
Highcharts JS theme

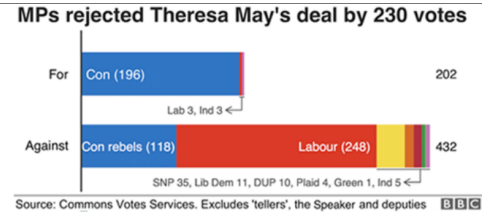
Theme

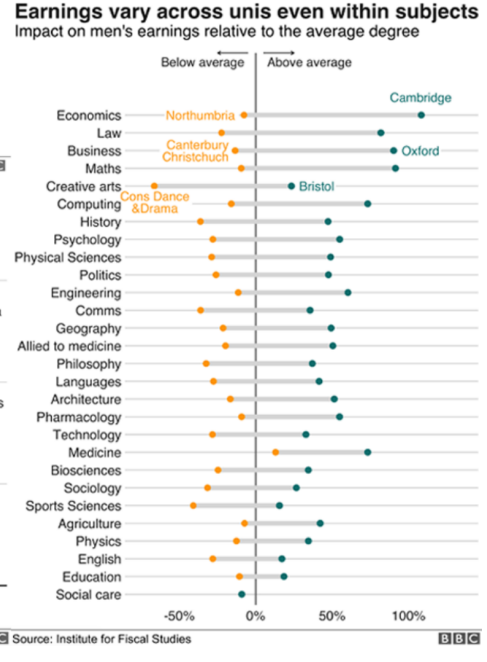
Organizations often make their own custom themes, like the BBC











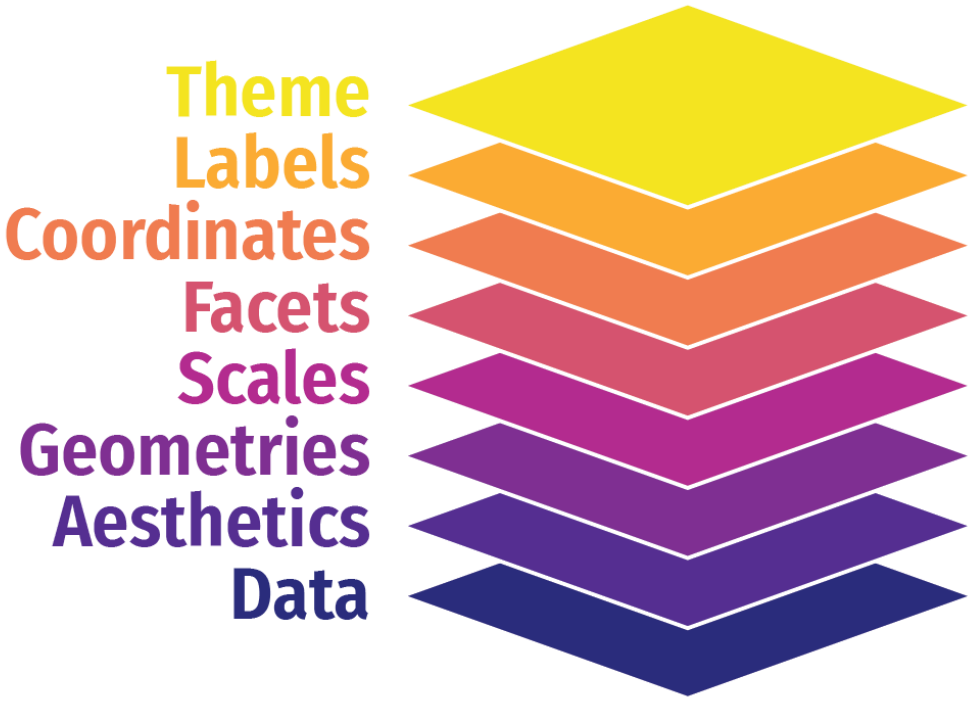
Theme options

Make theme adjustments with `theme()`

There are a billion options here!
We have a whole class session dedicated to this!

```
theme_bw() +
theme(legend.position = "bottom",
      plot.title = element_text(face = "bold"),
      panel.grid = element_blank(),
      axis.title.y = element_text(face = "italic"))
```

So many possibilities!



These were just a few examples of layers!

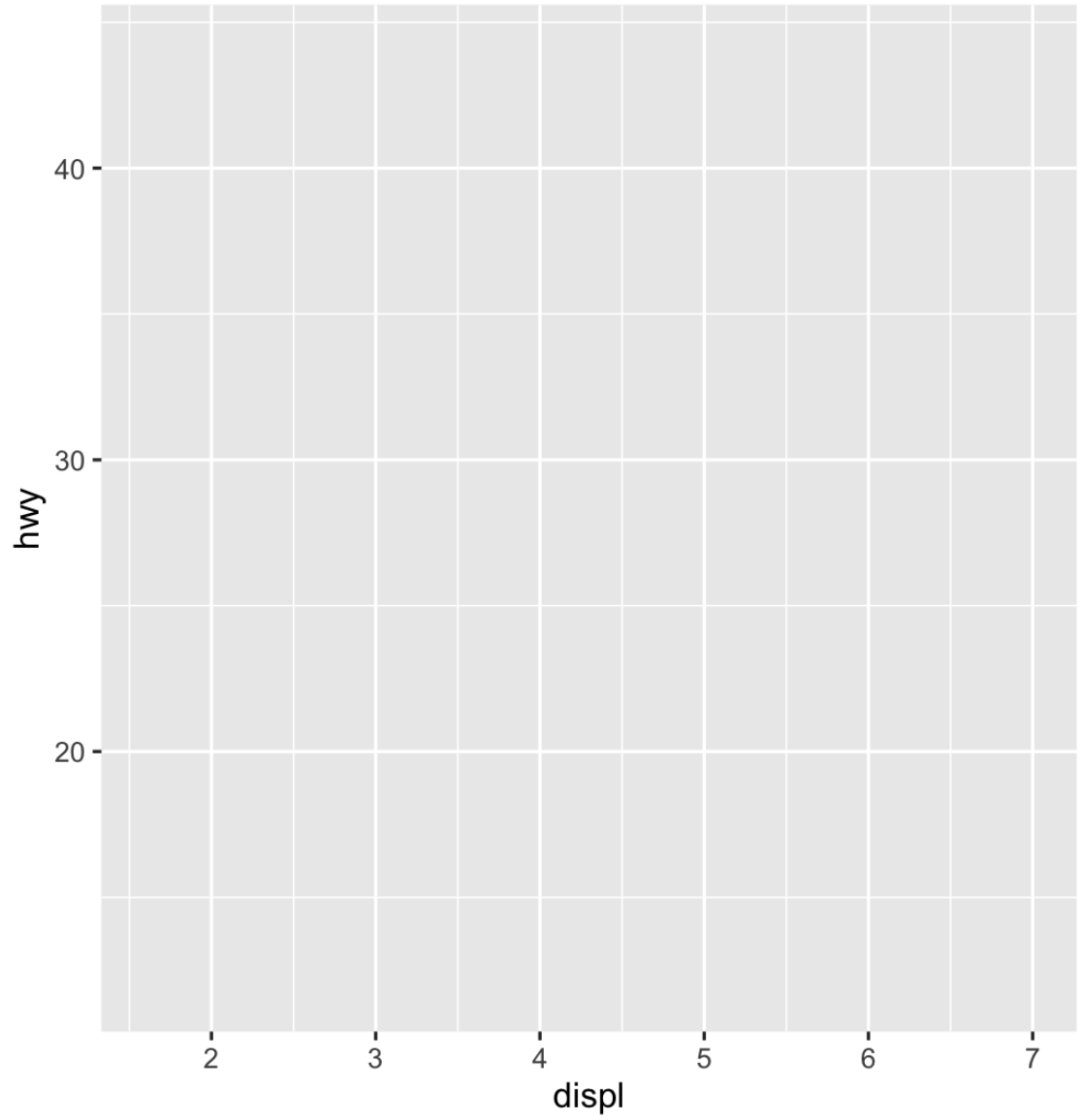
See the ggplot2 documentation for complete examples of everything you can do

Putting it all together

We can build a plot sequentially to see how each grammatical layer changes the appearance

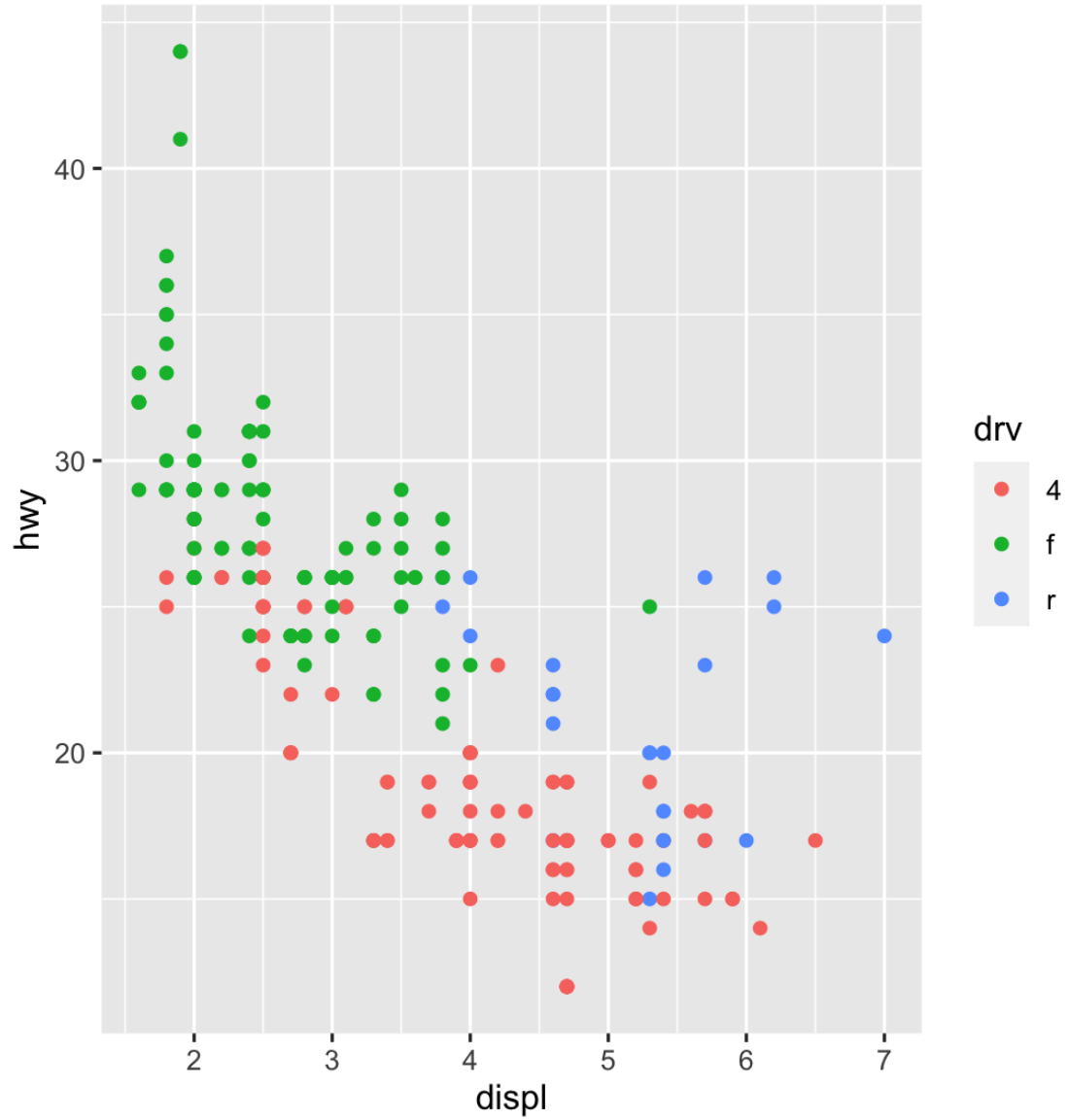
Start with data and aesthetics

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv))
```



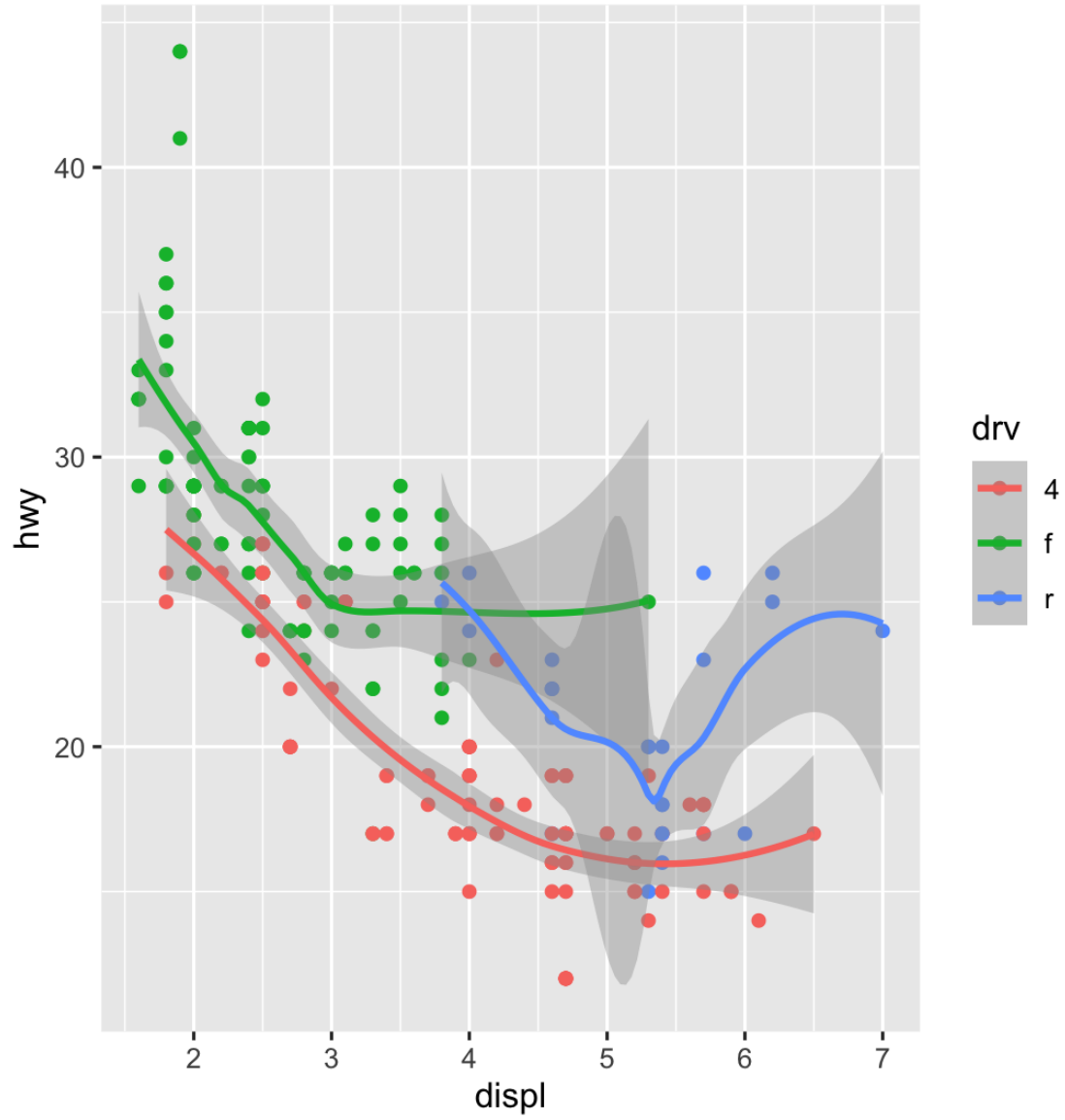
Add a point geom

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



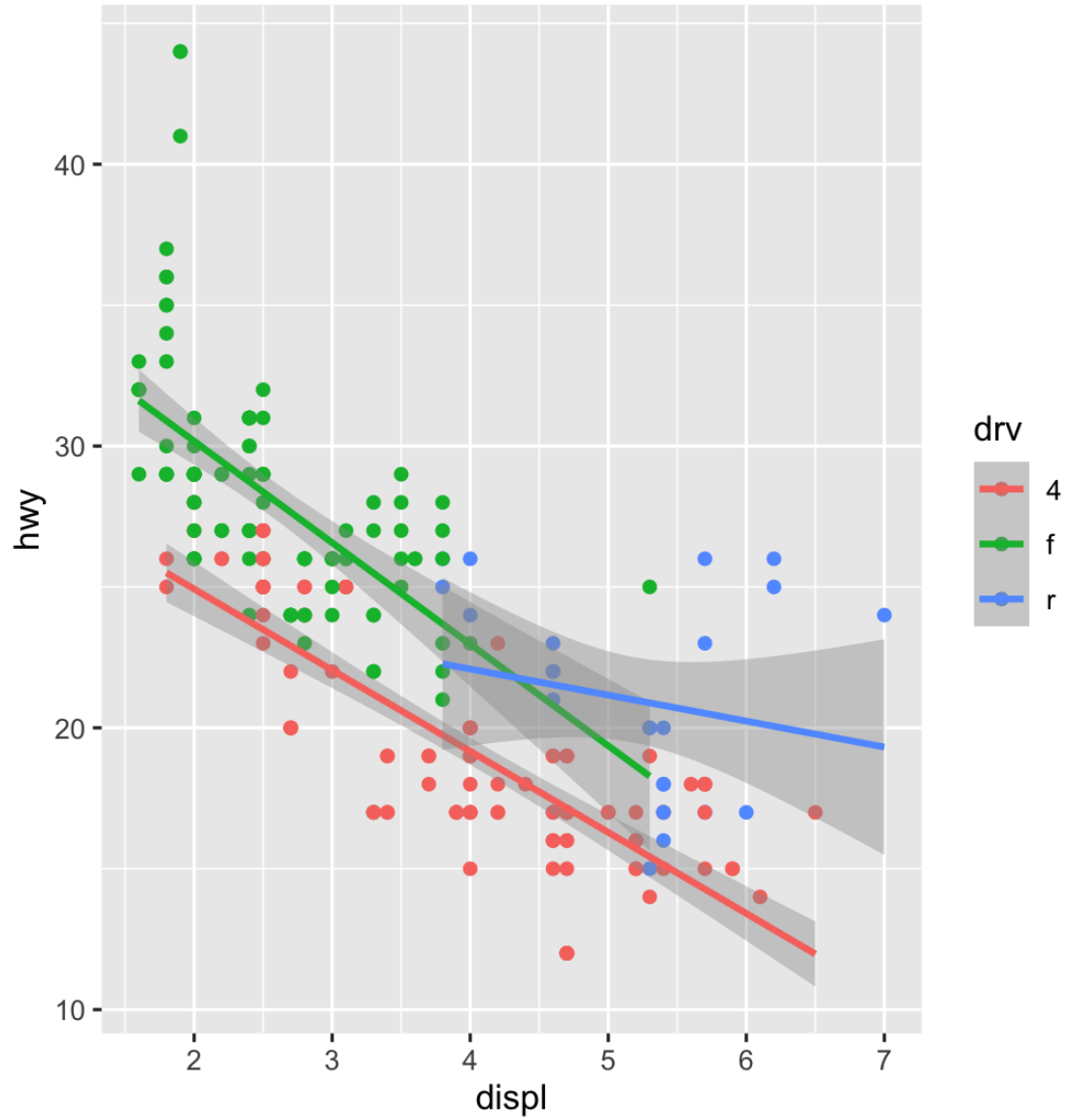
Add a smooth geom

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



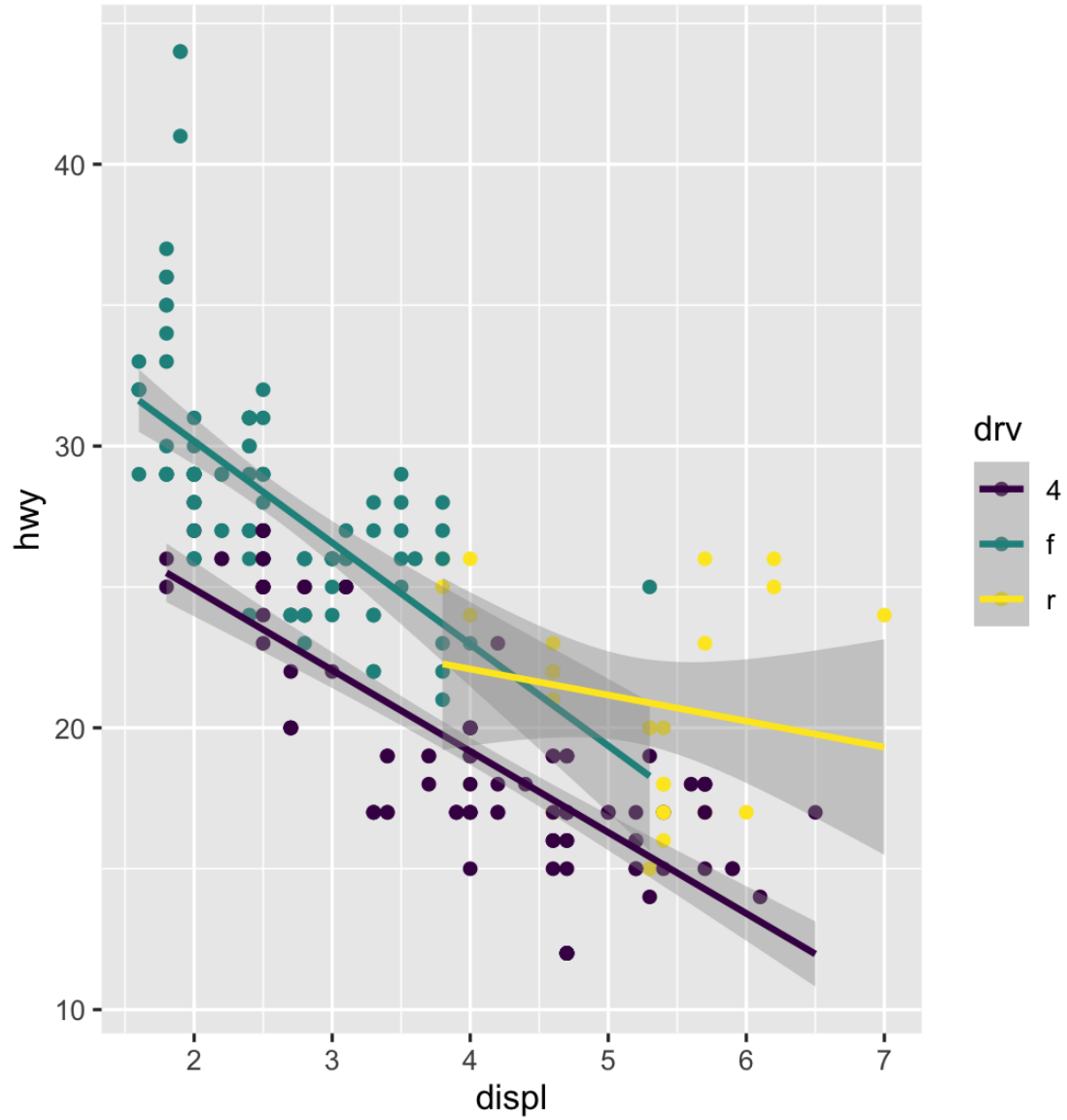
Make it straight

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm")
```



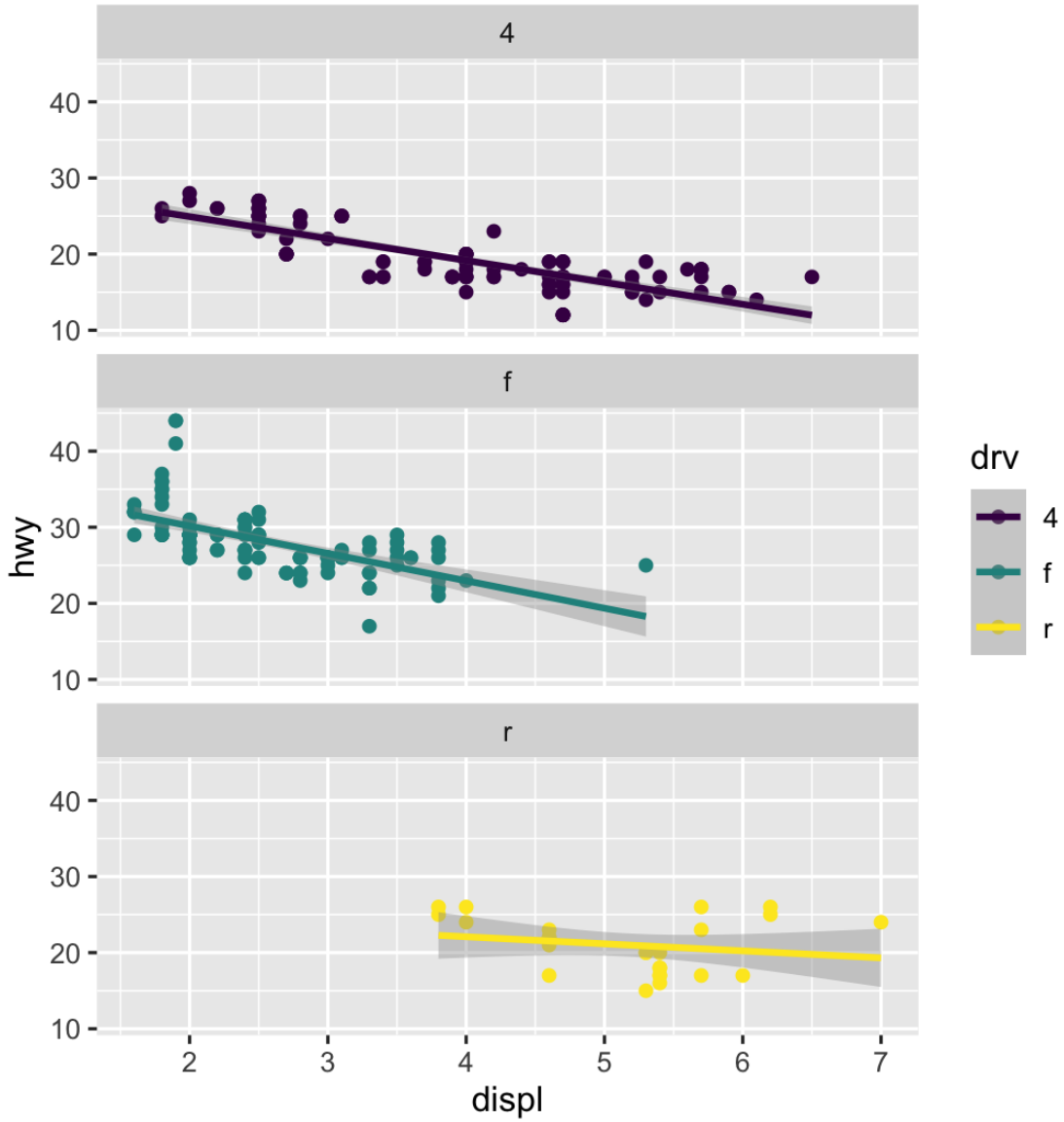
Use a viridis color scale

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d()
```



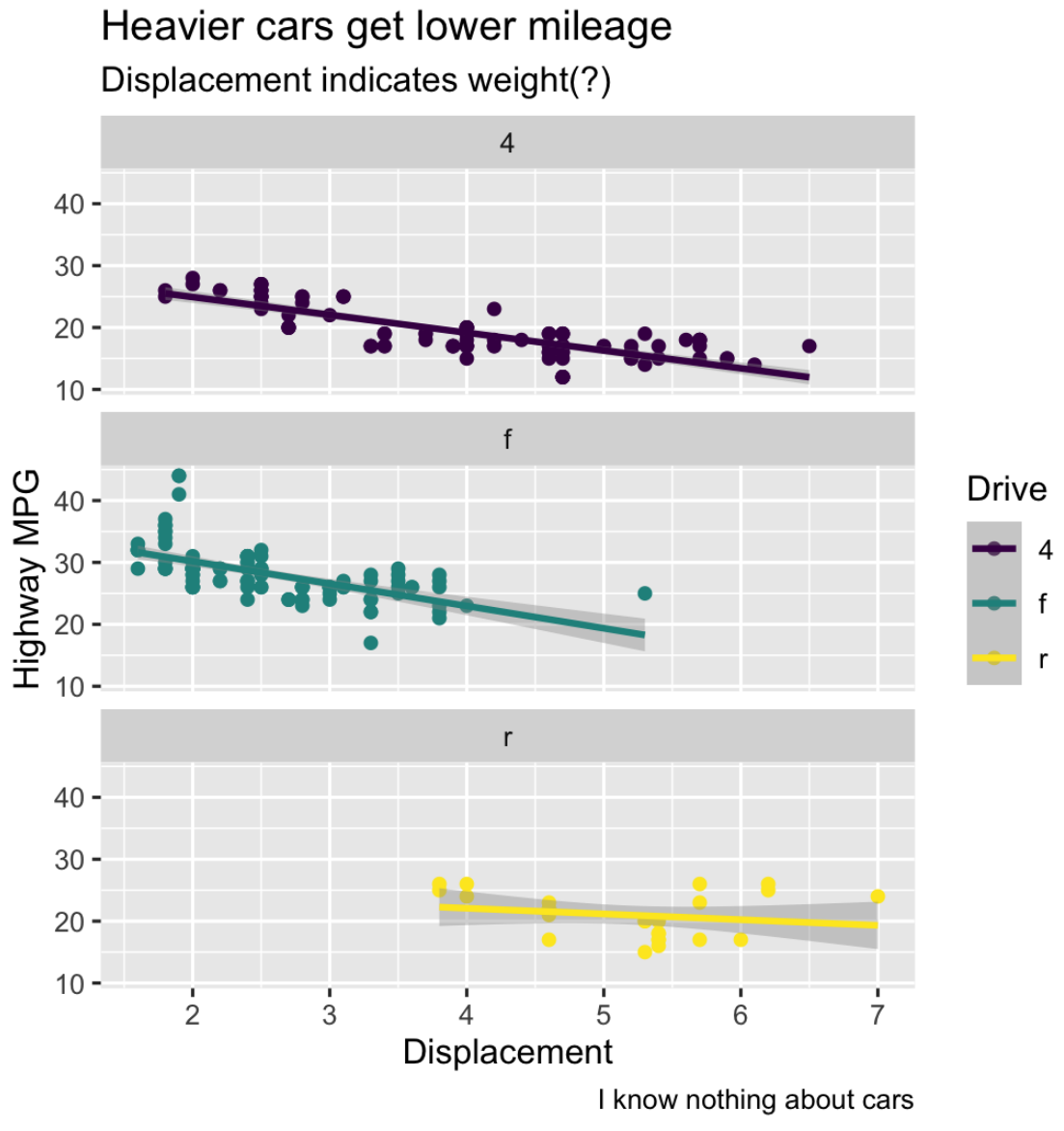
Facet by drive

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d() +
  facet_wrap(vars(drv), ncol = 1)
```



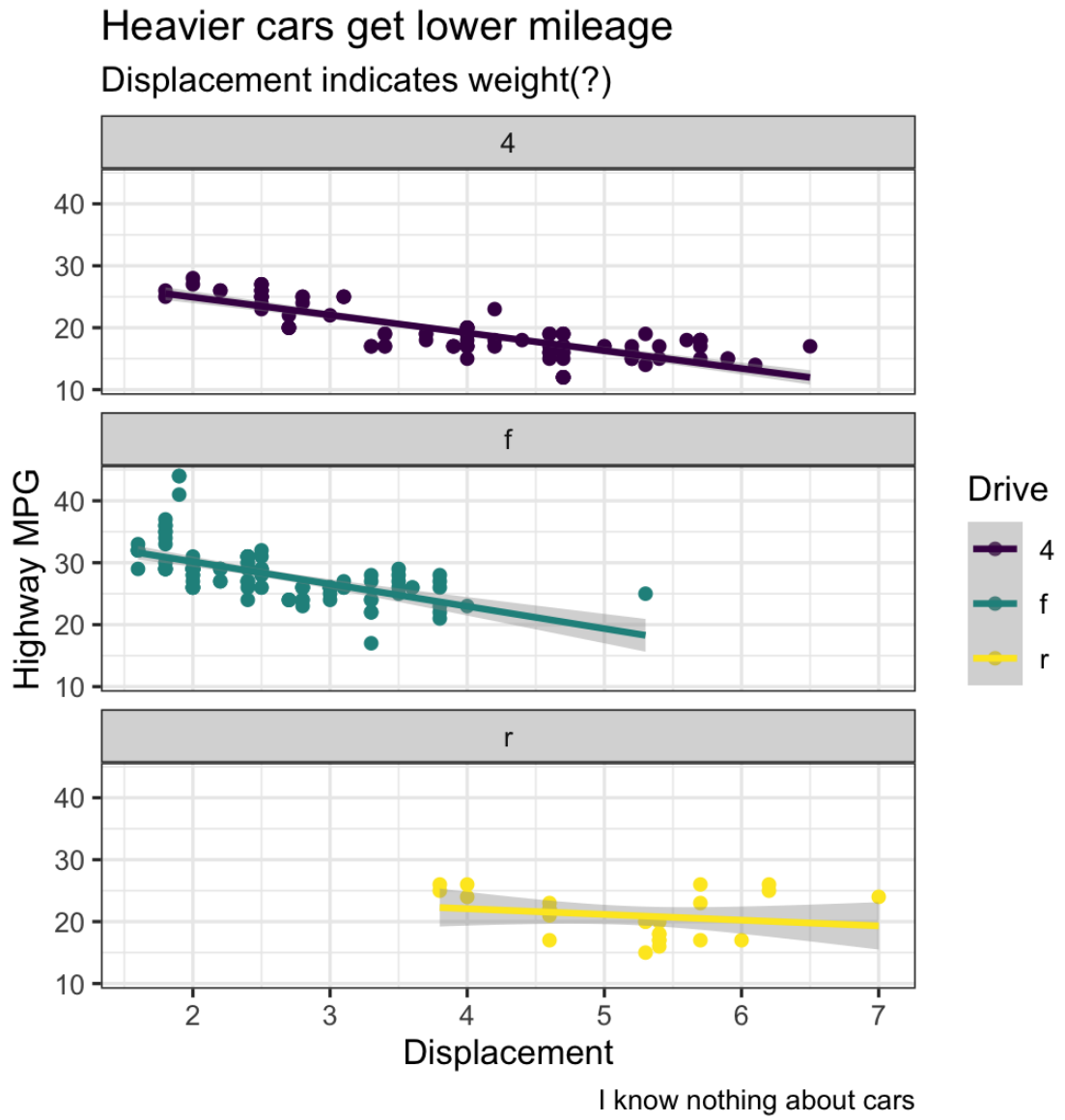
Add labels

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d() +
  facet_wrap(vars(drv), ncol = 1) +
  labs(x = "Displacement", y = "Highway MPG",
       color = "Drive",
       title = "Heavier cars get lower mileag
       subtitle = "Displacement indicates we
       caption = "I know nothing about cars")
```



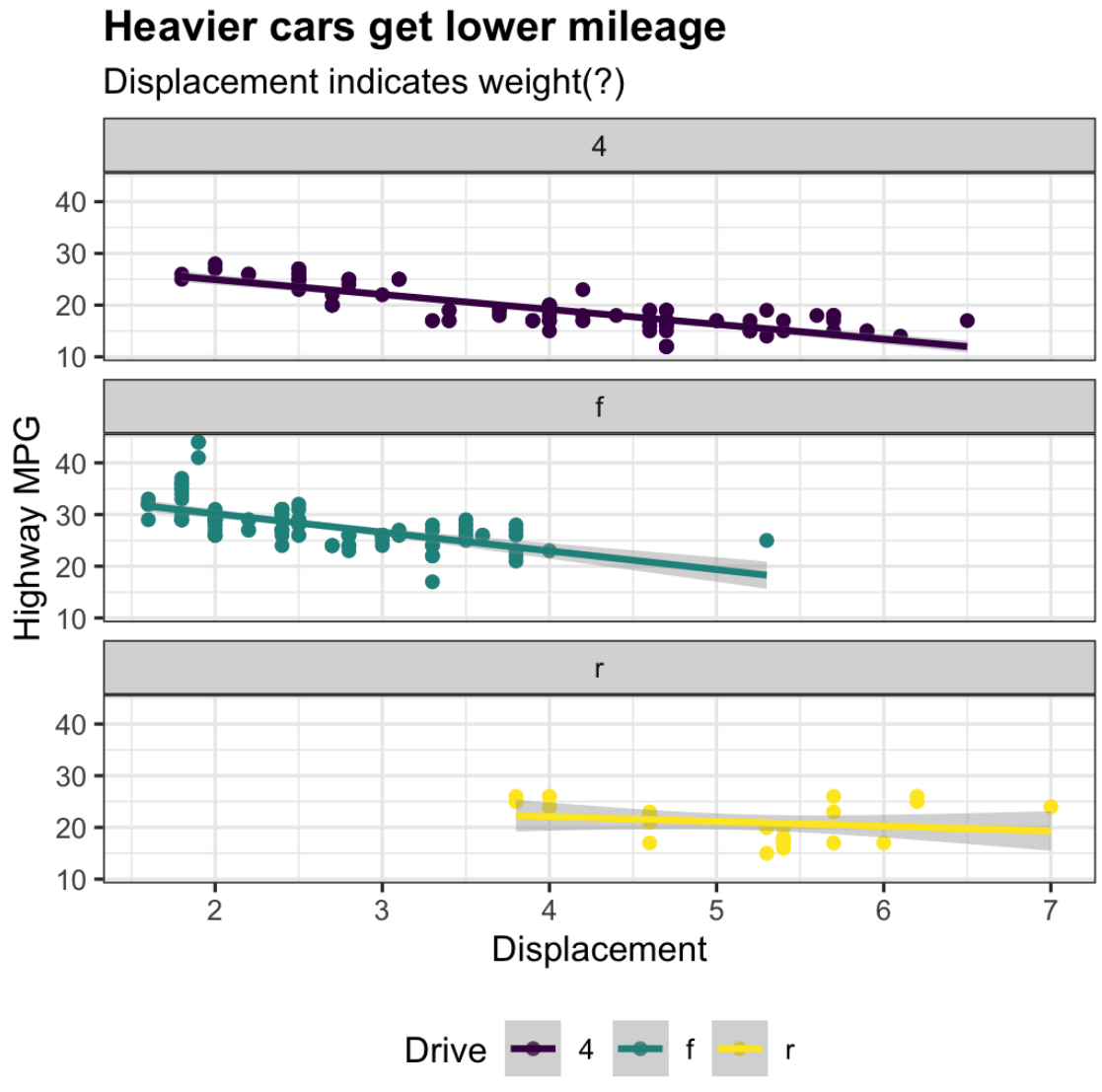
Add a theme

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d() +
  facet_wrap(vars(drv), ncol = 1) +
  labs(x = "Displacement", y = "Highway MPG",
       color = "Drive",
       title = "Heavier cars get lower mileag
       subtitle = "Displacement indicates wei
       caption = "I know nothing about cars")
  theme_bw()
```



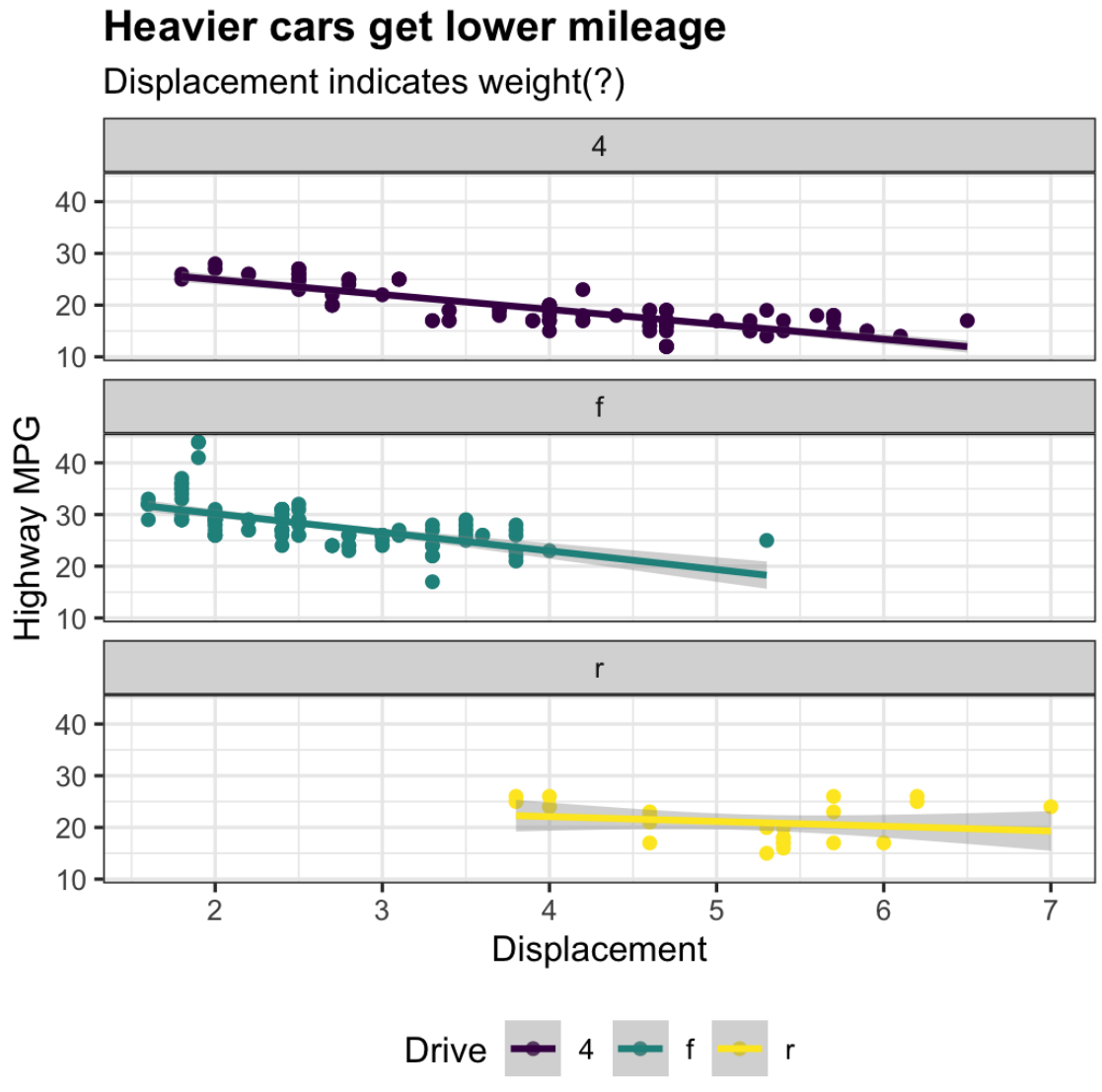
Modify the theme

```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d() +
  facet_wrap(vars(drv), ncol = 1) +
  labs(x = "Displacement", y = "Highway MPG",
       color = "Drive",
       title = "Heavier cars get lower mileag
       subtitle = "Displacement indicates we
       caption = "I know nothing about cars")
  theme_bw() +
  theme(legend.position = "bottom",
        plot.title = element_text(face = "bo
```



Finished!

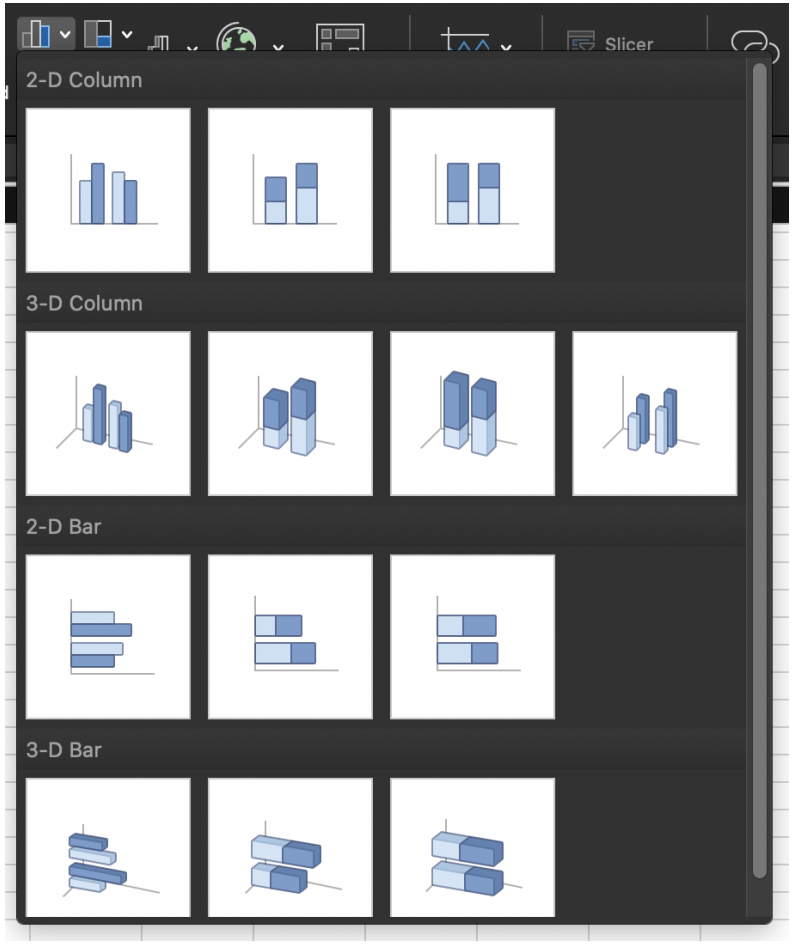
```
ggplot(data = mpg,
       mapping = aes(x = displ,
                     y = hwy,
                     color = drv)) +
  geom_point() +
  geom_smooth(method = "lm") +
  scale_color_viridis_d() +
  facet_wrap(vars(drv), ncol = 1) +
  labs(x = "Displacement", y = "Highway MPG",
       color = "Drive",
       title = "Heavier cars get lower mileag
       subtitle = "Displacement indicates we
       caption = "I know nothing about cars")
  theme_bw() +
  theme(legend.position = "bottom",
        plot.title = element_text(face = "bo
```



A true grammar

With the grammar of graphics, we don't talk about specific chart *types*

Hunt through Excel menus for a stacked bar chart and manually reshape your data to work with it

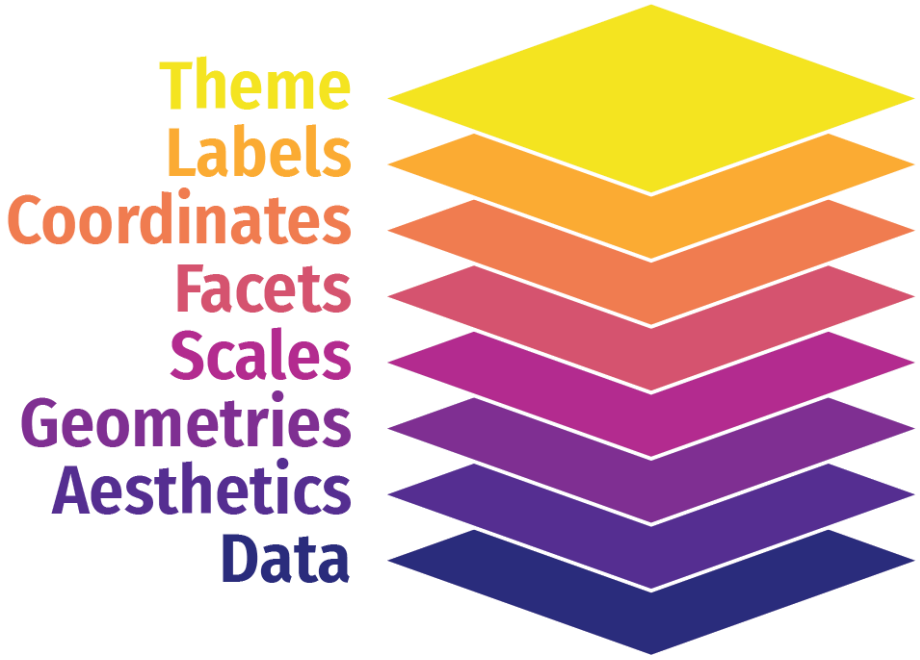


A true grammar

With the grammar of graphics, we *do* talk about specific chart *elements*

Map a column to the x-axis, fill by a different variable, and `geom_col()` to get stacked bars

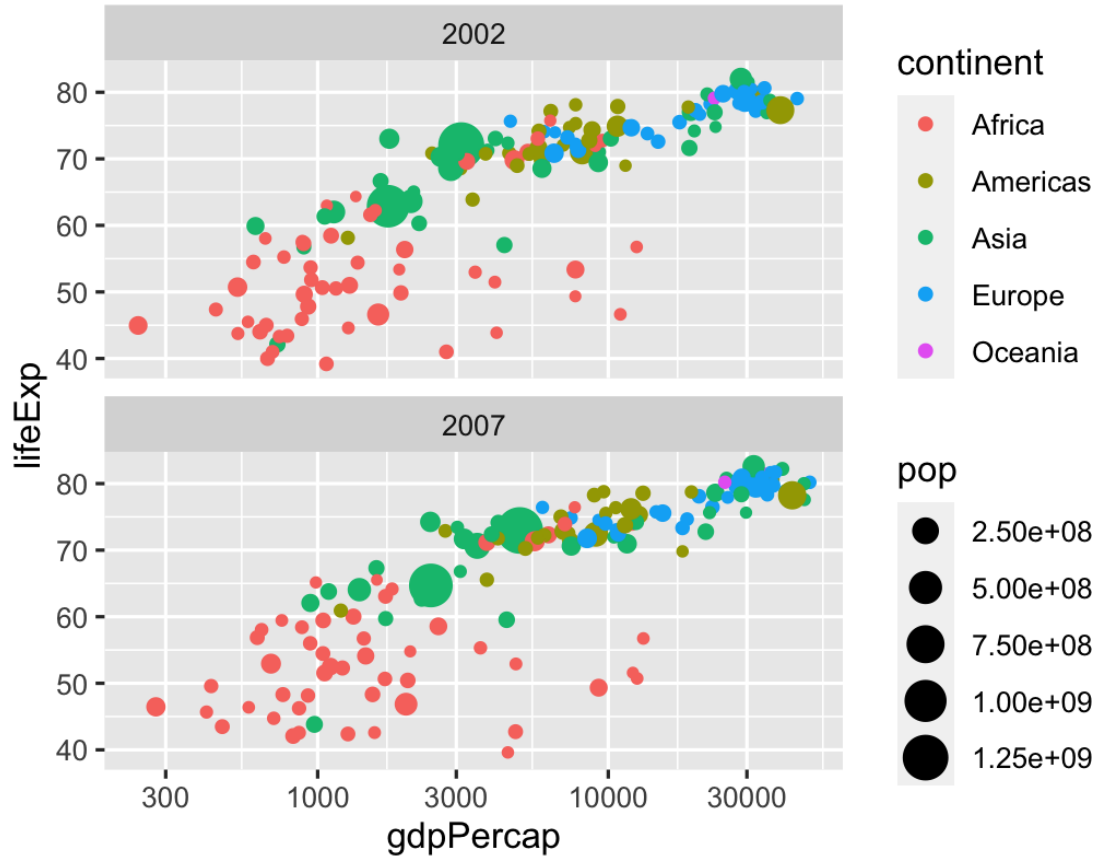
Geoms can be interchangable (e.g. switch `geom_violin()` to `geom_boxplot()`)



Describing graphs with the grammar

Map wealth to the x-axis, health to the y-axis, add points, color by continent, size by population, scale the y-axis with a log, and facet by year

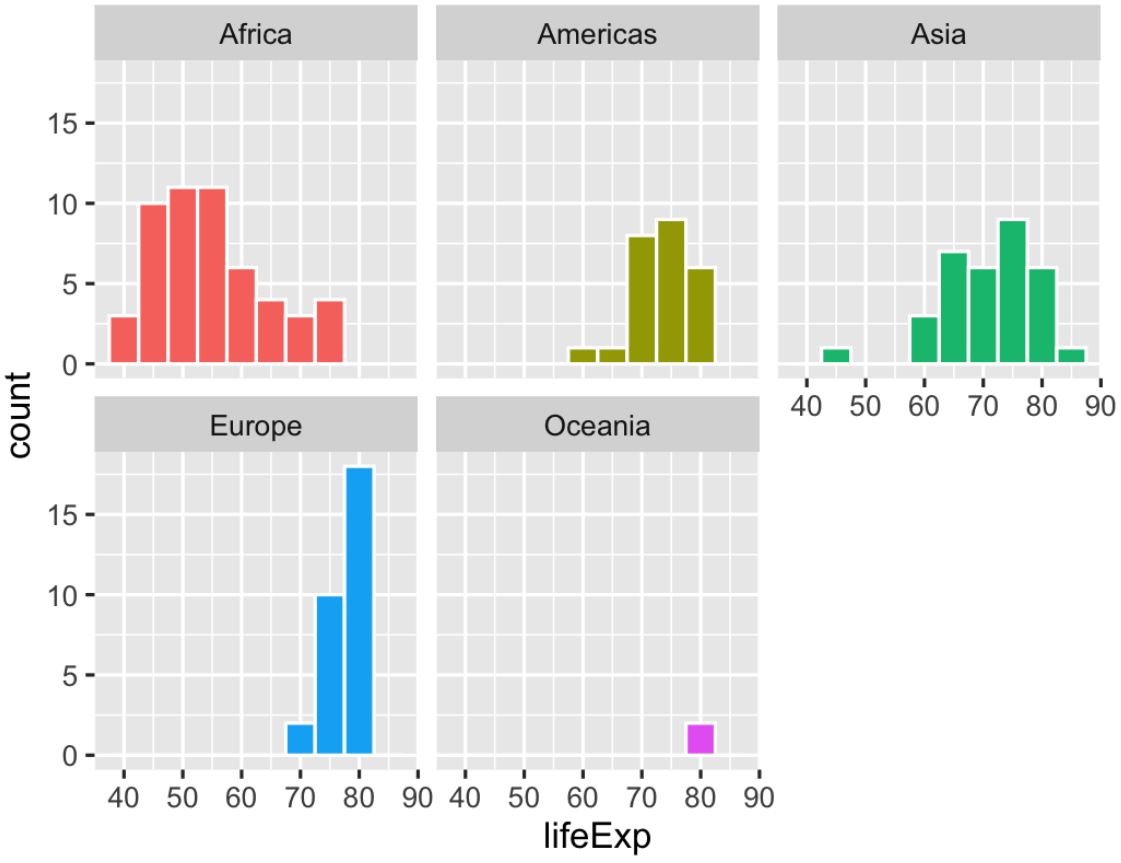
```
ggplot(data = filter(gapminder, year %in% c(
       mapping = aes(x = gdpPercap,
                     y = lifeExp,
                     color = continent,
                     size = pop)) +
  geom_point() +
  scale_x_log10() +
  facet_wrap(vars(year), ncol = 1)
```



Describing graphs with the grammar

Map health to the x-axis, add a histogram with bins for every 5 years, fill and facet by continent

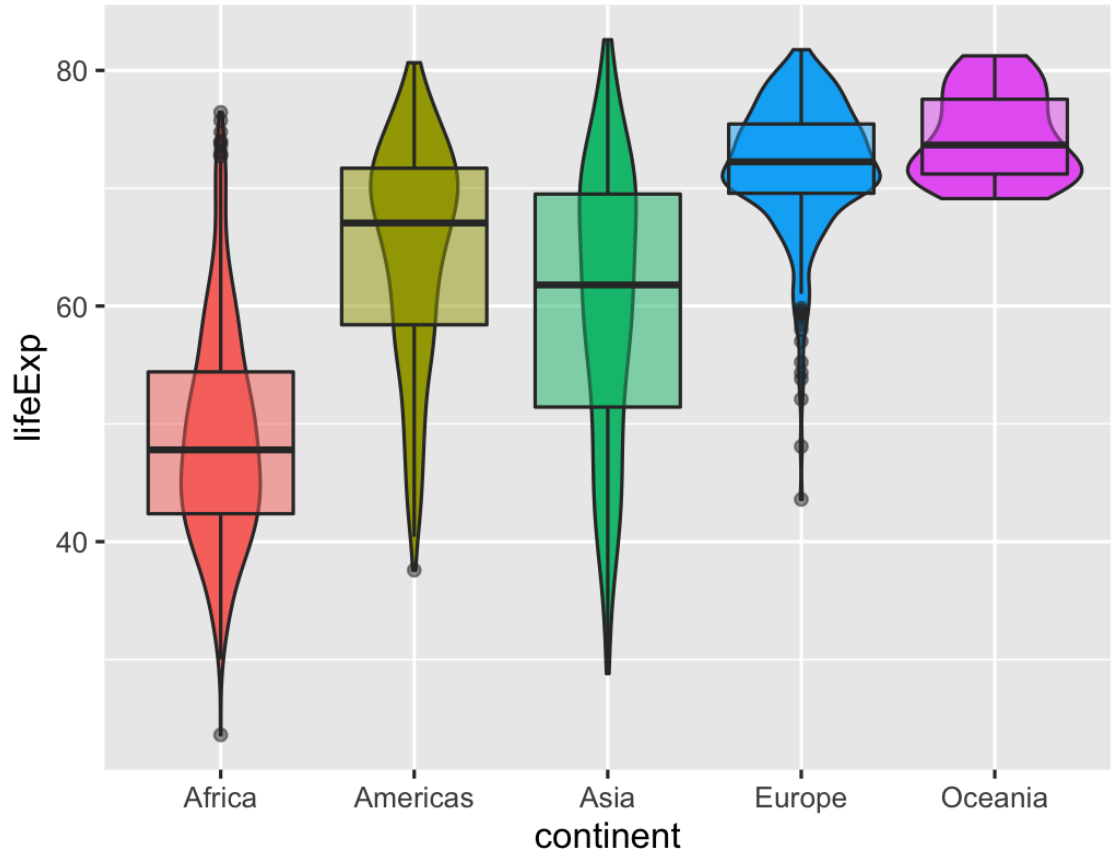
```
ggplot(data = gapminder_2007,
       mapping = aes(x = lifeExp,
                     fill = continent)) +
  geom_histogram(binwidth = 5,
                 color = "white") +
  guides(fill = FALSE) +  # Turn off legend
  facet_wrap(vars(continent))
```



Describing graphs with the grammar

Map continent to the x-axis, health to the y-axis, add violin plots and semi-transparent boxplots, fill by continent

```
ggplot(data = gapminder,
       mapping = aes(x = continent,
                     y = lifeExp,
                     fill = continent)) +
  geom_violin() +
  geom_boxplot(alpha = 0.5) +
  guides(fill = FALSE)  # Turn off legend
```

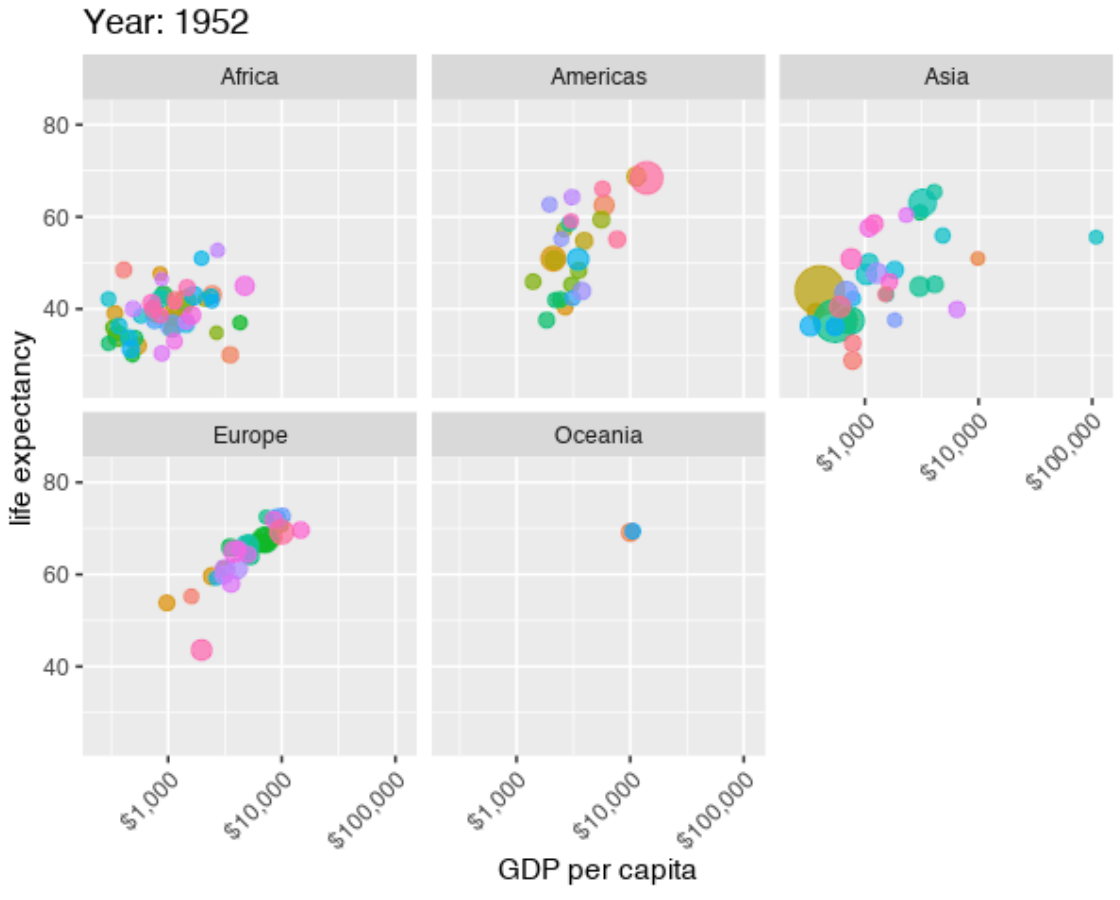


Aesthetics in extra dimensions

Time

Use gganimate to map variables to a time aesthetic

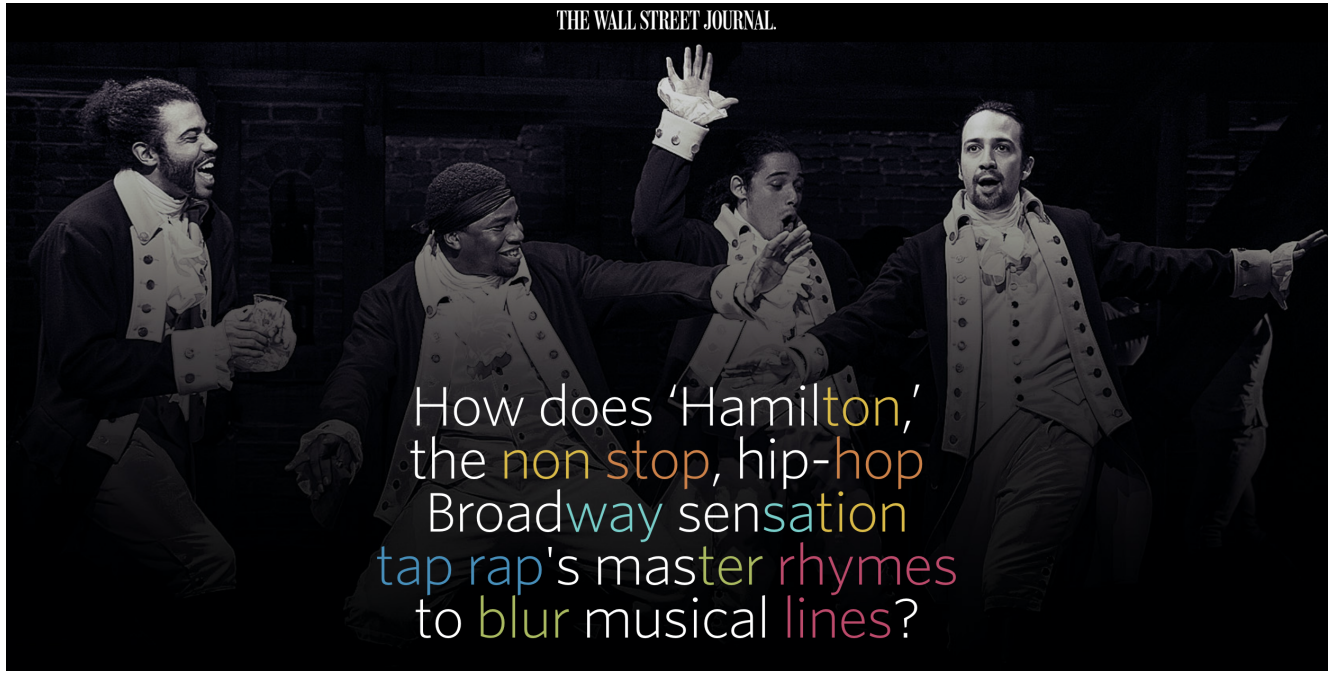
```
ggplot(gapminder, aes(x = gdpPercap, y = life
                      size = pop, color = cou
  geom_point(alpha = 0.7) +
  scale_size(range = c(2, 12)) +
  scale_x_log10(labels = scales::dollar) +
  guides(size = FALSE, color = FALSE) +
  facet_wrap(~continent) +
  # Special gganimate stuff
  labs(title = 'Year: {frame_time}', x = 'GDP
  transition_time(year) +
  ease_aes('linear')
```



Sound

Visualize internal rhyming schemes in music

http://graphics.wsj.com/hamilton/



Daveed Diggs

I'm **in** the **cabinet** I **am** com**plicit in**
Watching him grabbing at power **and kissing it**
If Washington isn't gon' listen
To **disciplined dissidents this is** the **difference**
This kid **is** out

"Washington On Your Side" on "Hamilton (Original Broadway Cast Recording)"

Kendrick Lamar

Trapped inside your de**sire** to **fire** bu**llets that stray**
Track attire just tell **you** I'm **tired** and ran **away**
I should **ask** a **choir "What do you require**
to sing a song **that acquire me** to have **faith?"**

"good kid" on "good kid, m.A.A.d city"

Animation, time, and sound

Tidy data

Data shapes

For `ggplot()` to work,
your data needs to be in a **tidy** format

This doesn't mean that it's clean—
it refers to the *structure* of the data

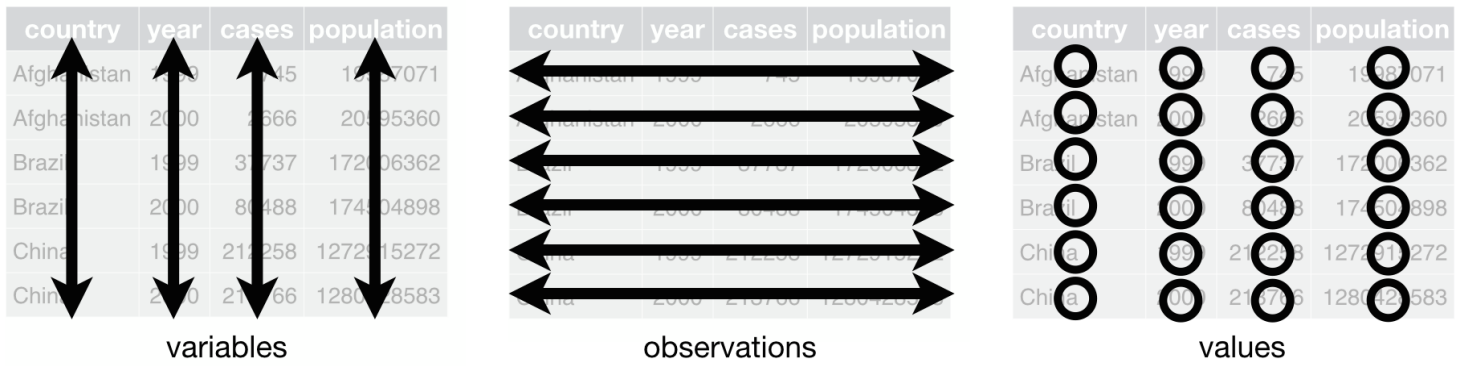
All the packages in the **tidyverse** work best with tidy data; that why it's called that!

Tidy data

Each variable has its own column

Each observation has its own row

Each value has its own cell



From chapter 12 of *R for Data Science*

Untidy data example

Real world data is often untidy, like this:

	A	B	C	D
1	Number of incidents			
2				
3	Office	2015	2016	2017
4	Utah County	134	145	**167**
5	Salt Lake County	**302**	334	331
6	Davis County	254	288	299
7	Juab County	78	**82**	87
8				
9	**bold = needs verification**			
10	yellow = compiled from different source			
11				

Tidy data example

Here's the tidy version of that same data:

	A	B	C	D	E
1	Office	Year	Incidents	Needs Verification	Different Source
2	Utah County	2015	134	FALSE	FALSE
3	Salt Lake County	2015	302	TRUE	FALSE
4	Davis County	2015	254	FALSE	FALSE
5	Juab County	2015	78	FALSE	FALSE
6	Utah County	2016	145	FALSE	TRUE
7	Salt Lake County	2016	334	FALSE	FALSE
8	Davis County	2016	288	FALSE	FALSE
9	Juab County	2016	82	TRUE	TRUE
10	Utah County	2017	167	TRUE	FALSE
11	Salt Lake County	2017	331	FALSE	FALSE
12	Davis County	2017	299	FALSE	TRUE
13	Juab County	2017	87	FALSE	FALSE

This is plottable!

Wide vs. long

Tidy data is also called "long" data

`wide`

id	x	y	z
1	a	c	e
2	b	d	f

`long`

id	key	val
1	x	a
2	x	b
1	y	c
2	y	d
1	z	e
2	z	f

Moving from wide to long

Nowadays, `gather()` is called `pivot_longer()` and `spread()` is called `pivot_wider()`

wide