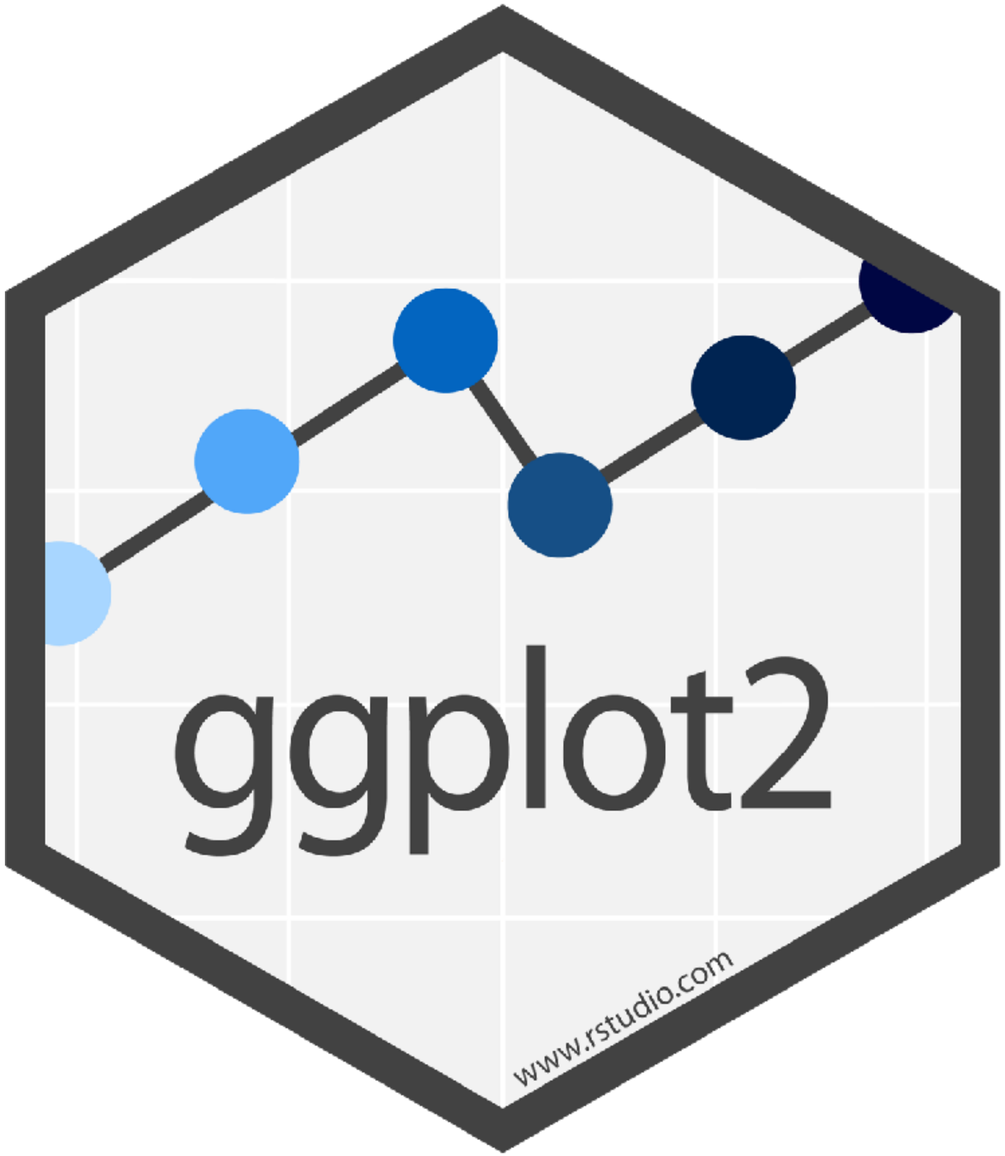
Data Visualization

Jake Thompson
wjakethompson.com
@wjakethompson

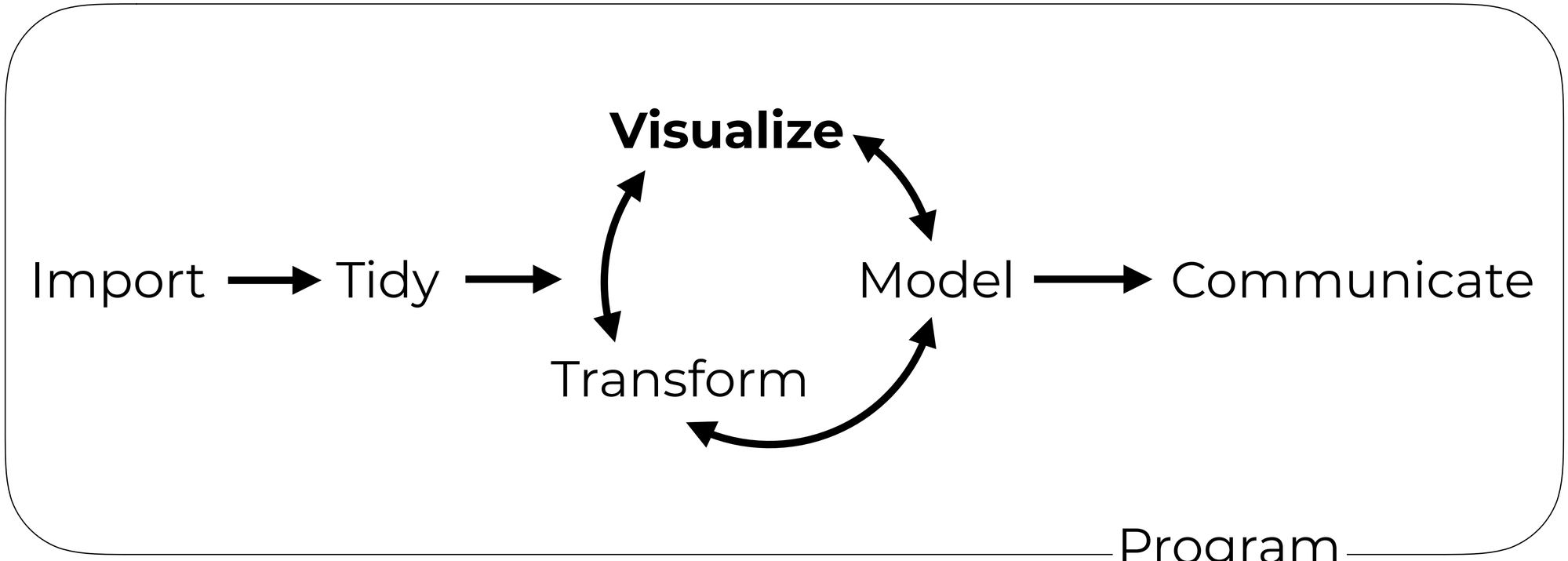
ATLAS
Accessible Teaching, Learning, and Assessment Systems



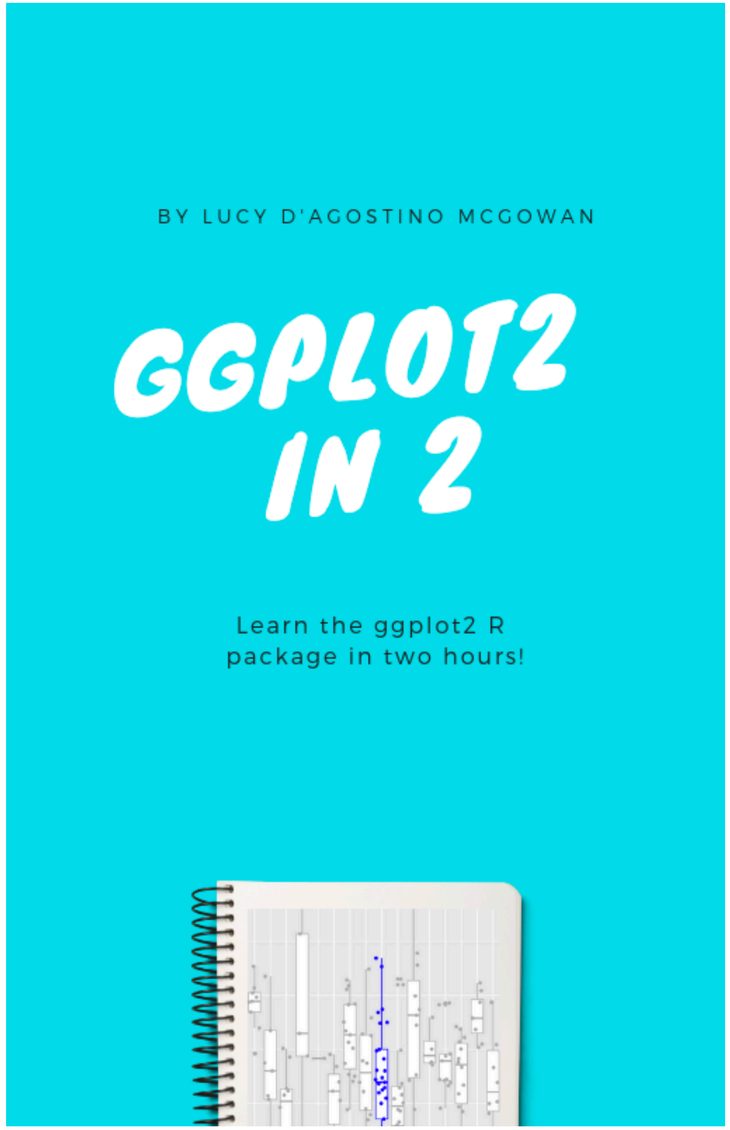
In R4DS

Data Visualisation

ATLAS

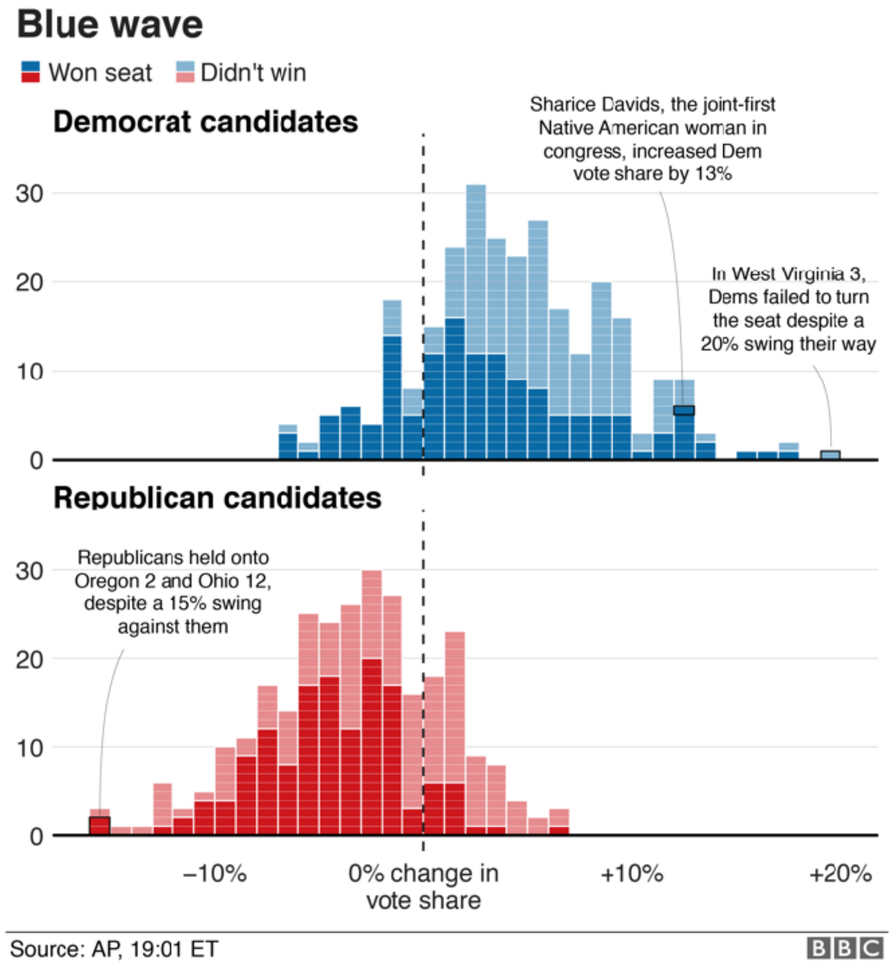


Lucy D'Agostino McGowan
Postdoctoral Researcher
Johns Hopkins University
@LucyStats

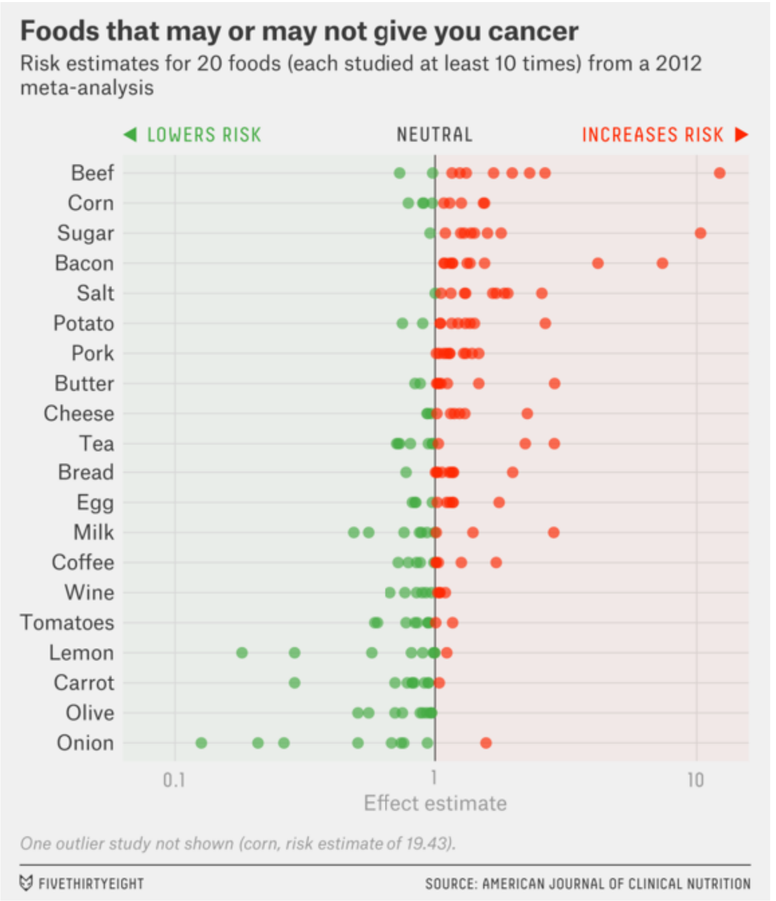


ATLAS

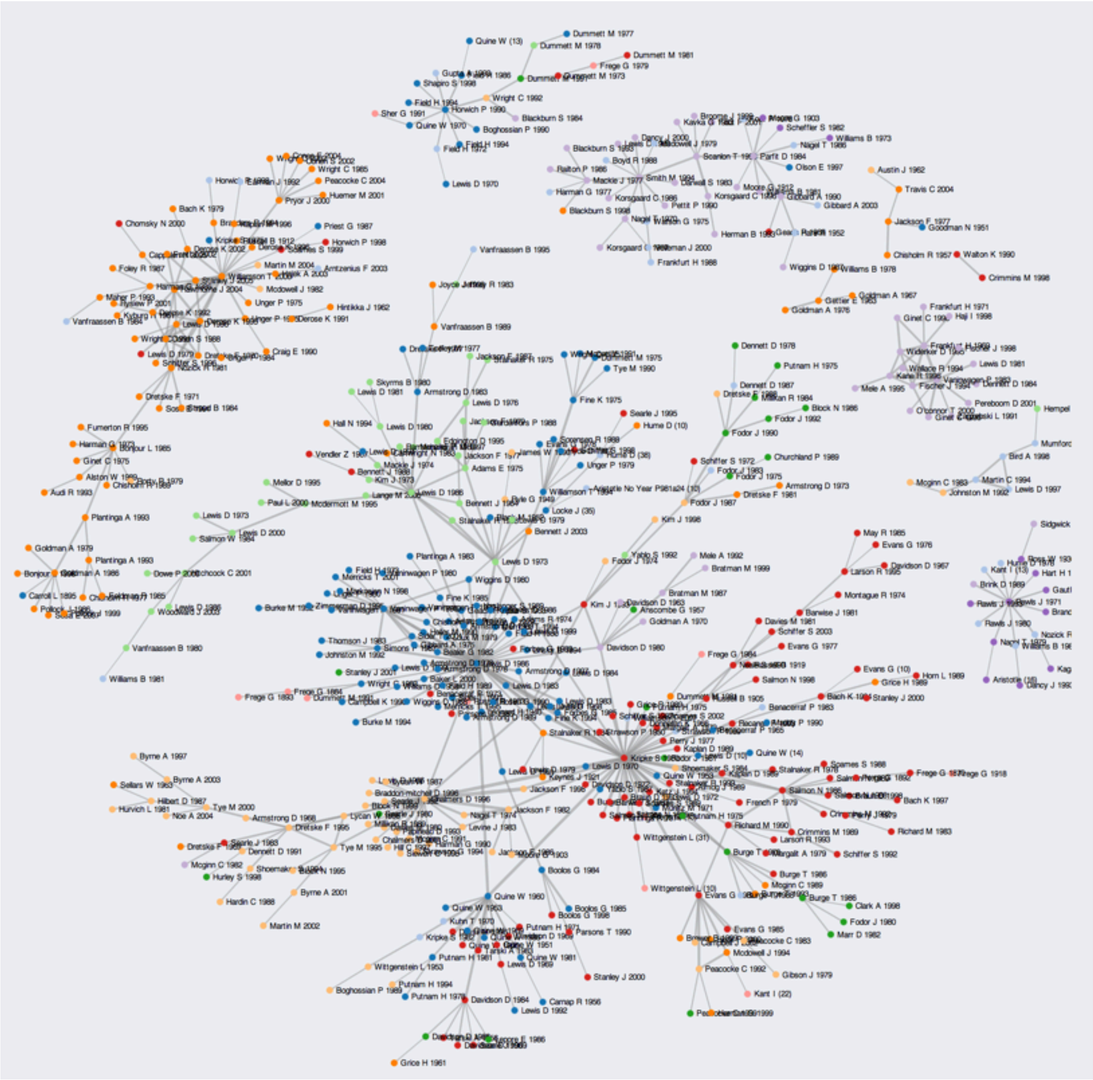
ggplot2



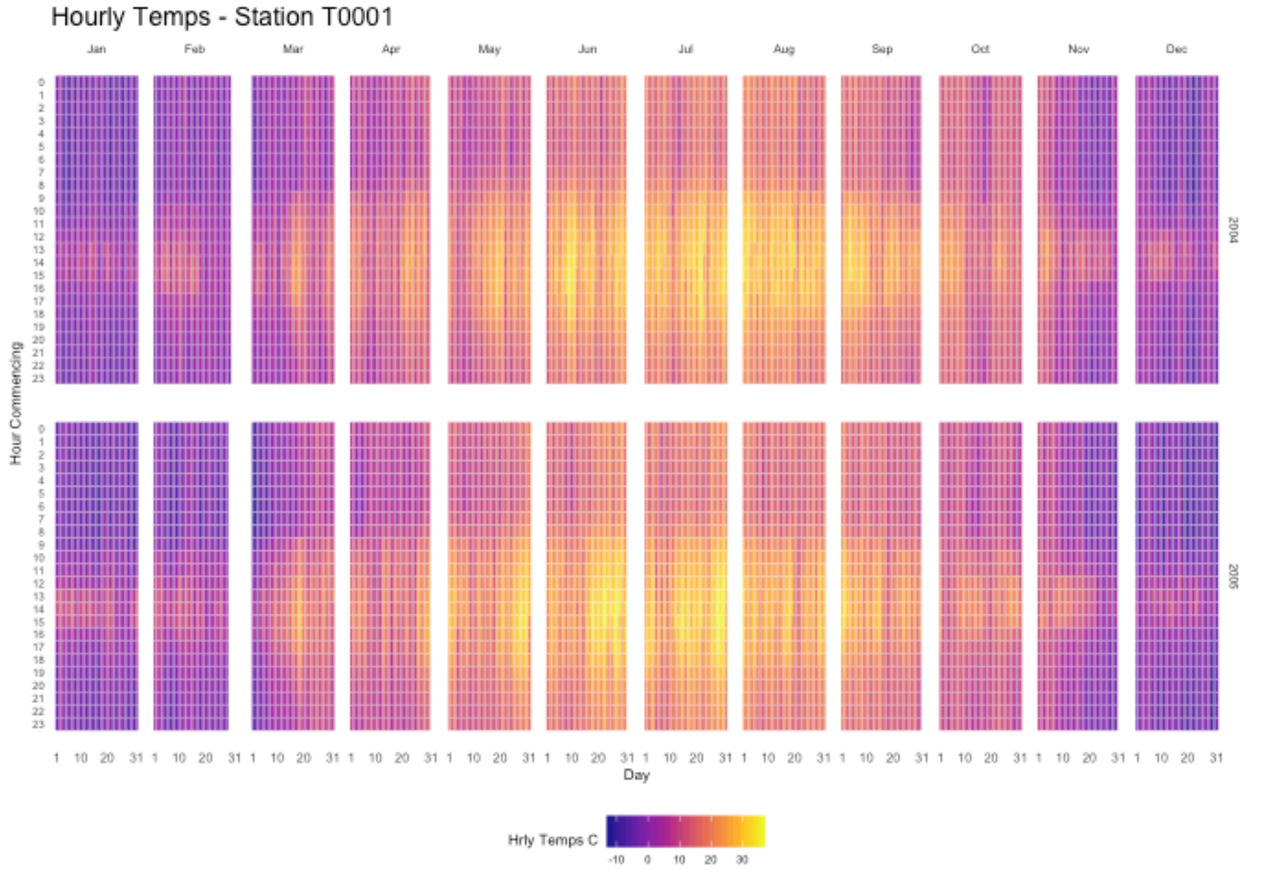
BBC News



FiveThirtyEight

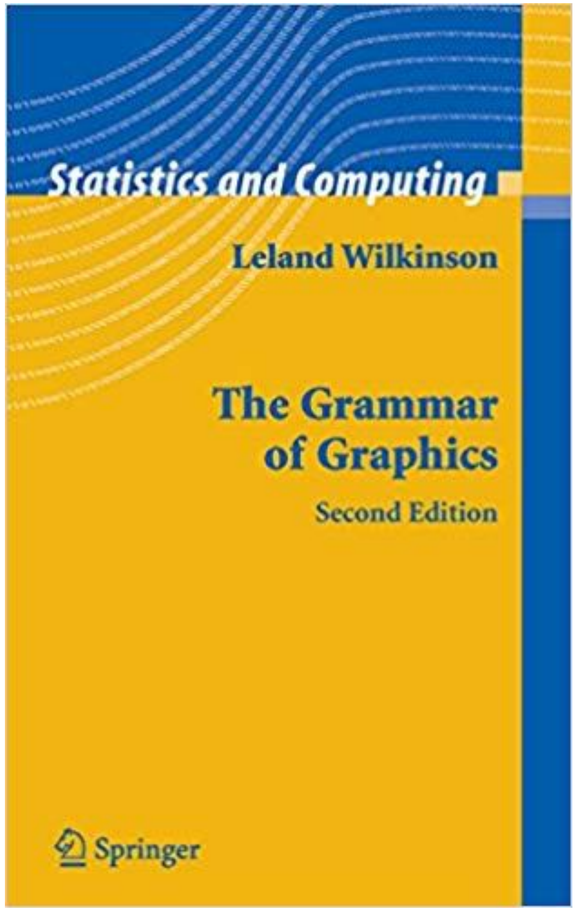


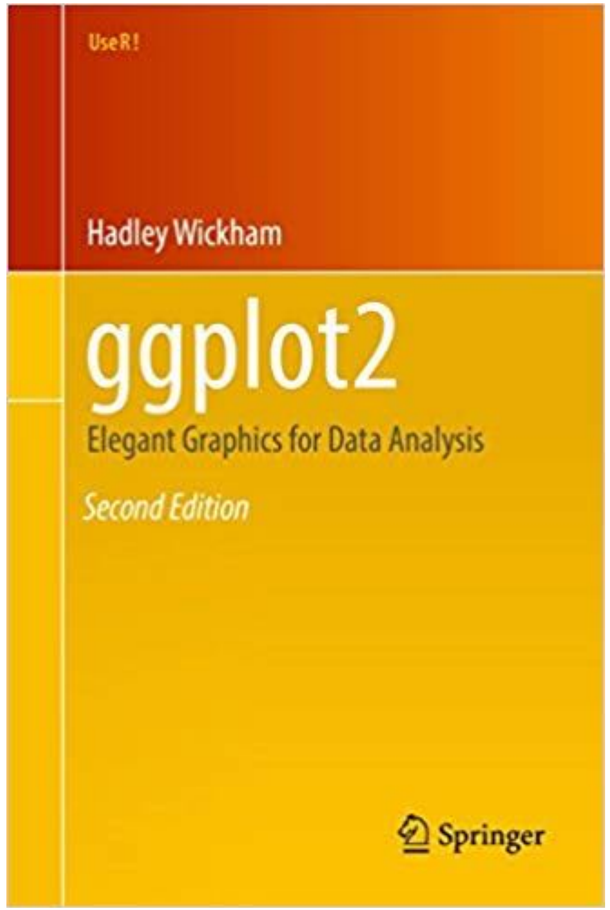
Philosophy Co-Citation Network, Kieran Healy



R Graph Gallery, John MacKintosh

Grammar of Graphics





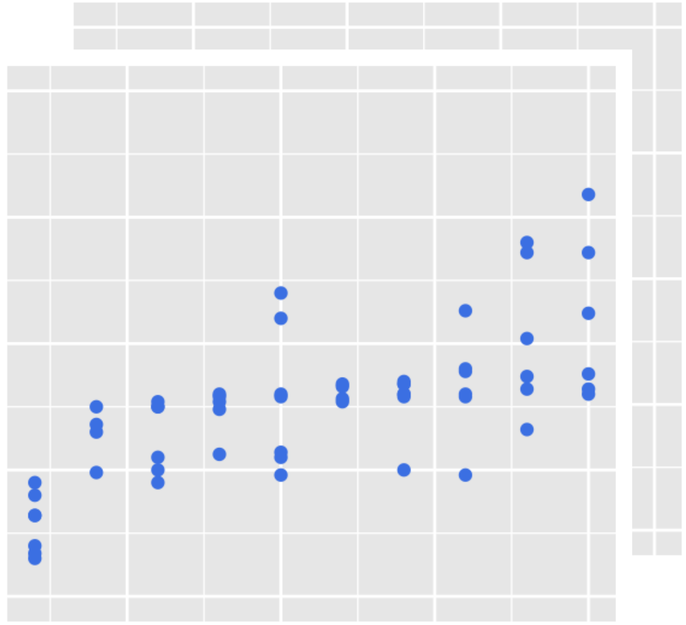
ggplot2

- **data** maps to
- **aes**thetics in
- layers

ggplot2 layers

ggplot2 layers

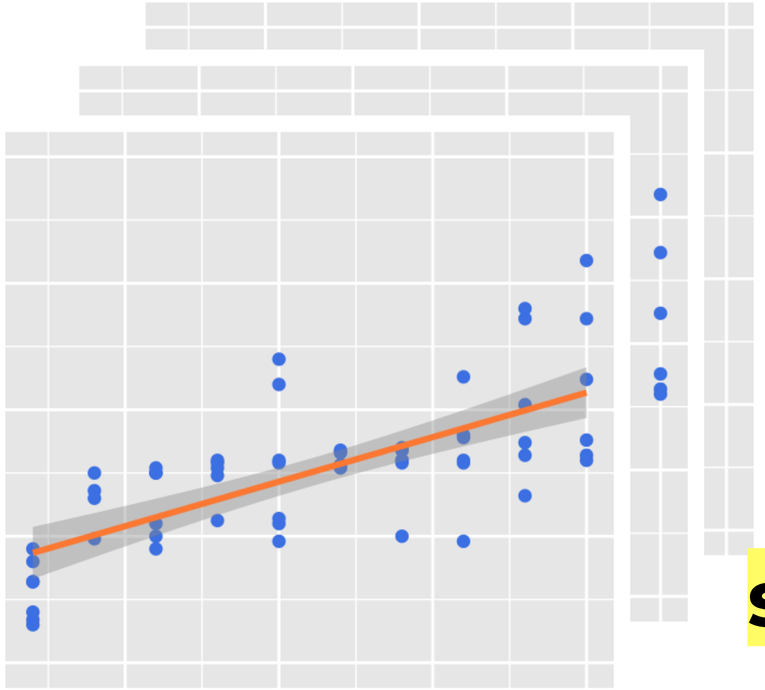
+



geometric objects

ggplot2 layers

+

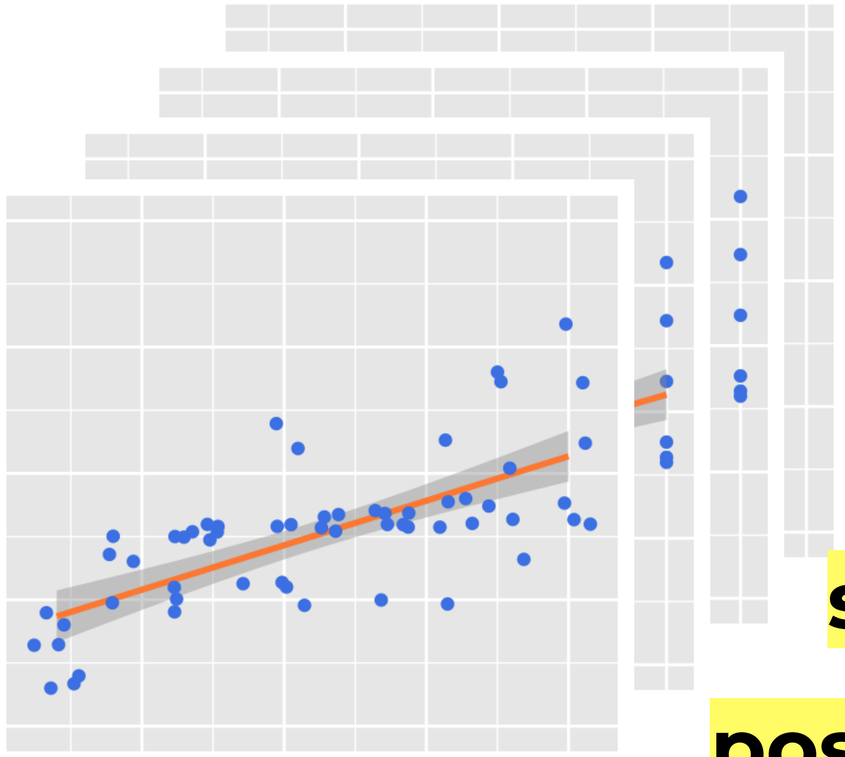


geometric objects

statistical transformations

ggplot2 layers

+

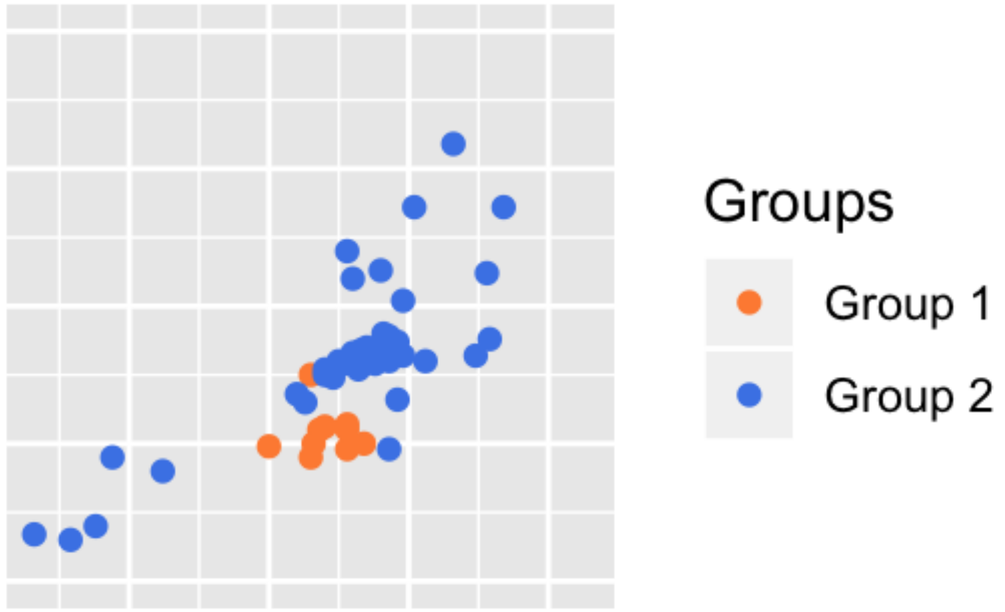


geometric objects

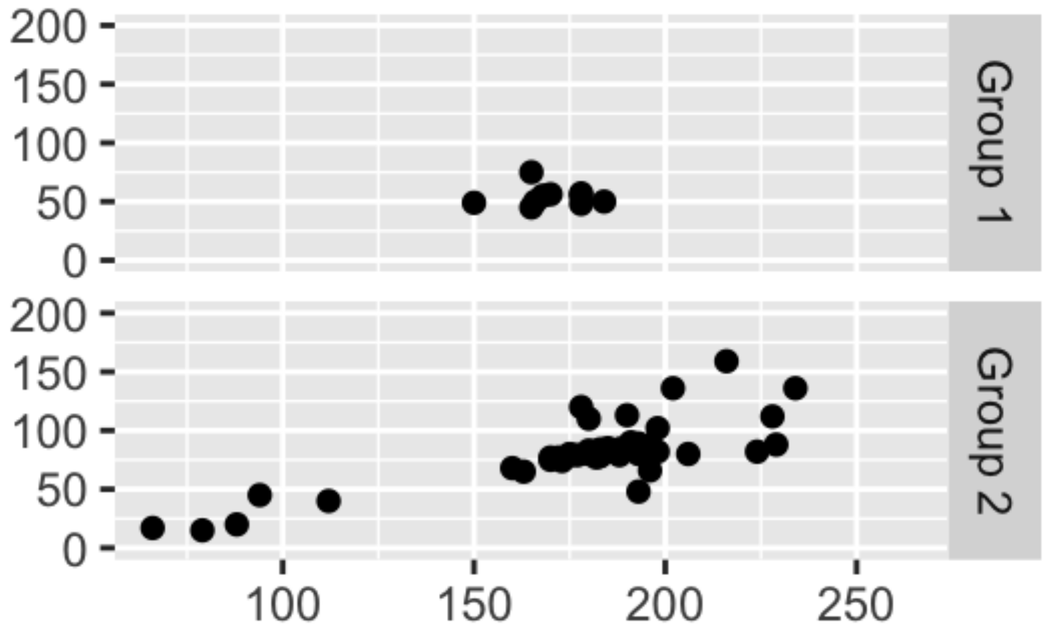
statistical transformations

position adjustments

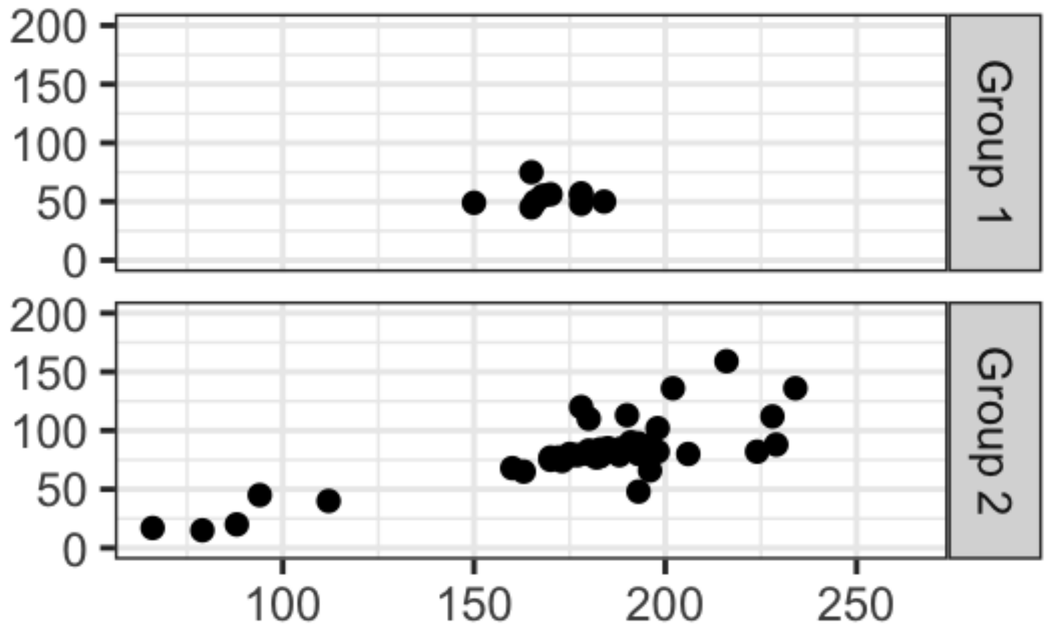
ggplot2 scales



ggplot2 facets



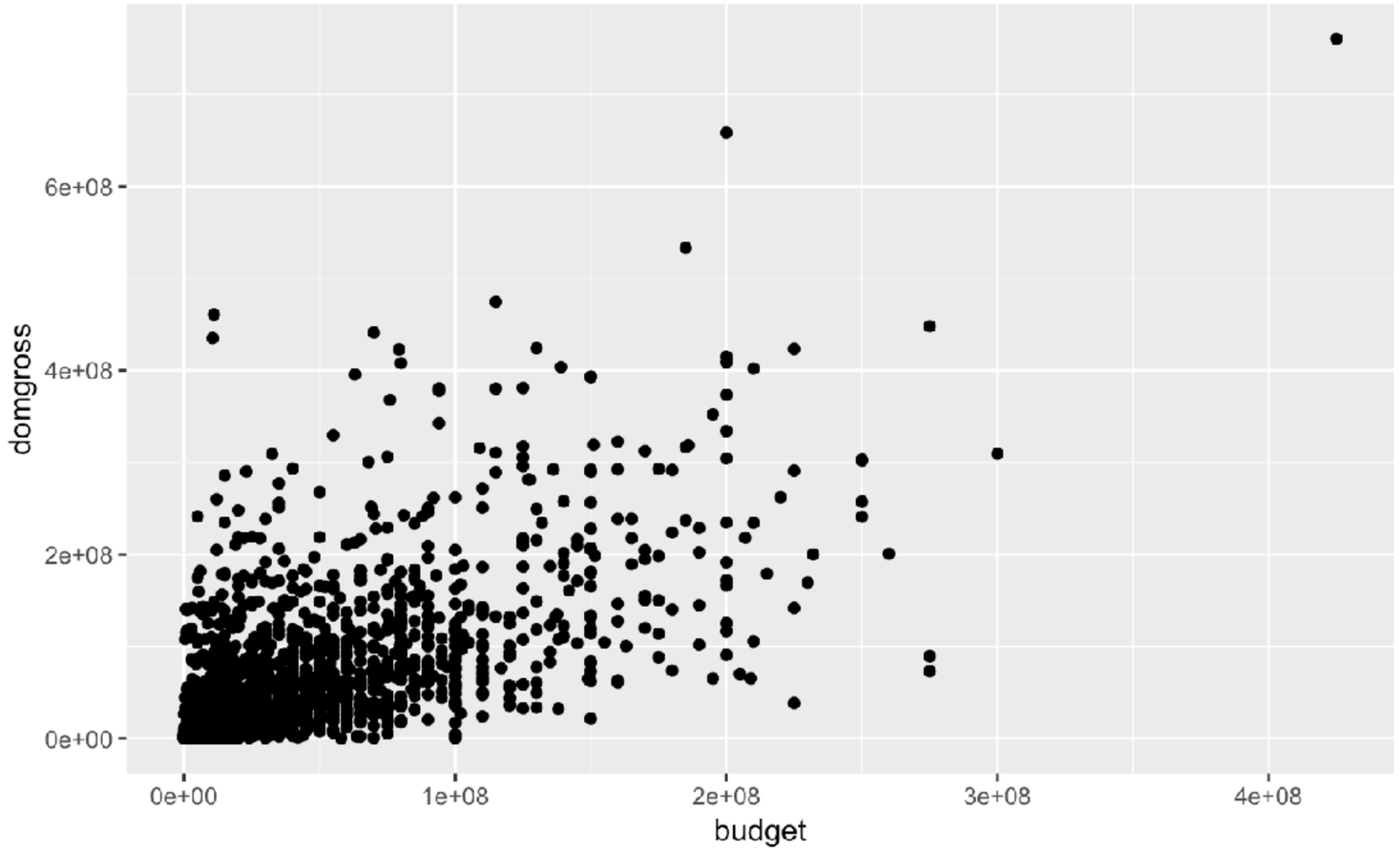
ggplot2 themes



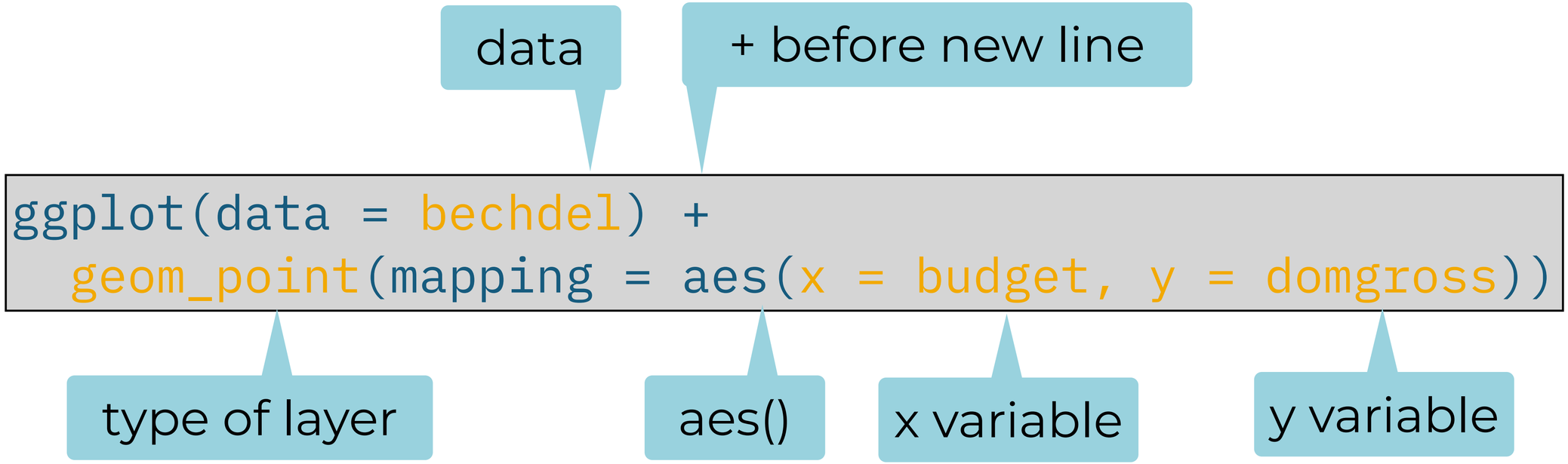
Your Turn 1

- Open the R Notebook **01-Visualize.Rmd**
- Let's look at the **bechdel** data set
- Run this code to make a graph:

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross))
```




```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross))
```

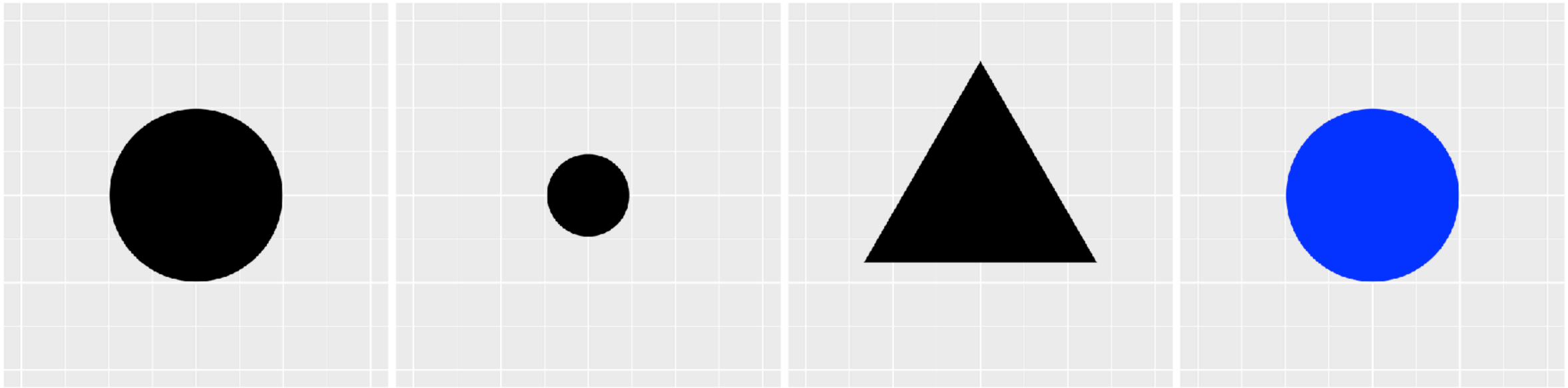


ggplot2 template

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

Aesthetics

Aesthetics



Aesthetics

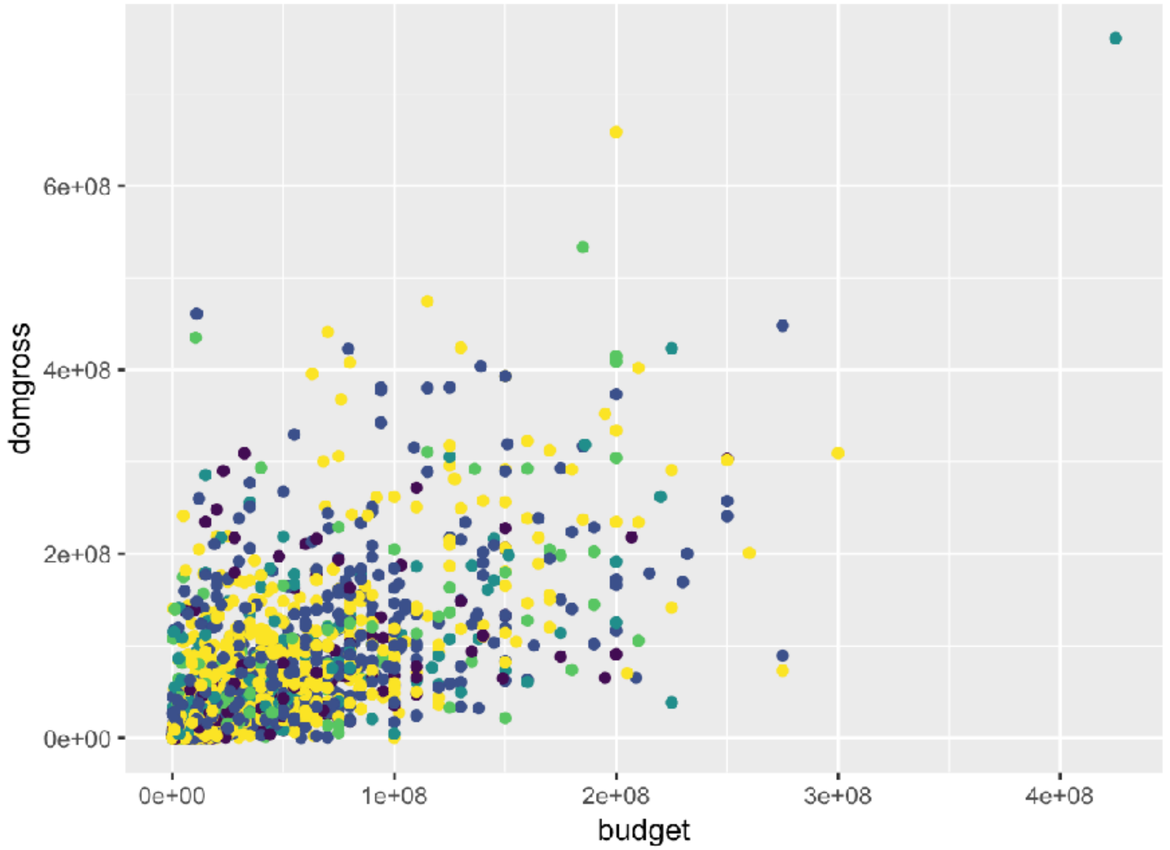
color		clean_test
Purple	⟷	nowomen
Blue	⟷	notalk
Teal	⟷	men
Lime	⟷	dubious
Yellow	⟷	ok

Aesthetic property

Variable to map it to

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```

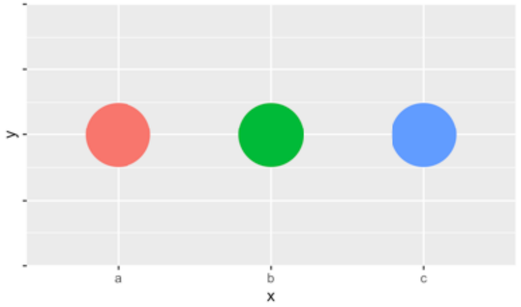
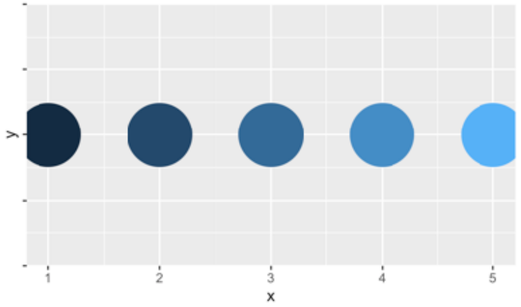
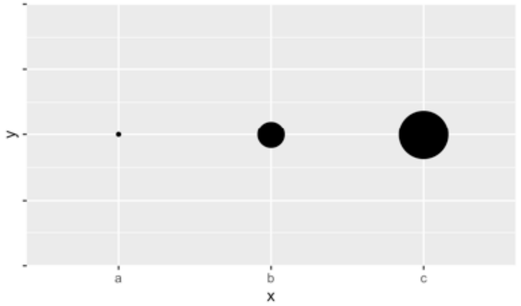
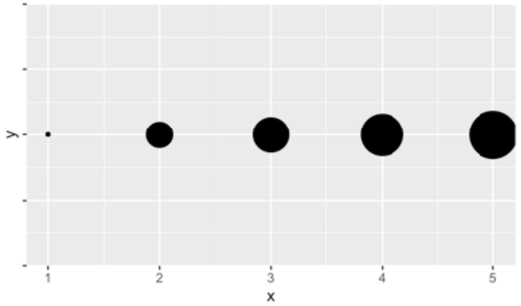
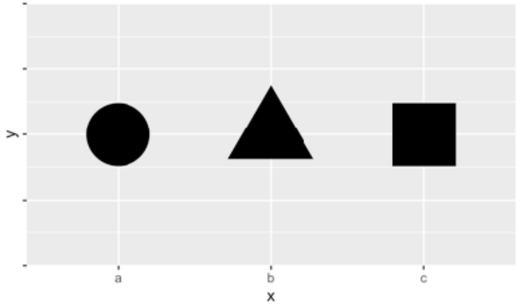
```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```



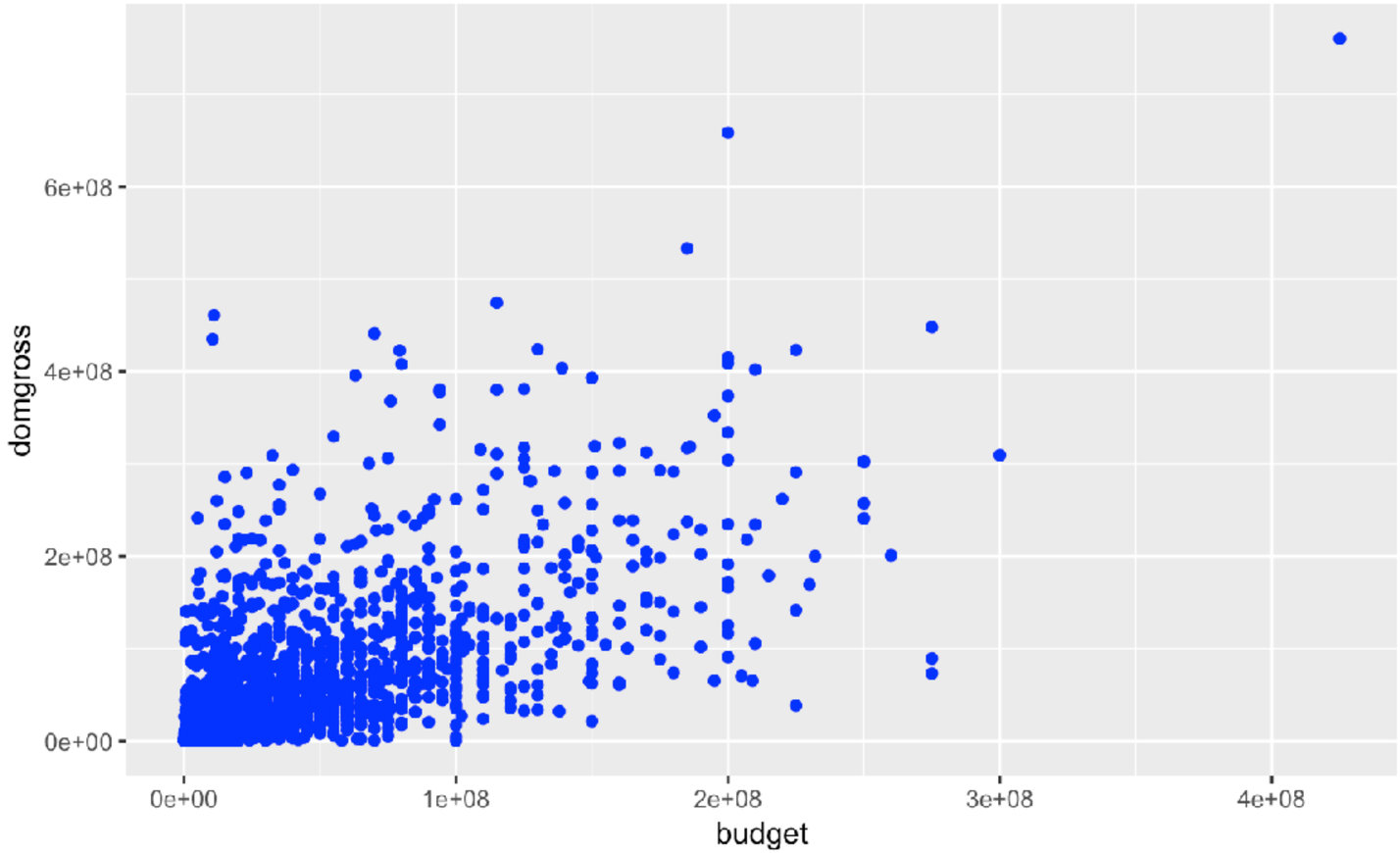
Legend added automatically

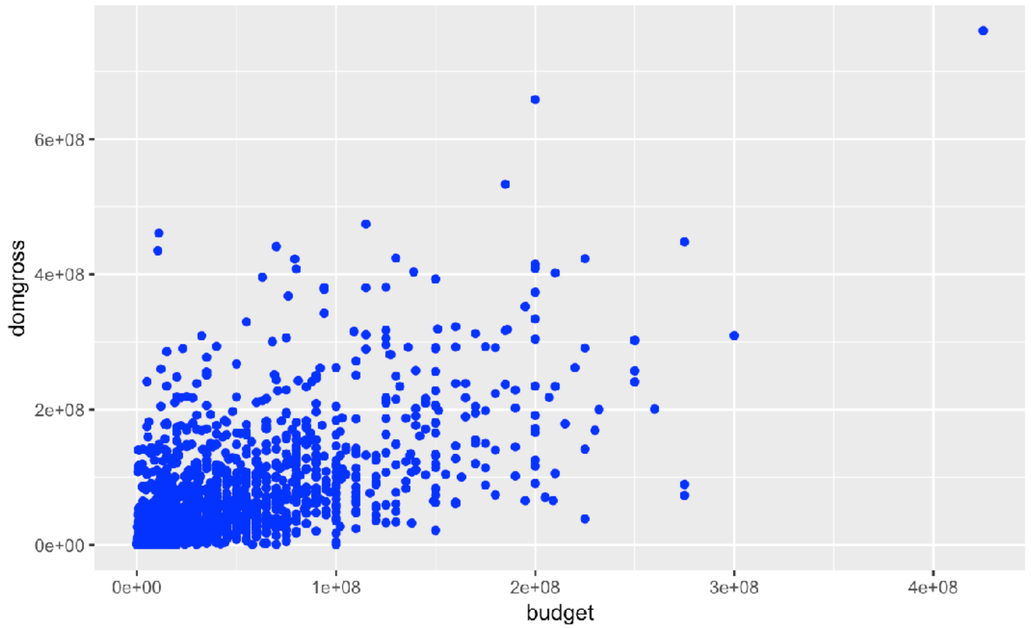
Your Turn 2

- Experiment with adding color, size, alpha, and shape aesthetics to your graph
- How do aesthetics behave different when mapped to discrete and continuous variables?
- What happens when you use more than one aesthetic?

	Discrete	Continuous
Color		
Size		
Shape		

Set vs. map

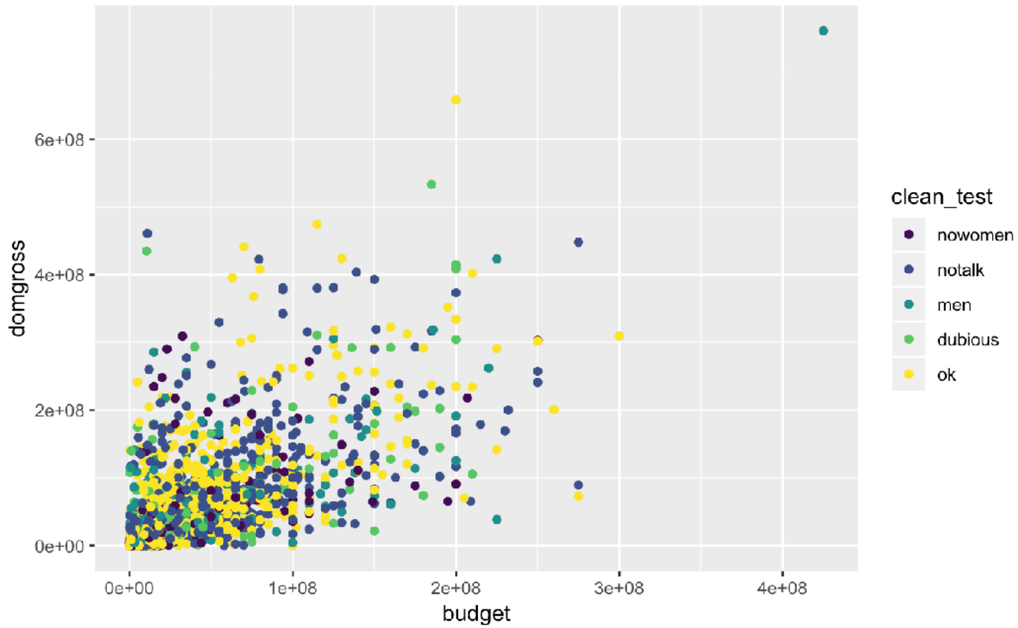


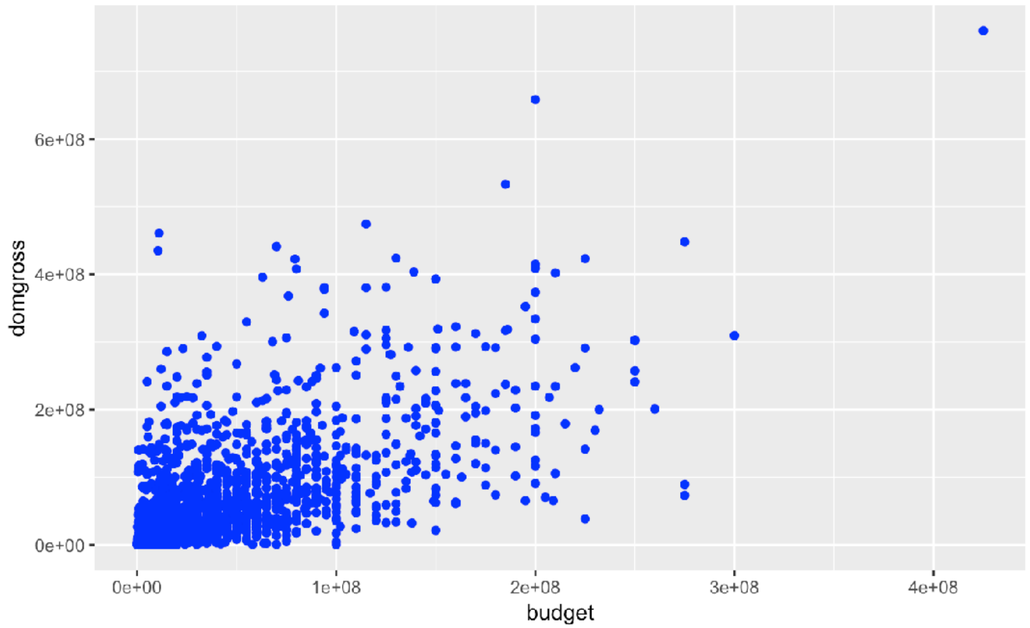


Outside of aes(): sets an aesthetic to a value

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross), color = "blue")
```

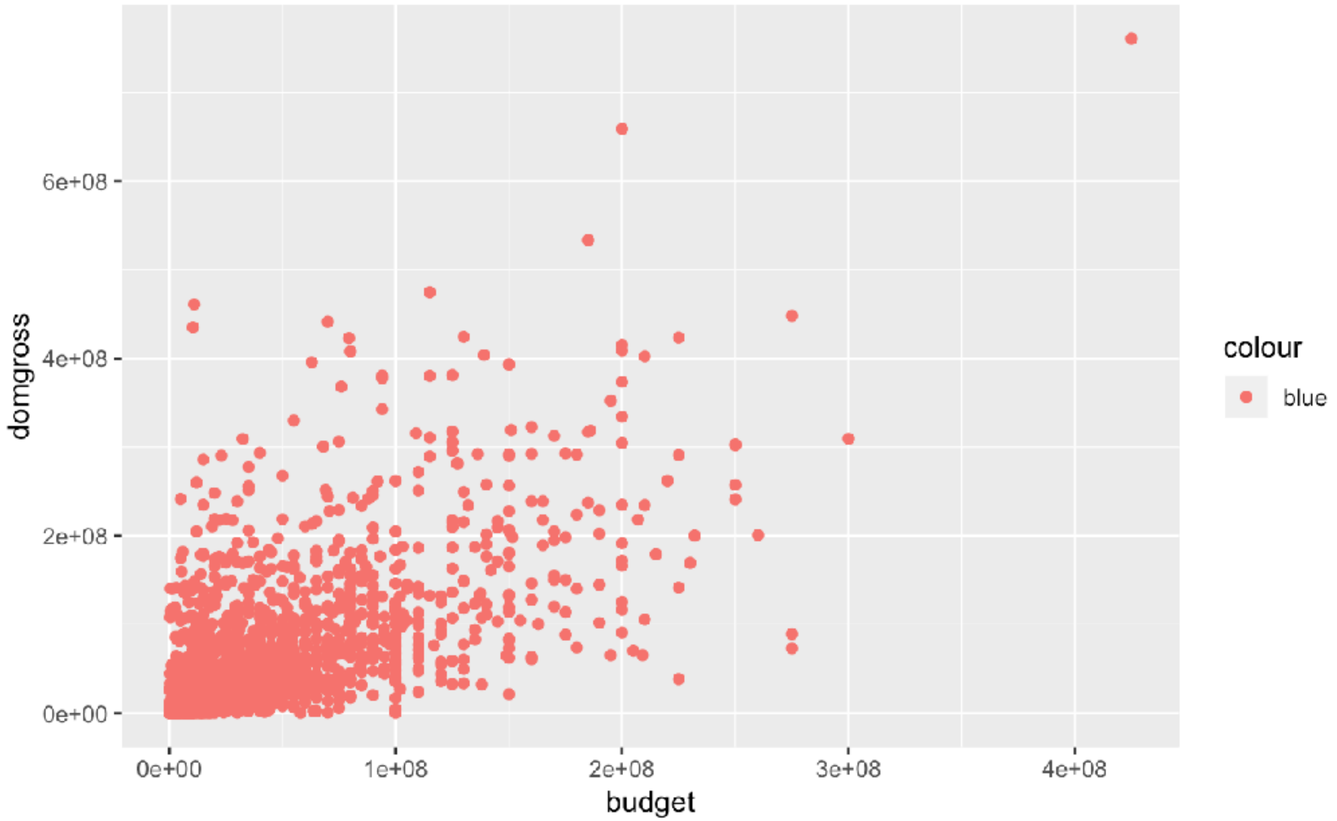




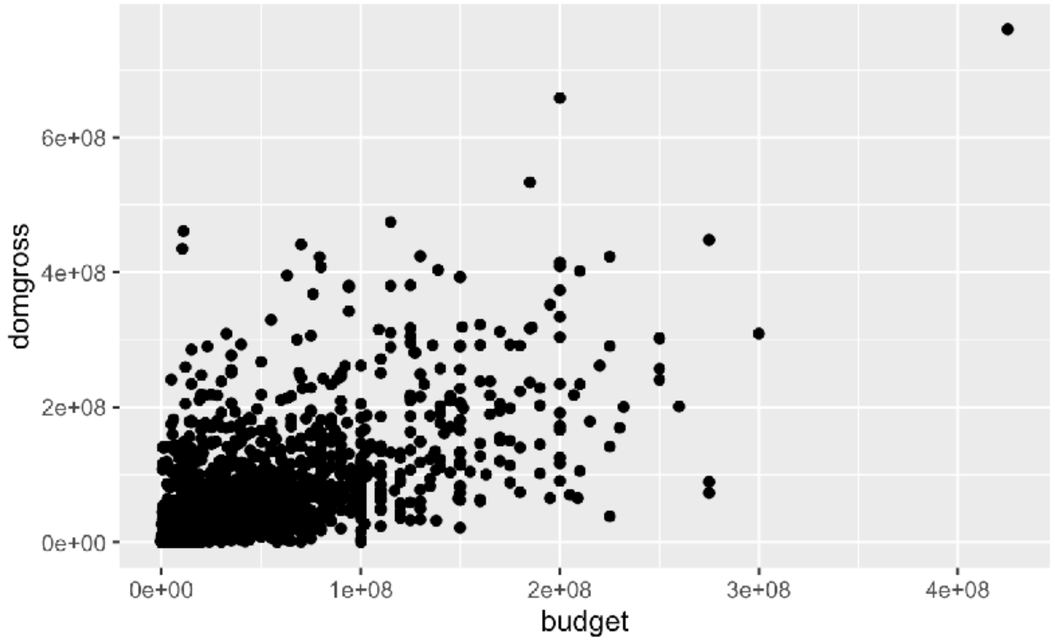

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```

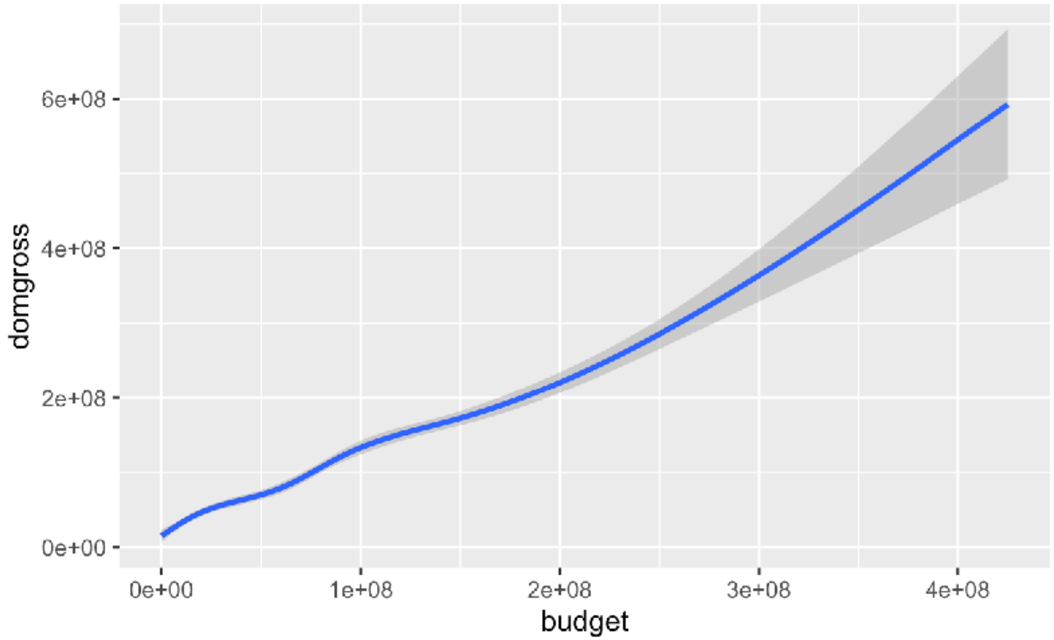
```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross), color = "blue")
```

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = "blue"))
```

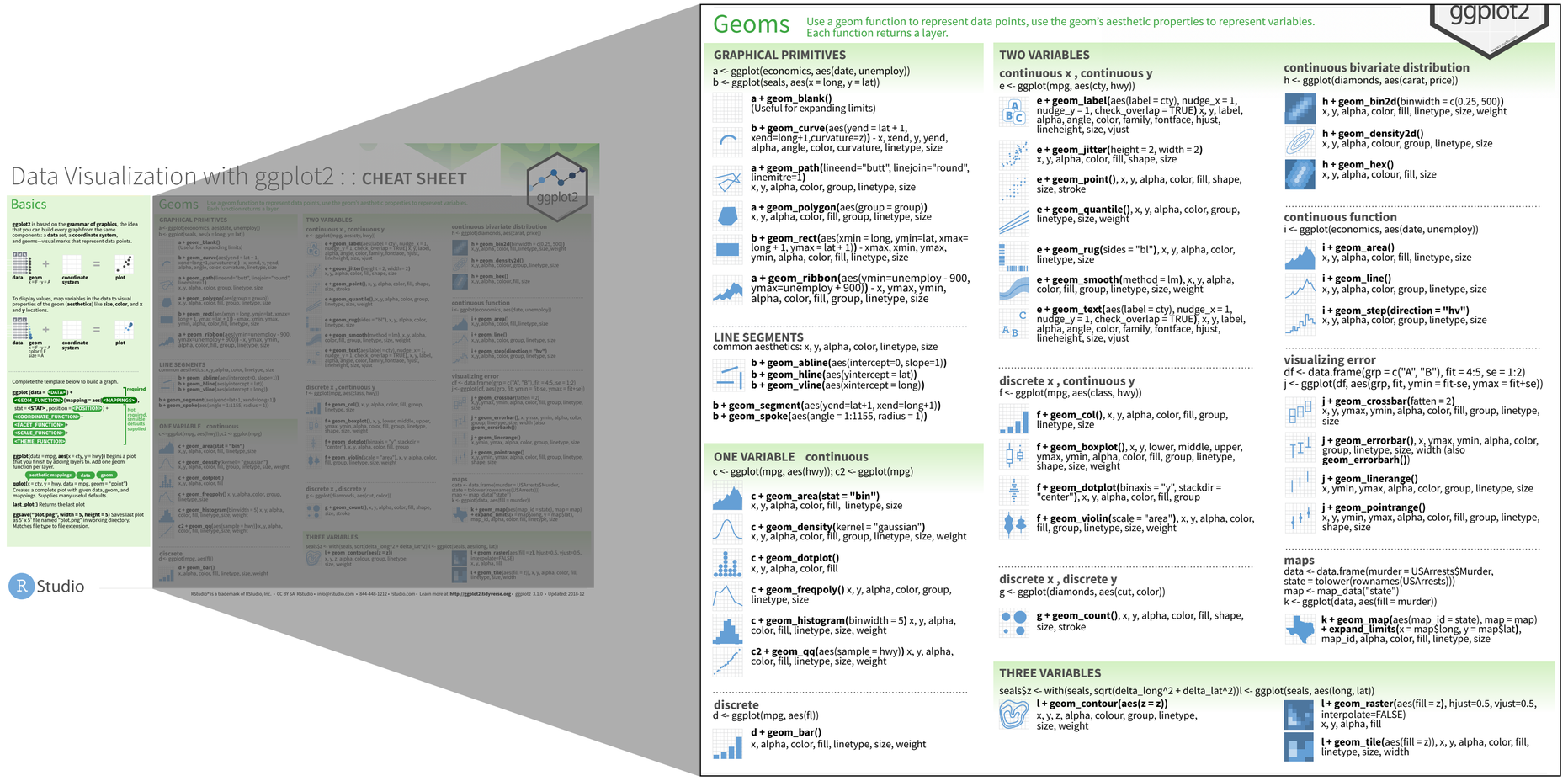


Geoms





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



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

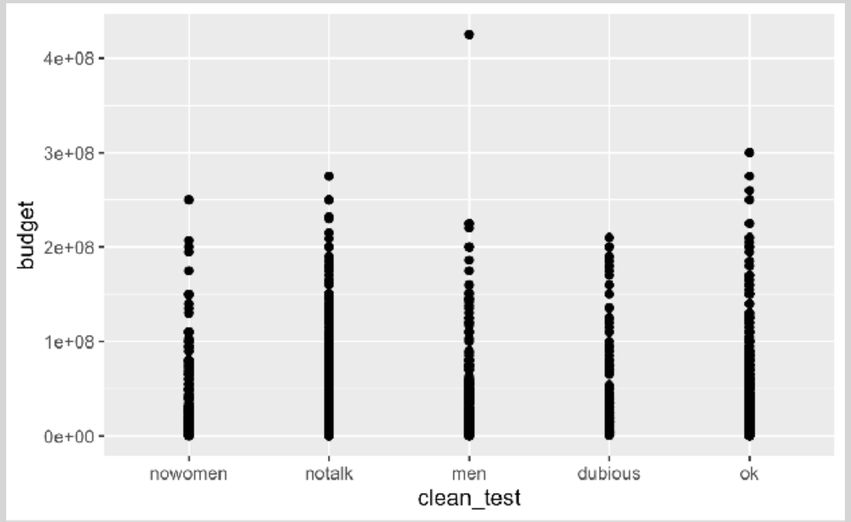
l + geom_raster(aes(fill = z**)**, hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

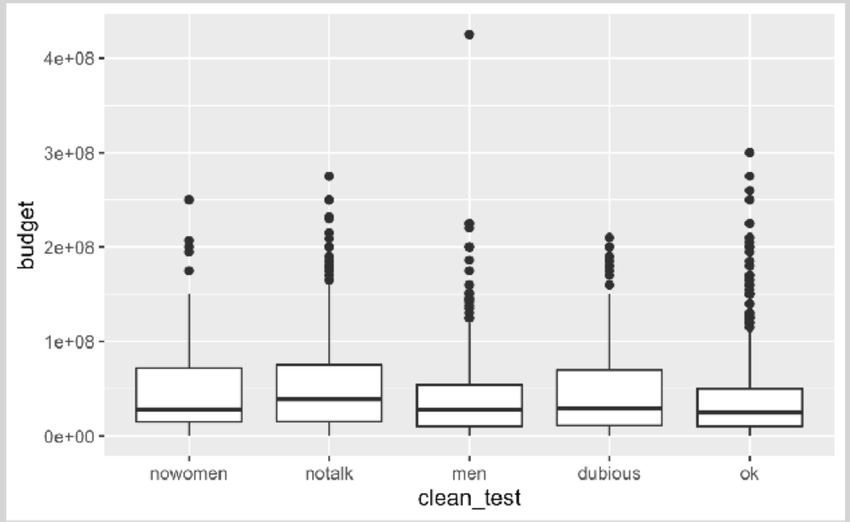
l + geom_tile(aes(fill = z**))**, x, y, alpha, color, fill, linetype, size, width

Your Turn 3

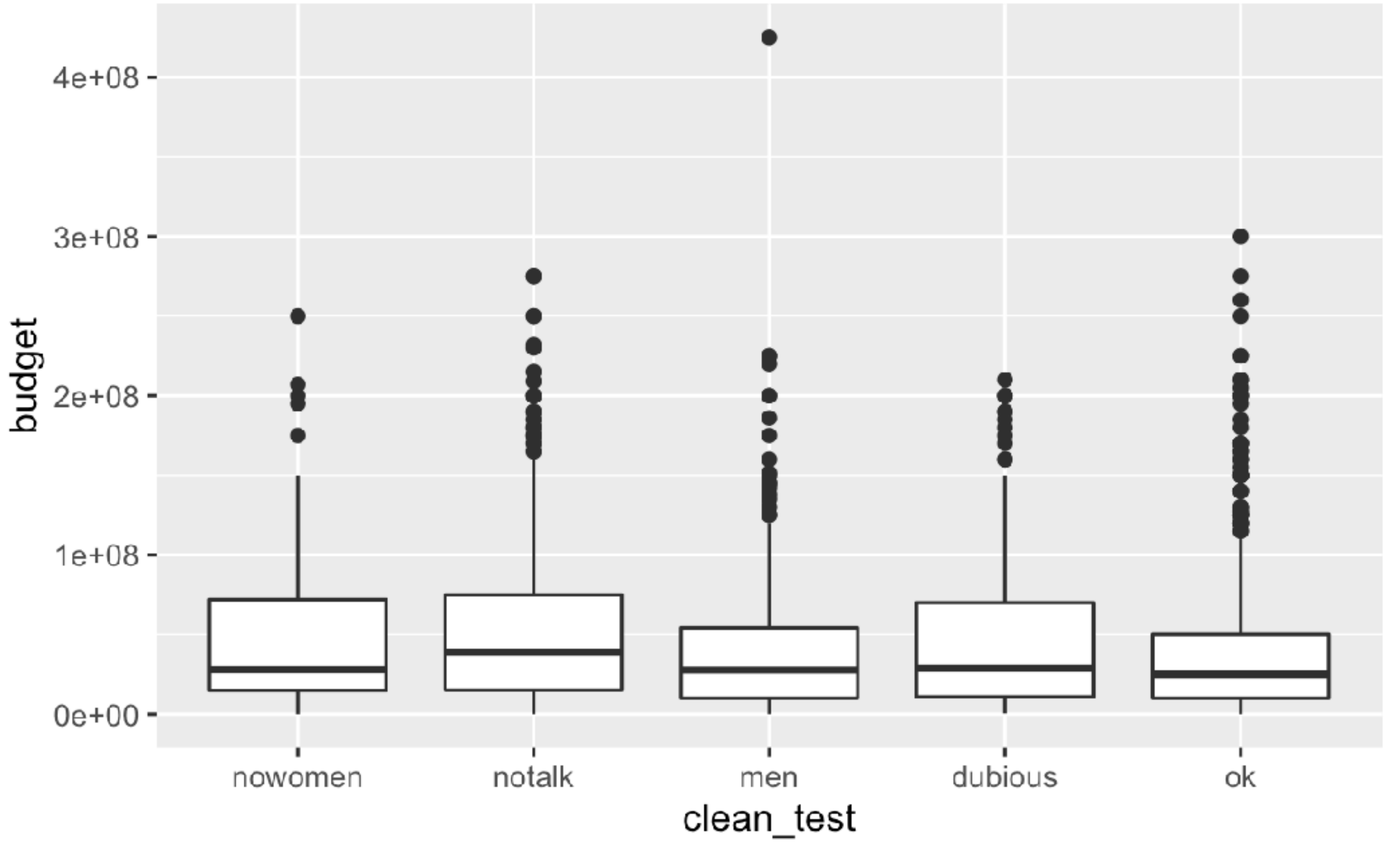
- Replace this scatterplot with one that draws boxplots

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = clean_test, y = budget))
```





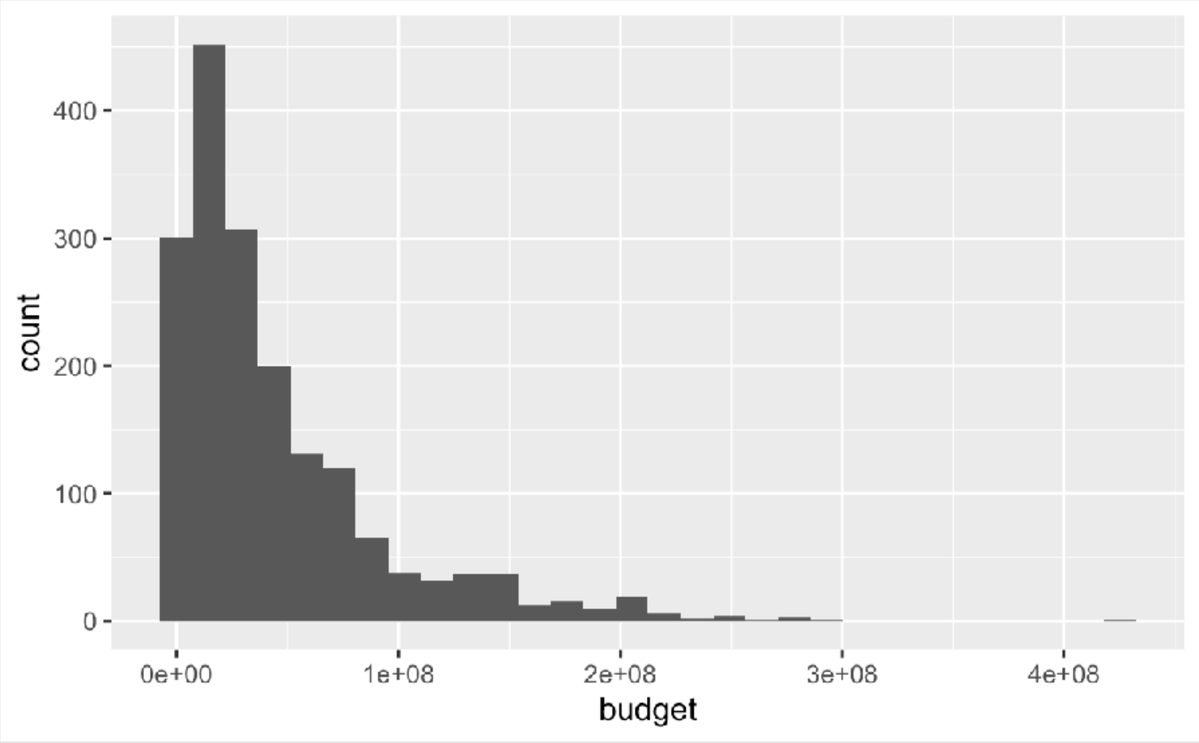
05 : 00



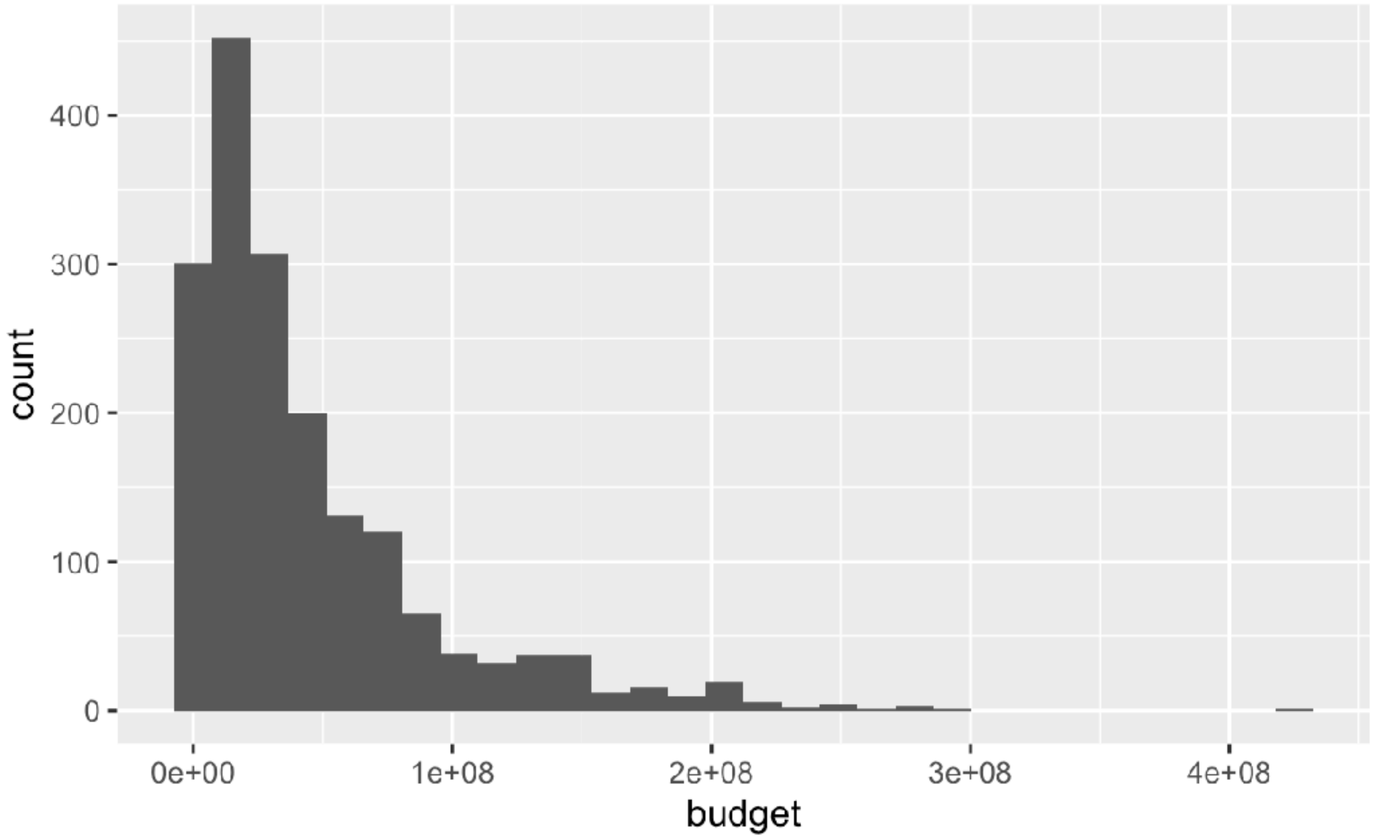

```
ggplot(data = bechdel) +
  geom_boxplot(mapping = aes(x = clean_test, y = budget))
```

Your Turn 4

- Make the histogram of **budget** shown below



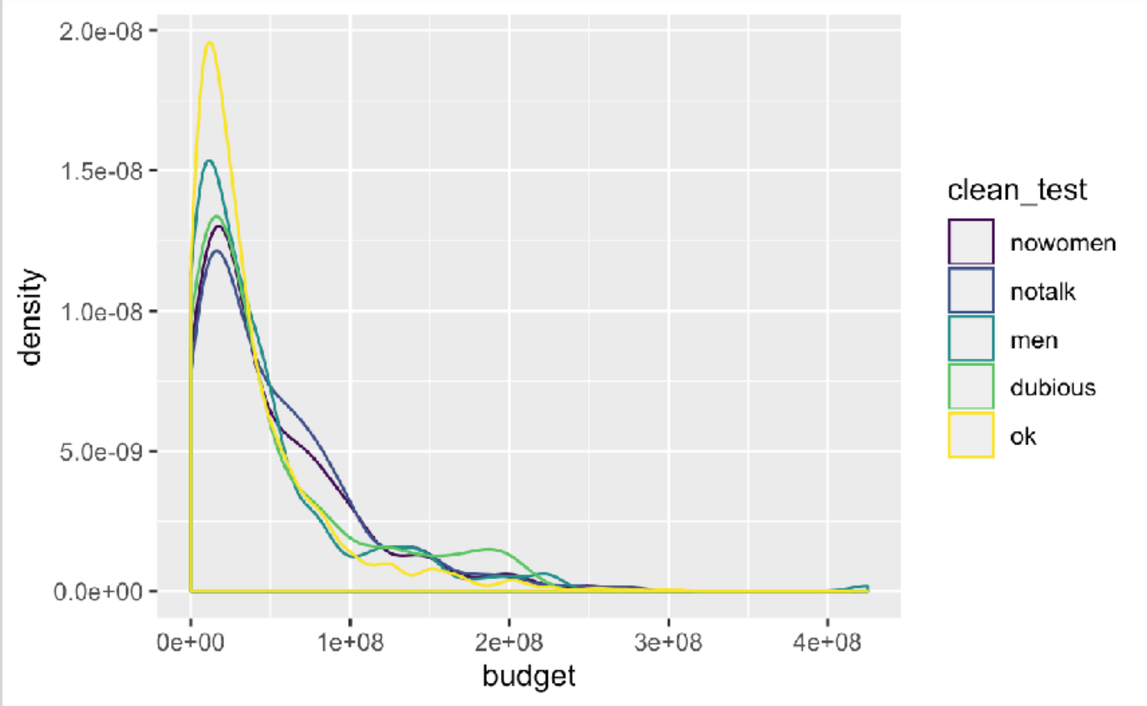
05 : 00



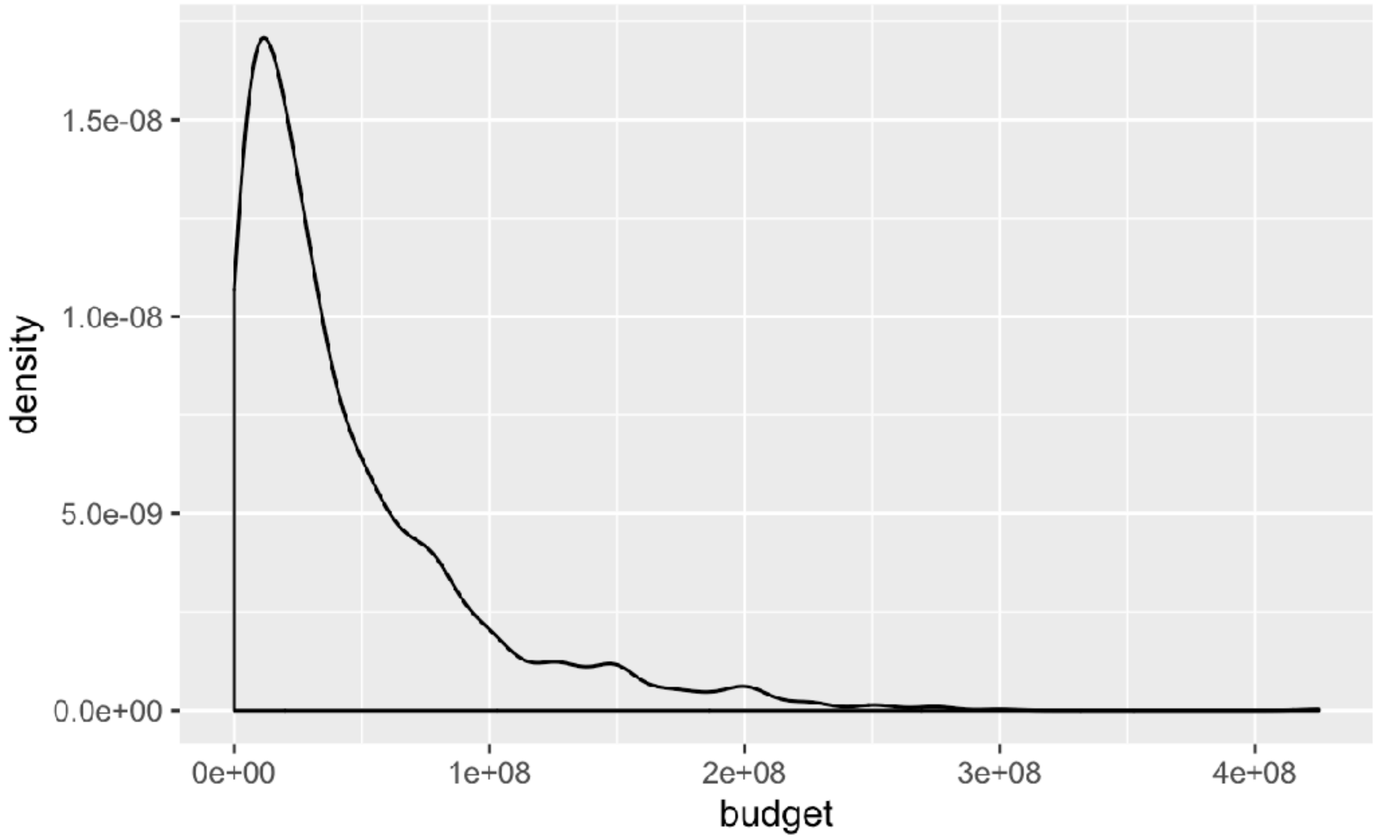

```
ggplot(data = bechdel) +
  geom_histogram(mapping = aes(x = budget))
```

Your Turn 5

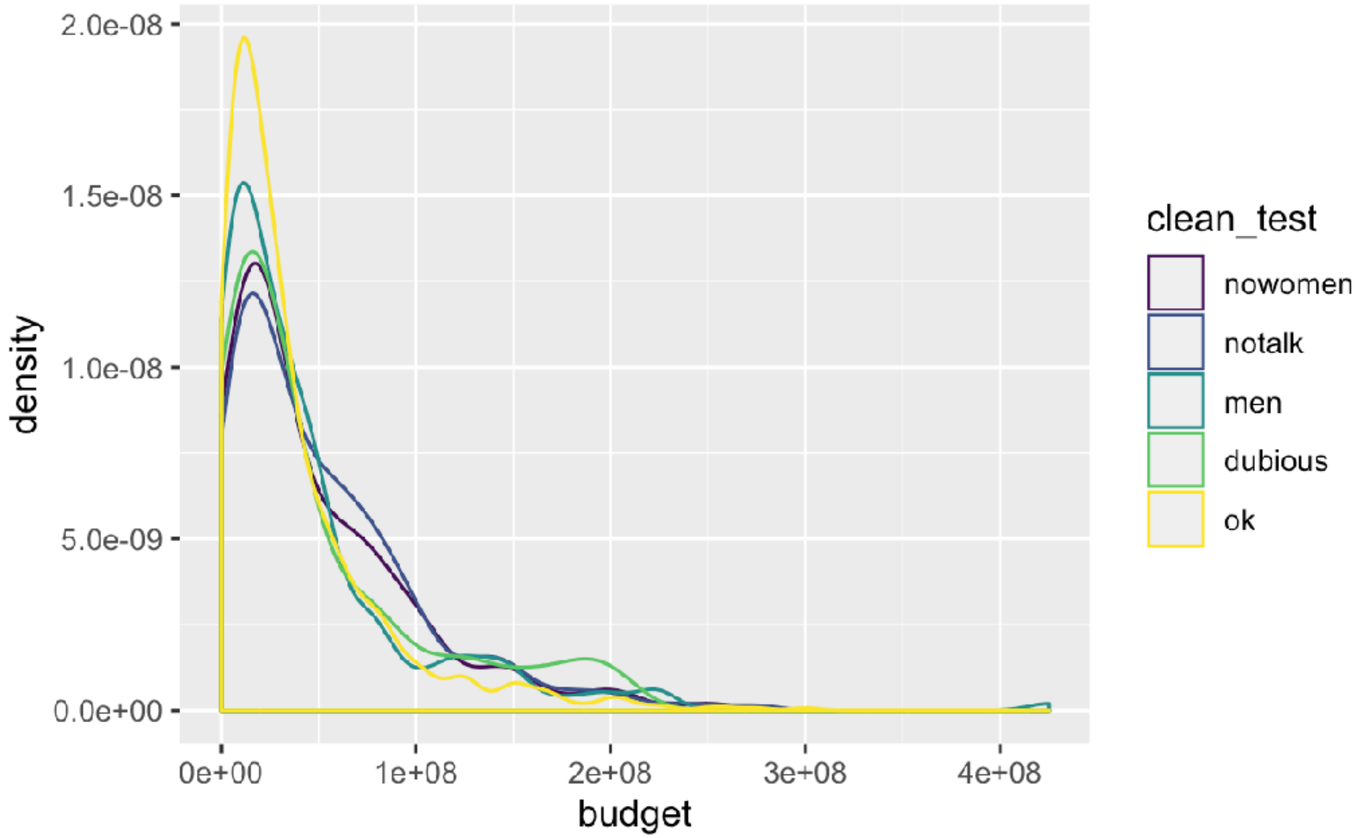
- Make the density plot of **budget** colored by **clean_test** shown below.



05 : 00



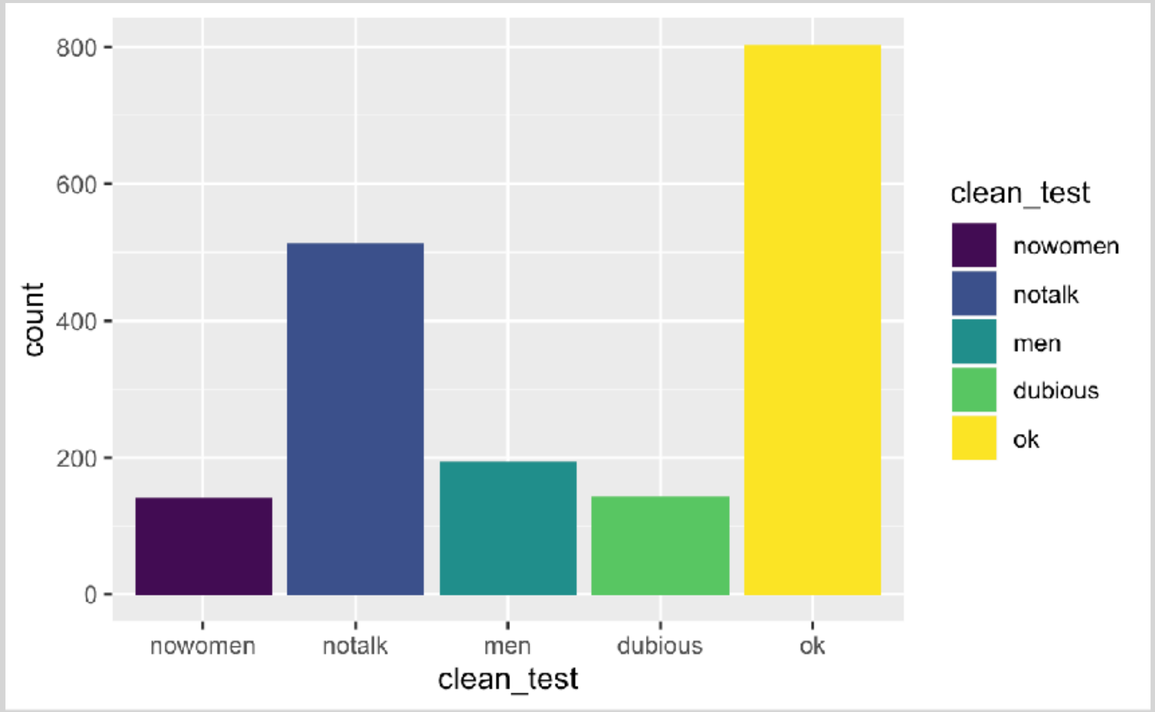

```
ggplot(data = bechdel) +
  geom_density(mapping = aes(x = budget))
```



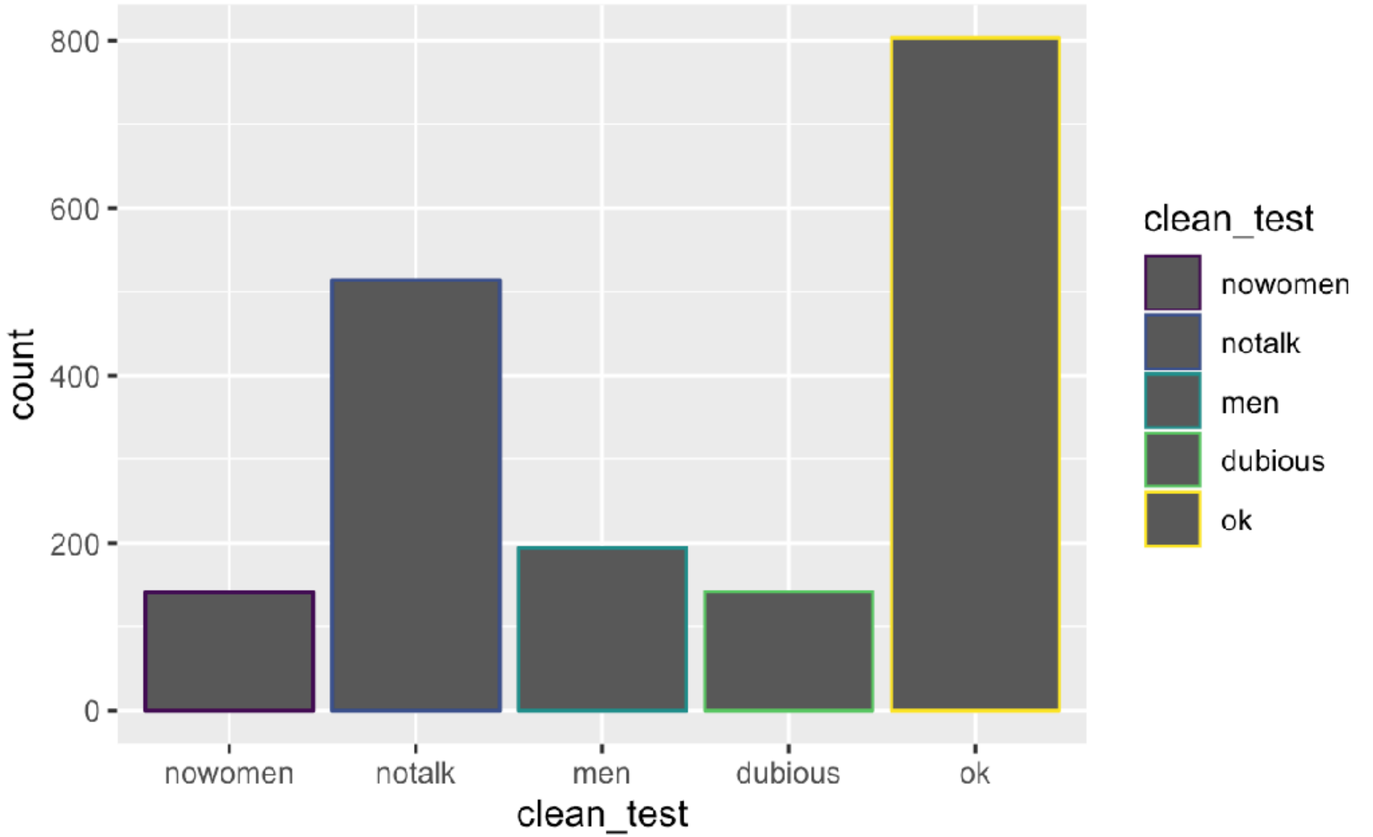

```
ggplot(data = bechdel) +
  geom_density(mapping = aes(x = budget, color = clean_test))
```

Your Turn 6

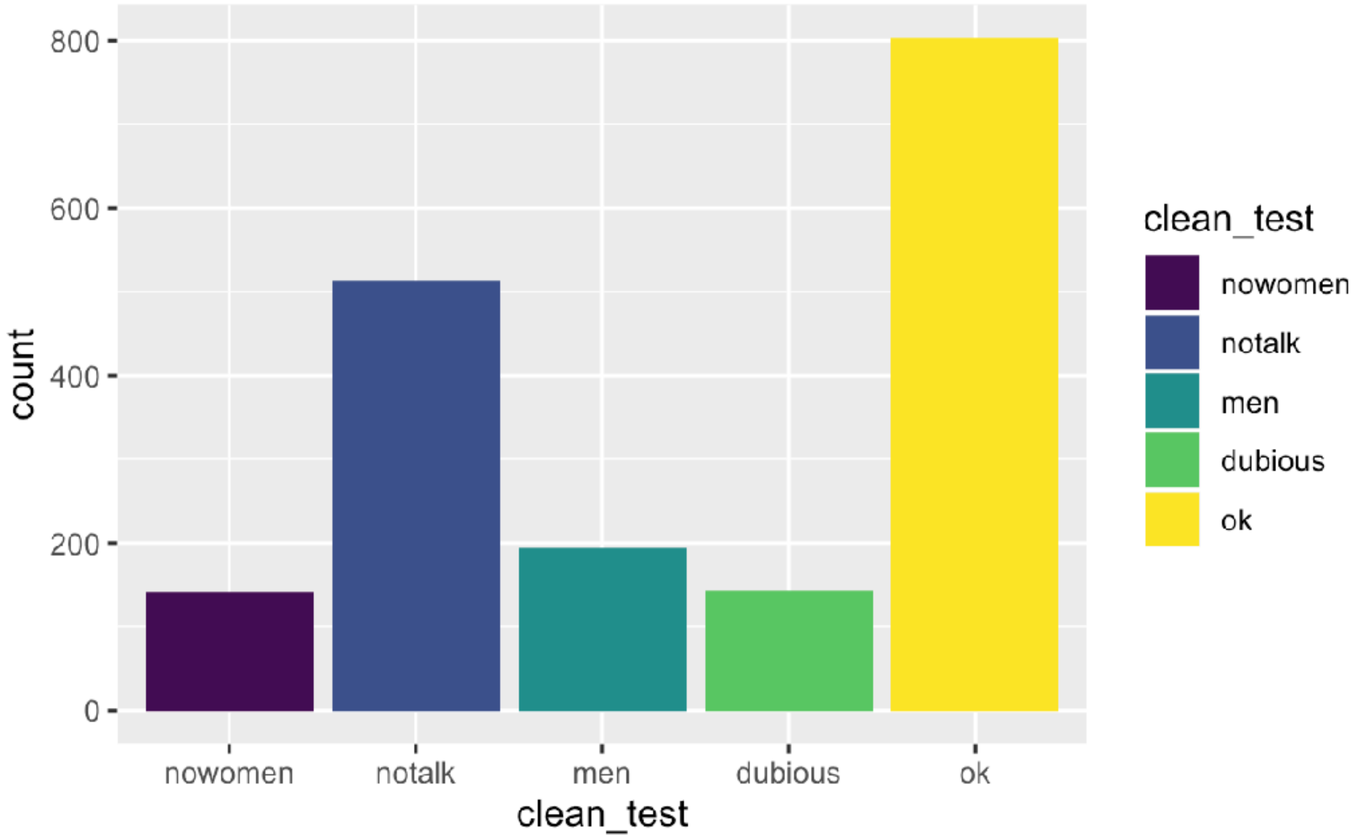
- Make the bar chart of **clean_test** colored by **clean_test** shown below.



05 : 00




```
ggplot(data = bechdel) +
  geom_bar(mapping = aes(x = clean_test, color = clean_test))
```

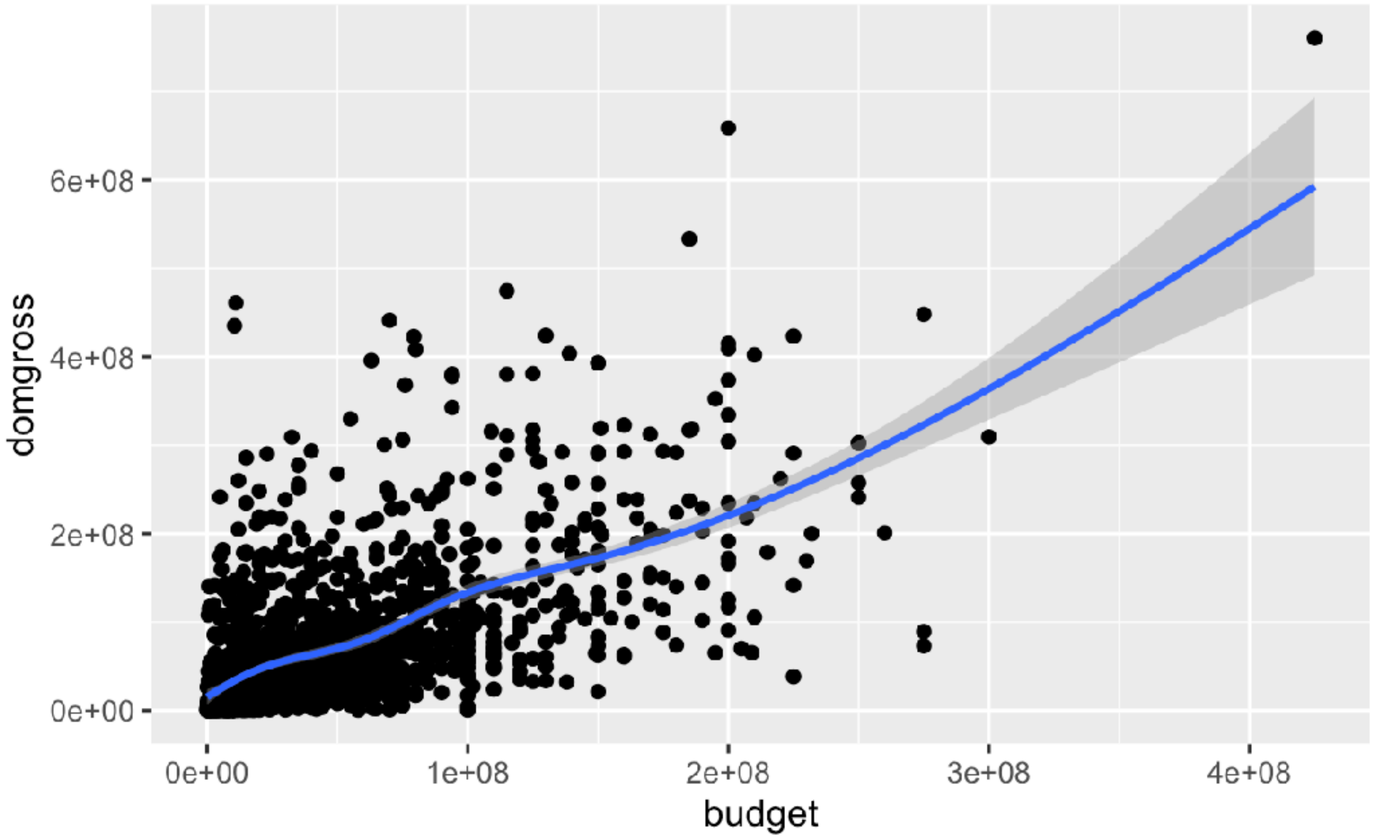



```
ggplot(data = bechdel) +
  geom_bar(mapping = aes(x = clean_test, fill = clean_test))
```

Your Turn 7

- Predict what this code will do.
- Then run it.

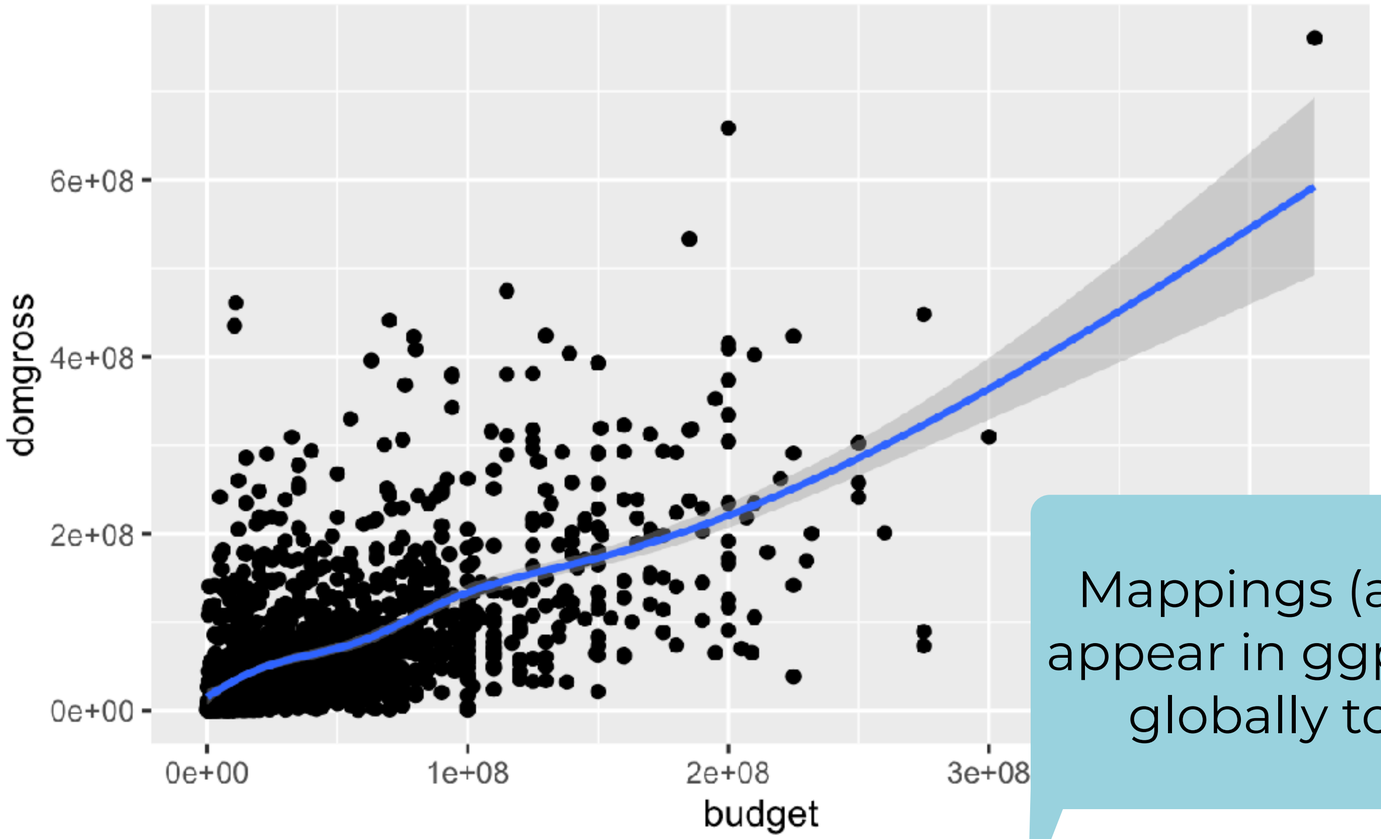
```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross)) +
  geom_smooth(mapping = aes(x = budget, y = domgross))
```



Each new geom adds a new layer

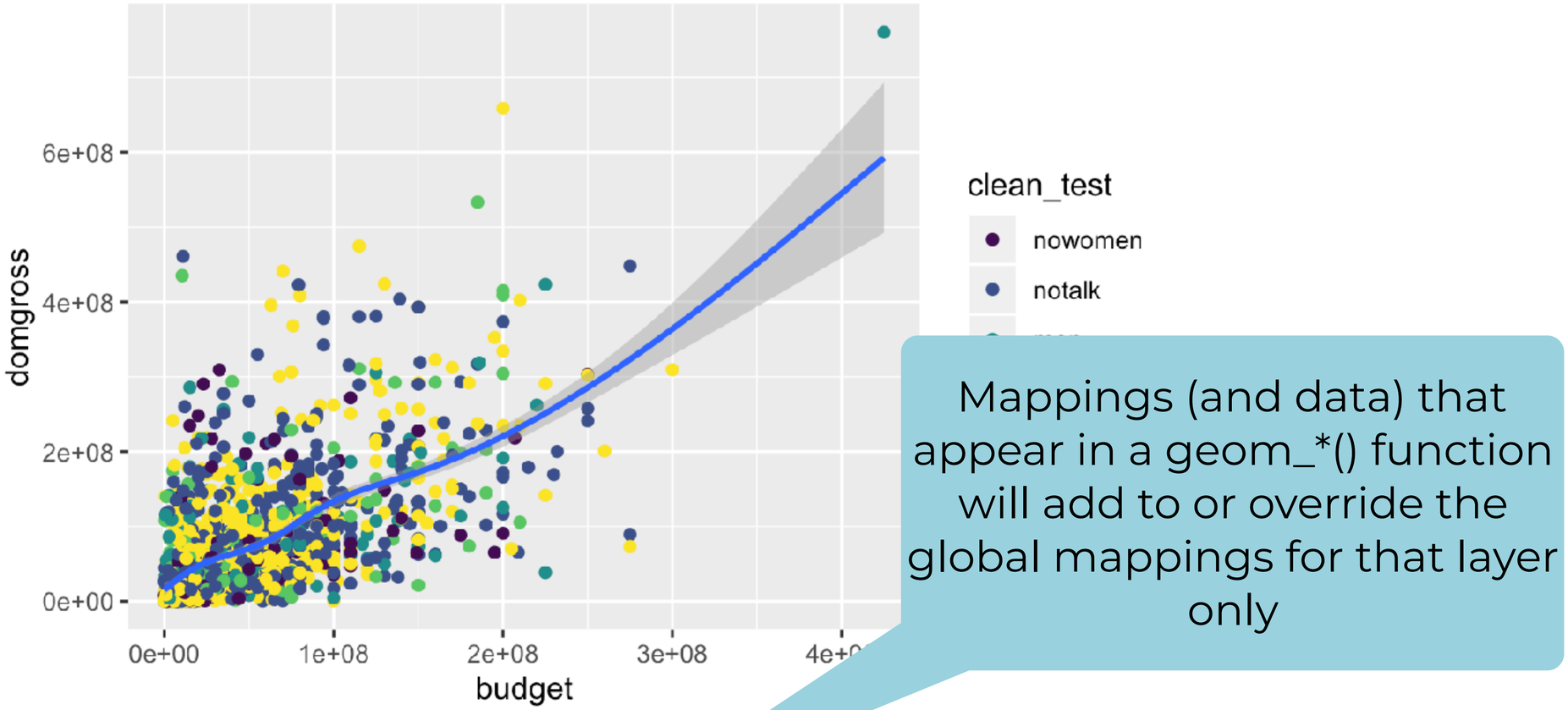
```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross)) +
  geom_smooth(mapping = aes(x = budget, y = domgross))
```

Global vs. Local



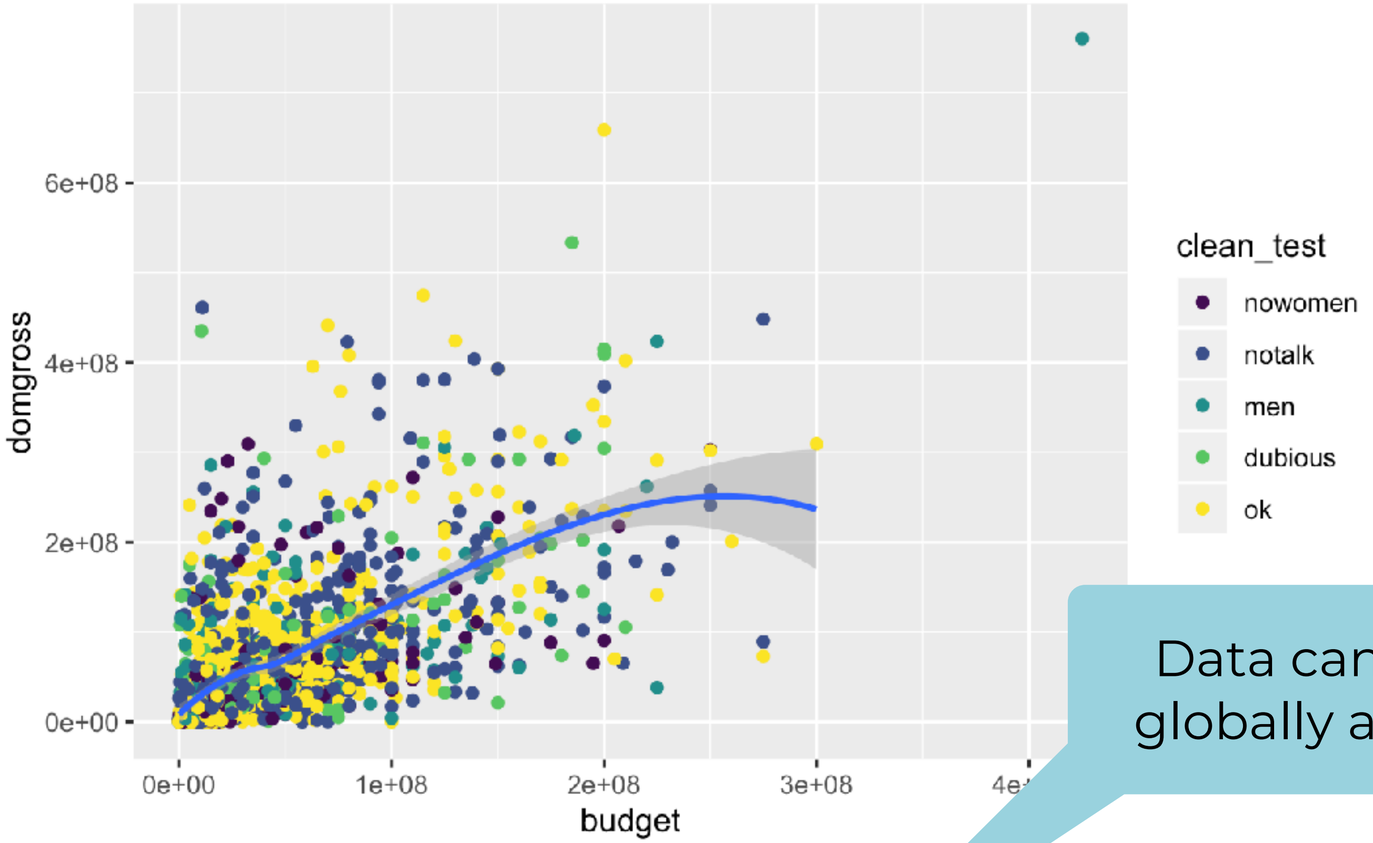
Mappings (and data) that appear in ggplot() will apply globally to every layer

```
ggplot(data = bechdel, mapping = aes(x = budget, y = domgross)) +
  geom_point() +
  geom_smooth()
```



Mappings (and data) that appear in a geom_*() function will add to or override the global mappings for that layer only

```
ggplot(data = bechdel, mapping = aes(x = budget, y = domgross)) +
  geom_point(mapping = aes(color = clean_test)) +
  geom_smooth()
```

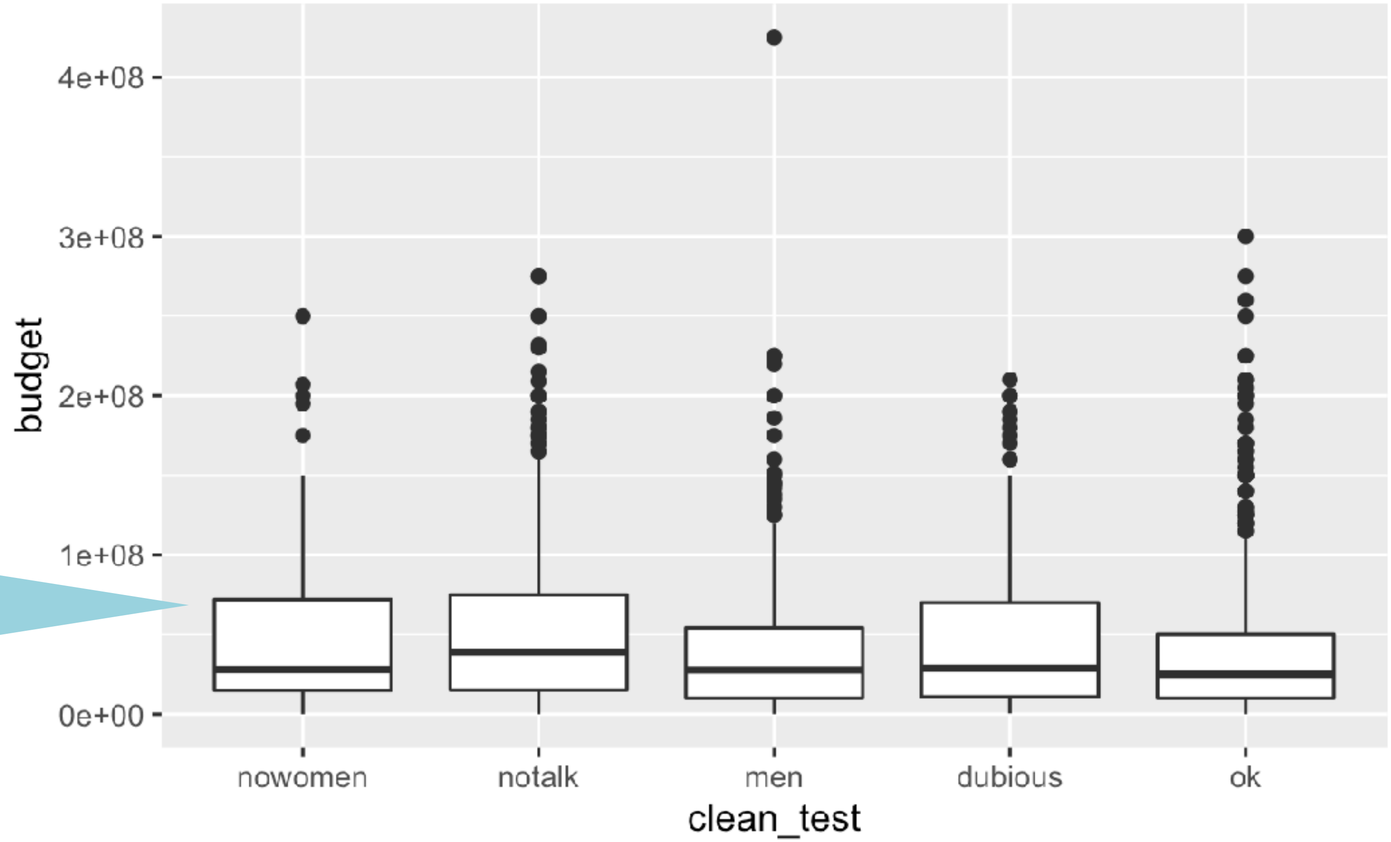


Data can also be set globally and/or locally

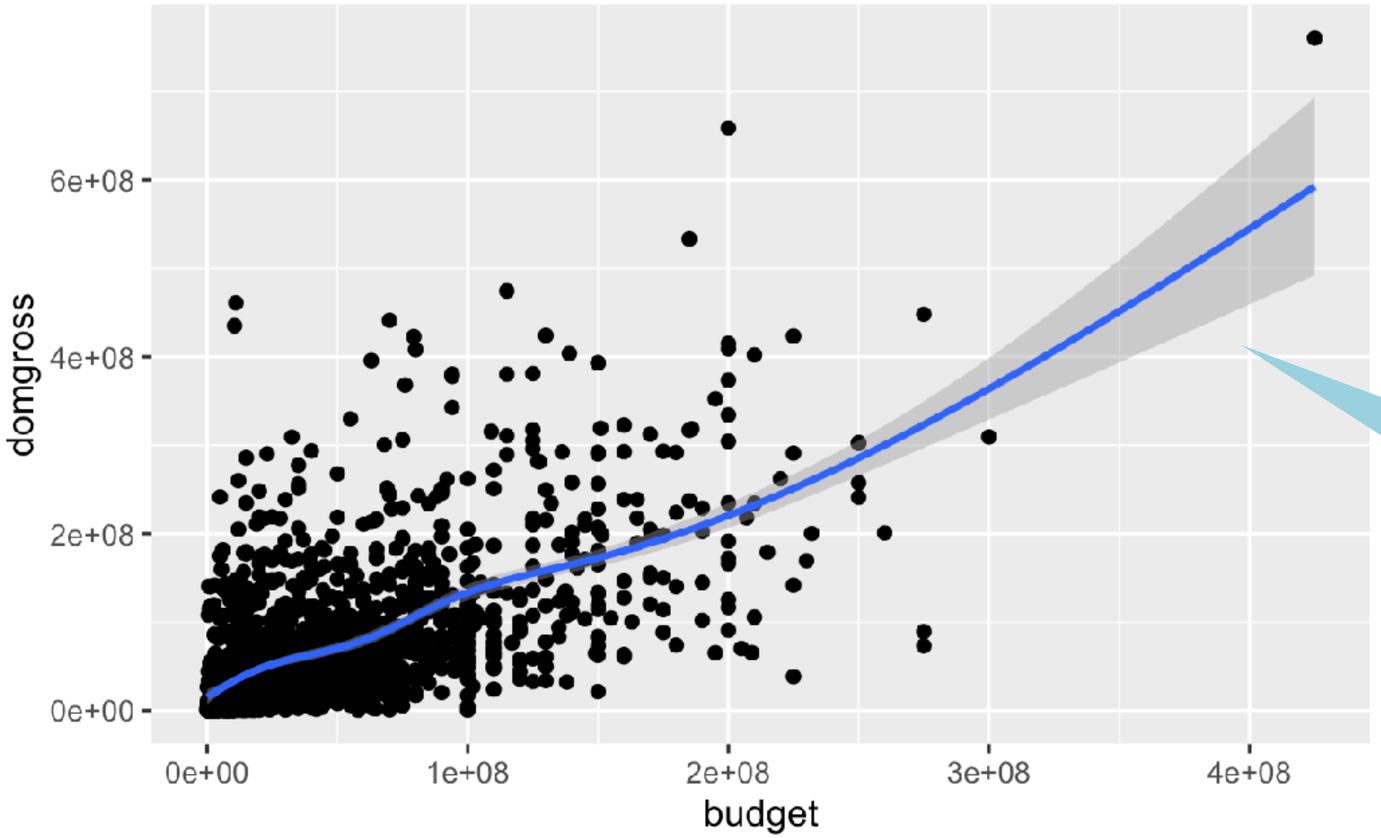
```
ggplot(data = bechdel, mapping = aes(x = budget, y = domgross)) +
  geom_point(mapping = aes(color = clean_test)) +
  geom_smooth(data = filter(bechdel, clean_test == "ok"))
```

Stats

Where do these values come from?

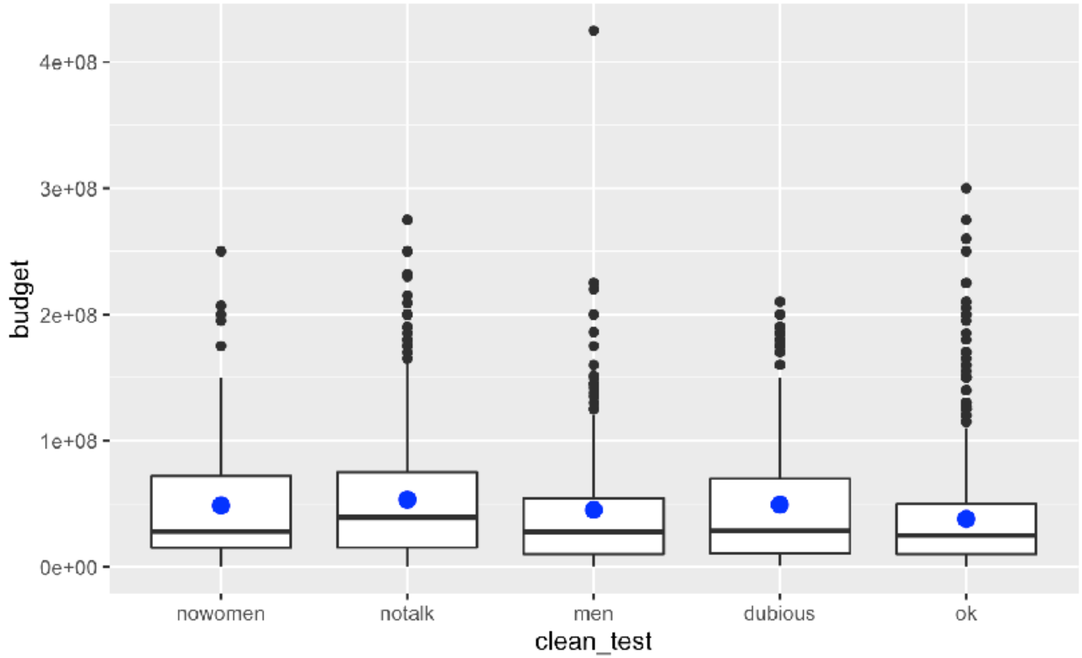



```
ggplot(data = bechdel) +
  geom_boxplot(mapping = aes(x = clean_test, y = budget))
```



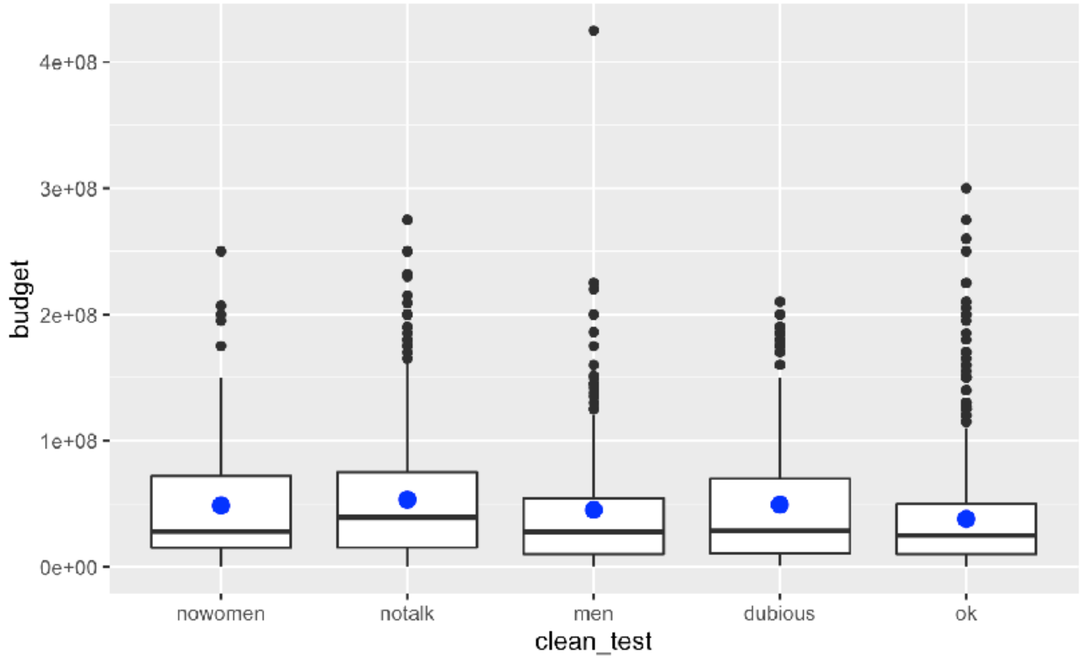

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross)) +
  geom_smooth(mapping = aes(x = budget, y = domgross))
```

Stats as layers



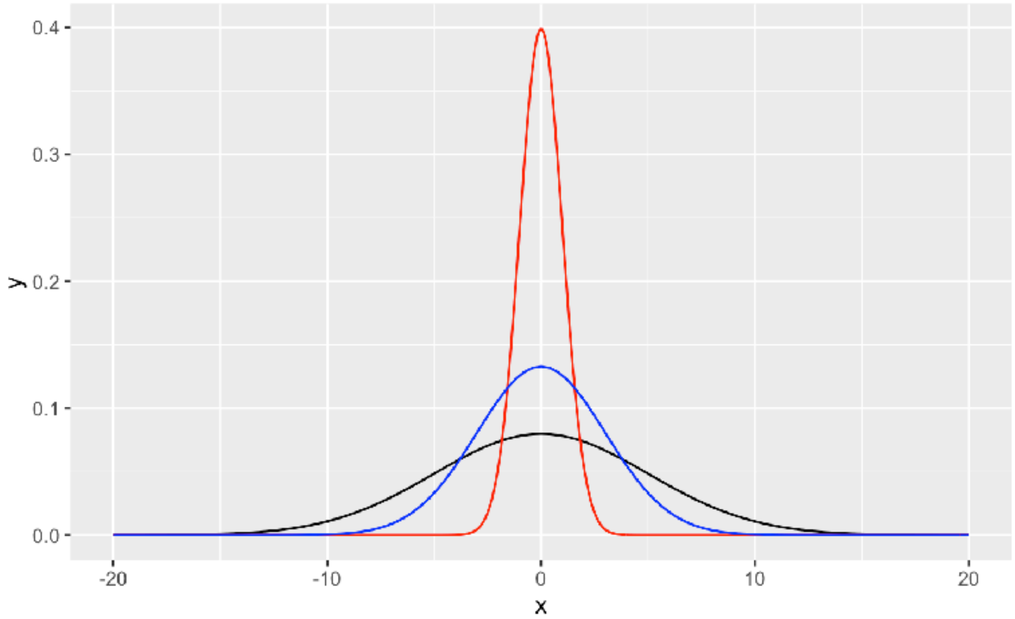

```
ggplot(data = bechdel, mapping = aes(x = clean_test, y = budget)) +
  geom_boxplot() +
  stat_summary(geom = "point", y.fun = "mean", color = "blue", size = 3)
```

Stats as layers



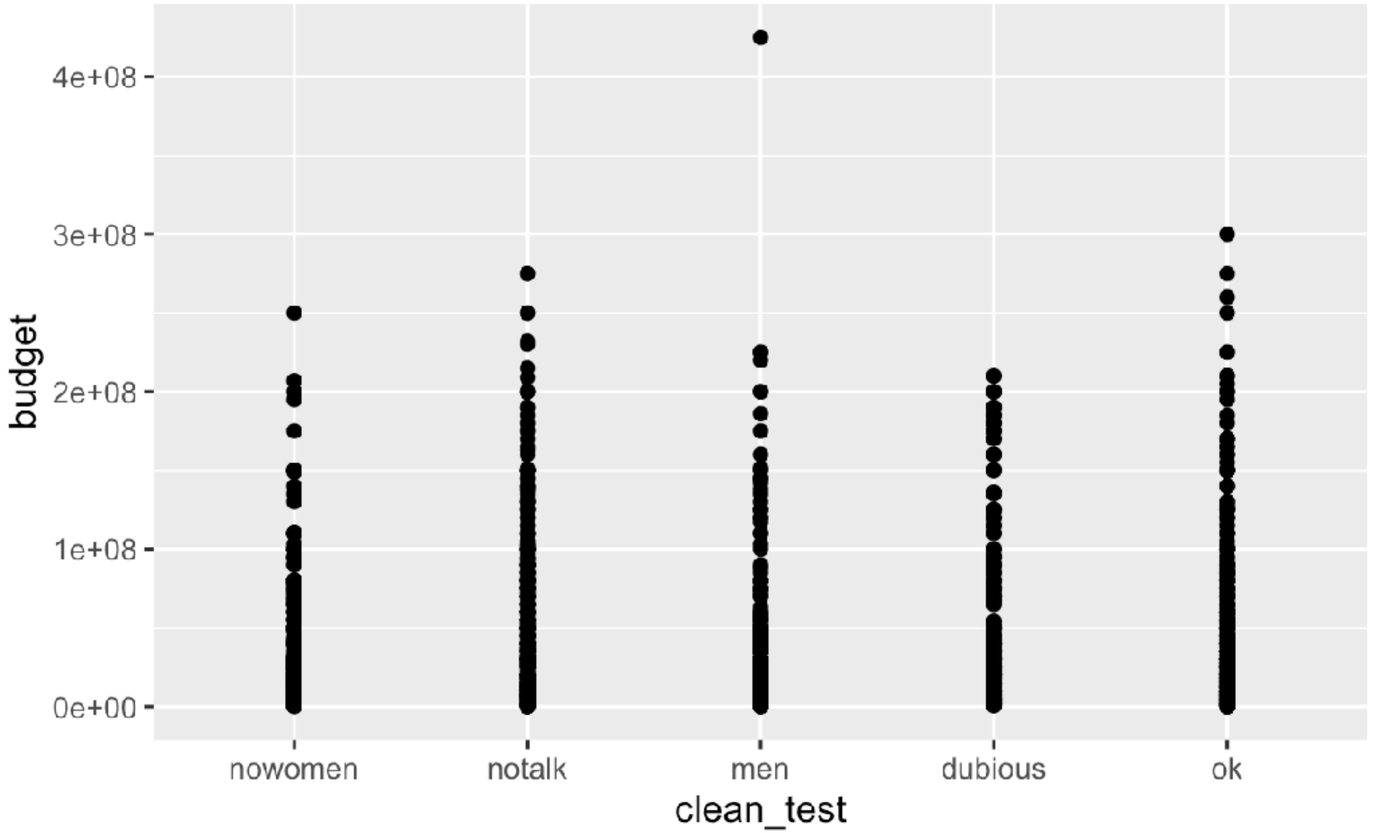

```
ggplot(data = bechdel, mapping = aes(x = clean_test, y = budget)) +
  geom_boxplot() +
  geom_point(stat = "summary", y.fun = "mean", color = "blue", size = 3)
```

Distributions

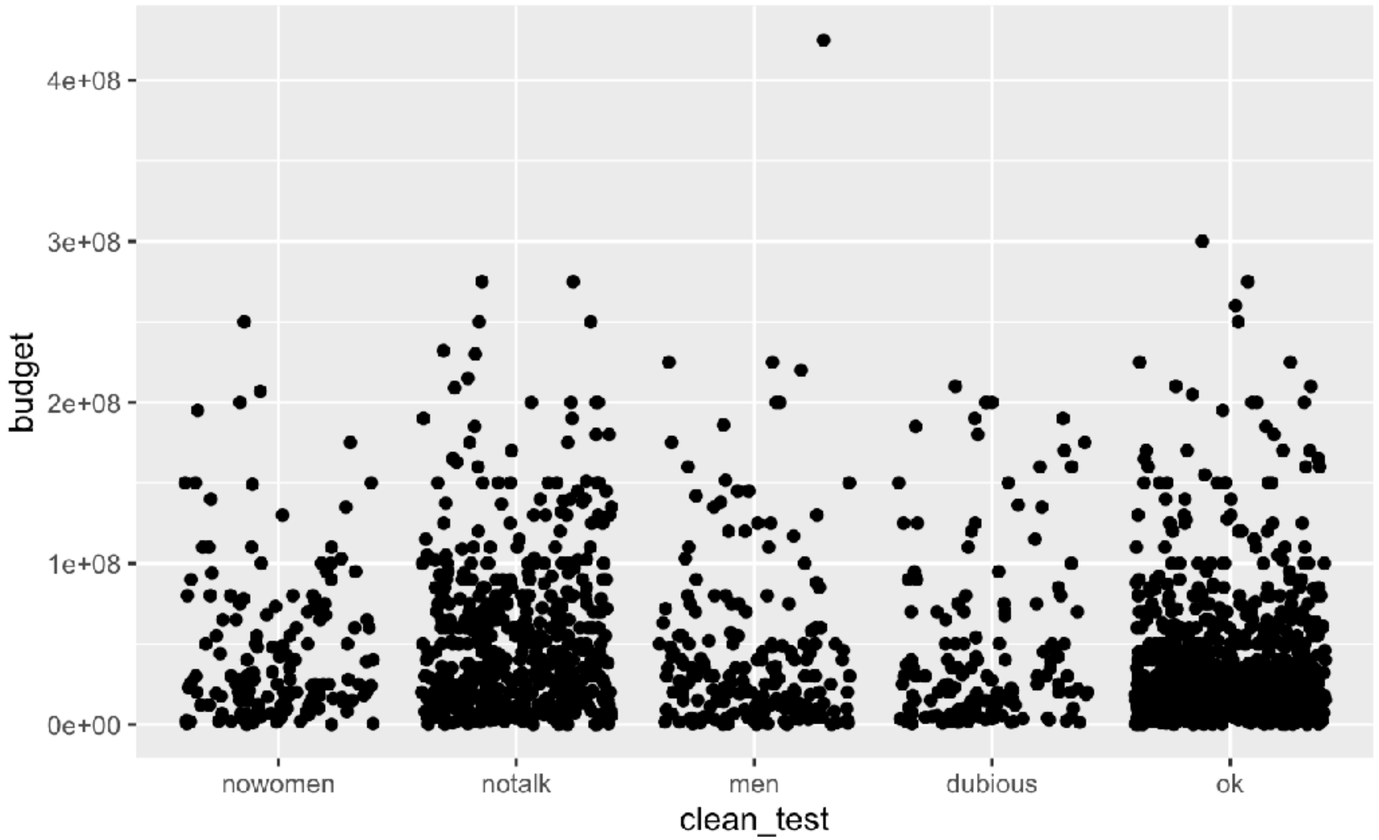



```
ggplot(data = tibble(x = c(-20, 20)), aes(x = x)) +
  stat_function(fun = dnorm, args = list(mean = 0, sd = 5), color = "black") +
  stat_function(fun = dnorm, args = list(mean = 0, sd = 1), color = "red") +
  stat_function(fun = dnorm, args = list(mean = 0, sd = 3), color = "blue")
```

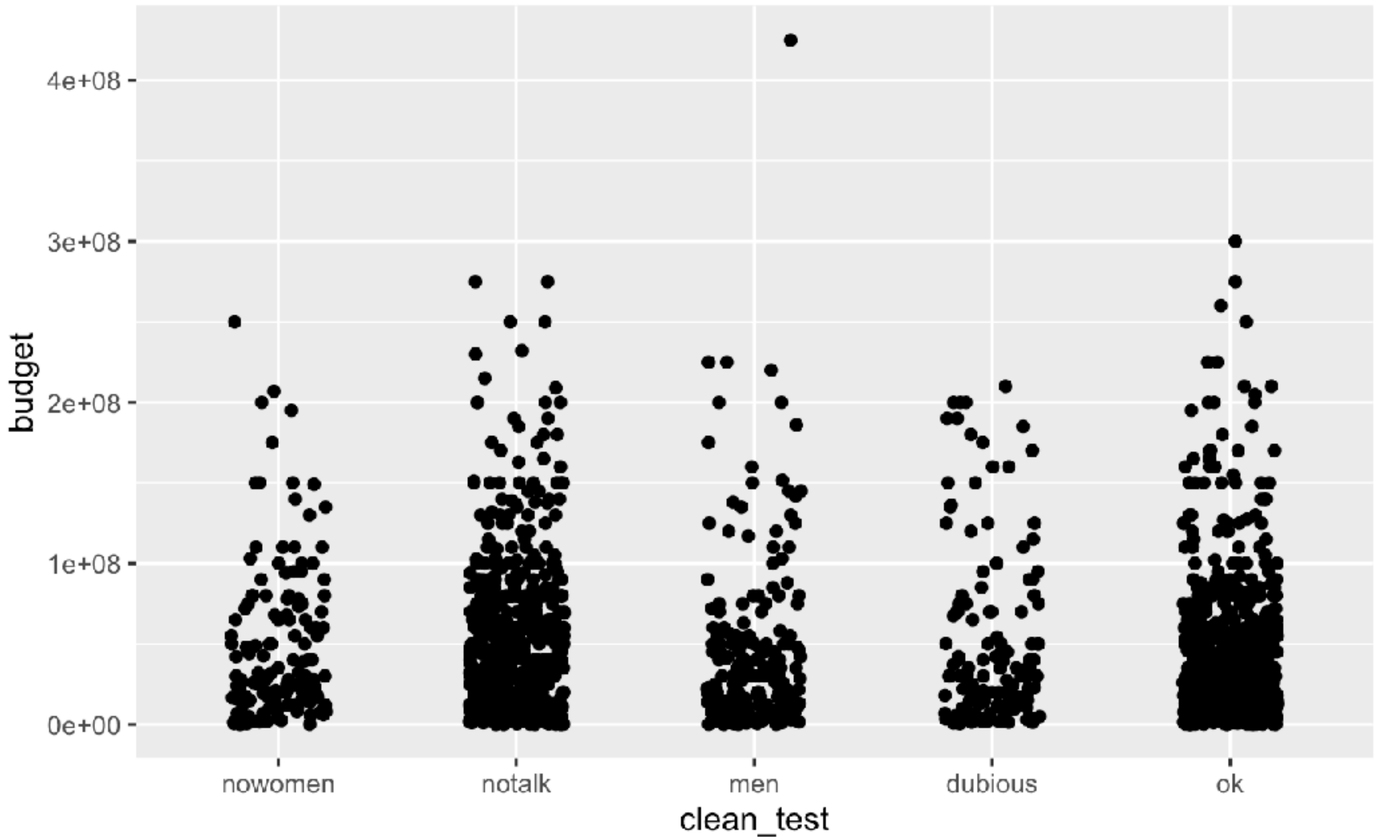
Position




```
ggplot(bechdel, aes(x = clean_test, y = budget)) +
  geom_point()
```



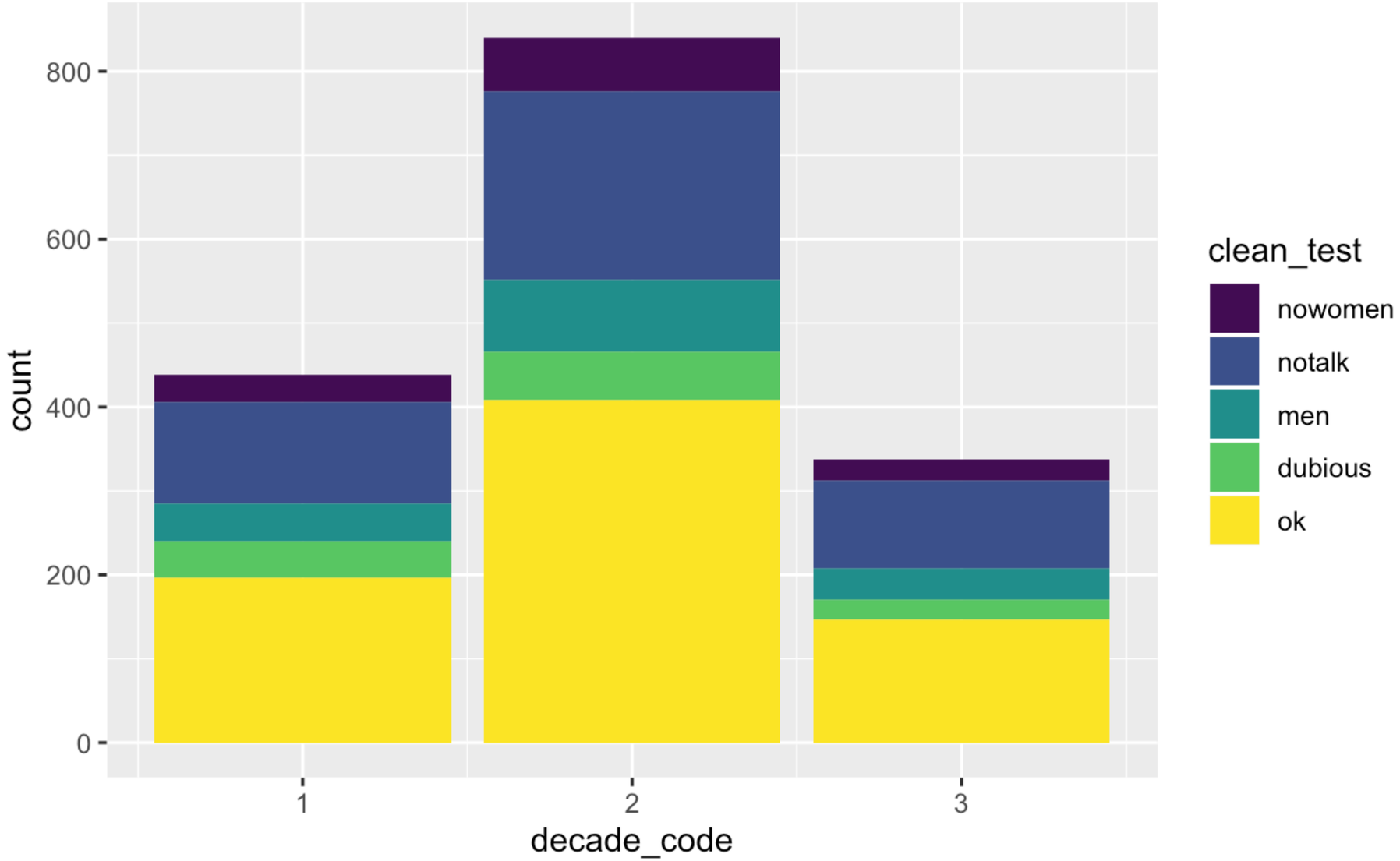

```
ggplot(bechdel, aes(x = clean_test, y = budget)) +
  geom_point(position = "jitter")
```




```
ggplot(bechdel, aes(x = clean_test, y = budget)) +
  geom_point(position = position_jitter(width = 0.2, height = 0))
```

Positions

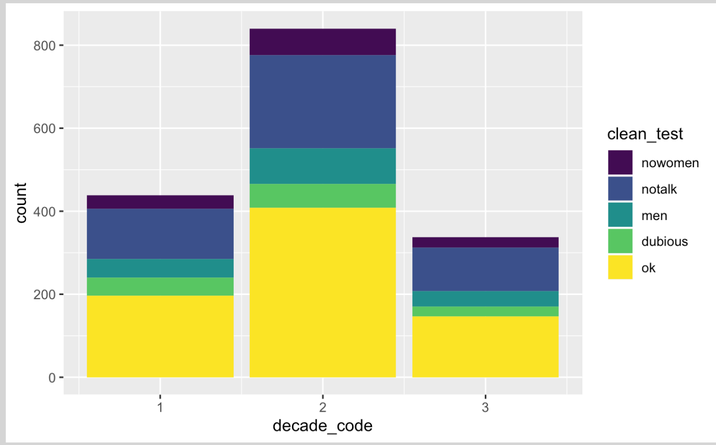
- position_identity()
- position_jitter()
- position_dodge()
- position_fill()
- And more...


800
600
400
200
0
count
1
2
3
decade_code
clean_test
nowomen
notalk
men
dubious
ok

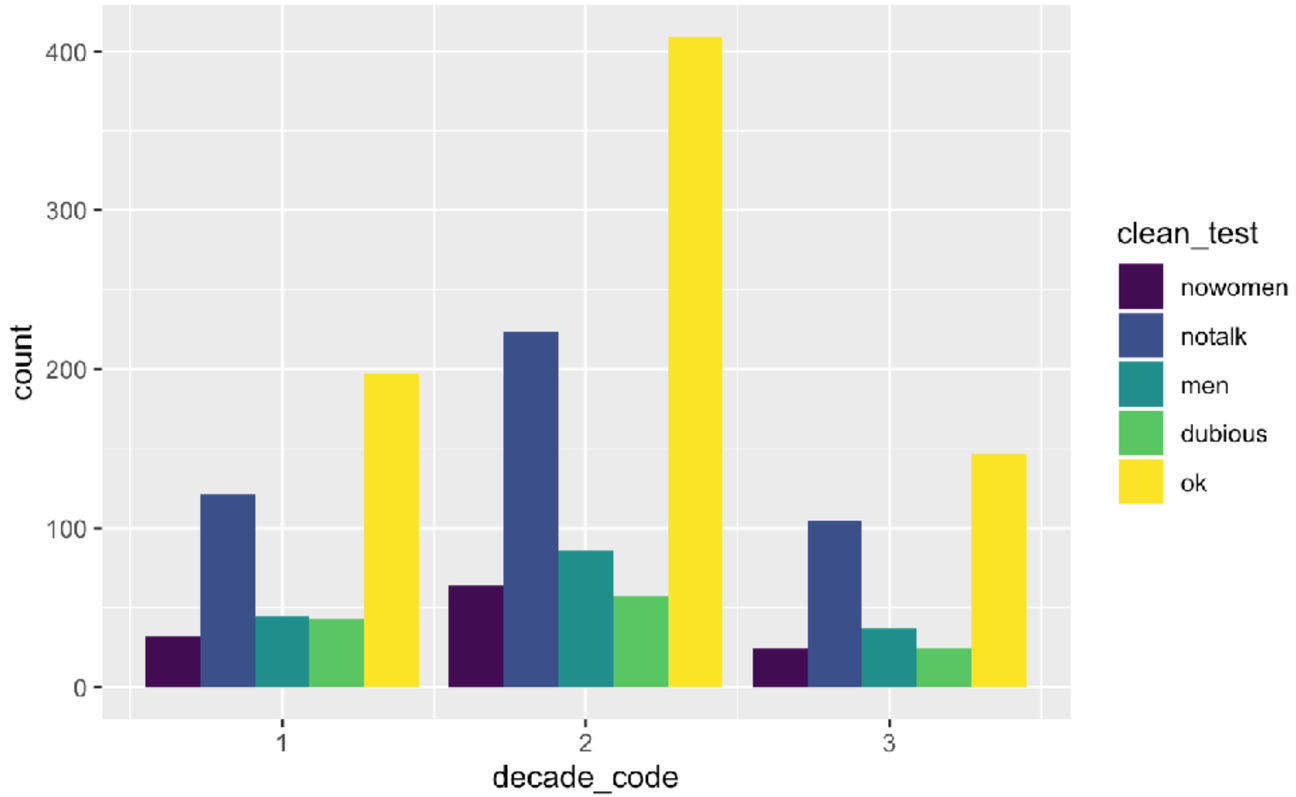
Your Turn 8

- Add a position adjustment to this plot to compare the frequency of test results across decades.

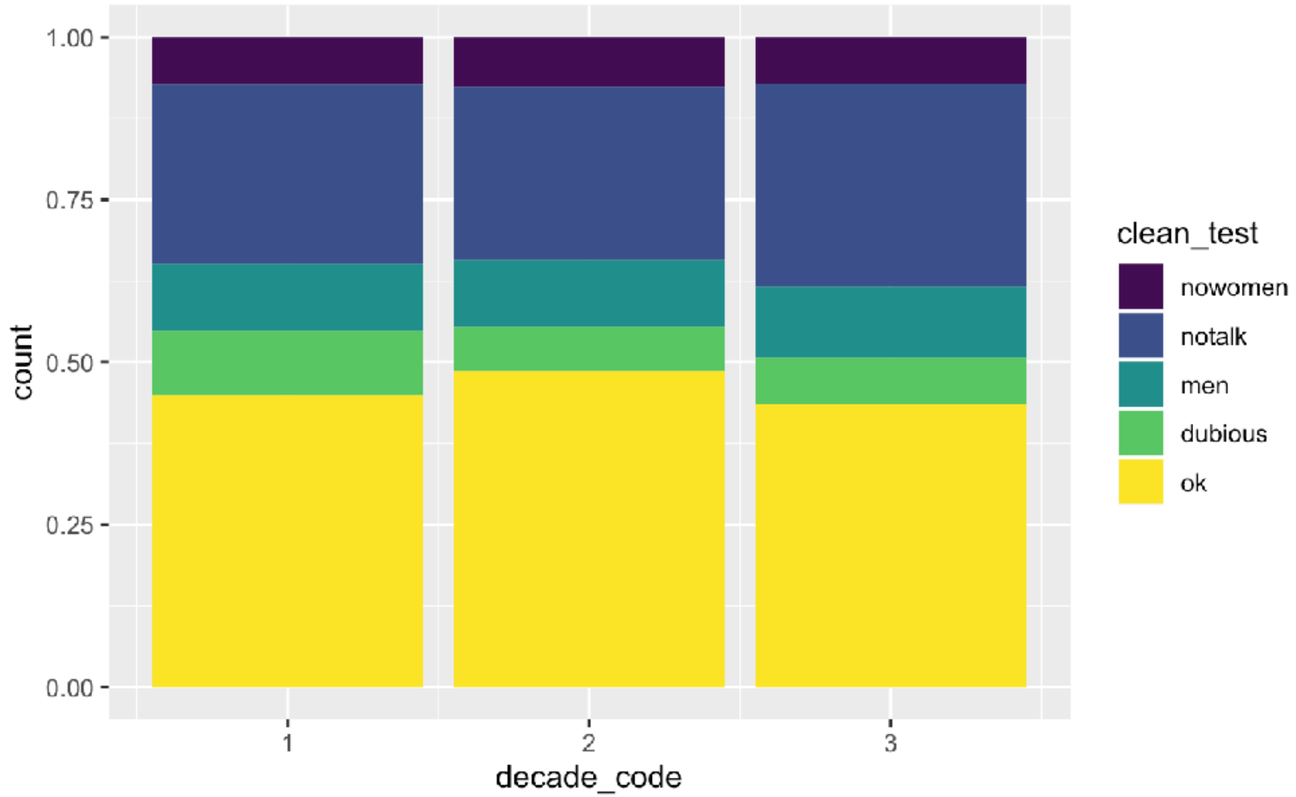
```
ggplot(data = bechdel, mapping = aes(x = decade_code)) +
  geom_bar(mapping = aes(fill = clean_test))
```



05 : 00

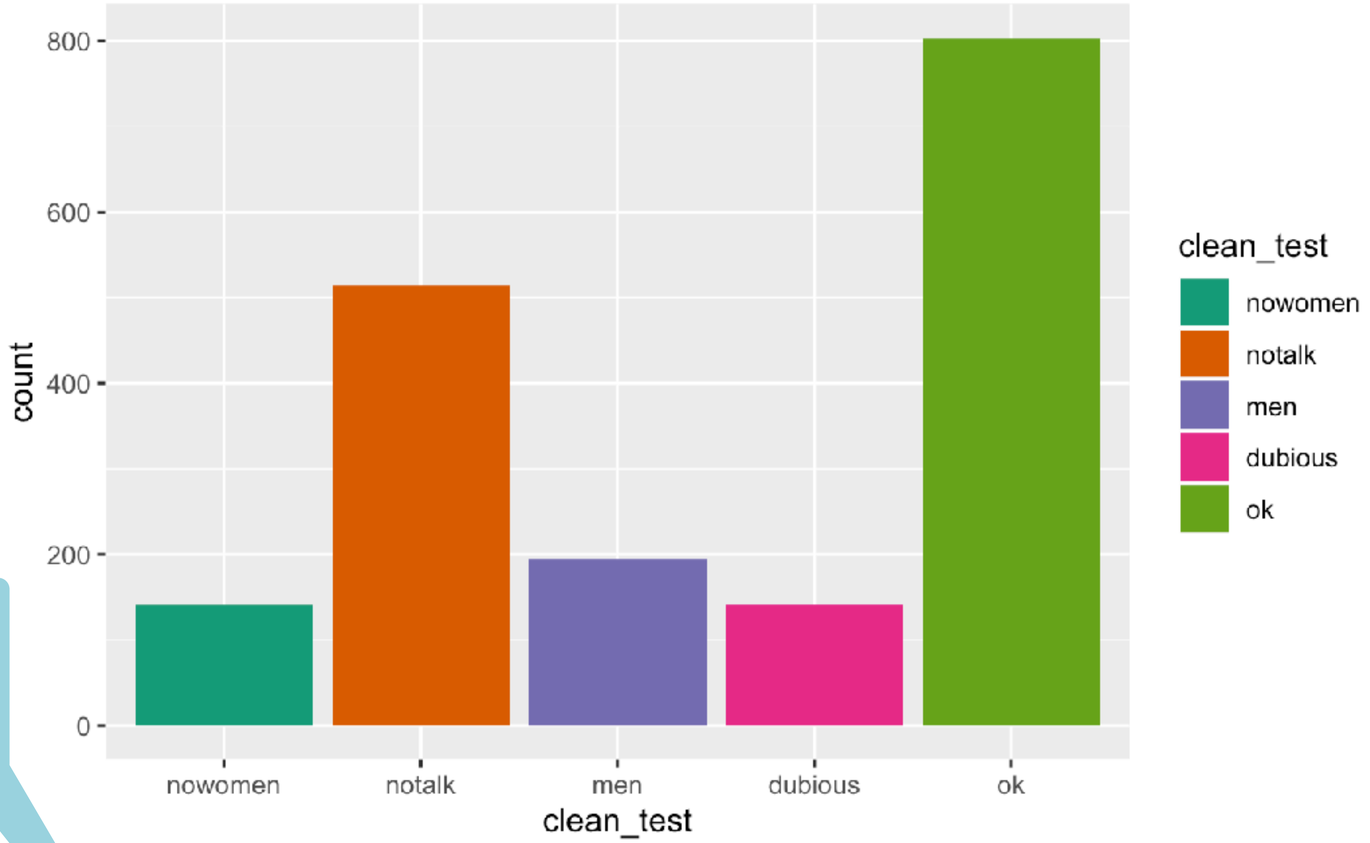



```
ggplot(bechdel, aes(x = decade_code)) +
  geom_bar(aes(fill = clean_test), position = "dodge")
```




```
ggplot(bechdel, aes(x = decade_code)) +
  geom_bar(aes(fill = clean_test), position = "fill")
```

Scales



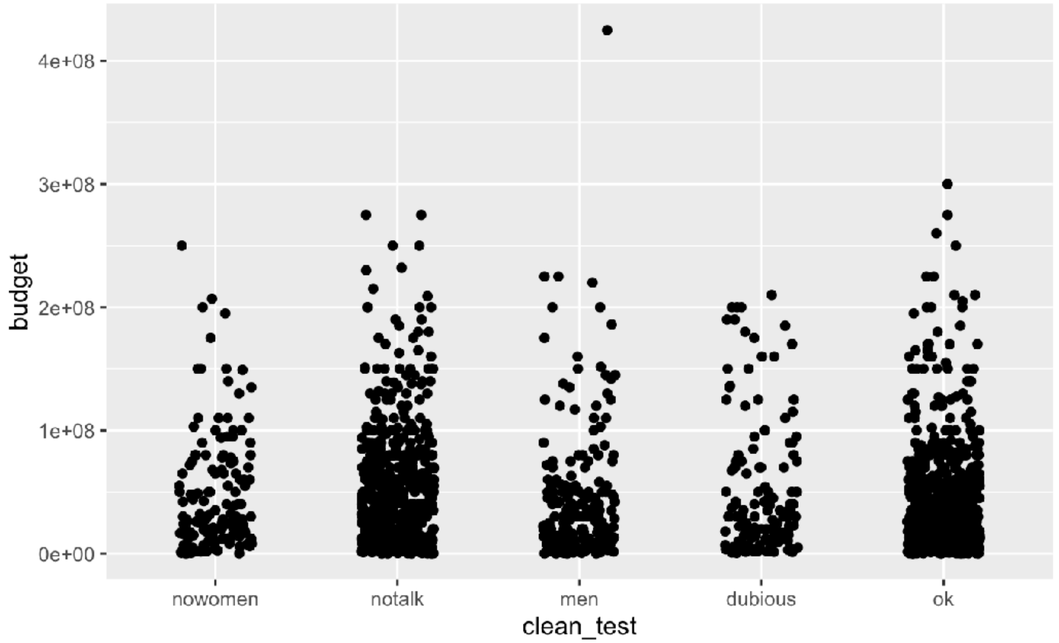
colorbrewer2.org

```
ggplot(data = bechdel) +
  geom_bar(mapping = aes(x = clean_test, fill = clean_test)) +
  scale_fill_brewer(palette = "Dark2")
```

Aesthetic scales

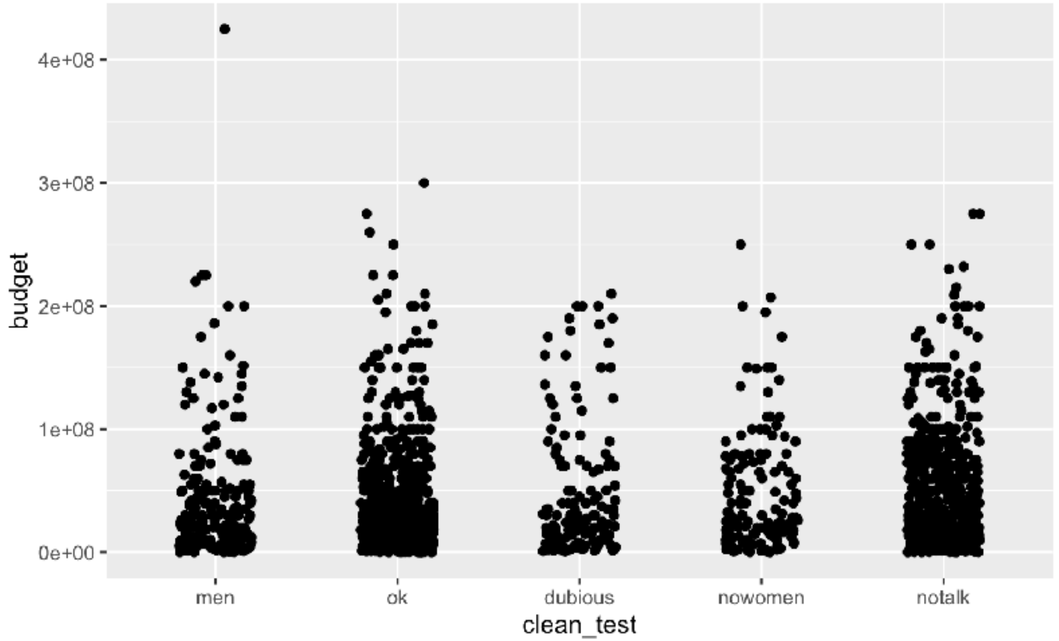
- scale_*_continuous()
- scale_*_discrete()
- scale_*_ordinal()
- scale_{color/fill}_brewer()
- scale_{color/fill}_distiller()
- scale_{color/fill}_gradient()

Coordinate scales



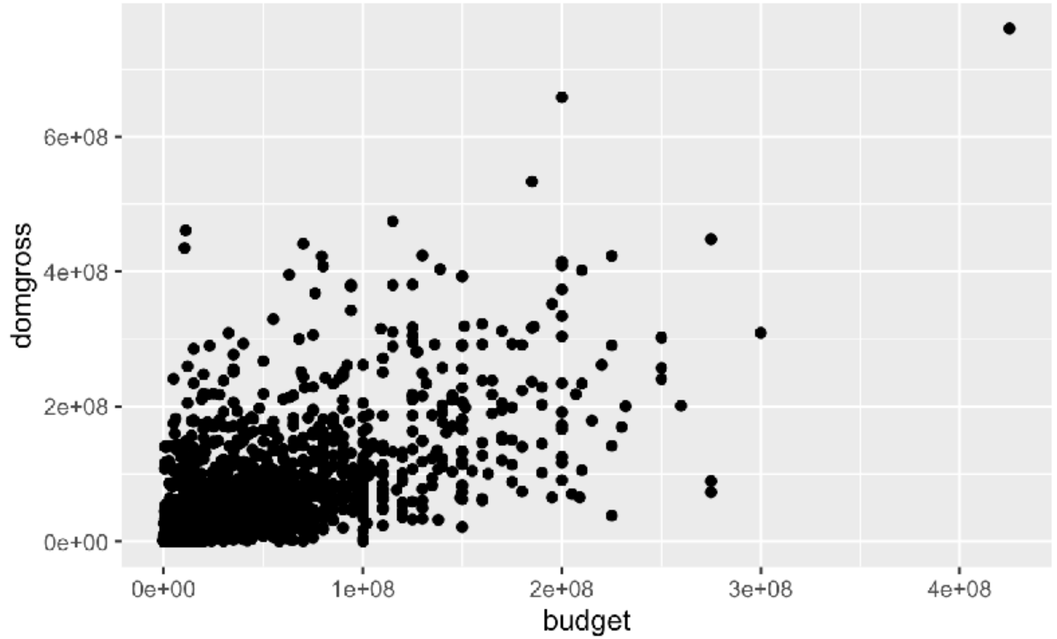

```
ggplot(bechdel, aes(x = clean_test, y = budget)) +
  geom_point(position = position_jitter(width = 0.2, height = 0))
```

Coordinate scales



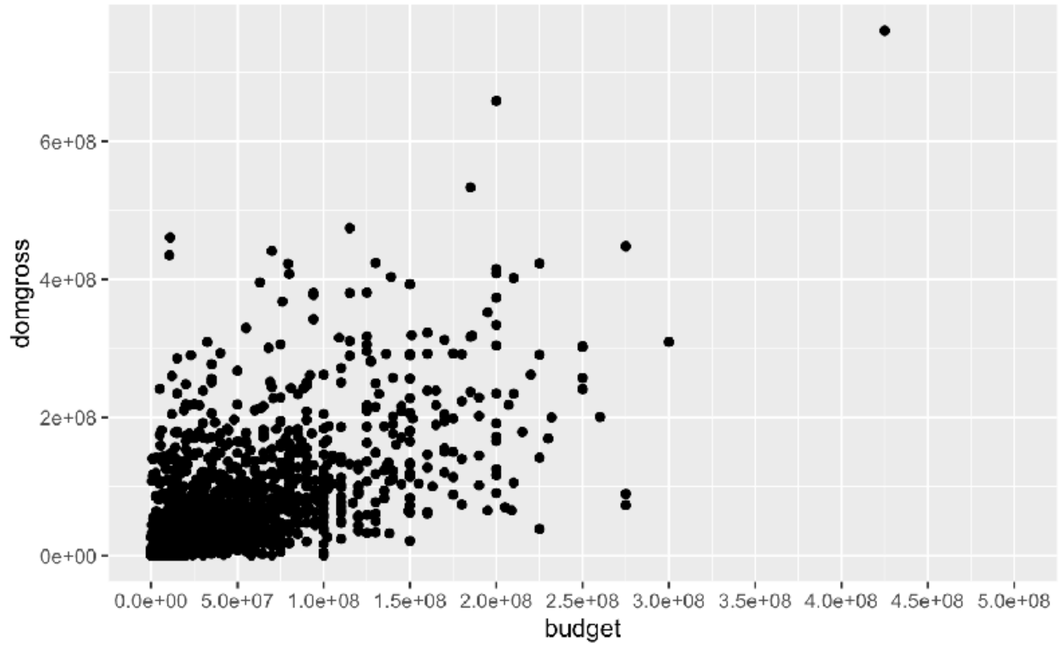

```
ggplot(bechdel, aes(x = clean_test, y = budget)) +
  geom_point(position = position_jitter(width = 0.2, height = 0)) +
  scale_x_discrete(limits = c("men", "ok", "dubious", "nowomen", "notalk"))
```

Coordinate scales



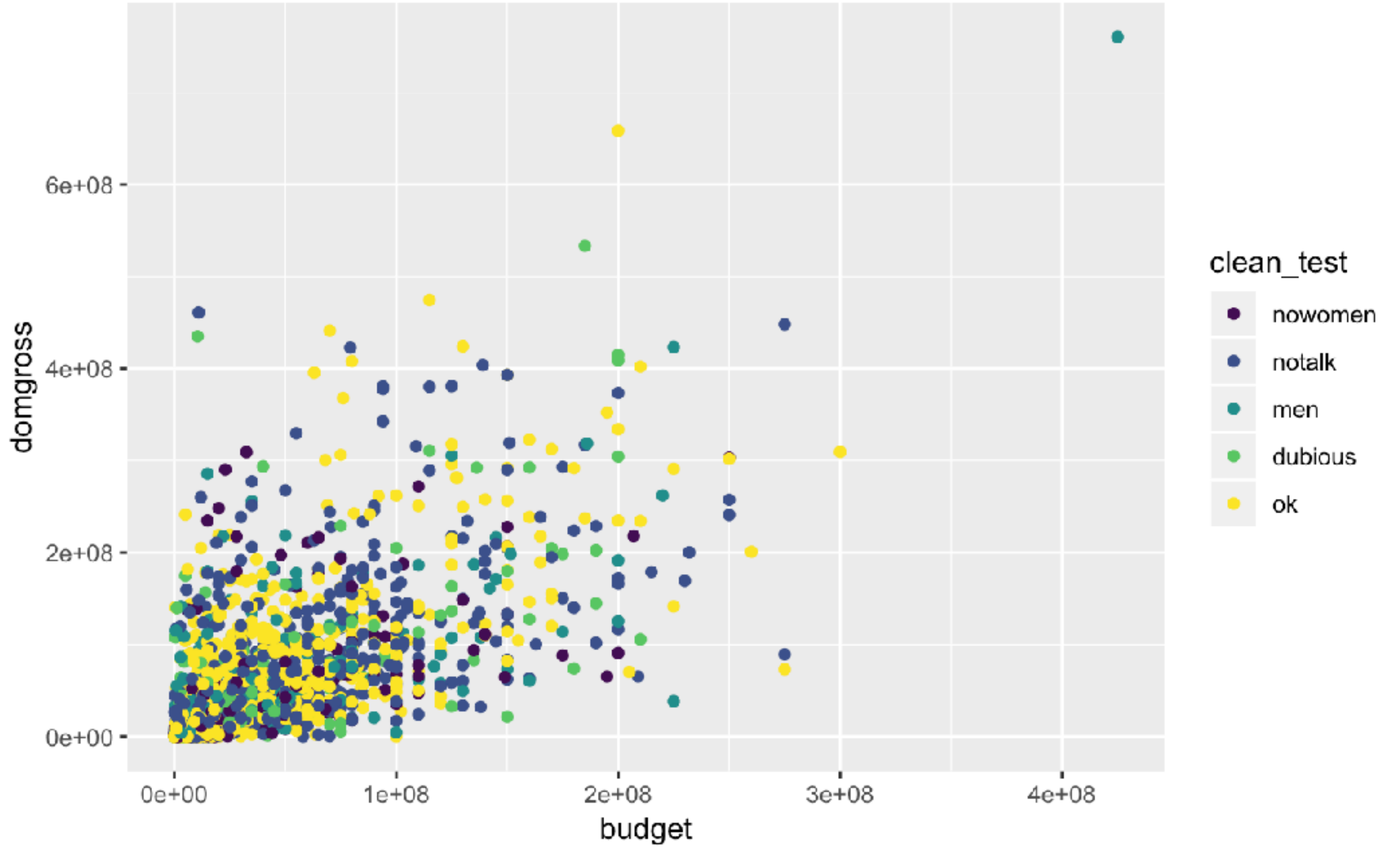

```
ggplot(bechdel, mapping = aes(x = budget, y = domgross)) +
  geom_point()
```

Coordinate scales

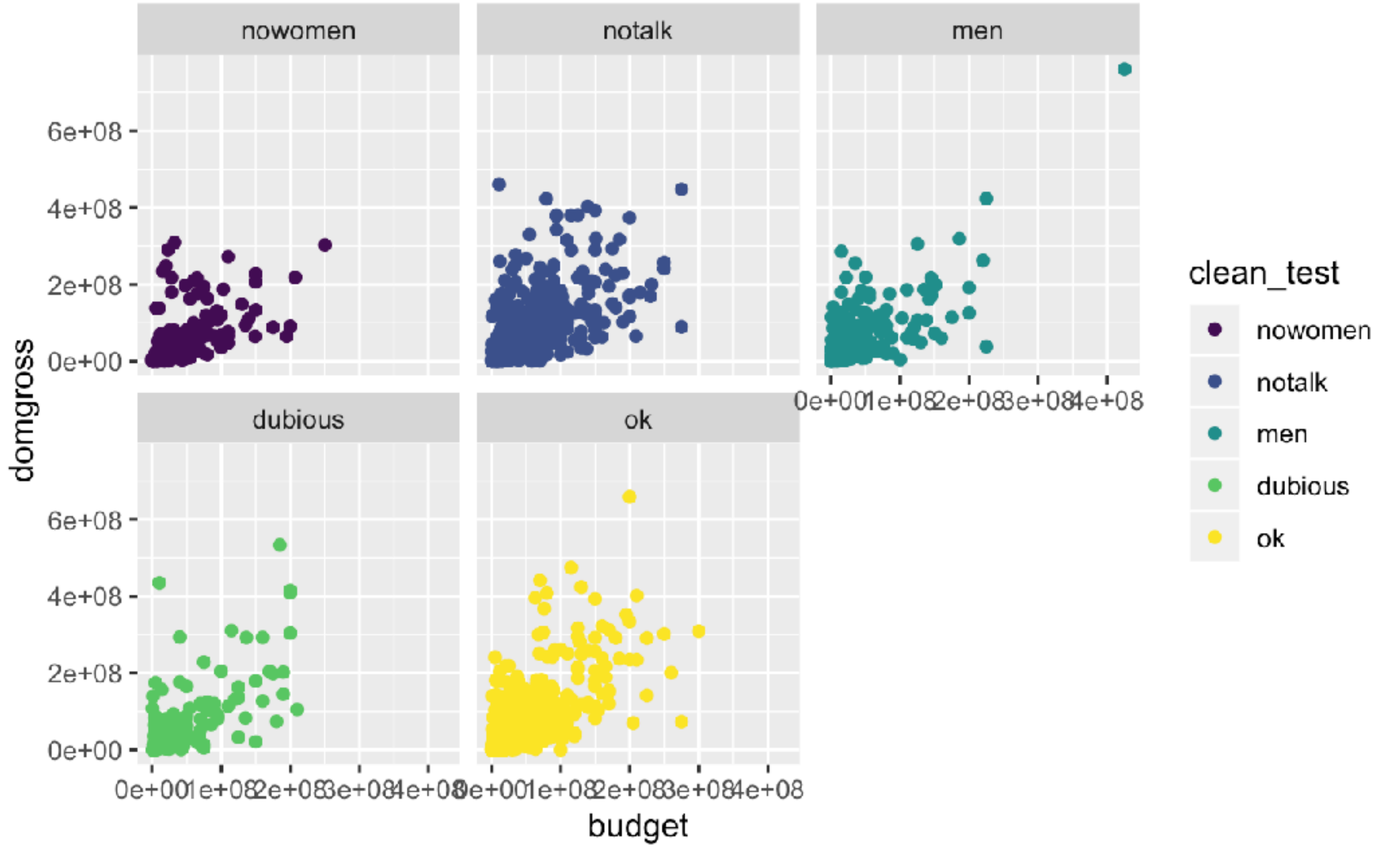



```
ggplot(bechdel, mapping = aes(x = budget, y = domgross)) +
  geom_point() +
  scale_x_continuous(limits = c(0, 5e+08), breaks = seq(0, 5e+08, 5e+07))
```

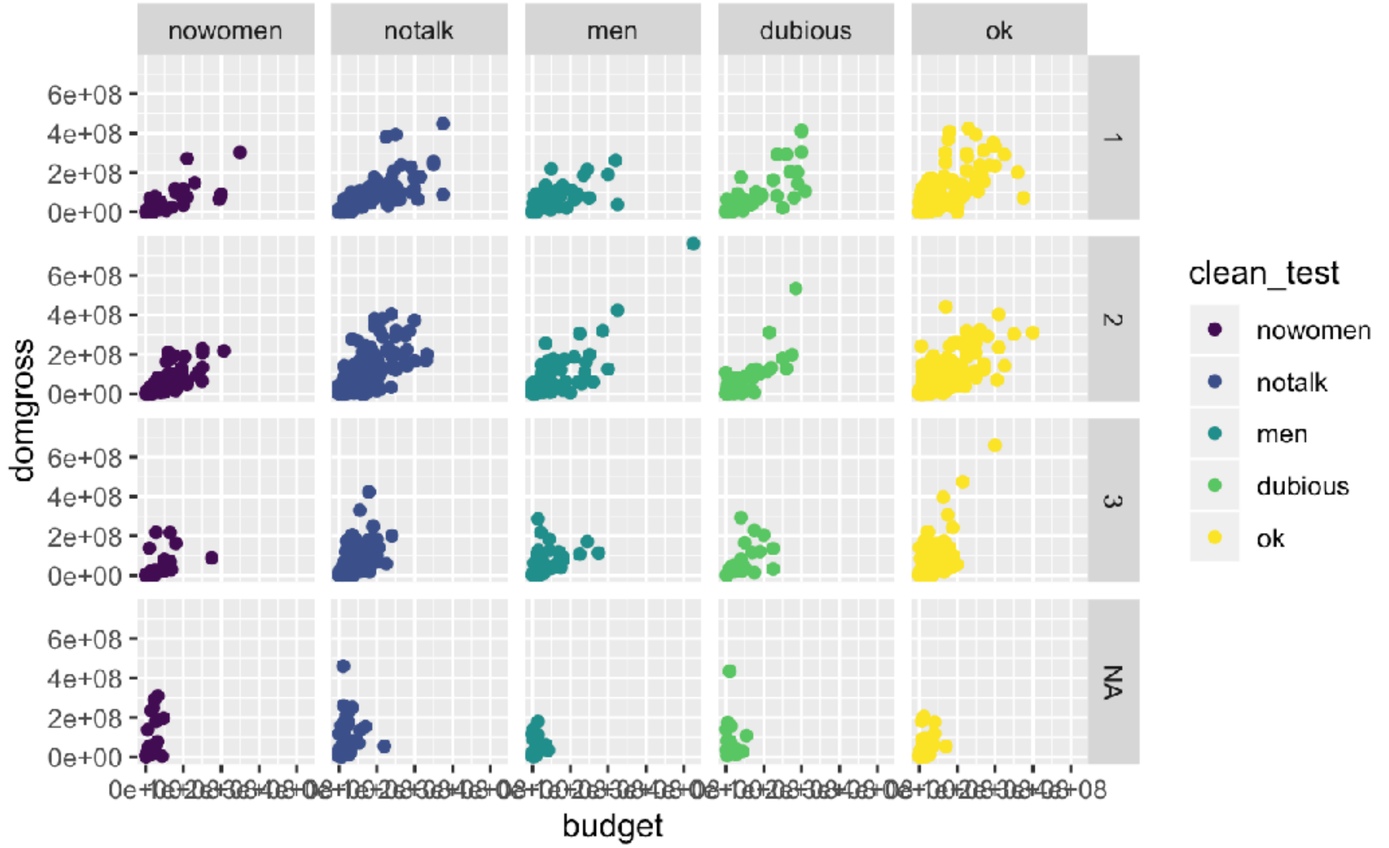
Facets




```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```

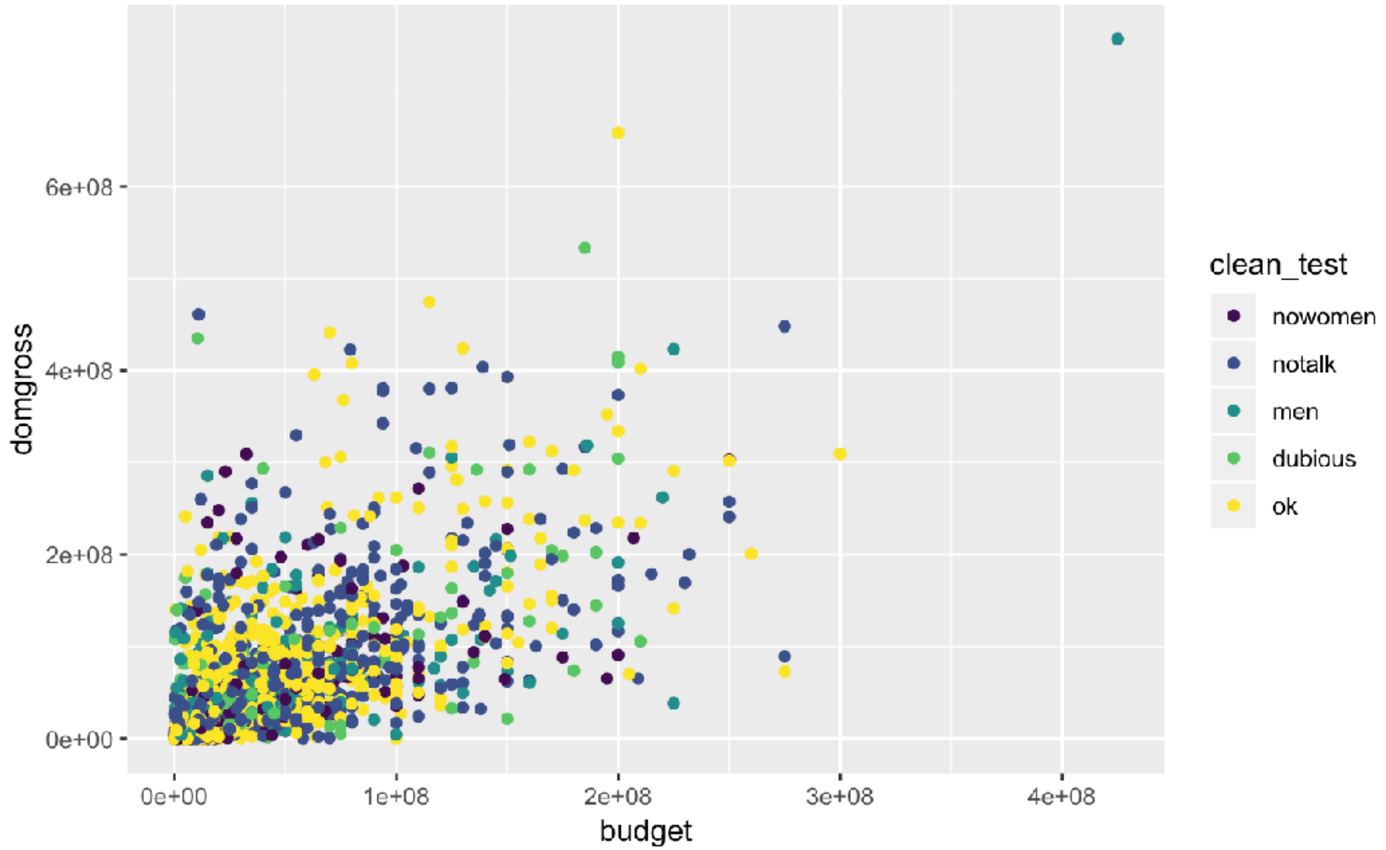



```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  facet_wrap(~ clean_test)
```

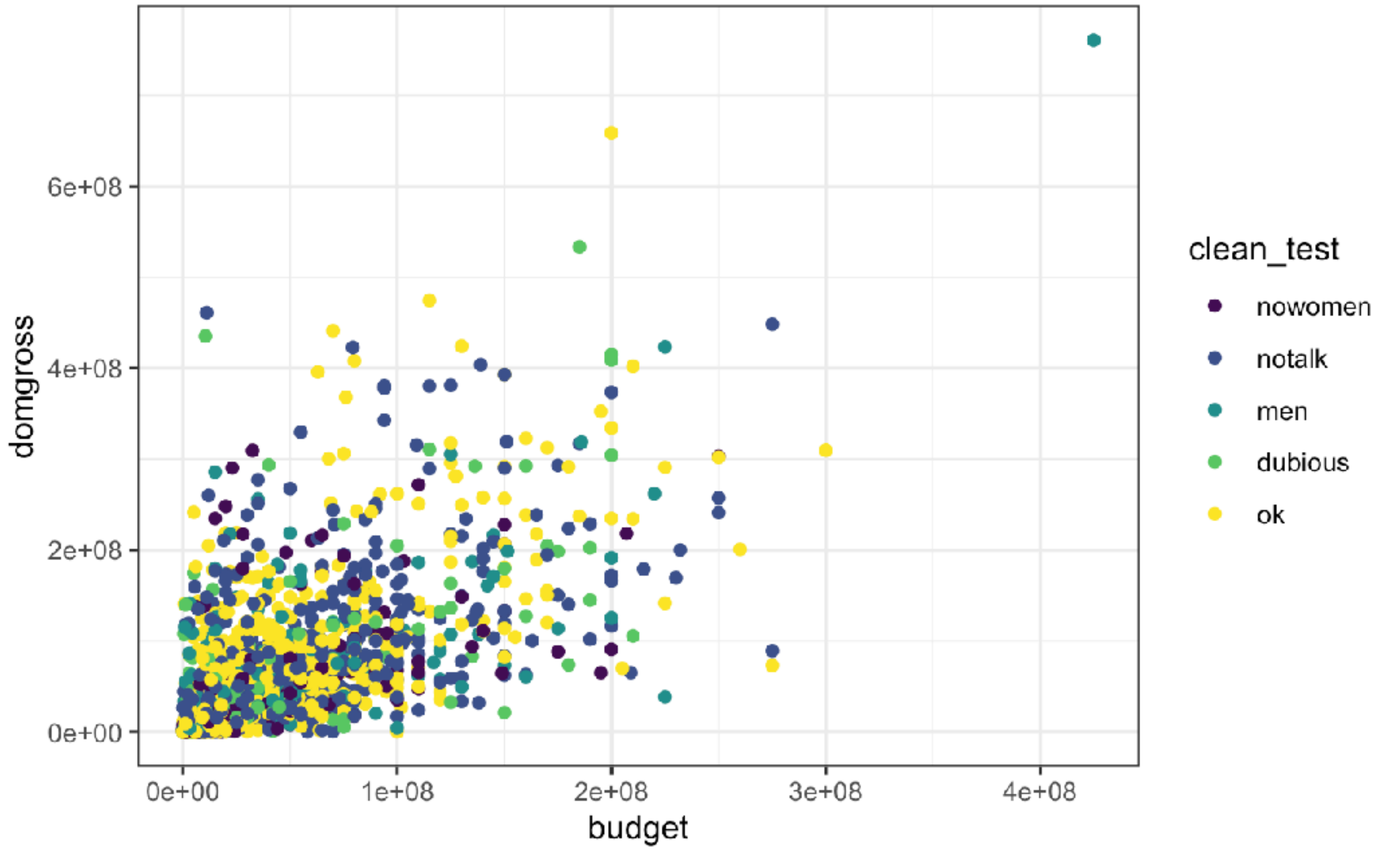



```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  facet_grid(decade_code ~ clean_test)
```

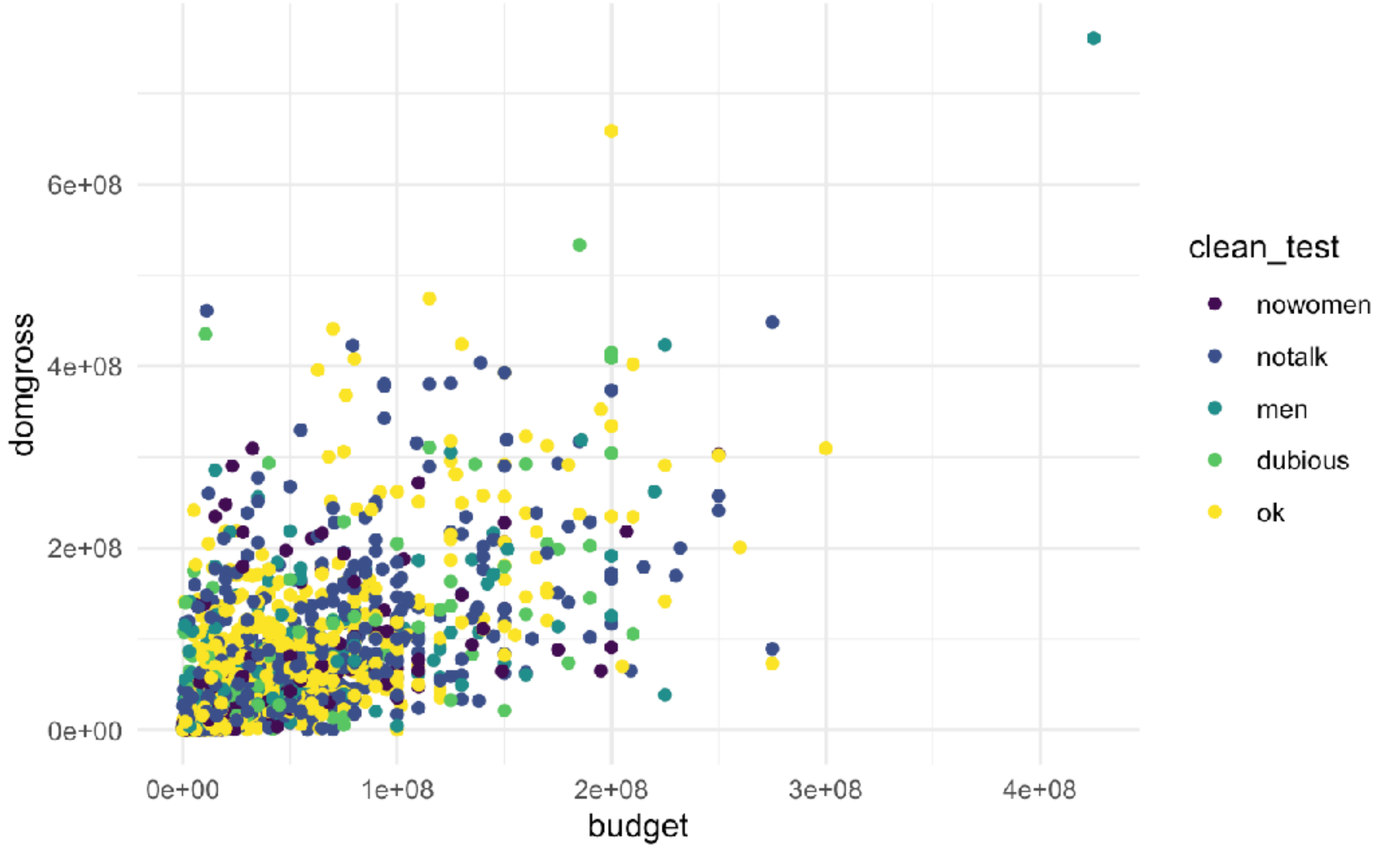
Themes



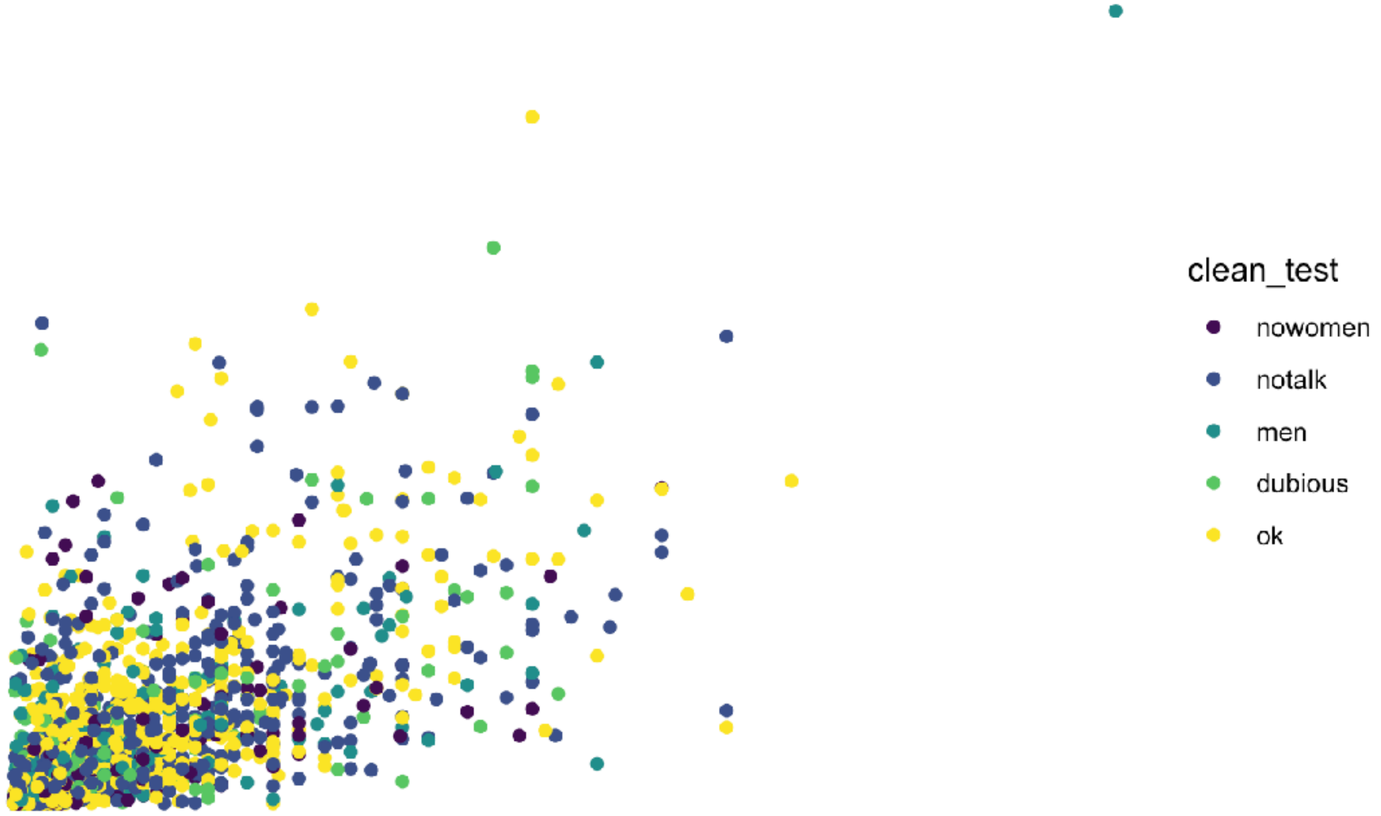

```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))
```




```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  theme_bw()
```

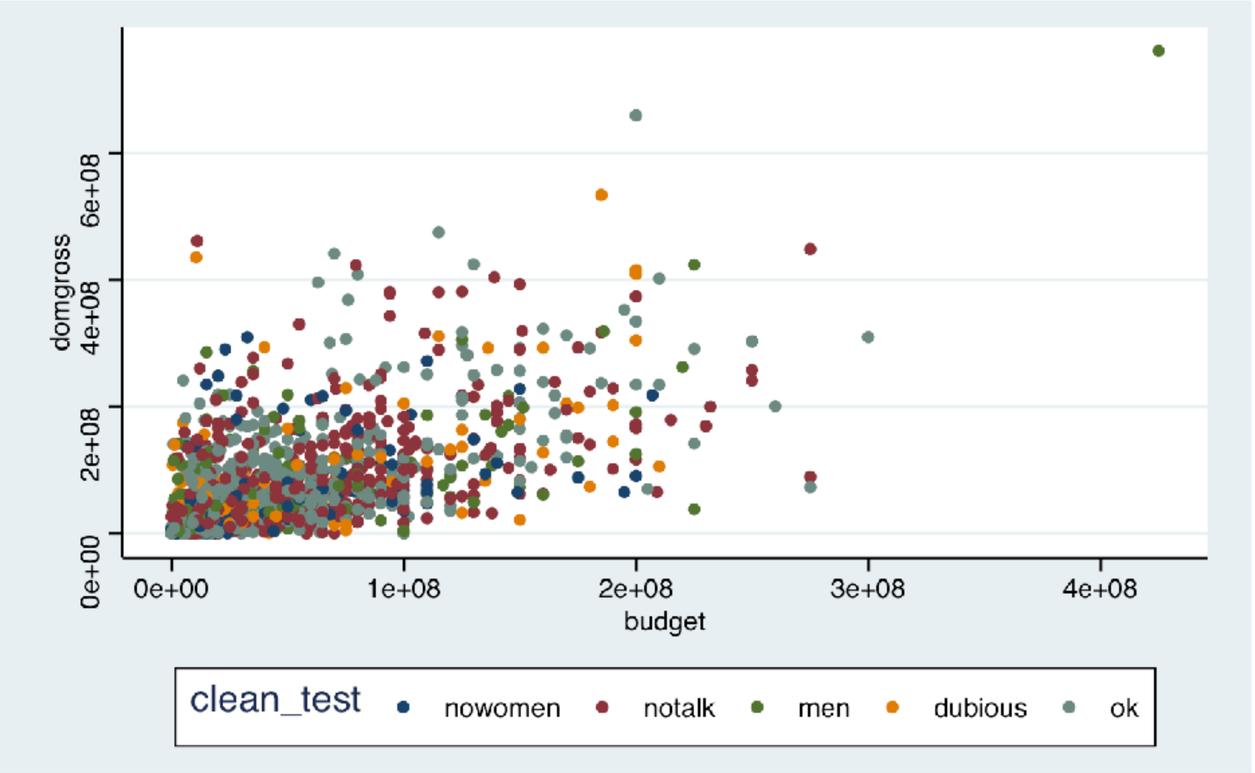



```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  theme_minimal()
```




```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  theme_void()
```

library(ggthemes)




```
ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test)) +
  scale_color_stata() +
  theme_stata()
```

ggplot2 template

Required

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>),
                  stat = <STAT>, position = <POSITION>) +
  <FACET_FUNCTION> +
  <SCALE_FUNCTION> +
  <THEME_FUNCTION>
```

Optional

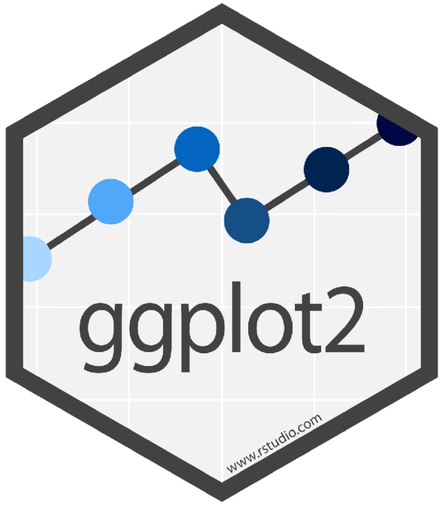
Saving plots

```
color_plot <- ggplot(data = bechdel) +
  geom_point(mapping = aes(x = budget, y = domgross, color = clean_test))

ggsave("filename.png", plot = color_plot, width = 8, height = 6,
       units = "in", dpi = "retina")
```

Will save the last plot created if not specified

Data Visualization



ATLAS
Accessible Teaching, Learning, and Assessment Systems

wjakethompson.com wjakethompson@ku.edu @wjakethompson @wjakethompson