Data Visualization in R

ggplot2 and the grammar of graphics

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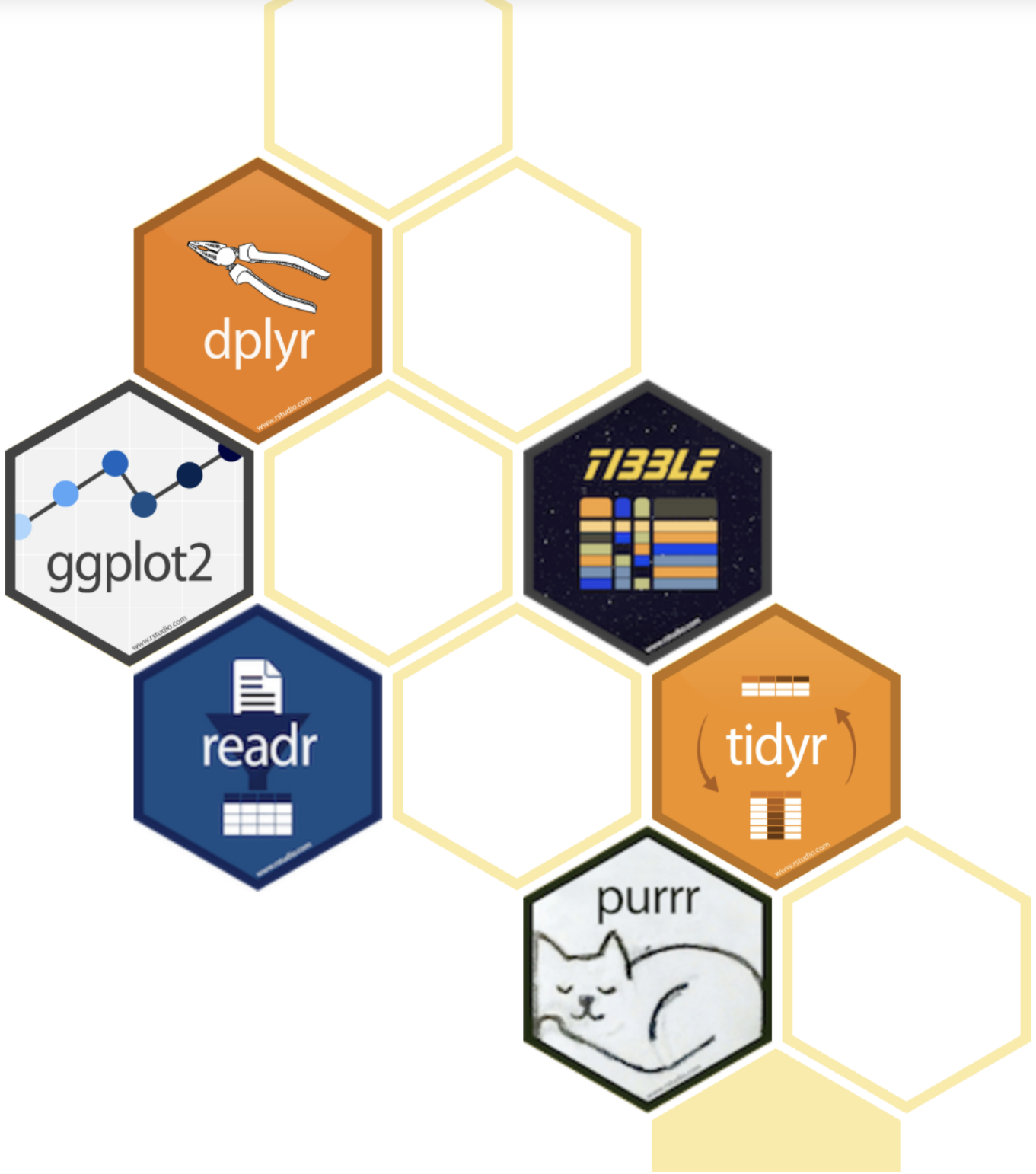
Data Visualization with R

ggplot2 works well with the **tidyverse** and is friendly and powerful

Better plots are **better communication**


dplyr
ggplot2
tibble
readr
tidyr
purrr

ggplot2: Elegant Data Visualizations in R

A Layered Grammar of Graphics

Data is mapped to *aesthetics*; Statistics and plot are linked

Sensible defaults; Infinitely extensible

Publication quality and beyond

https://nyti.ms/2jUp36n

http://bit.ly/2KSGZLu

```r
# print prettily
as_tibble(mtcars)
```

```
# A tibble: 32 × 11
     mpg   cyl  disp    hp  drat    wt  qsec    vs    am
   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
 1  21        6  160    110  3.9   2.62  16.5     0     1
 2  21        6  160    110  3.9   2.88  17.0     0     1
 3  22.8      4  108     93  3.85  2.32  18.6     1     1
 4  21.4      6  258    110  3.08  3.22  19.4     1     0
 5  18.7      8  360    175  3.15  3.44  17.0     0     0
 6  18.1      6  225    105  2.76  3.46  20.2     1     0
 7  14.3      8  360    245  3.21  3.57  15.8     0     0
 8  24.4      4  147.    62  3.69  3.19  20       1     0
 9  22.8      4  141.    95  3.92  3.15  22.9     1     0
10  19.2      6  168.   123  3.92  3.44  18.3     1     0
# … 22
```

new data alert!

mtcars

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160.0	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160.0	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108.0	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258.0	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360.0	175	3.15	3.440	17.02	0	0	3	2
Valiant	18.1	6	225.0	105	2.76	3.460	20.22	1	0	3	1
Duster 360	14.3	8	360.0	245	3.21	3.570	15.84	0	0	3	4
Merc 240D	24.4	4	146.7	62	3.69	3.190	20.00	1	0	4	2
Merc 230	22.8	4	140.8	95	3.92	3.150	22.90	1	0	4	2
Merc 280	19.2	6	167.6	123	3.92	3.440	18.30	1	0	4	4
Merc 280C	17.8	6	167.6	123	3.92	3.440	18.90	1	0	4	4
Merc 450SE	16.4	8	275.8	180	3.07	4.070	17.40	0	0	3	3
Merc 450SL	17.3	8	275.8	180	3.07	3.730	17.60	0	0	3	3
Merc 450SLC	15.2	8	275.8	180	3.07	3.780	18.00	0	0	3	3
Cadillac Fleetwood	10.4	8	472.0	205	2.93	5.250	17.98	0	0	3	4
Lincoln Continental	10.4	8	460.0	215	3.00	5.424	17.82	0	0	3	4
Chrysler Imperial	14.7	8	440.0	230	3.23	5.345	17.42	0	0	3	4
Fiat 128	32.4	4	78.7	66	4.08	2.200	19.47	1	1	4	1

Where does it come from?

`base R`

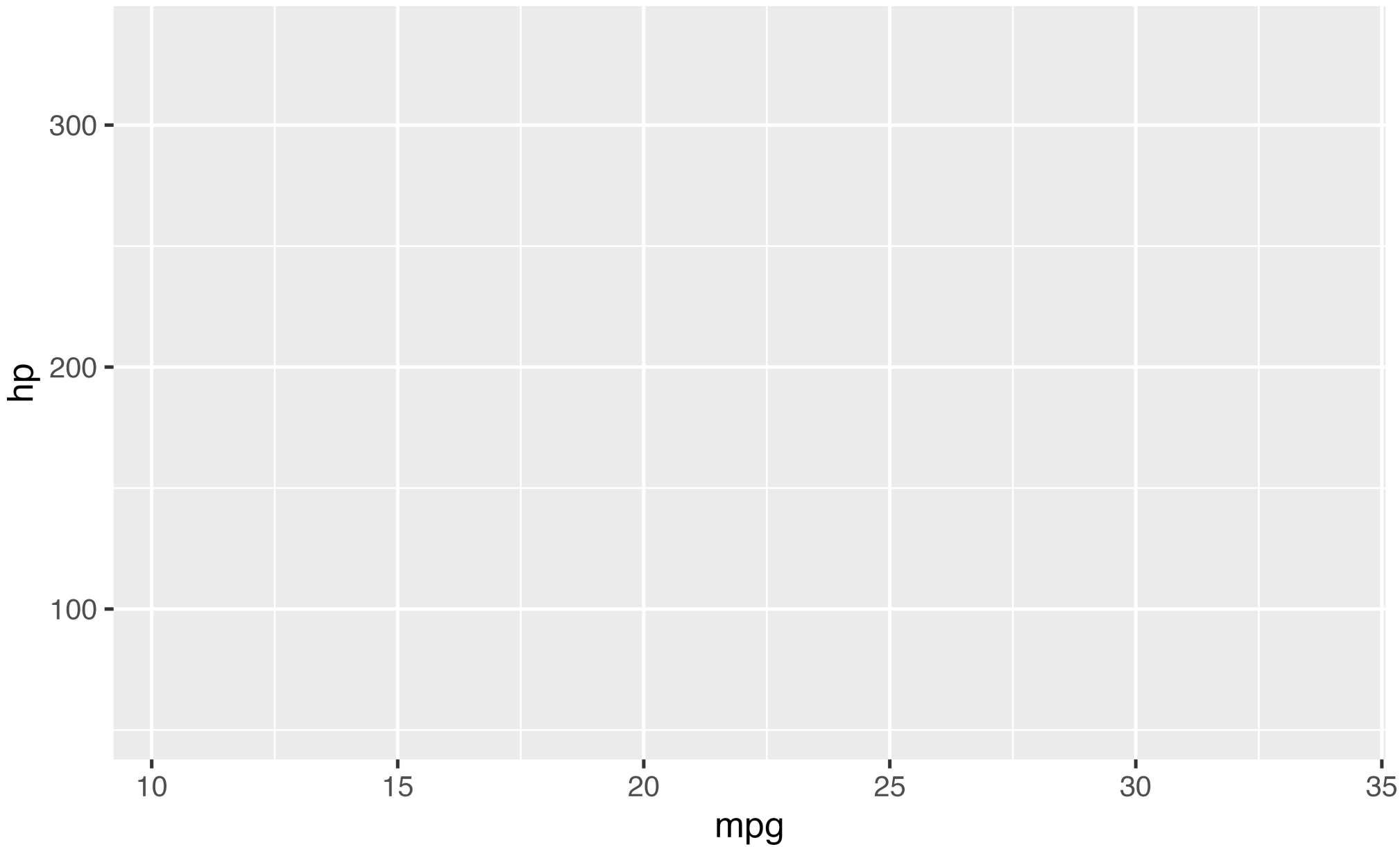
How can I use it?

```
View(mtcars)
```

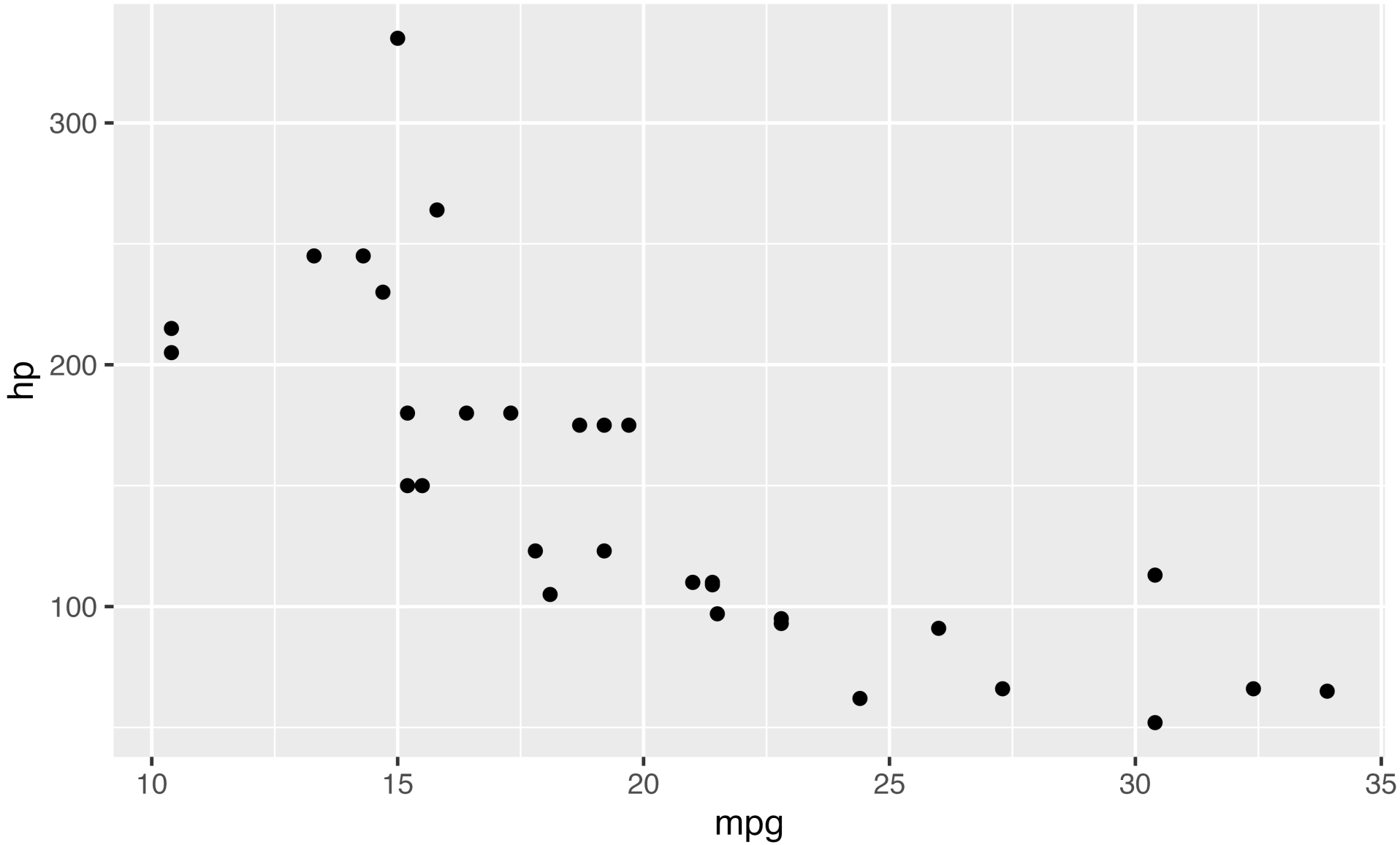
it's invisible!

```
1 ggplot()
```

```r
ggplot(mtcars, aes(x = mpg, y = hp))
```



```r
ggplot(mtcars, aes(x = mpg, y = hp)) +
  geom_point()
```



ggplot()

```
ggplot(data = <data>, mapping =
aes(<mapping>)) +
  <geom_function>()
```

. . .

Add layers with +

. . .

Put + at the **end** of a line

. . .

Connect *variables in your dataset* to *aesthetics in the plot* with `aes()`

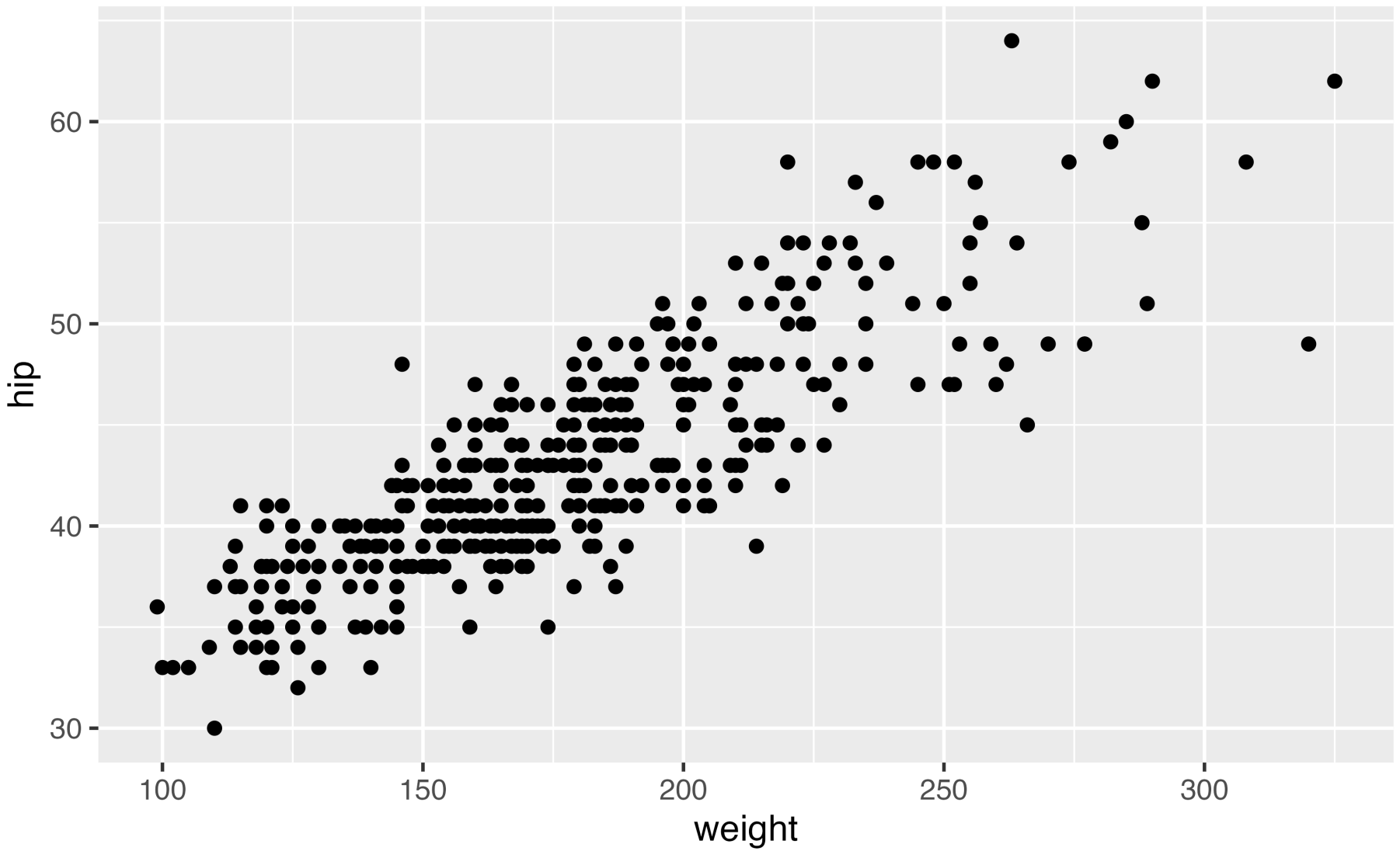
Your Turn 1

Read in the `diabetes` data.

Write and run the code from this slide to make a graph. Pay strict attention to spelling, capitalization, and parentheses!

```
1  ggplot(data = diabetes, mapping = aes(x = weight, y = hip)) +
2    geom_point()
```

```r
diabetes <- read_csv("diabetes.csv")
ggplot(data = diabetes, mapping = aes(x = weight, y = hip)) +
  geom_point()
```



Aesthetics: `aes()`

```
ggplot(data = <data>, mapping =
aes(<mapping>)) +
  <geom_function>()
```

. . .

Aesthetics *map* the data to the plot

Aesthetics: aes()

```
ggplot(mtcars, aes(x = mpg, y = hp, color = cyl)) + geom_point()

ggplot(mtcars, aes(x = mpg, y = hp, size = cyl)) + geom_point()

ggplot(mtcars, aes(x = mpg, y = hp, alpha = cyl)) + geom_point()

ggplot(mtcars, aes(x = mpg, y = hp, shape = cyl)) + geom_point()
```

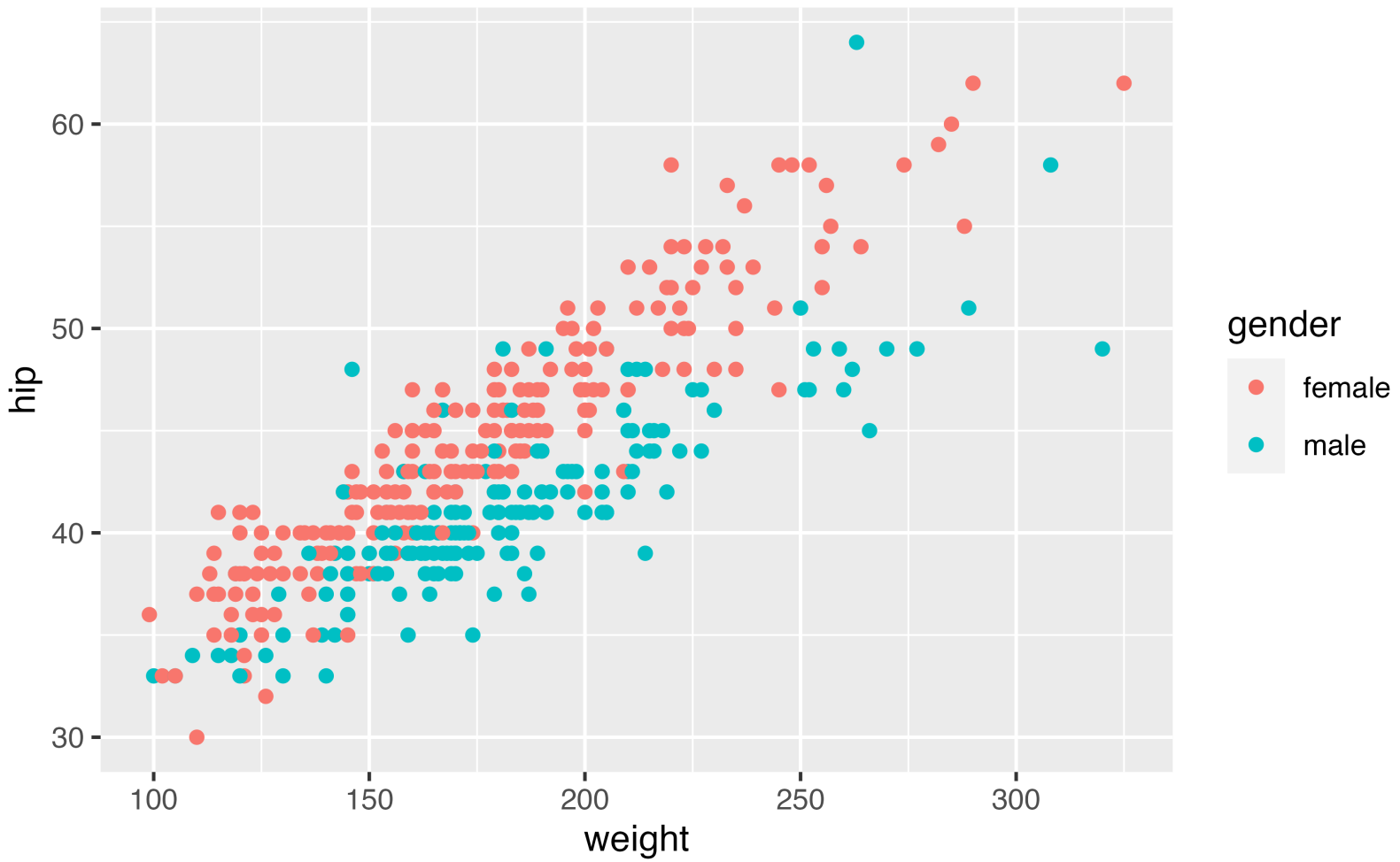
Your Turn 2

Add `color`, `size`, `alpha`, and `shape` aesthetics to your graph using the `gender` variable. Experiment.

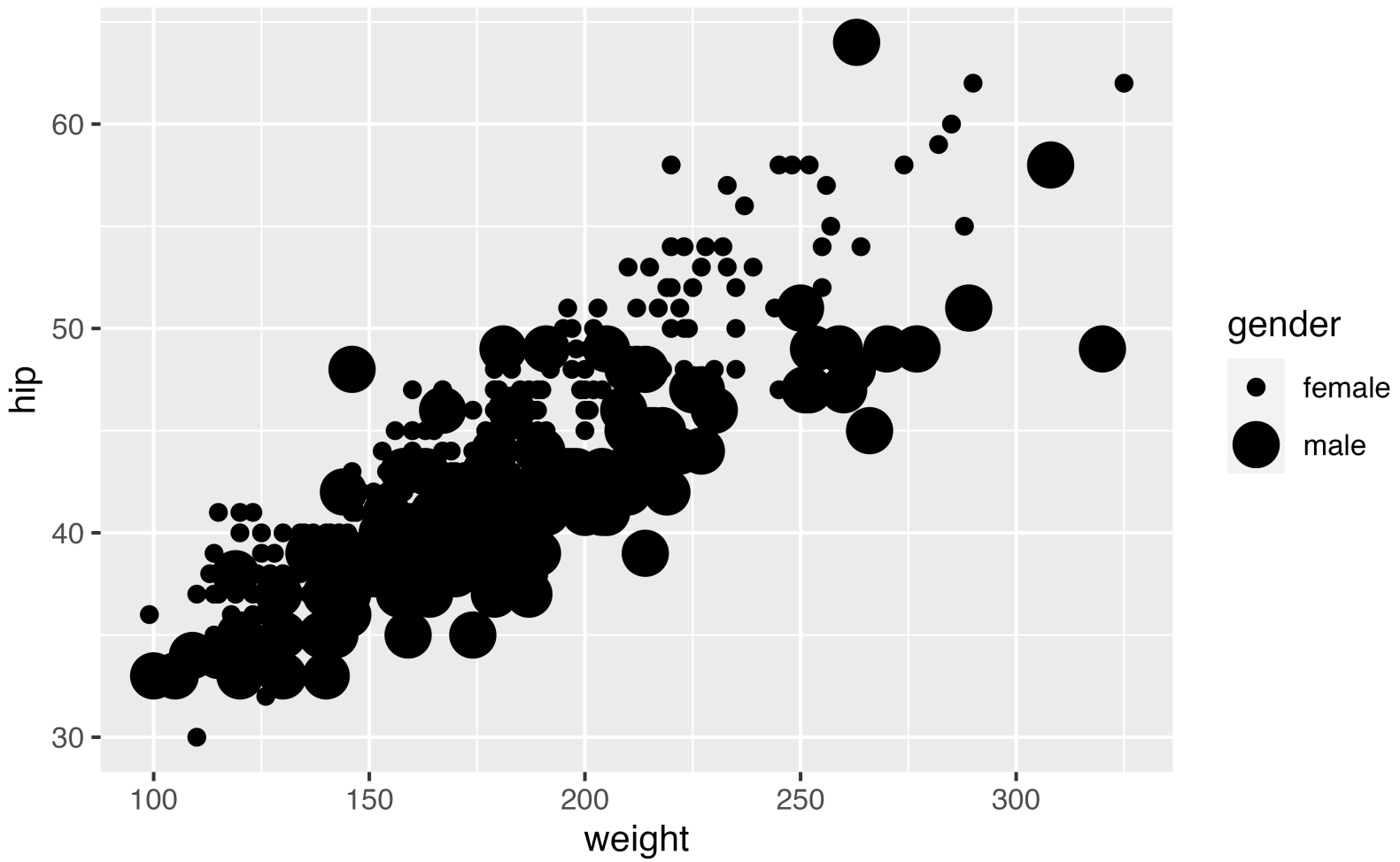
```
ggplot(
  data = diabetes,
  mapping = aes(x = weight, y = hip)
) +
  geom_point()
```

Try moving the mapping argument to `geom_point()`. Add in any aesthetics you found helpful.

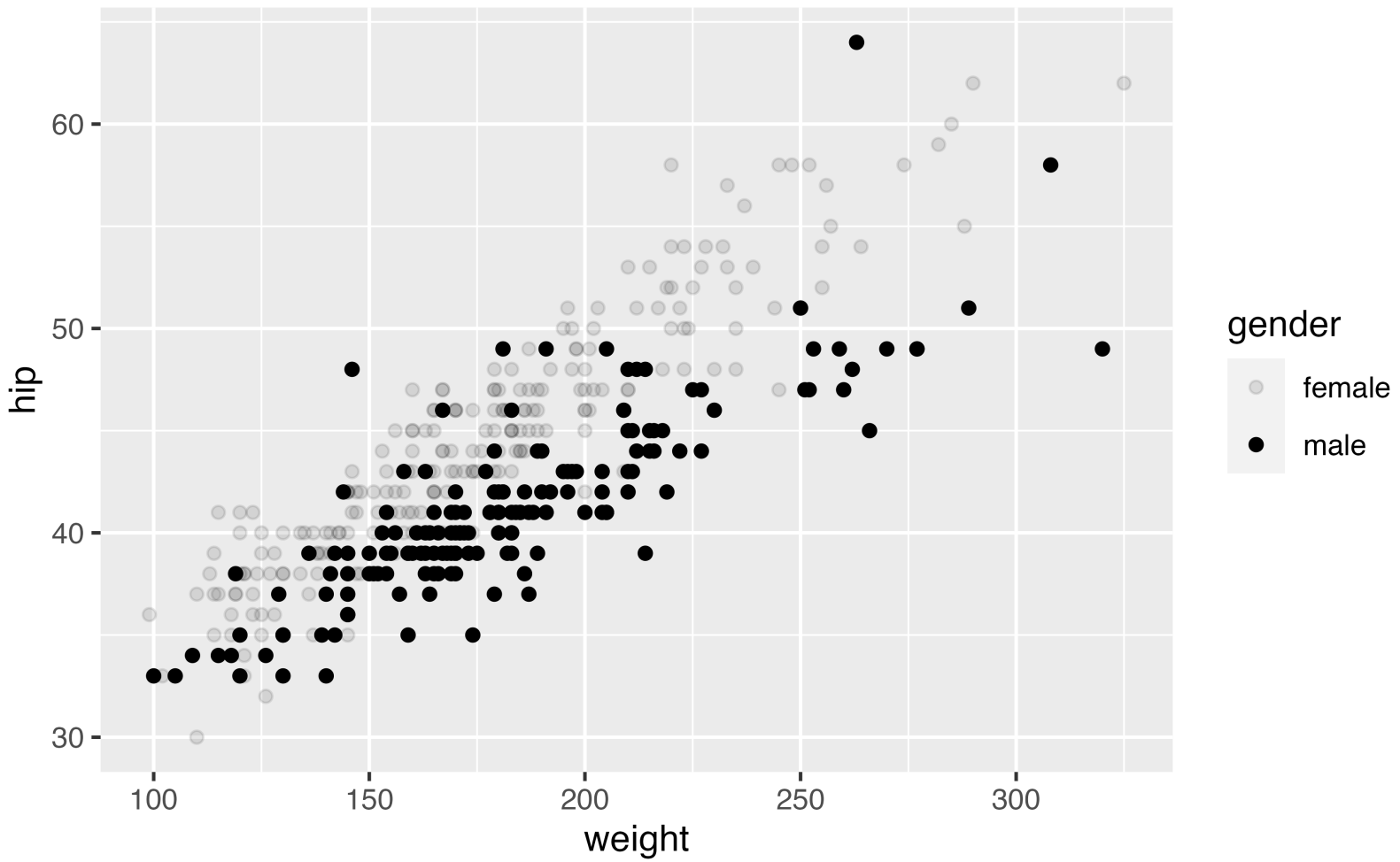
```r
ggplot(
  data = diabetes,
  mapping = aes(x = weight, y = hip, color = gender)
) +
  geom_point()
```



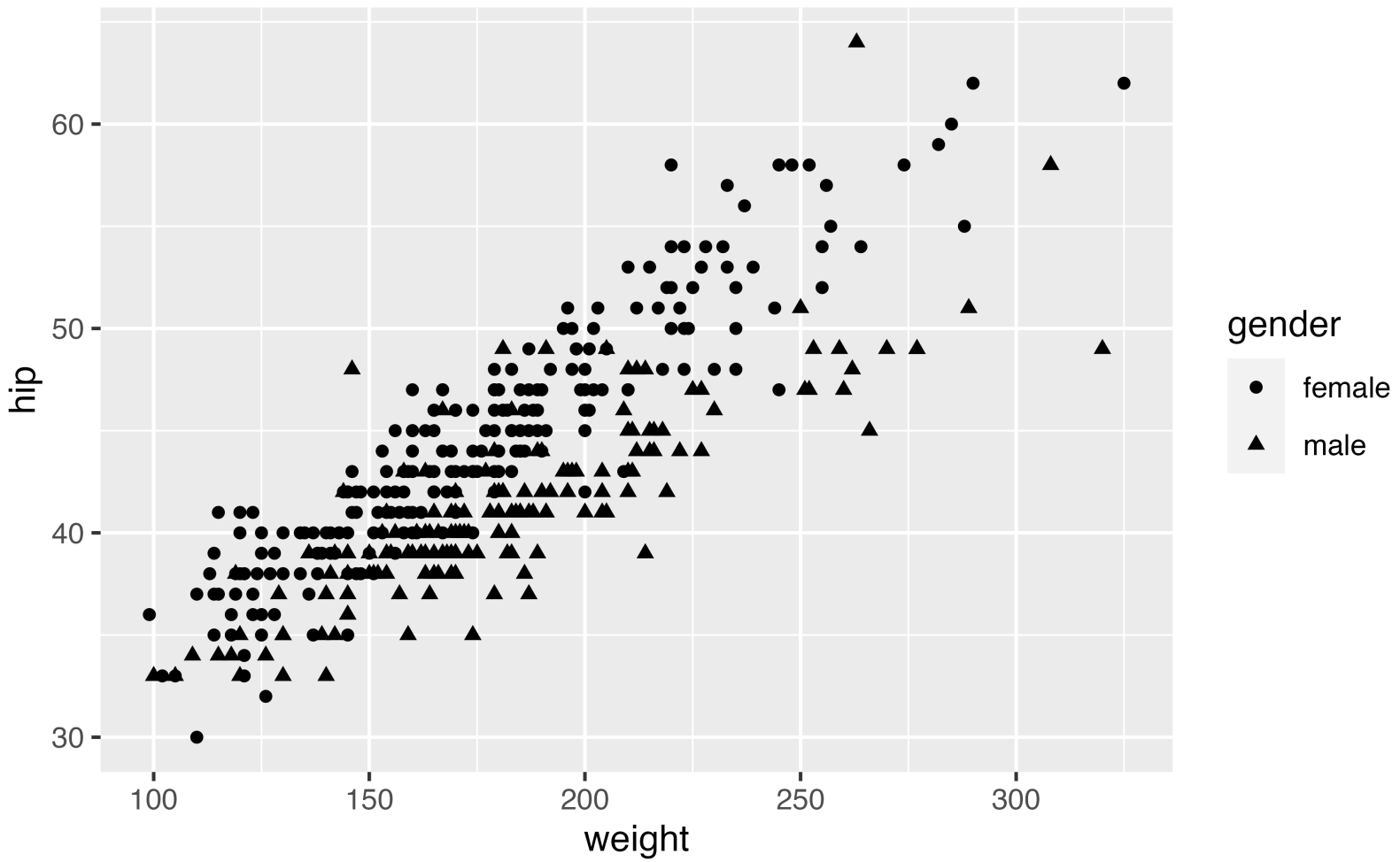
```r
ggplot(
  data = diabetes,
  mapping = aes(x = weight, y = hip, size = gender)
) +
  geom_point()
```



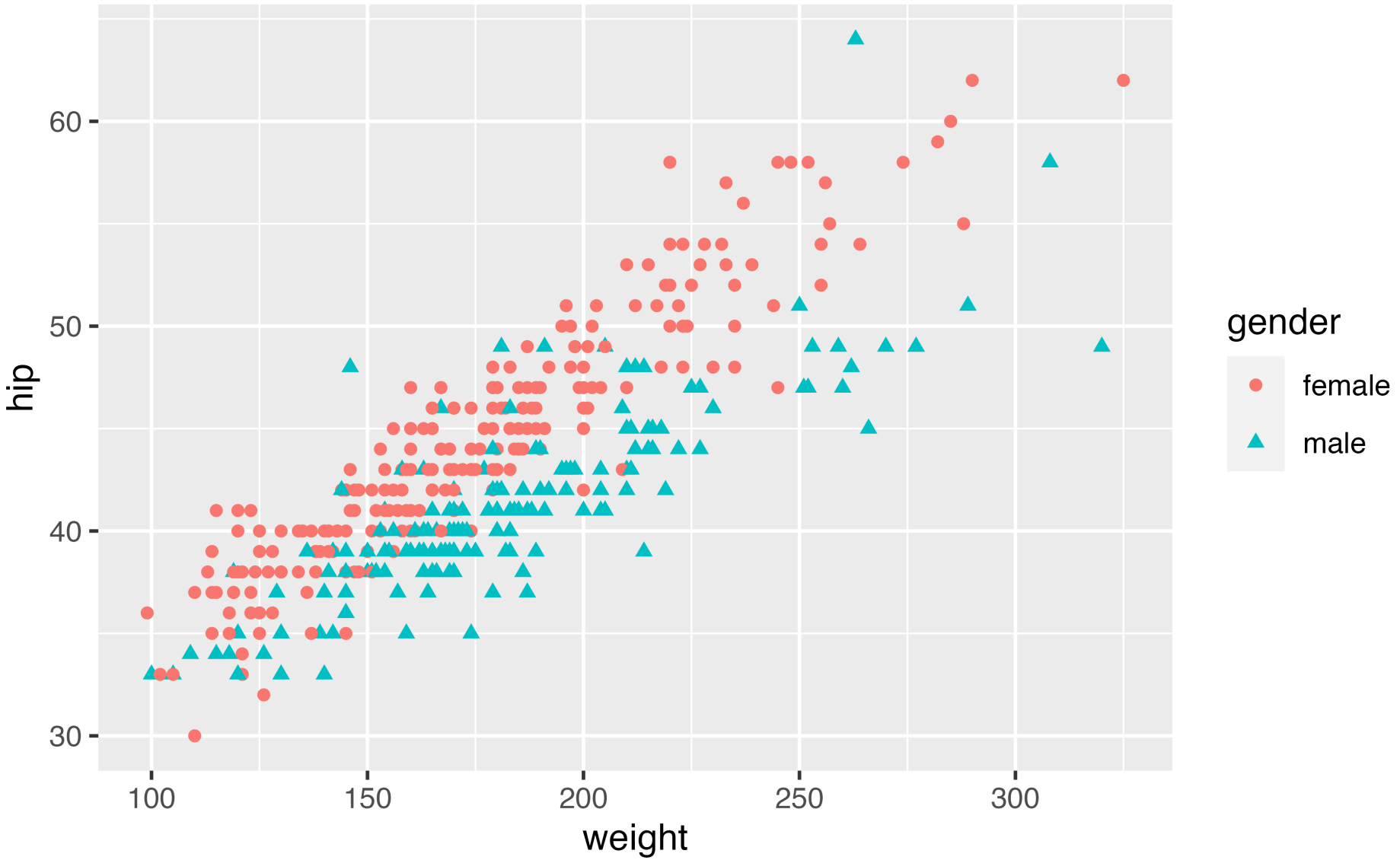
```r
ggplot(
  data = diabetes,
  mapping = aes(x = weight, y = hip, alpha = gender)
) +
  geom_point()
```



```r
ggplot(
  data = diabetes,
  mapping = aes(x = weight, y = hip, shape = gender)
) +
  geom_point()
```

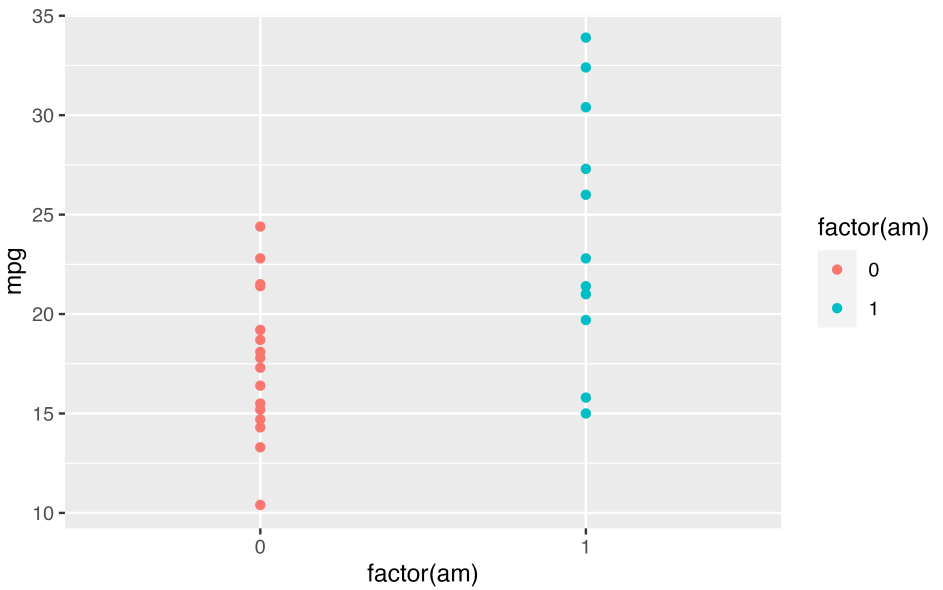


```
ggplot(data = diabetes) +
  geom_point(
    mapping = aes(
      x = weight,
      y = hip,
      color = gender,
      shape = gender
    )
  )
```


hip
60
50
40
30
100
150
200
250
300
weight
gender
female
male

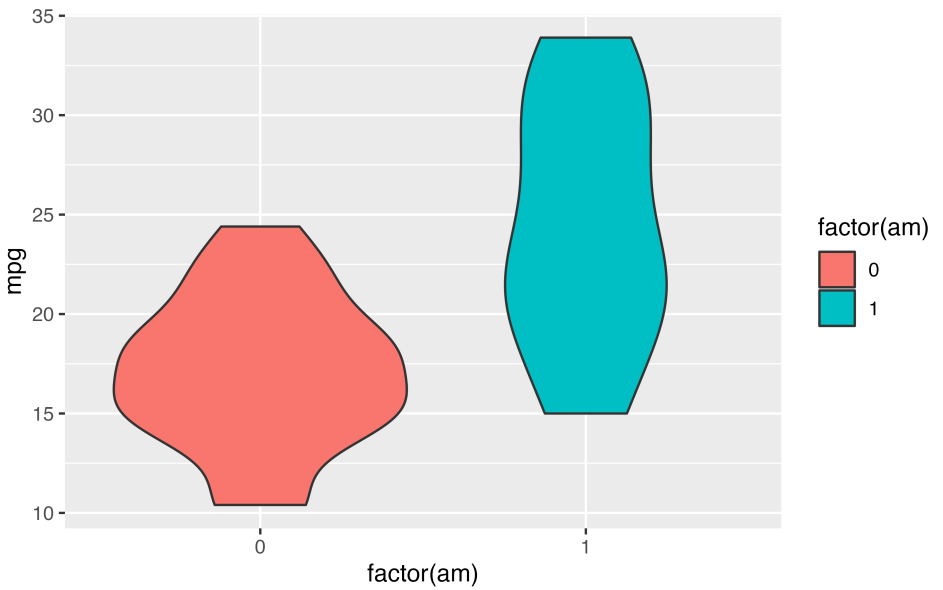
geoms: the shape of the data

```
ggplot(
  mtcars,
  aes(
    x = factor(am),
    y = mpg,
    color = factor(am)
  )
) +
  geom_point()
```



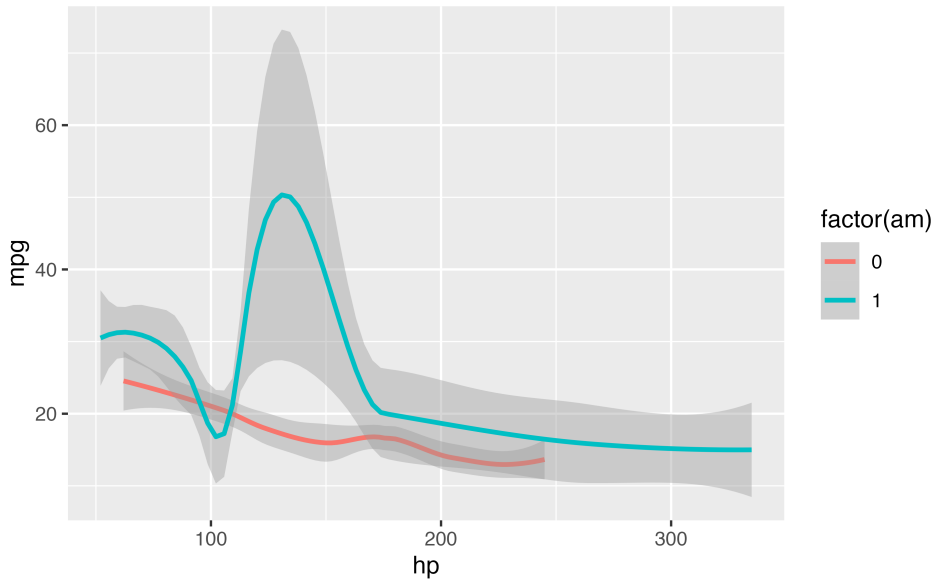
geoms: the shape of the data

```
ggplot(
  mtcars,
  aes(
    x = factor(am),
    y = mpg,
    fill = factor(am)
  )
) +
  geom_violin()
```

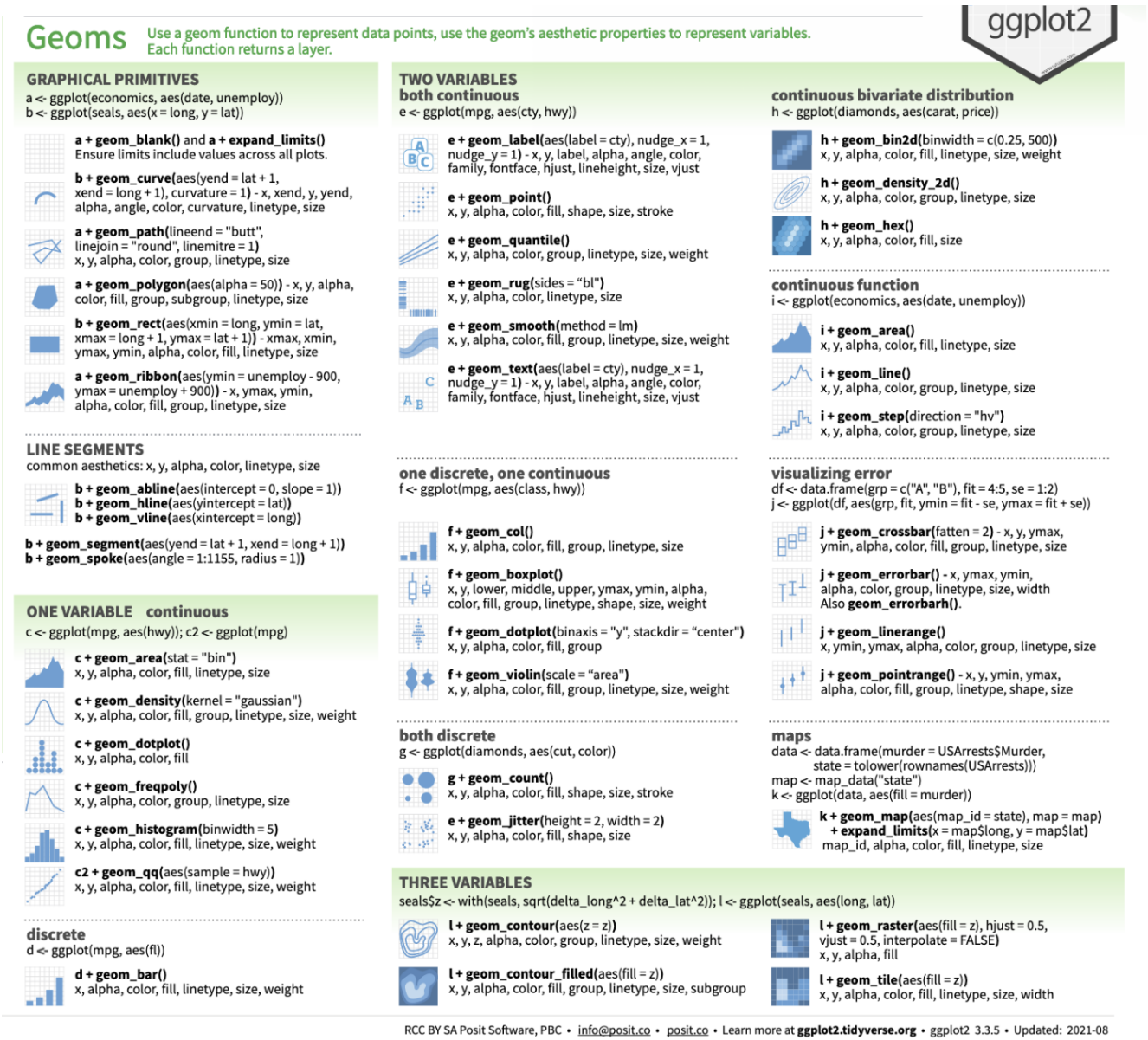


geoms: the shape of the data

```
ggplot(
  mtcars,
  aes(
    x = hp,
    y = mpg,
    color = factor(am)
  )
) +
  geom_smooth()
```



geoms: the shape of the data



Geoms

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

ggplot2

GRAPHICAL PRIMITIVES

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

a + geom_blank() and **a + expand_limits()**
Ensure limits include values across all plots.

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(alpha = 50)**)** - x, y, alpha, color, fill, group, subgroup, 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 both continuous

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

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

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**)** - x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

one discrete, one continuous

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

both discrete

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

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

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

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_density_2d()
x, y, alpha, color, group, linetype, size

h + geom_hex()
x, y, alpha, color, 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, color, group, linetype, size, weight

l + geom_contour_filled(aes(fill = z)**)**
x, y, alpha, color, fill, group, linetype, size, subgroup

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

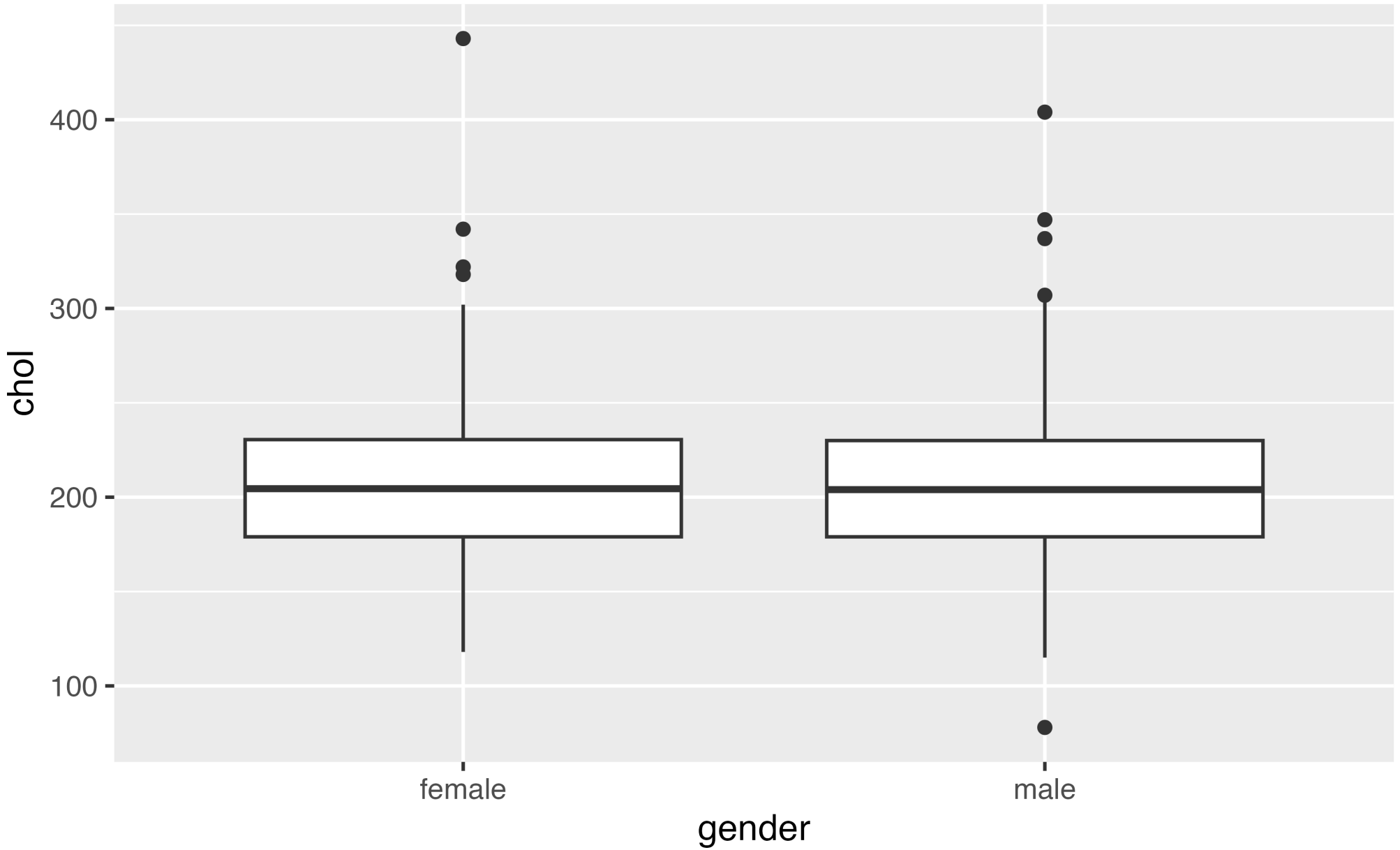
l + geom_tile(aes(fill = z)**)**
x, y, alpha, color, fill, linetype, size, width

Your Turn 3

Replace this scatterplot with one that draws boxplots.

```
1  ggplot(diabetes, aes(gender, chol)) + geom_point()
```

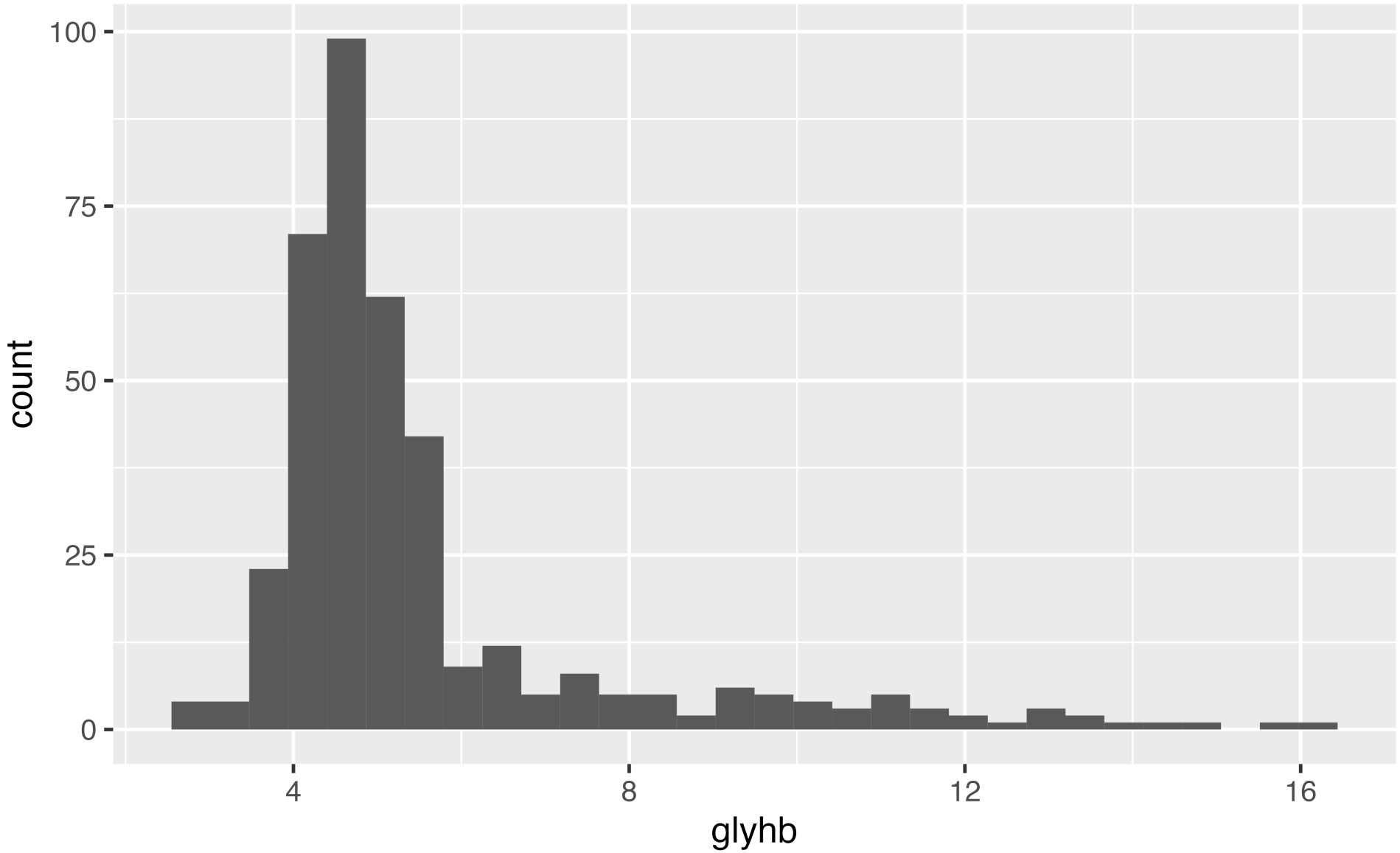
```r
ggplot(diabetes, aes(gender, chol)) + geom_boxplot()
```



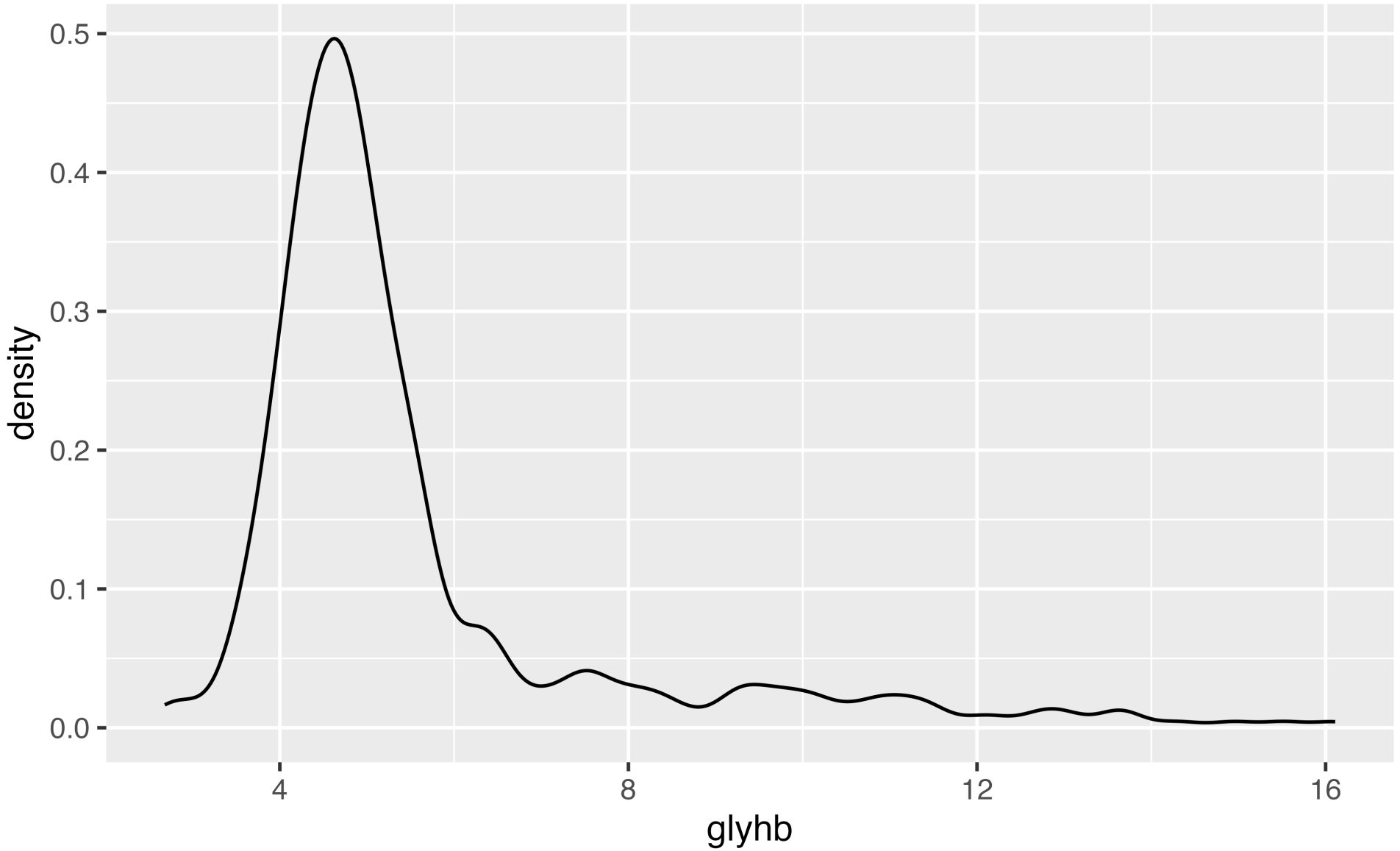
Your Turn 4

1. Make a histogram of the `glyhb` variable in `diabetes`.
2. Redo the `glyhb` plot as a density plot.

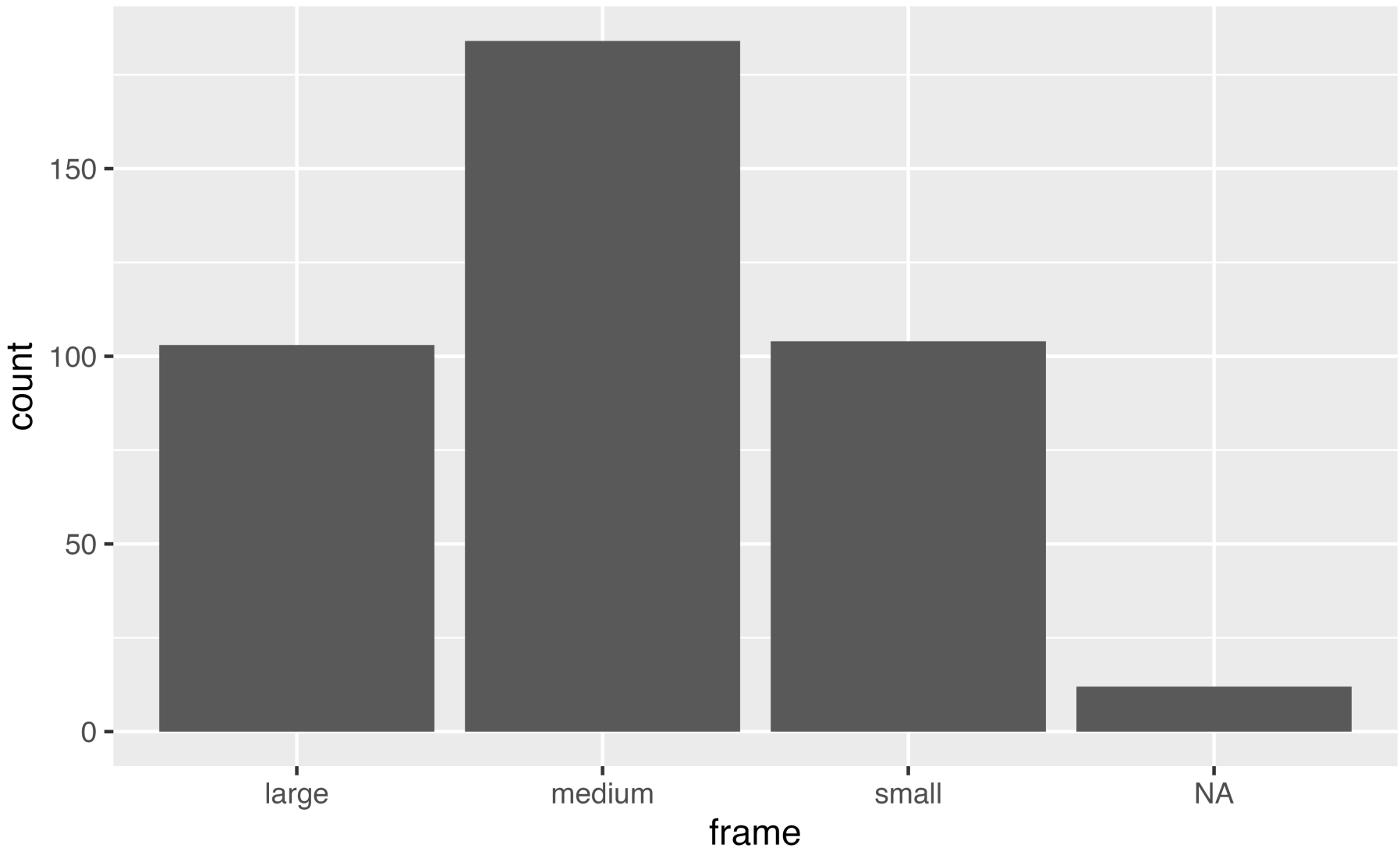
```r
ggplot(diabetes, aes(x = glyhb)) +
  geom_histogram()
```



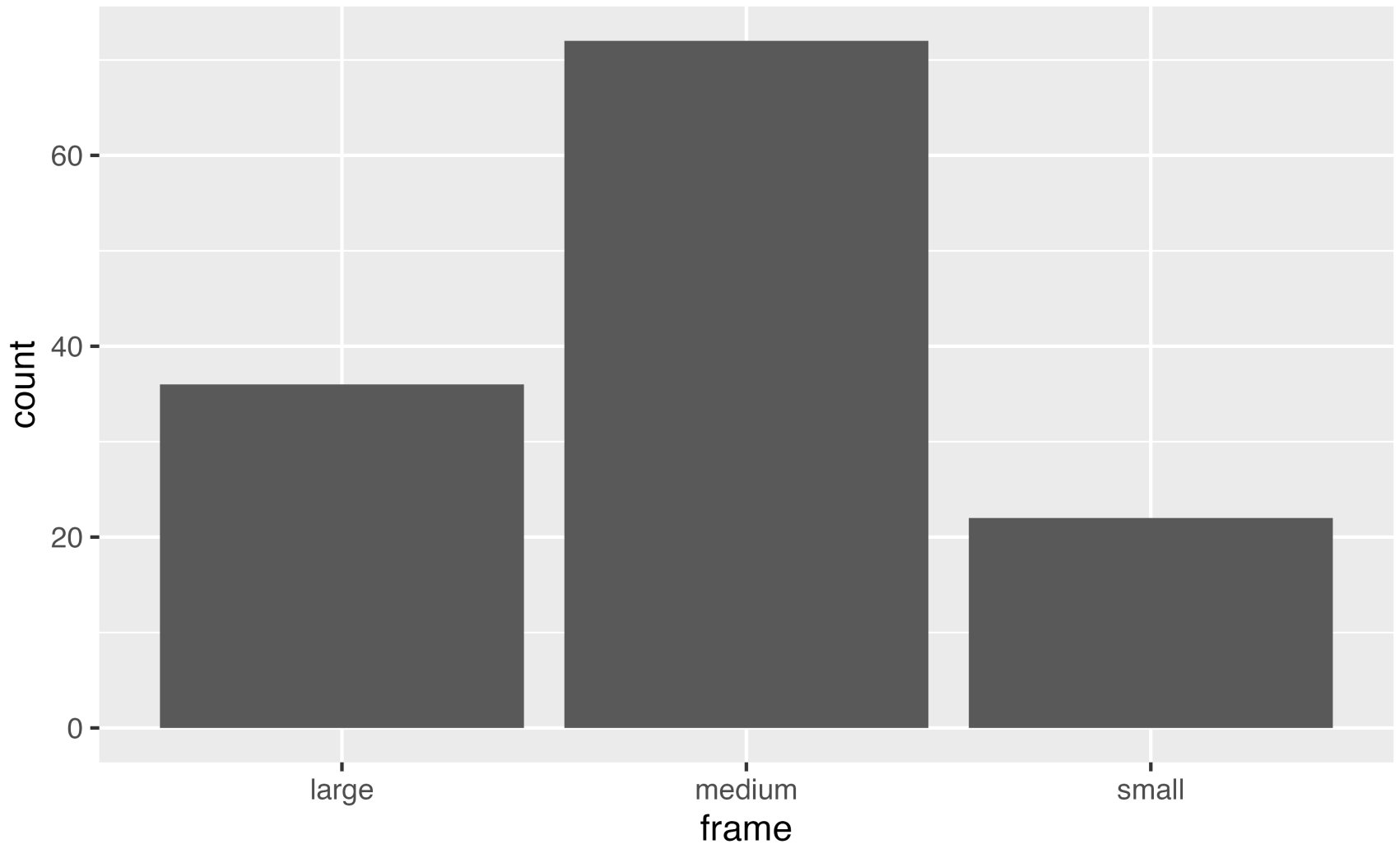
```r
ggplot(diabetes, aes(x = glyhb)) +
  geom_density()
```



```r
diabetes |>
  ggplot(aes(x = frame)) +
  geom_bar()
```



```r
diabetes |>
  drop_na() |>
  ggplot(aes(x = frame)) +
  geom_bar()
```

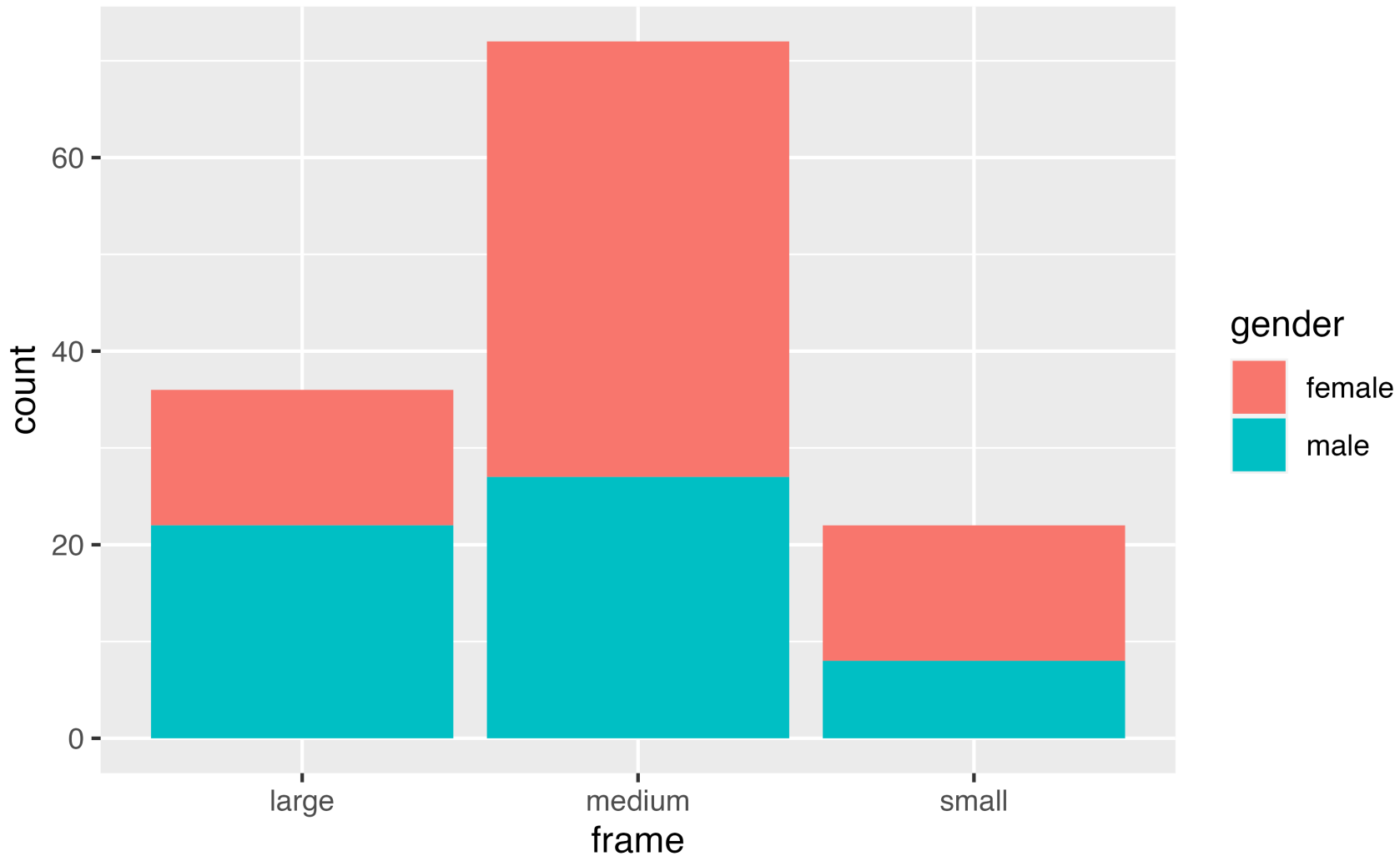


Your Turn 5

Make a bar chart of `frame` colored by `gender`. Then, try it with the `fill` aesthetic instead of `color`.

```
diabetes |>
  drop_na() |>
  _______() +
  _______()
```

```r
diabetes |>
  drop_na() |>
  ggplot(aes(x = frame, fill = gender)) +
  geom_bar()
```



Positions

```
geom_bar(position = "<POSITION>")
```

. . .

When we have aesthetics mapped, how are they positioned?

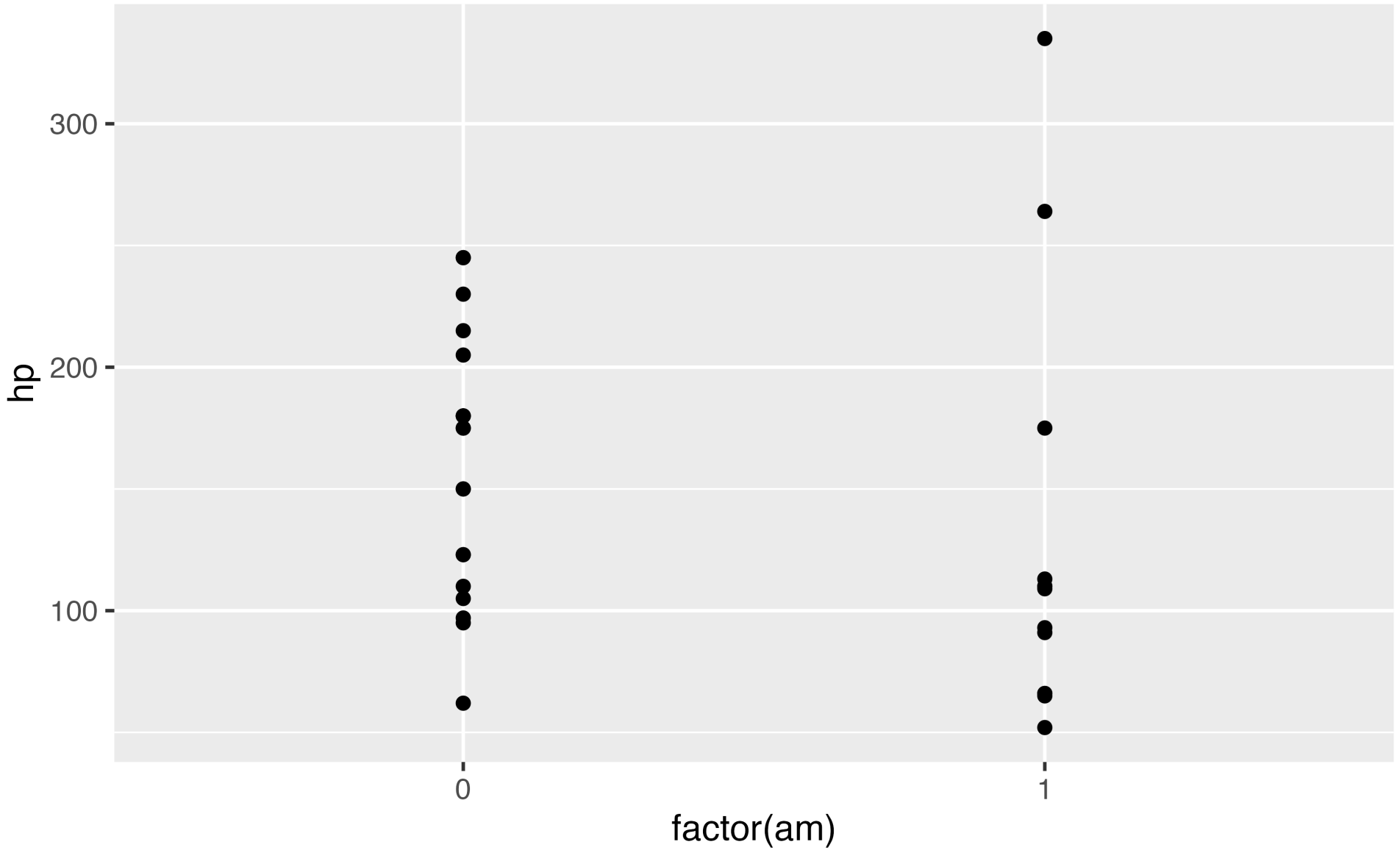
. . .

geom_bar: **dodge**, **fill**, **stacked** (default)

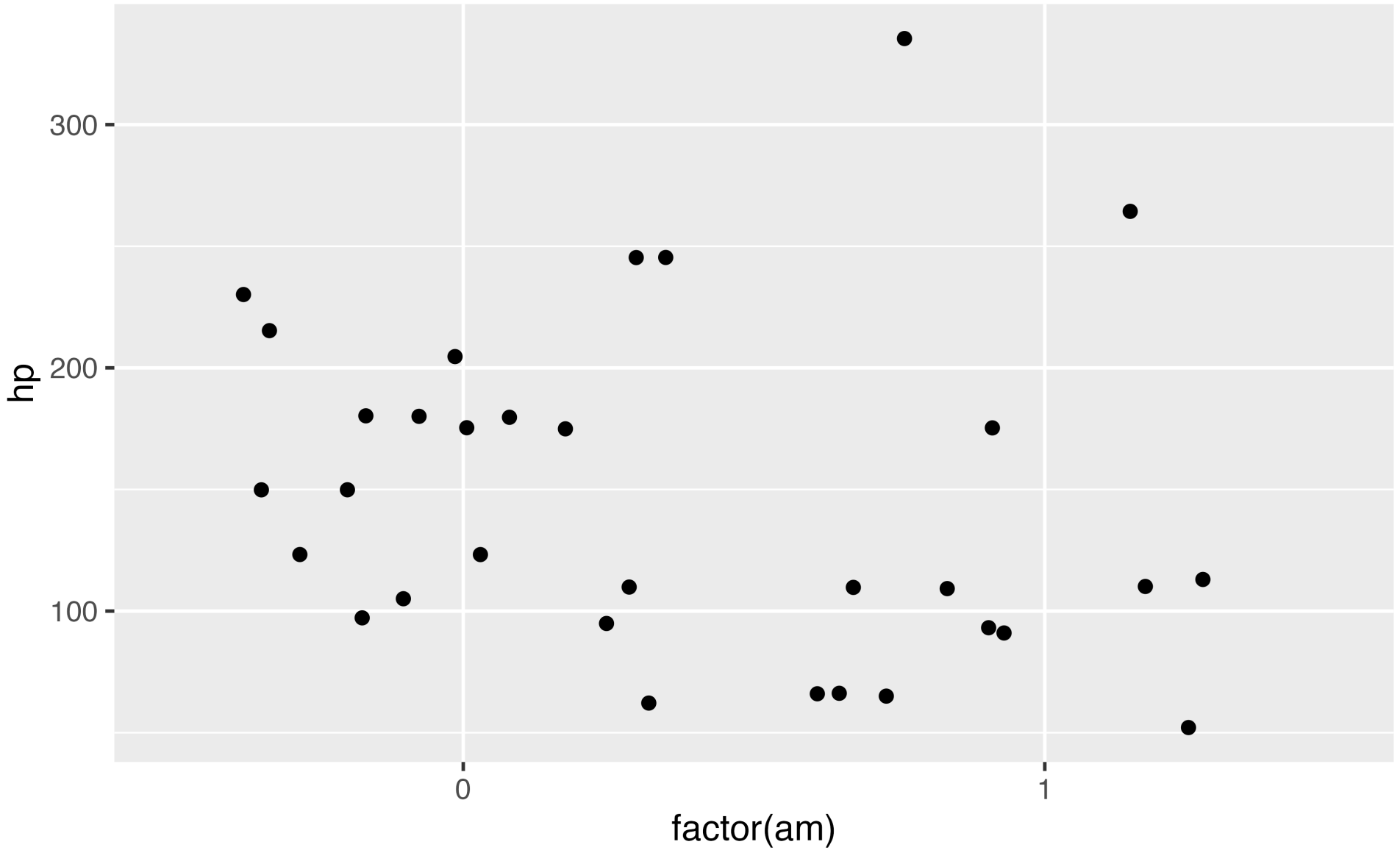
. . .

geom_point: jitter

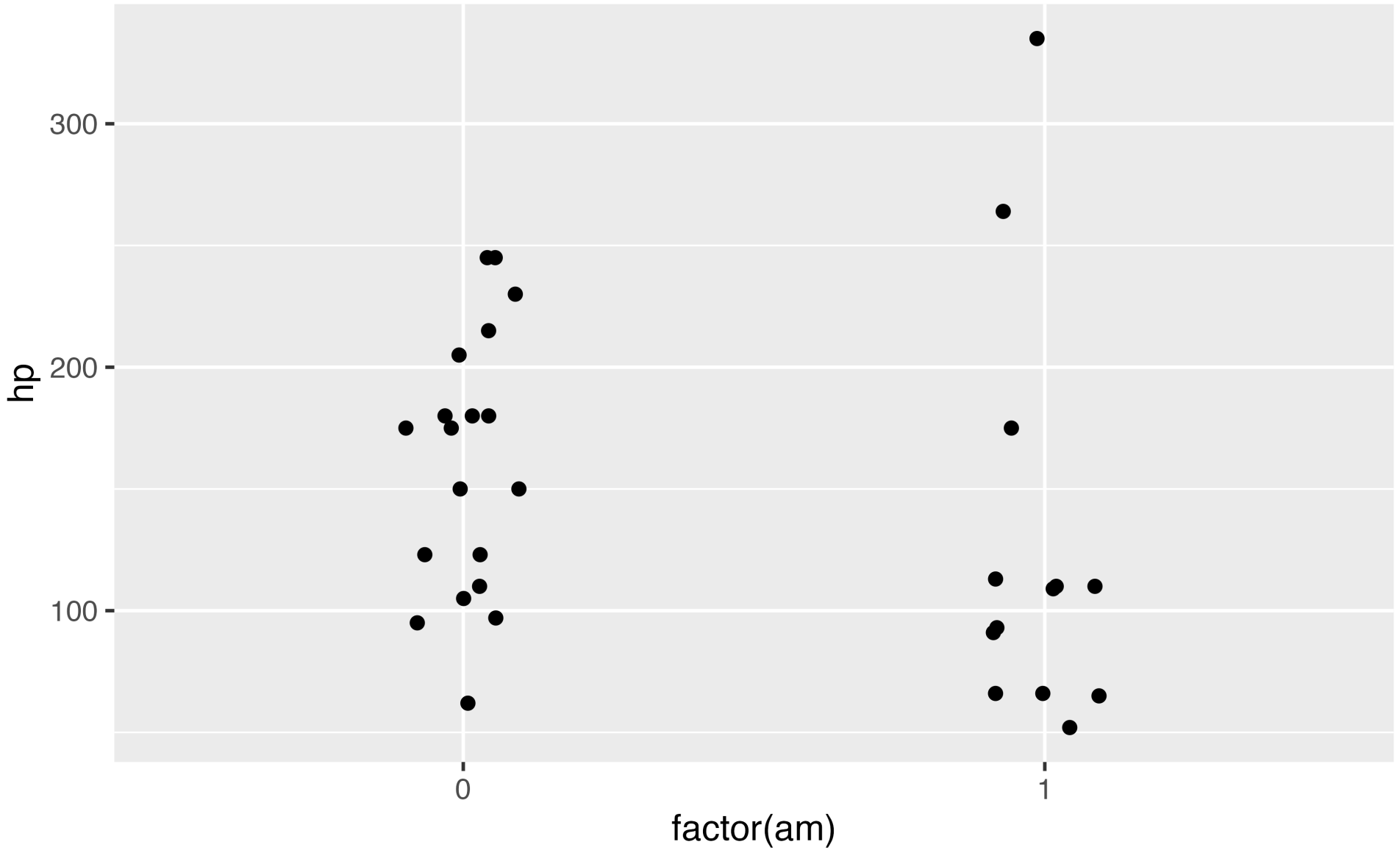
```r
ggplot(mtcars, aes(x = factor(am), y = hp)) +
  geom_point()
```



```r
ggplot(mtcars, aes(x = factor(am), y = hp)) +
  geom_point(position = "jitter")
```



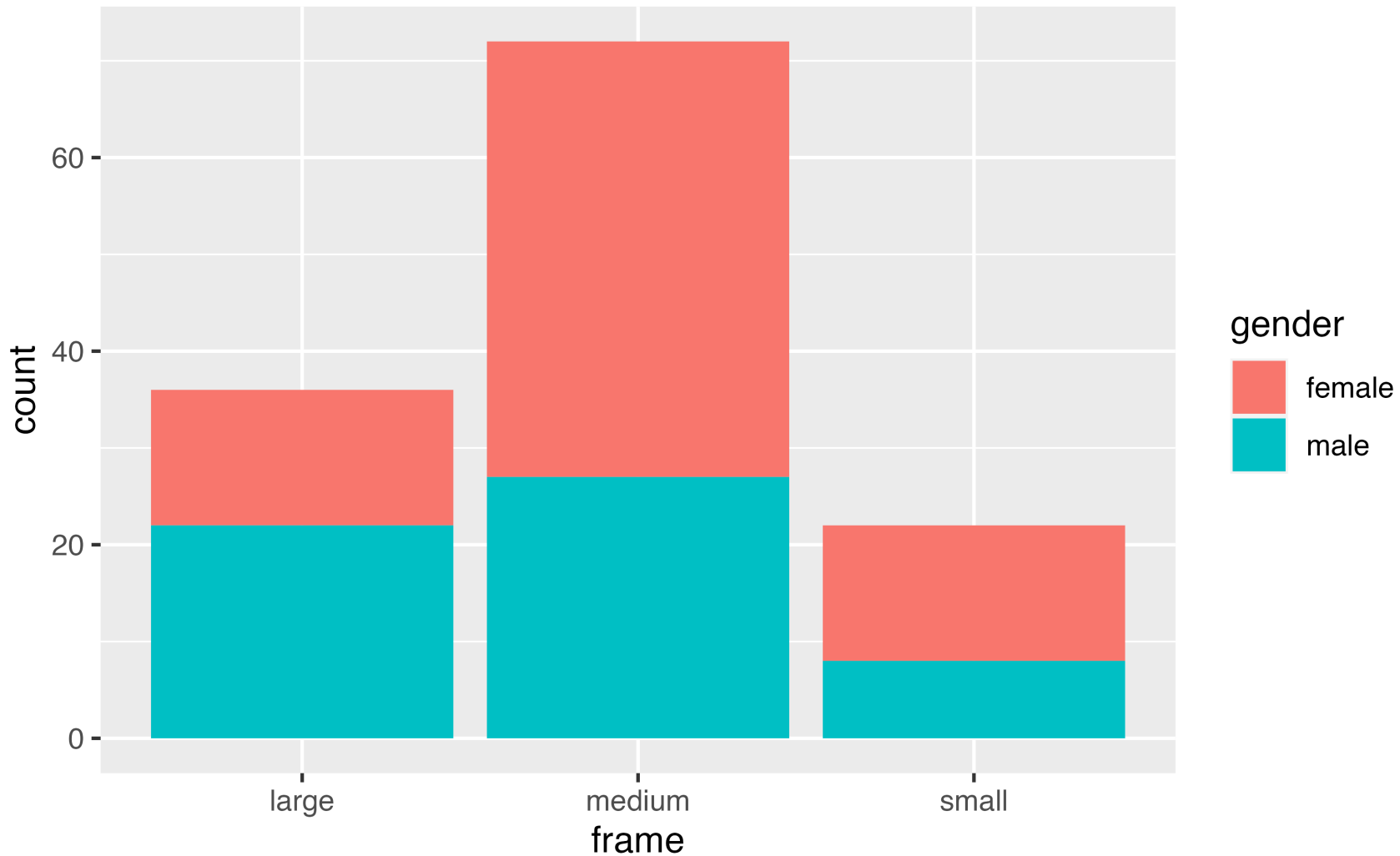
```r
ggplot(mtcars, aes(x = factor(am), y = hp)) +
  geom_jitter(width = .1, height = 0)
```



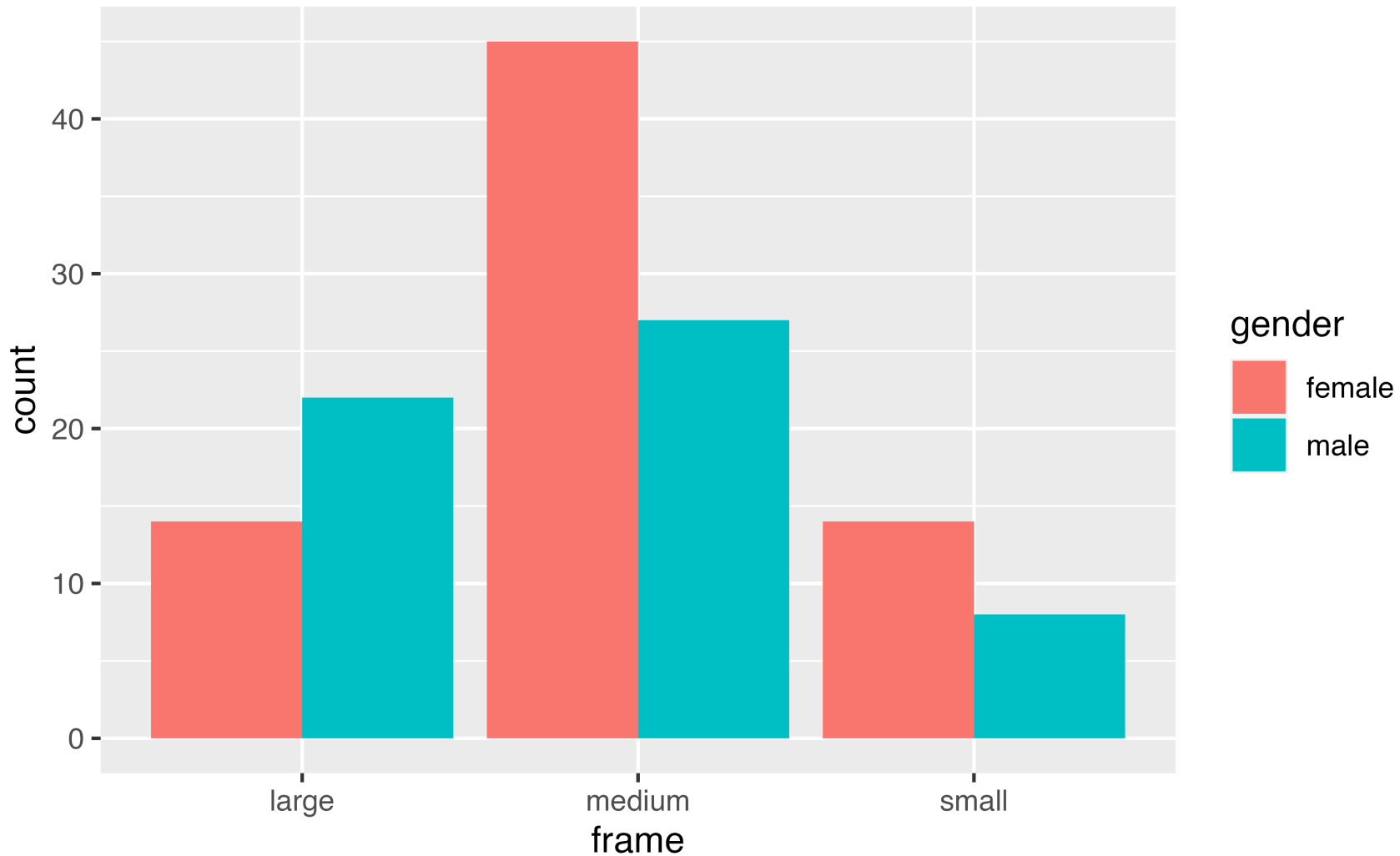
Your Turn 6

Take your code for the bar chart before (using the `fill` aesthetic). Experiment with different `position` values: `"dodge"`, `"fill"`, `"stack"`

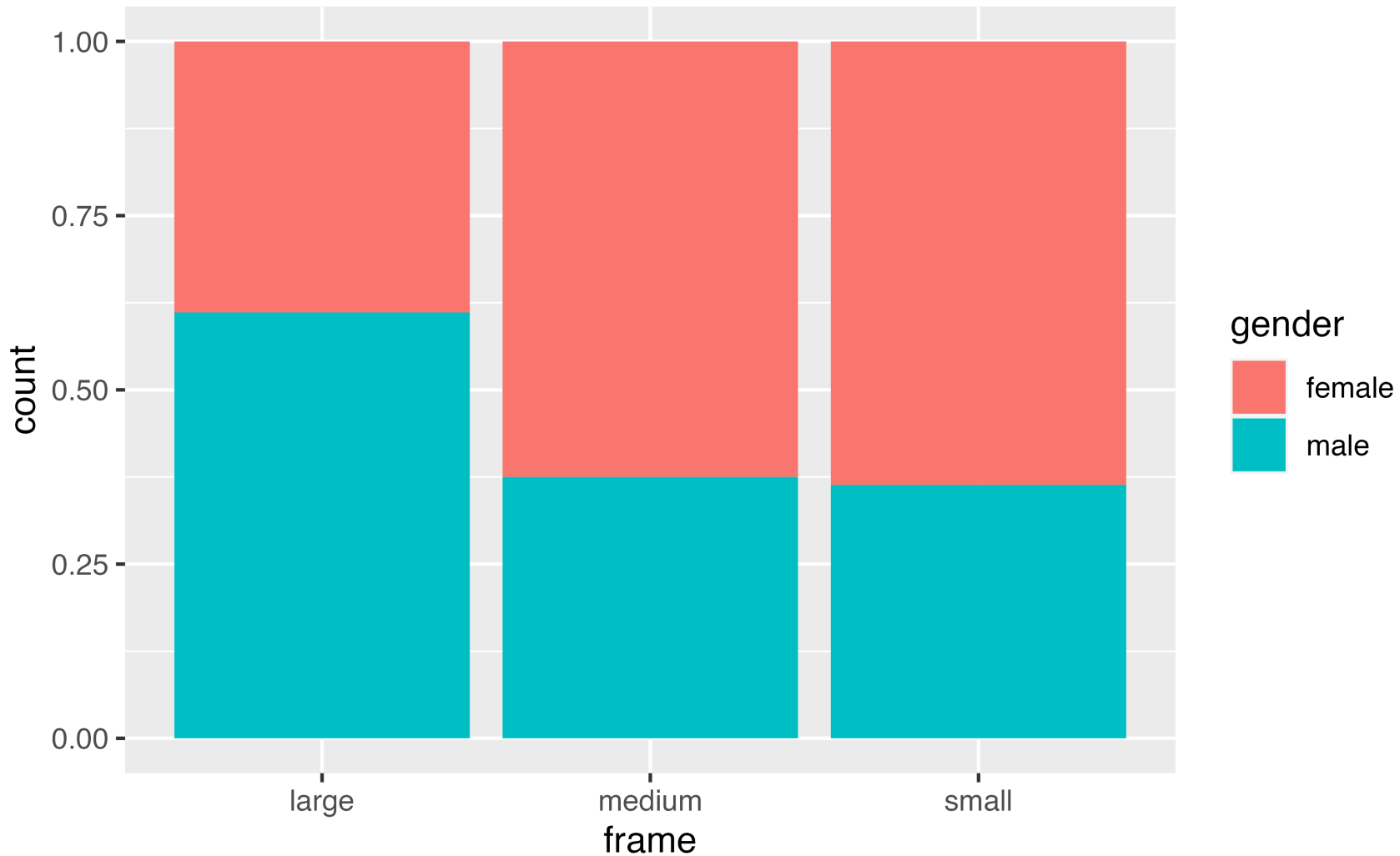
```r
diabetes |>
  drop_na() |>
  ggplot(aes(x = frame, fill = gender)) +
  geom_bar(position = "stack")
```



```r
diabetes |>
  drop_na() |>
  ggplot(aes(x = frame, fill = gender)) +
  geom_bar(position = "dodge")
```



```r
diabetes |>
  drop_na() |>
  ggplot(aes(x = frame, fill = gender)) +
  geom_bar(position = "fill")
```



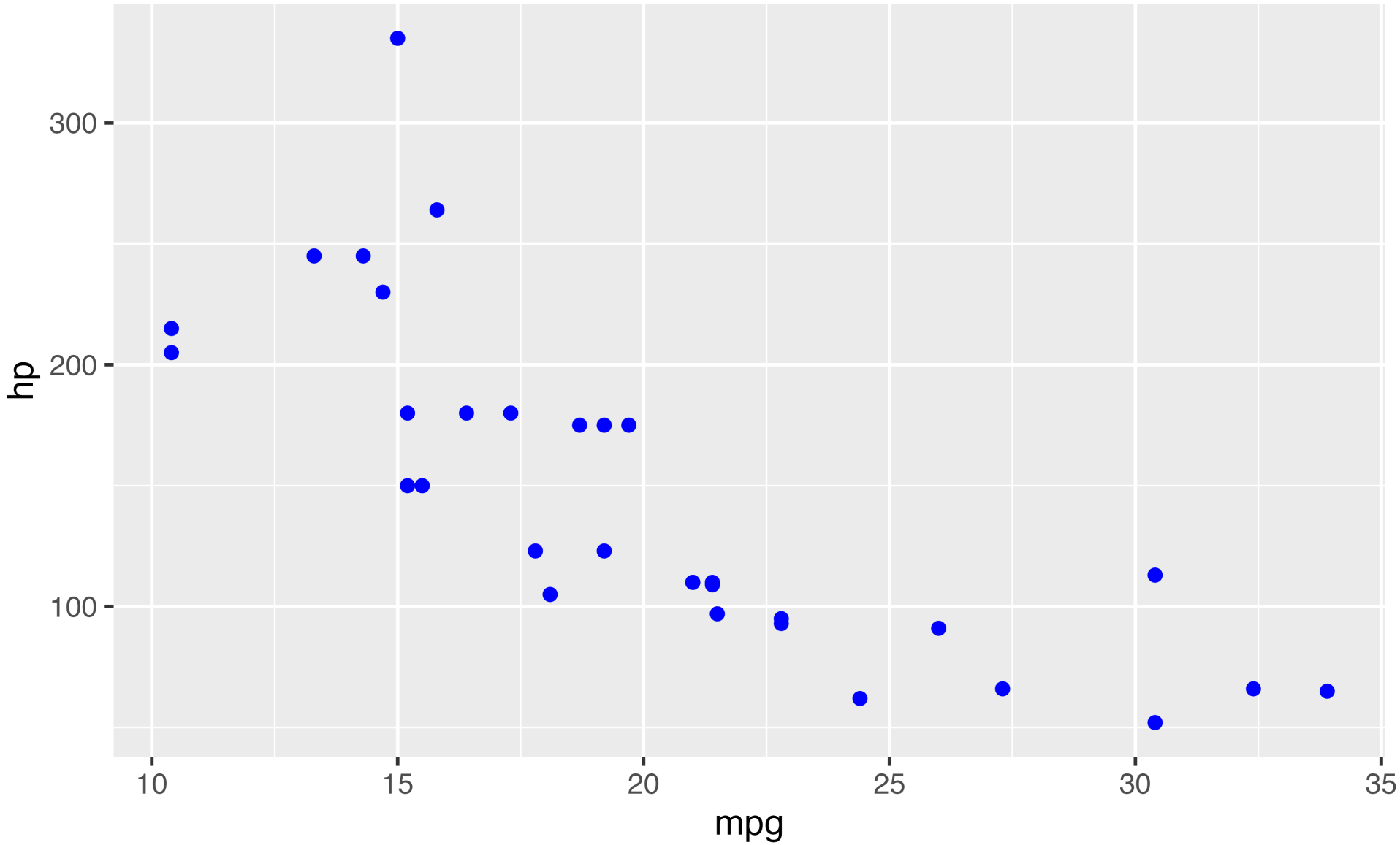
Mapping vs setting

Cool, but how do I just make everything ***blue***?

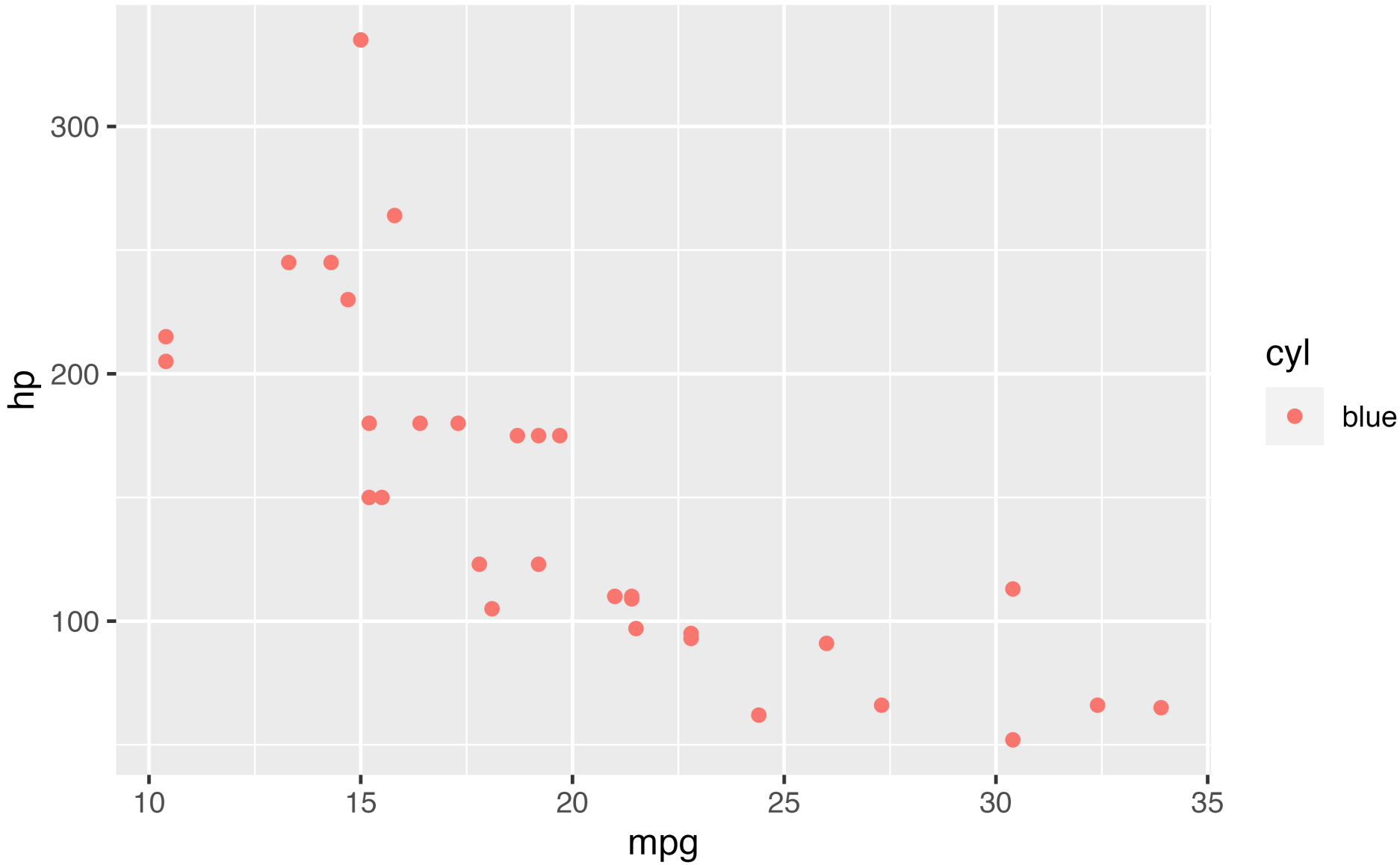
```
geom_point(aes(x, y), color = "blue")
geom_bar(aes(x, y), fill = "blue")
```

To set a color, put it **outside** `aes()`

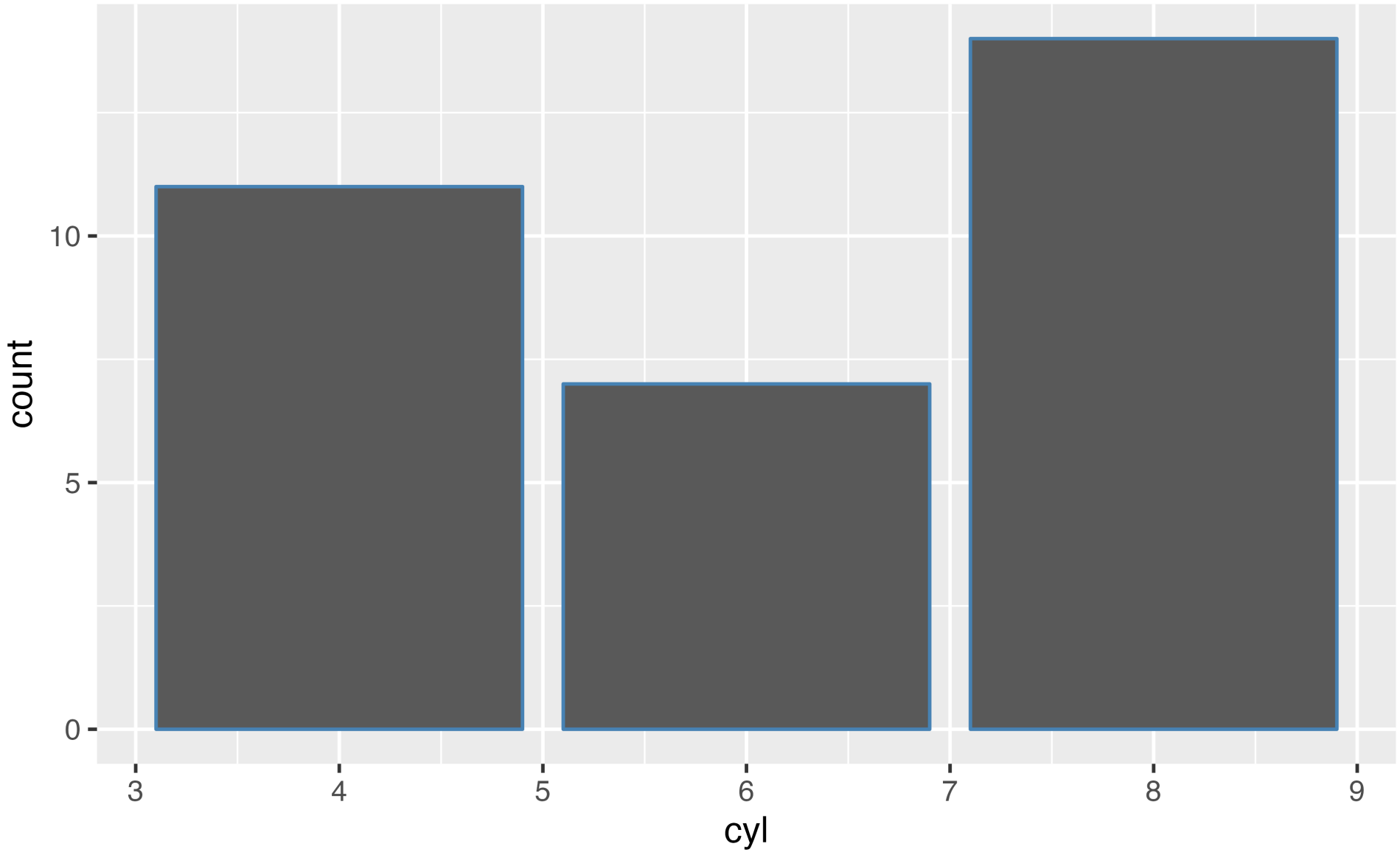
```r
ggplot(mtcars, aes(x = mpg, y = hp, color = cyl)) +
  geom_point(color = "blue")
```



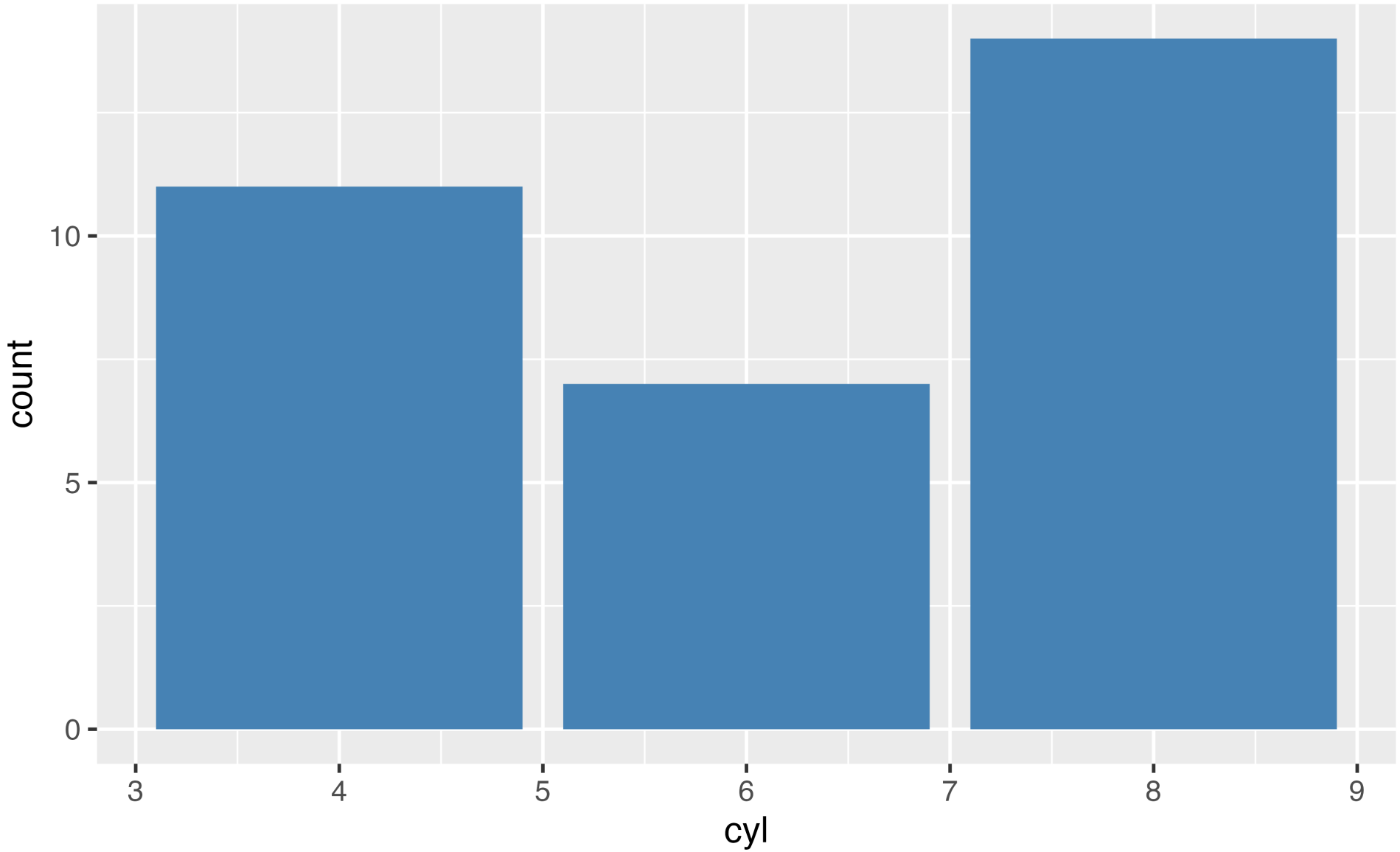
```r
ggplot(mtcars, aes(x = mpg, y = hp, color = cyl)) +
  geom_point(aes(color = "blue"))
```



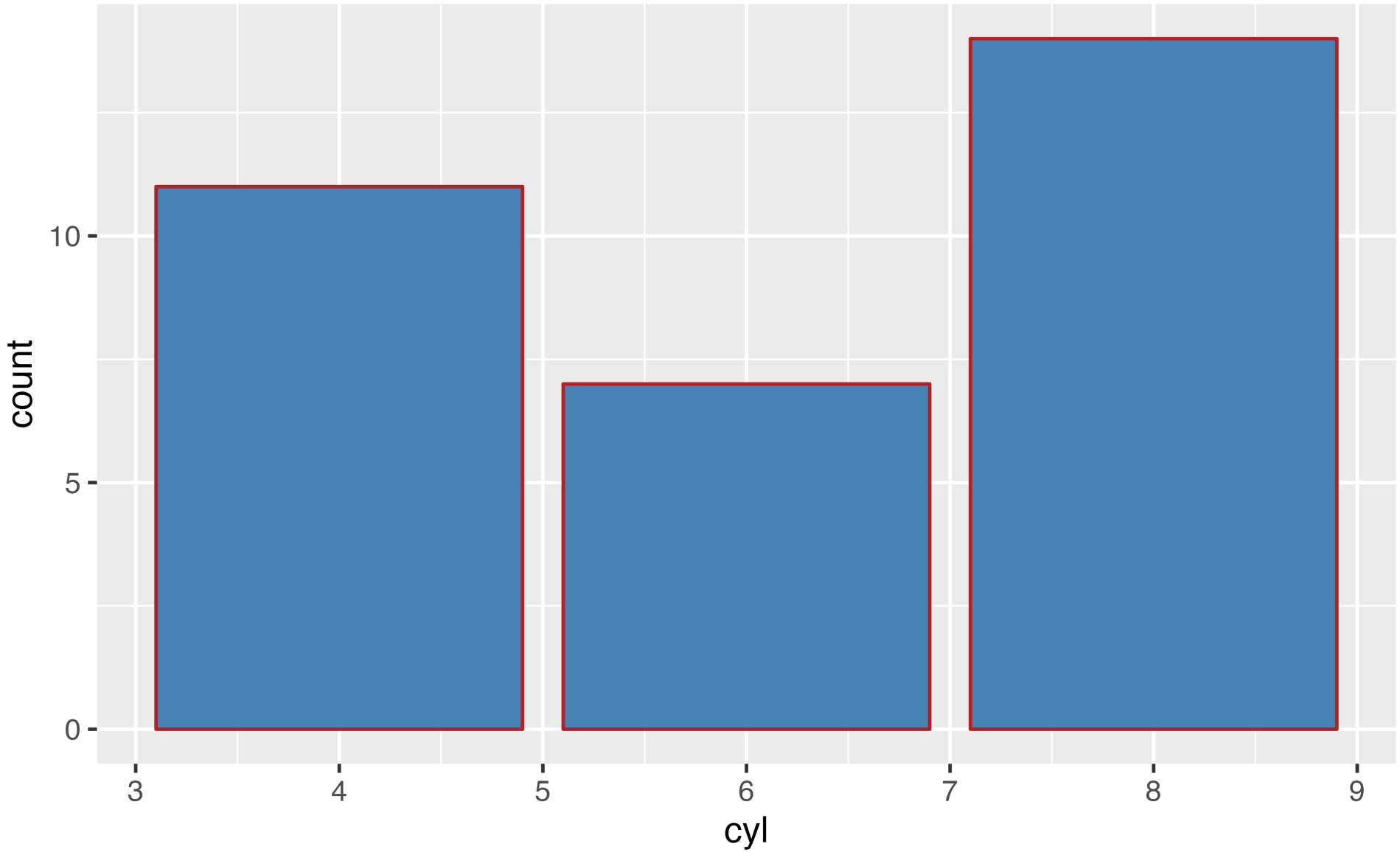
```r
ggplot(mtcars, aes(x = cyl)) +
  geom_bar(color = "steelblue")
```



```r
ggplot(mtcars, aes(x = cyl)) +
  geom_bar(fill = "steelblue")
```



```r
ggplot(mtcars, aes(x = cyl)) +
  geom_bar(color = "firebrick", fill = "steelblue")
```



Adding layers

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

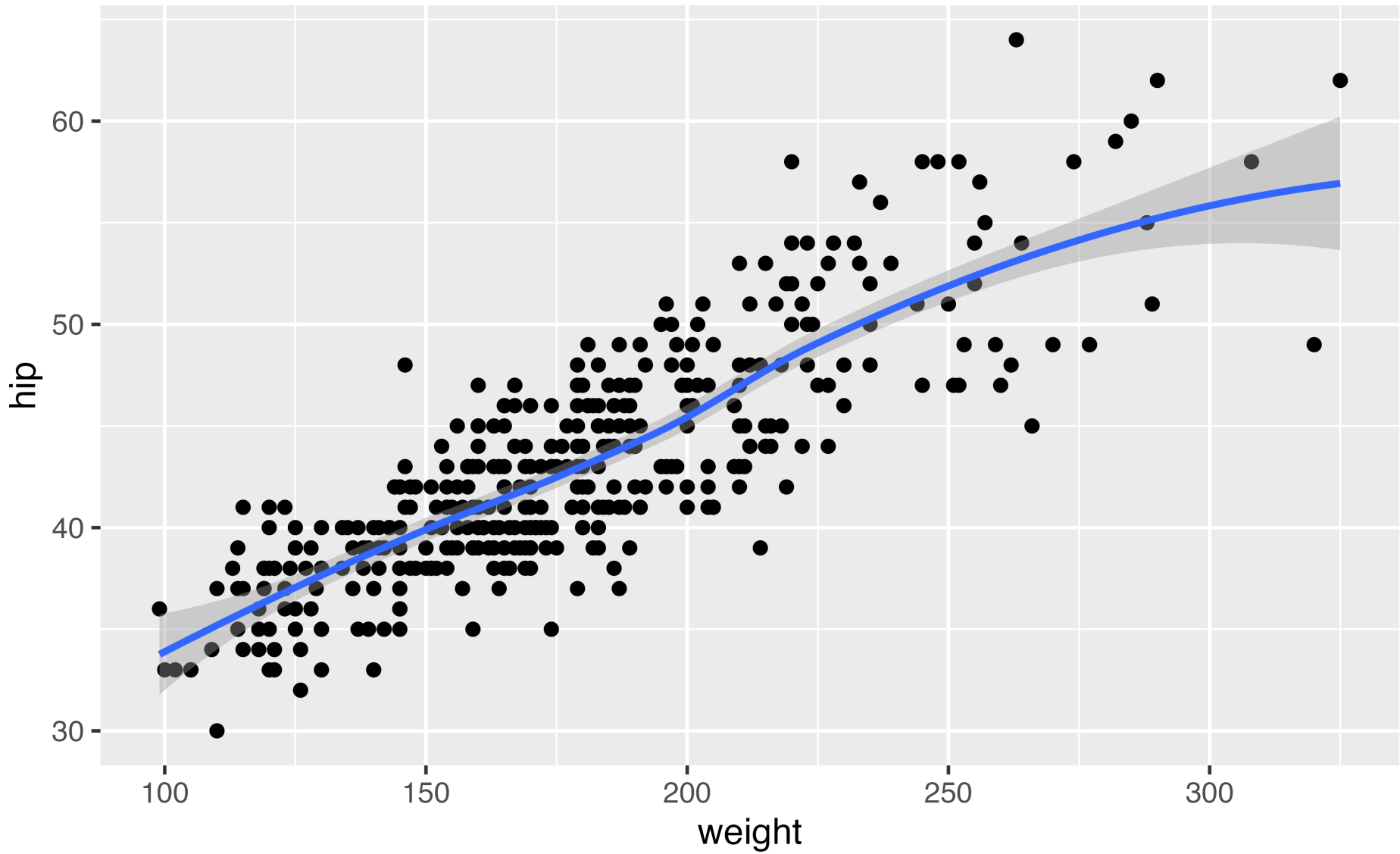
Your Turn 7

Run the code after every change you make.

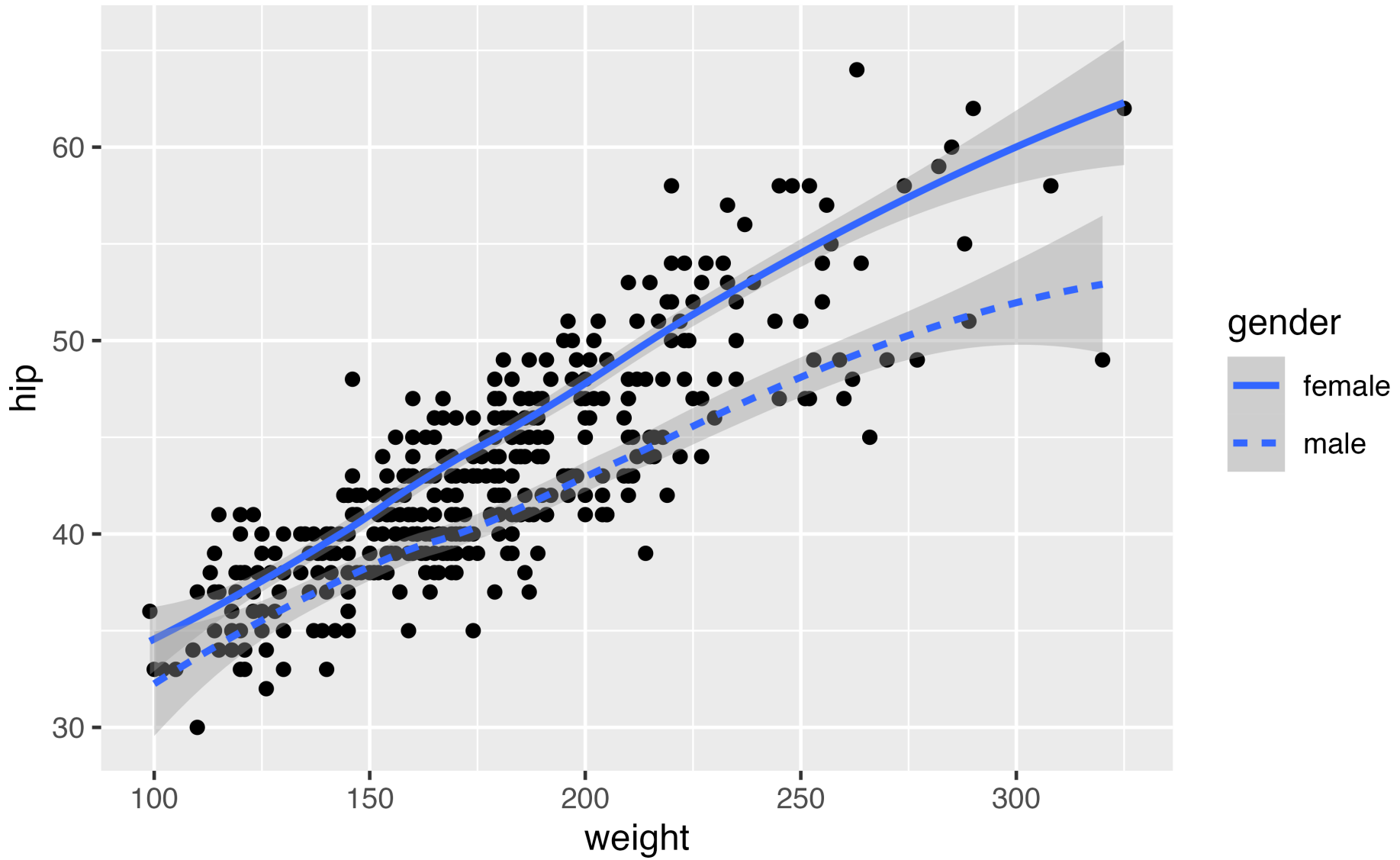
1. Predict what this code will do. Then run it.
2. Add a `linetype` aesthetic for `gender`. Run it again.
3. Set the color of `geom_smooth()` to "black"
4. Add `se = FALSE` to the `geom_smooth()`
5. It's hard to see the lines well now. How about setting `alpha = .2` in `geom_point()`?
6. Jitter the points. You can either change the geom or change the `position` argument.
7. Add another layer, `theme_bw()`. Remember to use `+`.

```
1 ggplot(diabetes, aes(weight, hip)) +
2   geom_point() +
3   geom_smooth()
```

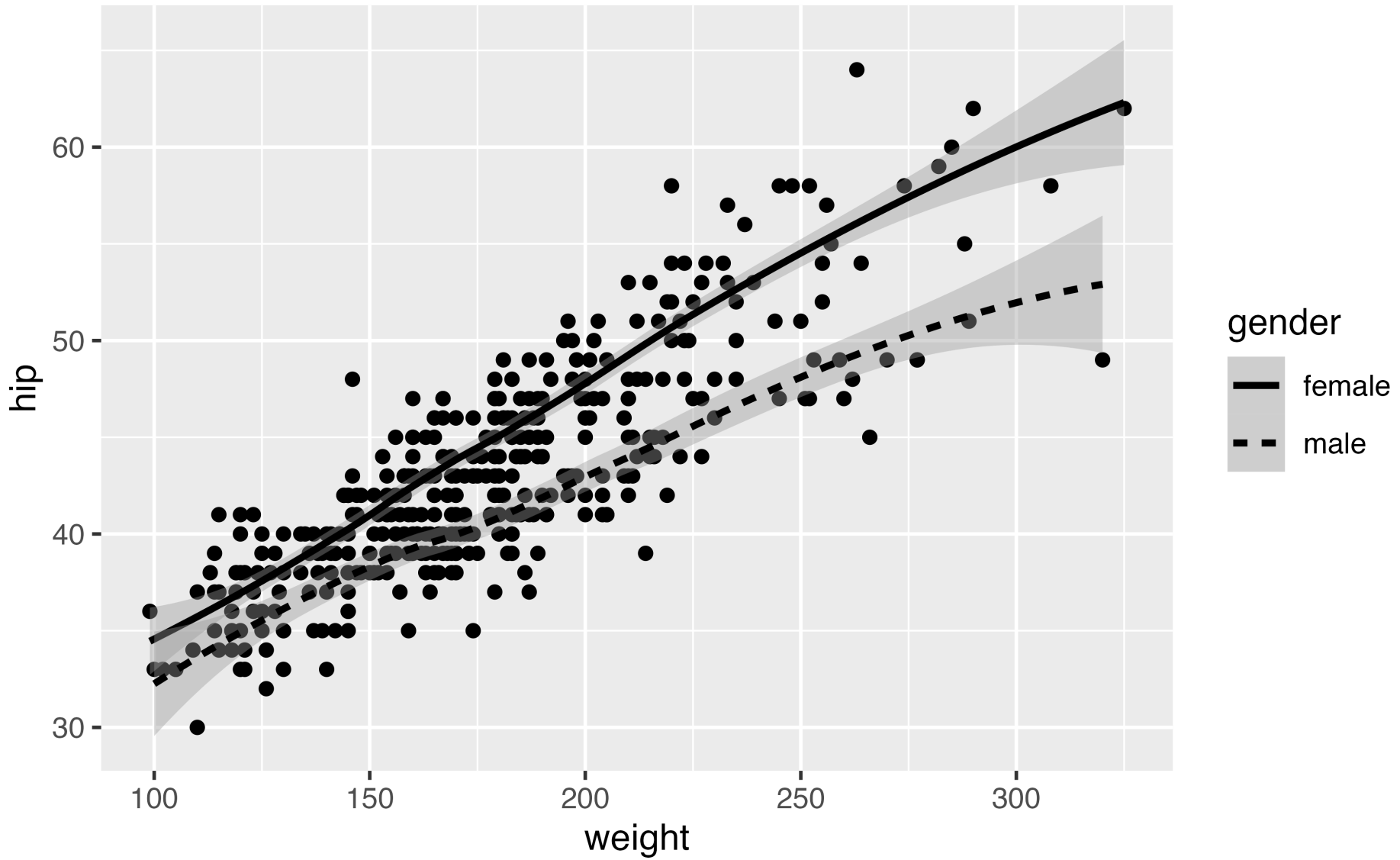
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point() +
  geom_smooth()
```



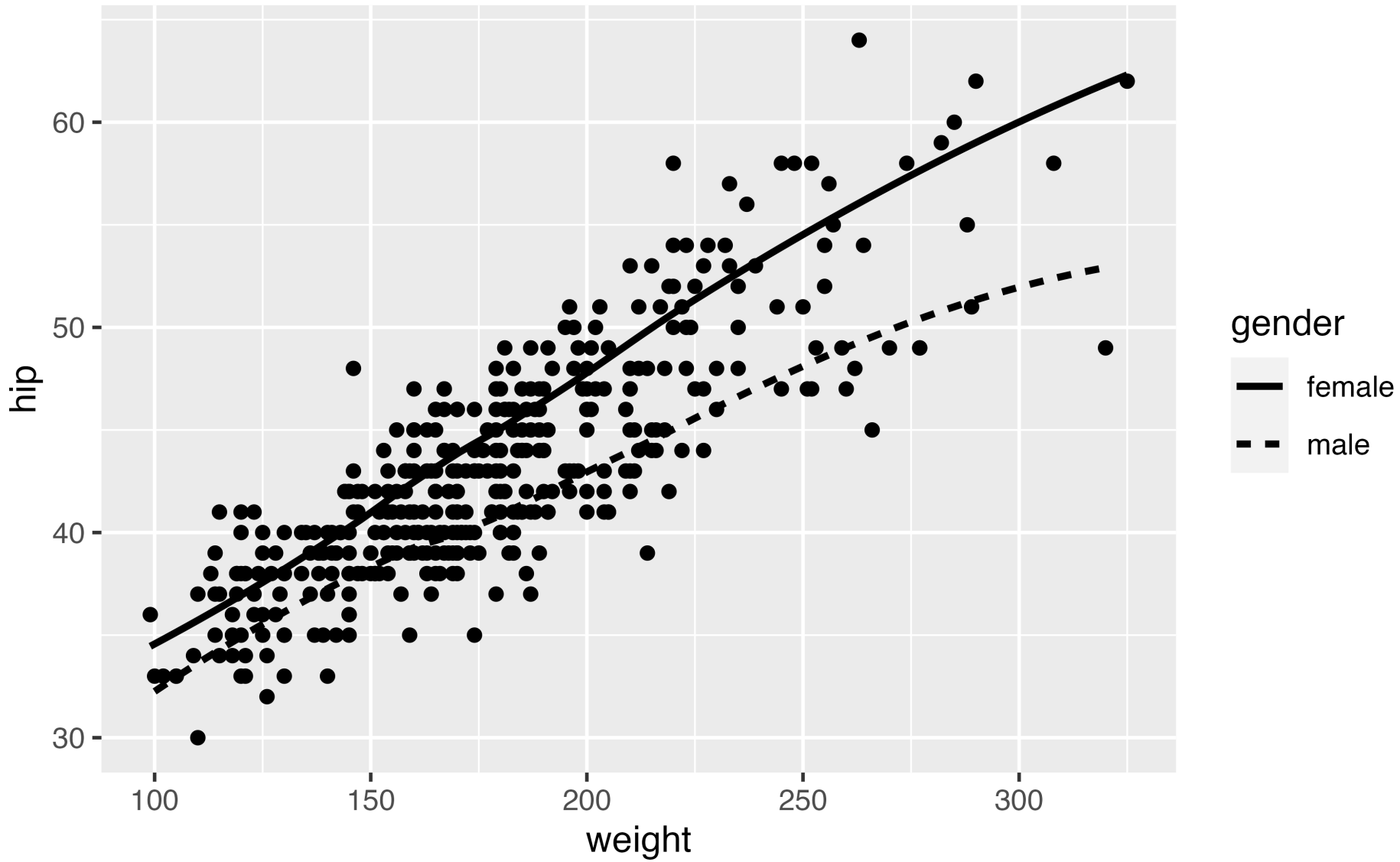
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point() +
  geom_smooth(aes(linetype = gender))
```



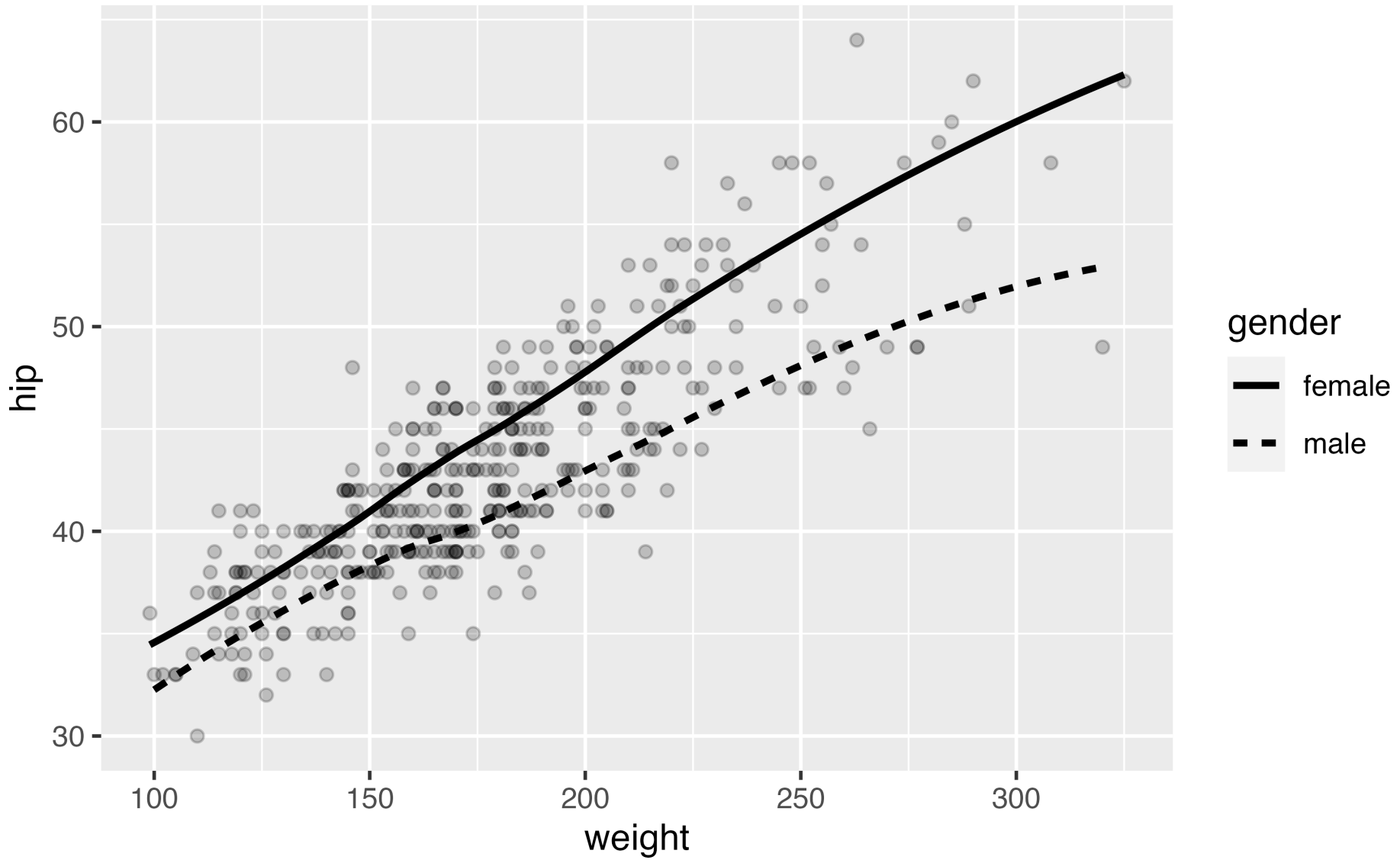
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point() +
  geom_smooth(aes(linetype = gender), color = "black")
```



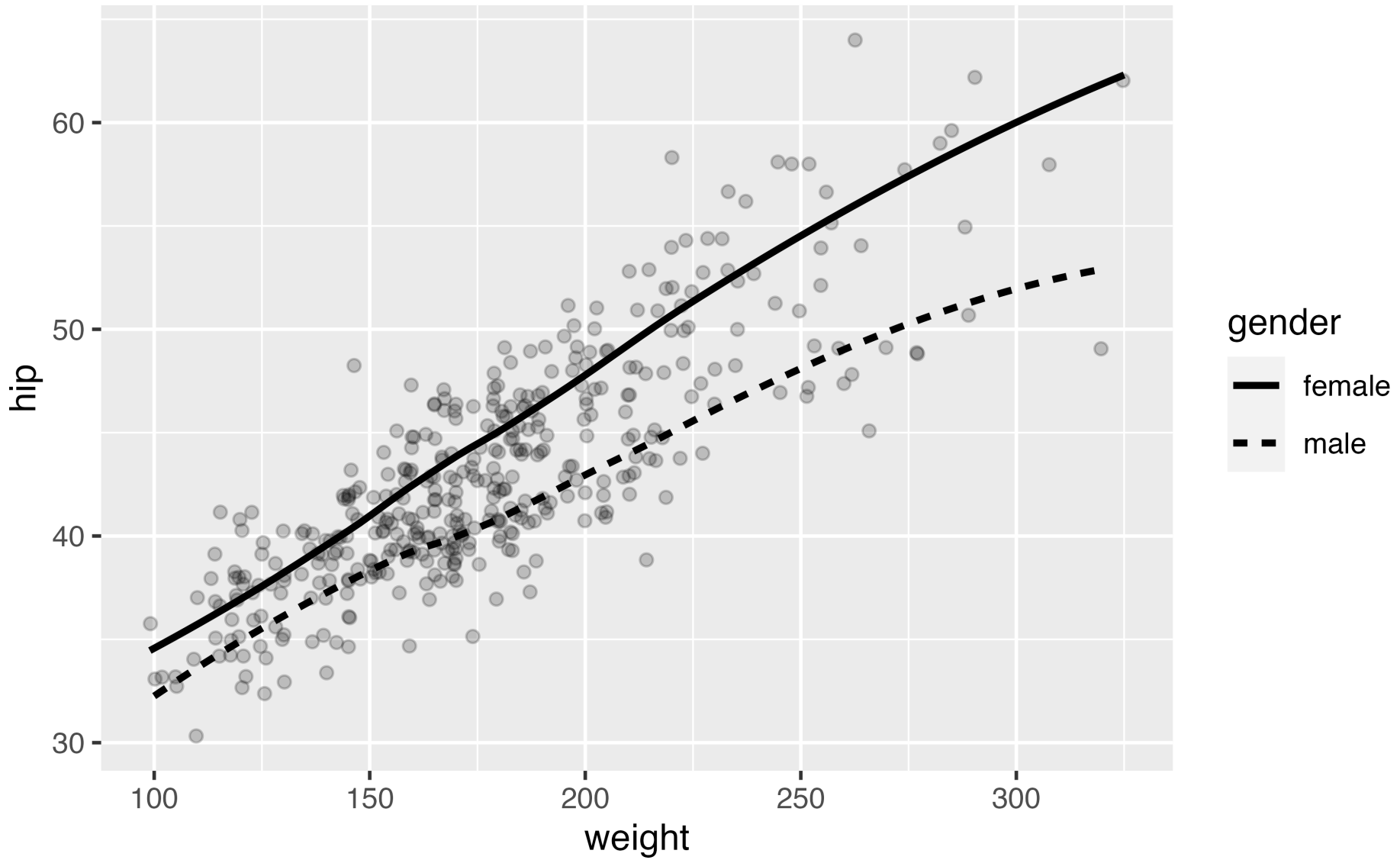
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point() +
  geom_smooth(aes(linetype = gender), color = "black", se = FALSE)
```



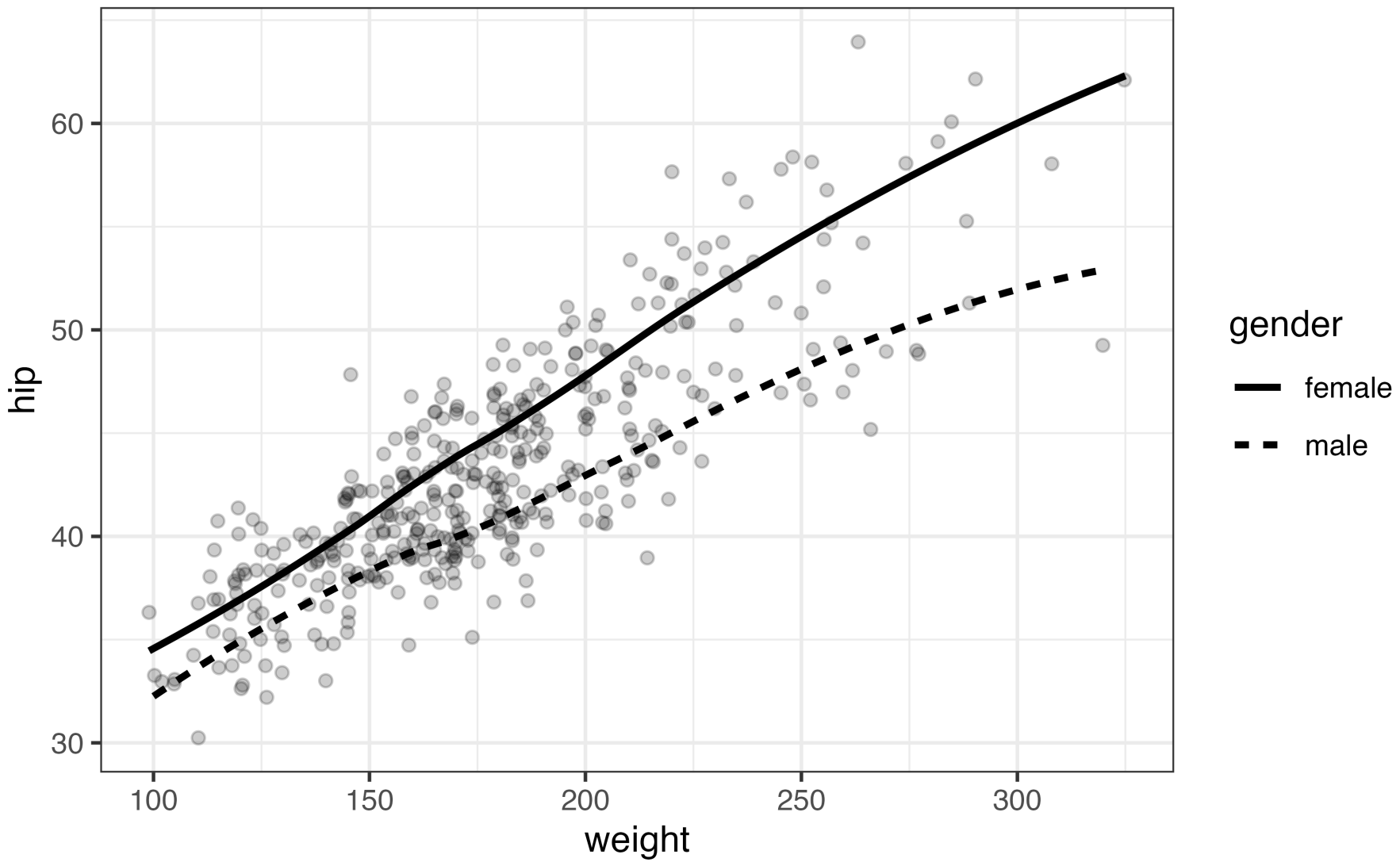
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point(alpha = .2) +
  geom_smooth(aes(linetype = gender), color = "black", se = FALSE)
```



```r
ggplot(diabetes, aes(weight, hip)) +
  geom_jitter(alpha = .2) +
  geom_smooth(aes(linetype = gender), color = "black", se = FALSE)
```



```r
ggplot(diabetes, aes(weight, hip)) +
  geom_jitter(alpha = .2) +
  geom_smooth(aes(linetype = gender), color = "black", se = FALSE) +
  theme_bw()
```

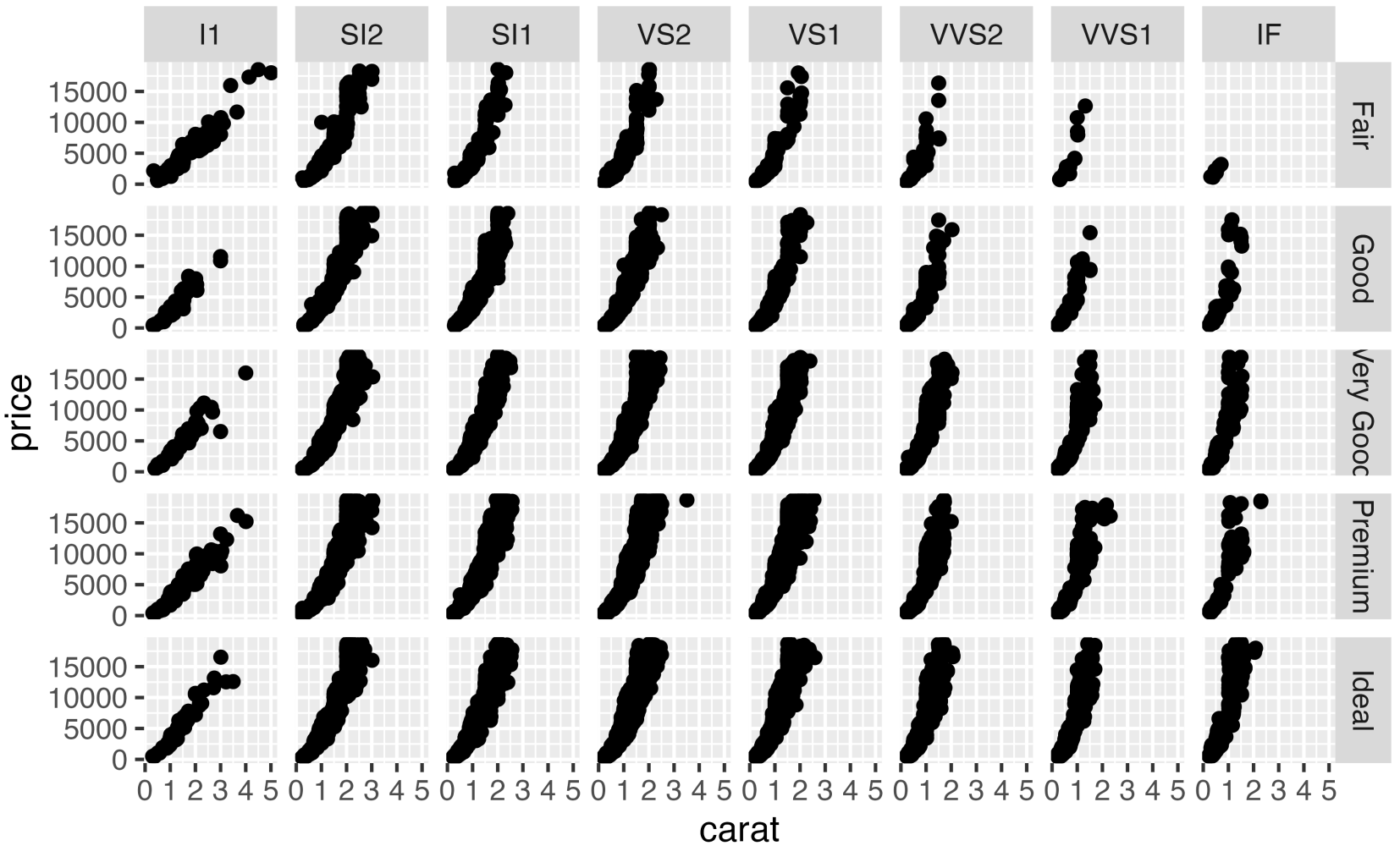


Facets

Easily split your plot into panels

```
facet_grid()
facet_wrap()
facet_grid(x ~ y)
facet_wrap(~ x)
```

```r
diamonds |>
  ggplot(aes(x = carat, y = price)) +
  geom_point() +
  facet_grid(cut ~ clarity)
```

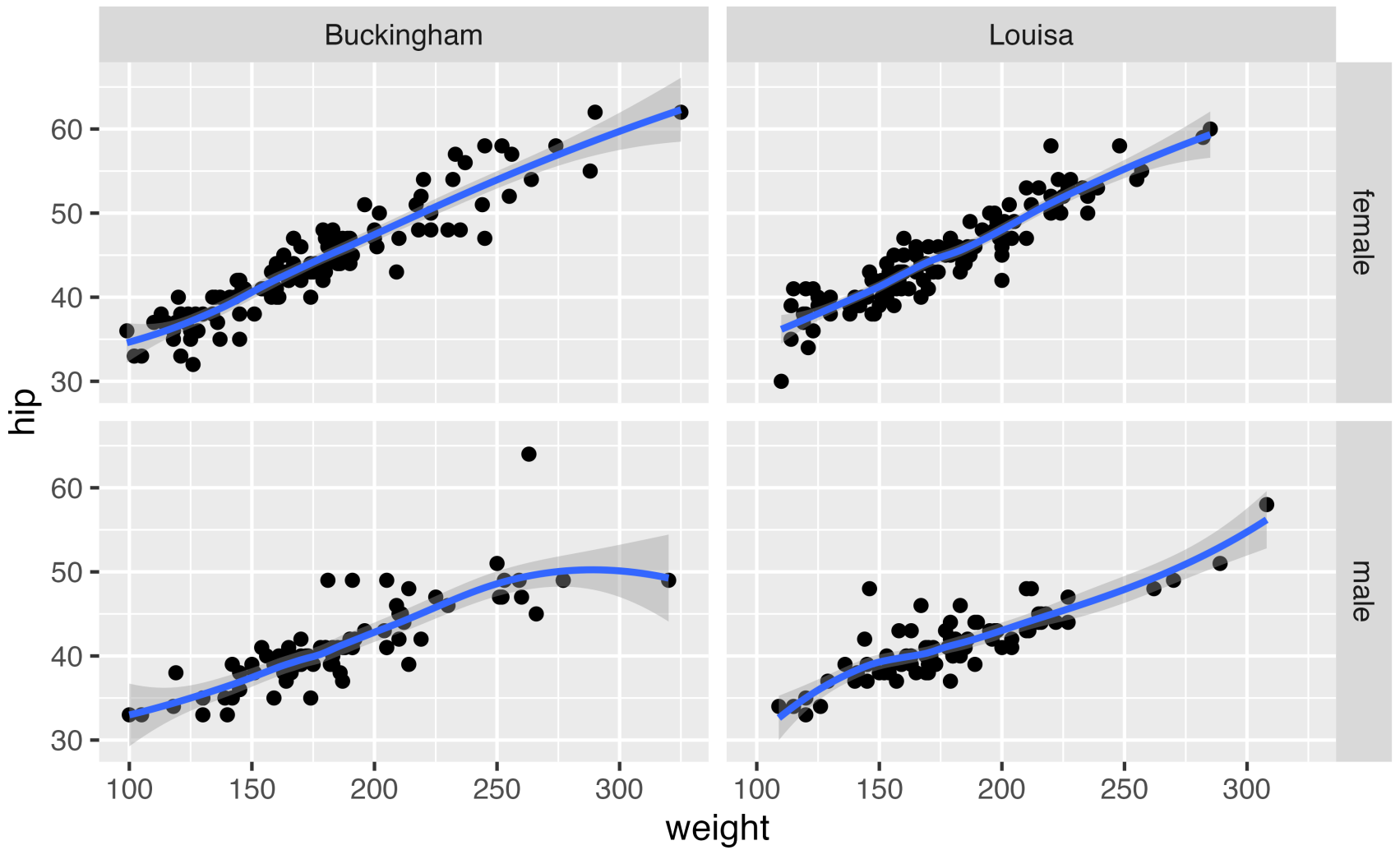


Your Turn 8

Use a facet grid by `gender` and `location`

```
1 ggplot(diabetes, aes(weight, hip)) +
2   geom_point() +
3   geom_smooth()
```

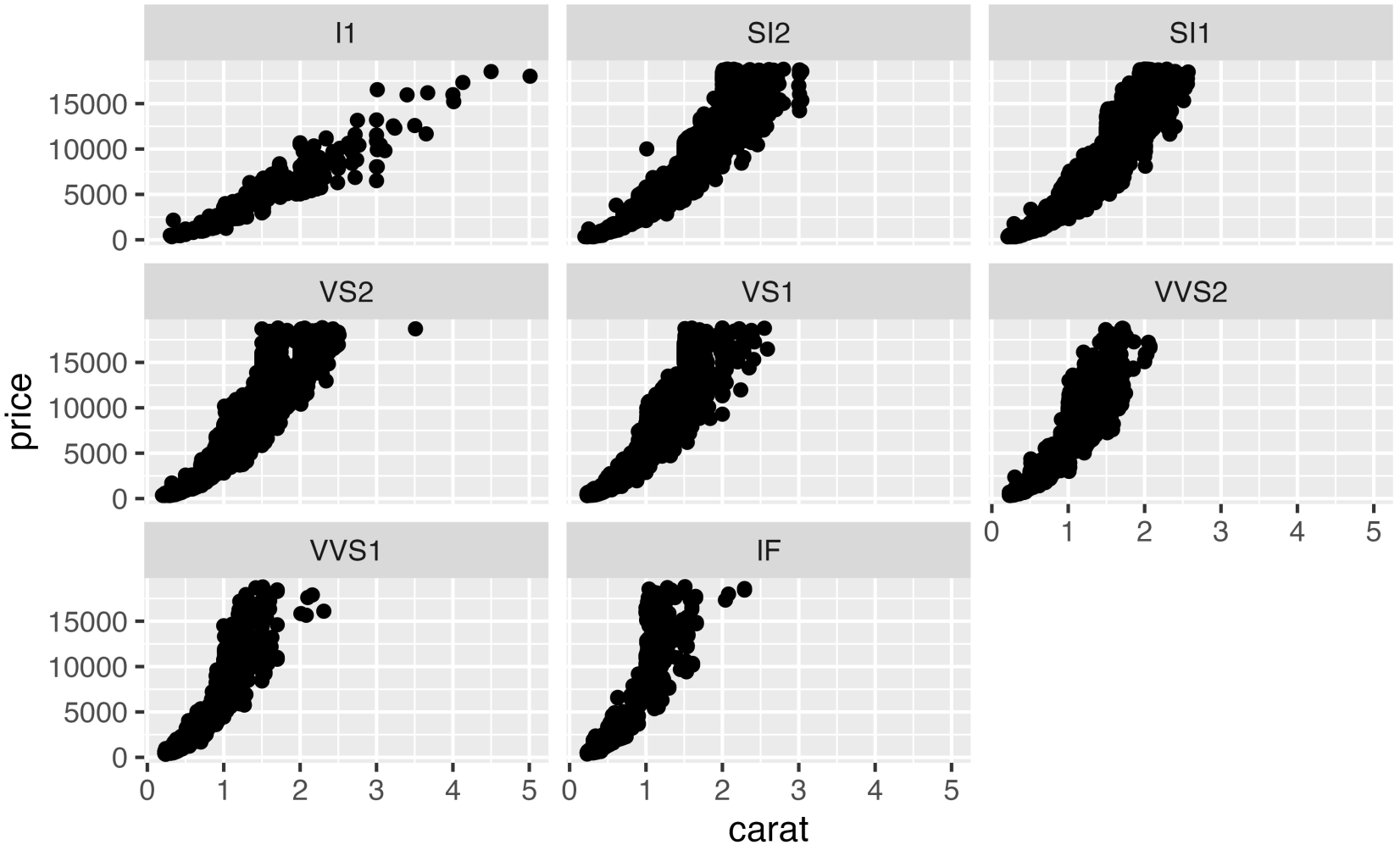
```r
ggplot(diabetes, aes(weight, hip)) +
  geom_point() +
  geom_smooth() +
  facet_grid(gender ~ location)
```



facet_wrap()

```
diamonds |>
  ggplot(aes(x = carat, y = price)) +
  geom_point() +
  facet_wrap(~ clarity)
```

facet_wrap()


I1
SI2
SI1
VS2
VS1
VVS2
VVS1
IF
price
carat
15000
10000
5000
0
0
1
2
3
4
5

datasauRus

```r
library(datasauRus)
datasaurus_dozen
```

```
# A tibble: 1,846 × 3
   dataset     x     y
   <chr>   <dbl> <dbl>
 1 dino     55.4  97.2
 2 dino     51.5  96.0
 3 dino     46.2  94.5
 4 dino     42.8  91.4
 5 dino     40.8  88.3
 6 dino     38.7  84.9
 7 dino     35.6  79.9
 8 dino     33.1  77.6
 9 dino     29.0  74.5
10 dino     26.2  71.4
# ℹ 1,836
```

new data alert!

datasaurus_dozen

	dataset	x	y
1	dino	55.38460	97.179500
2	dino	51.53850	96.025600
3	dino	46.15380	94.487200
4	dino	42.82050	91.410300
5	dino	40.76920	88.333300
6	dino	38.71790	84.871800
7	dino	35.64100	79.871800
8	dino	33.07690	77.564100
9	dino	28.97440	74.487200
10	dino	26.15380	71.410300
11	dino	23.07690	66.410300
12	dino	22.30770	61.794900
13	dino	22.30770	57.179500
14	dino	23.33330	52.948700
15	dino	25.89740	51.025600
16	dino	29.48720	51.025600
17	dino	32.82050	51.025600
18	dino	35.38460	51.410300

Where does it come from?

The `datasauRus` R package

How can I use it?

```
library(datasauRus)
View(datasaurus_dozen)
```

it's invisible!

Your Turn 9: Challenge!

1. Load the `datasauRus` package. This package includes a data set called `datasaurus_dozen`.

2. Use dplyr to summarize the correlation between `x` and `y`. First, group it by `dataset`, and then summarize with the `cor()` function. Call the new variable `corr`. What's it look like?

3. Mutate `corr`. Round it to 2 digits. Then, mutate it again (or wrap it around your first change) using: `paste("corr:", corr)`

4. Save the summary data frame as `corrs`.

5. Pass `datasaurus_dozen` to `ggplot()` and add a point geom

6. Use a facet (wrap) for `dataset`.

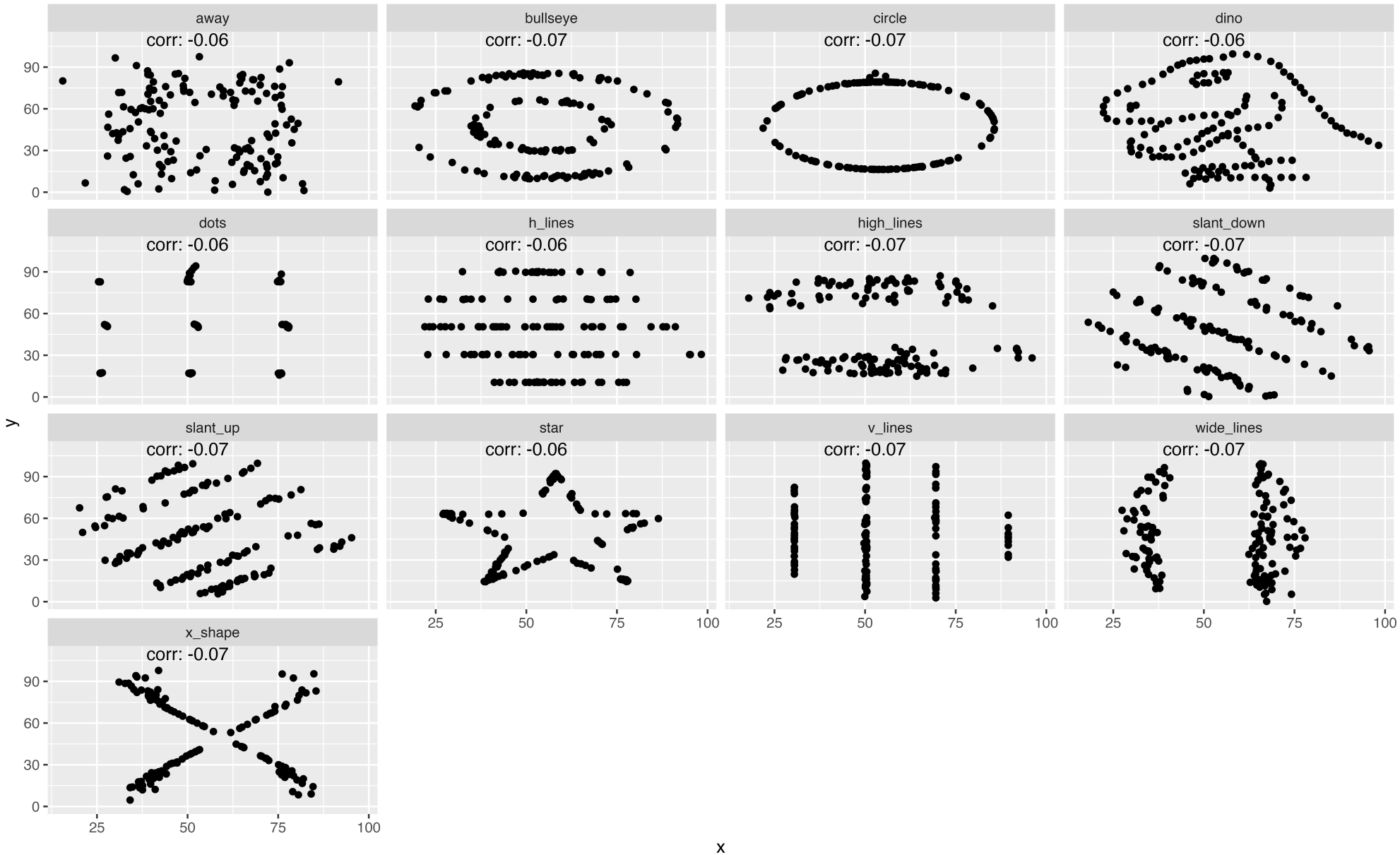
7. Add a text geom. For this geom, set `data = corrs`. You also need to use `aes()` in this call to set `label = corr`, `x = 50`, and `y = 110`.

```r
corrs <- datasaurus_dozen |>
  group_by(dataset) |>
  summarize(corr = cor(x, y)) |>
  mutate(
    corr = round(corr, 2),
    corr = paste("corr:", corr)
  )
```

```r
corrs
```

```
# A tibble: 13 × 2
   dataset    corr
   <chr>      <chr>
 1 away       corr: -0.06
 2 bullseye   corr: -0.07
 3 circle     corr: -0.07
 4 dino       corr: -0.06
 5 dots       corr: -0.06
 6 h_lines    corr: -0.06
 7 high_lines corr: -0.07
 8 slant_down corr: -0.07
 9 slant_up   corr: -0.07
10 star       corr: -0.06
```

```r
datasaurus_dozen |>
  ggplot(aes(x, y)) +
  geom_point() +
  geom_text(data = corrs, aes(label = corr, x = 50, y = 110)) +
  facet_wrap(~ dataset)
```


away
corr: -0.06
bullseye
corr: -0.07
circle
corr: -0.07
dino
corr: -0.06
dots
corr: -0.06
h_lines
corr: -0.06
high_lines
corr: -0.07
slant_down
corr: -0.07
slant_up
corr: -0.07
star
corr: -0.06
v_lines
corr: -0.07
wide_lines
corr: -0.07
x_shape
corr: -0.07
y
x
0
30
60
90
25
50
75
100