

# LECTURE 4: DATA VISUALIZATION

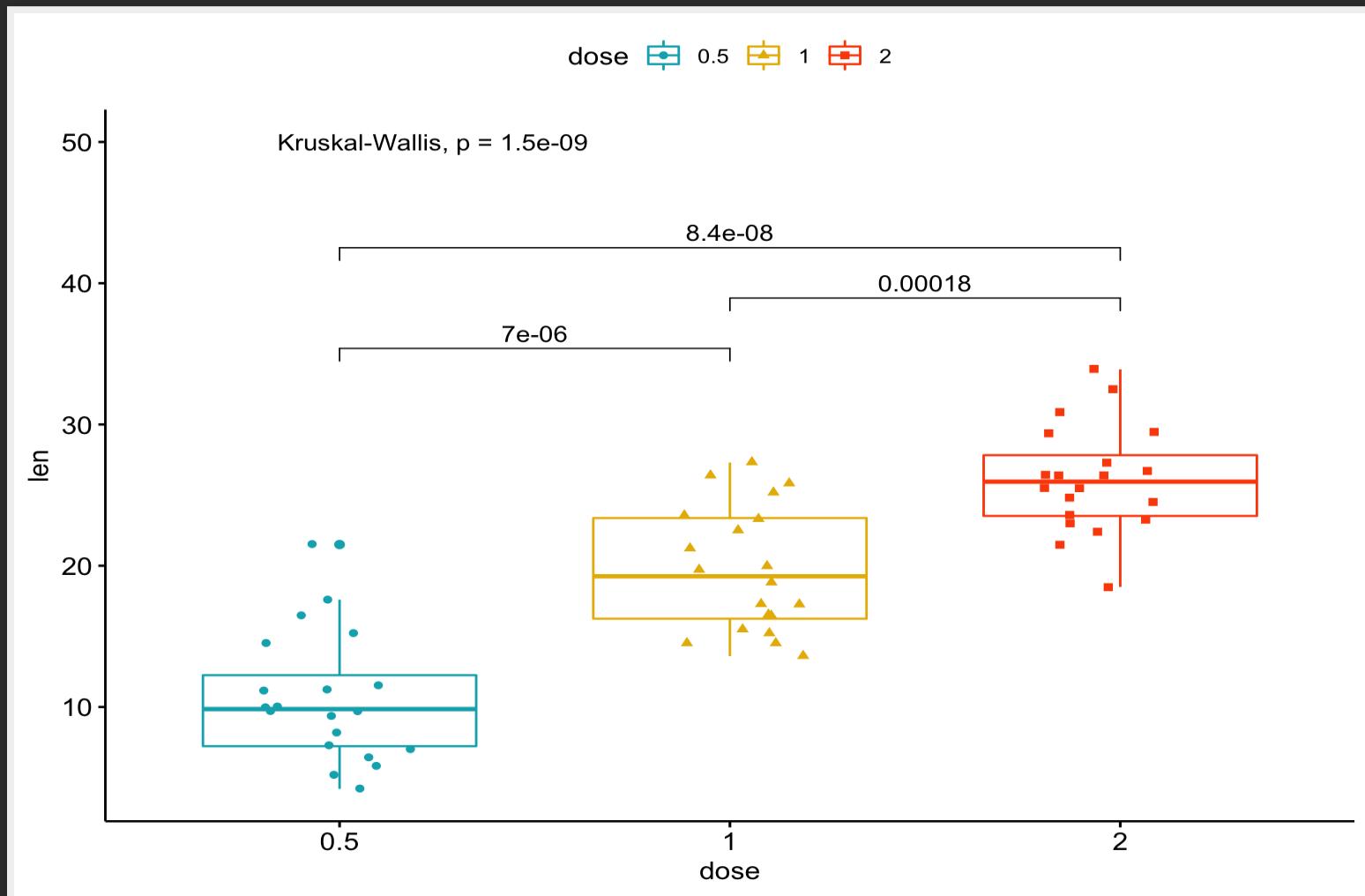
BIOF 339

OCTOBER 3, 2018

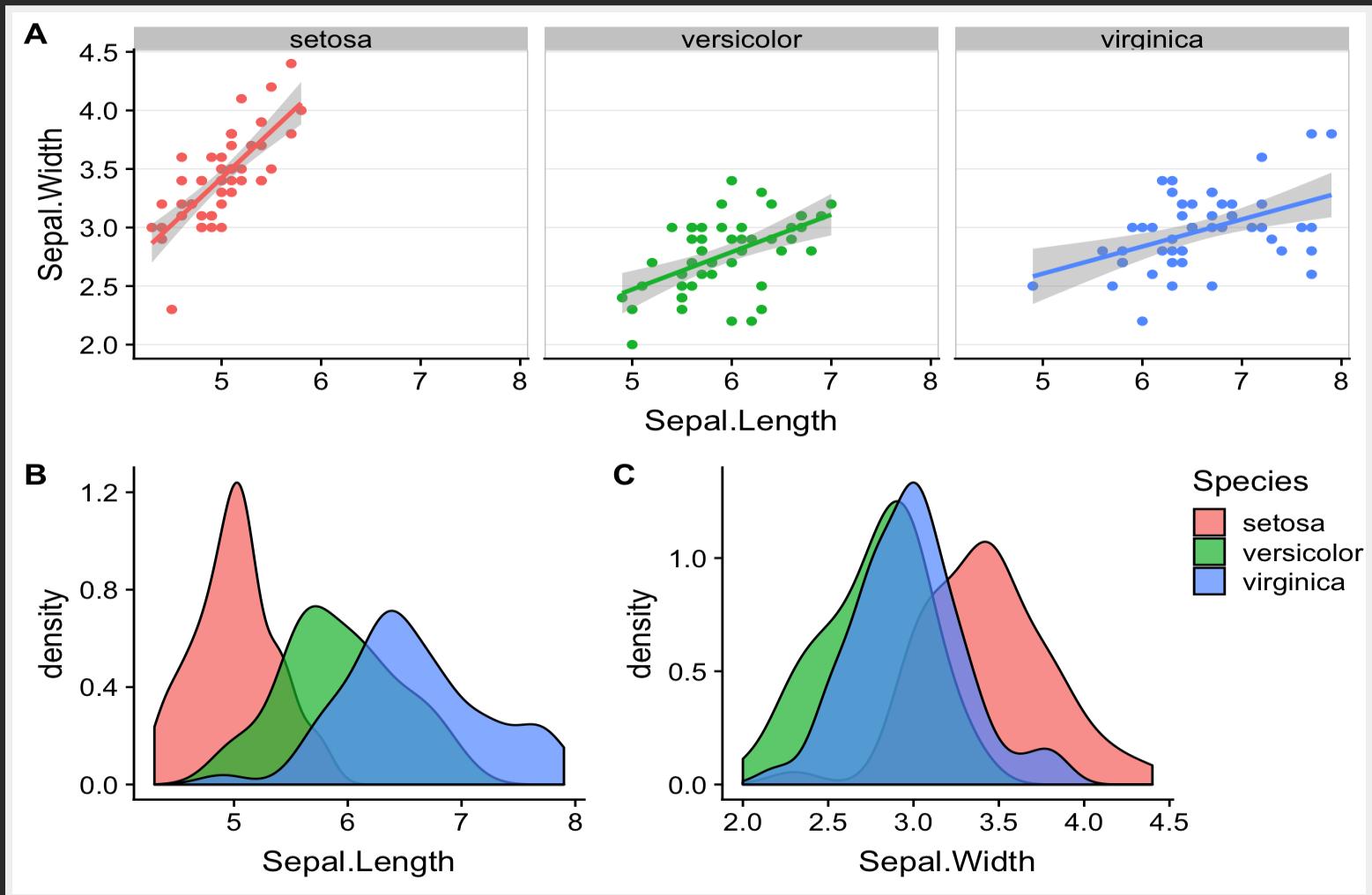


# DATA VISUALIZATION IN R

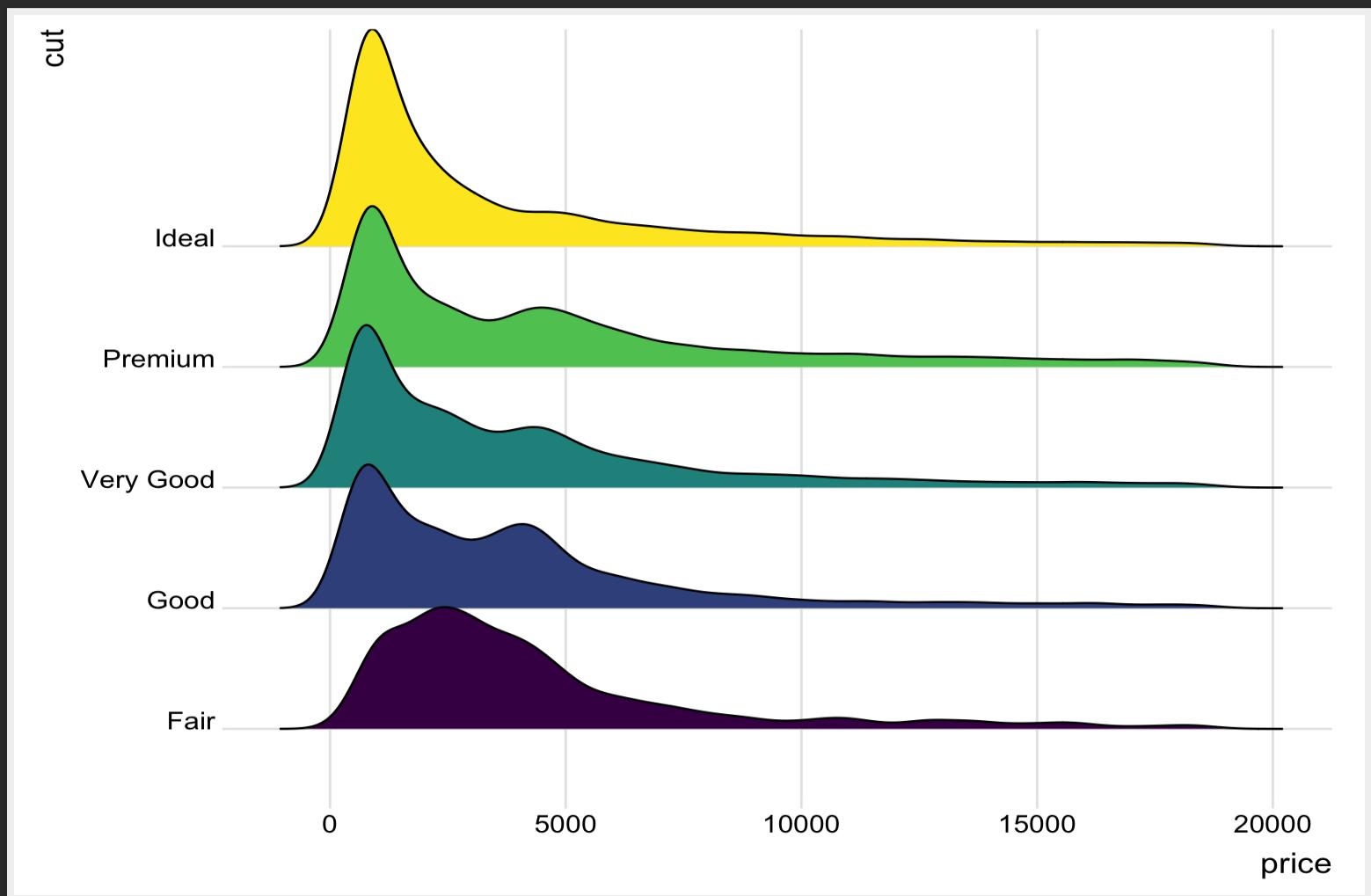
# GALLERY



# GALLERY

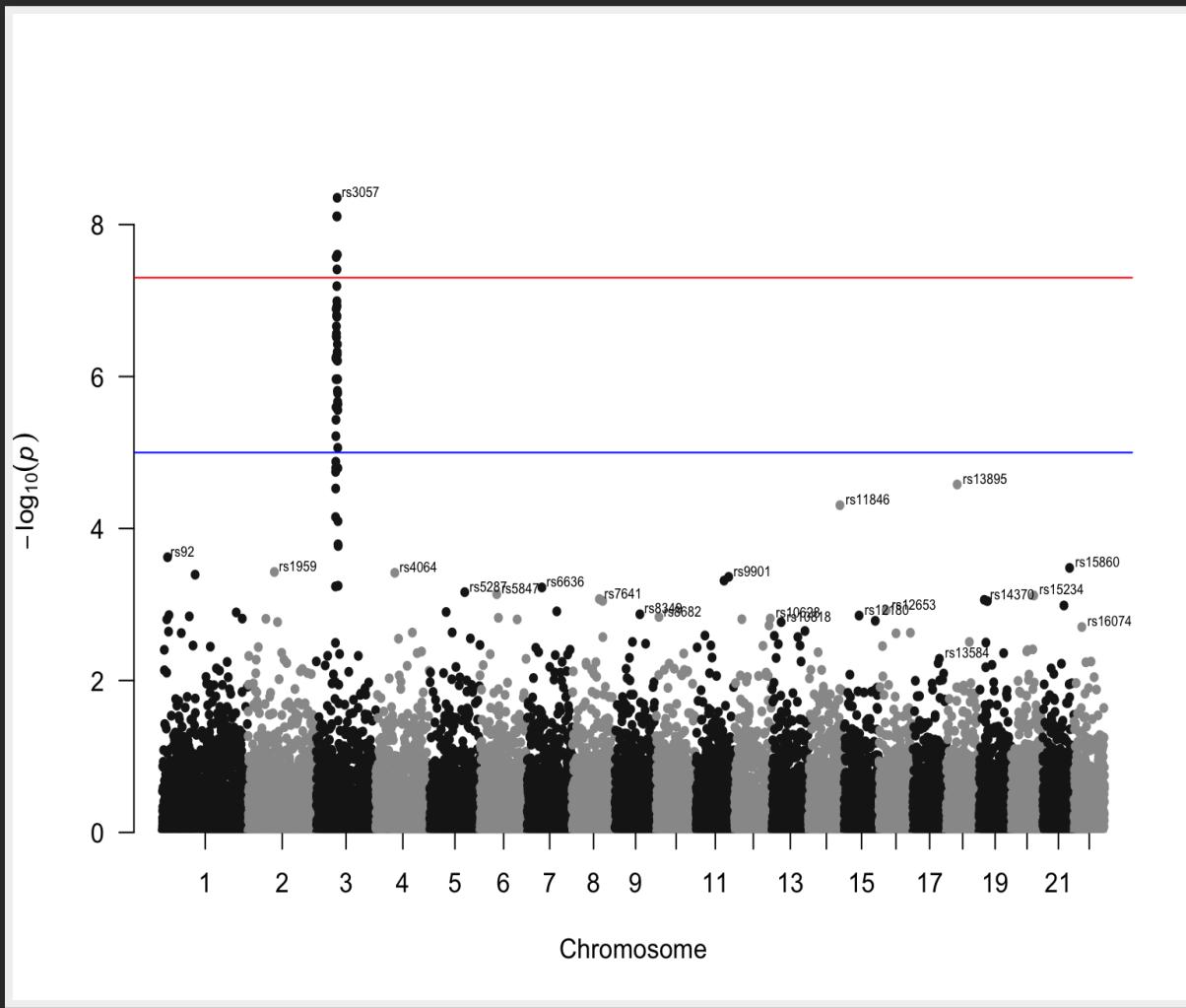


# GALLERY



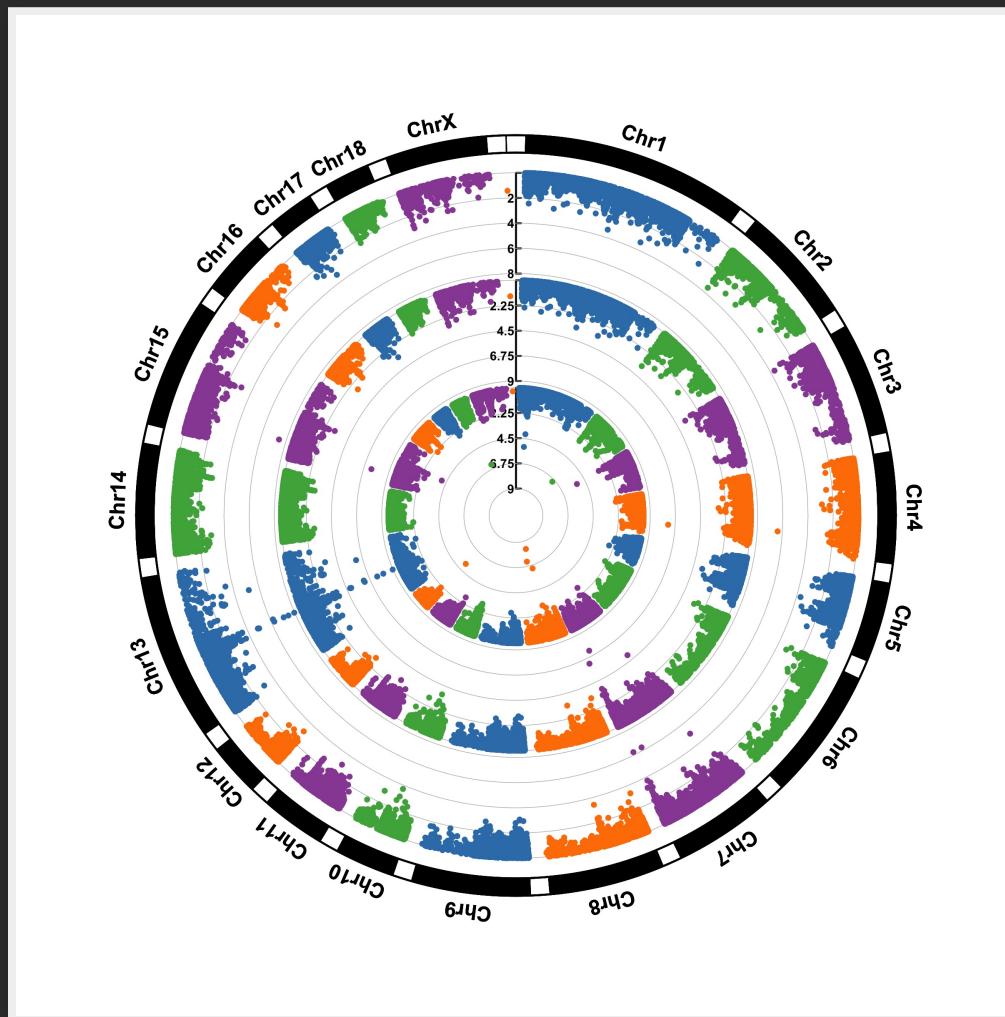
# GALLERY

## MANHATTAN PLOT



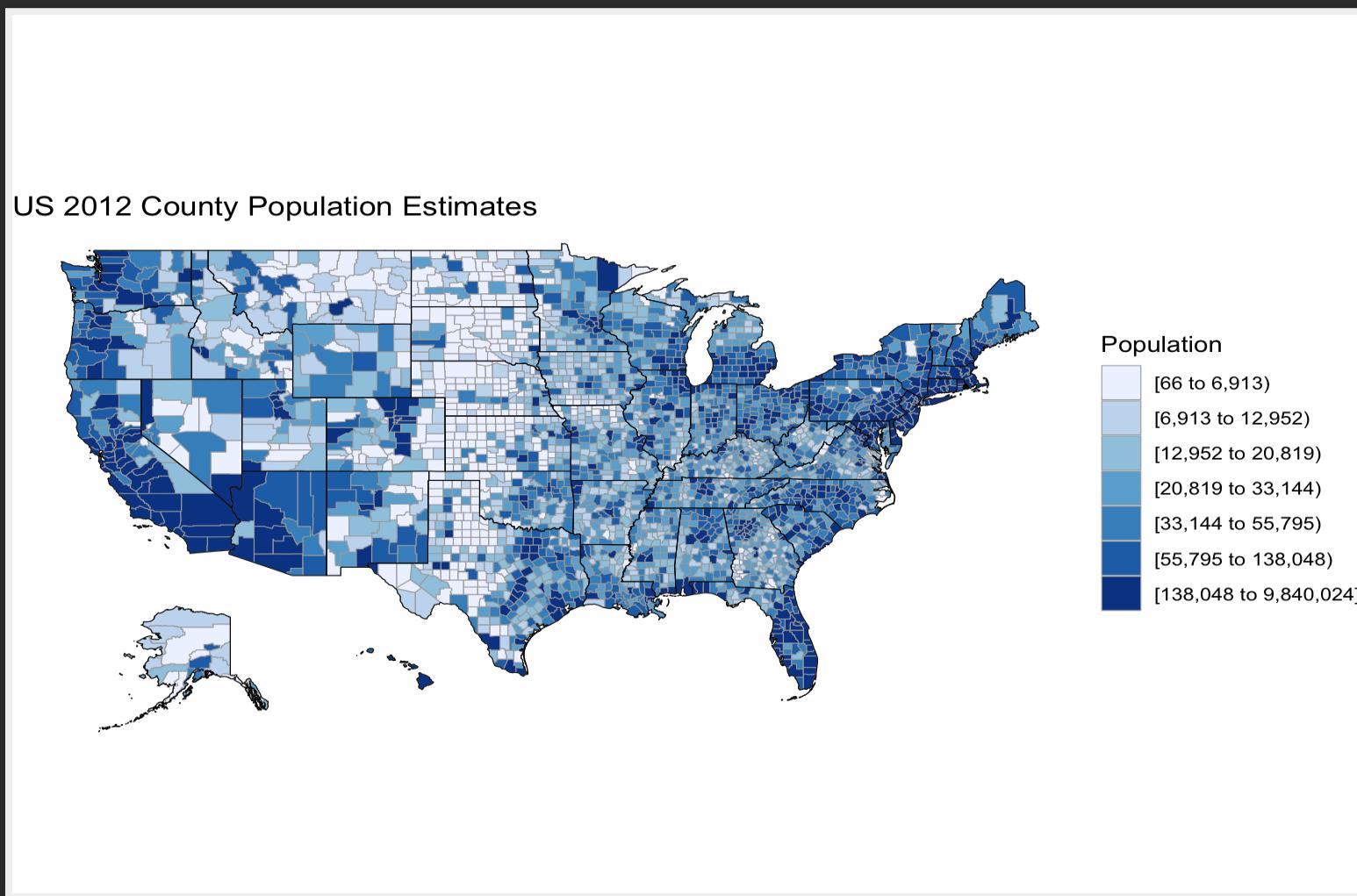
# GALLERY

## CIRCULAR MANHATTAN PLOT



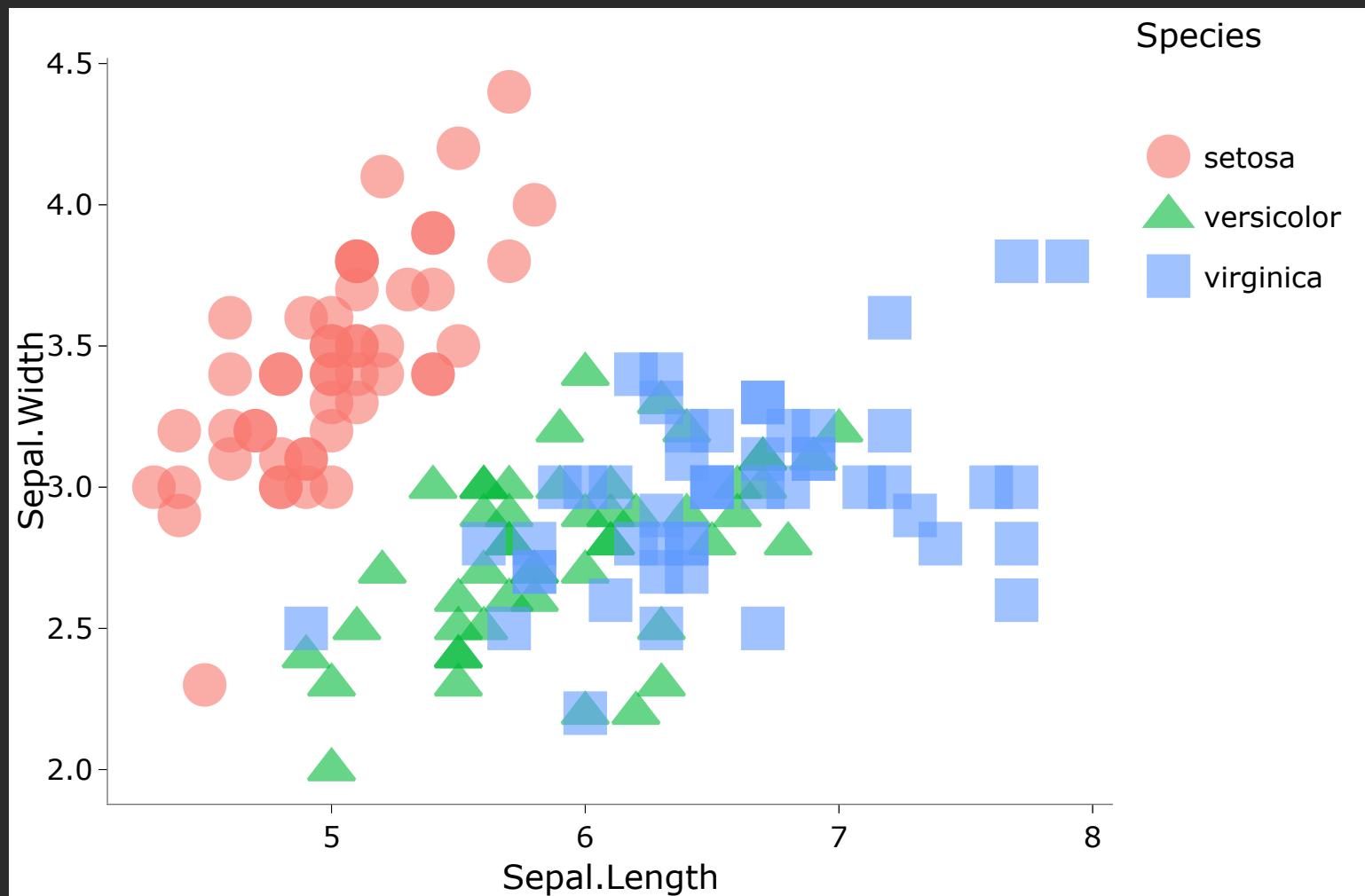
# GALLERY

## MAPS



# GALLERY

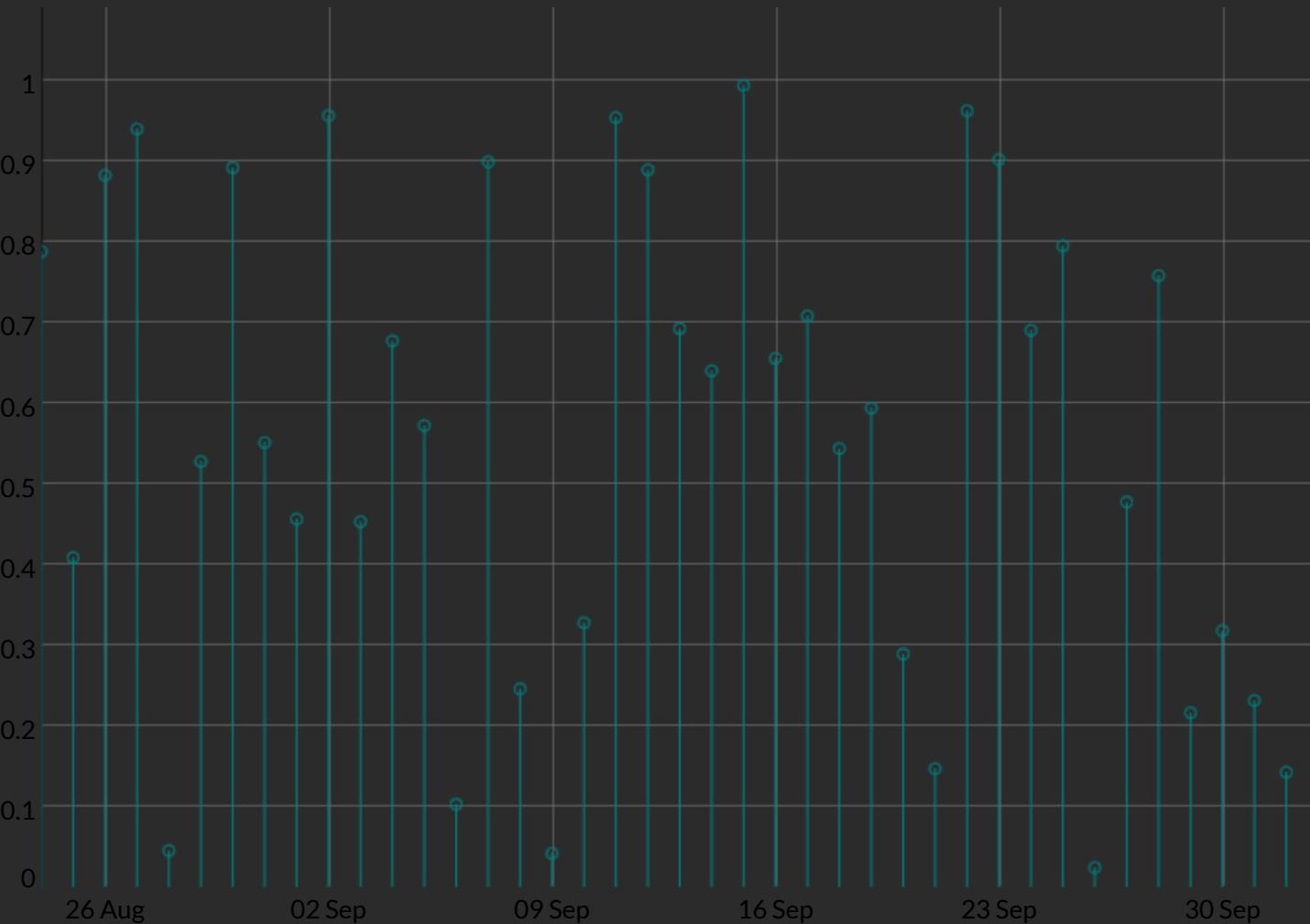
## INTERACTIVE GRAPHS



# GALLERY

## INTERACTIVE GRAPHS

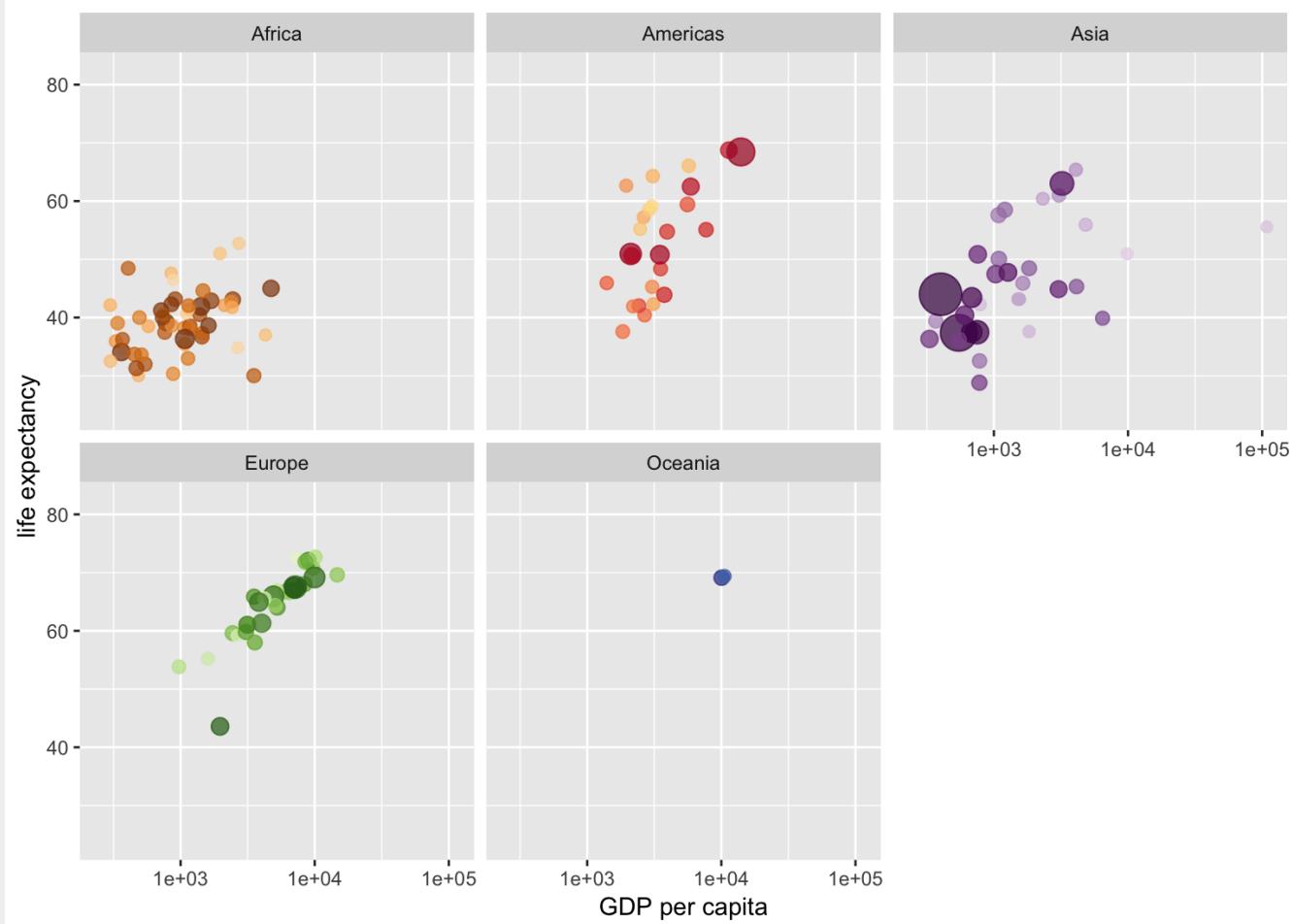
```
#      Date[1:41], format: "2018-08-24" "2018-08-25" "2018-08-26" "2018-08-
```



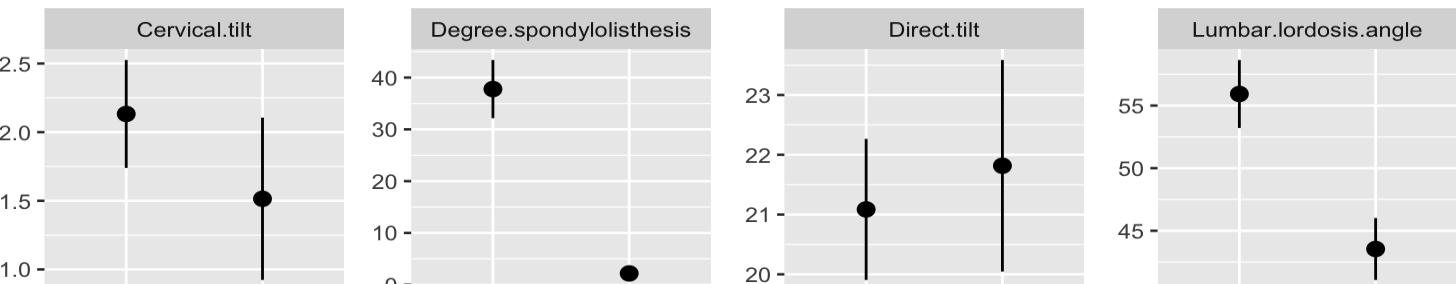
# GALLERY

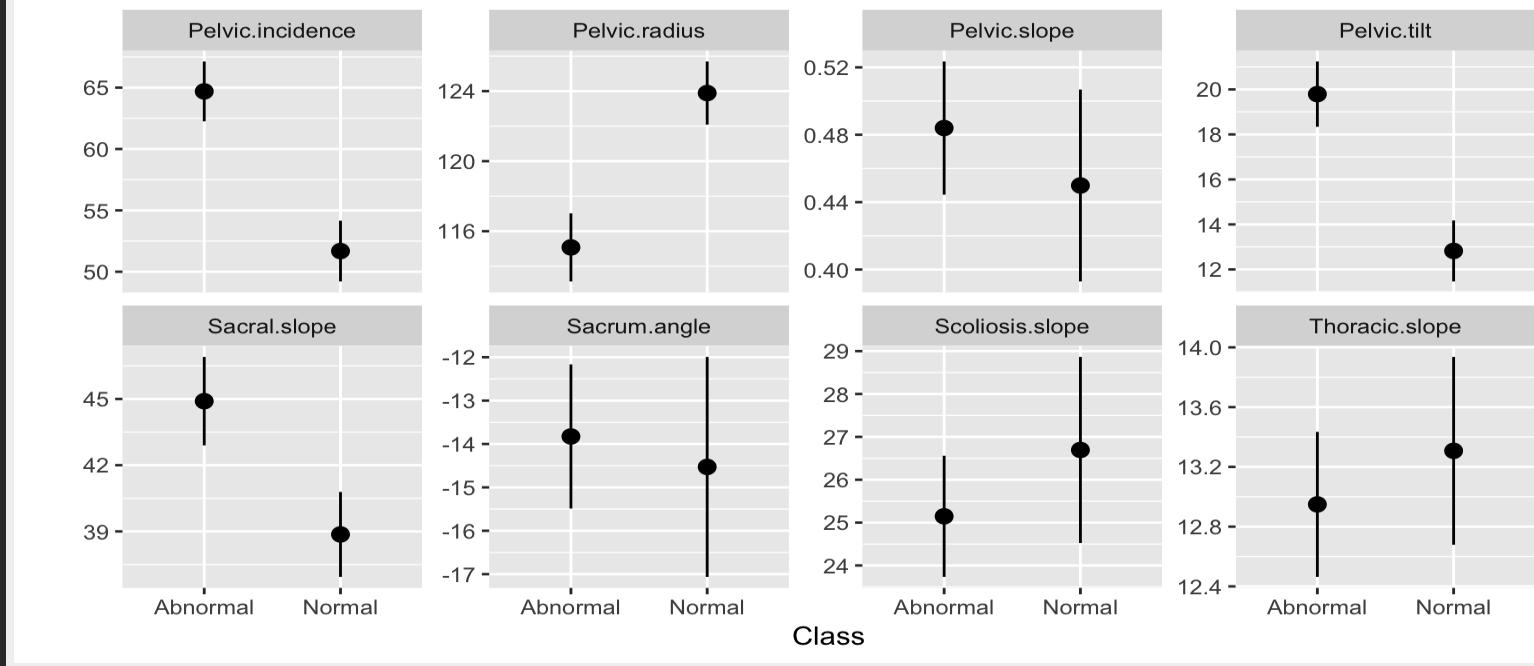
## ANIMATION

Year: 1952



#### Confidence intervals of the mean





# GGPLOT2

We're making the decision to use `ggplot2` for graphics

- Makes pretty good formatting choices out of the box
- Works like pipes!!
- Is declarative (tell it what you want) without getting caught up in minutiae
- Strongly leverages data frames (good practice)
- Fast enough
- There are good templates if you want to change the look

# INTRODUCTION TO GG PLOT2

```
# install.packages('tidyverse')
library(ggplot2)
```

# INTRODUCTION TO GGPLOT2

The `ggplot2` package is a very flexible and (to me) intuitive way of visualizing data. It is based on the concept of layering elements on a canvas.

*This idea of layering graphics on a canvas is,  
to me, a nice way of building graphs*

# INTRODUCTION TO GGPLOT2

You need:

- A `data.frame` object
- *Aesthetic mappings* (`aes`) to say what data is used for what purpose in the viz
  - x- and y-direction
  - shapes, colors, lines
- A *geometry object* (`geom`) to say what to draw
  - You can “layer” geoms on each other to build plots

# INTRODUCTION TO GGPLOT2

ggplot used pipes before pipes were a thing.

However, it uses the + symbol for piping rather than the %>% operator, since it pre-dates the tidyverse

# INTRODUCTION TO GGPLOT2

```
library(ggplot2)
ggplot(mtcars, aes(x = wt, y = mpg)) + geom_point()
```

- A `data.frame` object: mtcars
- Aesthetic mapping:
  - x-axis: wt
  - y-axis: mpg
- Geometry:
  - `geom_point`: draw points

# INTRODUCTION TO GGPLOT2

```
library(ggplot2)
ggplot(mtcars, aes(x = wt, y = mpg)) + geom_point() + geom_smooth()
```

- A `data.frame` object: `mtcars`
- Aesthetic mapping:
  - x-axis: `wt`
  - y-axis: `mpg`
- Geometry:
  - `geom_point`: draw points
  - `geom_smooth`: Add a layer which draws a best-fitting line

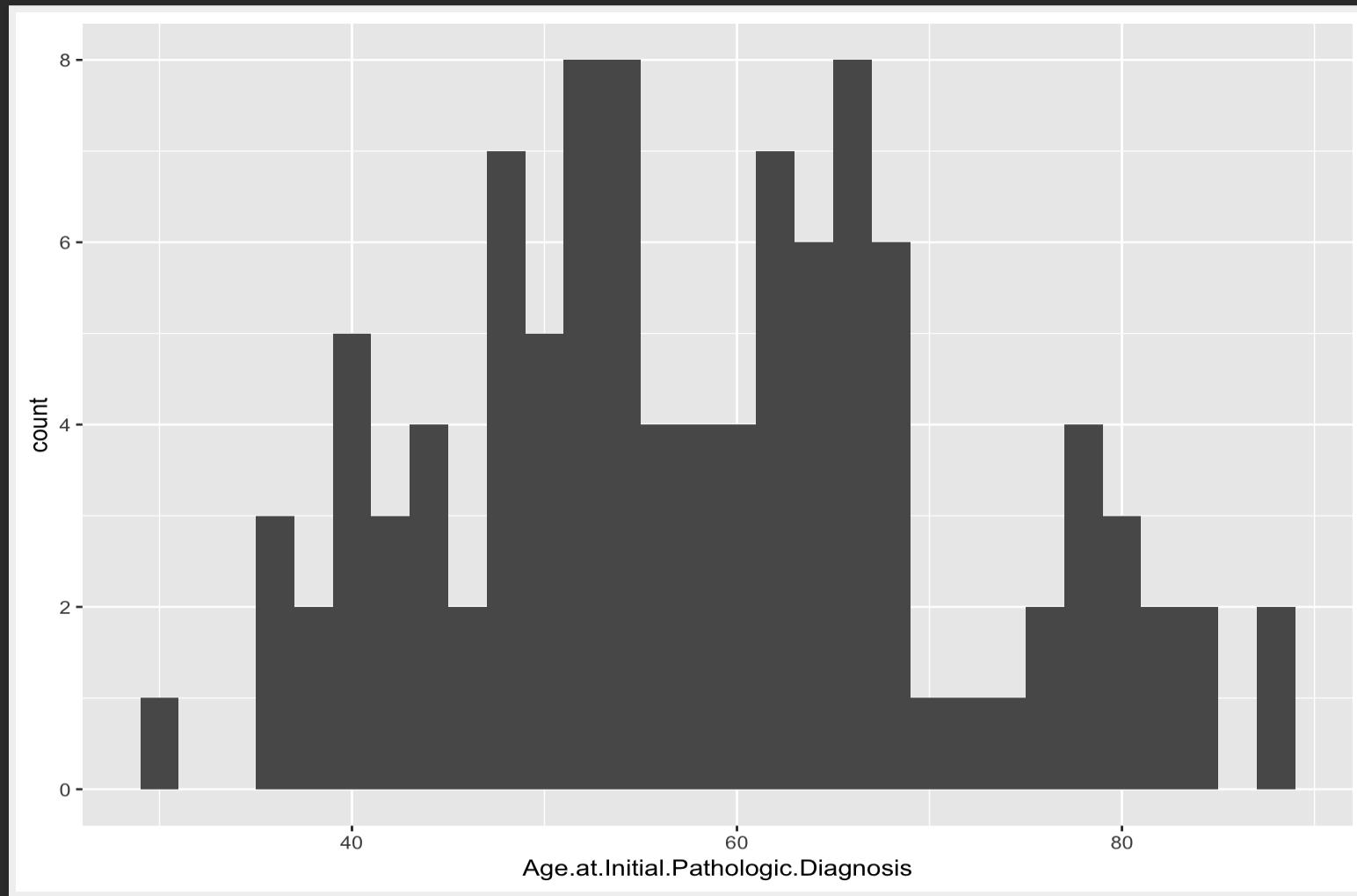
# GGPLOT2 EXAMPLES

# We will use the two data sets:

# PLOTTING ONE VARIABLE

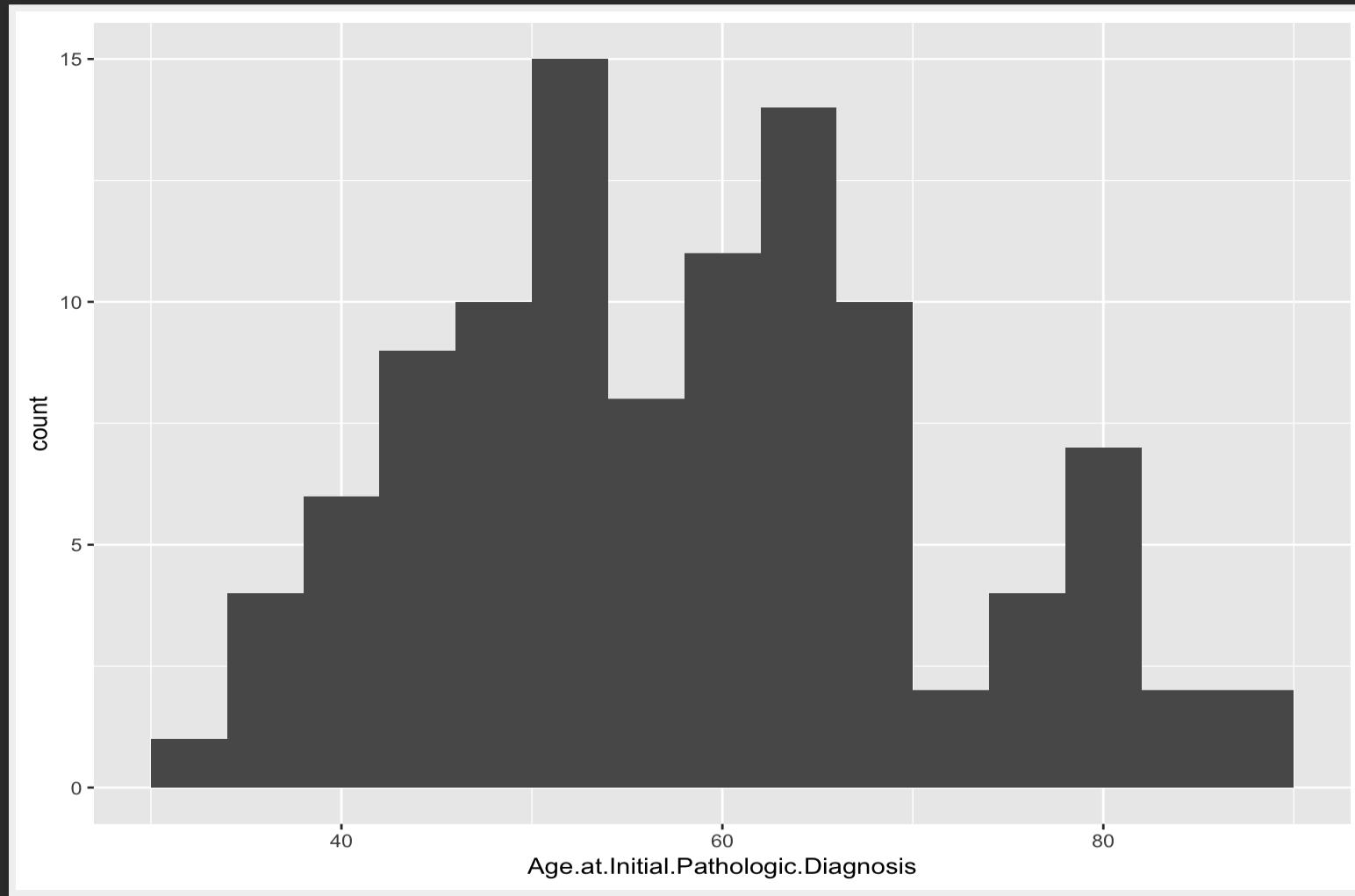
# HISTOGRAMS

```
ggplot(data_brca, aes(x = Age.at.Initial.Pathologic.Diagnosis)) +  
  geom_histogram()
```



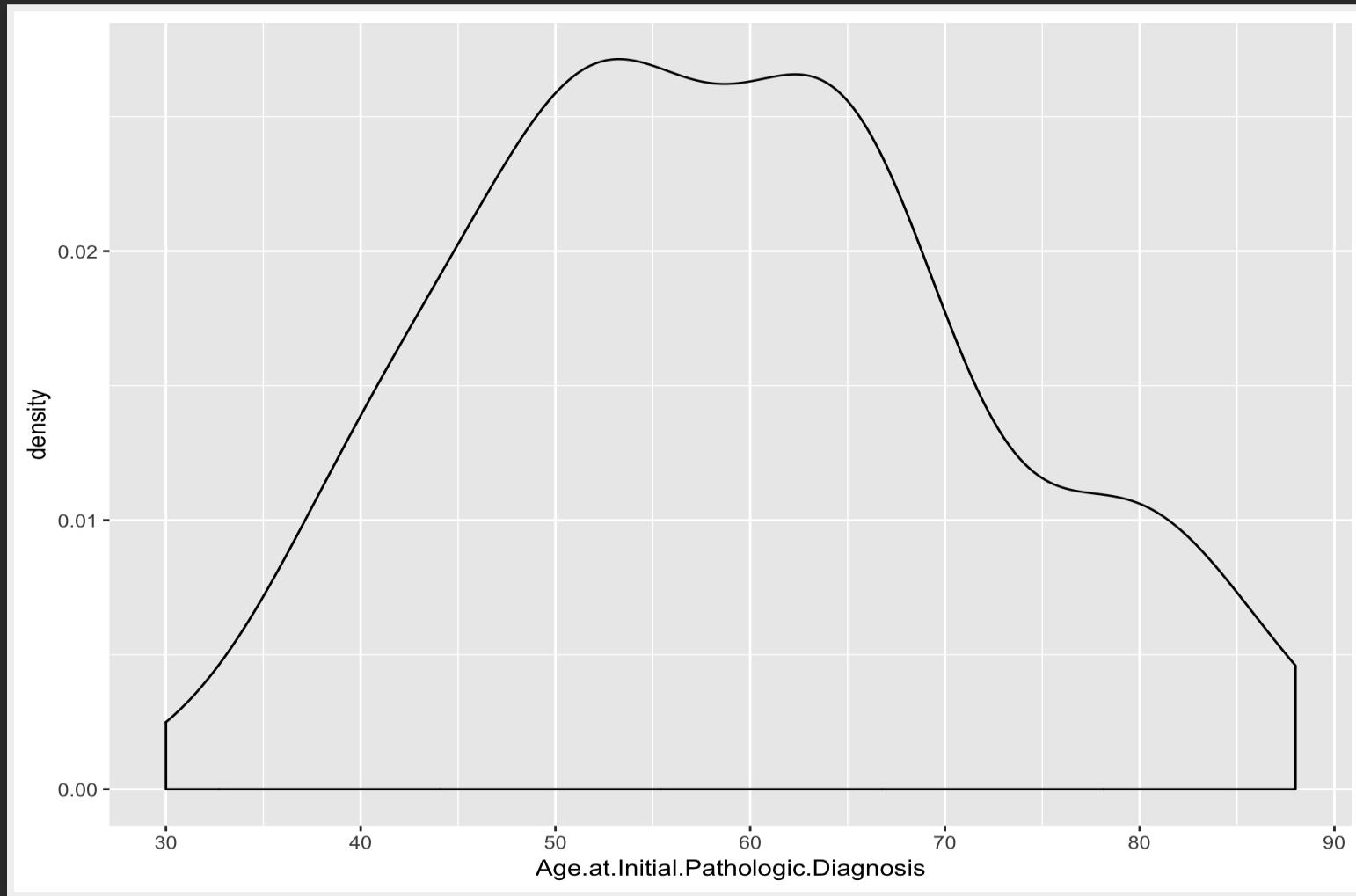
# HISTOGRAMS

```
ggplot(data_brca, aes(x = Age.at.Initial.Pathologic.Diagnosis)) +  
  geom_histogram(binwidth=4)
```



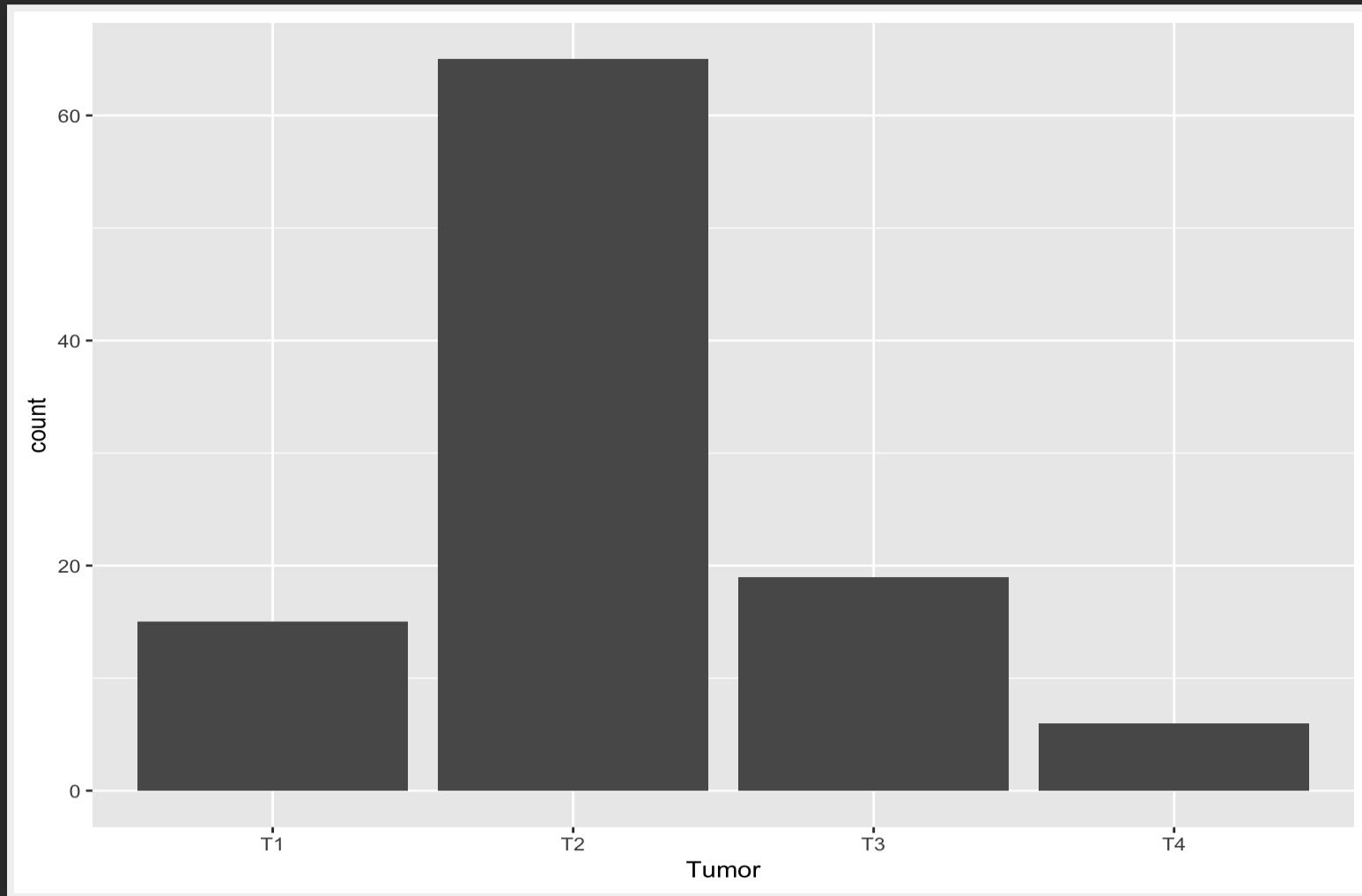
# DENSITY PLOT

```
ggplot(data_brca, aes(x = Age.at.Initial.Pathologic.Diagnosis)) +  
  geom_density()
```



# BAR PLOT

```
ggplot(data_brca, aes(x = Tumor))+geom_bar()
```



# EXERCISE

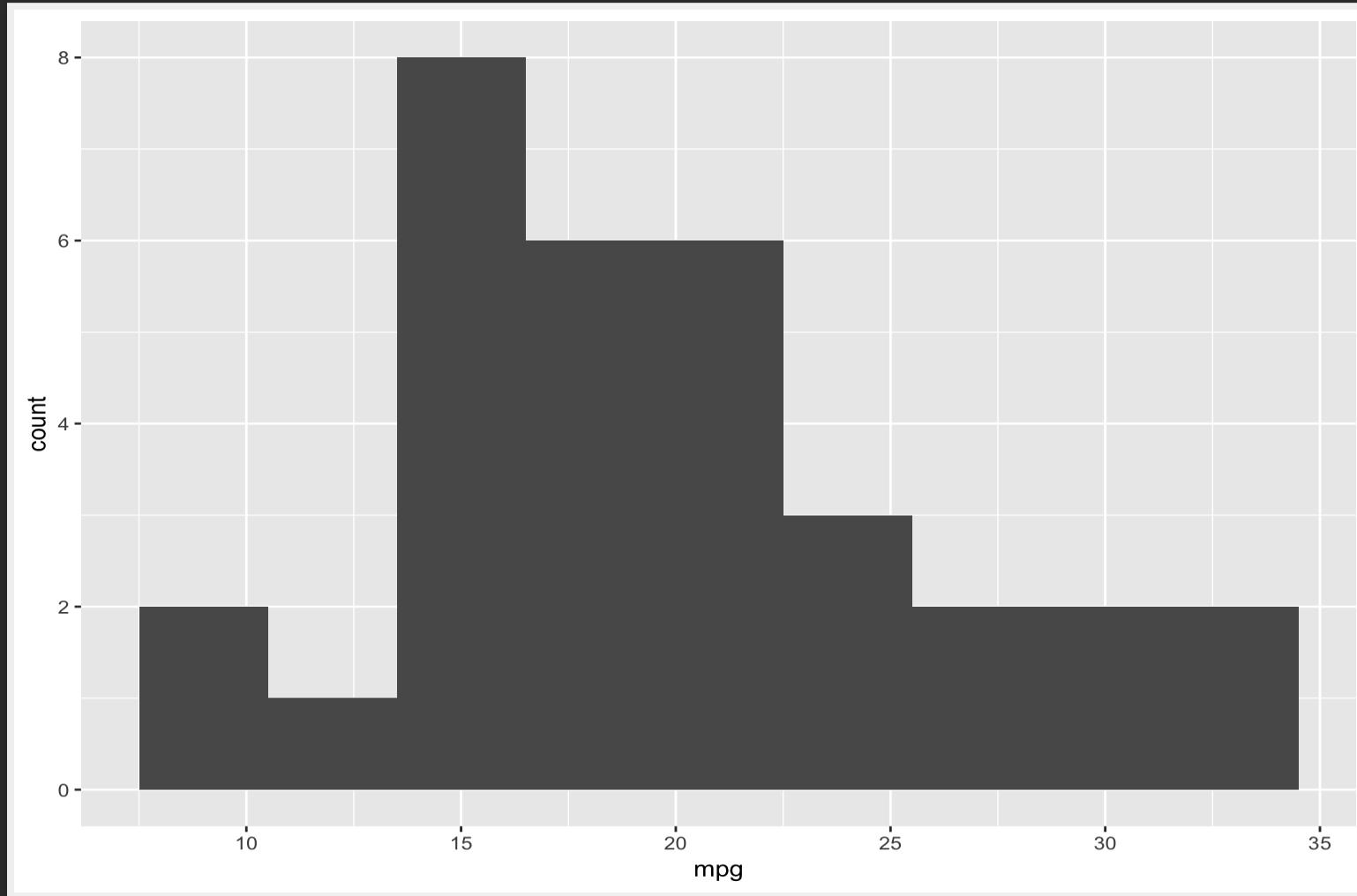
# EXERCISE

Using the `mtcars` dataset in R, create:

1. A histogram of the fuel efficiencies (`mpg`) in the data set
2. A bar plot of frequencies of number of cylinders (`cyl`) in the car

# SOLUTION

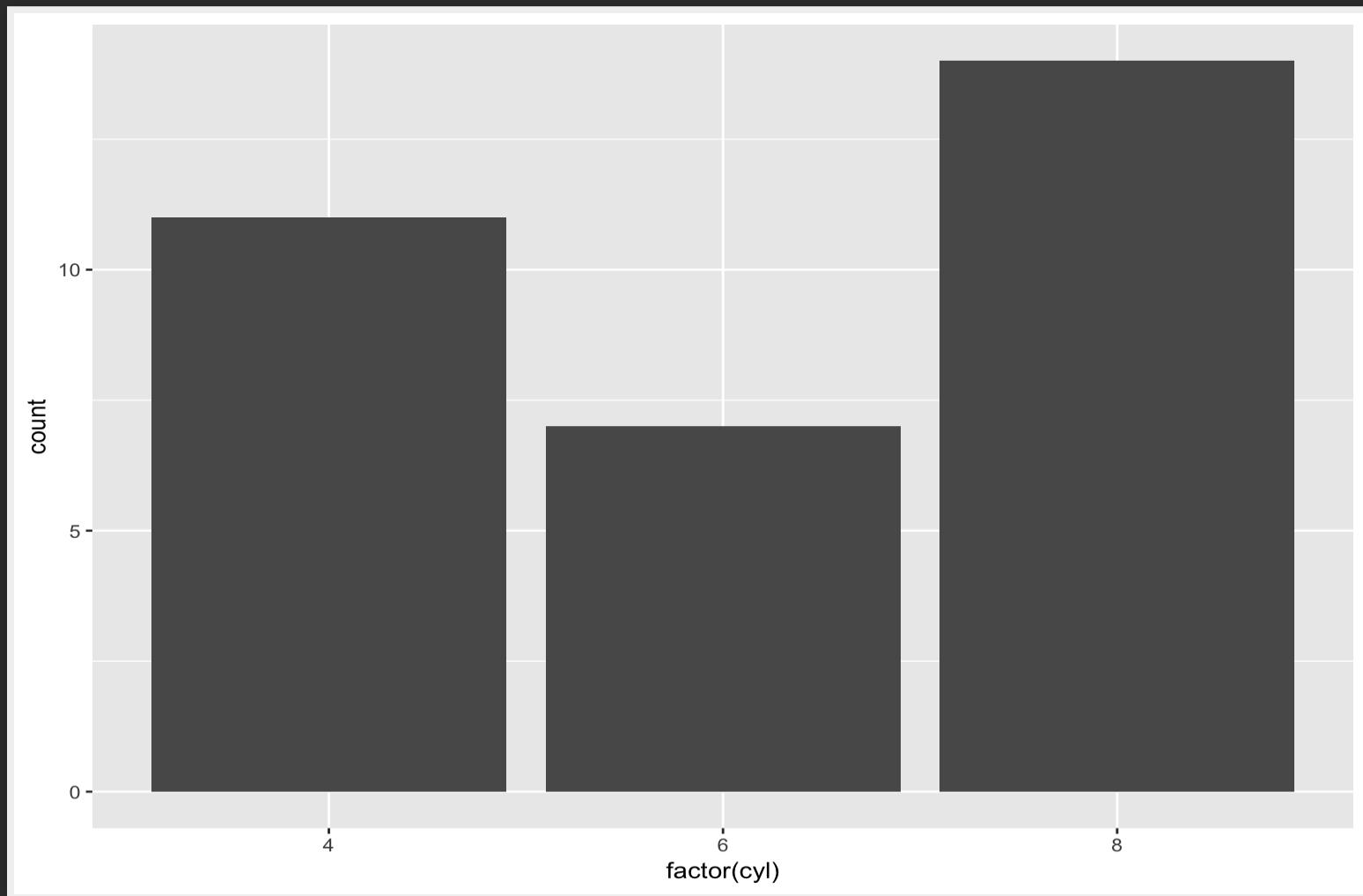
```
ggplot(mtcars, aes(x = mpg)) + geom_histogram(binwidth=3)
```



```
# ggplot(mtcars) + geom_histogram(aes(x = mpg), binwidth = 3)
```

# SOLUTION

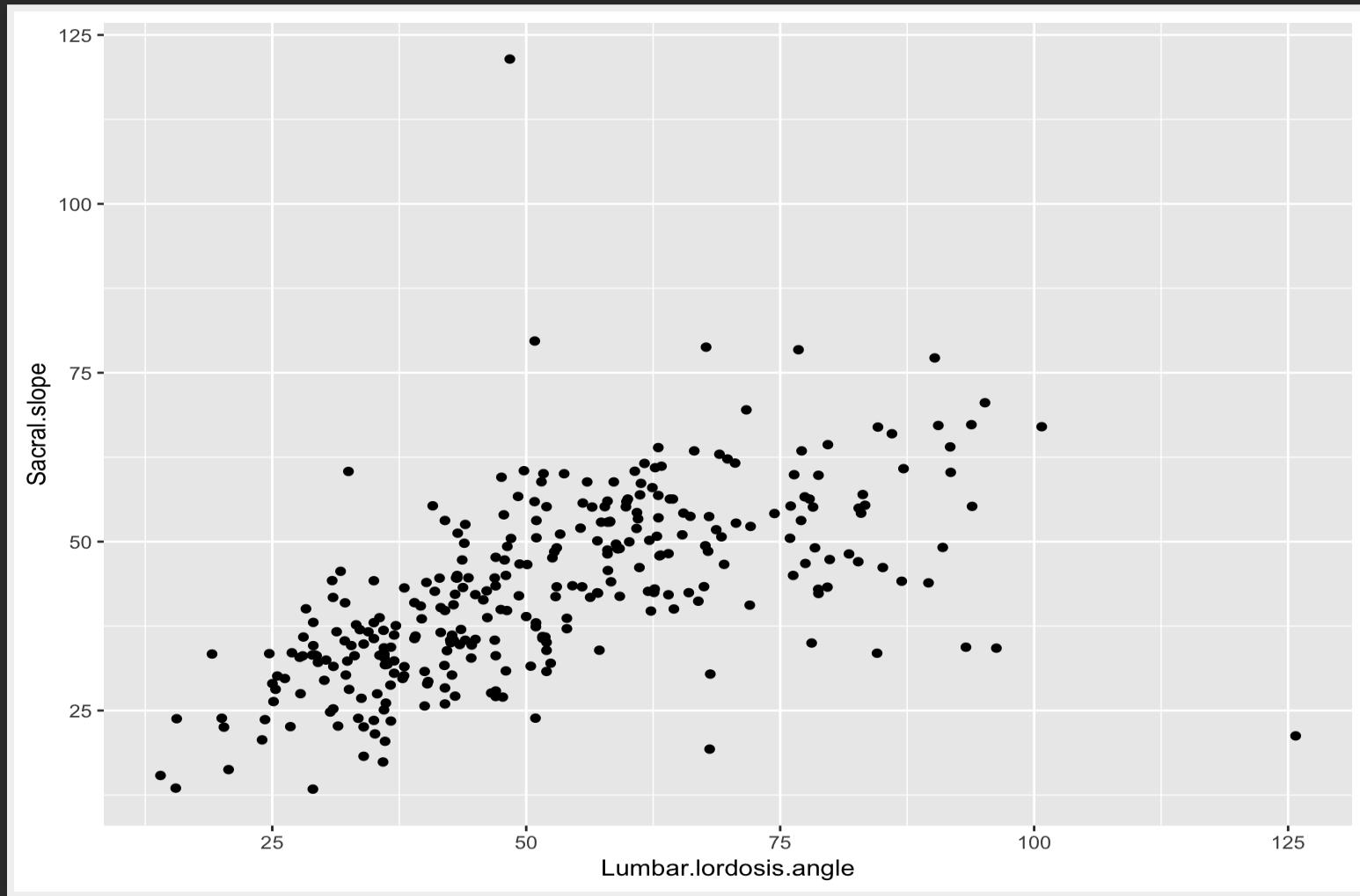
```
ggplot(mtcars, aes(x = factor(cyl))) + geom_bar()
```



# TWO CONTINUOUS VARIABLES

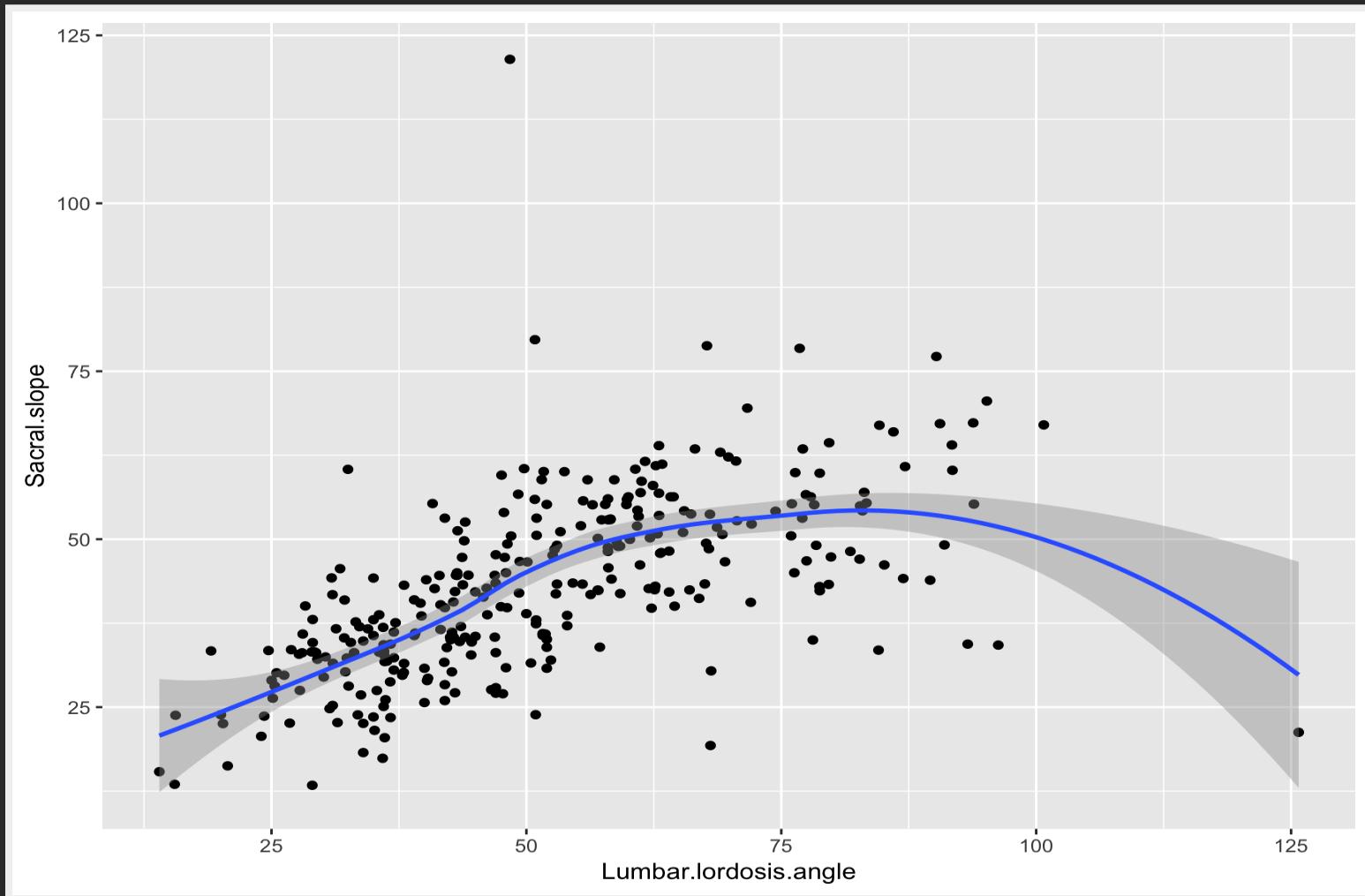
# SCATTER PLOTS

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point()
```



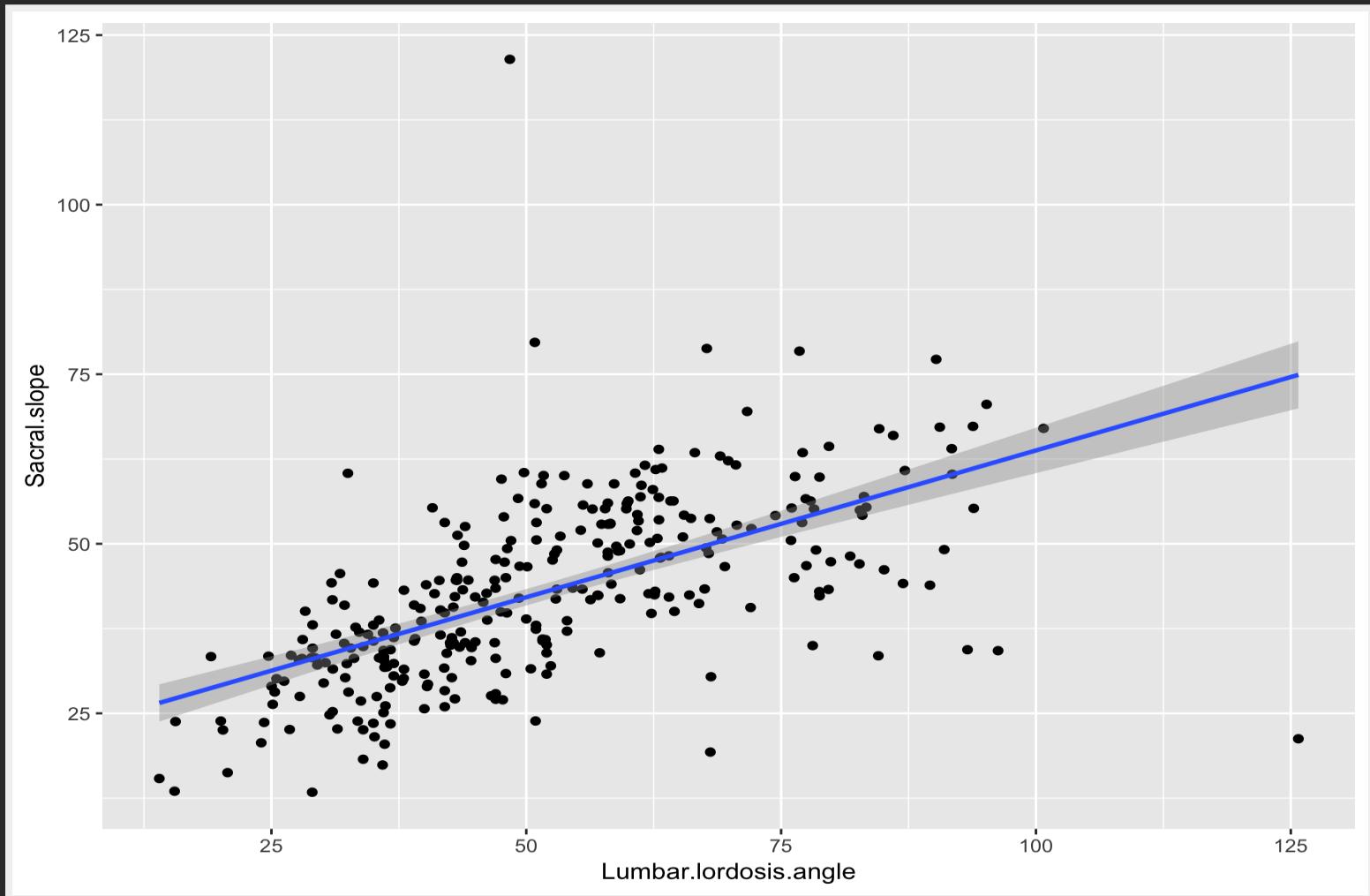
# SCATTER PLOT WITH A SMOOTH LINE

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point() +  
  geom_smooth()
```



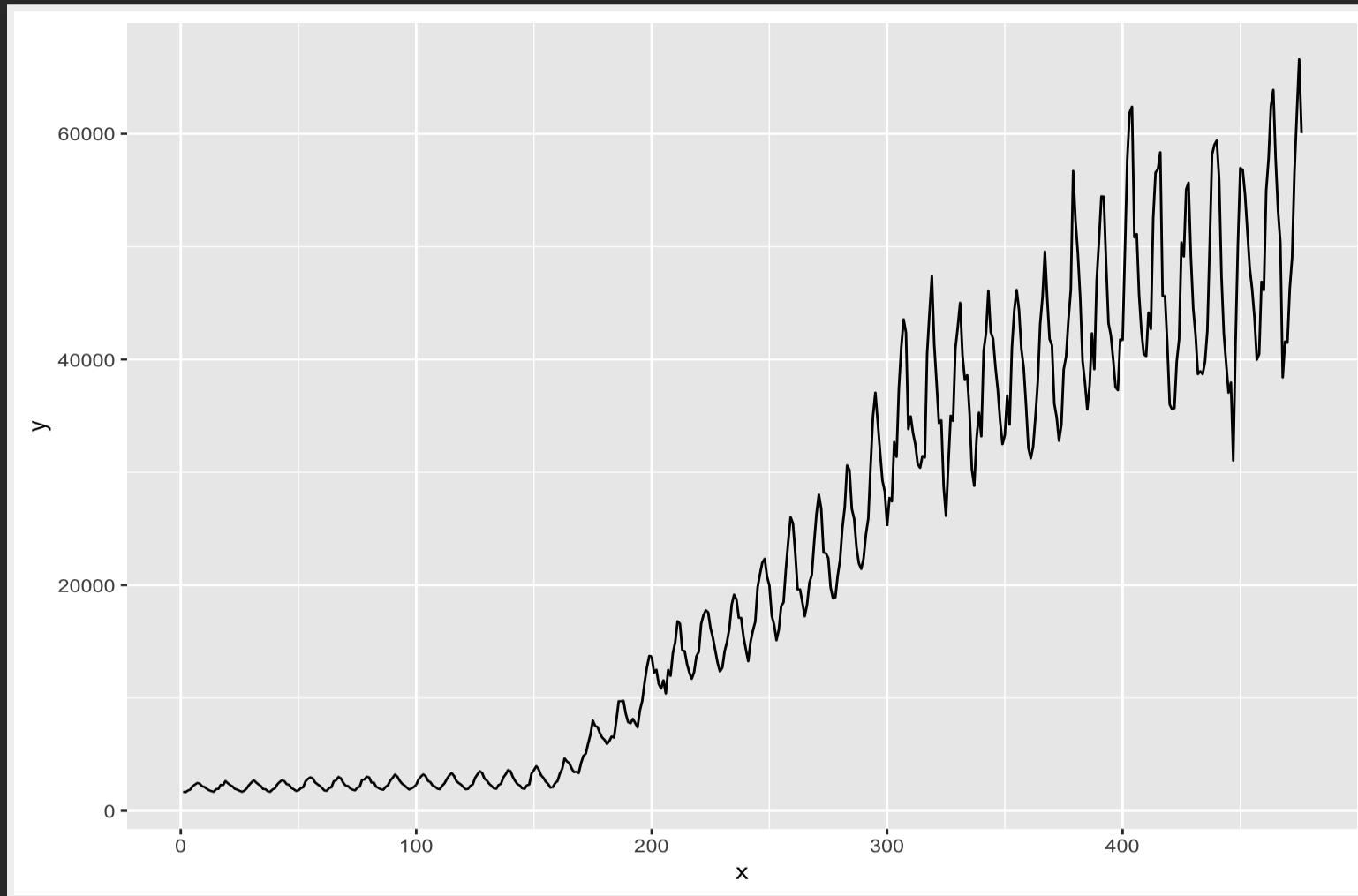
# SCATTER PLOT WITH A SMOOTH STRAIGHT LINE

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point() +  
  geom_smooth(method='lm')
```



# LINE PLOT (FOR TIME SERIES)

```
library(forecast)
d <- data.frame(x = 1:length(gas), y = gas) # Australian monthly gas
      production
ggplot(d, aes(x, y)) + geom_line()
```



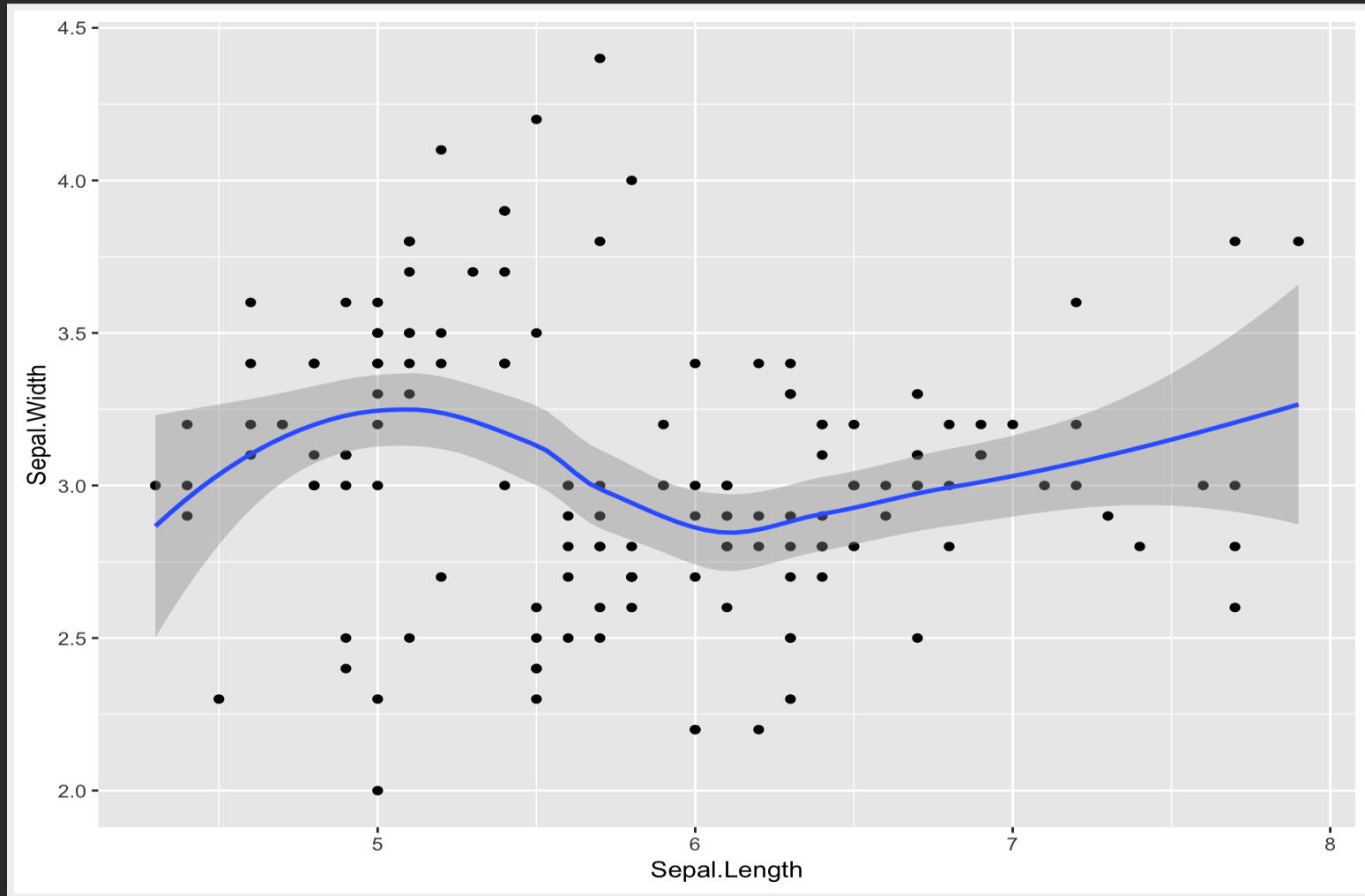
# EXERCISE

# EXERCISE

1. Create a scatter plot of sepal length and sepal width from the `iris` dataset, and add a smooth line through it

# SOLUTION

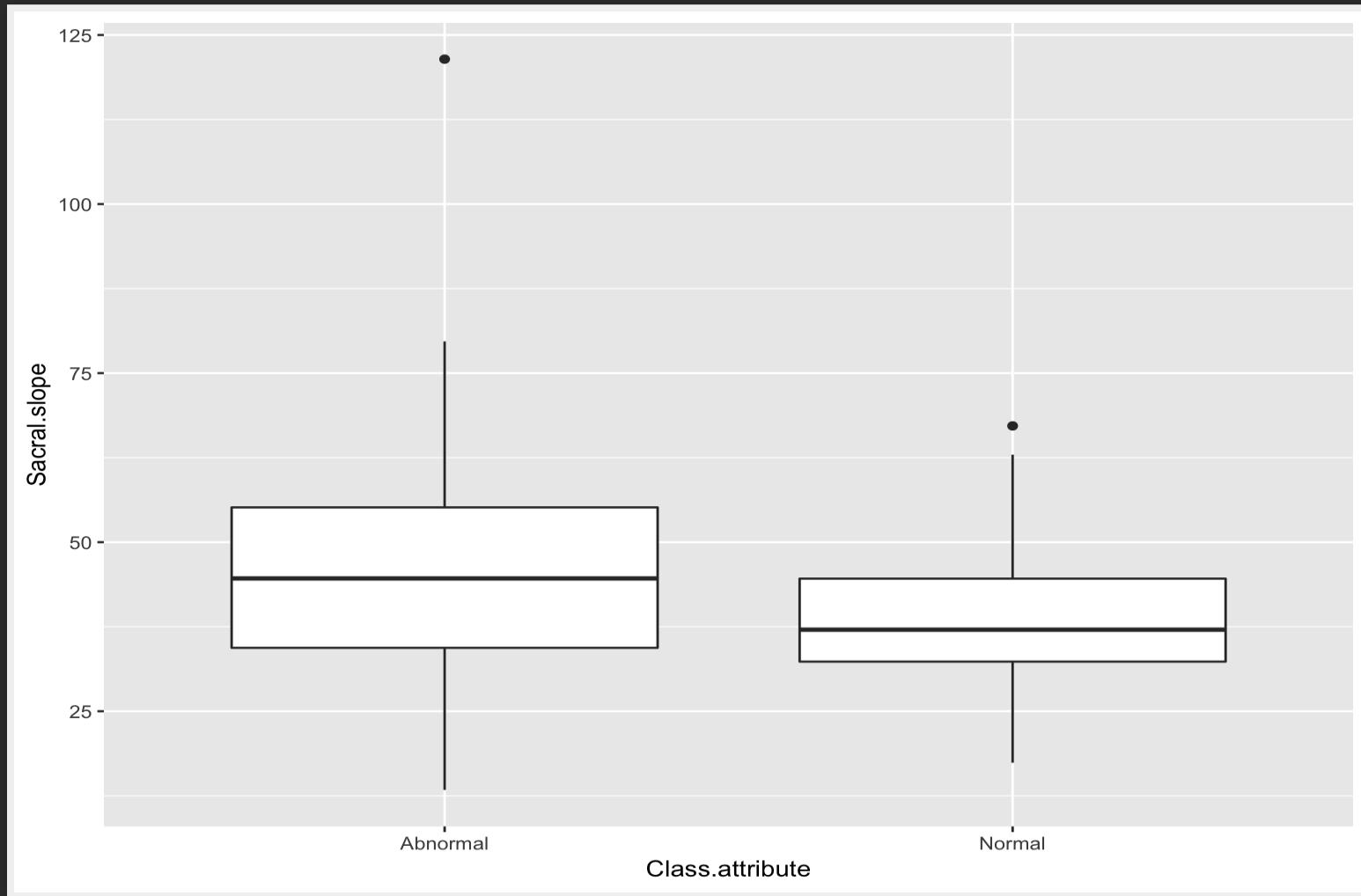
```
ggplot(iris, aes(Sepal.Length, Sepal.Width)) + geom_point() +  
  geom_smooth()
```



# CONTINUOUS VARIABLE WITH DISCRETE VARIABLE

# BOXPLOTS

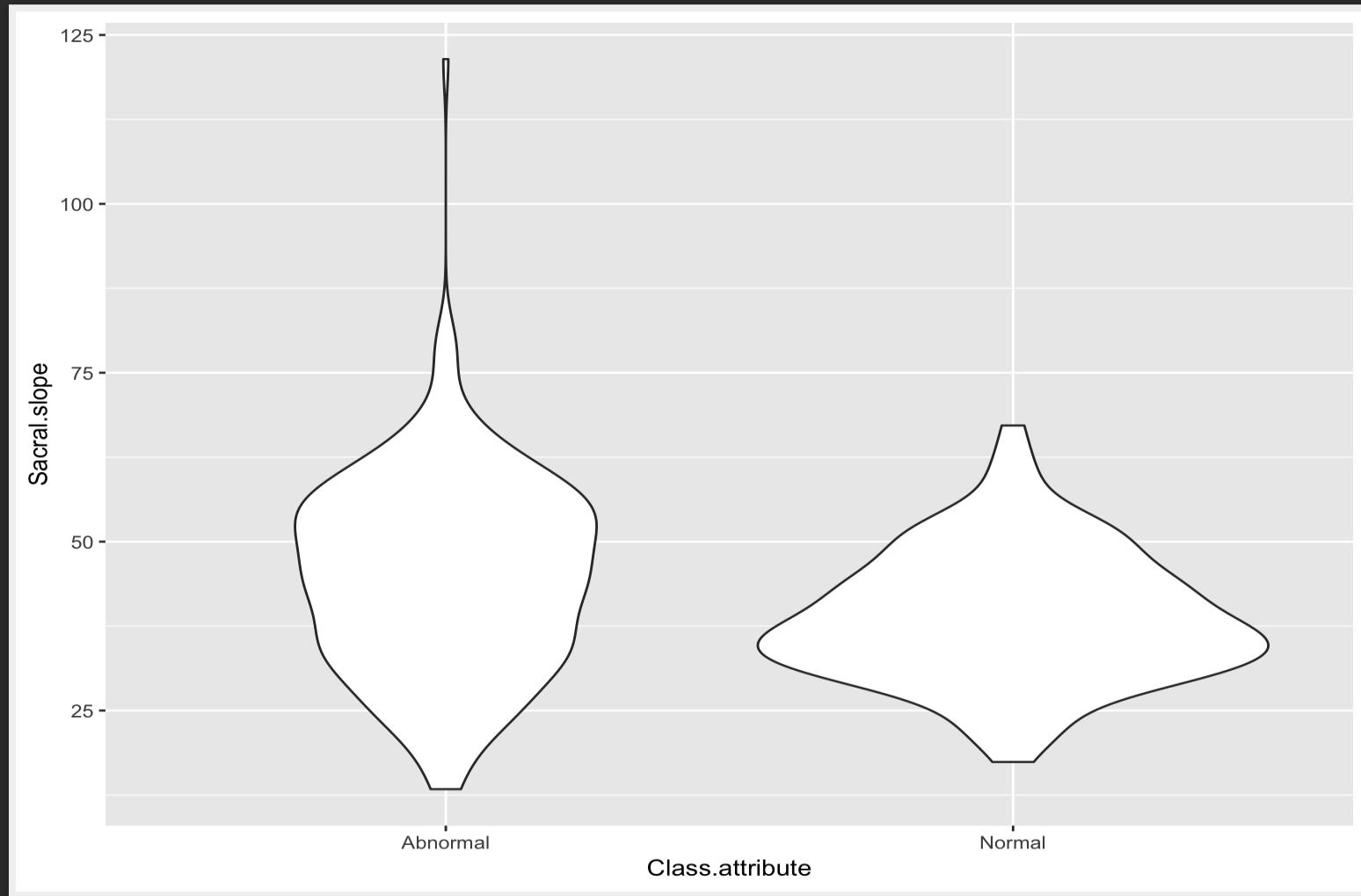
```
ggplot(data_spine, aes(x = Class.attribute, y = Sacral.slope)) +  
  geom_boxplot()
```



# Factor/discrete variable is always x

# VIOLIN PLOTS

```
ggplot(data_spine, aes(x = Class.attribute, y = Sacral.slope)) +  
  geom_violin()
```



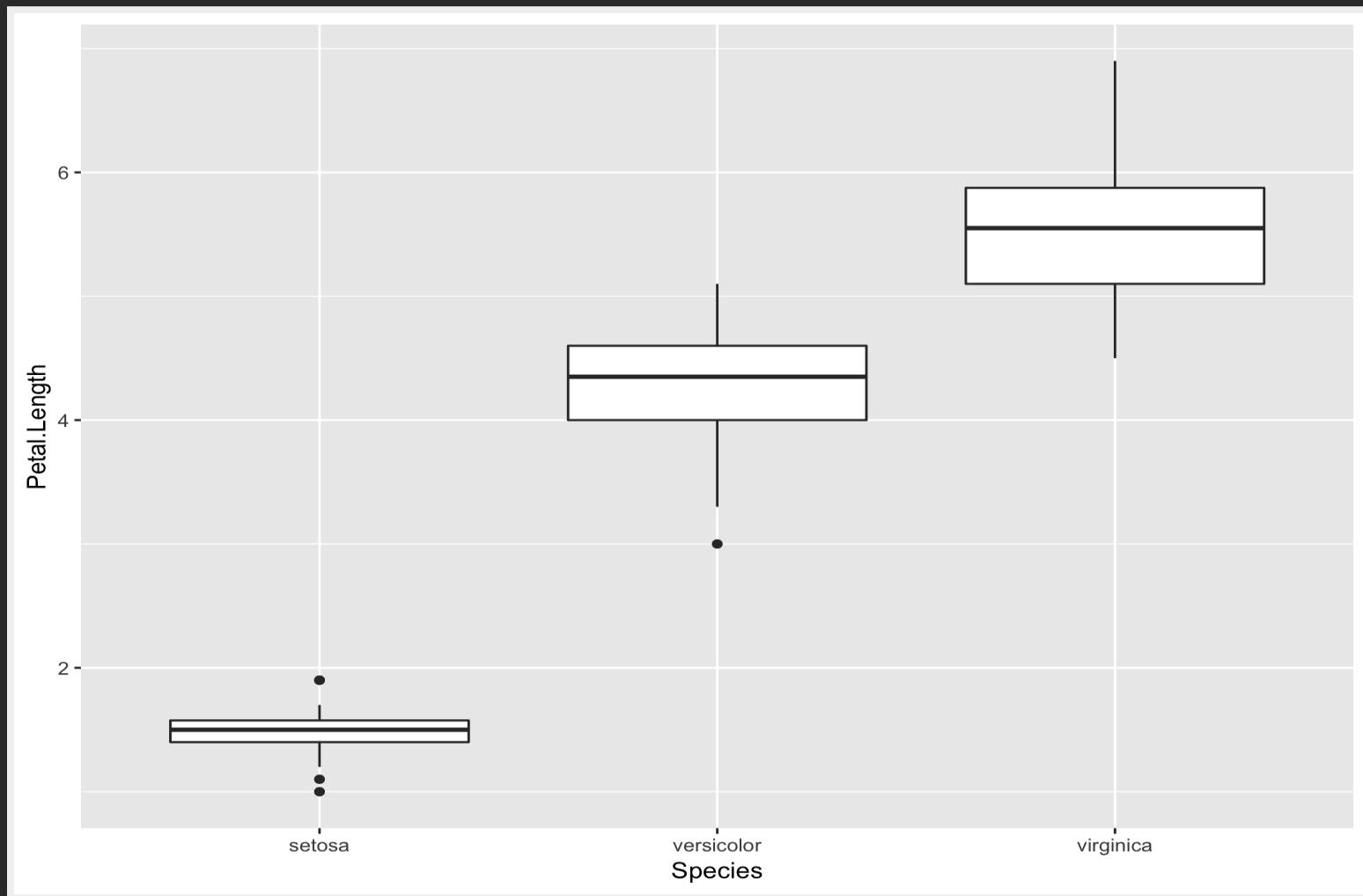
# EXERCISE

# EXERCISE

1. Plot a boxplot of petal length by species using the `iris` dataset

# SOLUTION

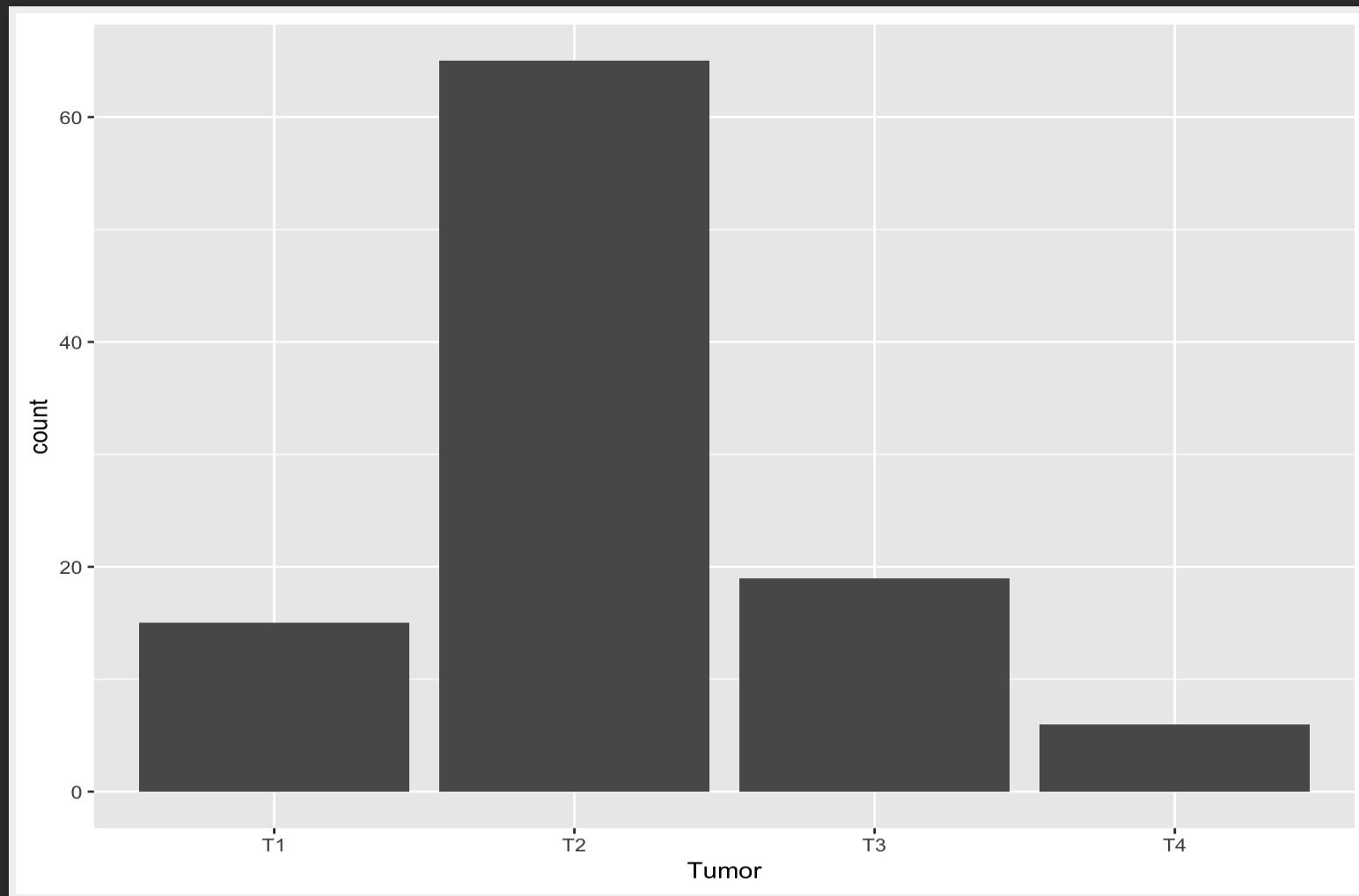
```
ggplot(iris, aes(x = Species, y = Petal.Length)) + geom_boxplot()
```



# FLIPPING AXES

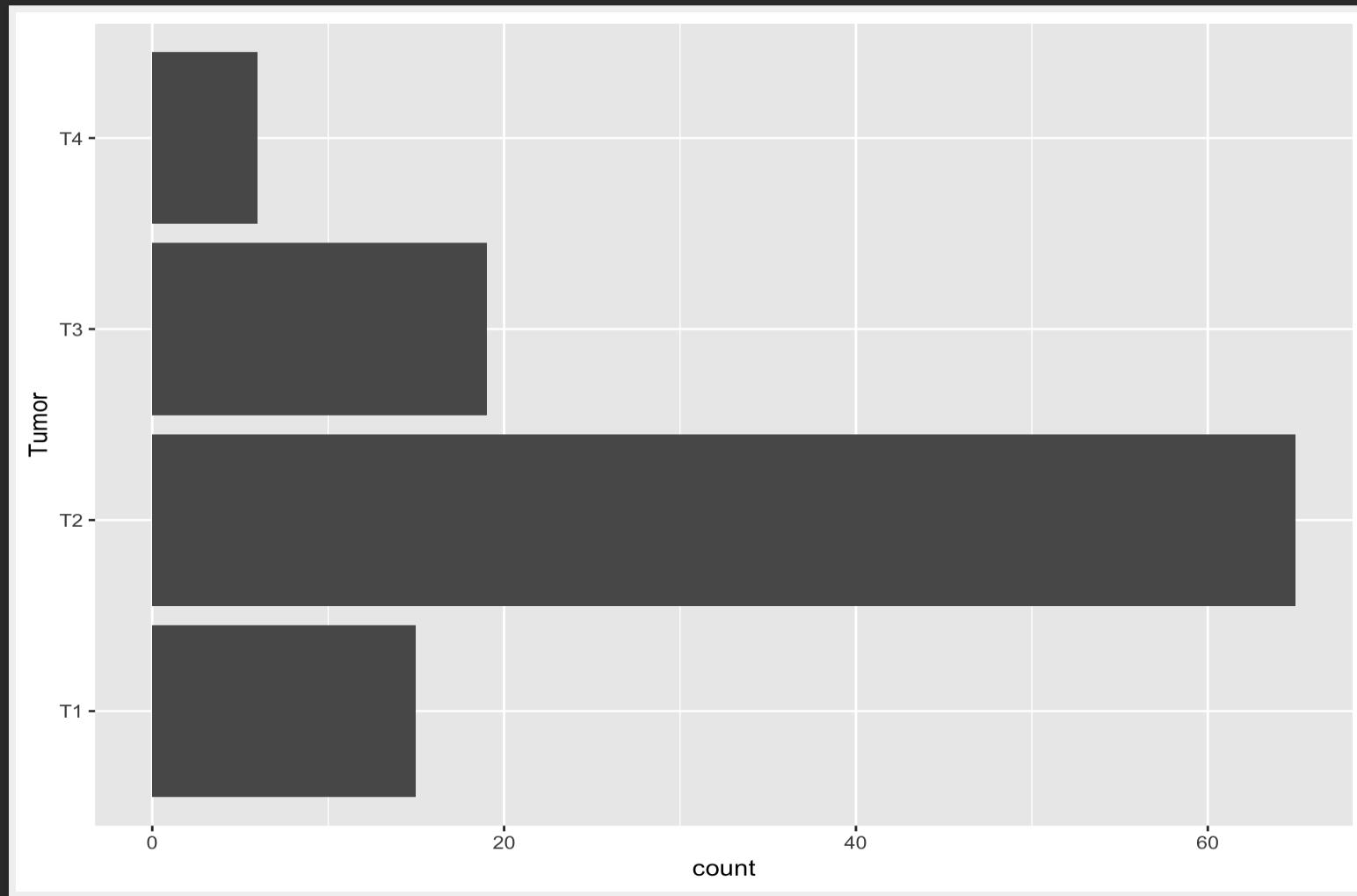
# VERTICAL BARS

```
ggplot(data_brca, aes(x = Tumor))+geom_bar()
```



# HORIZONTAL BARS

```
ggplot(data_brca, aes(x = Tumor)) + geom_bar() +  
  coord_flip()
```



# RESOURCES

# ONLINE RESOURCES

- The ggplot [website](#) has many resources to help create visualizations
- The [R Graph Gallery](#)
- There are a lot of blogs showing many capabilities of ggplot2
- [StackOverflow](#) is the place for Q & A.

## OTHER PACKAGES

- The `cowplot` and `ggpubr` packages provide several improvements on `ggplot2`, including more themes and an easy way to put several graphs together in a panel
- There is a rich ecosystem around `ggplot2`, which can be explored [here](#)

# GROUP-WISE DESCRIPTIVES AND VISUALIZATIONS

# GROUPING

- It is common to look at statistics within subgroups of the data
- The idea is to see if secondary variables affect your primary outcome or relationship

# INTRODUCING THE DPLYR PACKAGE

`dplyr` is the most lucid package for manipulating and analyzing data organized in a data frame.

- It has a `group_by` function which creates a *grouped data frame*

```
library(dplyr)
grouped_data_spine = data_spine %>% group_by(Class.attribute)
```

Note that you have to group using a discrete valued variable (factor, character, integer)

# GROUPED SUMMARIES

```
grouped_data_spine %>%  
  summarize(mean(Pelvic.incidence),  
           sd(Pelvic.incidence),  
           min(Pelvic.incidence),  
           max(Pelvic.incidence))
```

Class.attribute	mean(Pelvic.incidence)	sd(Pelvic.incidence)	min(Pelvic.incidence)
Abnormal	64.69	17.66	26.15
Normal	51.69	12.37	30.74

# GROUPED SUMMARIES

```
grouped_data_spine %>% summarize(Mean = mean(Pelvic.incidence),  
                                     SD = sd(Pelvic.incidence),  
                                     Min = min(Pelvic.incidence),  
                                     Max = max(Pelvic.incidence))
```

Class.attribute	Mean	SD	Min	Max	-----	-----	-----	-----
Abnormal	64.69	17.66	26.15	129.83	Normal	51.69		
	12.37	30.74	89.83					

# GROUPED SUMMARIES

```
grouped_data_spine %>% summarize_all(mean)
```

```
# # A tibble: 2 x 13
#   Class.attribute Pelvic.incidence Pelvic.tilt Lumbar.lordosis...
#   <fct>                <dbl>        <dbl>        <dbl>
# 1 Abnormal             64.7         19.8        55.9
# 2 Normal               51.7         12.8        43.5
# # ... with 9 more variables: Sacral.slope <dbl>, Pelvic.radius <dbl>,
# #   Degree.spondylolisthesis <dbl>, Pelvic.slope <dbl>, Direct.tilt <dbl>,
# #   Thoracic.slope <dbl>, Cervical.tilt <dbl>, Sacrum.angle <dbl>,
# #   Scoliosis.slope <dbl>
```

# A NOTE ON TIBBLES

- Tibbles are a new-generation object meant to enhance the `data.frame`.
  - Central to the **tidyverse** packages
- If you want to just get back to a more familiar `data.frame` object, use `as.data.frame`
- A tibble is built on a `data.frame`, so all operations on `data.frame`'s will work.
- To see all columns, set  
`options(dplyr.width=Inf)`.

# A NOTE ON TIBBLES

Differences between a tibble and a `data.frame`:

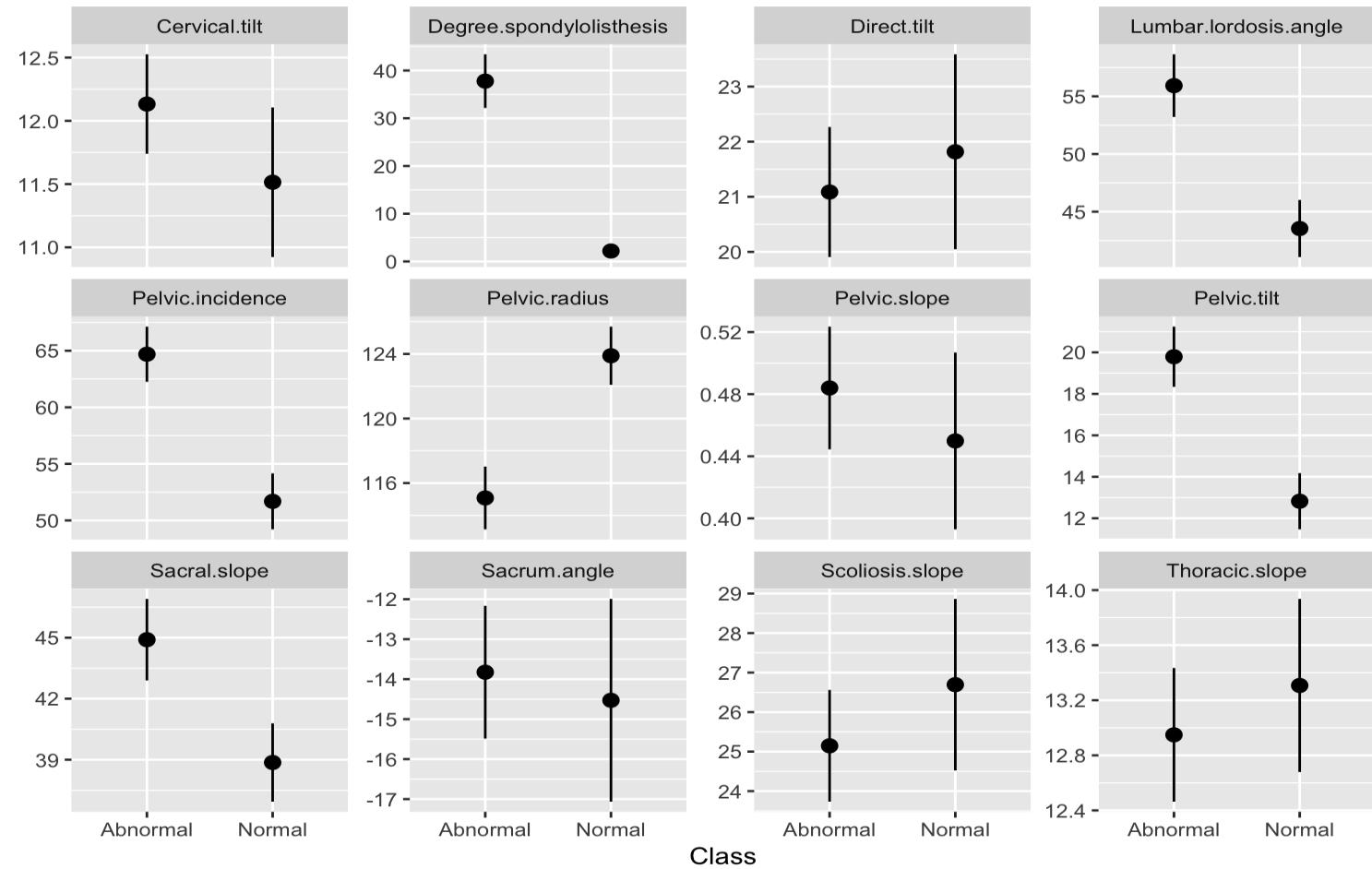
1. Printing a tibble is restricted to the first 10 lines, and includes column types
2. Stricter subsetting rules that make the types of objects created consistent

# USING GGPLOT IN A PIPELINE

```
data_spine %>%
  group_by(Class.attribute) %>%
  summarize_all(funs(Mean = mean(., na.rm=T),
                     SEM = sd(., na.rm=T)/sqrt(n())))) %>%
  gather(variable, value, -Class.attribute) %>%
  separate(variable, c('Variable','stat'), sep = '_') %>%
  spread(stat, value) %>%
  mutate(lcb = Mean - 2 * SEM, ucb = Mean + 2 * SEM) %>%
  ggplot(aes(x = Class.attribute, y = Mean, ymin = lcb, ymax = ucb)) +
  geom_pointrange() +
  facet_wrap(~Variable, scales = 'free_y') +
  labs( x = 'Class', y = '') +
  ggtitle('Confidence intervals of the mean')
```

Work through the pipeline yourself to understand what each step does, just like last week

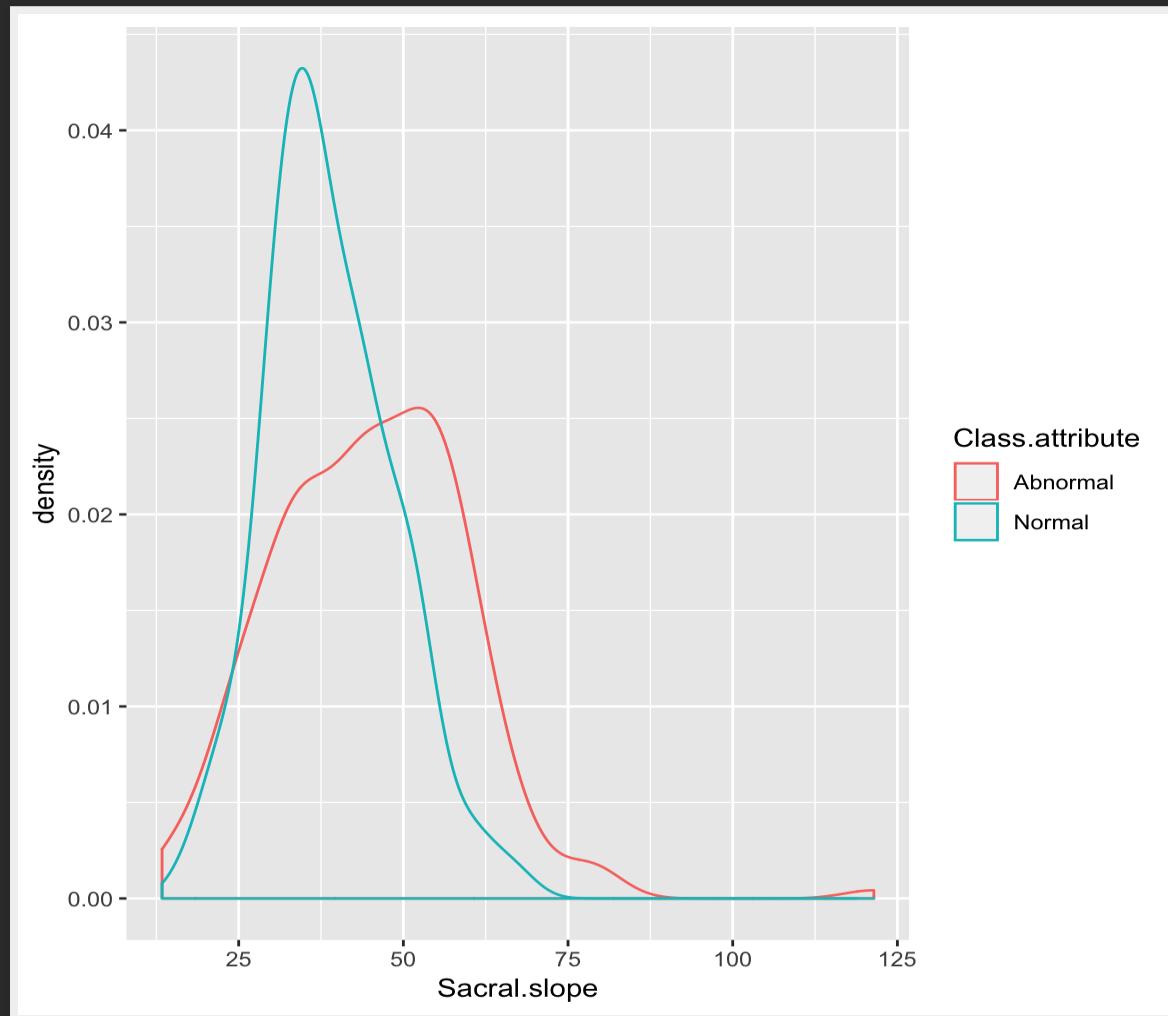
### Confidence intervals of the mean



# GROUPED VISUALIZATION

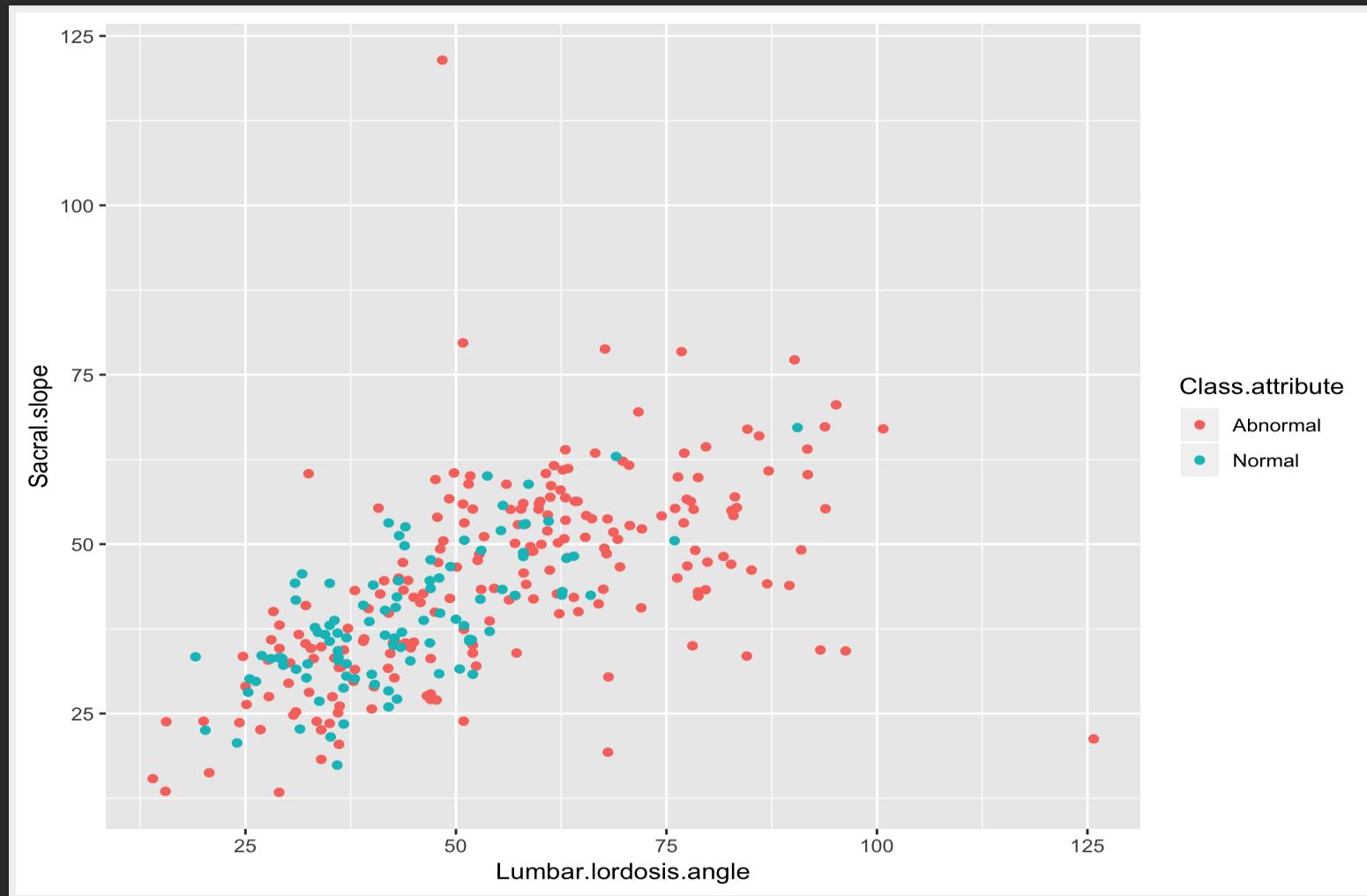
# DENSITY PLOT

```
ggplot(data_spine, aes(x= Sacral.slope, group= Class.attribute,  
color=Class.attribute))+  
  geom_density()
```



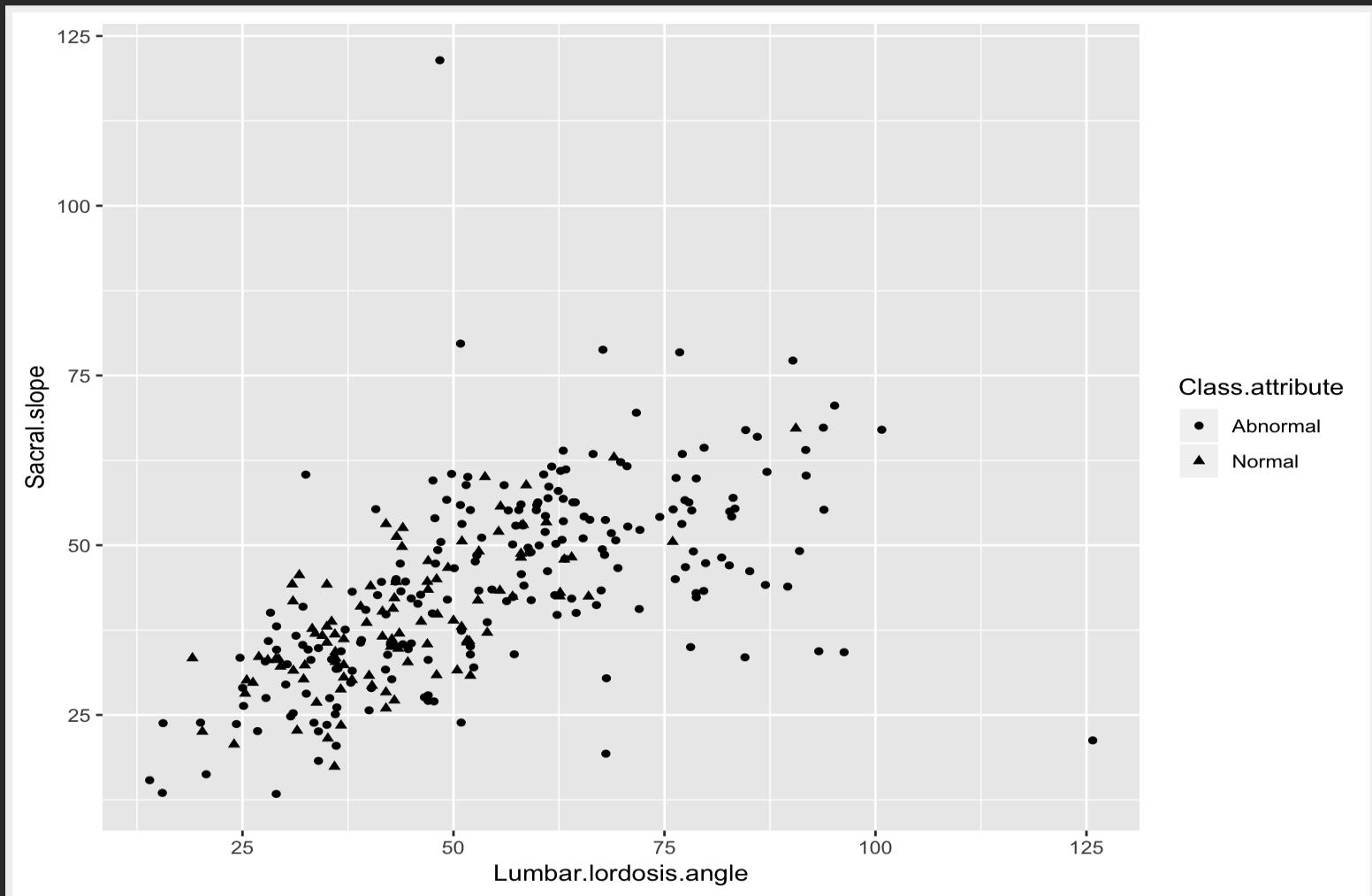
# SCATTER PLOT

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope,  
group = Class.attribute, color =  
Class.attribute))+  
geom_point()
```



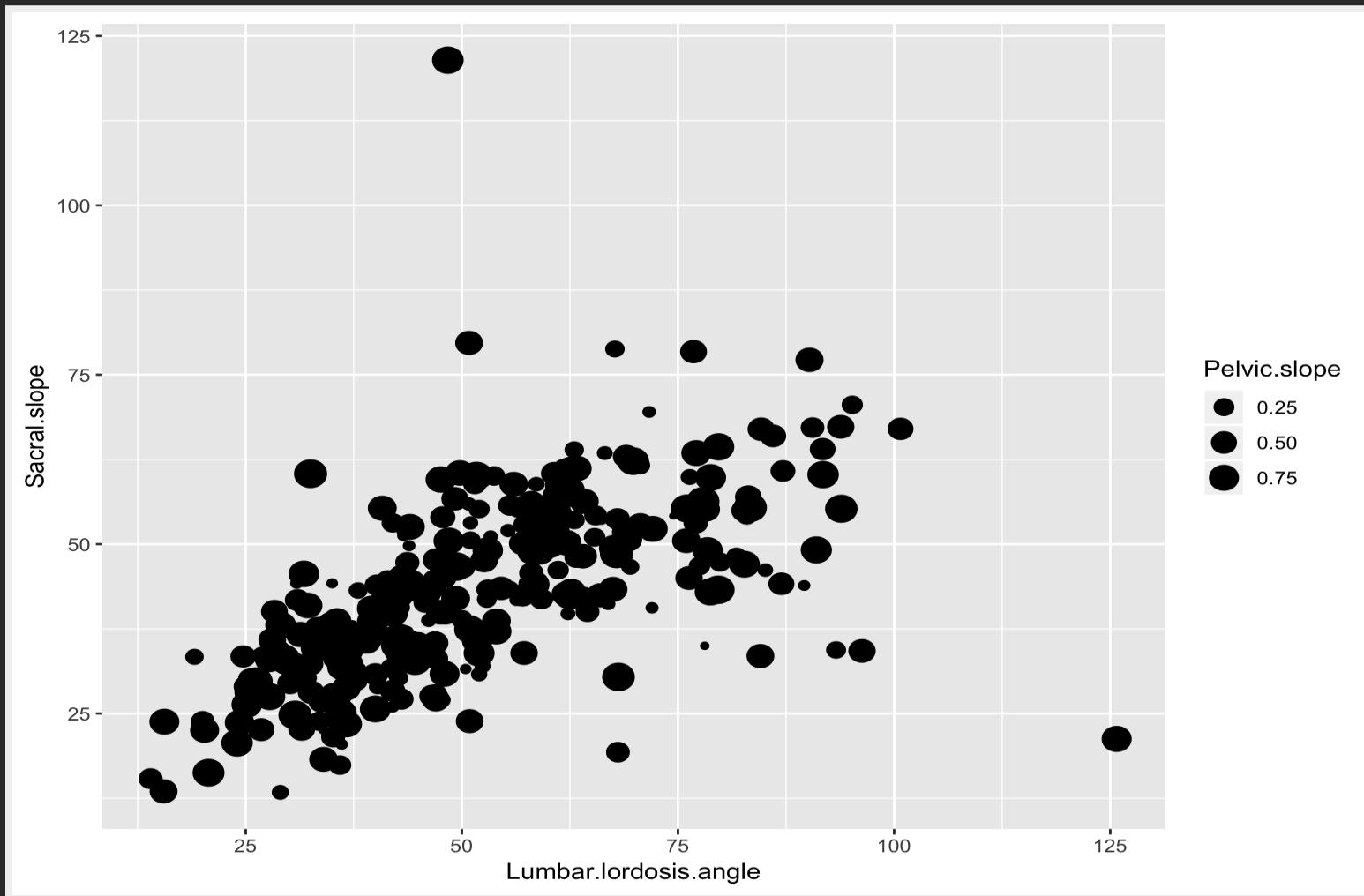
# SCATTER PLOT (BLACK AND WHITE)

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope,  
group = Class.attribute, shape =  
Class.attribute))+  
geom_point()
```



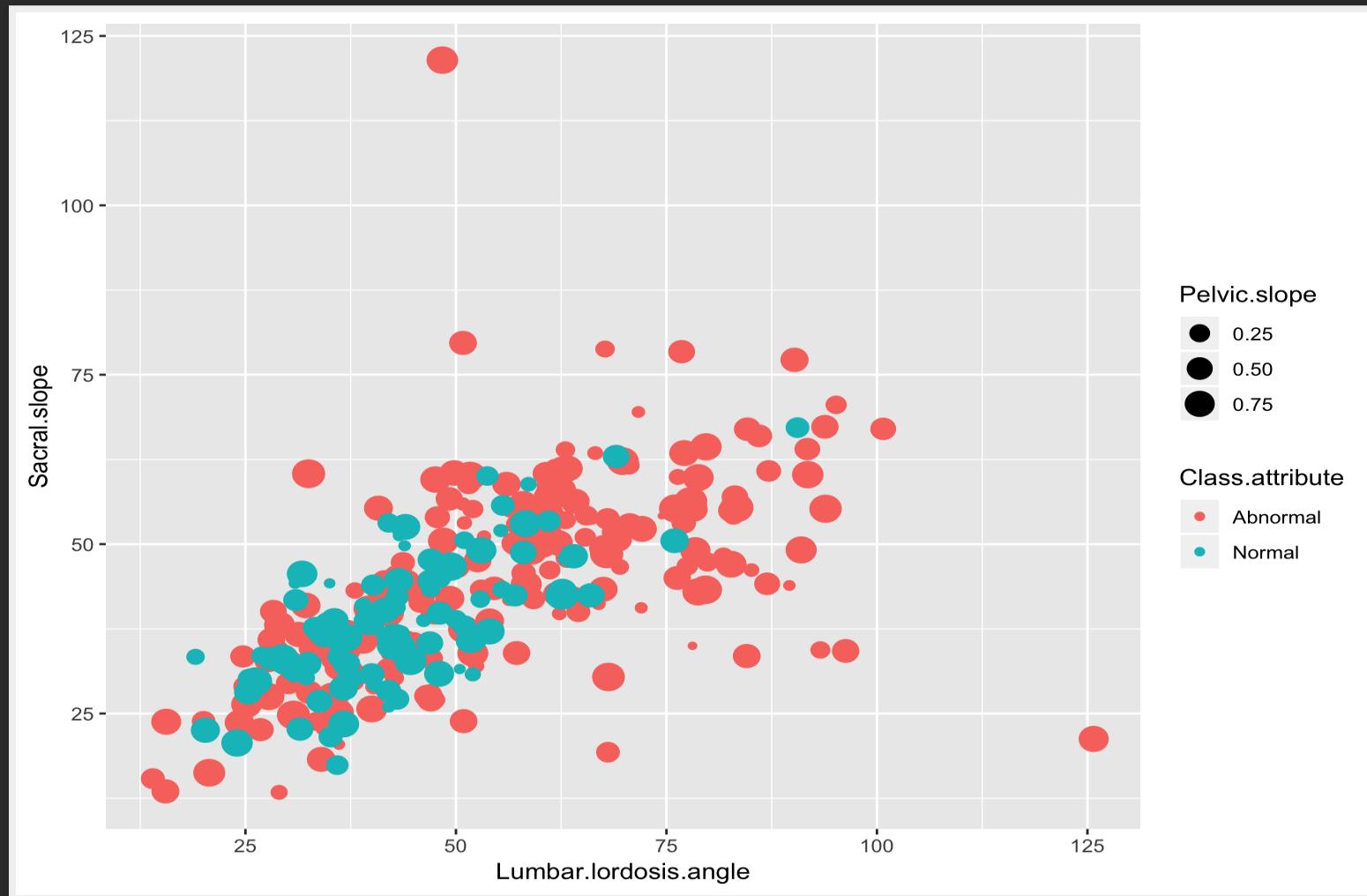
# SCATTER PLOT WITH SIZE REPRESENTING THIRD VARIABLE

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point(aes(size = Pelvic.slope))
```



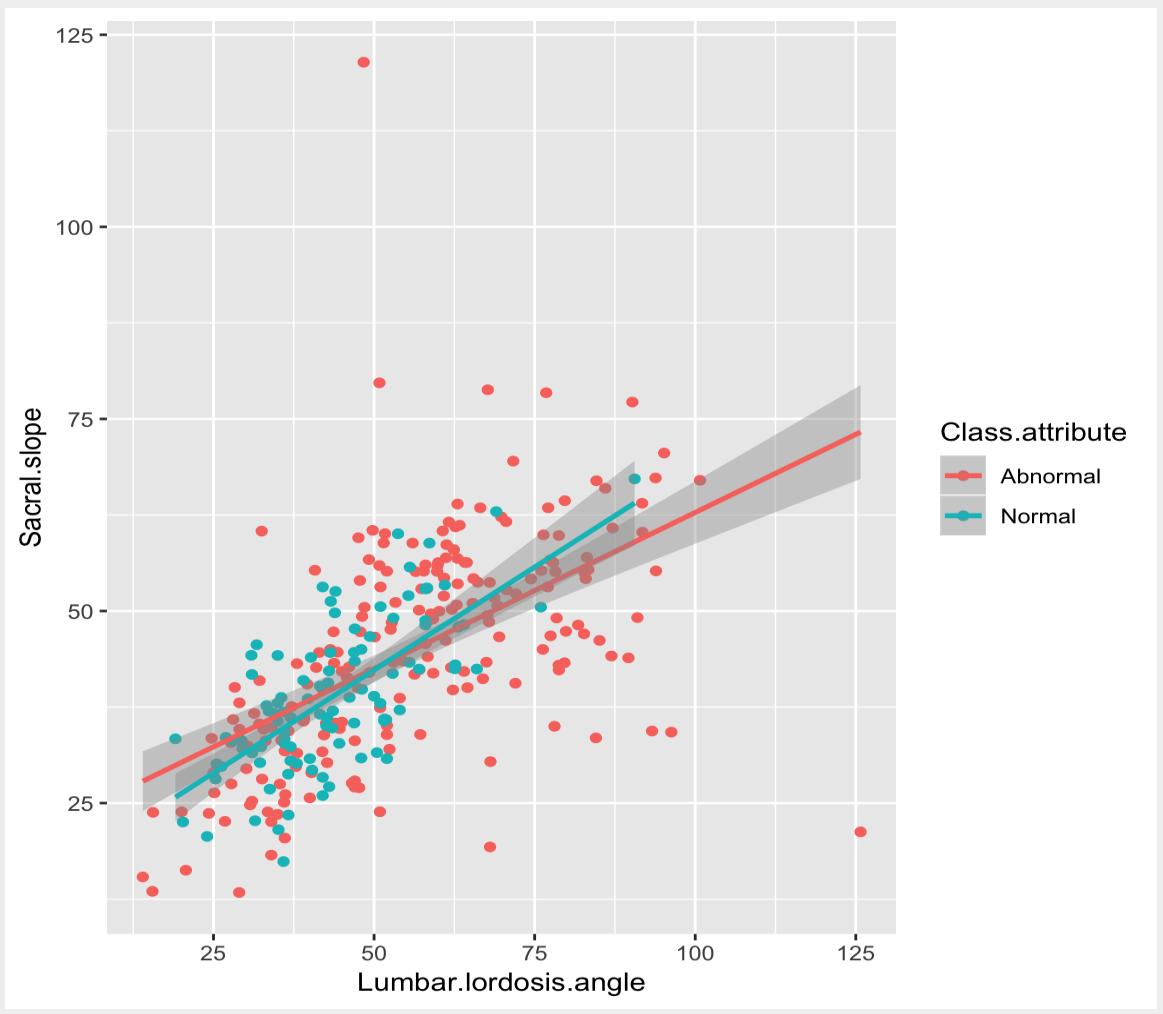
# SCATTER PLOT COMBINATIONS

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope,  
group = Class.attribute, color =  
Class.attribute))+  
geom_point(aes(size = Pelvic.slope))
```



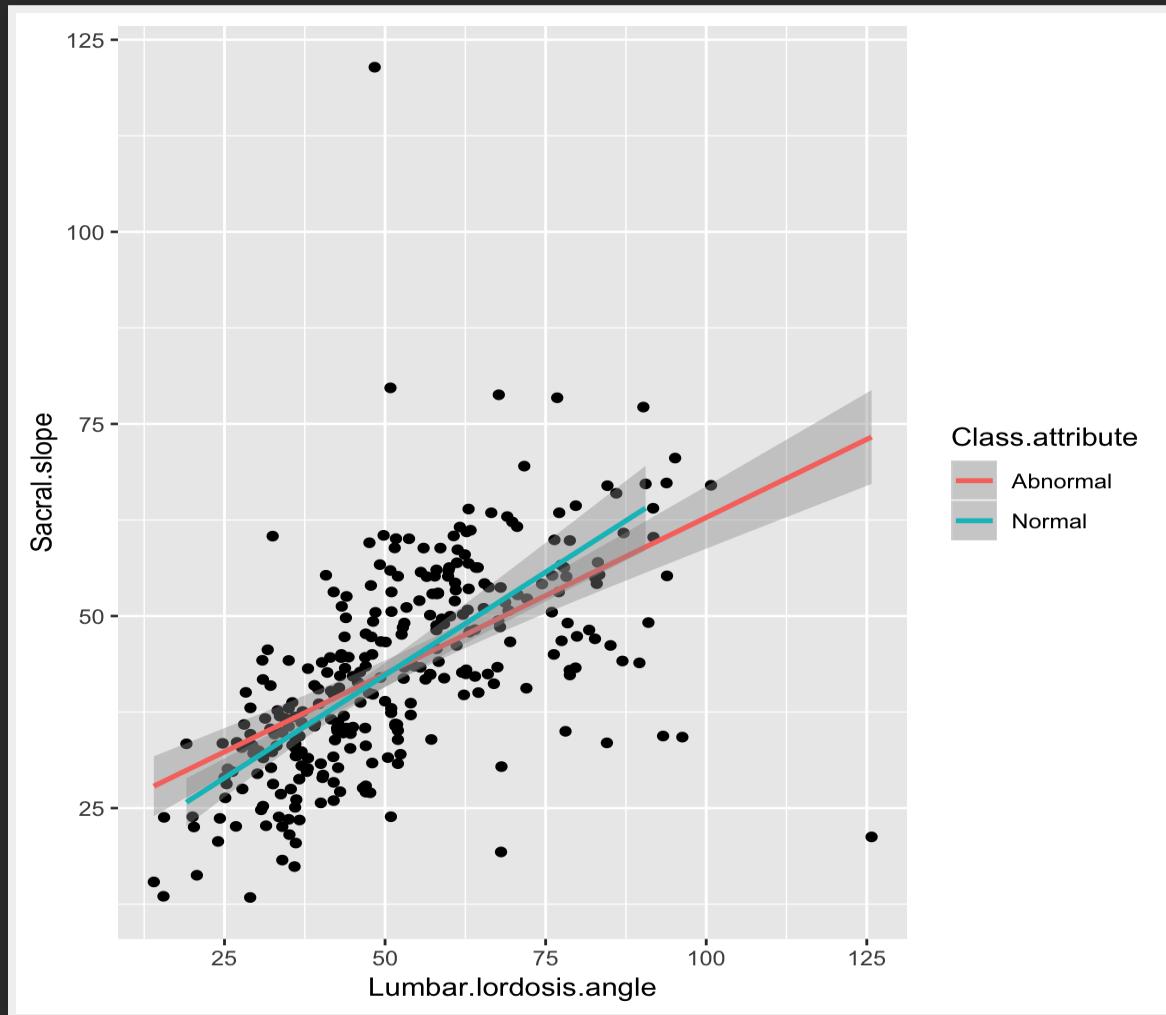
# SCATTER PLOT WITH LINES

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope,  
                      group = Class.attribute,  
                      color=Class.attribute))+  
  geom_point() +  
  geom_smooth(method='lm')
```



# SCATTER PLOT WITH LINES

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point() +  
  geom_smooth(aes(color = Class.attribute), method = 'lm')
```



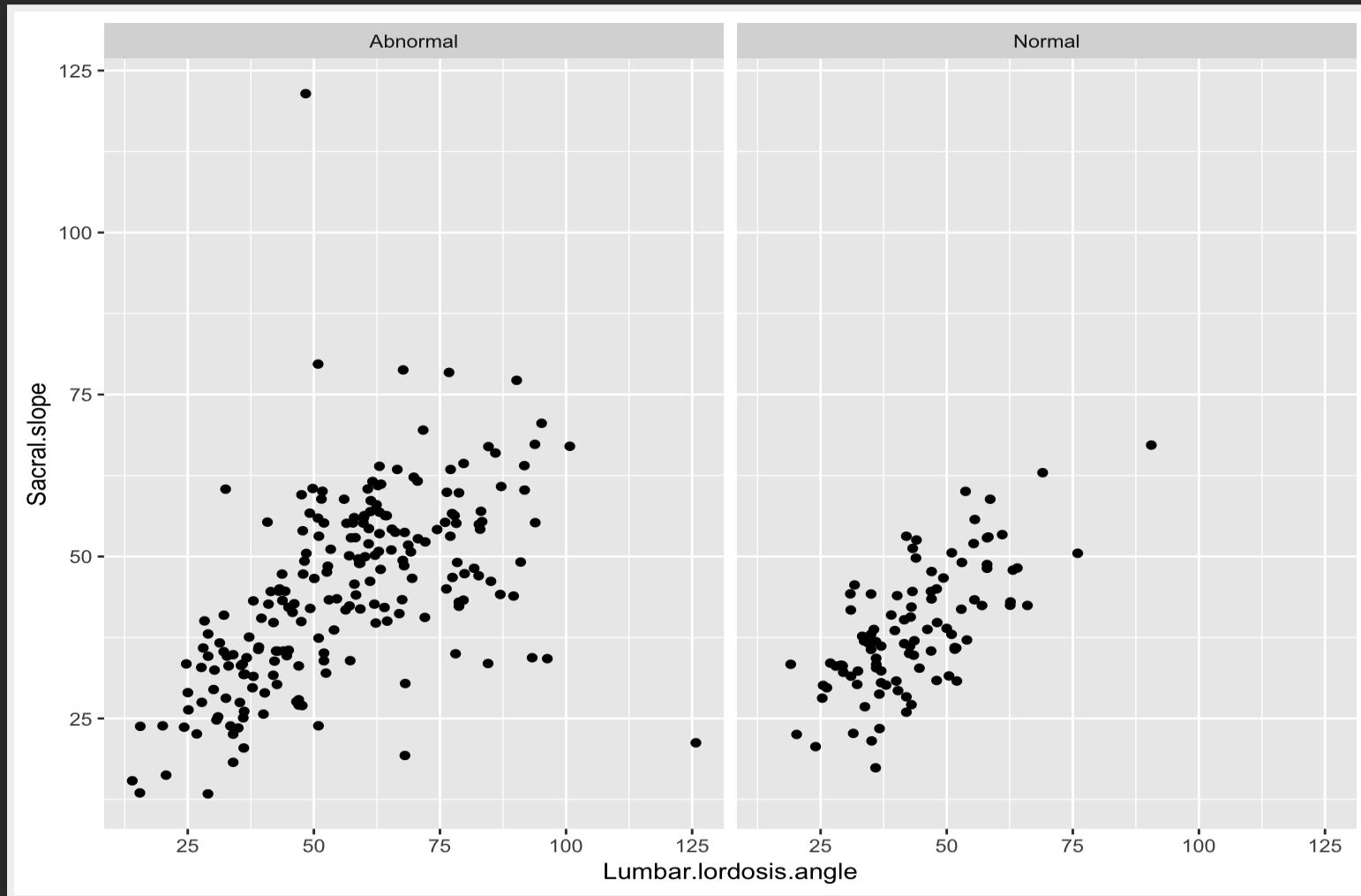
# FACETTING

# FACETTING

Facetted graphs are a panel of graphs, each of which corresponds to a particular subgroup of the data.

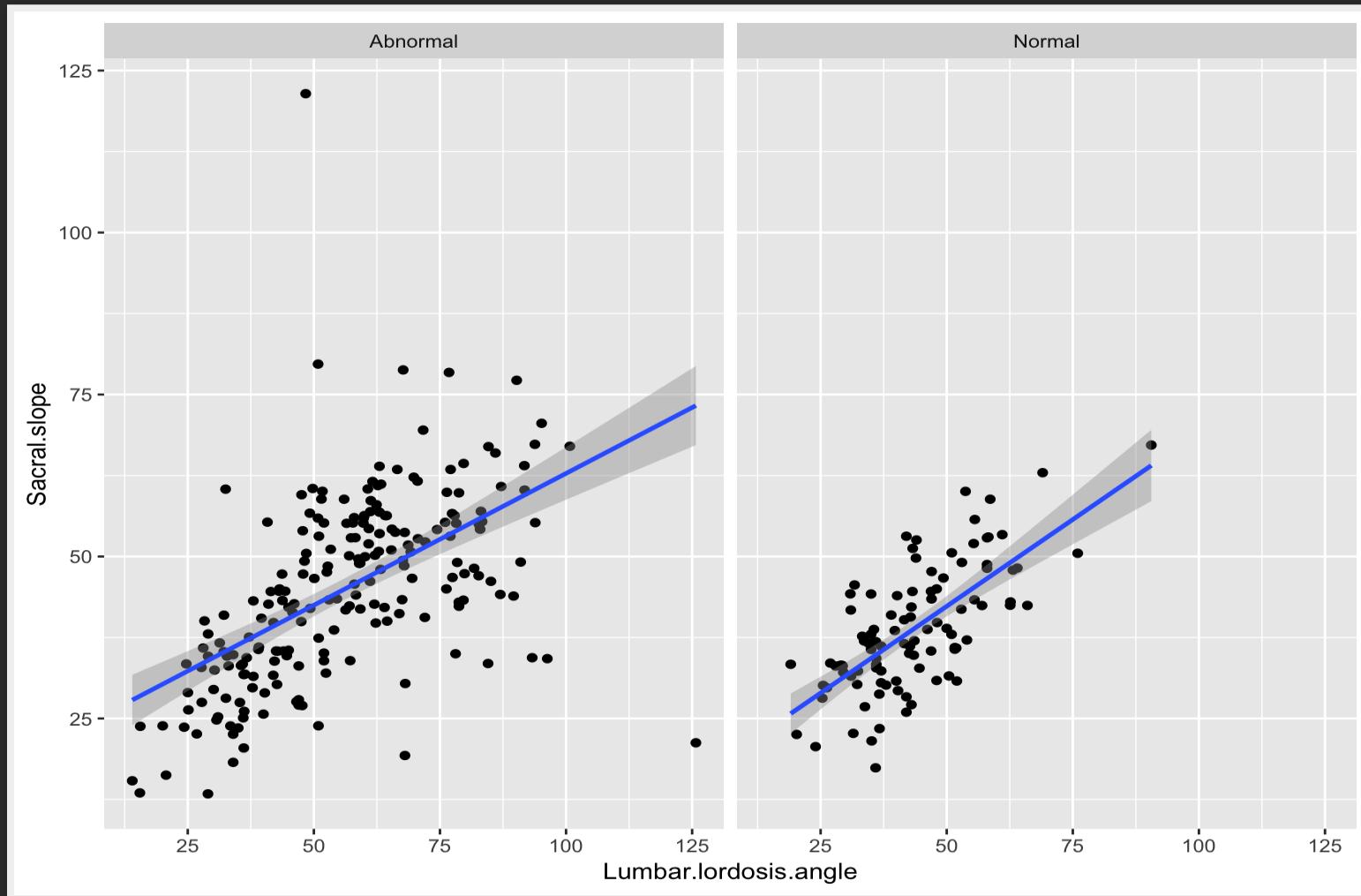
# FACETTED SCATTER PLOT

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point() +  
  facet_wrap(~ Class.attribute, nrow=1)
```



# FACETTED SCATTER PLOT WITH LINES

```
ggplot(data_spine, aes(x = Lumbar.lordosis.angle, y = Sacral.slope)) +  
  geom_point() + geom_smooth(method='lm') +  
  facet_wrap(~ Class.attribute, nrow=1)
```



# MANHATTAN PLOT

# MANHATTAN PLOT

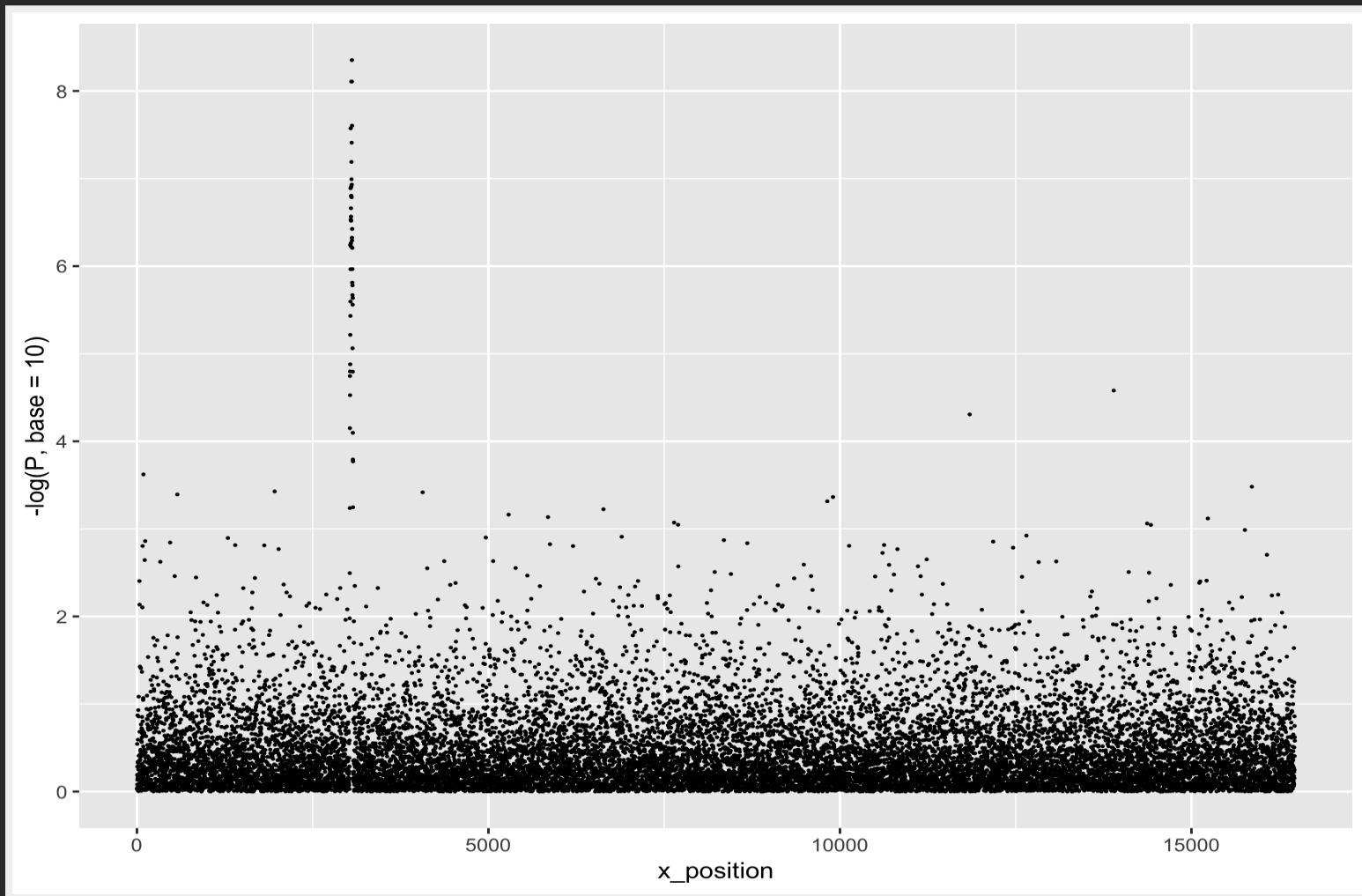
```
library(qqman)
data(gwasResults)
head(gwasResults)
```

```
#      SNP CHR  BP          P
# 1 rs1    1   1 0.9148060
# 2 rs2    1   2 0.9370754
# 3 rs3    1   3 0.2861395
# 4 rs4    1   4 0.8304476
# 5 rs5    1   5 0.6417455
# 6 rs6    1   6 0.5190959
```

```
gwasResults <- gwasResults %>%
  mutate(x_position = 1:n())
```

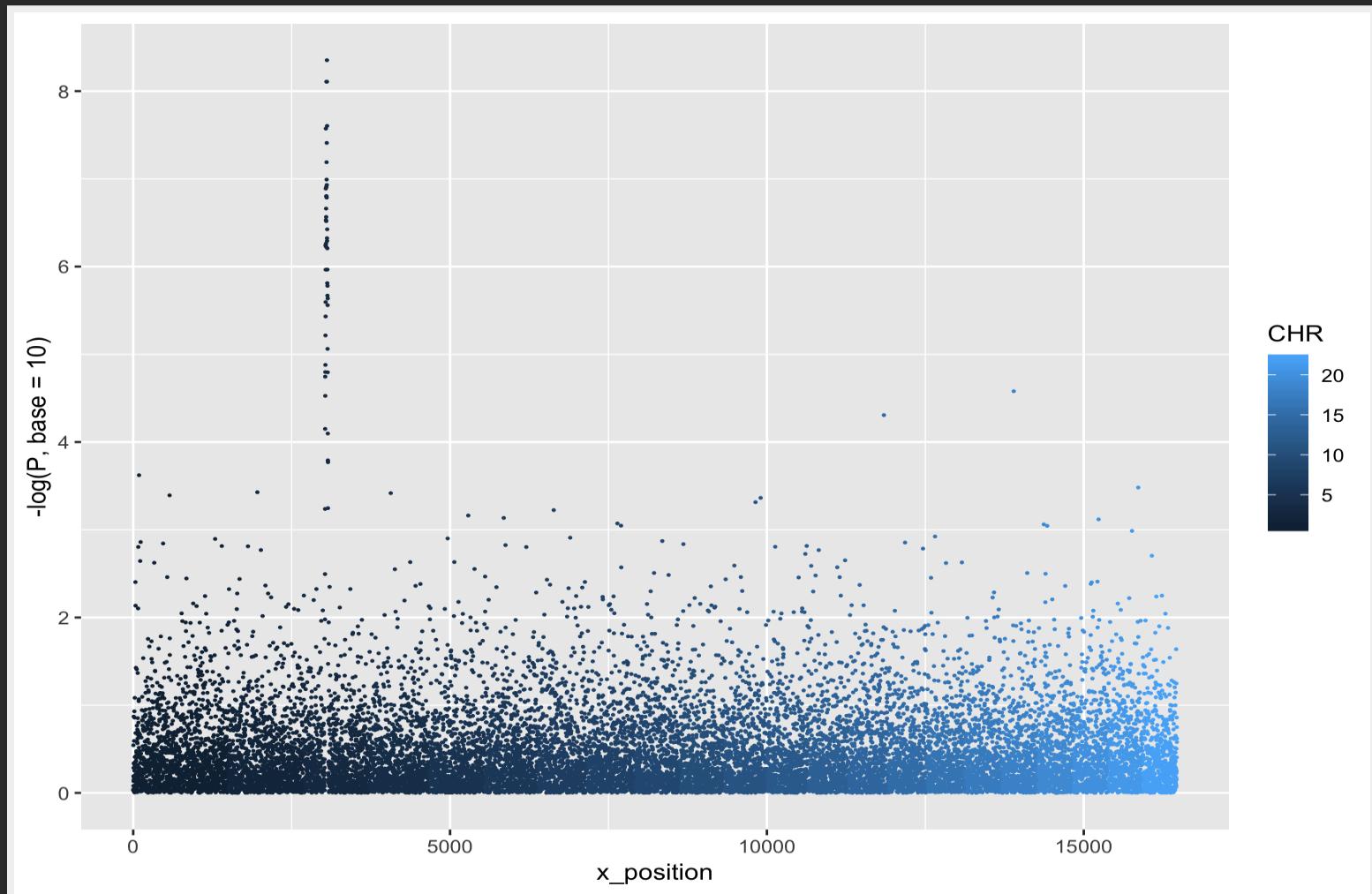
# MANHATTAN PLOT

```
ggplot(gwasResults, aes(x = x_position, y = -log(P, base=10)))+  
  geom_point(size = 0.2)
```



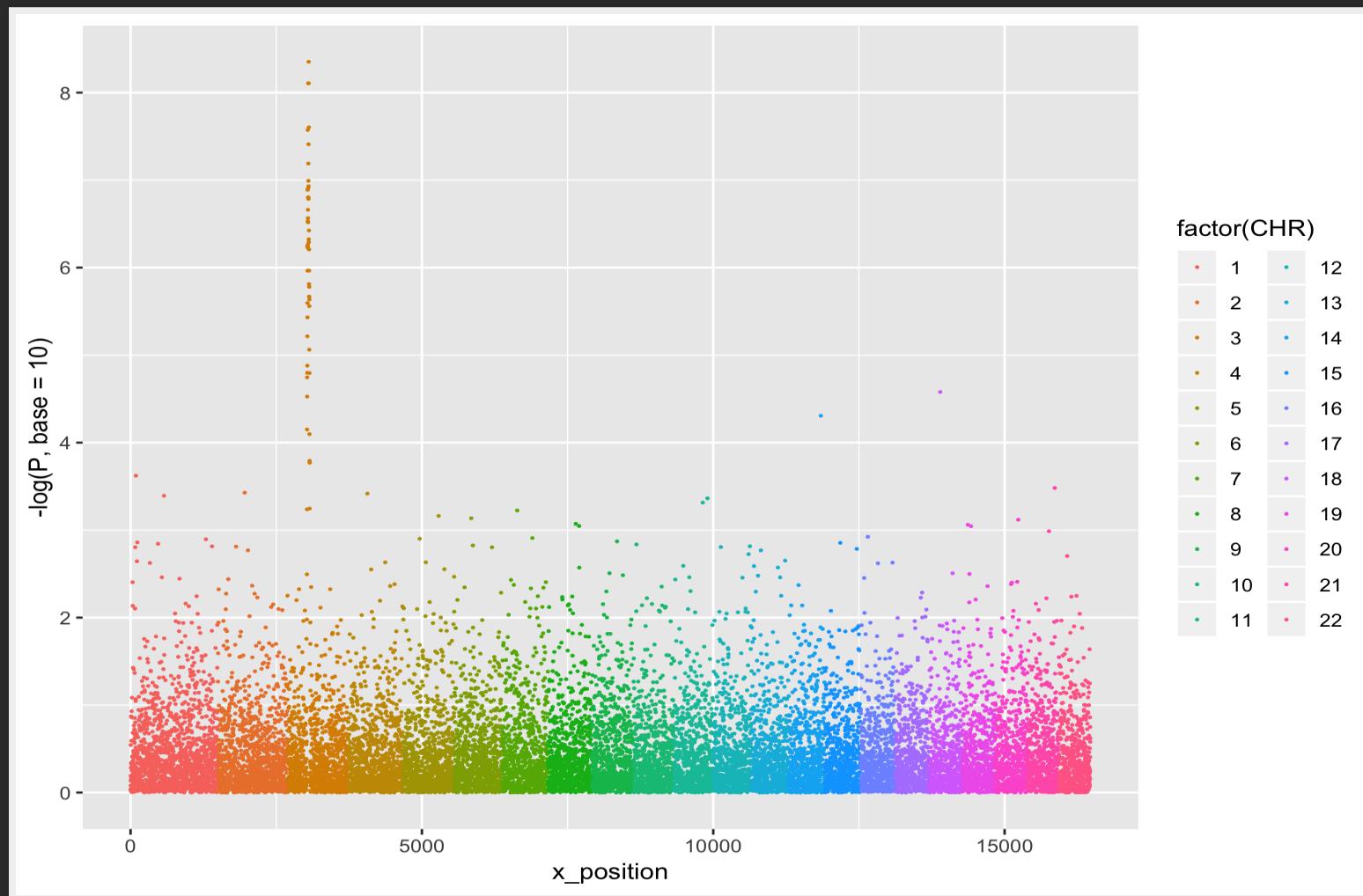
# MANHATTAN PLOT

```
ggplot(gwasResults, aes(x=x_position, y=-log(P, base=10),  
                        group=CHR, color=CHR)) +  
  geom_point(size=0.2)
```



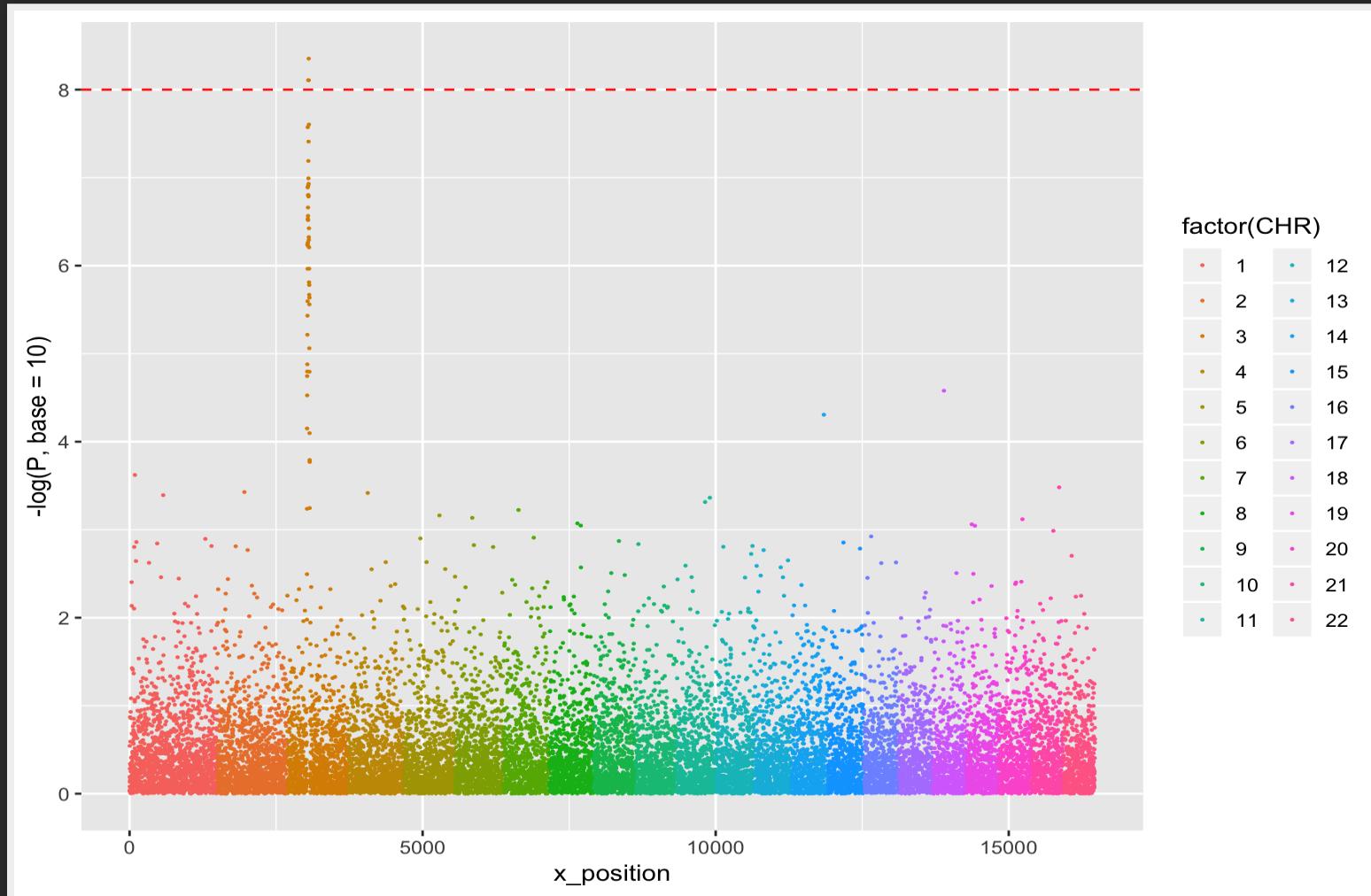
# MANHATTAN PLOT

```
ggplot(gwasResults, aes(x = x_position, y = -log(P, base=10),  
group=factor(CHR), color=factor(CHR)))+  
geom_point(size=0.2)
```



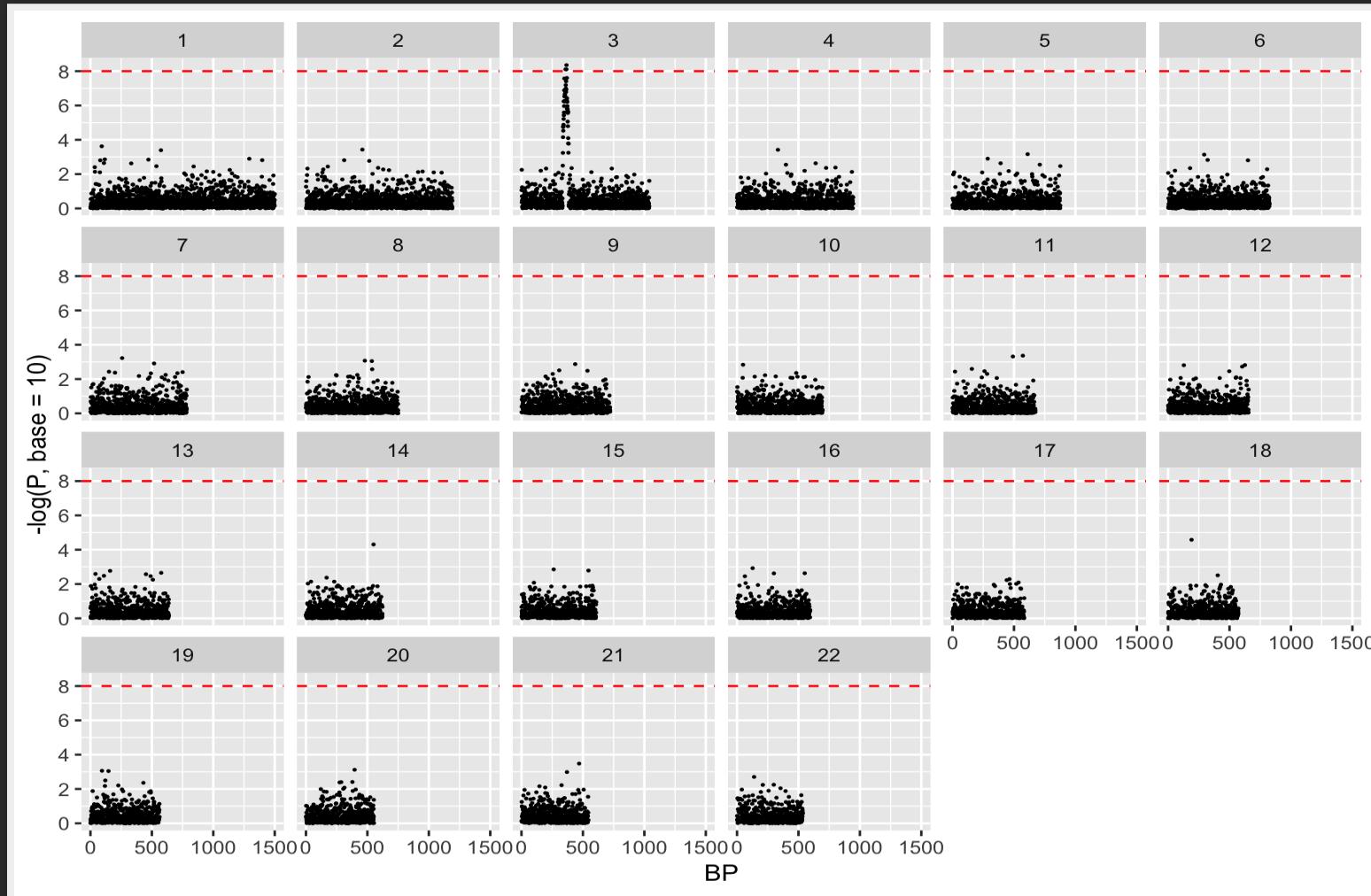
# MANHATTAN PLOT

```
ggplot(gwasResults, aes(x = x_position, y = -log(P, base=10),  
                        group=factor(CHR), color=factor(CHR)))+  
  geom_point(size=0.2)+  
  geom_hline(yintercept = 8, color='red', linetype=2)
```



# MANHATTAN PLOT, EXPLODED

```
ggplot(gwasResults, aes(x = BP, y = -log(P, base=10)))+  
  geom_point(size=0.2)+  
  facet_wrap(~ CHR, nrow=4)+  
  geom_hline(yintercept = 8, color='red', linetype=2)
```



# MANHATTAN PLOT, EXPLODED

