# Data Visualization Using R & ggplot2

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August 6, 2017

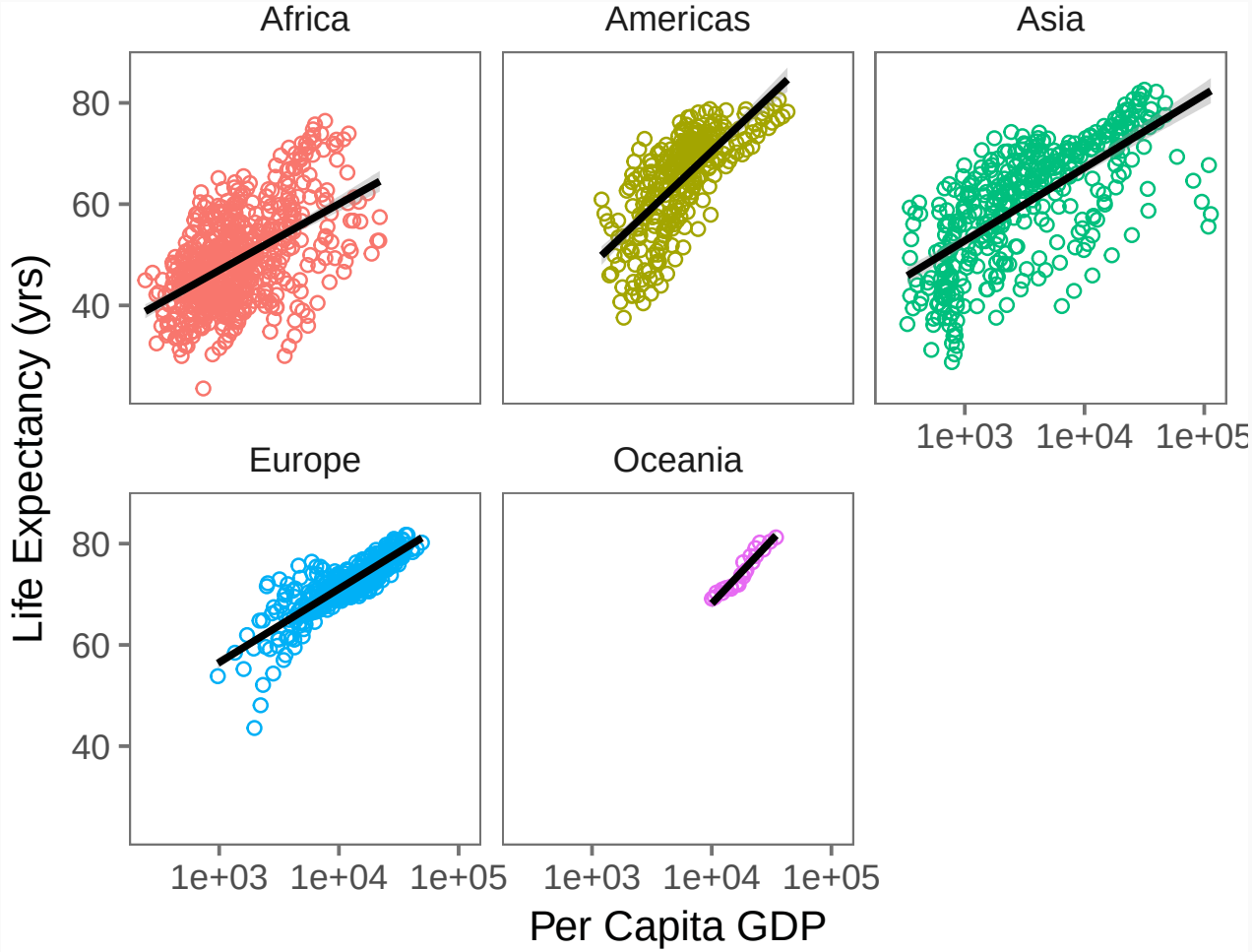
# Some housekeeping

Install some packages

```
install.packages("ggplot2", dependencies = TRUE)
install.packages("ggthemes")
install.packages("tidyr")
install.packages("dplyr")
```

# Why ggplot?

# 1 minute

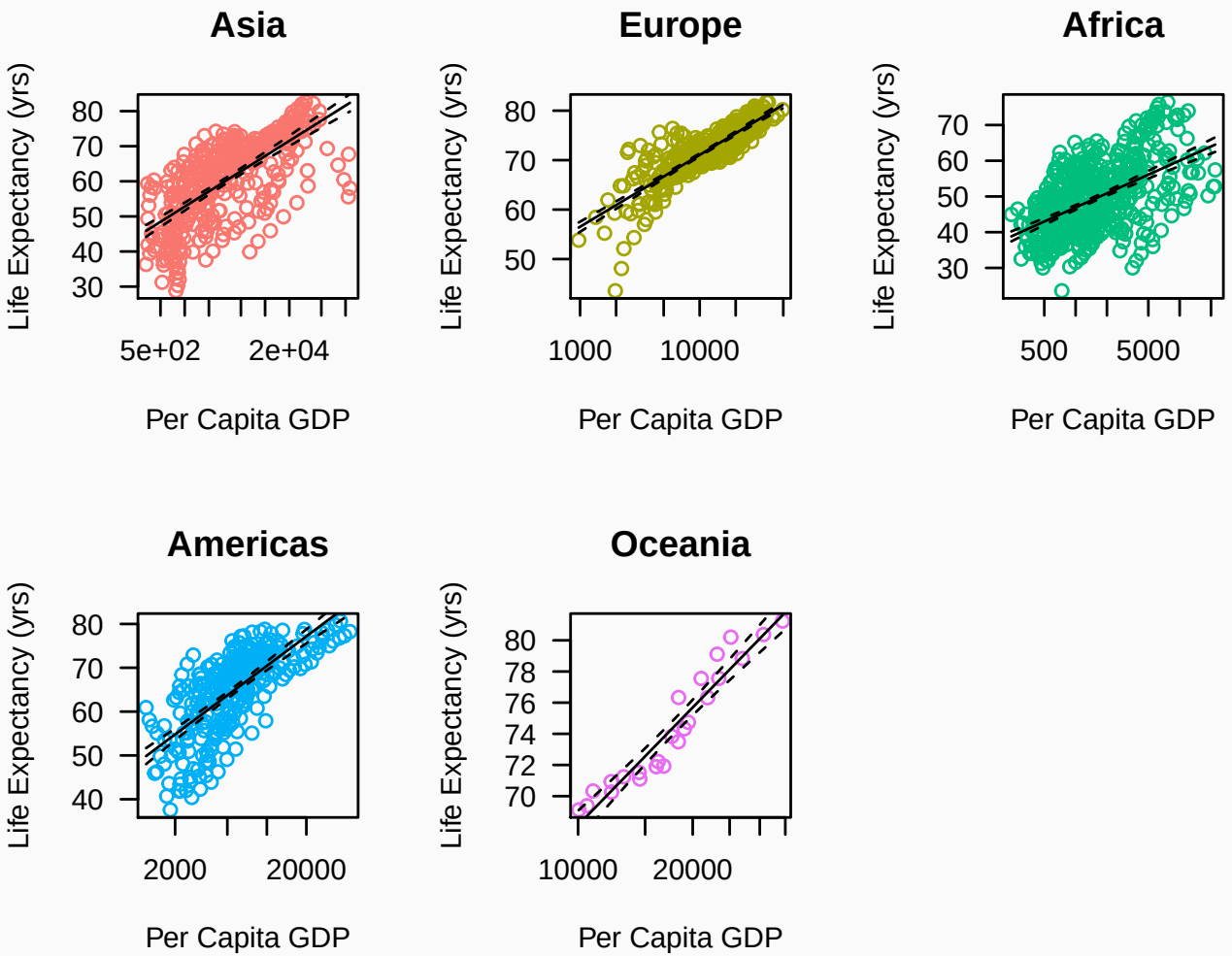

Africa
Americas
Asia
Europe
Oceania
Life Expectancy (yrs)
80
60
40
1e+03
1e+04
1e+05
Per Capita GDP

# 1 minute

```
library(ggplot2)
library(gapminder)
library(ggthemes)

ggplot(gapminder, aes(x = gdpPercap, y = lifeExp)) +
  geom_point(shape = 1, aes(color = continent)) +
  stat_smooth(method = "lm", size = 1, color = "black") +
  scale_x_log10() +
  xlab("Per Capita GDP") +
  ylab("Life Expectancy (yrs)") +
  facet_wrap(~continent) +
  theme_few() +
  guides(color = FALSE)
```

# 30 minutes


Asia
Life Expectancy (yrs)
80
70
60
50
40
30
5e+02
2e+04
Per Capita GDP
Europe
Life Expectancy (yrs)
80
70
60
50
1000
10000
Per Capita GDP
Africa
Life Expectancy (yrs)
70
60
50
40
30
500
5000
Per Capita GDP
Americas
Life Expectancy (yrs)
80
70
60
50
40
2000
20000
Per Capita GDP
Oceania
Life Expectancy (yrs)
80
78
76
74
72
70
10000
20000
Per Capita GDP

# 30 minutes

```
library(scales)
library(gapminder)
gapminder <- as.data.frame(gapminder)
conts <- unique(gapminder[,"continent"])
cols <- scales::hue_pal()(length(conts))
par(mfrow = c(2,3))
counter <- 1
for (i in conts) {
  plot(gapminder[which(gapminder$continent == i), "gdpPercap"],
       gapminder[which(gapminder$continent == i), "lifeExp"], col = col
       xlab = "Per Capita GDP", ylab = "Life Expectancy (yrs)",
       main = i, las = 1, log = "x")
  fit <- lm(gapminder[which(gapminder$continent == i), "lifeExp"] ~
```

# But wait, there's more...

```
log(gapminder[which(gapminder$continent == i), "gdpPercap"]))
  pred <- predict(fit, interval = "confidence")
  lines(sort(gapminder[which(gapminder$continent == i), "gdpPercap"]),
  lines(sort(gapminder[which(gapminder$continent == i), "gdpPercap"]),
  lines(sort(gapminder[which(gapminder$continent == i), "gdpPercap"]),
  counter <- counter + 1
}
```

# Why ggplot?

# Why ggplot?

- More elegant and compact code than with base graphics
- More aesthetically pleasing defaults than lattice
- Very powerful for exploratory data analysis

# Why ggplot?

- gg is for grammar of graphics (term by Lee Wilkinson)
- A set of terms that defines the basic components of a plot
- Used to produce figures using coherant, consistant syntax

# Why ggplot?

- Supports a continuum of expertise
- Easy to get started, plenty of power for complex figures

# The Grammar

# Some terminology

**Data**

- Must be a data frame (`data.frame()`, `as.data.frame()`)
- Gets pulled into the `ggplot()` object

# A quick example

## The iris dataset

```
head(iris)
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
## 3          4.7         3.2          1.3         0.2  setosa
## 4          4.6         3.1          1.5         0.2  setosa
## 5          5.0         3.6          1.4         0.2  setosa
## 6          5.4         3.9          1.7         0.4  setosa
```

# tidyr

Helps your data play nice with ggplot

# tidyr

```
iris[1:2, ]
```

```
##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
```

```
library(tidyr)
df <- gather(iris, key = flower_attribute,
             value = measurement, -Species)
df[1:2, ]
```

```
##   Species flower_attribute measurement
## 1  setosa     Sepal.Length         5.1
## 2  setosa     Sepal.Length         4.9
```

# Aesthetics

# Some terminology

**aesthetics**

- How your data are represented visually
- a.k.a. mapping
- which data on the x
- which data on the y
- but also: color, size, shape, transparency

# An example

```
myplot <- ggplot(data = iris, aes(x = Sepal.Length,
                                  y = Sepal.Width))
summary(myplot)
```

```
## data: Sepal.Length, Sepal.Width, Petal.Length, Petal.Width,
##   Species [150x5]
## mapping:  x = Sepal.Length, y = Sepal.Width
## faceting: <ggproto object: Class FacetNull, Facet>
##     compute_layout: function
##     draw_back: function
##     draw_front: function
##     draw_labels: function
##     draw_panels: function
##     finish_data: function
##     init_scales: function
##     map: function
##     map_data: function
##     params: list
```

# Geometries

# Some terminology

**geometry**

- The geometric objects in the plot
- points, lines, polygons, etc.
- functions: `geom_point()`, `geom_bar()`, `geom_line()`

# Basic structure

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
  geom_point()

# Equivalently...
myplot <- ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width))
myplot + geom_point()
```

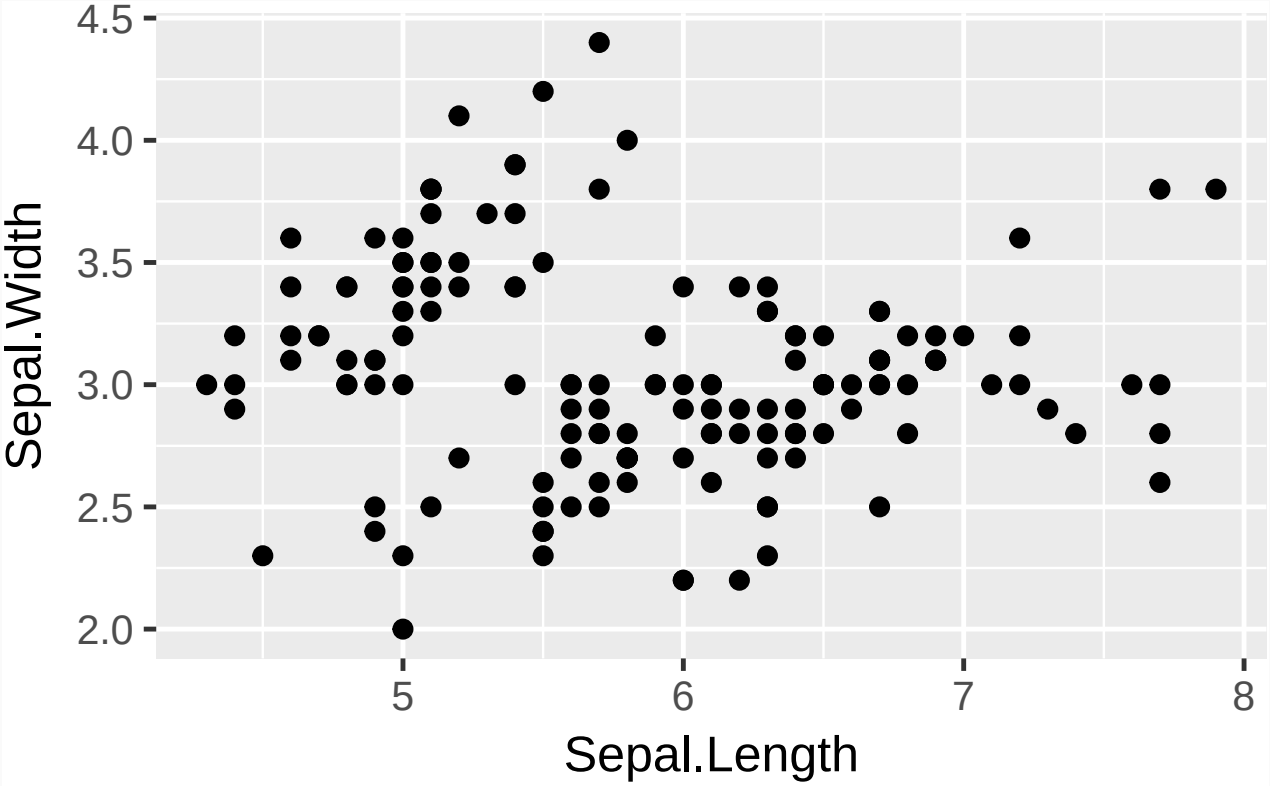
- Specify the data and variables inside the `ggplot()` function.
- Anything else that goes in here becomes a *global* setting.
- Then add layers: geometric objects, statistical models, and facets.

# Don’t be tempted!

- NEVER use `qplot()` - short for quick plot.
- You‘ll end up unlearning and relearning a good bit.

# Let's try an example

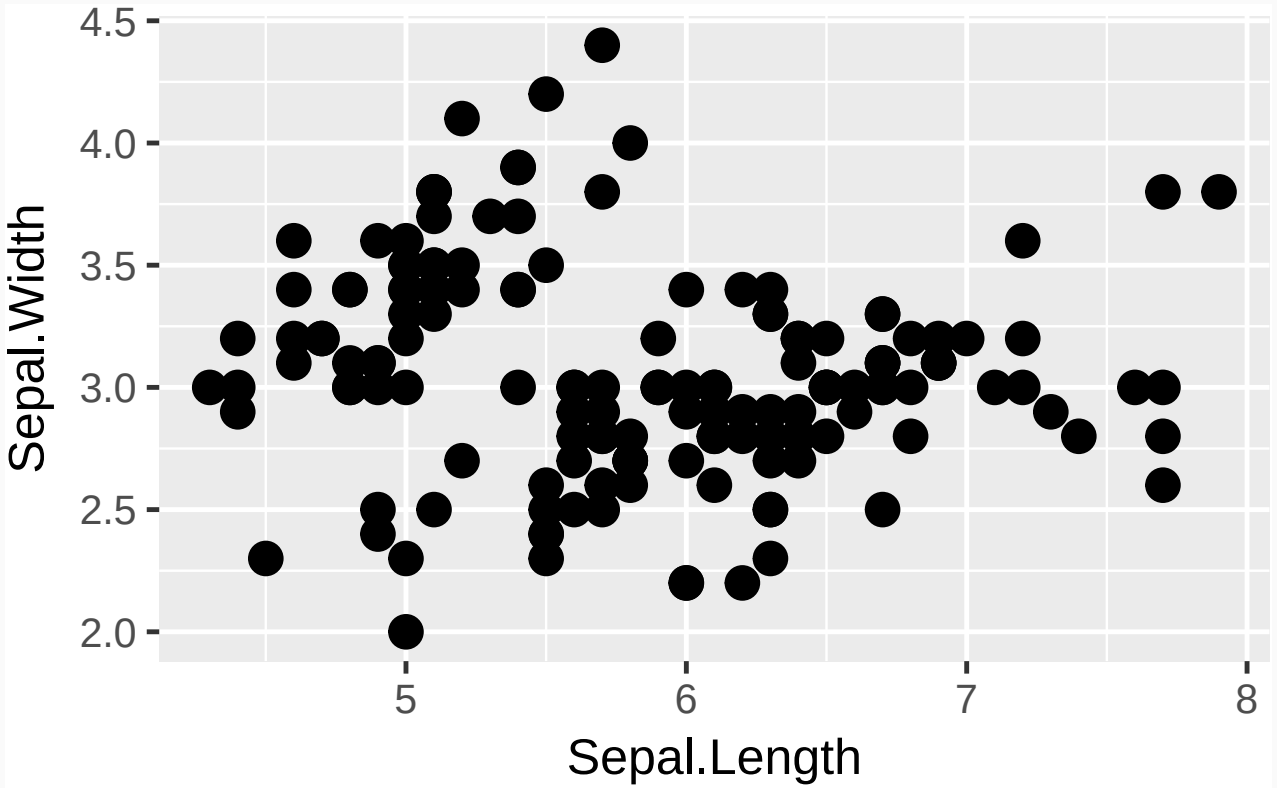
```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
    geom_point()
```



# Changing the aesthetics of a geom

## Increase the size of points

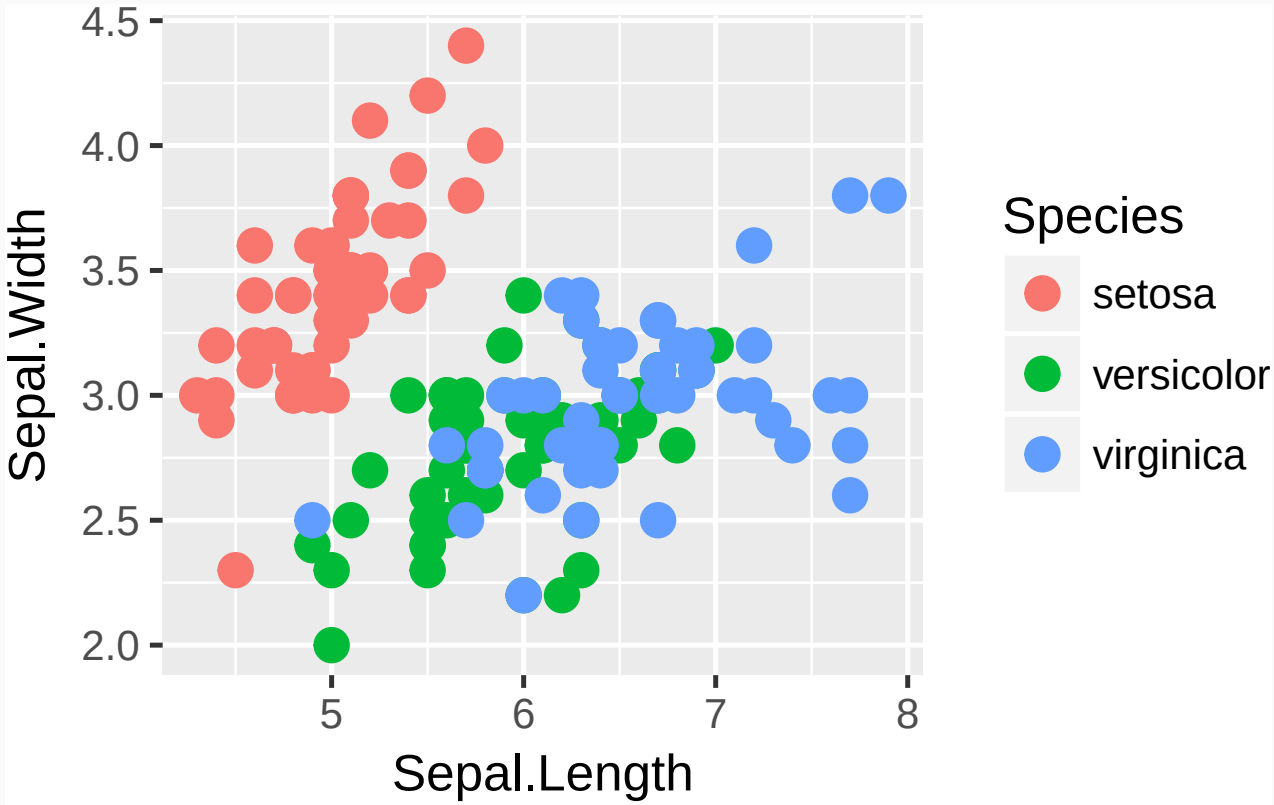
```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
    geom_point(size = 3)
```



# Changing the aesthetics of a geom

## Color by species (*mapping*!)

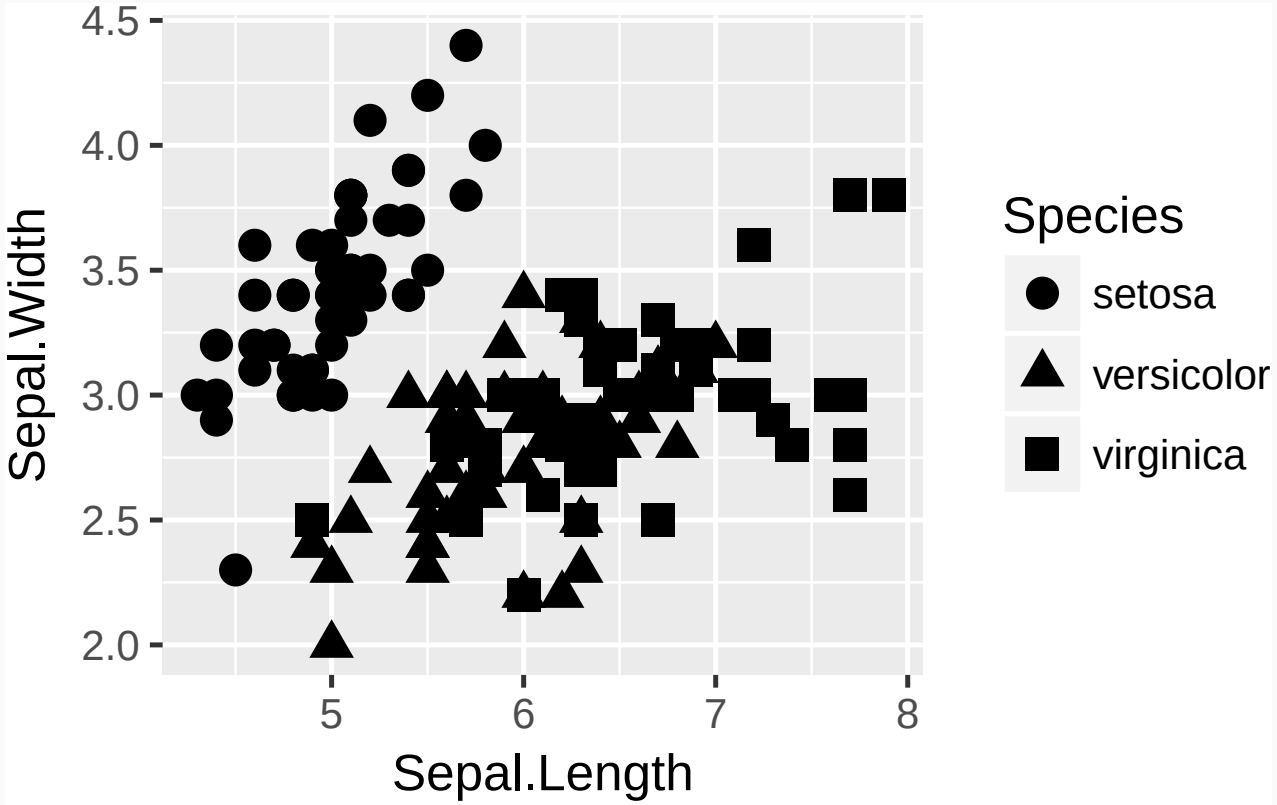
```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width,
                        color = Species)) +
    geom_point(size = 3)
```



# Changing the aesthetics of a geom

## Differentiate points by shape

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
    geom_point(size = 3, aes(shape = Species))
```

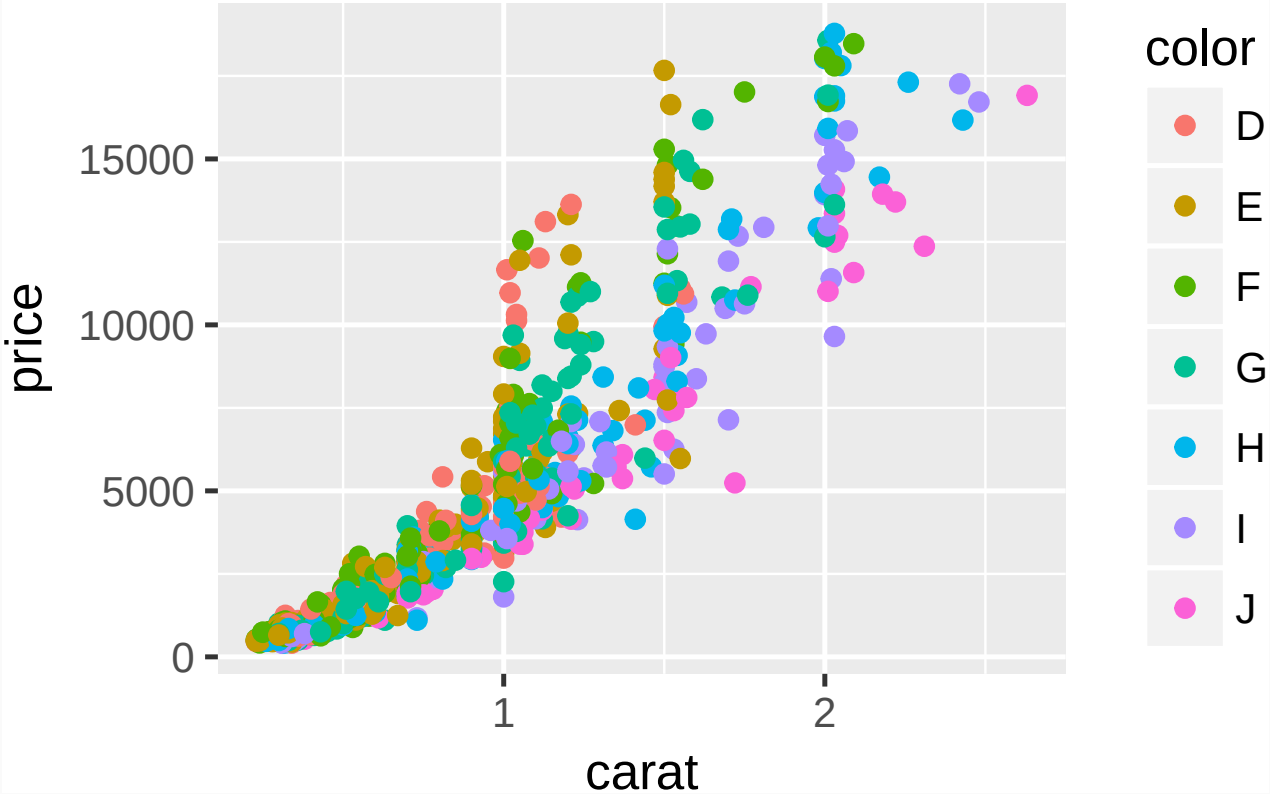


# Exercise 1

# Exercise 1

```
# Make a small sample of the diamonds dataset
d2 <- diamonds[sample(x = 1:nrow(diamonds), size = 1000), ]
```

The make this plot:



# Stats

# Some terminology

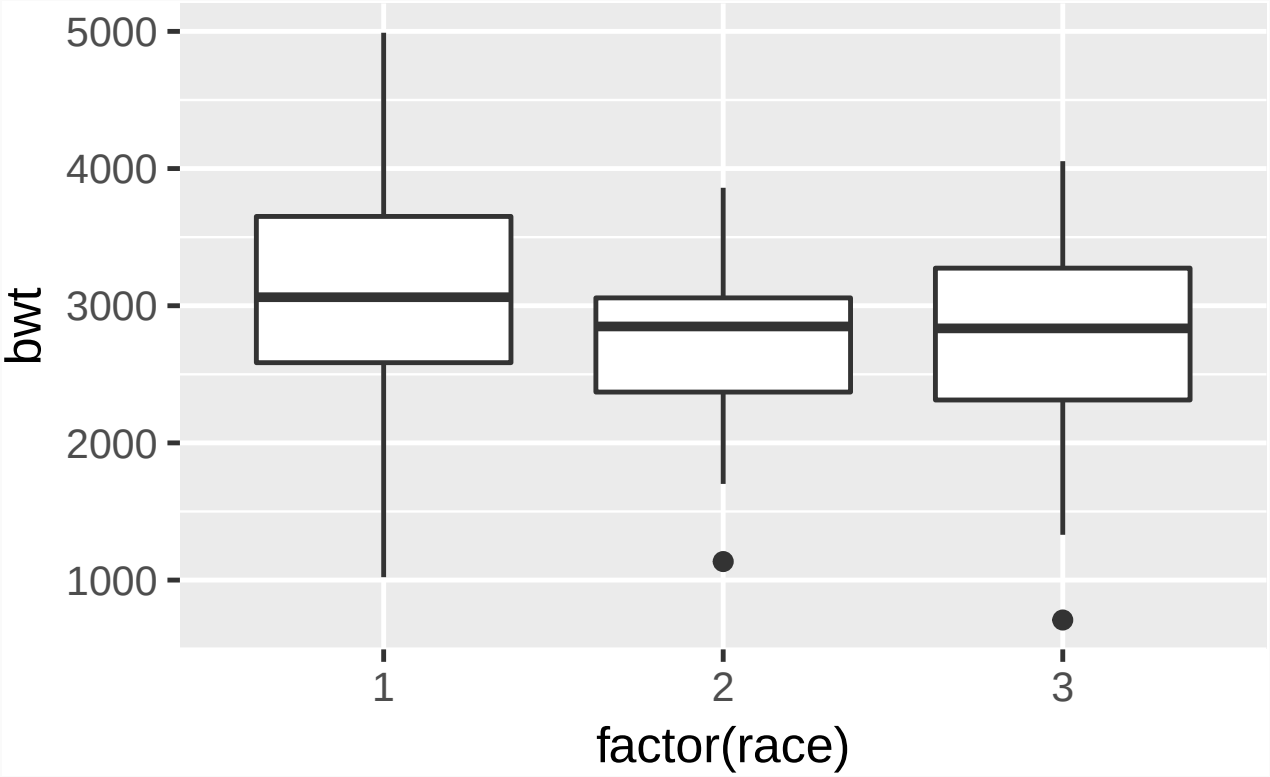
**stats**

- Statistical transformations and data summary
- All geoms have associated default stats, and vice versa
- e.g. binning (the stat) for a histogram or fitting a linear model

# Built-in stat example

See `?geom_boxplot` for options

```
library(MASS)
ggplot(birthwt, aes(factor(race), bwt)) +
  geom_boxplot()
```



# Built-in stat example

```
myplot <- ggplot(birthwt, aes(factor(race), bwt)) +
  geom_boxplot()
summary(myplot)
```

```
## data: low, age, lwt, race, smoke, ptl, ht, ui, ftv, bwt [189x10]
## mapping:  x = factor(race), y = bwt
## faceting: <ggproto object: Class FacetNull, Facet>
##     compute_layout: function
##     draw_back: function
##     draw_front: function
##     draw_labels: function
##     draw_panels: function
##     finish_data: function
##     init_scales: function
##     map: function
##     map_data: function
##     params: list
##     render_back: function
```

# Facets

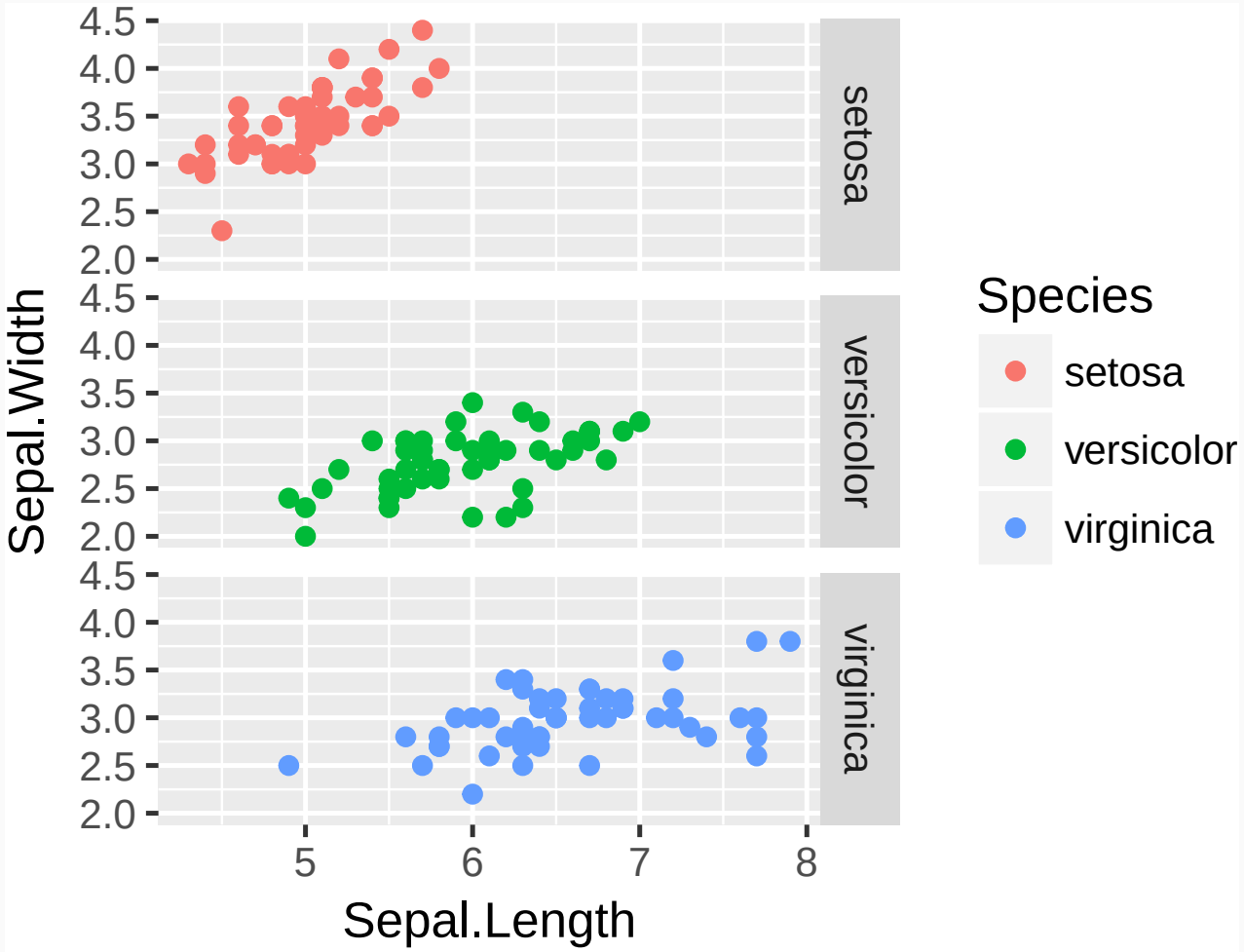
# Some terminology

**facets**

- Subsetting data to make lattice plots
- Really powerful
- I use in almost every publication

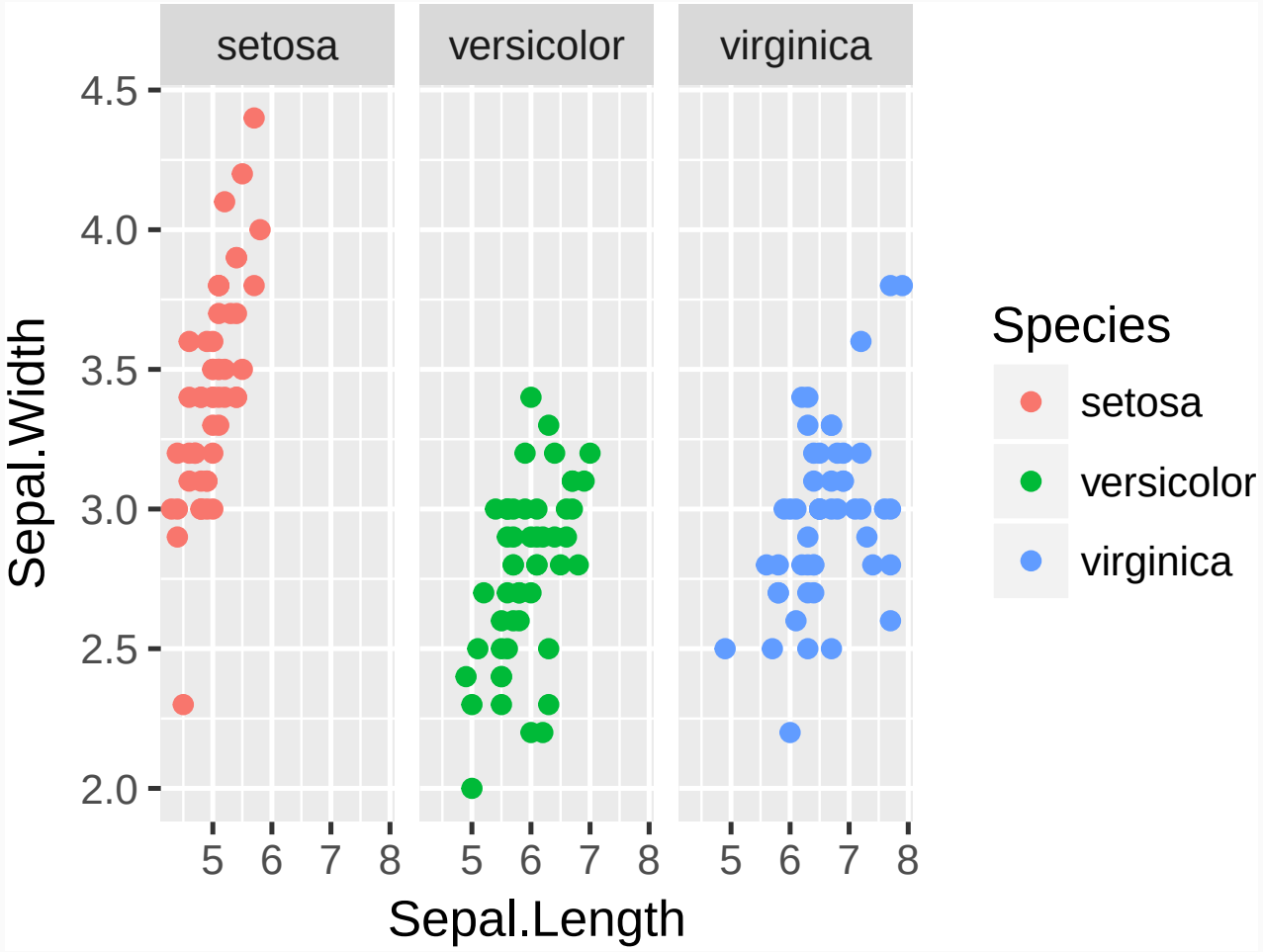
# Faceting: single column, multiple rows

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_grid(Species ~ .)
```



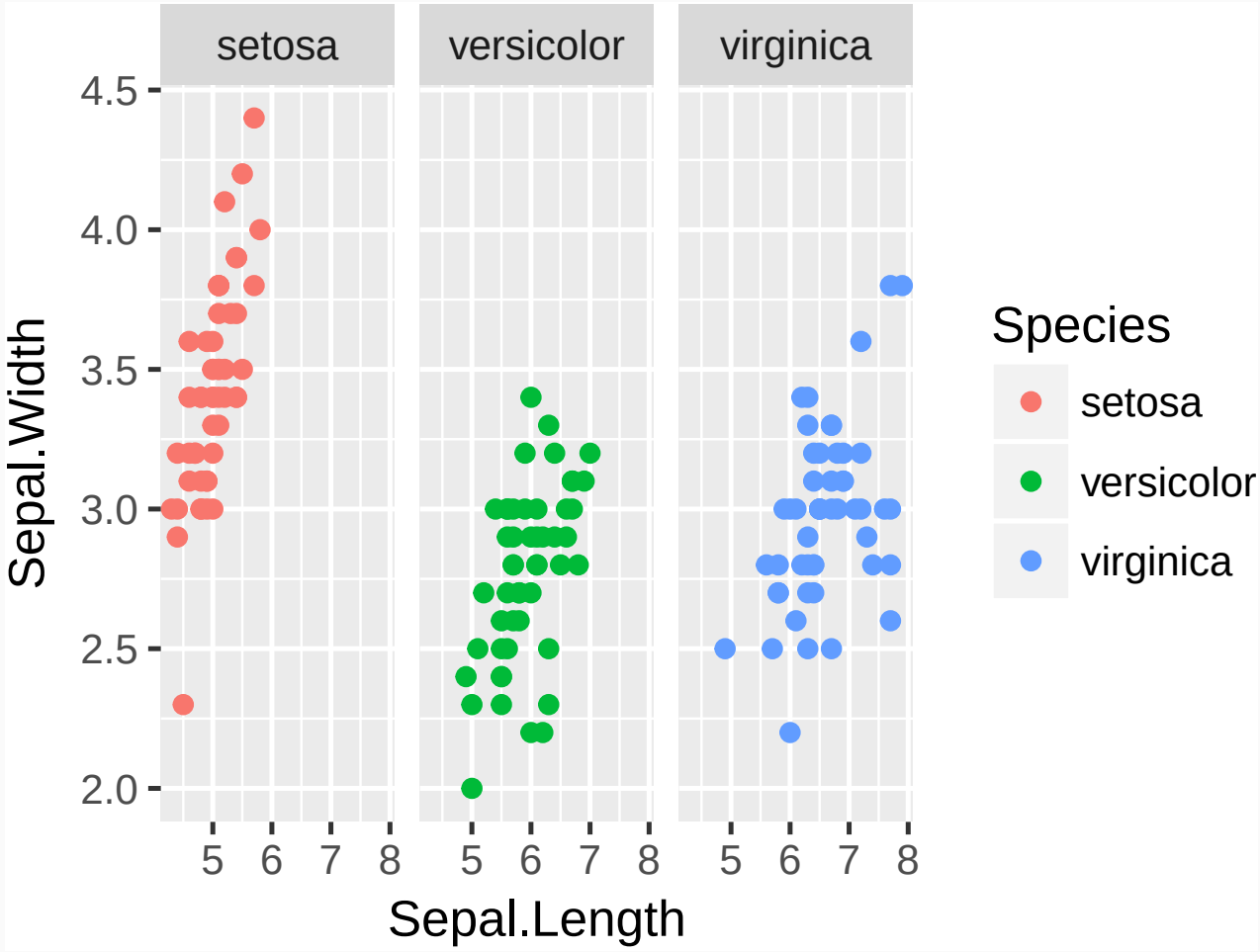
# Faceting: single row, multiple columns

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_grid(. ~ Species)
```



# Or, just wrap them

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_wrap( ~ Species) # notice lack of .
```



# Scales

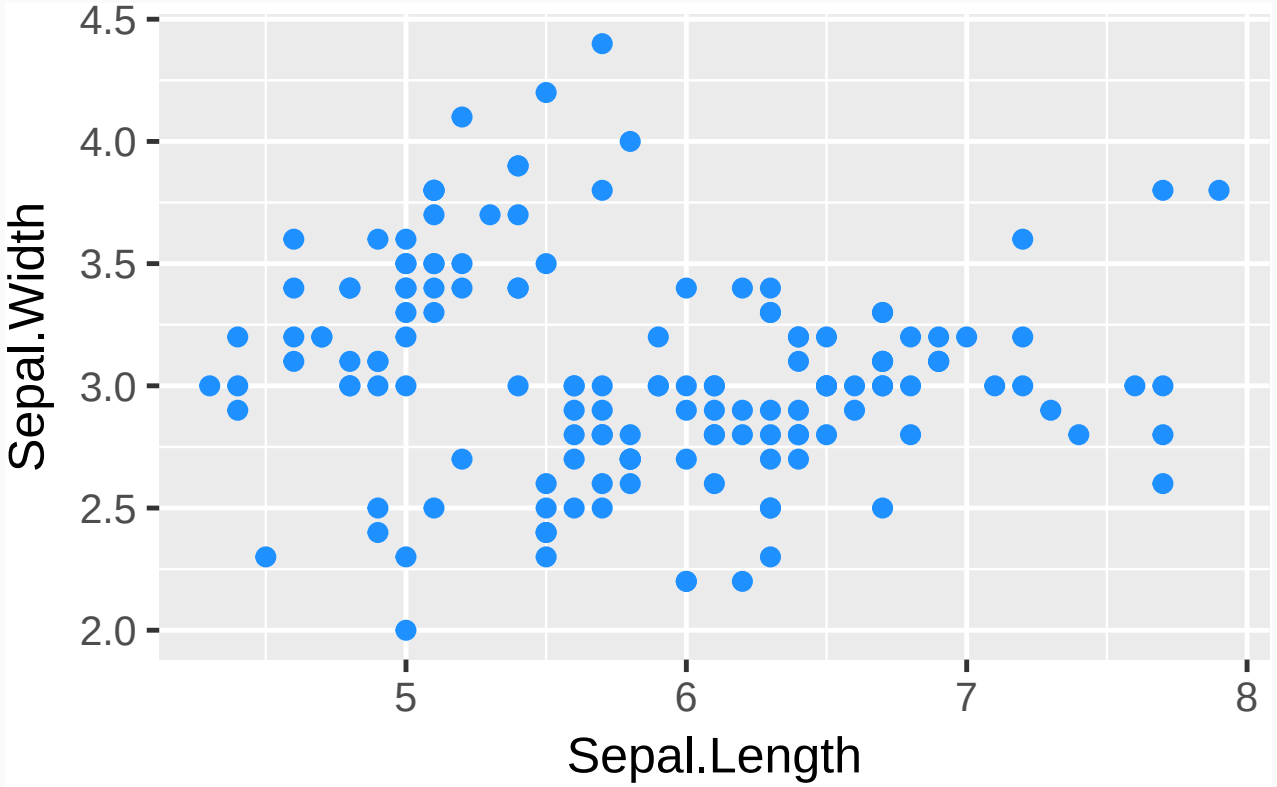
# Some terminology

**scales**

- Control the *mapping* from data to aesthetics
- Often used for adjusting color mapping (i.e., setting colors manually)

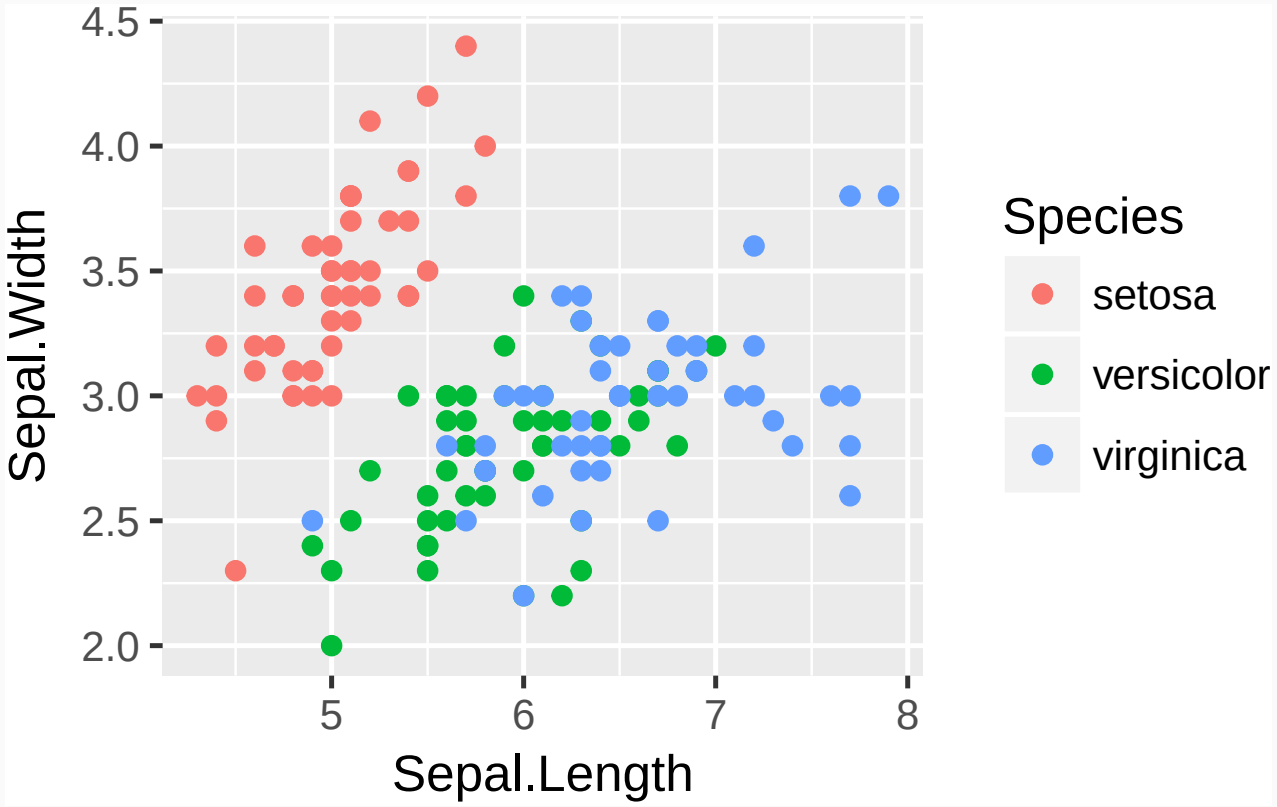
# Setting color

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(color = "dodgerblue")
```



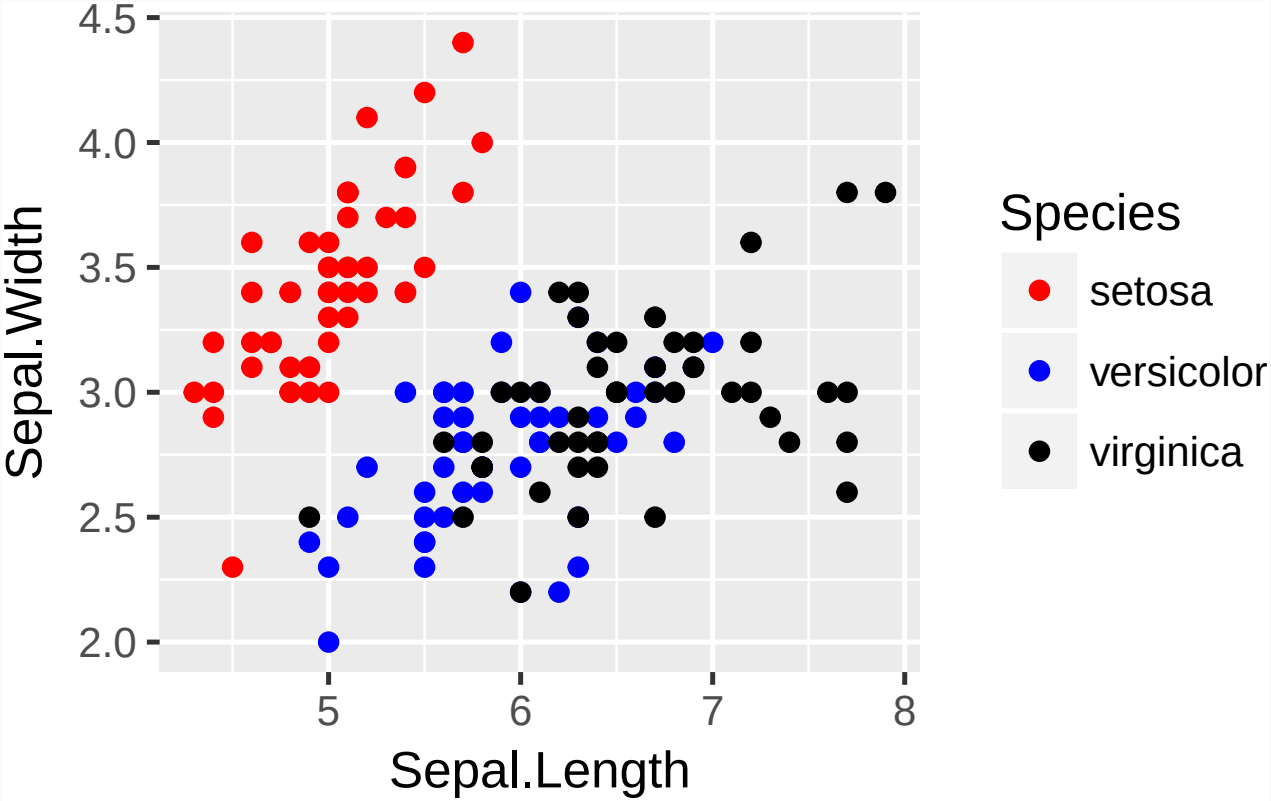
# Mapping color

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(aes(color = Species))
```



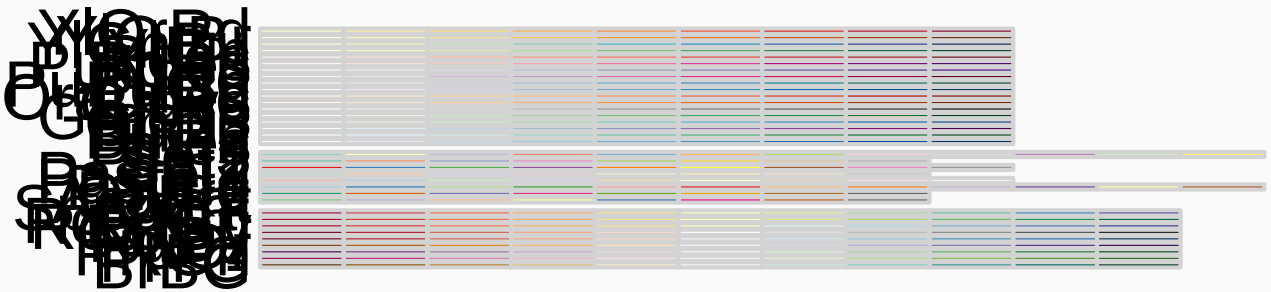
# Map custom color

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(aes(color = Species)) +
  scale_color_manual(values = c("red", "blue", "black"))
```



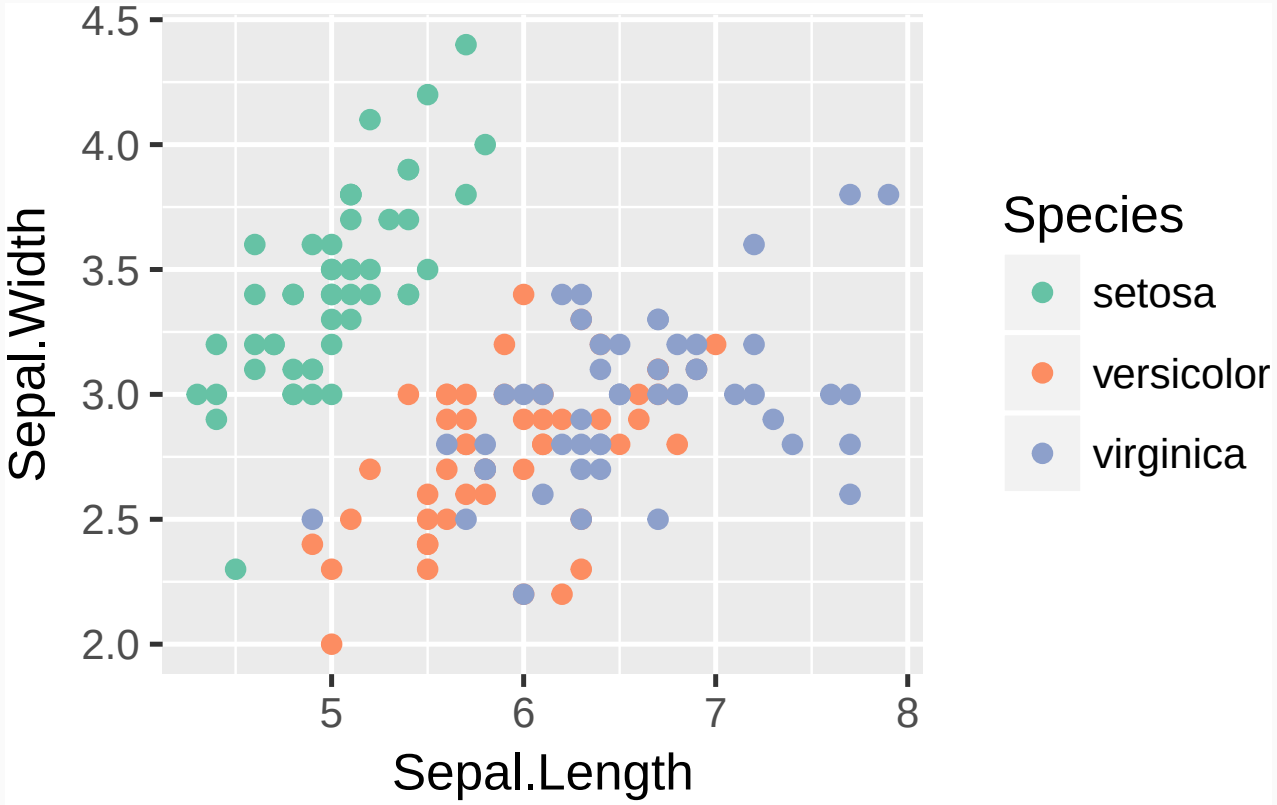
# RColorBrewer

```
library("RColorBrewer")
display.brewer.all()
```



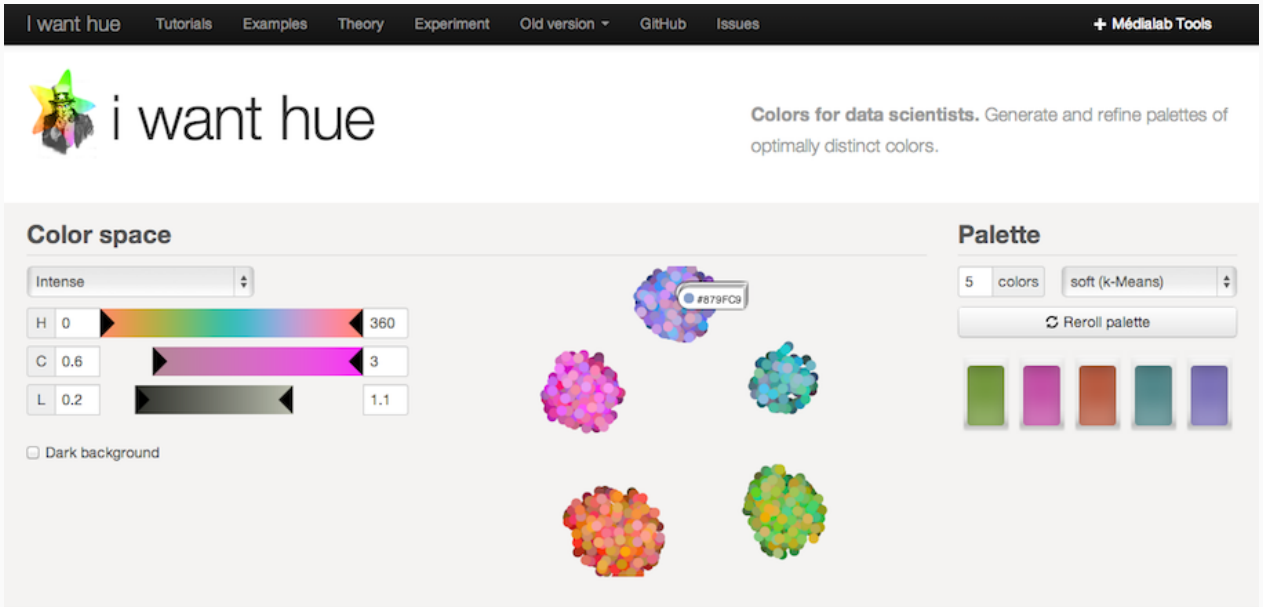
# Map custom color with brewer

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(aes(color = Species)) +
  scale_color_brewer(palette = "Set2")
```



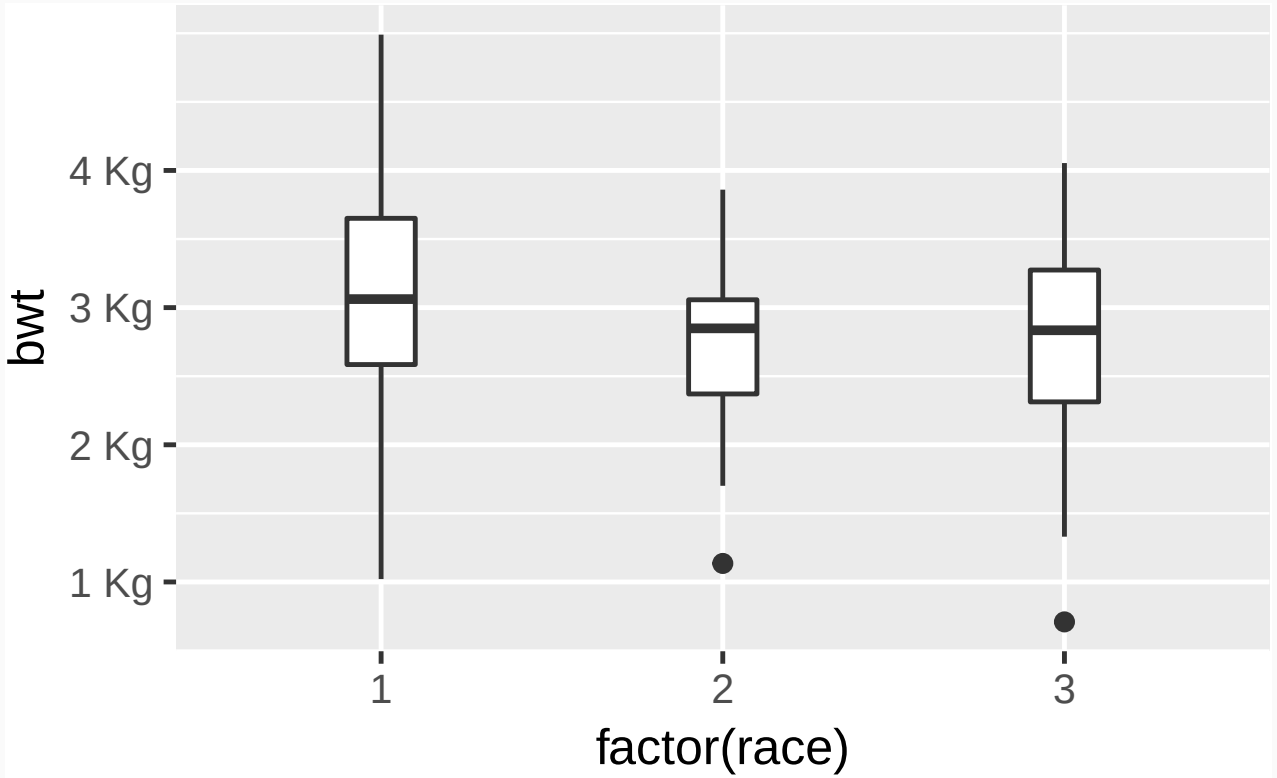
# Refer to a color chart for beautiful visualizations

http://tools.medialab.sciences-po.fr/iwanthue/



# Altering a continuous scale

```
library(MASS)
ggplot(birthwt, aes(x = factor(race), y = bwt)) +
  geom_boxplot(width = 0.2) +
  scale_y_continuous(labels = (paste0(1:4, " Kg")),
                     breaks = seq(1000, 4000, by = 1000))
```



# Some common scales

```
scale_fill_discrete(); scale_colour_discrete()
scale_fill_hue(); scale_color_hue()
scale_fill_manual();  scale_color_manual()
scale_fill_brewer(); scale_color_brewer()
scale_linetype(); scale_shape_manual()
```

# Coordinates

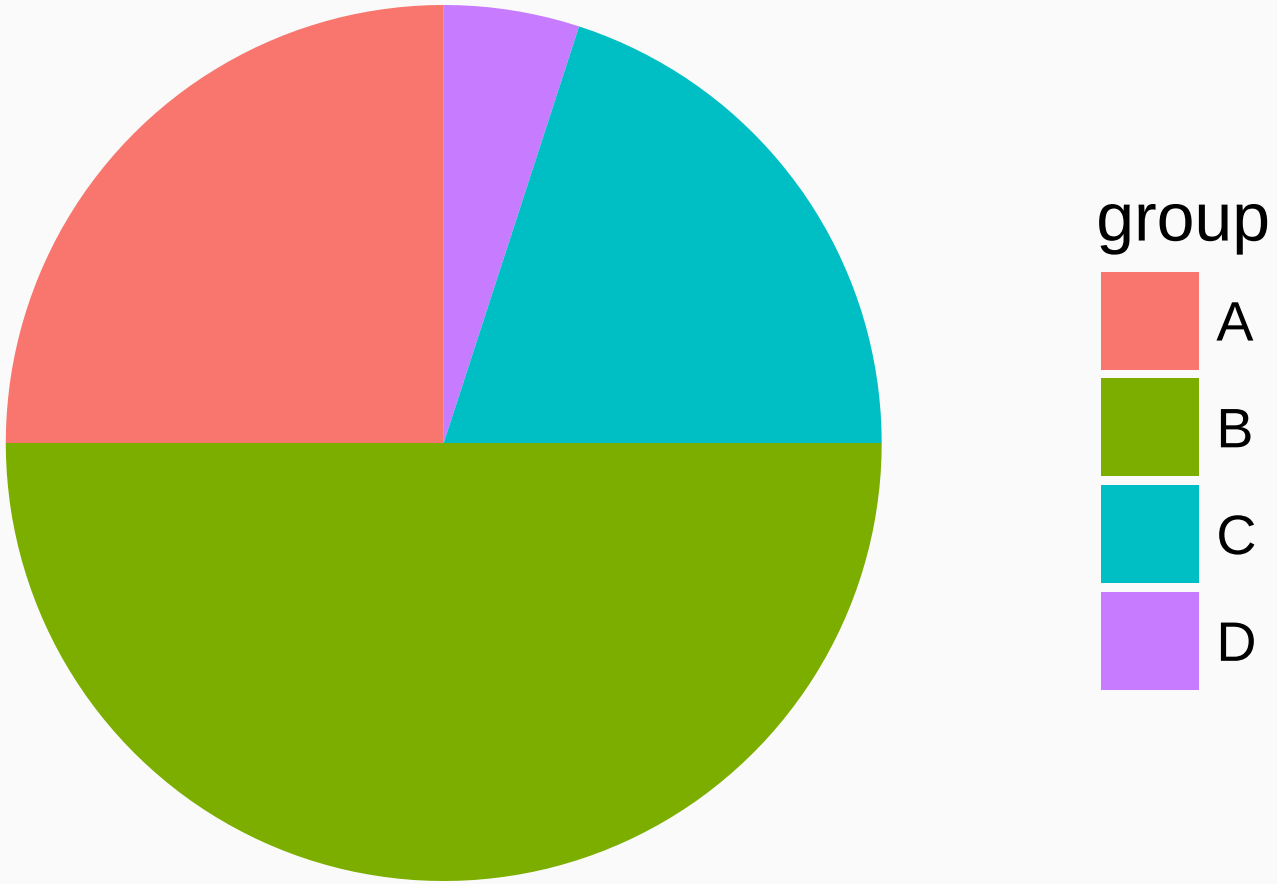
# Some terminology

**coordinates**

- Not going to cover this in detail
- e.g. polar coordinate plots

# Don't try this at home. . . please!

```
ggplot(mydata, aes(x = "", y = proportion, fill = group)) +
  geom_bar(stat = "identity", width = 1) +
  coord_polar("y", start=0) +
  theme_void()
```

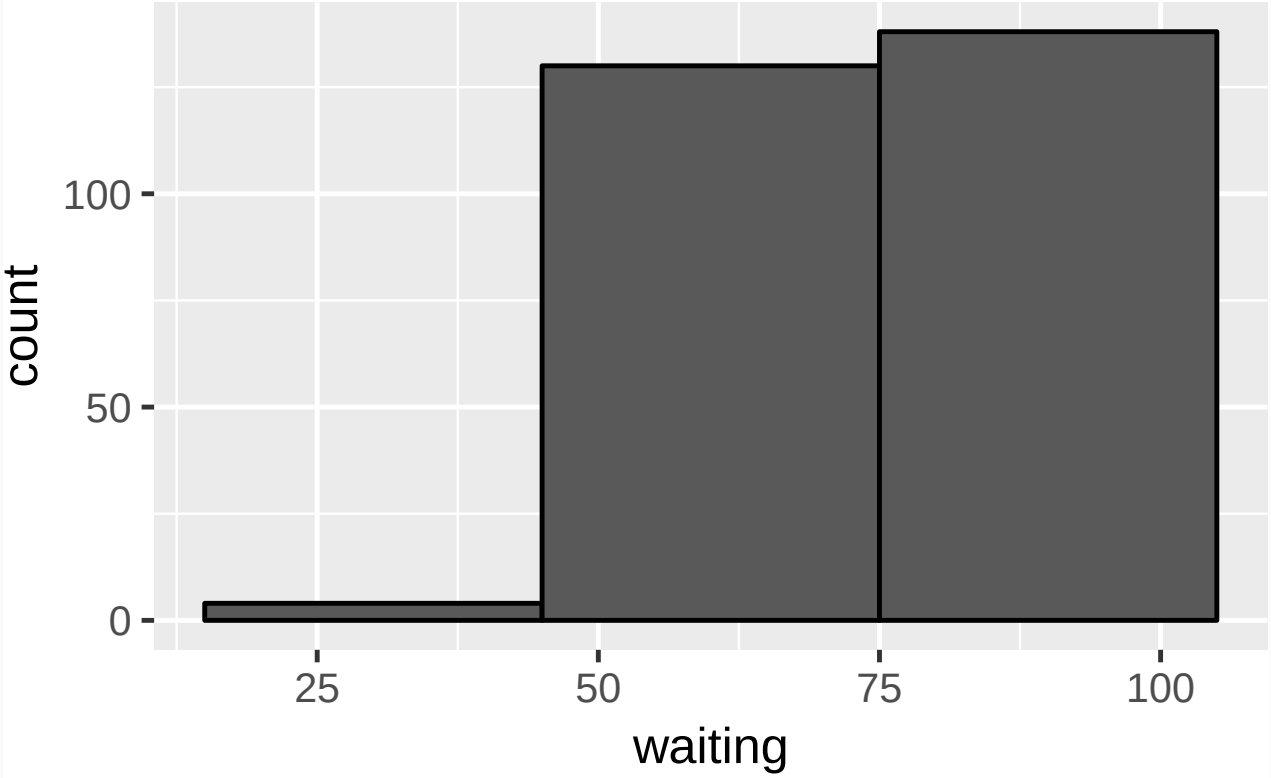


# Putting it all together with more examples

# Histograms

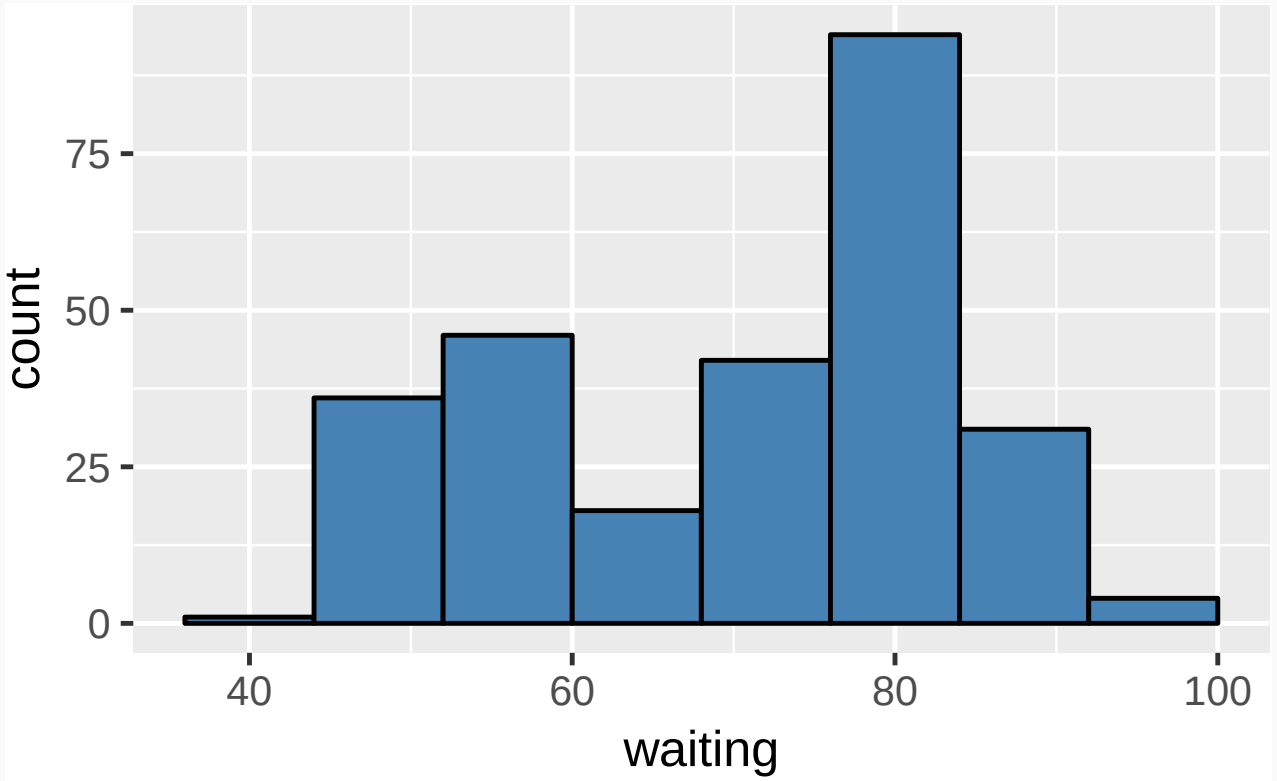
# Simple histogram

```
ggplot(faithful, aes(x = waiting)) +
  geom_histogram(binwidth = 30, color = "black")
```



# Simple histogram

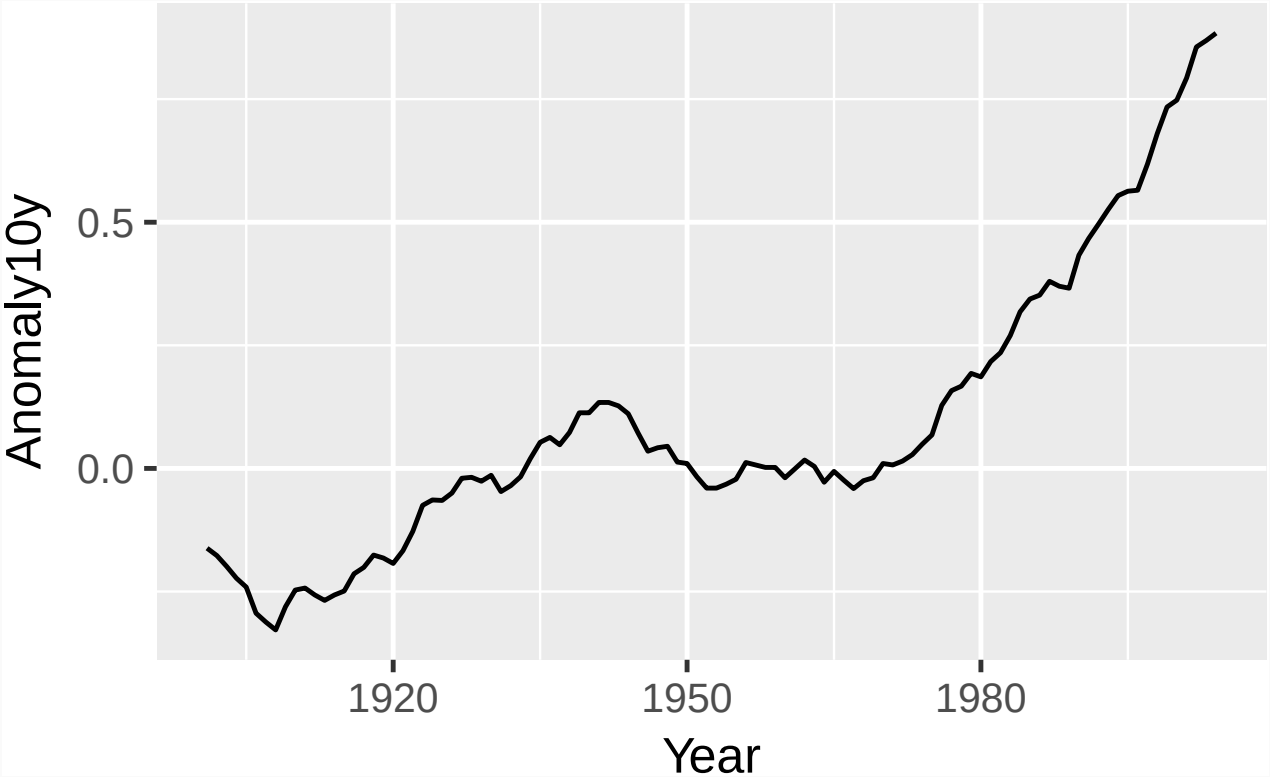
```
ggplot(faithful, aes(x = waiting)) +
  geom_histogram(binwidth = 8, color = "black", fill = "steelblue")
```



# Line plots

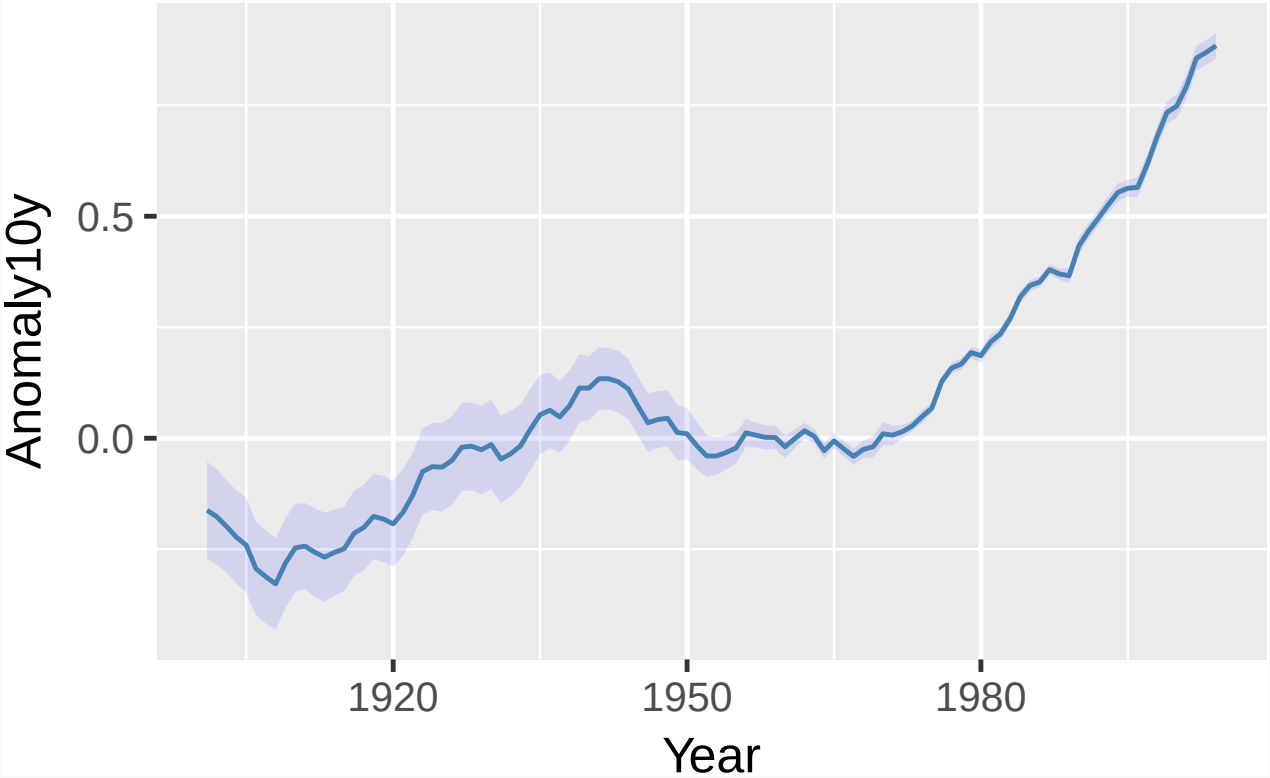
# Line plot

```
climate <- read.csv("../data/climate.csv", header = TRUE)
ggplot(climate, aes(Year, Anomaly10y)) +
  geom_line()
```



# Line with confidence interval

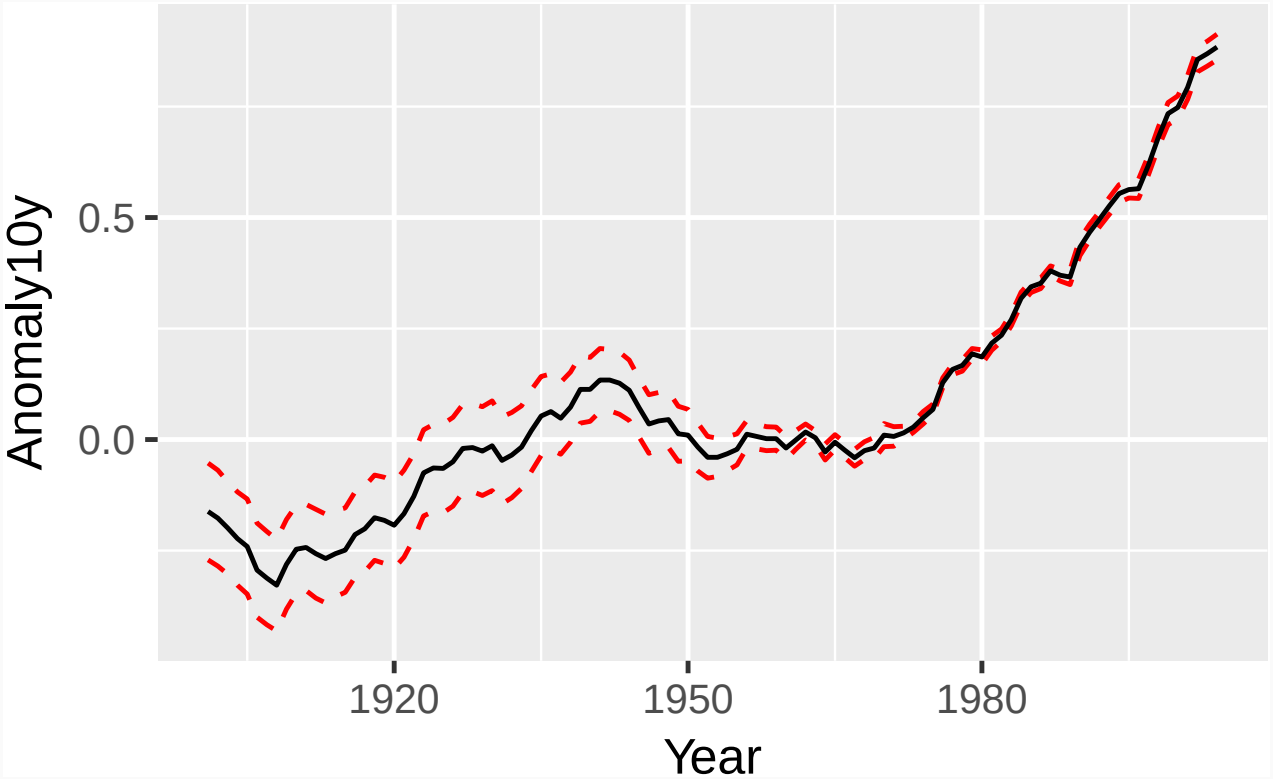
```
ggplot(climate, aes(x = Year, y = Anomaly10y)) +
  geom_ribbon(aes(ymin = Anomaly10y - Unc10y,
                  ymax = Anomaly10y + Unc10y),
              fill = "blue", alpha = 0.1) +
  geom_line(color = "steelblue")
```



# Exercise 2

# Exercise 2

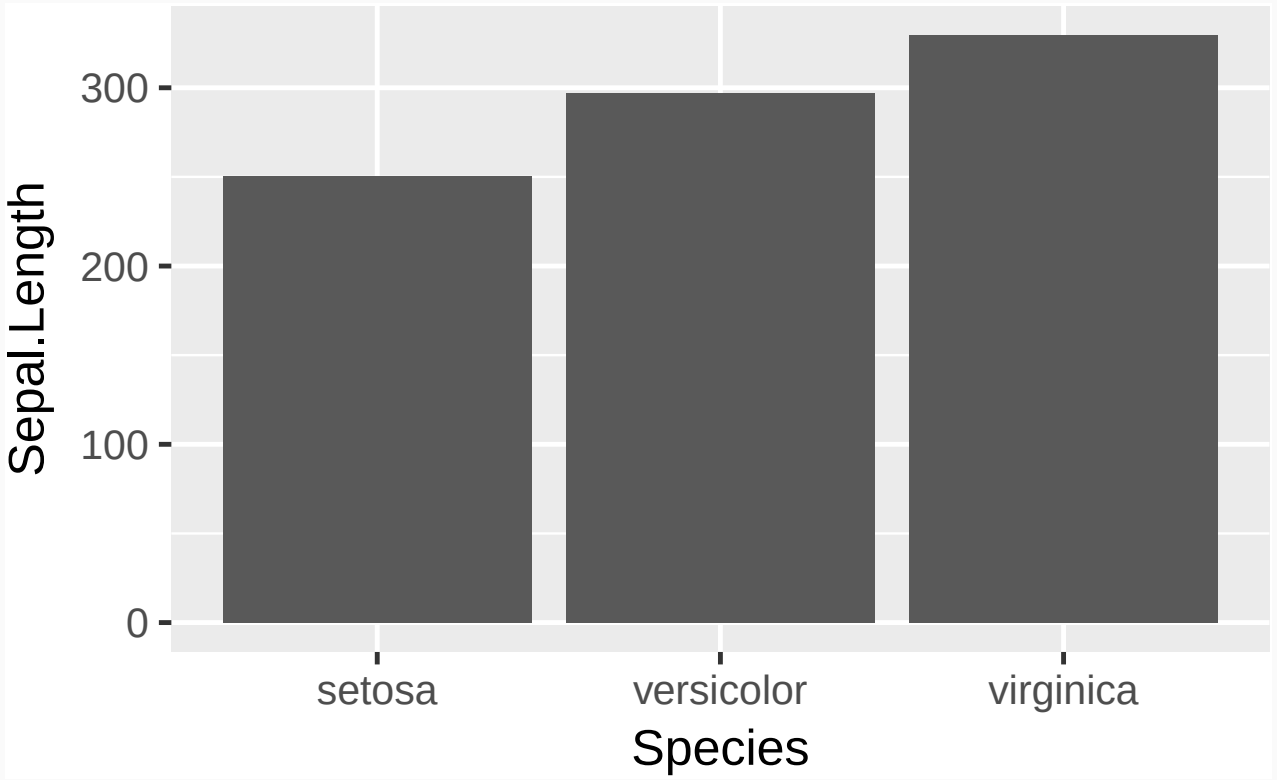
- Modify the last plot and change the ribbon to three separate lines, like below:



# Bar plots

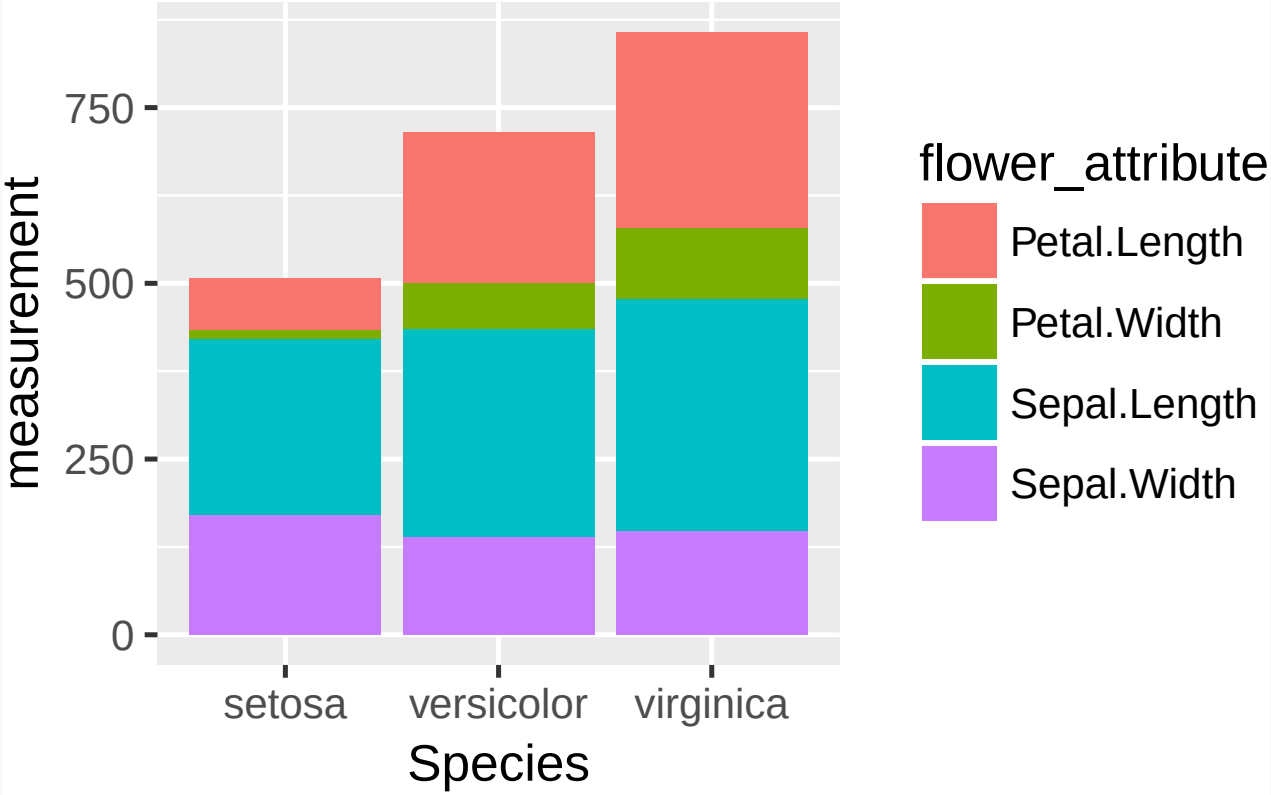
# geom_bar() can be tricky

```
ggplot(iris, aes(Species, Sepal.Length)) +
  geom_bar(stat = "identity")
```



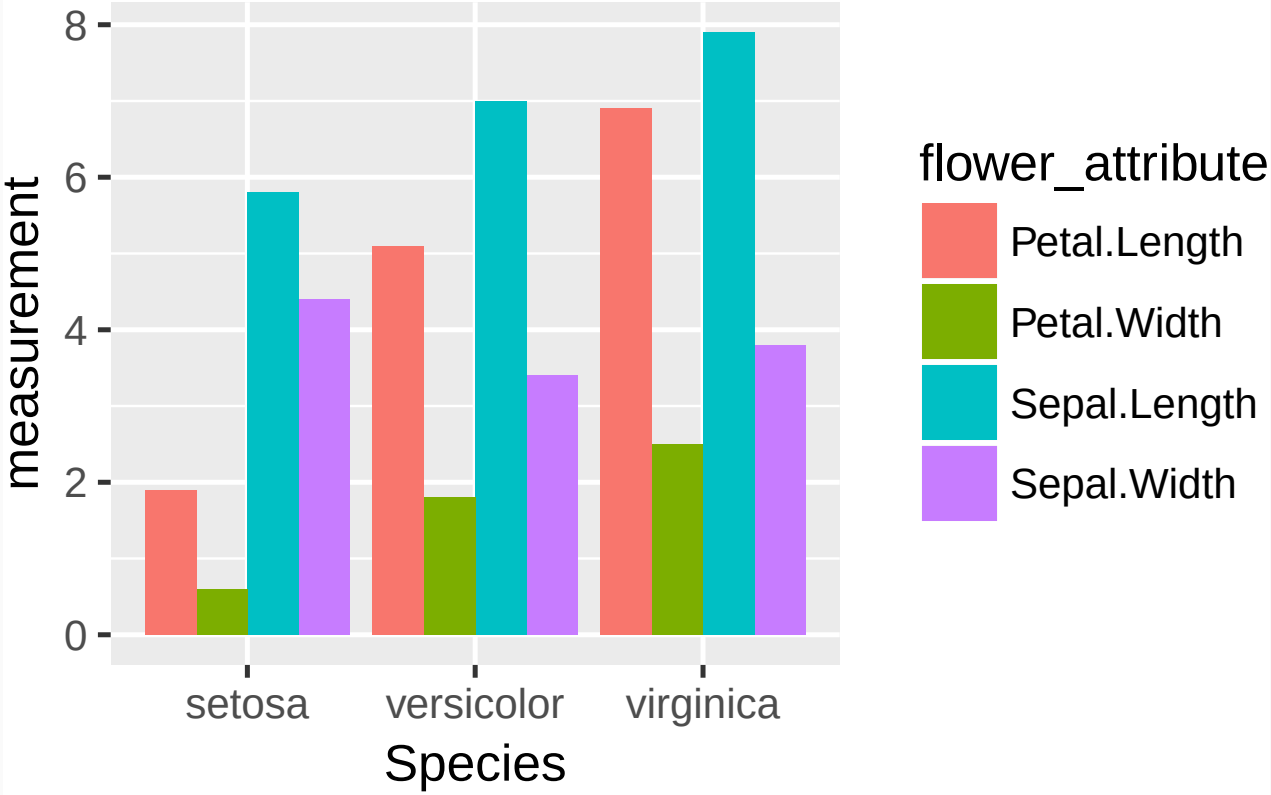
# geom_bar() can be tricky

```
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
  geom_bar(stat = "identity")
```



# geom_bar() can be tricky

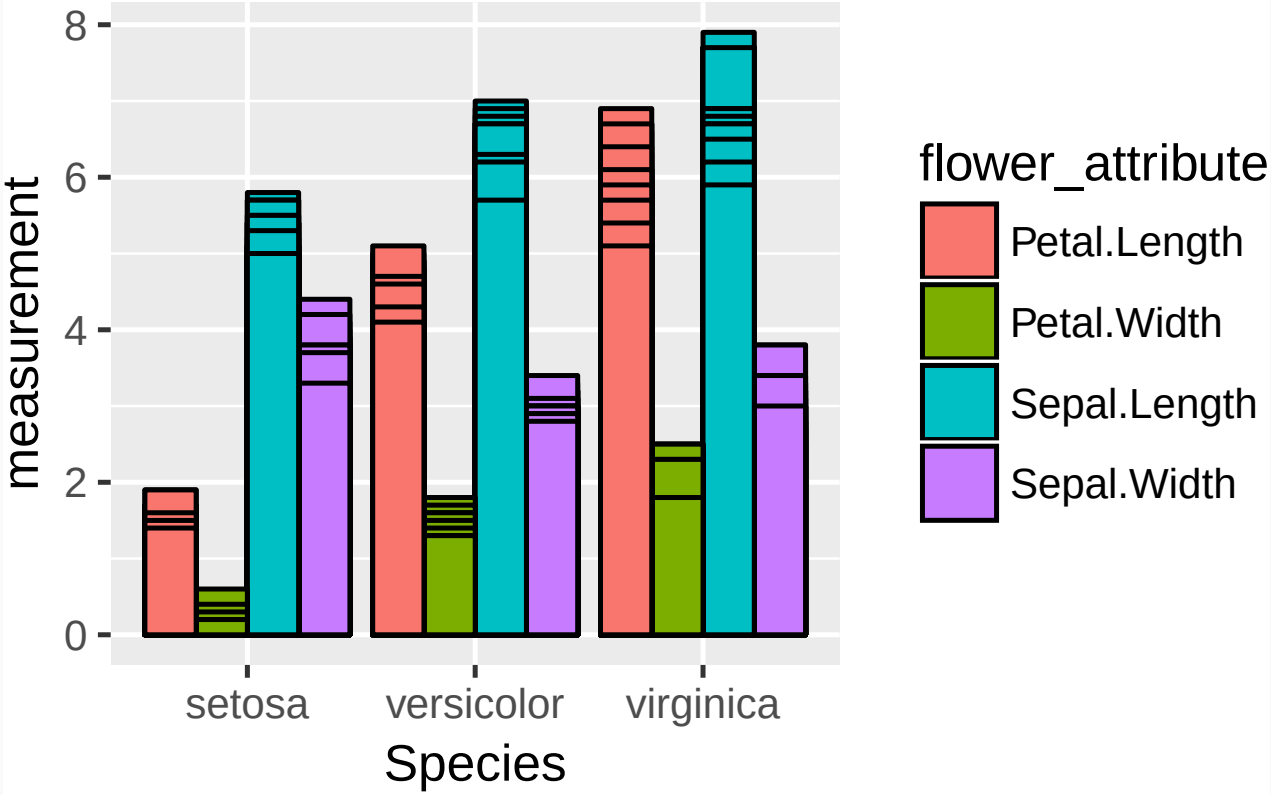
```
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity", position = "dodge")
```




What's up with the y-axis?

# geom_bar() can be tricky

```
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity", position = "dodge", color = "black")
```



# Summarize the data first, usually

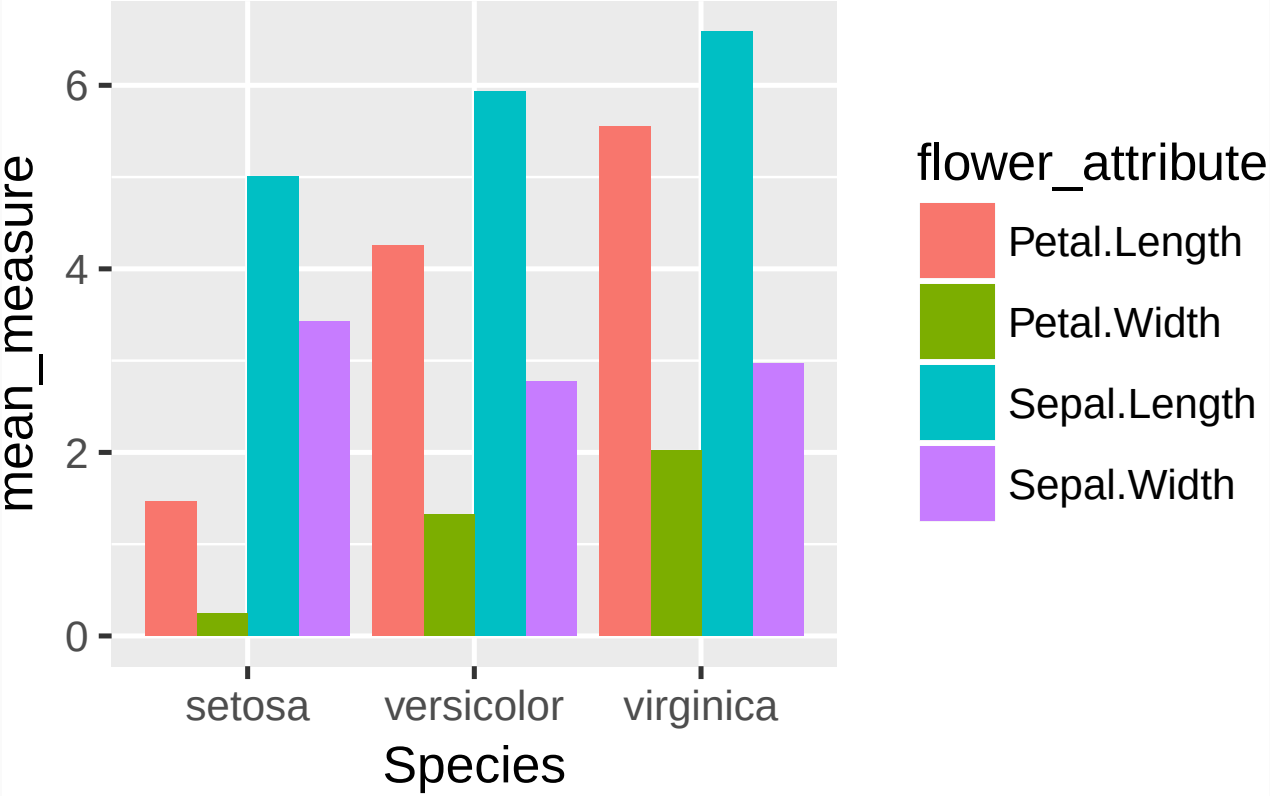
```
df_agg <- df %>%
  group_by(Species, flower_attribute) %>%
  summarise(mean_measure = mean(measurement))

head(df_agg)
```

```
## Source: local data frame [6 x 3]
## Groups: Species [2]
##
## # A tibble: 6 x 3
##      Species flower_attribute mean_measure
##       <fctr>            <chr>        <dbl>
## 1     setosa     Petal.Length        1.462
## 2     setosa      Petal.Width        0.246
## 3     setosa     Sepal.Length        5.006
## 4     setosa      Sepal.Width        3.428
## 5 versicolor     Petal.Length        4.260
## 6 versicolor      Petal.Width        1.326
```

# Then plot the summary with geom_col

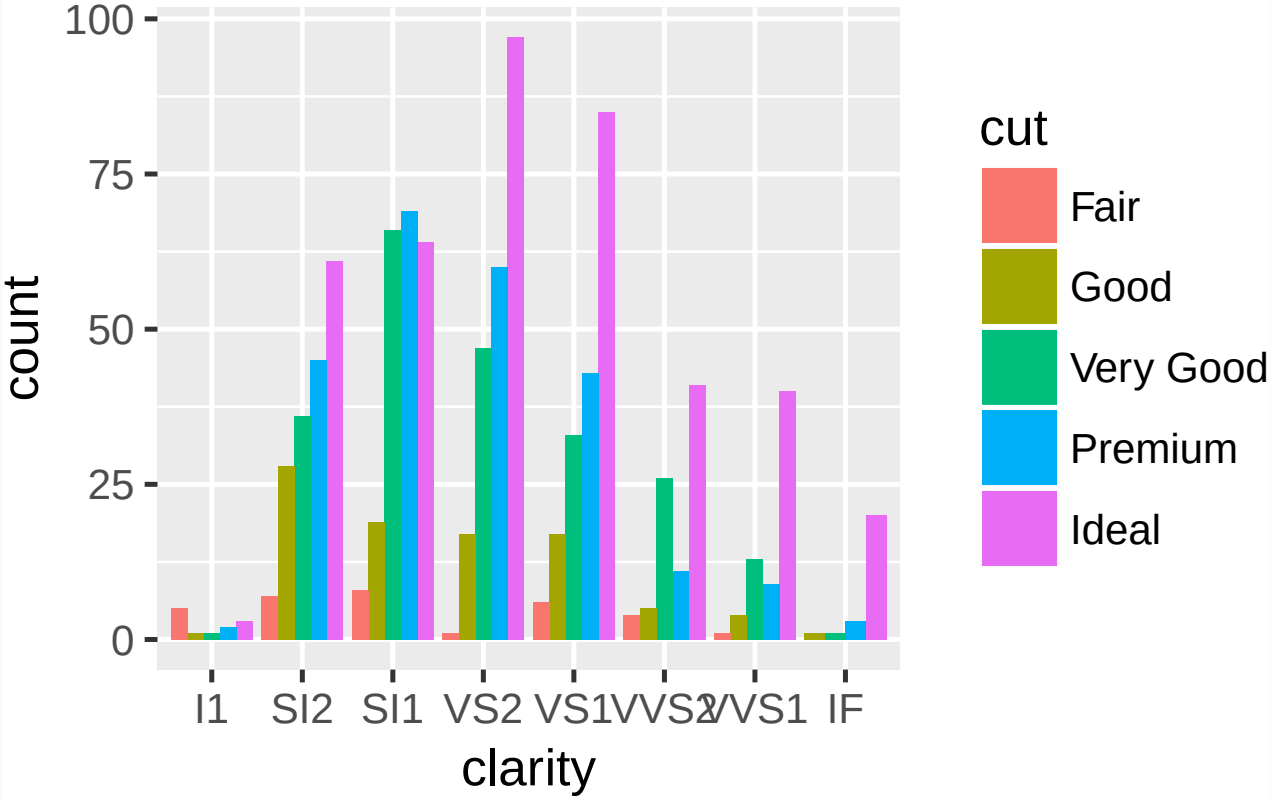
```
ggplot(df_agg, aes(x = Species, y = mean_measure, fill=flower_attribute
  geom_col(position = "dodge")
```



# Exercises 3, 4, & 5

# Exercise 3

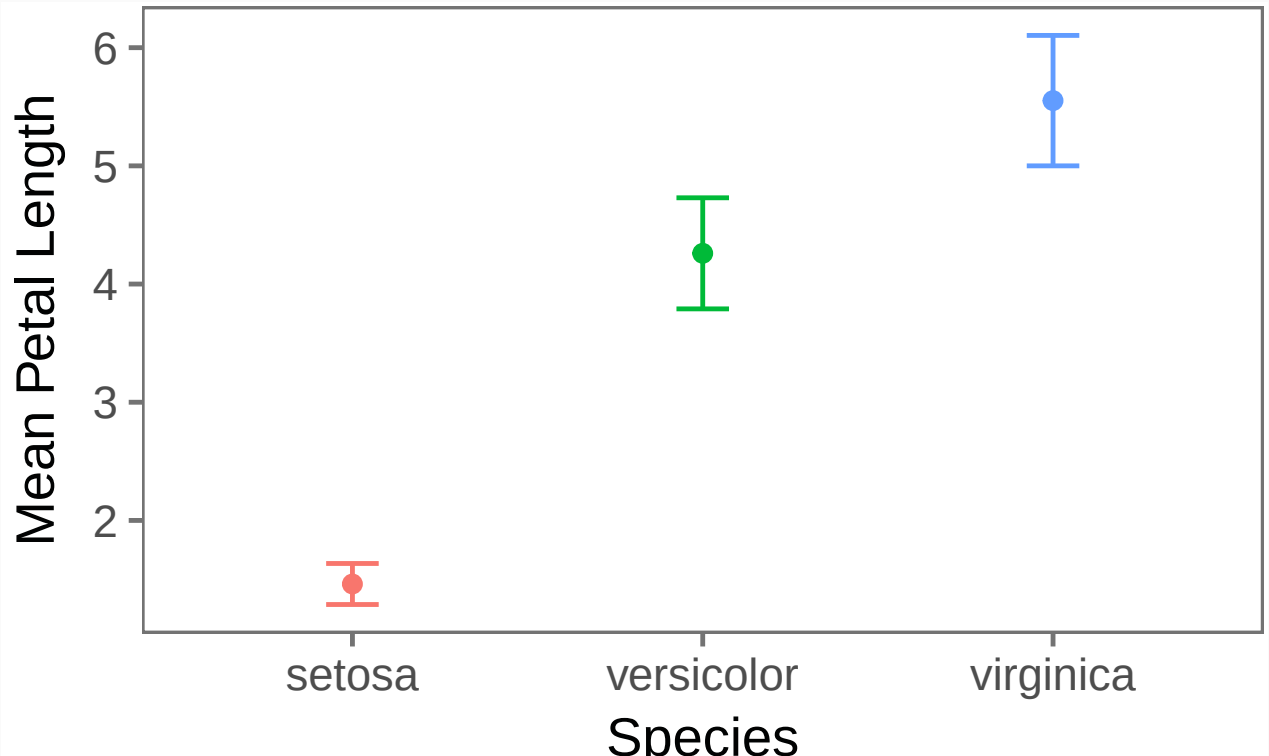
Using the d2 dataset you created earlier, make this plot:



# Exercise 4

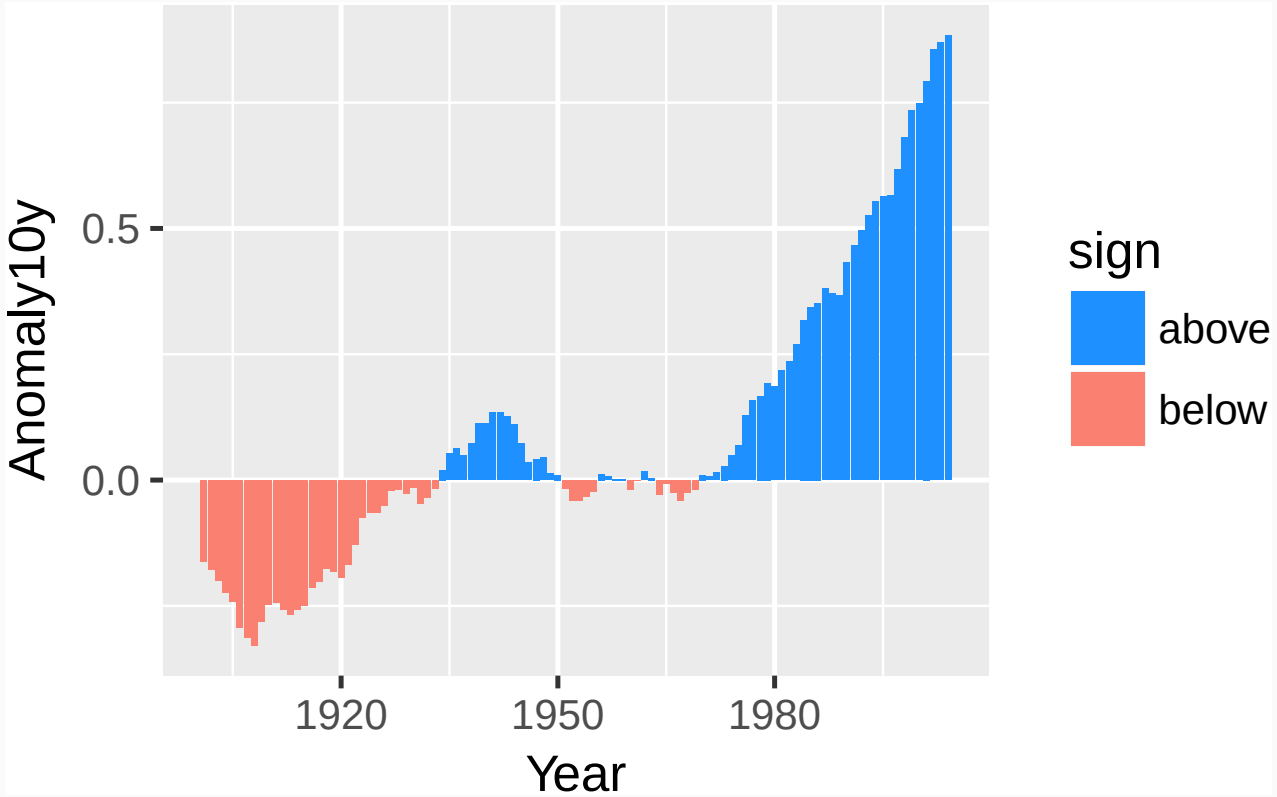
Use dplyr to summarize the iris data, then make the plot below.

```
iris_agg <- iris %>%
  group_by(Species) %>%
  summarise(mean_petal_len = mean(Petal.Length),
            sd_petal_len = sd(Petal.Length))
# ?geom_errorbar()
```



# Exercise 5

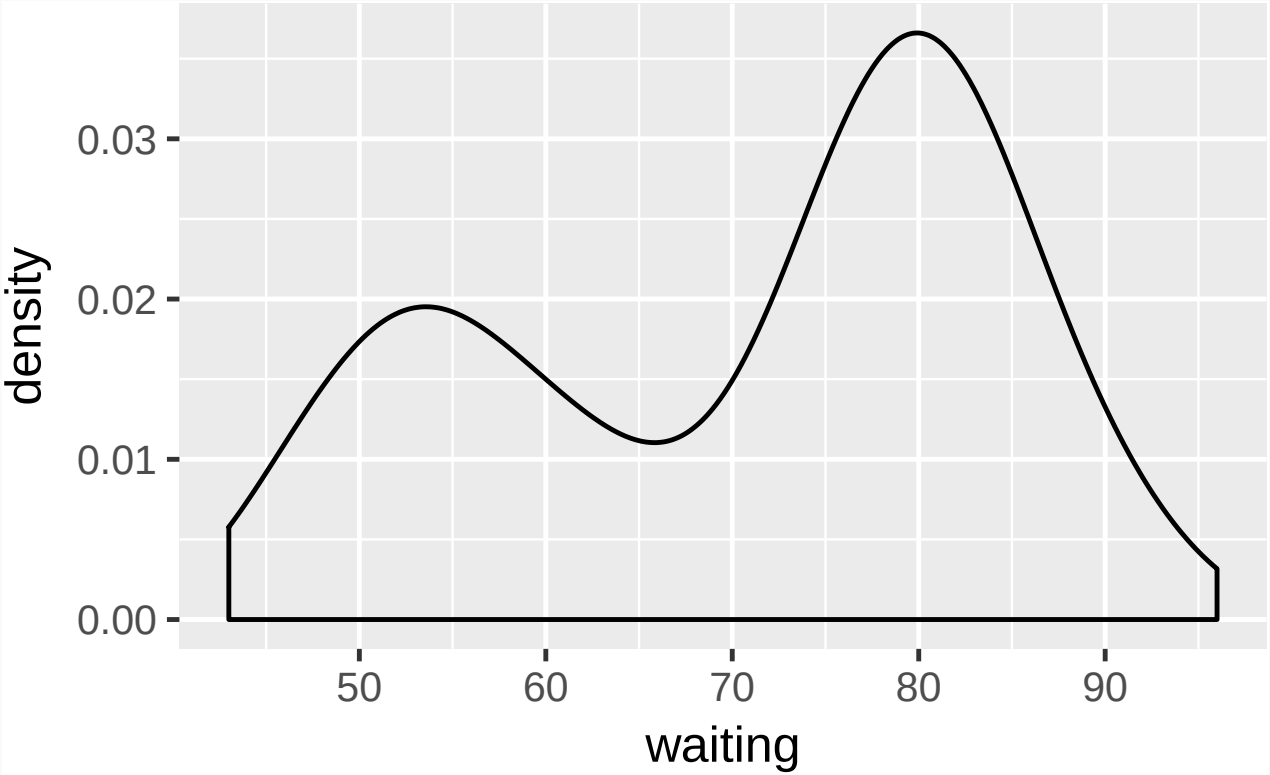
- Using the `climate` dataset, create a new variable called `sign`. Make it categorical (above/below) based on the sign of `Anomaly10y`.
- Plot a bar plot and use sign variable as the fill.



# Density plots

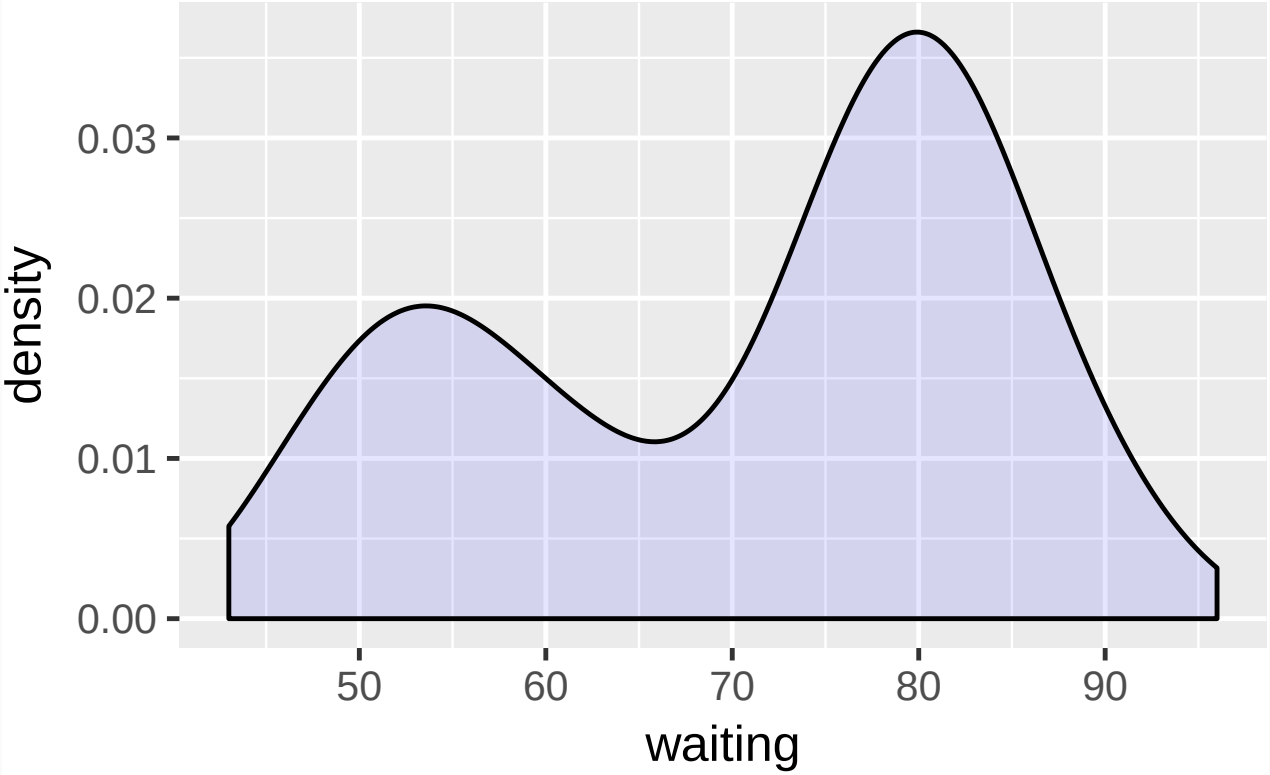
# Density plot

```
ggplot(faithful, aes(waiting)) +
  geom_density()
```



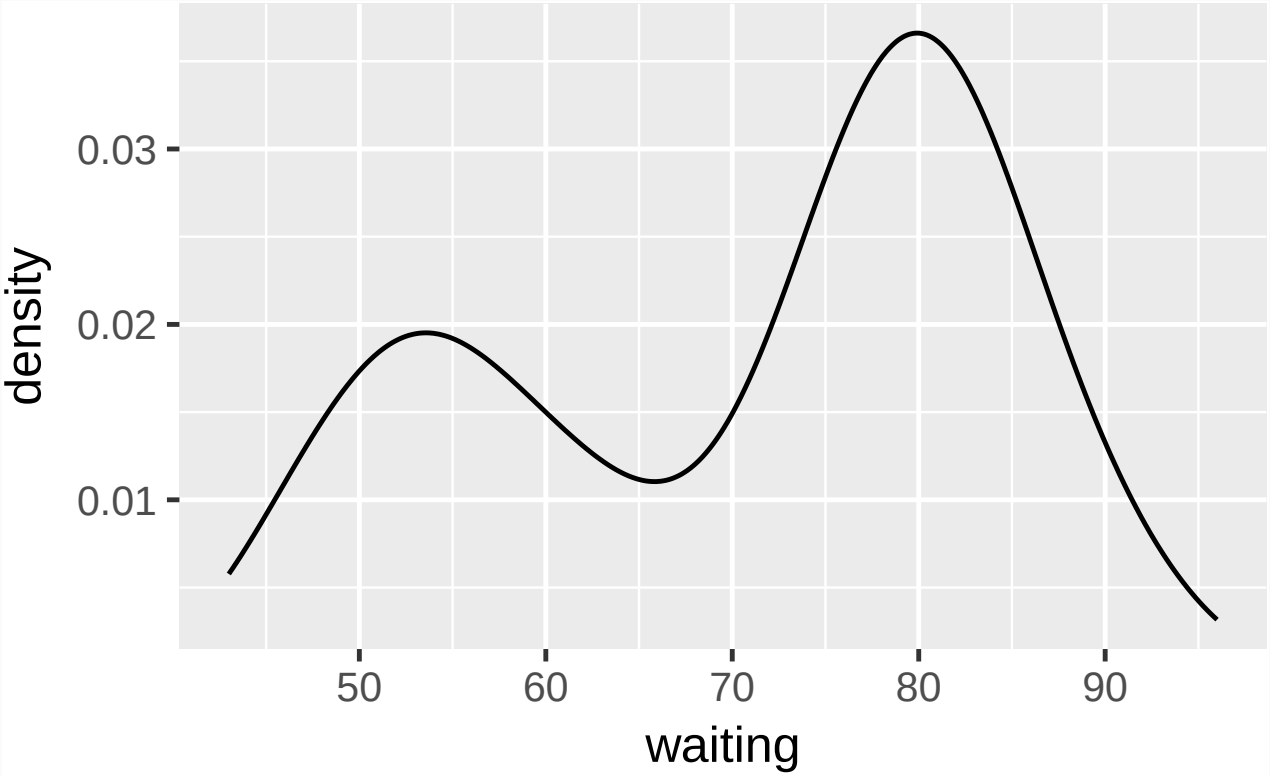
# Density plot

```
ggplot(faithful, aes(waiting)) +
  geom_density(fill = "blue", alpha = 0.1)
```



# Density plot

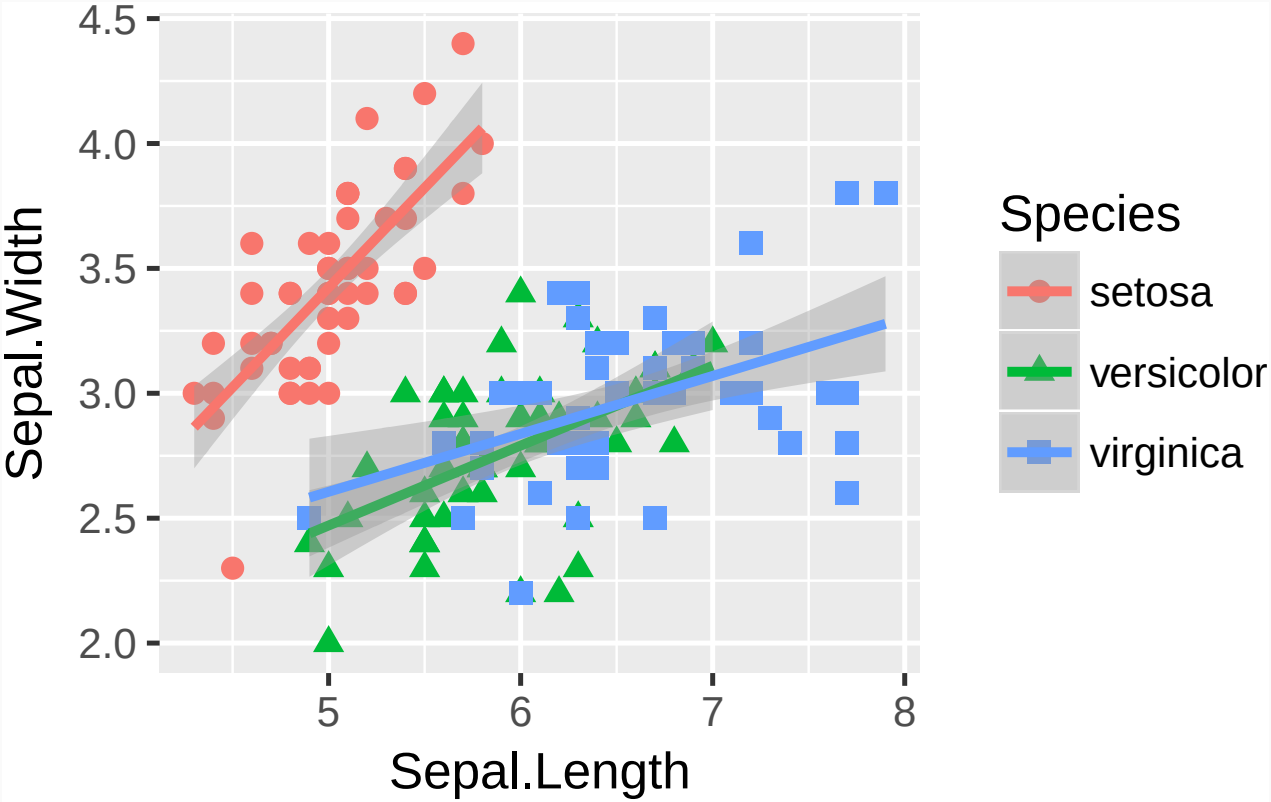
```
ggplot(faithful, aes(waiting)) +
  geom_line(stat = "density")
```



# Adding smoothers

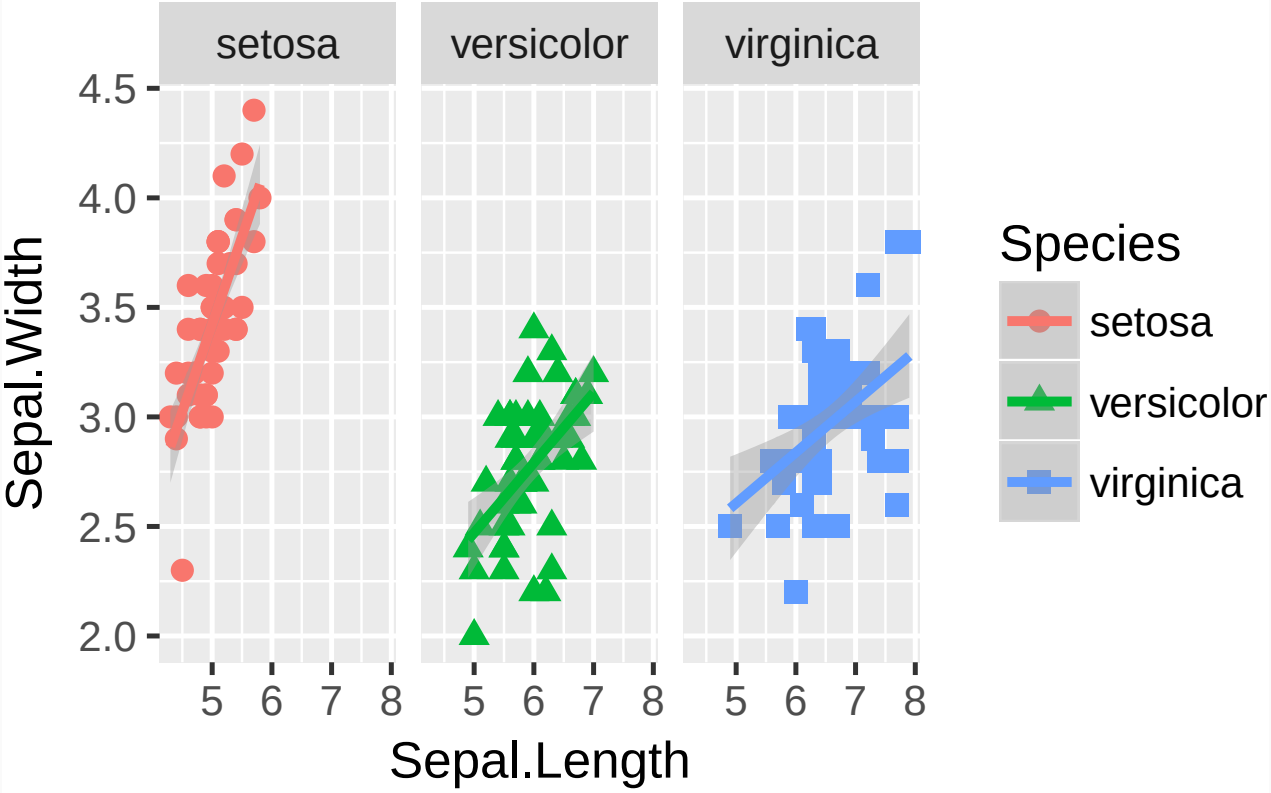
# Linear fits

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(aes(shape = Species), size = 2) +
  geom_smooth(method = "lm")
```



# Linear fits, facetted

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(aes(shape = Species), size = 2) +
  geom_smooth(method = "lm") +
  facet_grid(. ~ Species)
```



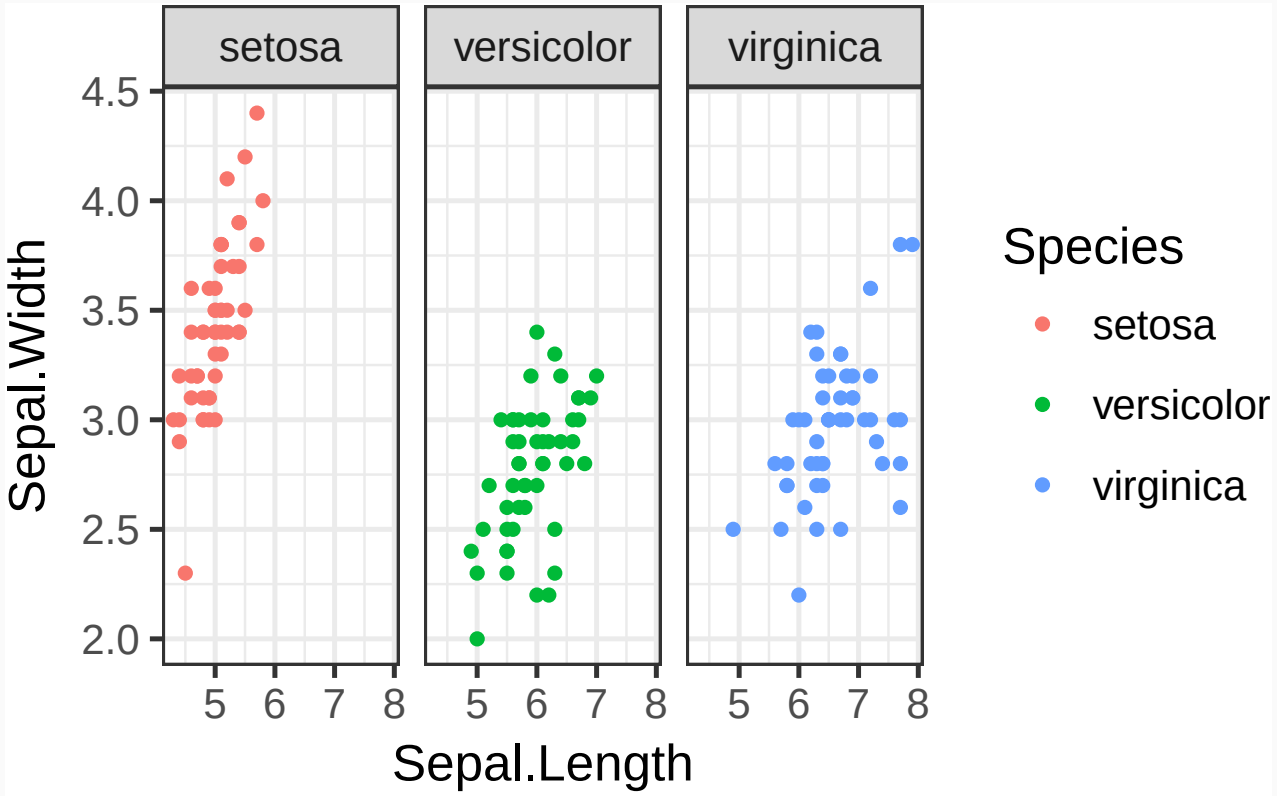
# Themes!

# Adding themes

- Everything can be customized using `theme()` settings
- `http://ggplot2.tidyverse.org/reference/theme.html`

# Out-of-the-box themes

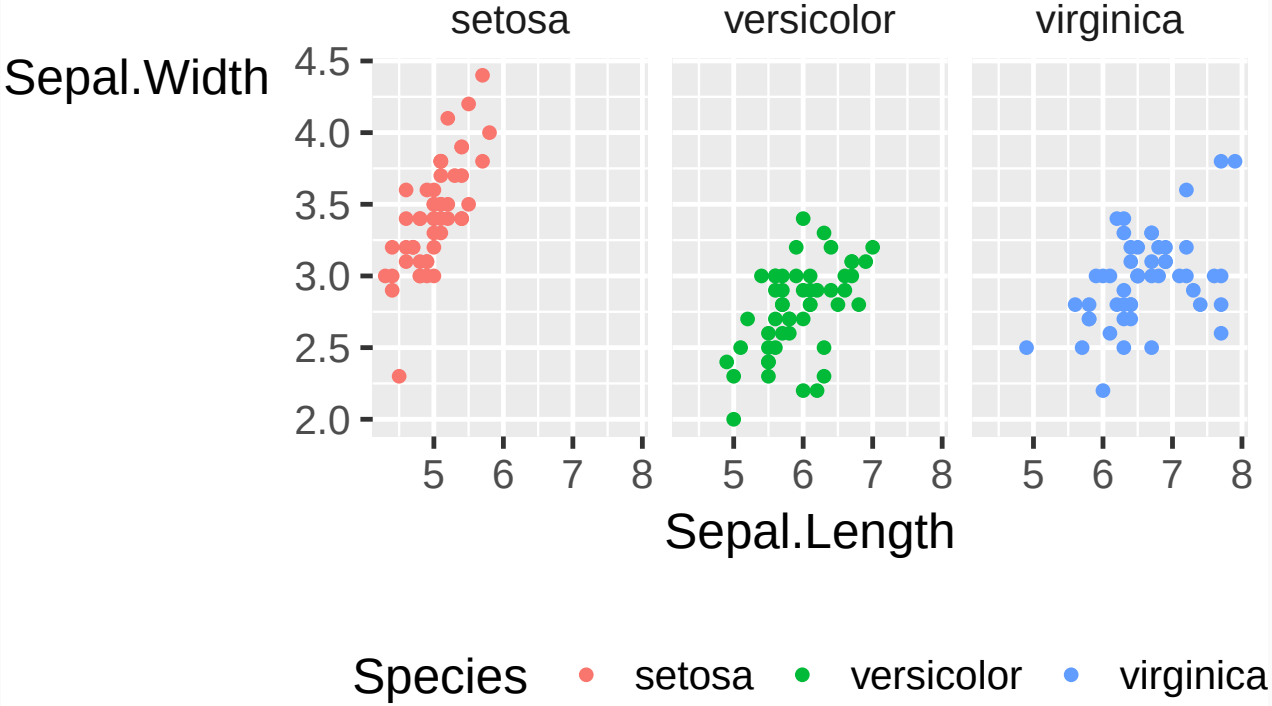
```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(size = 1.2, shape = 16) +
  facet_wrap( ~ Species) +
  theme_bw()
```



# A ‘themed’ plot

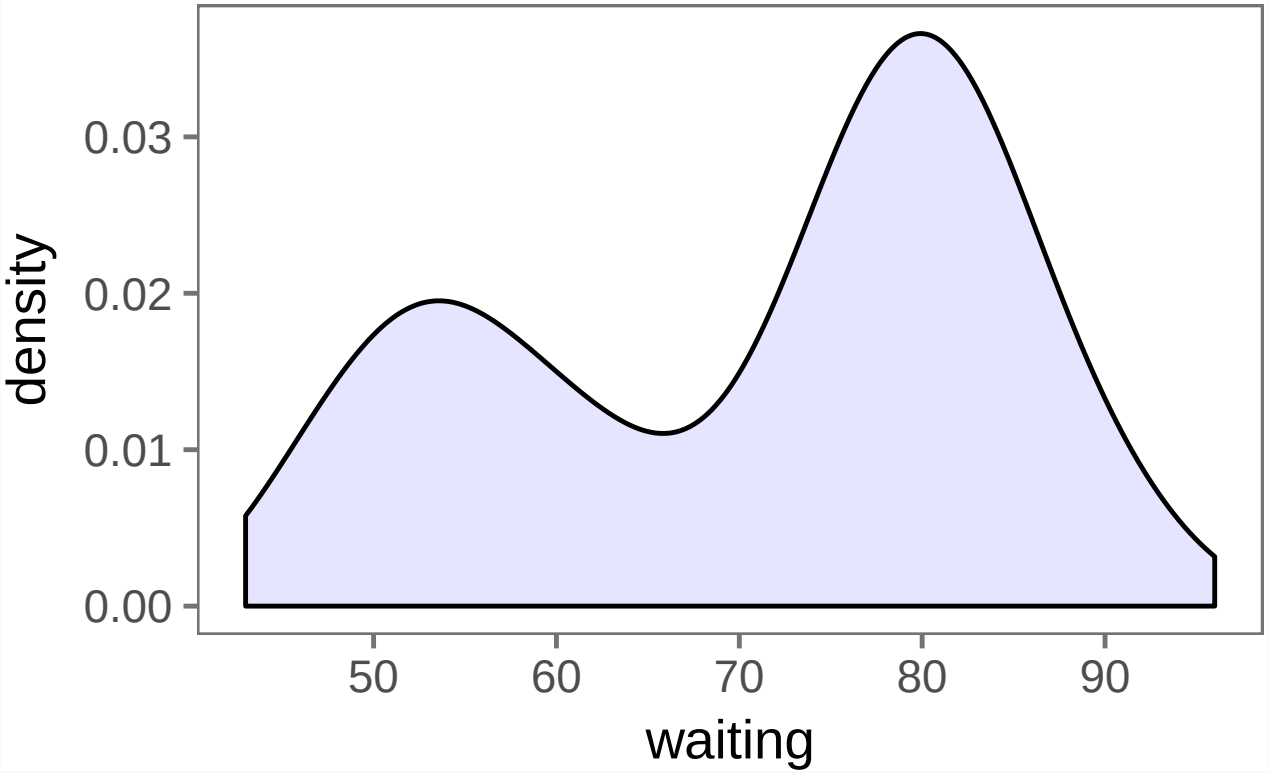
```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(size = 1.2, shape = 16) +
  facet_wrap( ~ Species) +
  ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
  geom_point(size = 1.2, shape = 16) +
  facet_wrap( ~ Species) +
  theme(legend.key = element_rect(fill = NA),
        legend.position = "bottom",
        strip.background = element_rect(fill = NA),
        axis.title.y = element_text(angle = 0))
```

# A ‘themed’ plot



# ggthemes library

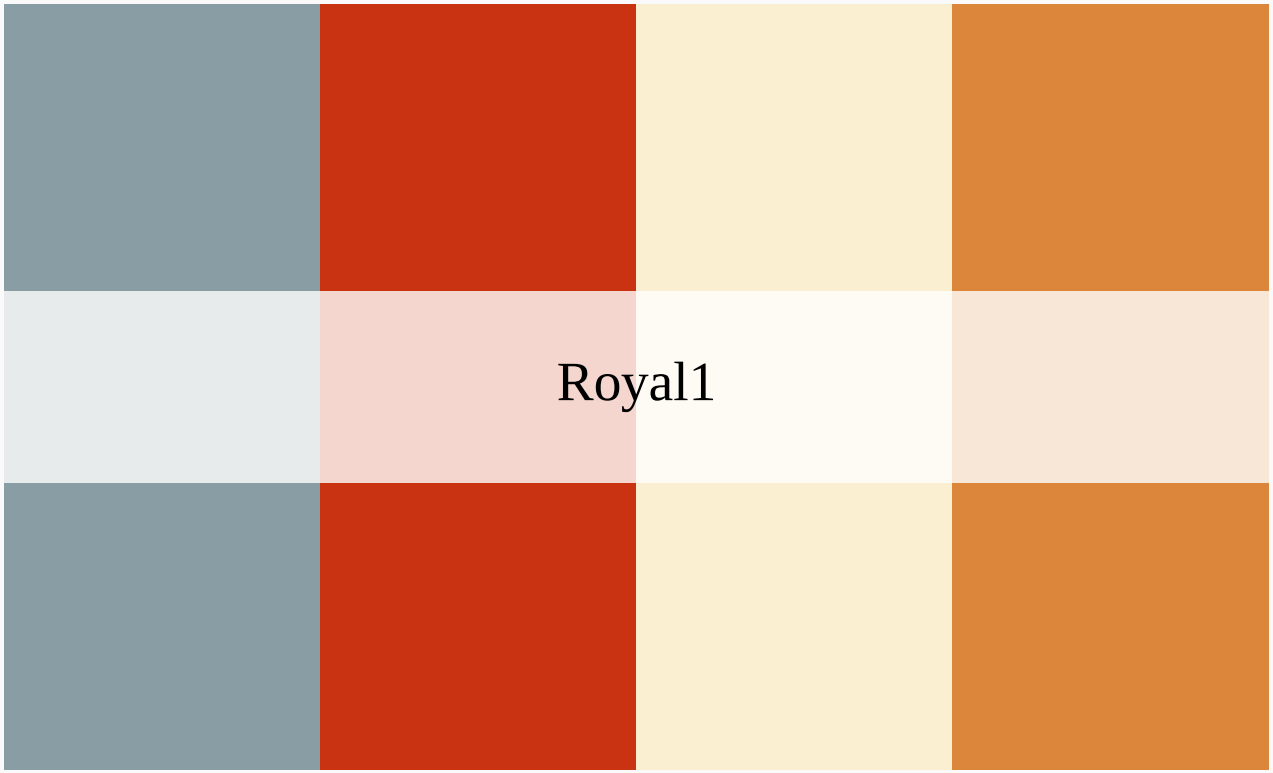
```
library(ggthemes)
ggplot(faithful, aes(waiting)) +
  geom_density(fill = "blue", alpha = 0.1) +
  theme_few()
```



# What about Wes Anderson?

# There's a theme for that!

```
# install.packages('wesanderson')
library("wesanderson")
# display a palette
wes_palette("Royal1")
```



# Save your beautiful plot

# ggsave

- If the plot is on the screen

```
ggsave('~/path/to/figure/filename.png')
```

- If your plot is assigned to a named object

```
ggsave(plot1, '~/path/to/figure/filename.png')
```

- Specify size

```
ggsave(file = '~/path/filename.png', width = 4, height = 3, units = "in
```

- And format

```
ggsave(file = "/path/to/figure/filename.eps")
ggsave(file = "/path/to/figure/filename.jpg")
ggsave(file = "/path/to/figure/filename.pdf")
```

# Further help

- We've only scratched the surface
- Practice
- Read: `http://ggplot2.tidyverse.org/index.html`
- Work together