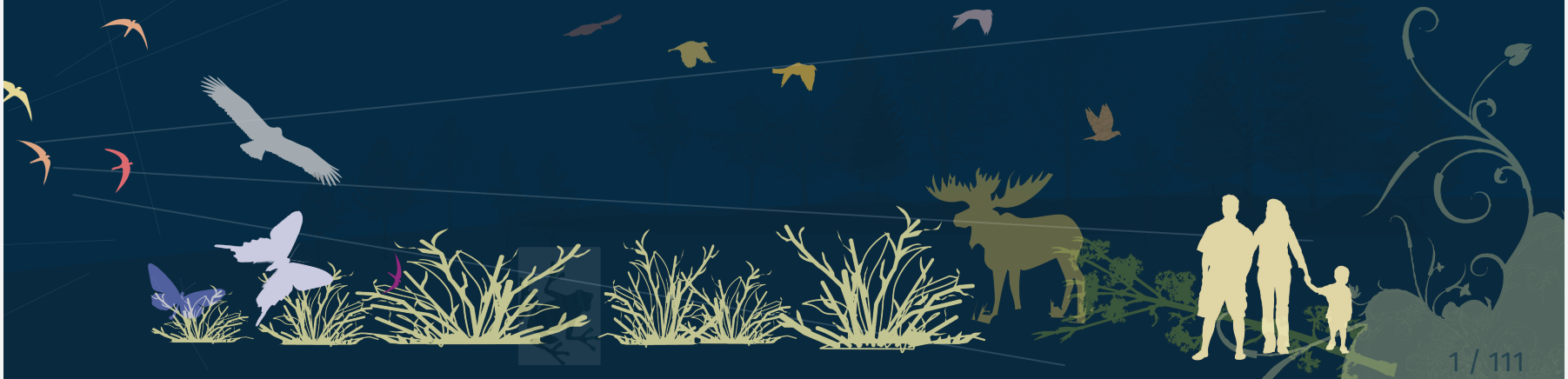
Workshop 3: Introduction to `ggplot2`

QCBS R Workshop Series

Québec Centre for Biodiversity Science



About this workshop

Required packages

- grid
- gridExtra
- ggplot2
- ggsignif
- ggdendro
- maps
- mapproj
- RColorBrewer
- GGally
- patchwork
- plotly

```
install.packages(c('grid', 'gridExtra', 'ggplot2', 'ggsignif', 'ggdendro', 'maps', '
```

Leaning objectives

1. Use R to create various plots

Introduction

Introduction

To follow along:

Code and .HTML available at http://qcbs.ca/wiki/r/workshop3

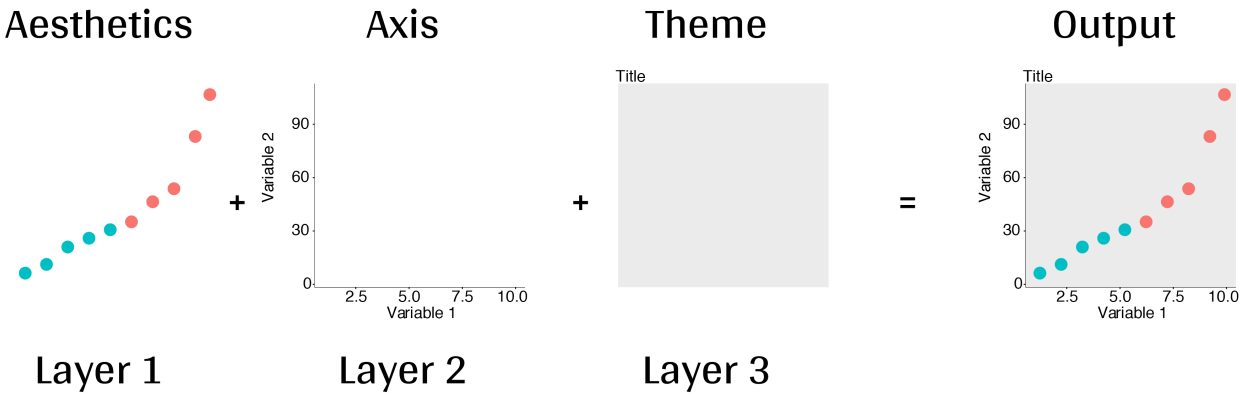
Recommendations:

1. create your own new script;
2. refer to provided code only if needed;
3. avoid copy-pasting or running the code directly from the script.

ggplot2 is also on GitHub: https://github.com/tidyverse/ggplot2

Outline

1. `ggplot2` mechanics



2. Advanced visualization
3. Fine-tuning
4. Saving plots
5. Conclusion

Learning objectives

- Teach the basics of data visualization using R.
- Find packages and resources to meet your needs.
- Inspire creativity in science!
- Develop understanding of design for effective graphical communication.

Visualization in science

Visualization in science

Why are we using data visualization?

What makes an effective visualization?

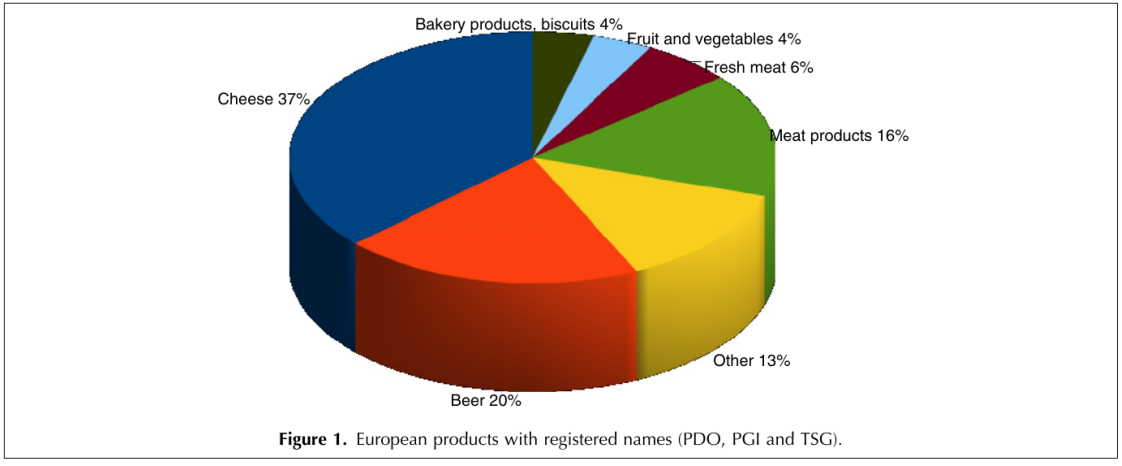


Figure 1. European products with registered names (PDO, PGI and TSG).

What do you think about this one ↑?

Visualization in science

1. To represent results of statistical analyses
2. To formulate hypotheses and understand summarize theory
3. To explore your own data (exploratory analysis, outlier detection)
4. To communicate and report
    - Clearly (using good design principles)
    - Precisely and accurately (a plot is worth 1000 words)
    - Effectively and efficiently

Visualization in science

Important questions:

- What do you want to communicate?
- Who is your audience?
- What is the best way to do it?

A rule of thumb: think simple — use less ink!

Additional resources

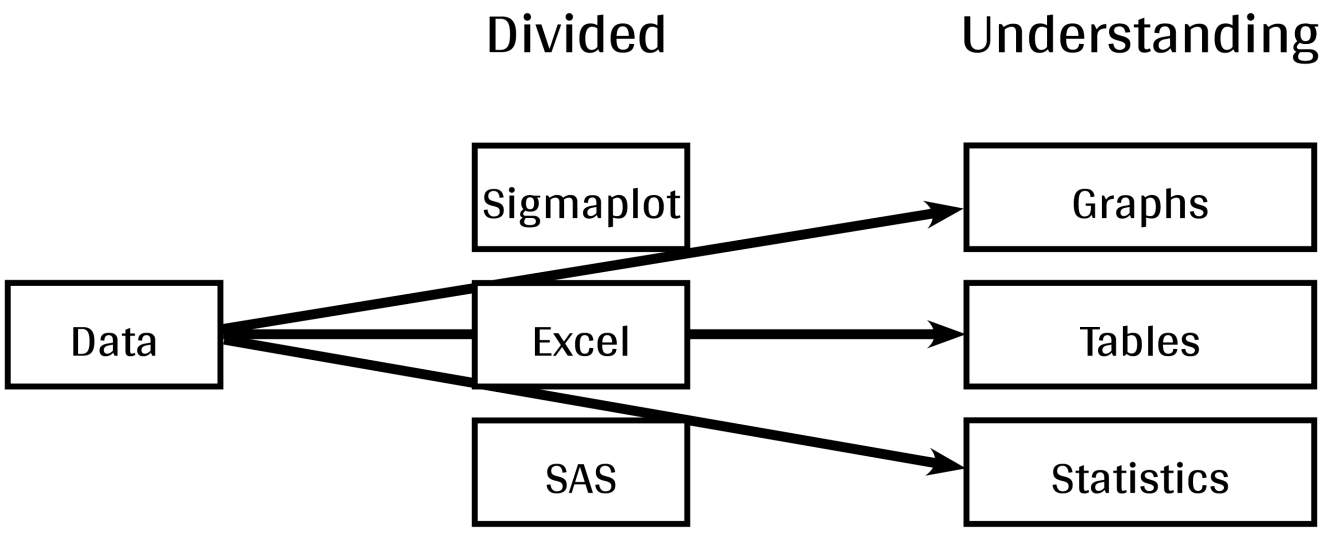
- Fundamentals of Data Visualization (ggplot)
- A Compendium of Clean Graphs in R (base plot)
- Graphics Principles (design tips)

WARNING!

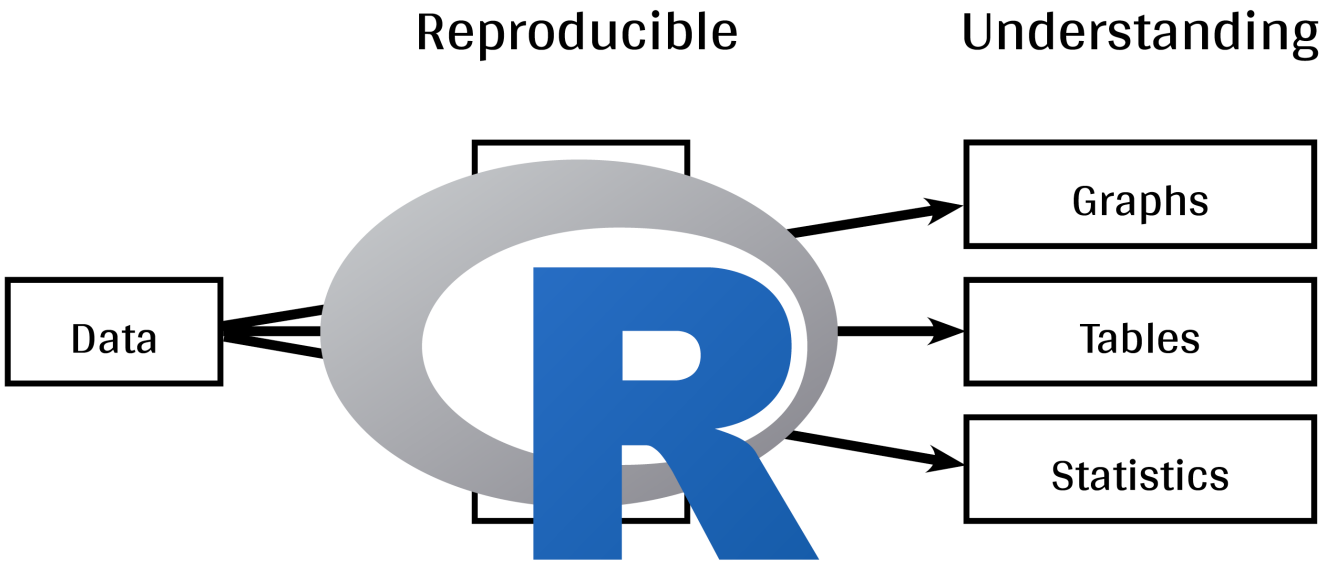
R is not made for drawings.

Other drawing softwares are probably better options such as GIMP or Inkscape.
It is important to get the right tool for the right task!

Why use R for plotting?



Why use R for plotting? Reproducibility



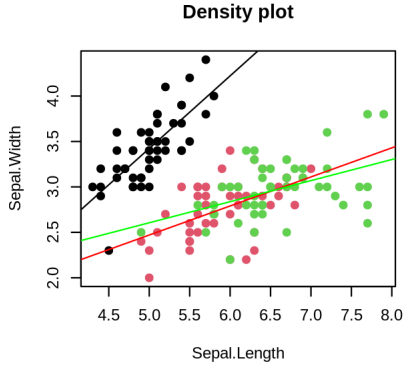
Reproducible science comes with effort:

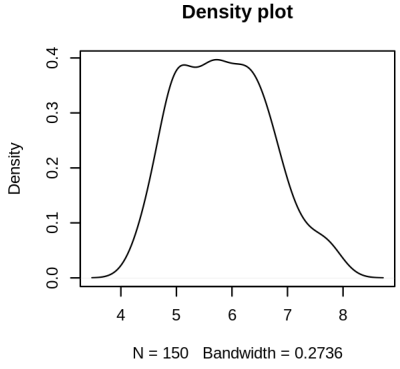
- comment your script
- add information in the figures (titles, labels, captions, annotations)

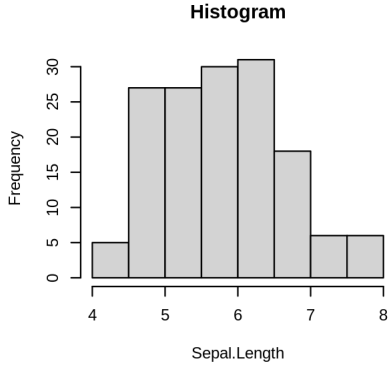
Why R for graphs?

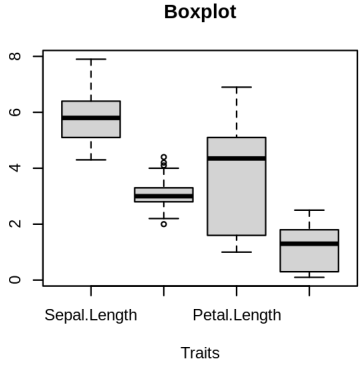
Because of its powerful features!

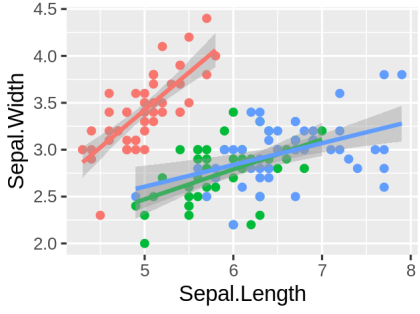
In this workshop, we focus only on `ggplot2`, but multiple packages and functions can be used for great visualization (e.g., `base R`, `plotly`, `sjPlot`, `mapview`, `igraph`).

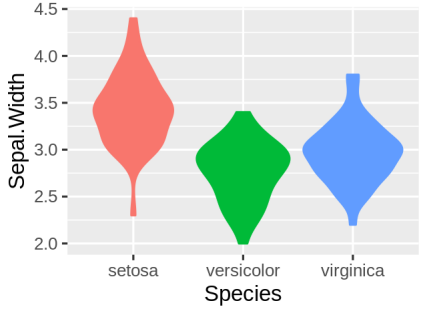






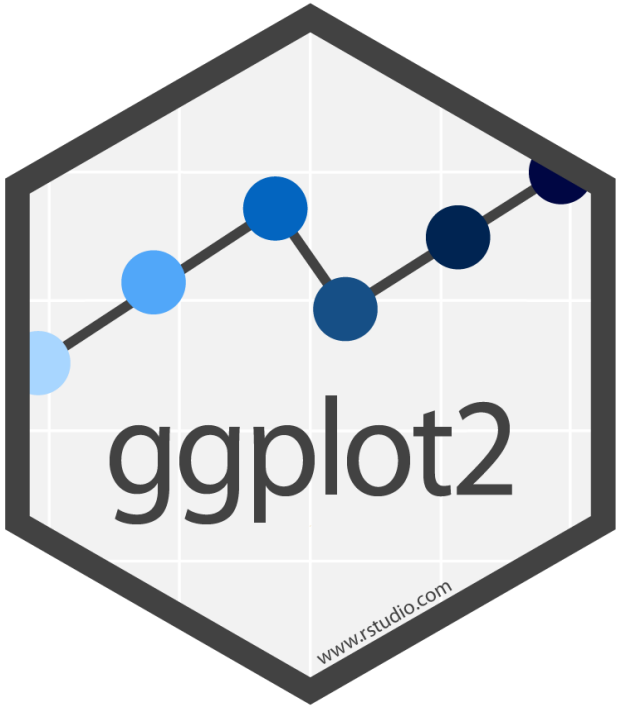






`ggplot2` is versatile

1. `ggplot2` package lets you make *beautiful* and customizable plots;
2. it implements the grammar of graphics, an reliable system for building plots.
3. it has many extensions.

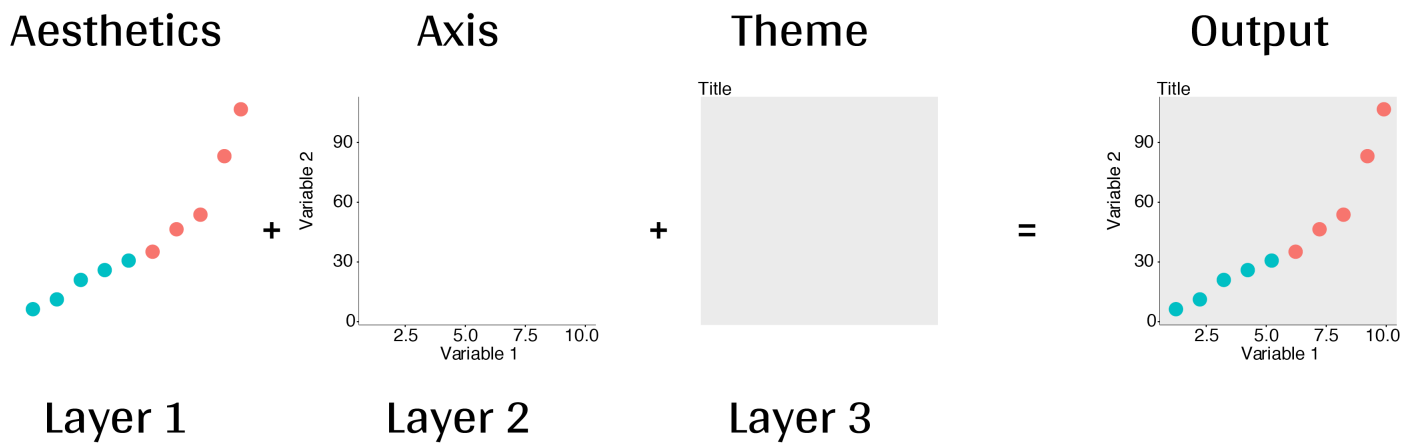


`ggplot2` mechanics: the basics

Grammar of Graphics (GG) basics

```
install.packages("ggplot2") # if not already installed
library(ggplot2)
```

A graphic is made of different layers:



Using the GG system, we can build graphs step by step for customizable results.

Grammar of Graphics (GG) basics

GG layers have specific names that you will see throughout the presentation:

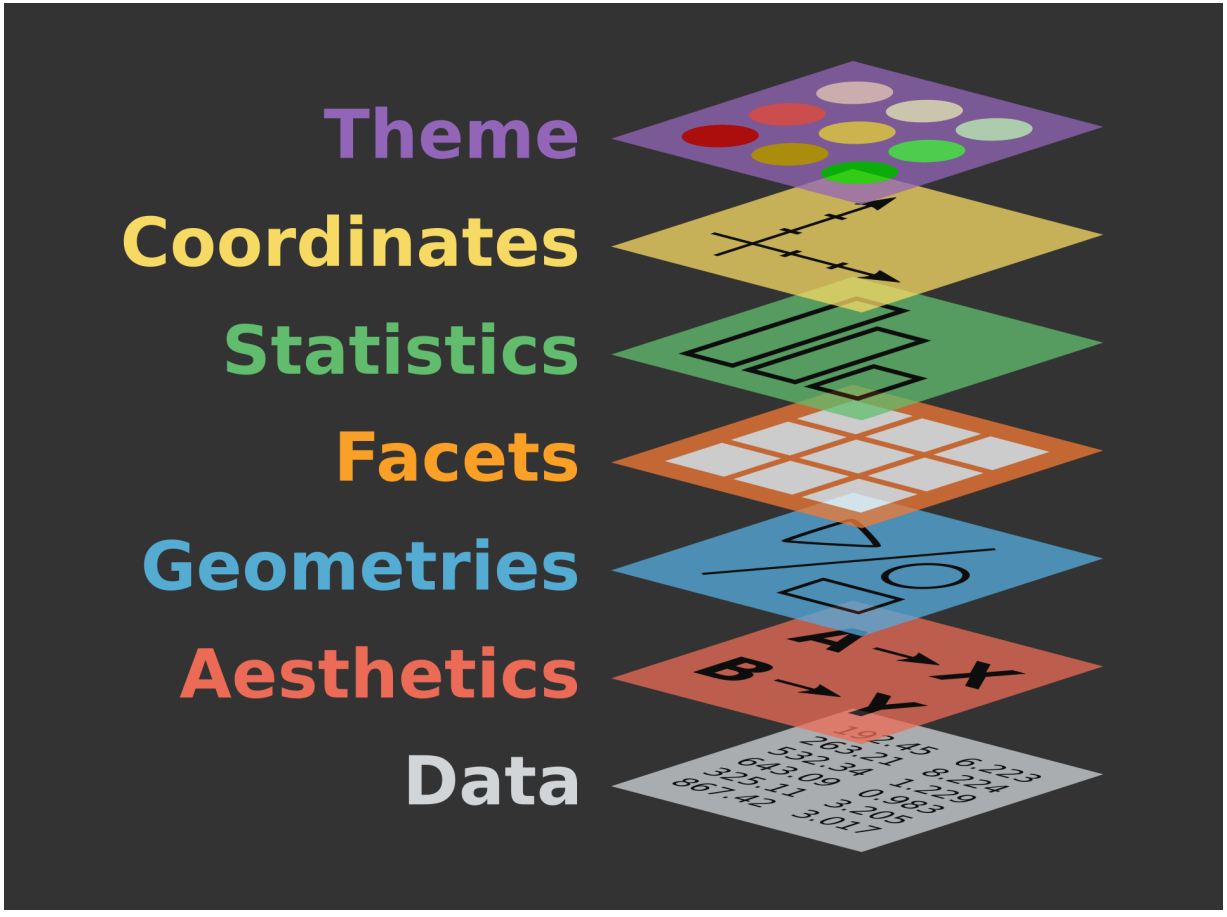


image adapted from [The Grammar of Graphics]

Grammar of Graphics (GG) basics

Here are the basic requirements to draw the simplest `ggplot`:

```
ggplot(data = <DATA>) +
    <GEOM function>(mapping=aes(<mappings>),
                                stat = <STAT>, position = <POSITION> ) +
    <COORDINATE function> +
    <SCALE function> +
    <THEME function> +
    <FACET function> +...
```

Required

Not required

Grammar of Graphics (GG)

GG layers:

- Data
  - your data, in tidy format, will provide ingredients for your plot
  - use `dplyr` techniques to prep data for optimal plotting format
  - usually, one row for every observation that you want to plot

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes), to make data visible
  - `x`, `y`: variable along the x and y axis
  - `colour`: color of geoms according to data
  - `fill`: the inside color of the geom
  - `group`: what group a geom belongs to
  - `shape`: the figure used to plot a point
  - `linetype`: the type of line used (solid, dashed, etc)
  - `size`: size scaling for an extra dimension
  - `alpha`: the transparency of the geom

Grammar of Graphics (GG)

GG layers:

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  - `size`: size scaling for an extra dimension
  - `alpha`: the transparency of the geom

note: aesthetics are based on quantities in your data, but plots may have some of these qualities not based in data as well. (ie, colouring based on a data group is an aesthetic, but points will always have a colour even if not based on data.)

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes)
- Geometric objects (geoms)
  - `geom_point()`: scatterplot
  - `geom_line()`: lines connecting points by increasing value of x
  - `geom_path()`: lines connecting points in sequence of appearance
  - `geom_boxplot()`: box and whiskers plot for categorical variables
  - `geom_bar()`: bar charts for categorical x axis
  - `geom_histogram()`: histogram for continuous x axis
  - `geom_violin()`: distribution kernel of data dispersion
  - `geom_smooth()`: function line based on data

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes)
- Geometric objects (geoms)
- Facets
  - `facet_wrap()` or `facet_grid()` for small multiples

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes)
- Geometric objects (geoms)
- Facets
- Statistics
  - similar to geoms, but computed
  - show means, counts, and other statistical summaries of data

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes)
- Geometric objects (geoms)
- Facets
- Statistics
- Coordinates - fitting data onto a page
  - `coord_cartesian` to set limits
  - `coord_polar` for circular plots
  - `coord_map` for different map projections

Grammar of Graphics (GG)

GG layers:

- Data
- Aesthetics (aes)
- Geometric objects (geoms)
- Facets
- Statistics
- Coordinates
- Themes
    - overall visual defaults
    - fonts, colors, shapes, outlines

How layer in ggplot works

1. Create a simple plot object:
   - `plot.object <- ggplot()`
2. Add geometric layers:
   - `plot.object <- plot.object + geom_*()`
3. Add appearance layers:
   - `plot.object <- plot.object + coord_*() + theme()`
4. Repeat step 2-3 until satisfied, then print:
   - `plot.object` or `print(plot.object)`

Prepare data for `ggplot2`

`ggplot2` requires you to prepare the data as an object of class `data.frame` or `tibble` (common in the `tidyverse`).

```
library(tibble)
class(iris) # all set!
# [1] "data.frame"

ir <- as_tibble(iris) # acceptable
class(ir)
# [1] "tbl_df"     "tbl"        "data.frame"
```

♻ **Recall from the *Loading and manipulating data* workshop**:

More complex plots in `ggplot` require the long data frame format

iris dataset

```
## ?iris
str(iris)
# 'data.frame':    150 obs. of  5 variables:
#  $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
#  $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
#  $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
#  $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
#  $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1
```

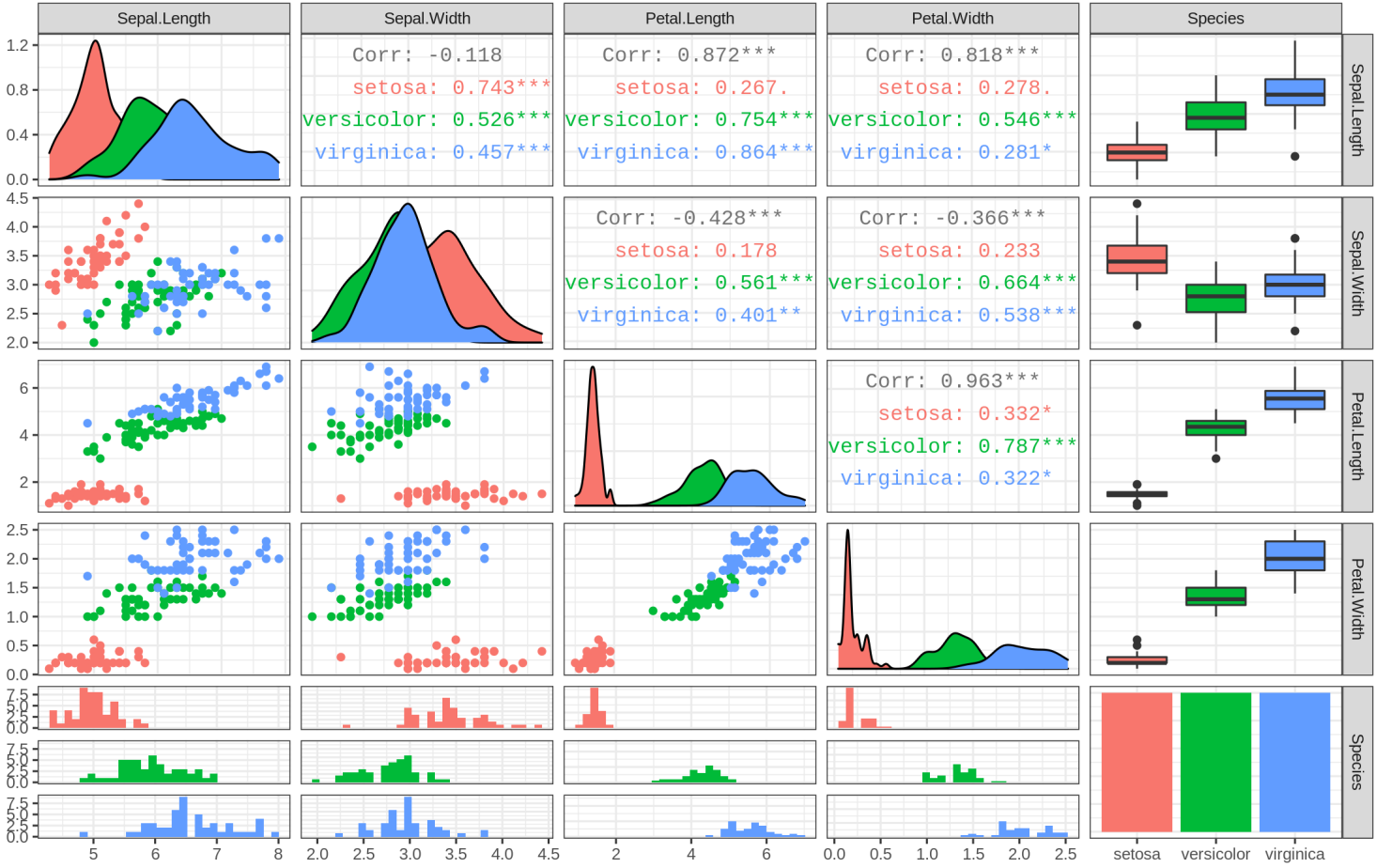
Scientific questions

- Is there a relation between the **length** & the **width** of the iris **Sepal** ?
- Does the size of the **Petal & Sepal** vary together ?
- How are these measures distributed among the **3 Iris species** ?

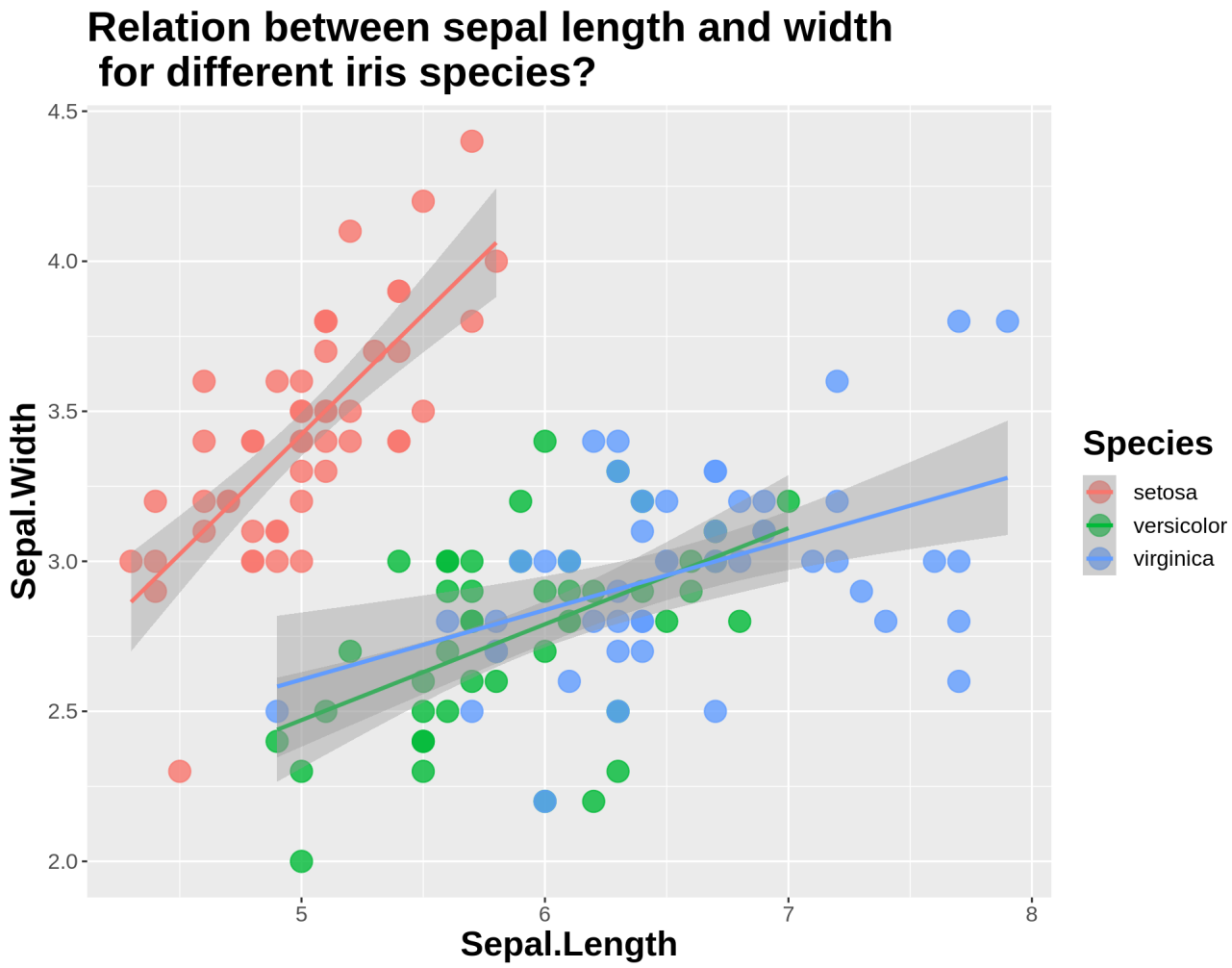
How can we graphically address these questions with `ggplot`?

Exploring data structure

```
install.packages("GGally")
library(GGally)
ggpairs(iris,aes(colour=Species)) + theme_bw()
```



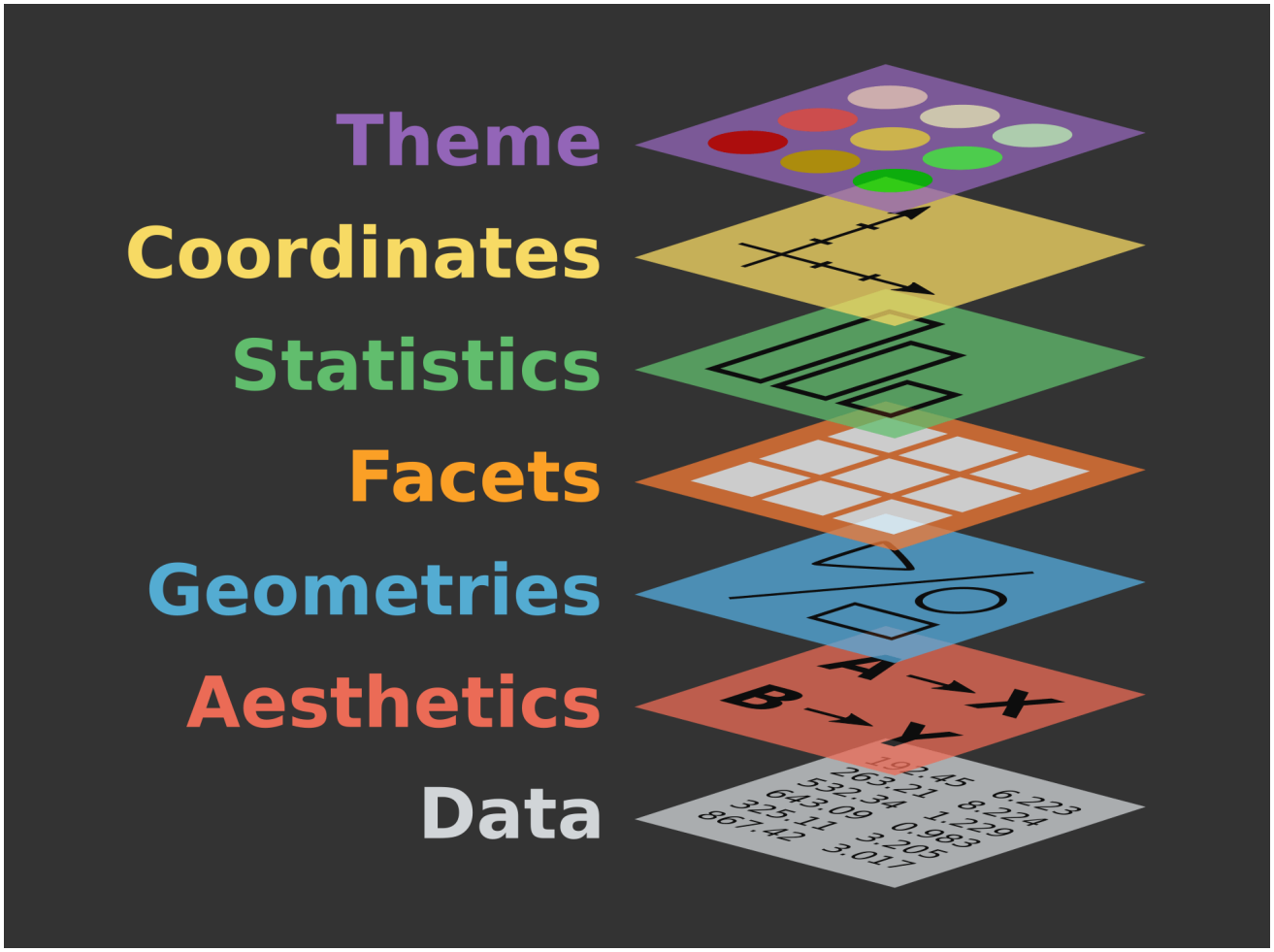
Exploring data structure



♻ See *Loading and manipulating data workshop* to learn how to clean your dataset.

Grammar of Graphics: *recall*

Remember: a graphic is made of different layers:

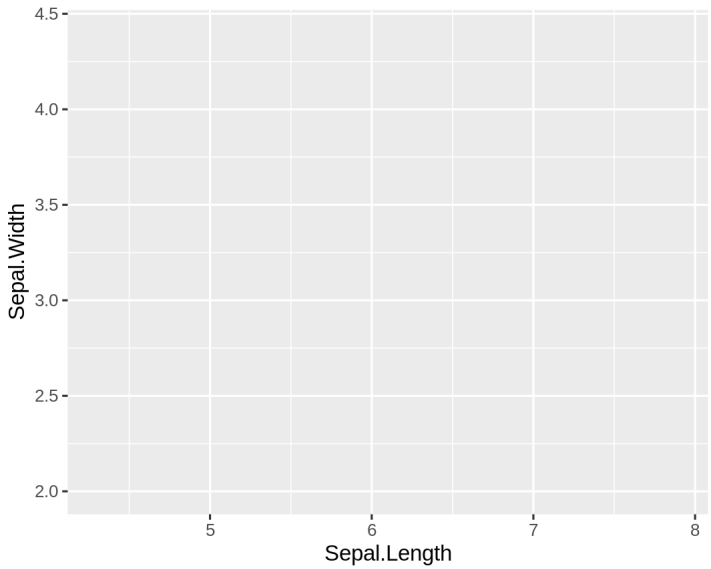


`ggplot()` dynamics: data layer

```
ggplot(data = iris)
```

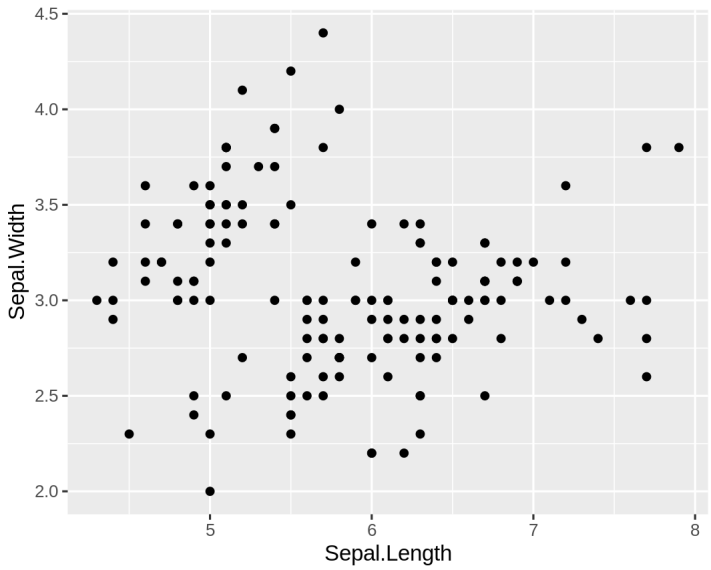
`ggplot()` dynamics: aesthetics layer

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



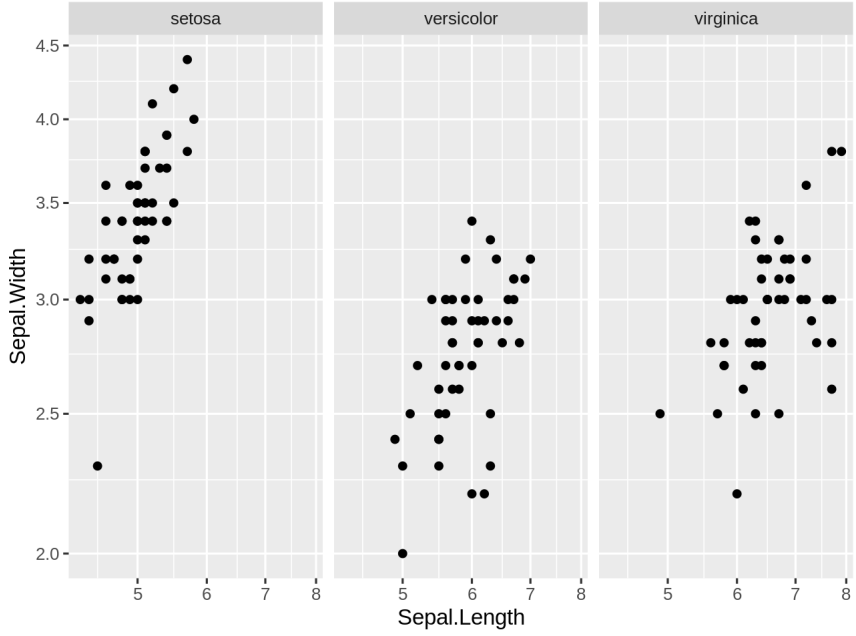
`ggplot()` dynamics: geometric Layer

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



`ggplot()` dynamics: extras- facet, stats, coord layers

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
  geom_point() +
  facet_wrap(~Species) +
  coord_trans(x = "log10",
              y = "log10")
```



Challenge #1 (5min)

Draw your 1st ggplot!

Question

Is there a relation between the **length** & the **width** of the iris **petal** ?

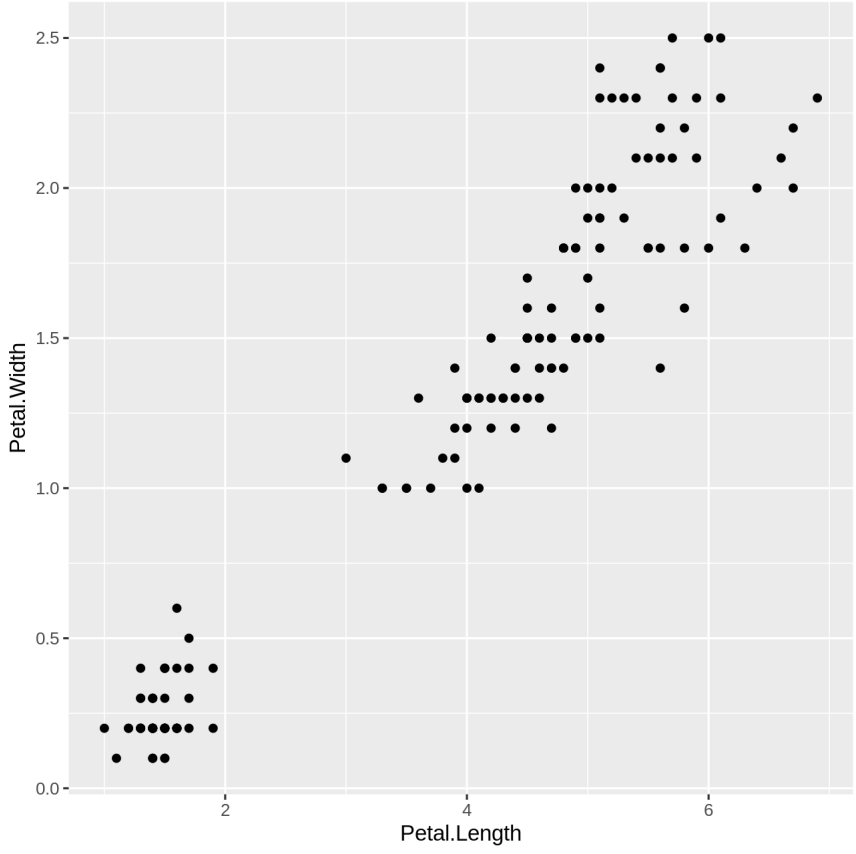
Does the *width* of the petal increase with its *length* ?

Parameters to consider when addressing this question:

data	**geom**	**x value**	**y value**
iris	geom_point	Petal length	Petal width

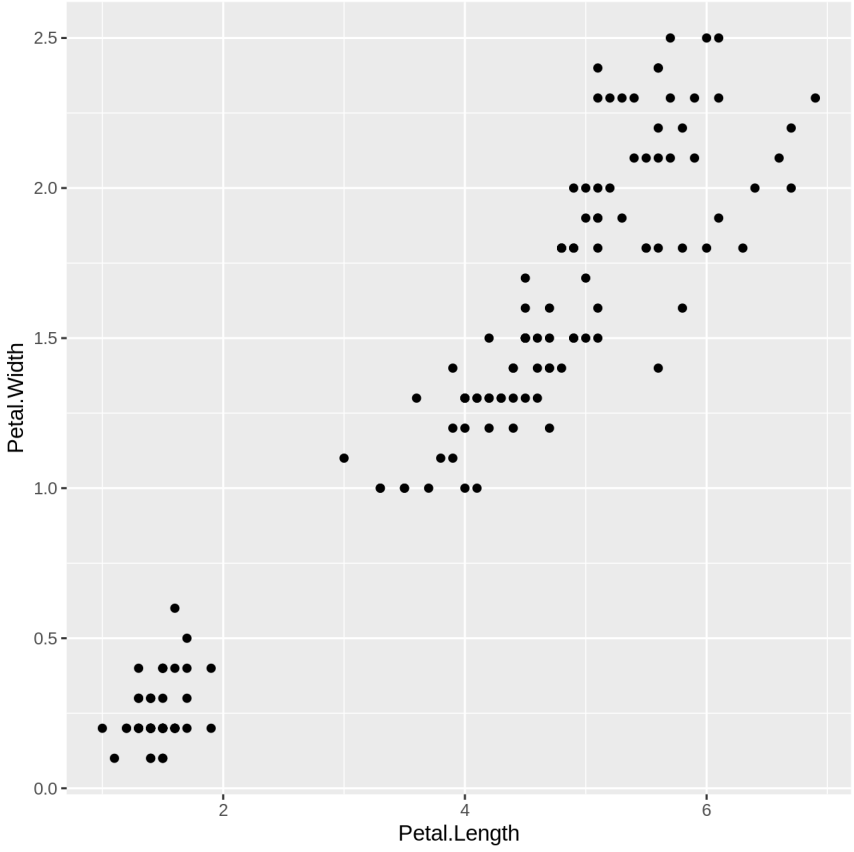
Challenge 1#: Solution

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



Challenge 1#: Solution

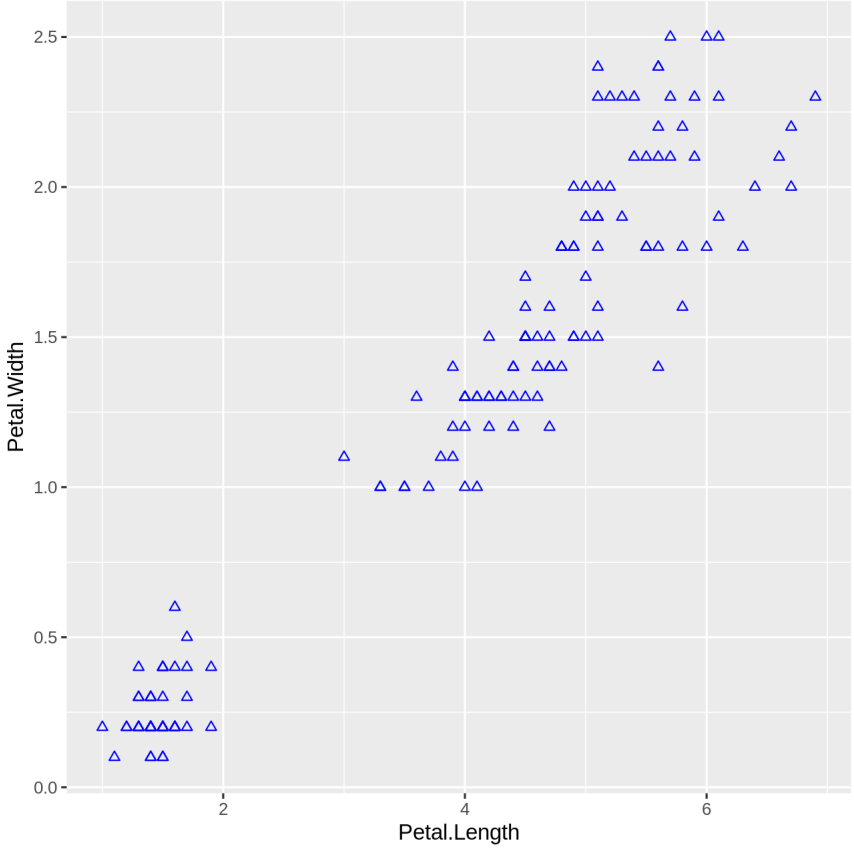
```
ggplot(data = iris, aes(x = Petal.Lengt
                        y = Petal.Width
  geom_point()
```



note: aesthetics can either be in the `ggplot()` line, and will be inherited by every geom, or in the `geom_*()` line to apply to that geom only!

Challenge 1#: Solution

```
ggplot(data = iris, aes(x = Petal.Lengt
                        y = Petal.Width
  geom_point(shape = 2, color="blue")
```



note: aesthetics can either be in the `ggplot()` line, and will be inherited by every geom, or in the `geom_*()` line to apply to that geom only!

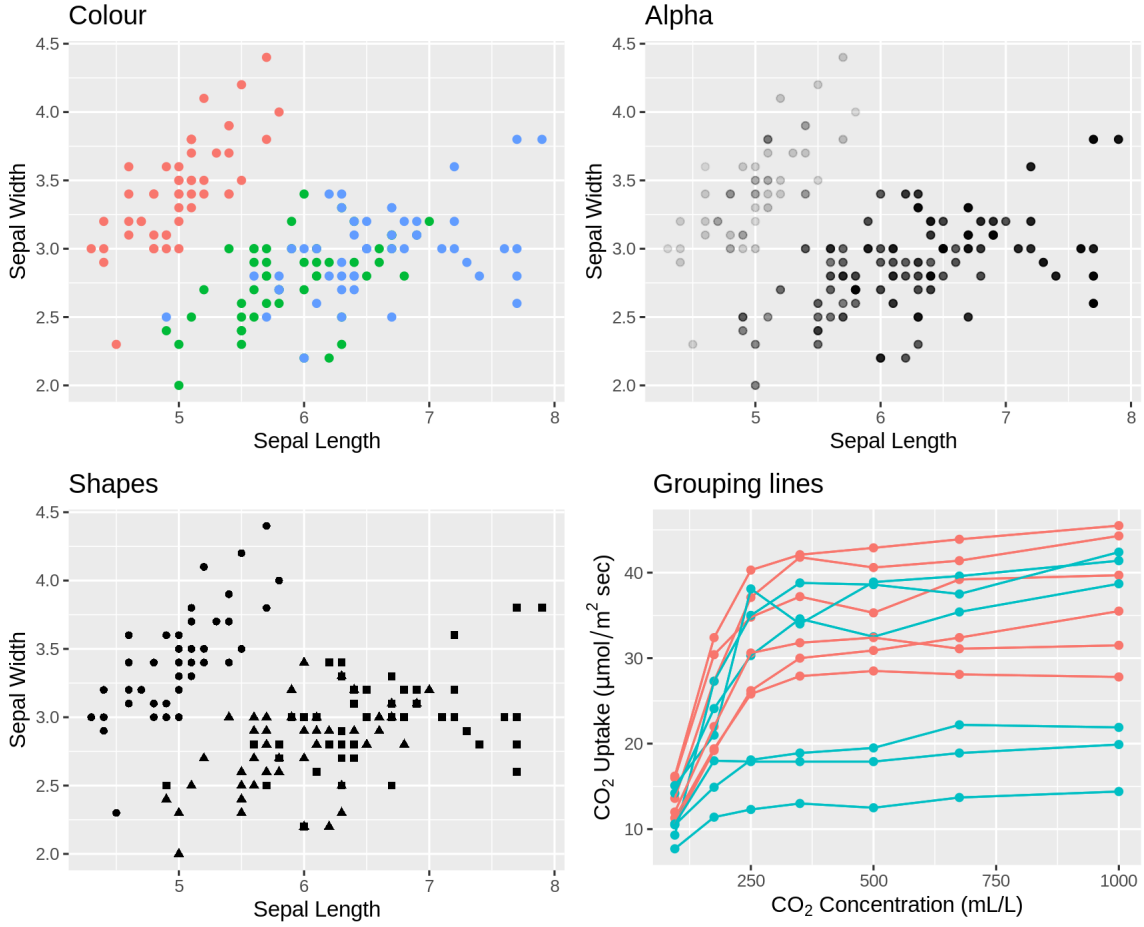
note 2: colour, alpha, shape, and size commands can be set outside of `aes()` values, and will be static, not data-dependent.

Aesthetic mapping

colour, shape, size, labels and transparency

Aesthetic

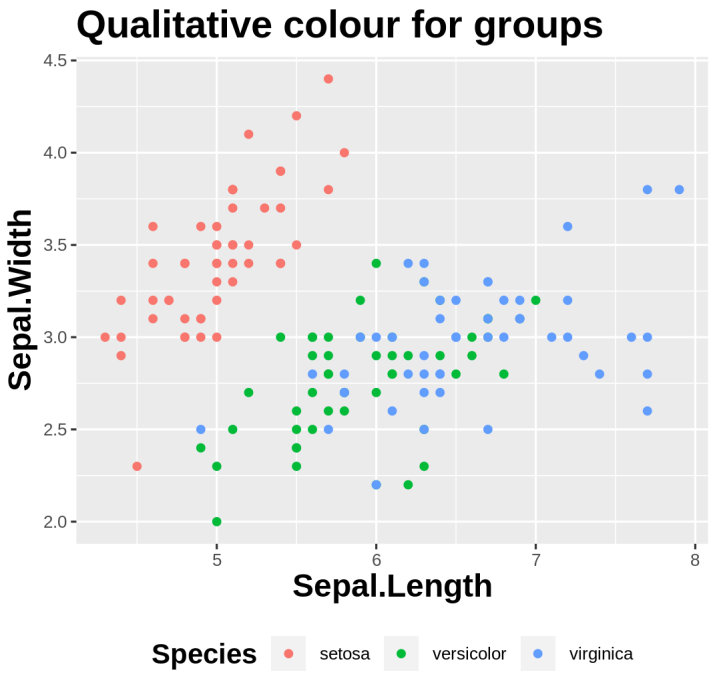
Use aesthetics (`aes()`) to distinguish classes, groups and structure

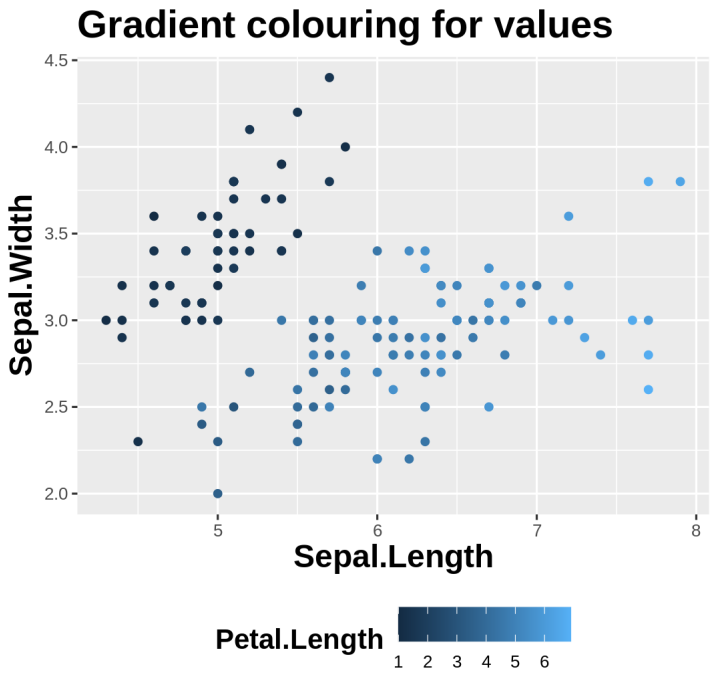


Colouring: make your points talk

Change **colour** to

- ➔ differentiate between groups
- ➔ represent data values
- ➔ highlight specific elements





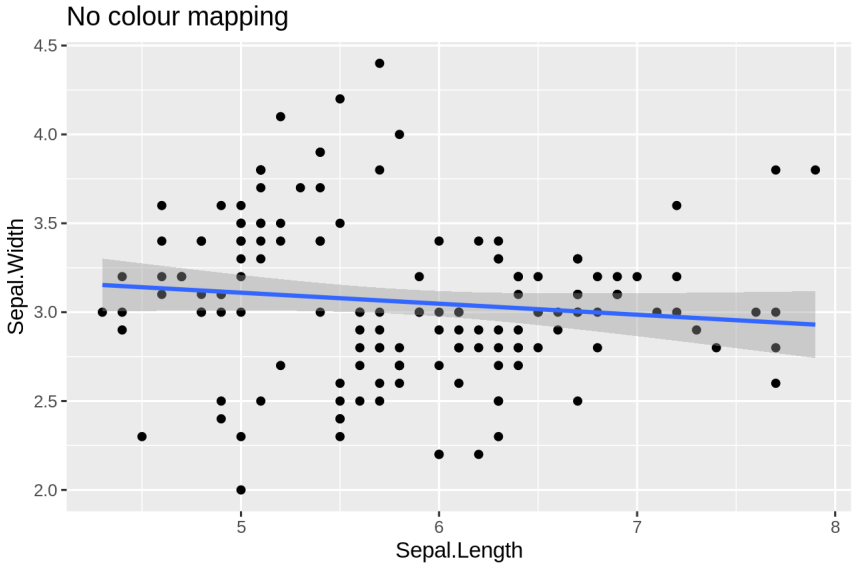
See [Fundamentals of Data Visualization]

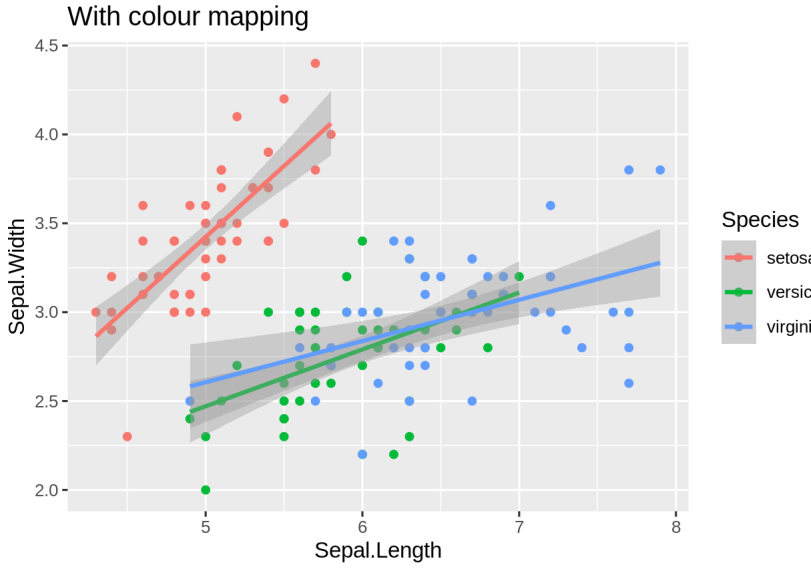
Using `aes()` use to change colour

Do the sepal length and width vary differently across species?

```
# No colour mapping
ggplot(data = iris,aes(x = Sepal.Length
  geom_point() +
  geom_smooth(method=lm)+
  labs(title = "No colour mapping")
```

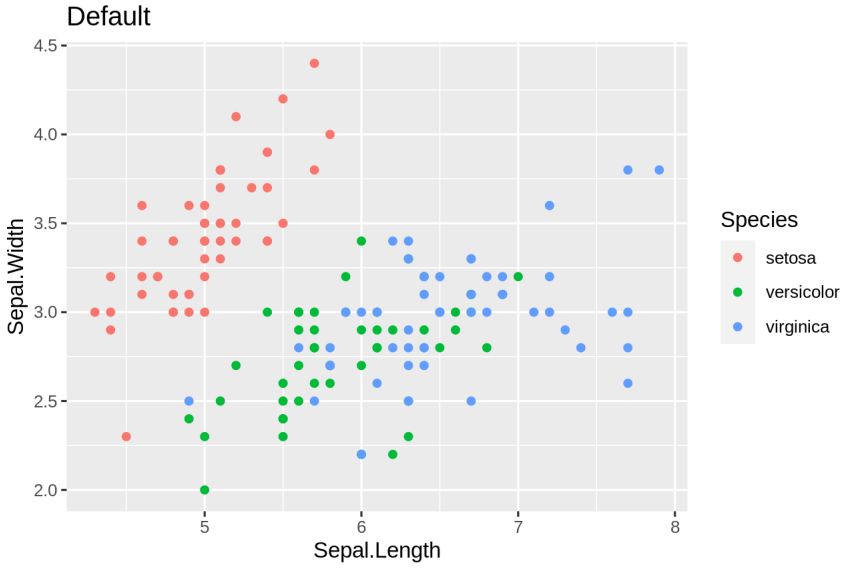
```
# With colour mapping
ggplot(data = iris, aes(x = Sepal.Leng
  geom_point() +
  geom_smooth(method=lm) +
  labs(title = "With colour mapping")
```



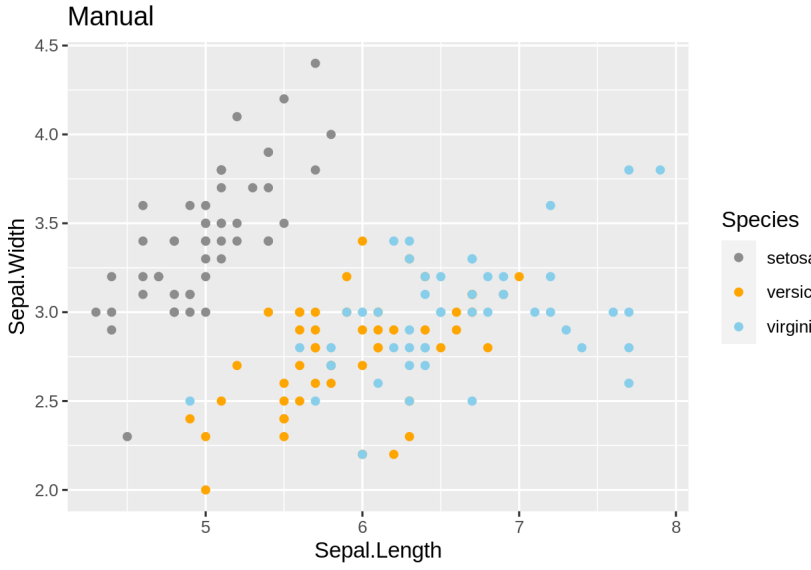


Change colour manually

```
# Default
pp <- ggplot(data = iris) +
  geom_point(mapping = aes(x = Sepal.Le
pp + labs(title = "Default")
```

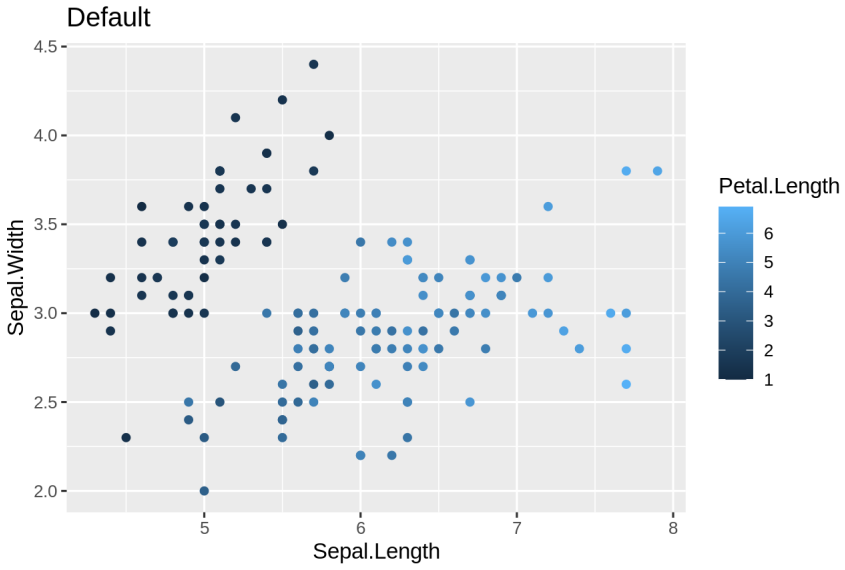



```
# Manual
pp +
  scale_colour_manual(values = c("grey5
  labs(title = "Manual")
```

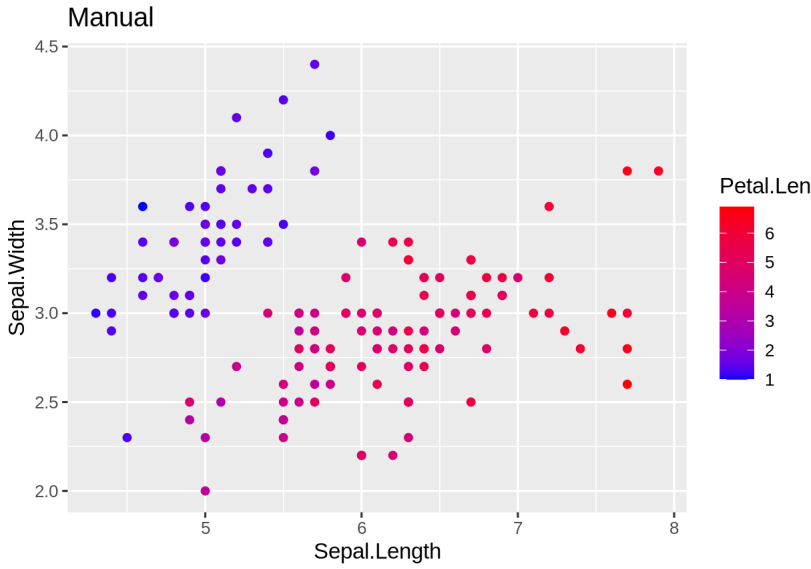


Colour gradients

```
# Default
pp2 <- ggplot(data = iris) +
  geom_point(mapping = aes(x = Sepal.Le
                           colour = Pet
pp2 + labs(title = "Default")
```

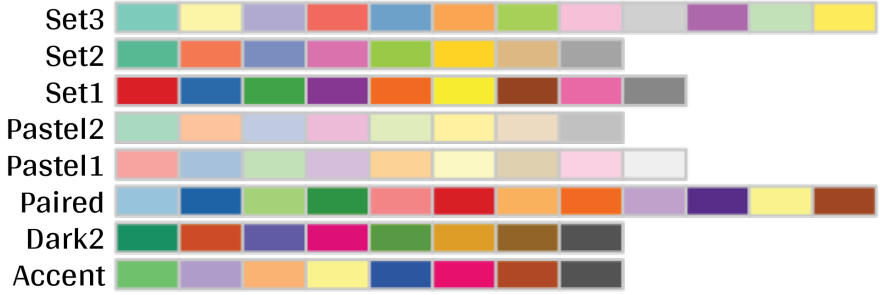


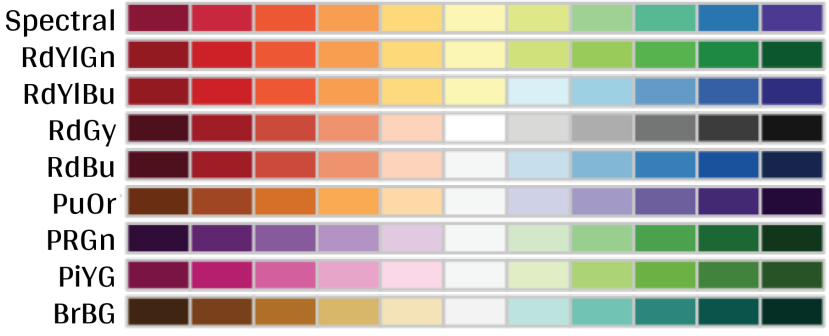

```
# Manual
pp2 + scale_colour_gradient(low = "blue
  labs(title = "Manual")
```

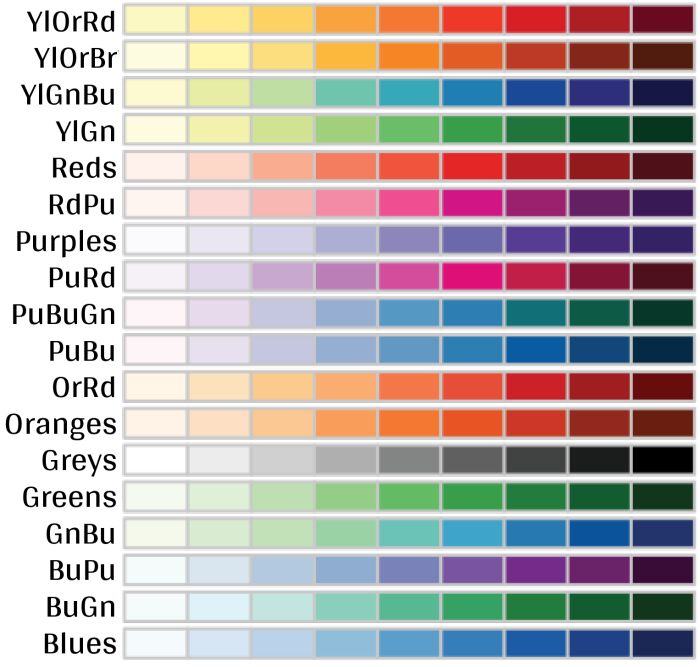


Use a predefined colour palette

```
install.packages("RColorBrewer")
require(RColorBrewer)
display.brewer.all()
```

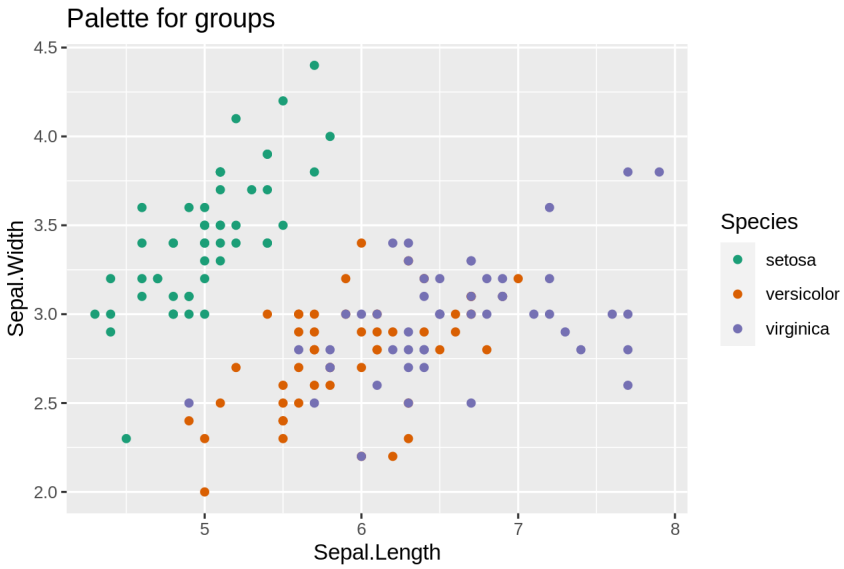






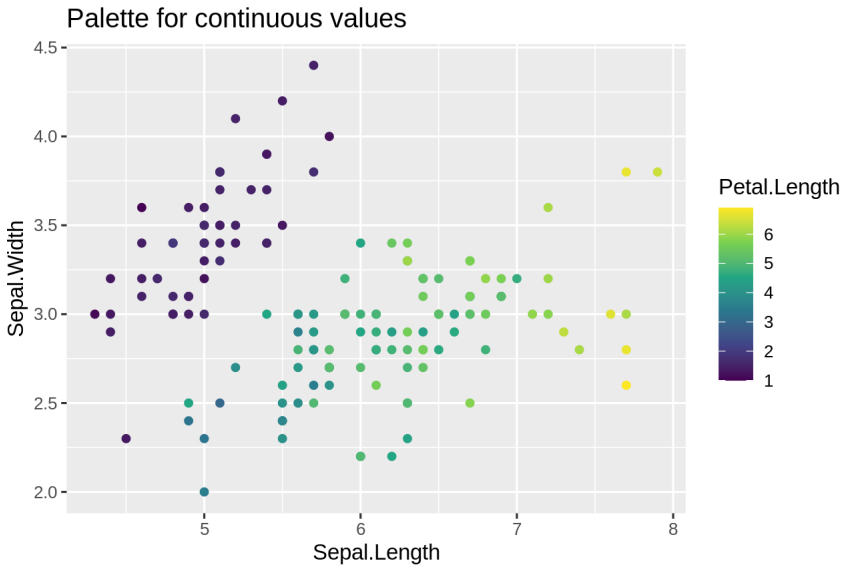
Use a predefined colour palette

```
# Palette for groups
pp + scale_colour_brewer(palette = "Dark2") +
  labs(title = "Palette for groups")
```



Use a predefined colour palette

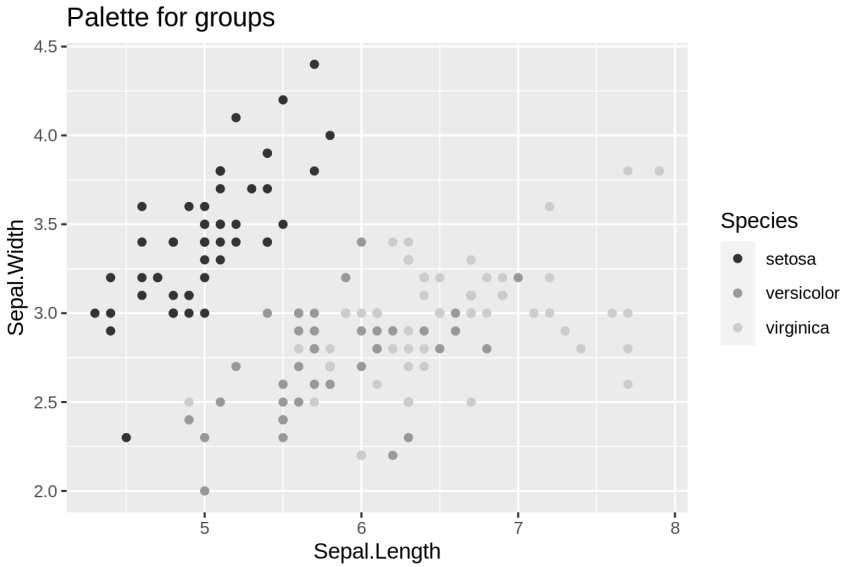
```
# Palette for continuous values
pp2 + scale_color_viridis_c()+
  labs(title = "Palette for continuous values")
```



Use a predefined colour palette

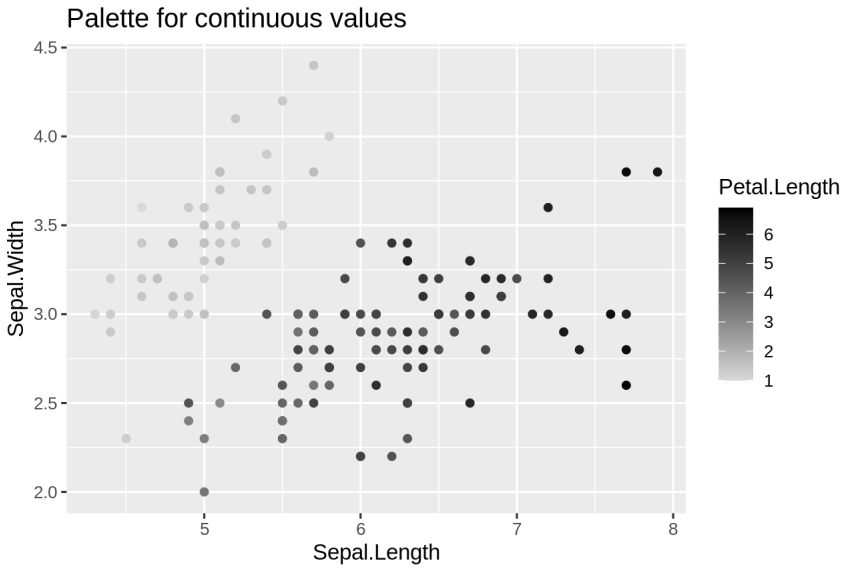
Grey-scale palette for publication purposes

```
# Palette for groups
pp + scale_colour_grey() +
  labs(title = "Palette for groups")
```



Use a predefined colour palette

```
# Palette for continuous values
pp2 + scale_colour_gradient(low = "grey85", high = "black") +
  labs(title = "Palette for continuous values")
```



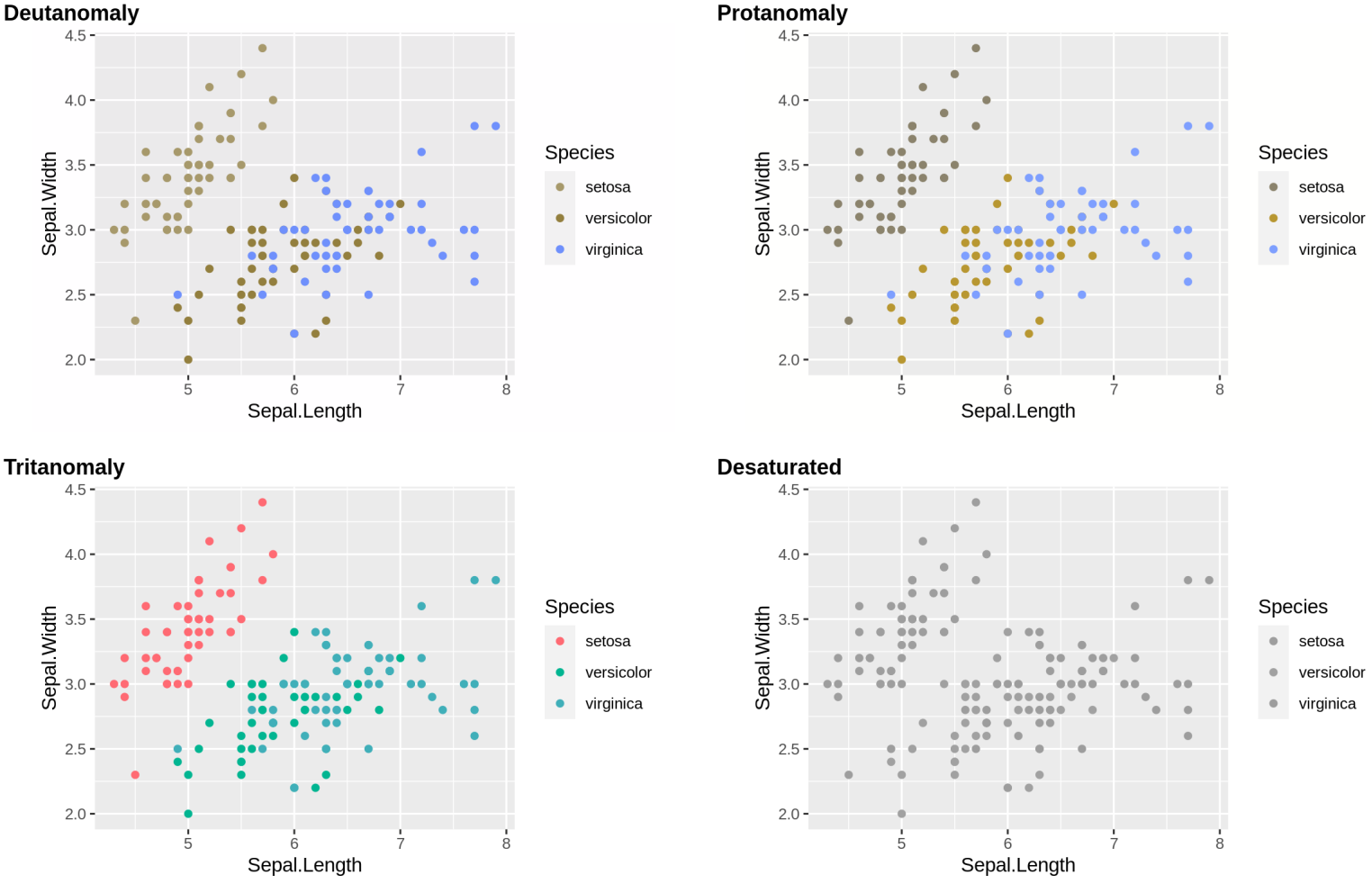
Use colourblind-friendly palettes

How your figure might appear under various forms of colourblindness? We can use colorblindr that is not currently on CRAN, so we install it with the packages remotes.

```
remotes::install_github("clauswilke/colorblindr", quiet = TRUE)
library(colorblindr)
```

Use colourblind-friendly palettes

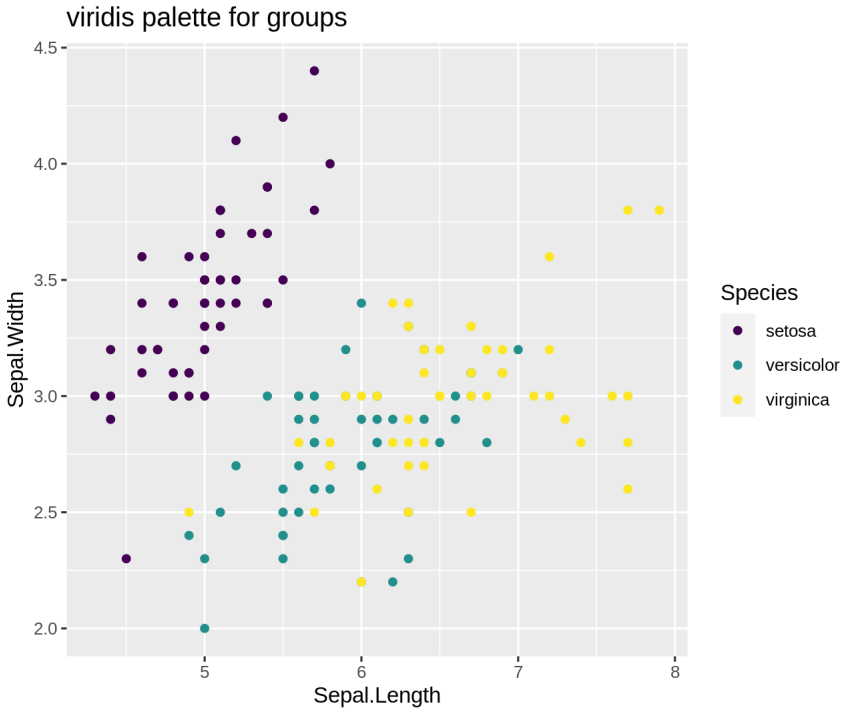
```
cvd_grid(pp)
```

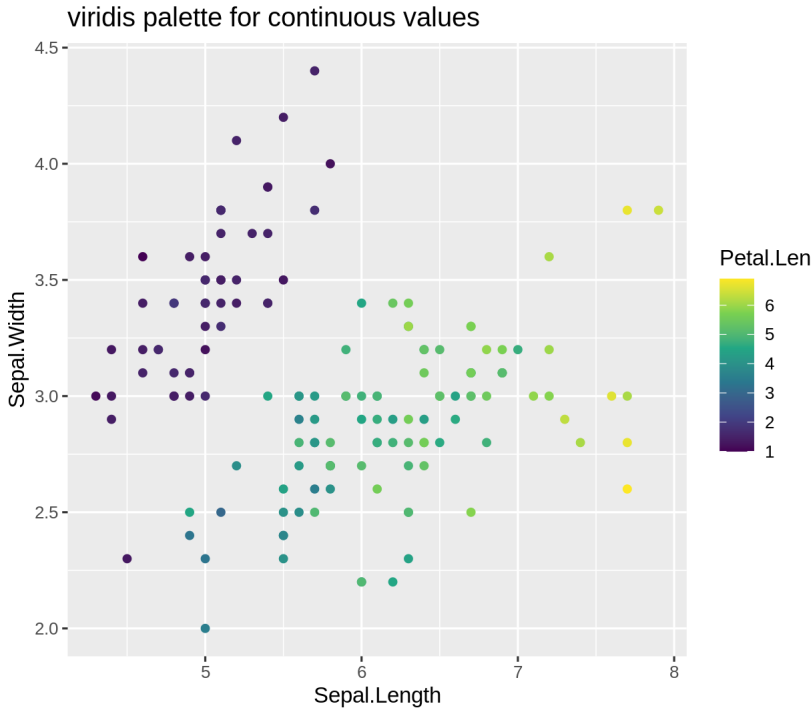


Use colourblind-friendly palettes

```
# Palette for groups
pp + scale_colour_viridis_d() +
  labs(title = "viridis palette for gr
```

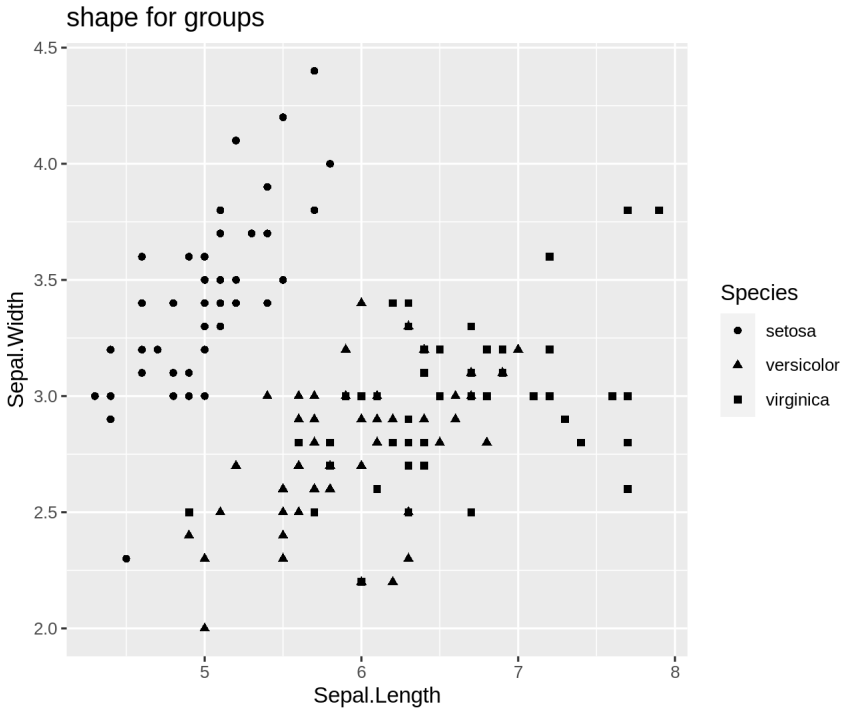
```
# Palette for continuous values
pp2 + scale_colour_viridis_c() +
  labs(title = "viridis palette for co
```



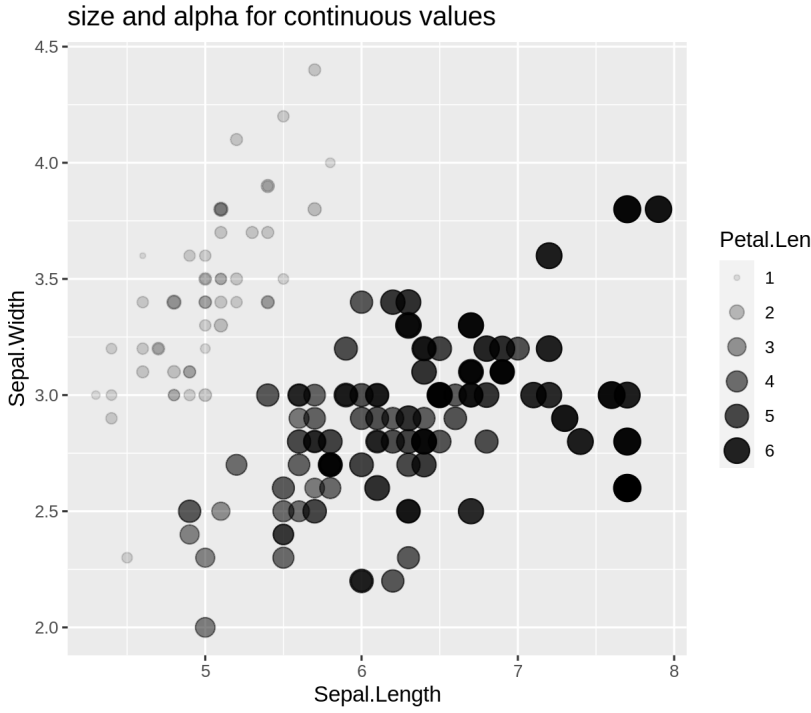


Changing `shape`, `size` and `alpha`

```
# shape for groups
ggplot(data = iris) +
  geom_point(aes(x = Sepal.Length, y =
  labs(title = "shape for groups")
```




```
# size and alpha for continuous values
ggplot(data = iris) +
  geom_point(aes(x = Sepal.Length, y =
                 size = Petal.Length, a
  labs(title = "size and alpha for cont
```



Challenge #2

- Produce an informative plot from built-in datasets such as `mtcars`, `CO2` or `msleep`.
- Use appropriate aesthetic mappings for different data types

Data	**x**	**y**	**Aesthetics**
mtcars	*wt*	*mpg*	*disp* and *hp*
CO2	*conc*	*uptake*	*Treatment* and *Type*
msleep	log10(*bodywt*)	*awake*	*vore* and *conservation*
ToothGrowth	*dose*	*len*	*supp*

⚠ Pay attention to the data types!

Challenge #2

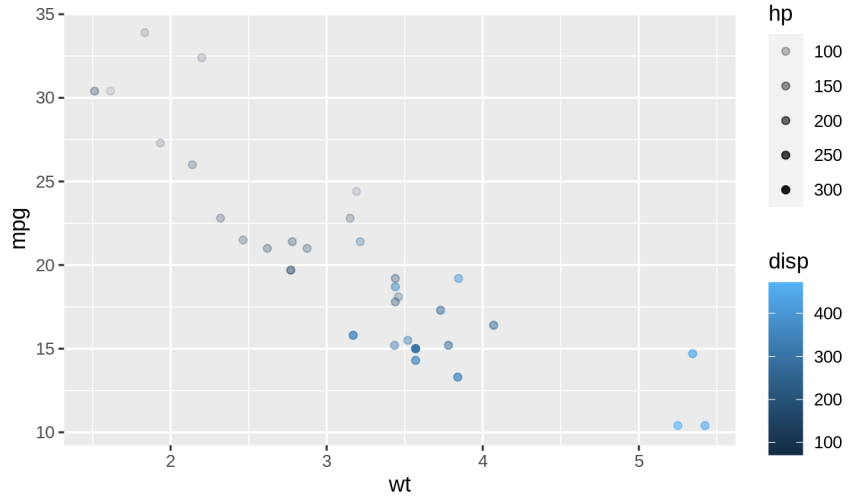
Breakout rooms! - 15 min

make a plot to share with the group

Challenge #2 - Solution example #1

Data	x	y	Aesthetics
mtcars	*wt*	*mpg*	*disp* and *hp*

```
data(mtcars)
ggplot(data = mtcars) +
  geom_point(mapping = aes(x = wt, y = mpg,
                           colour = disp,
                           alpha = hp))
```

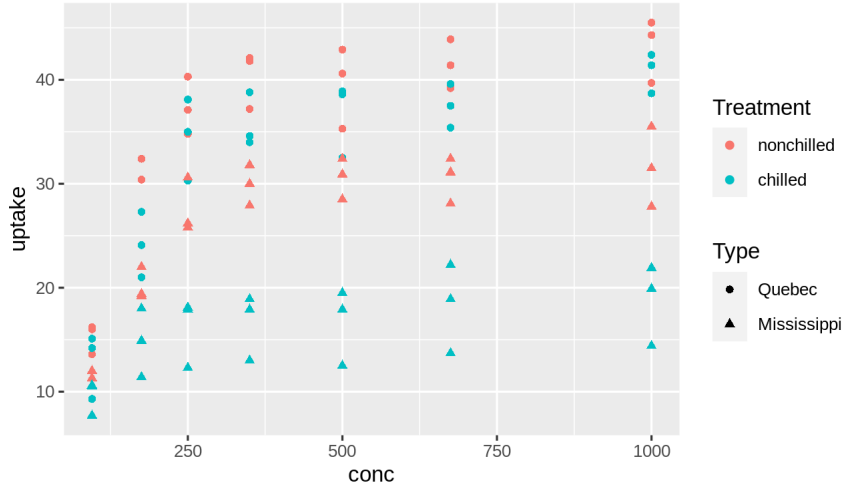


Could you use `size` instead of `alpha`? What about `shape`?

Challenge #2 - Solution example #2

Data	x	y	Aesthetics
CO2	*conc*	*uptake*	*Treatment* and *Type*

```
data(CO2)
ggplot(data = CO2) +
    geom_point(mapping = aes(x = conc, y = uptake,
                             colour = Treatment, shape = Type))
```

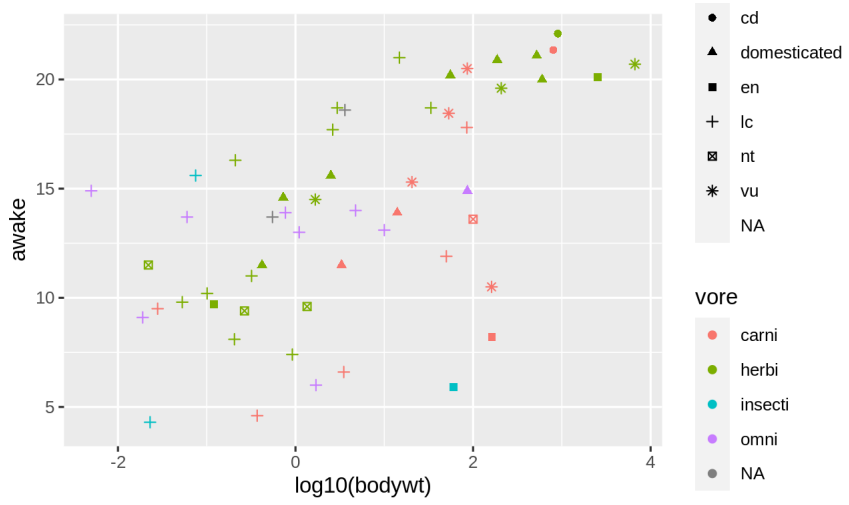


Why not use `size = Type`*?*

Challenge #2 - Solution example #3

Data	x	y	Aesthetics
msleep	log10(*bodywt*)	*awake*	*vore* and *conservation*

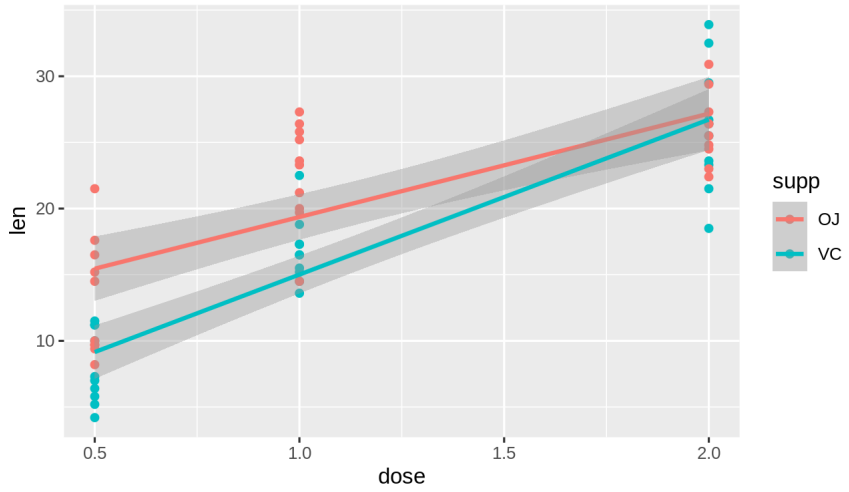
```
data(msleep)
ggplot(data = msleep) +
    geom_point(mapping = aes(x = log10(bodywt), y = awake,
                             colour = vore, shape = conservation))
```



Challenge #2 - Solution example #4

Data	x	y	Aesthetics
ToothGrowth	*dose*	*len*	*supp*

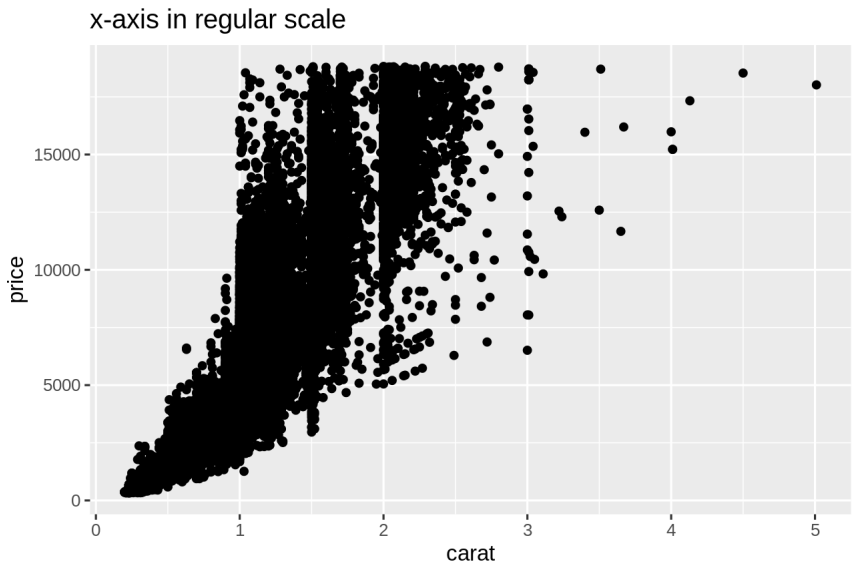
```
data(ToothGrowth)
ggplot(ToothGrowth, aes(x=dose,y=len,color=supp)) +
  geom_point() +
  geom_smooth(method = lm, formula='y~x')
```



Changing the scale of the axes

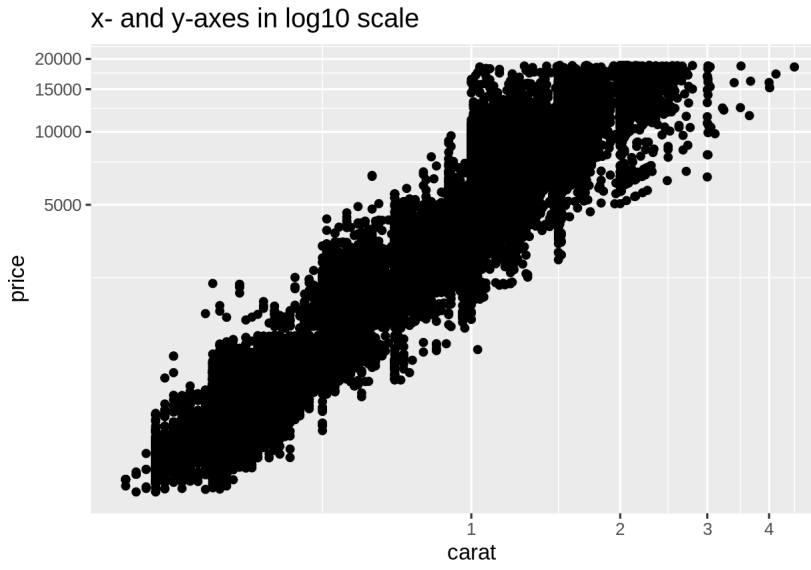
x axis in regular scale

```
ggplot(diamonds) +
  geom_point(mapping = aes(x = carat, y
  labs(title = "x-axis in regular scale
```



x-axis and y-axis in log10() scale

```
ggplot(diamonds) + geom_point(mapping =
  coord_trans(x = "log10",
              y = "log10") +
  labs(title = "x- and y-axes in log10
```



It is also possible to transform the coordinate system using `scale_x_log10()` and `scale_y_log10()`

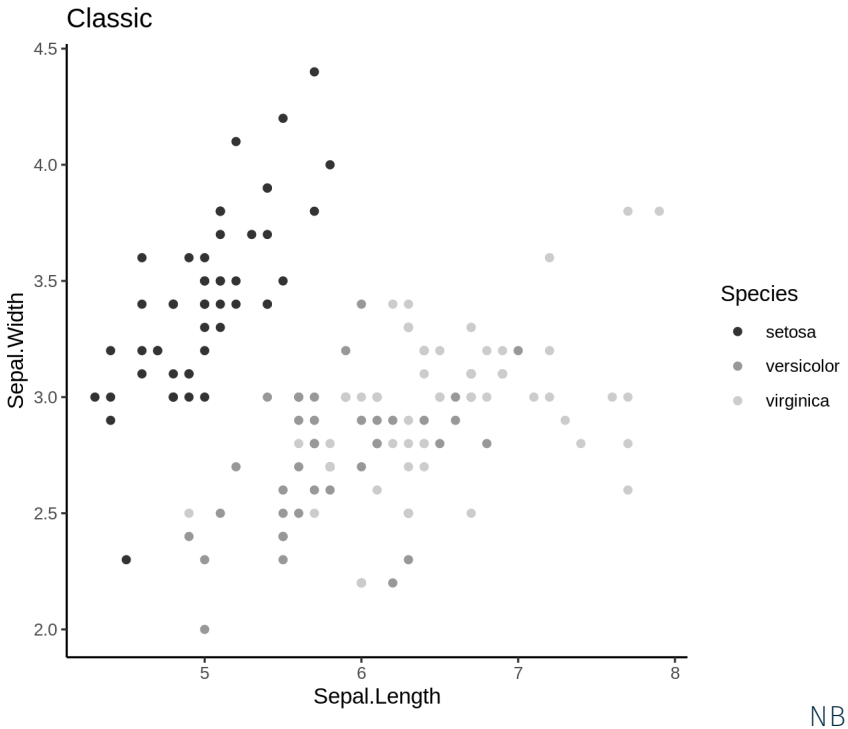
Fine-tuning your plots

Using `theme()` to make it look good!

theme()

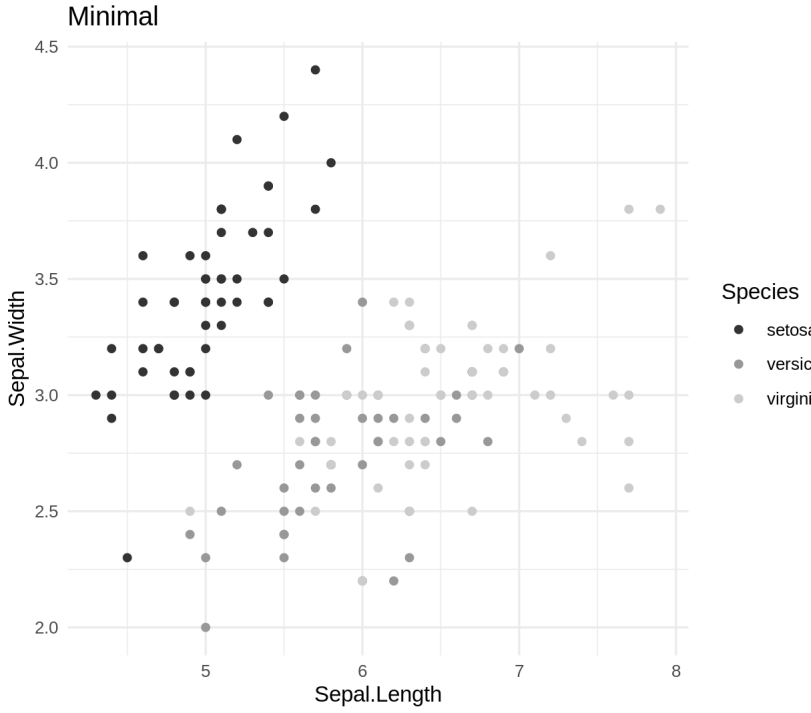
Theme Classic

```
# Theme classic
pp + scale_colour_grey() +
  theme_classic() +
  labs(title = "Classic")
```



Theme Minimal

```
pp + scale_colour_grey() +
  theme_minimal() +
  labs(title = "Minimal")
```



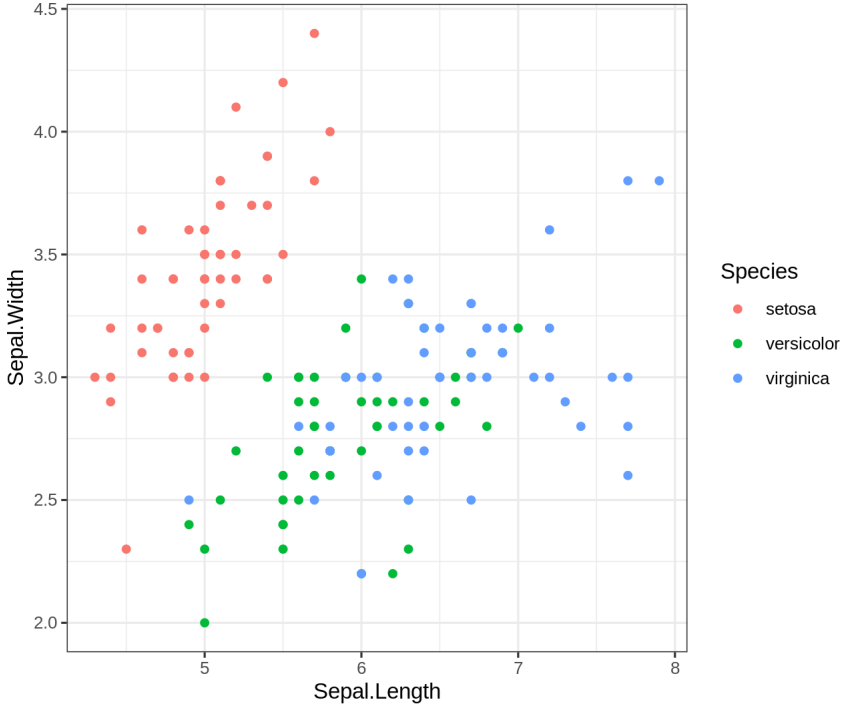
NB: Good choices for publication purposes!

`theme()`

Use `theme_set()` to change theme for all your future plots, or `theme_update()` to edit aspects of a theme setting.

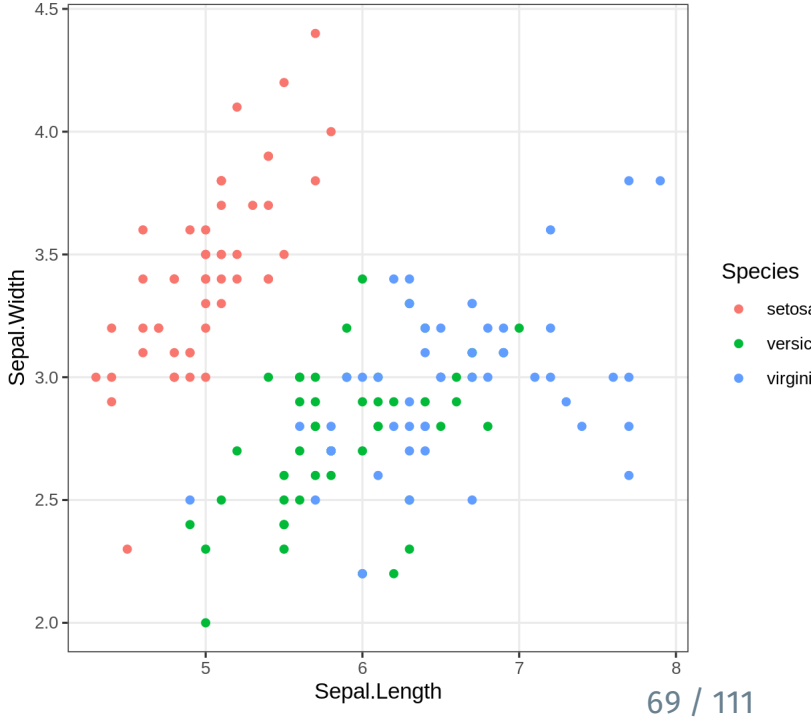
Set theme

```
# Set Classic as default
theme_set(theme_bw())
pp
```



Update theme

```
# remove minor gridlines
theme_update(panel.grid.minor = elemen
pp
```



Elements of a theme

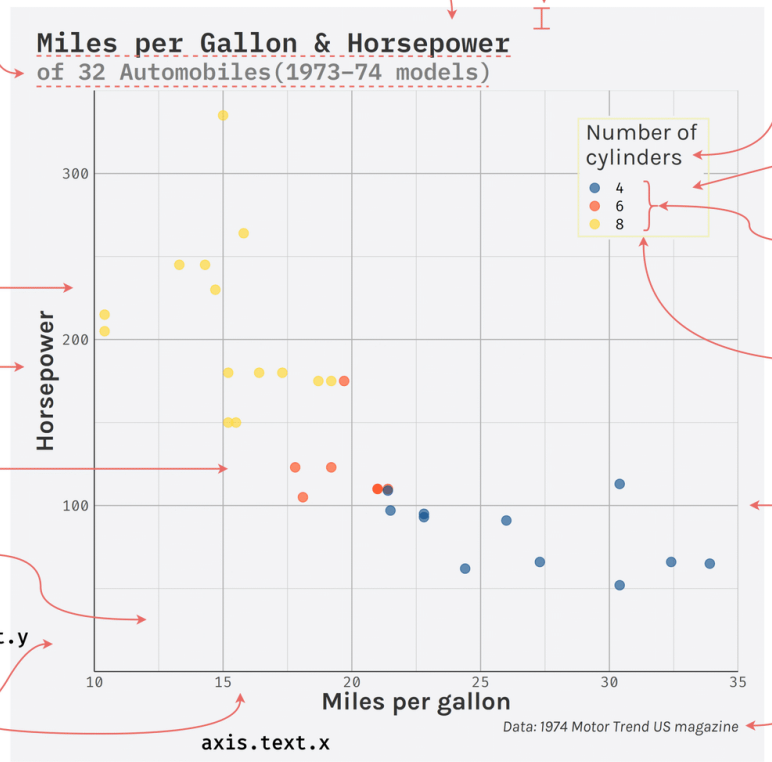
ggplot2
theme elements
reference

Set `minimal` as the baseline theme:

```
theme_minimal() +
theme(theme.element = element_type())
```

Use `element_blank()` to **remove an element**

Axis titles, **text**, **ticks**, and **lines** can be specified per axis using theme inheritance by putting `.x/.y` at the end of the theme element.



isabella-b

`text = element_text()` ← modifications will be applied to all text elements

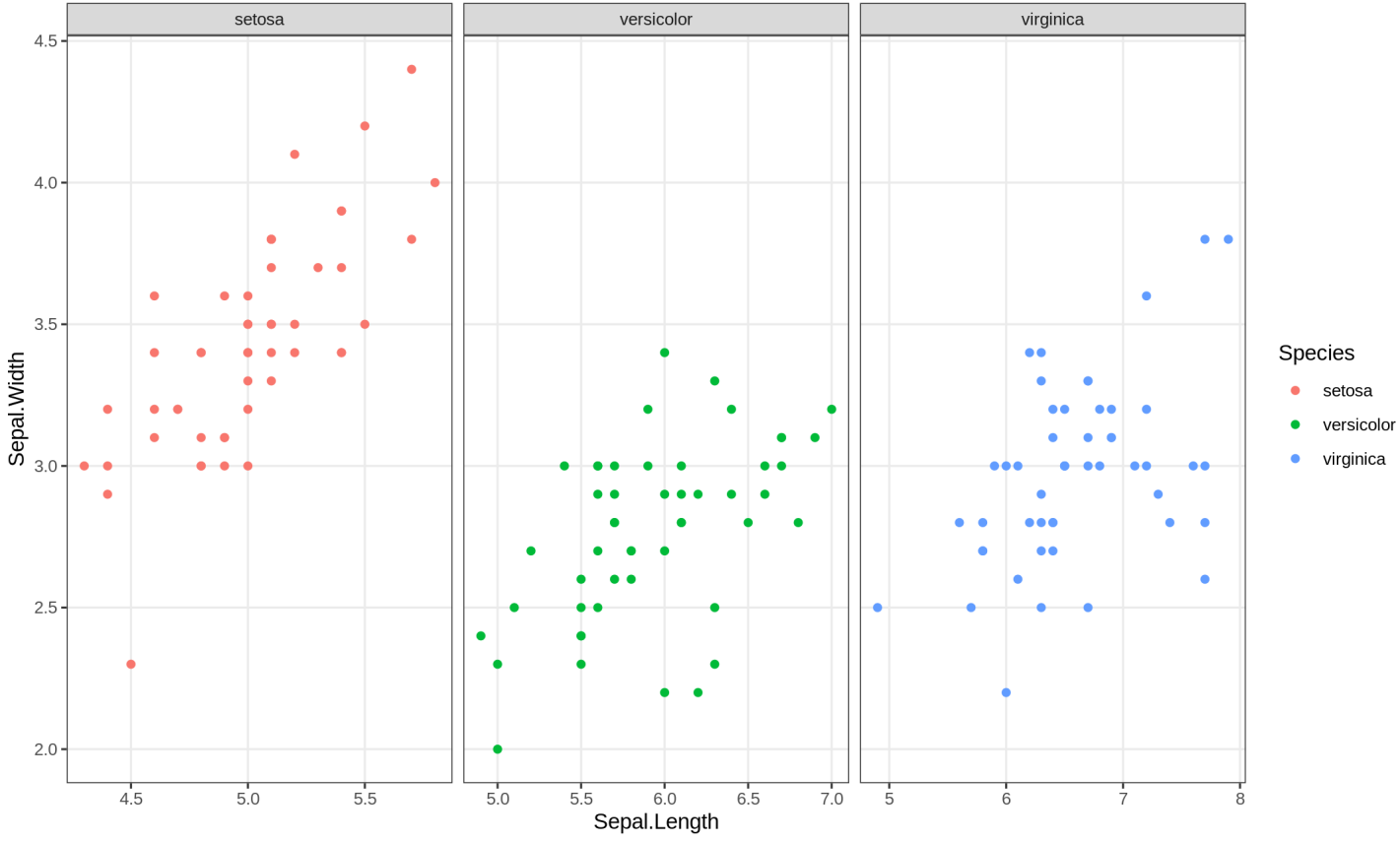
Full list of elements at ggplot2.tidyverse.org/reference/theme

Fine-tuning your plots

Using `facet_grid()` to change the arrangement of plots

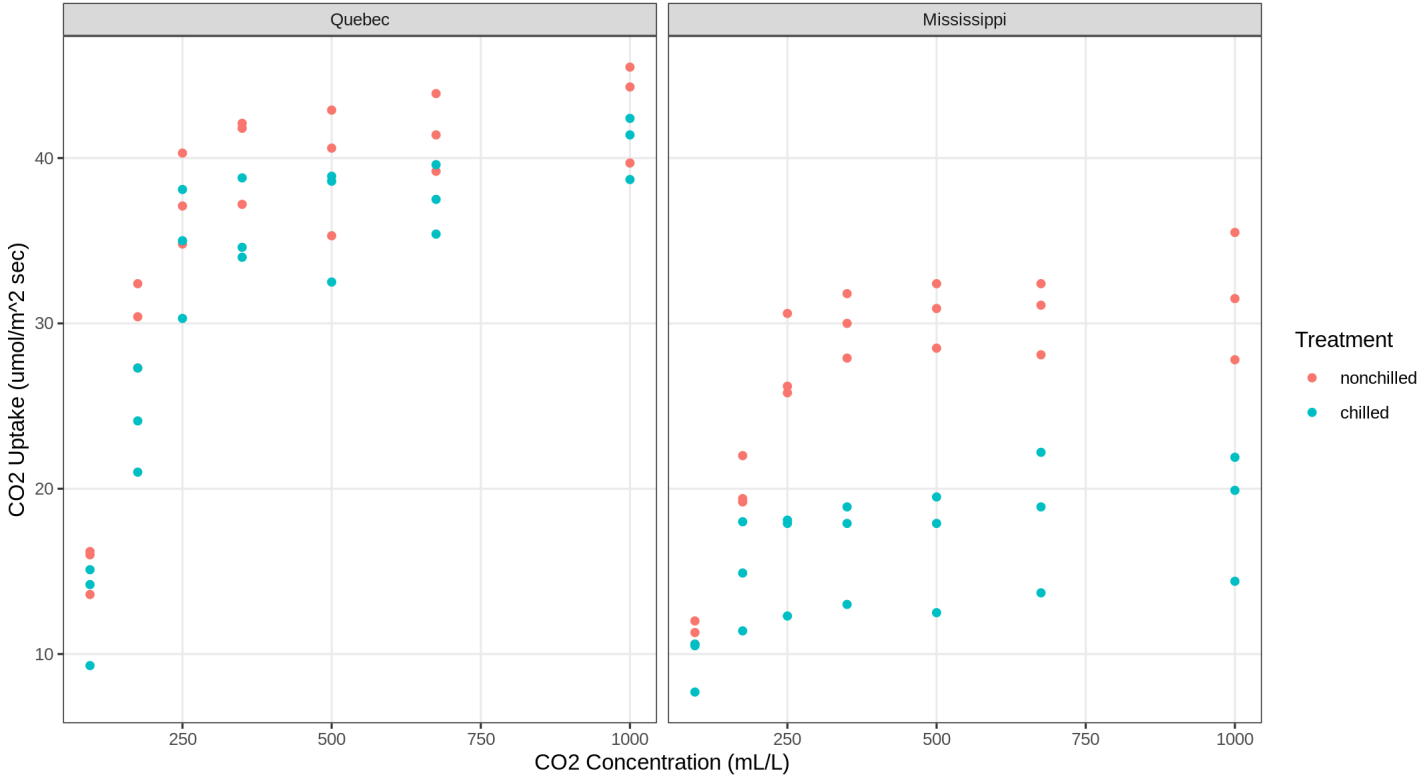
iris dataset: per-species facets

```
ggplot(data = iris) +
  geom_point(mapping = aes(x = Sepal.Length, y = Sepal.Width, colour = Species)) +
  facet_grid(~ Species, scales = "free")
```



CO2 dataset: per-type facets

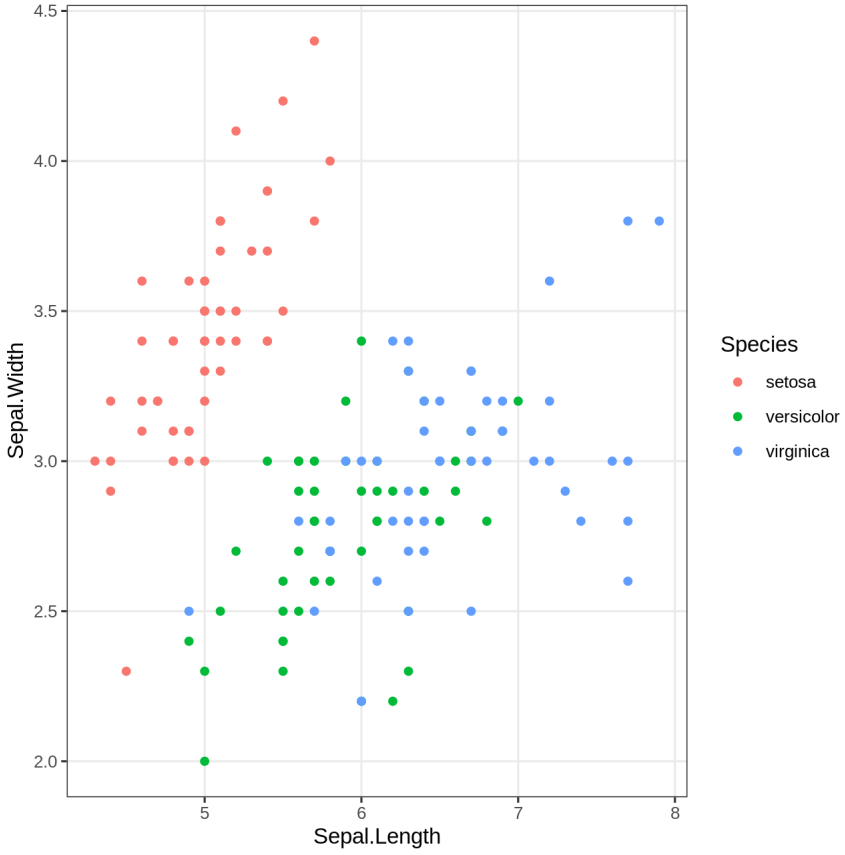
```
ggplot(data = CO2) +
  geom_point(mapping = aes(x = conc, y = uptake, colour = Treatment)) +
  xlab("CO2 Concentration (mL/L)") + ylab("CO2 Uptake (umol/m^2 sec)") +
  facet_grid(~ Type)
```



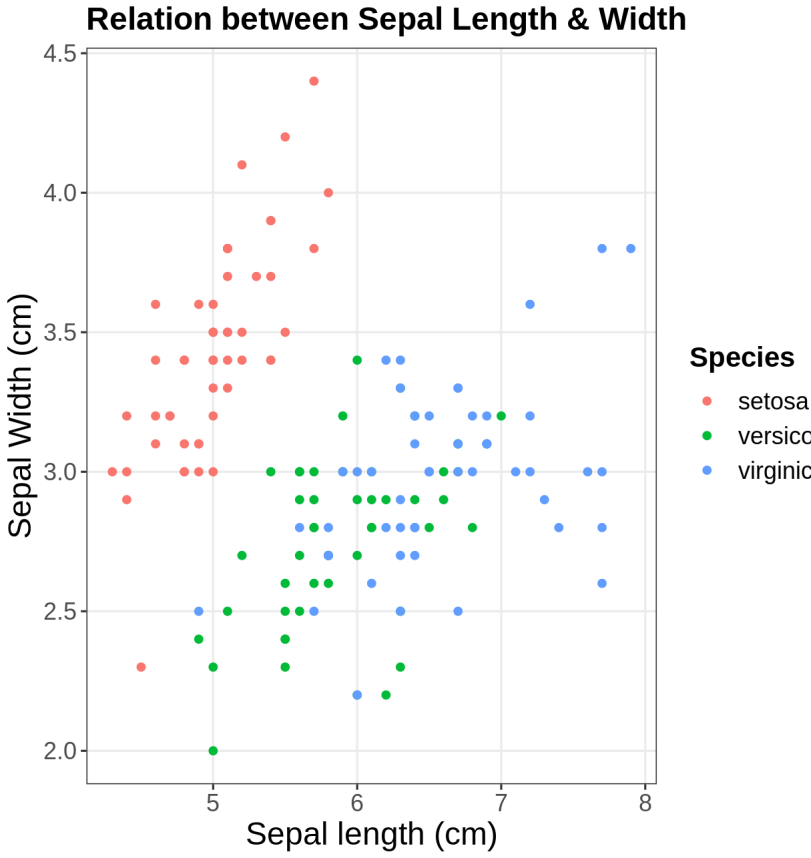
Title and axes components: changing size, colour and face

Title and axes components: size, colour and face

Default



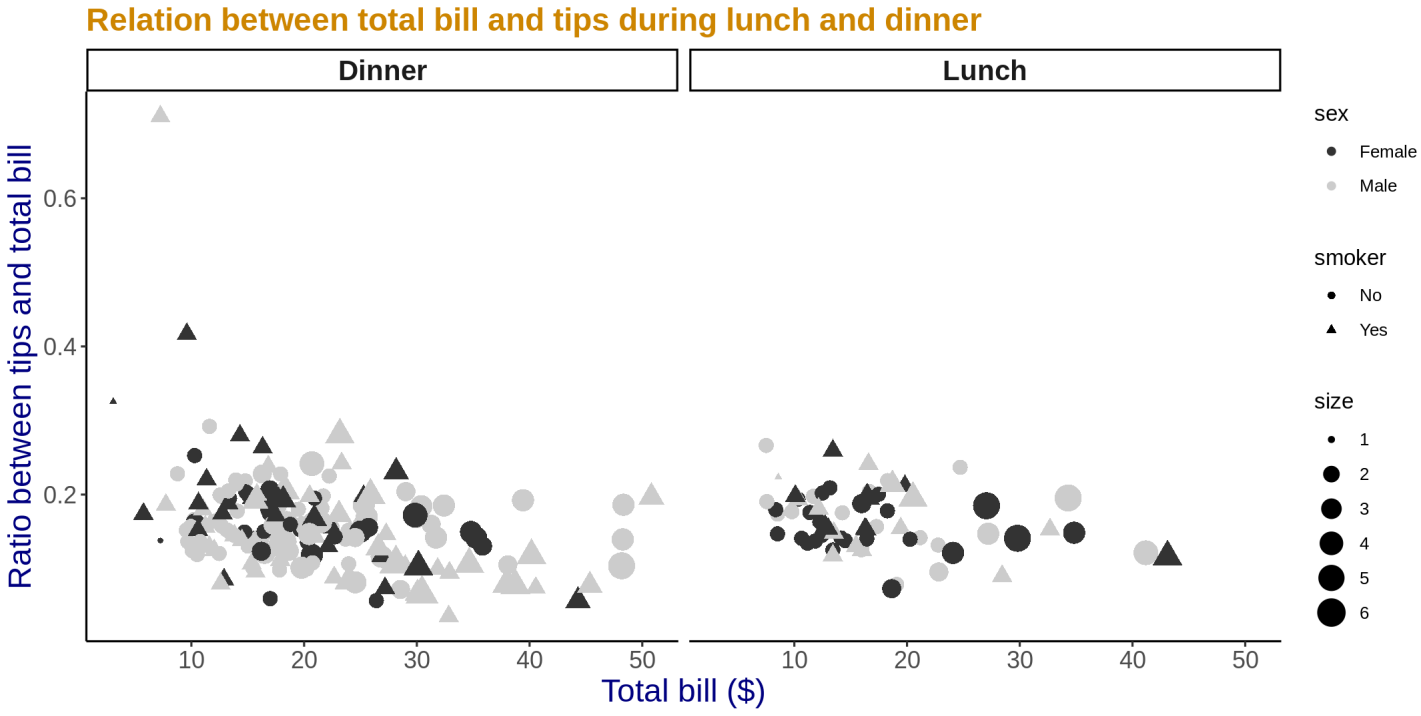
Axes and title tuning



Challenge #3

Use the `tips` dataset found in `reshape2` 📦 to reproduce the plot below.

Our tip: start from `theme_classic()` and add `theme()` to make your additional changes.



Challenge #3

Breakout rooms! - 15 min

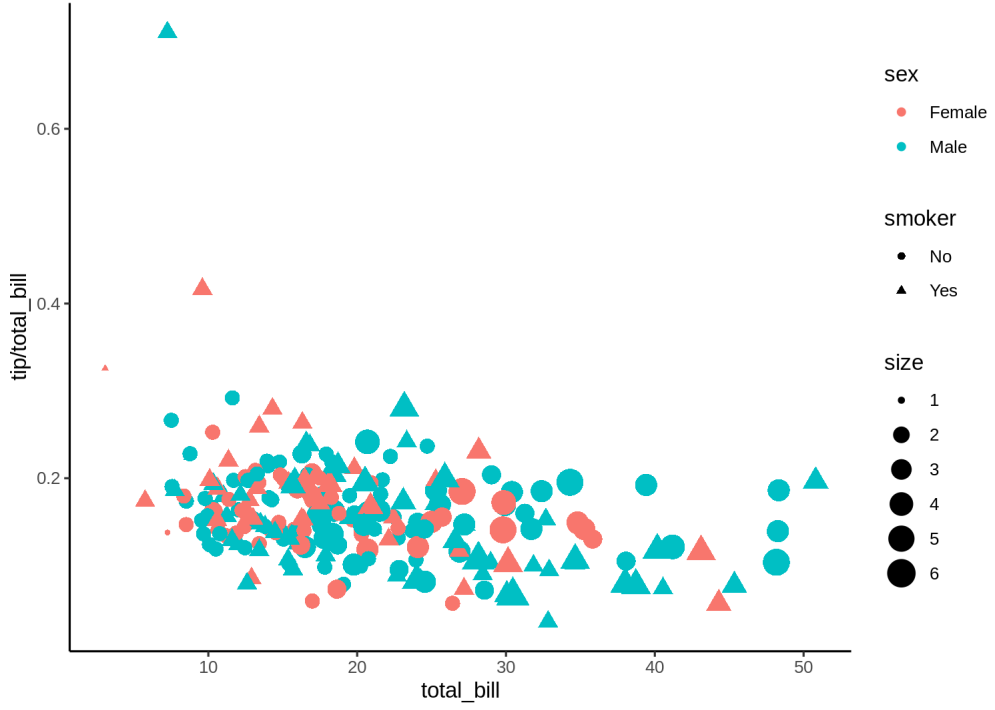
Challenge #3: Solution

```
library(reshape2)
tips.gg <- ggplot(tips, aes(x = total_bill,
                            y = tip/total_bill,
                            shape = smoker,
                            colour = sex,
                            size = size)) +
  geom_point() +
  facet_grid( ~ time) +
  scale_colour_grey() +
  labs(title = "Relation between total bill and tips during lunch and dinner",
       x = "Total bill ($)", y = "Ratio between tips and total bill") +
  theme_classic() +
  theme(axis.title = element_text(size = 16,
                                  colour = "navy"),
        axis.text = element_text(size = 12),
        plot.title = element_text(size = 16,
                                  colour = "orange3",
                                  face = "bold"),
        strip.text.x = element_text(size = 14, face="bold"))
tips.gg
```

Challenge #3: step-by-step solution

`aes()`

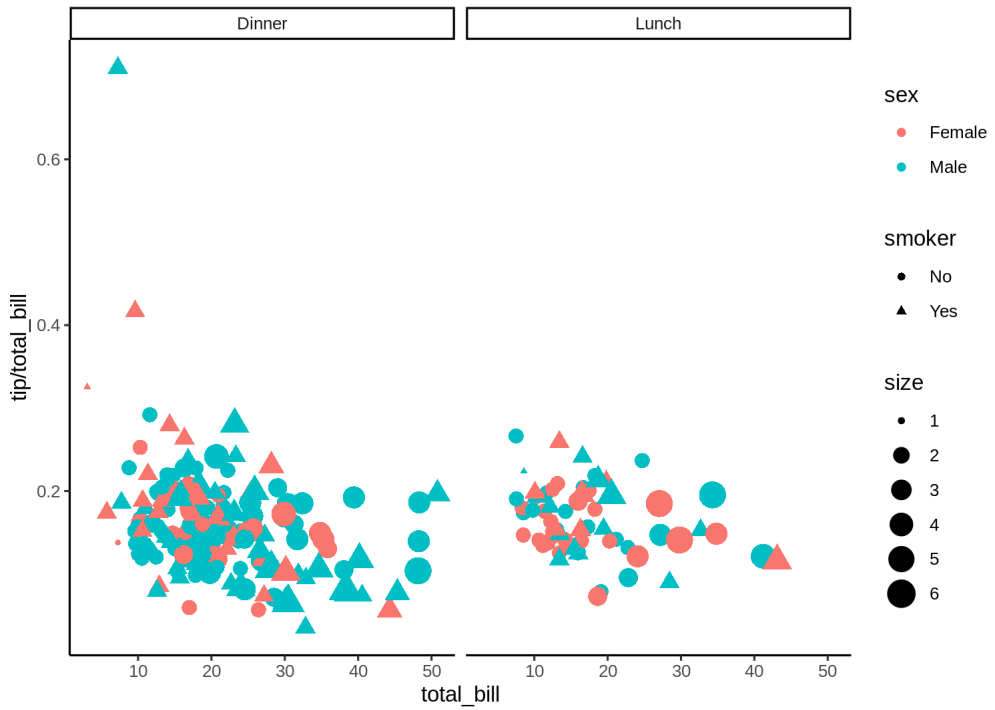
```
theme_set(theme_classic())
tips.gg <- ggplot(tips) +
  geom_point(mapping = aes(x = total_bill, y = tip/total_bill,
                           shape = smoker, colour = sex, size = size))
tips.gg
```



Challenge #3: step-by-step solution

`facet_grid()`

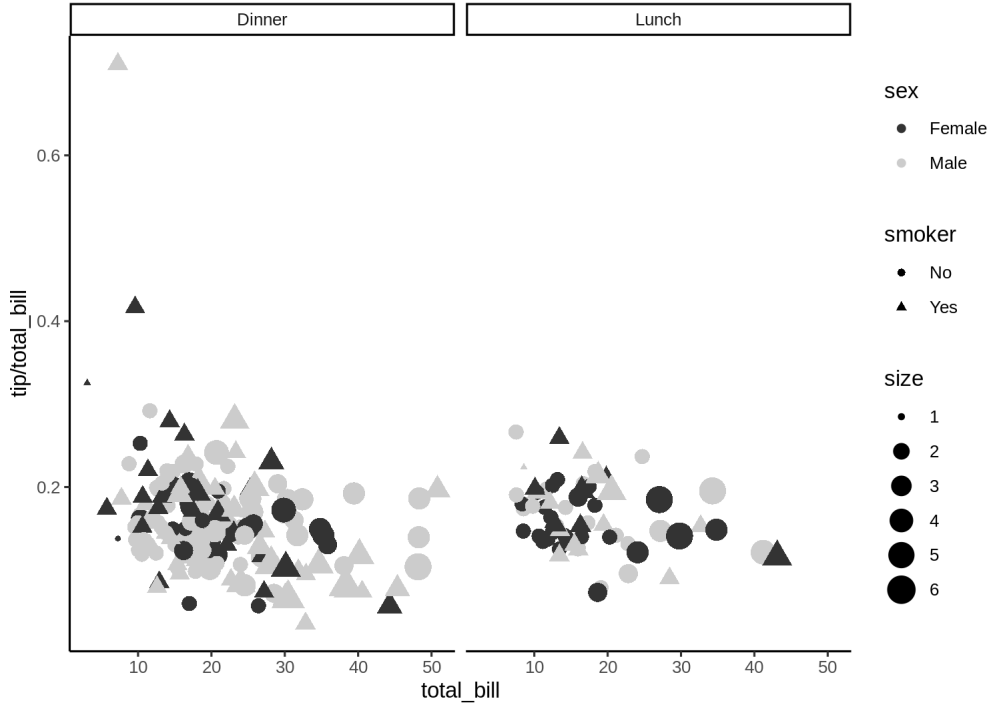
```
tips.gg <- tips.gg +
  facet_grid( ~ time)
tips.gg
```



Challenge #3: step-by-step solution

Grey-scale palette

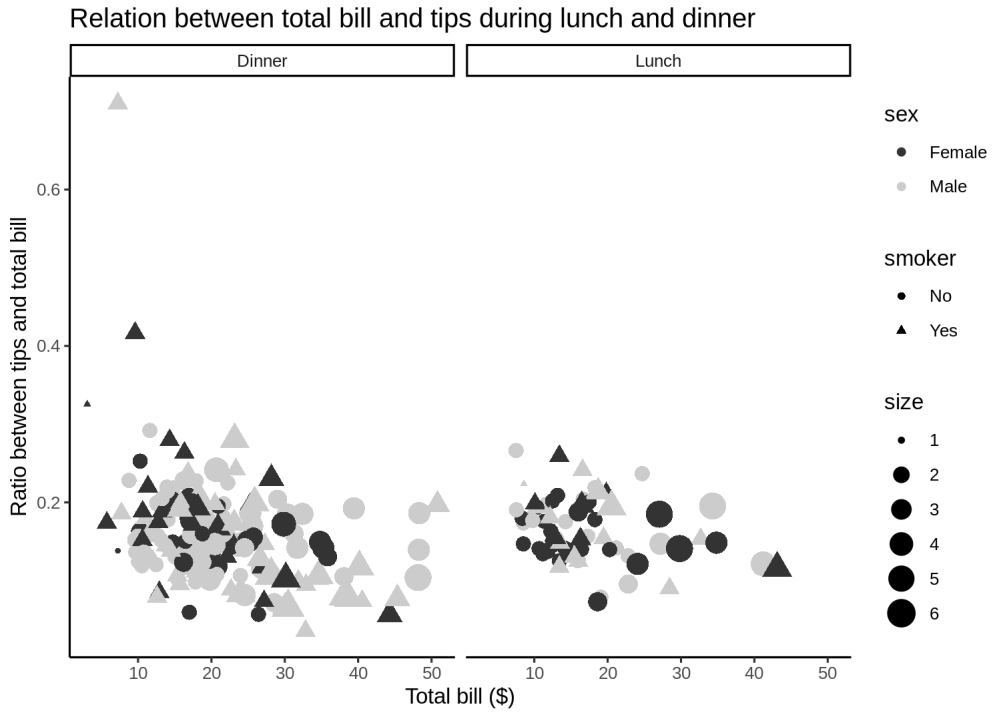
```
tips.gg <- tips.gg +
  scale_colour_grey()
tips.gg
```



Challenge #3: step-by-step solution

Adding plot title and labels

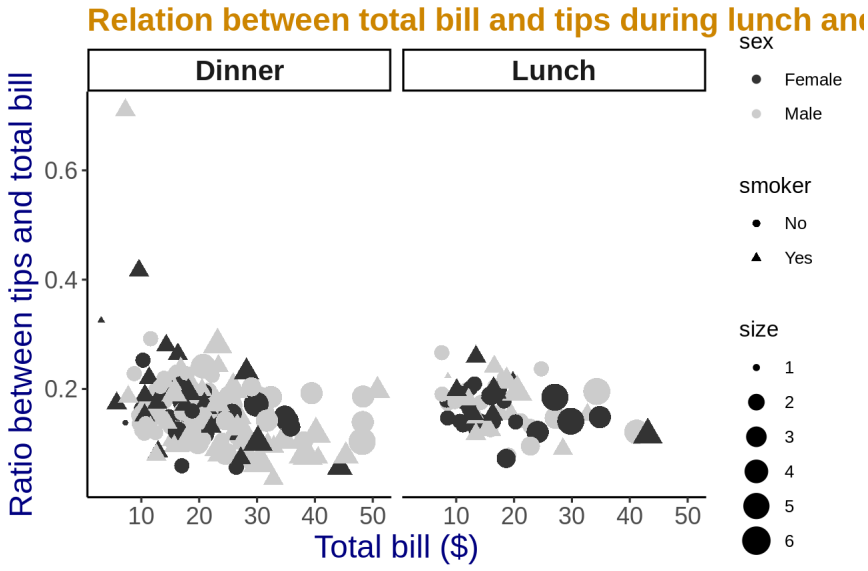
```
tips.gg <- tips.gg +
  labs(title = "Relation between total bill and tips during lunch and dinner",
       x = "Total bill ($)", y = "Ratio between tips and total bill")
tips.gg
```



Challenge #3: step-by-step solution

Adding a theme and fine tuning it

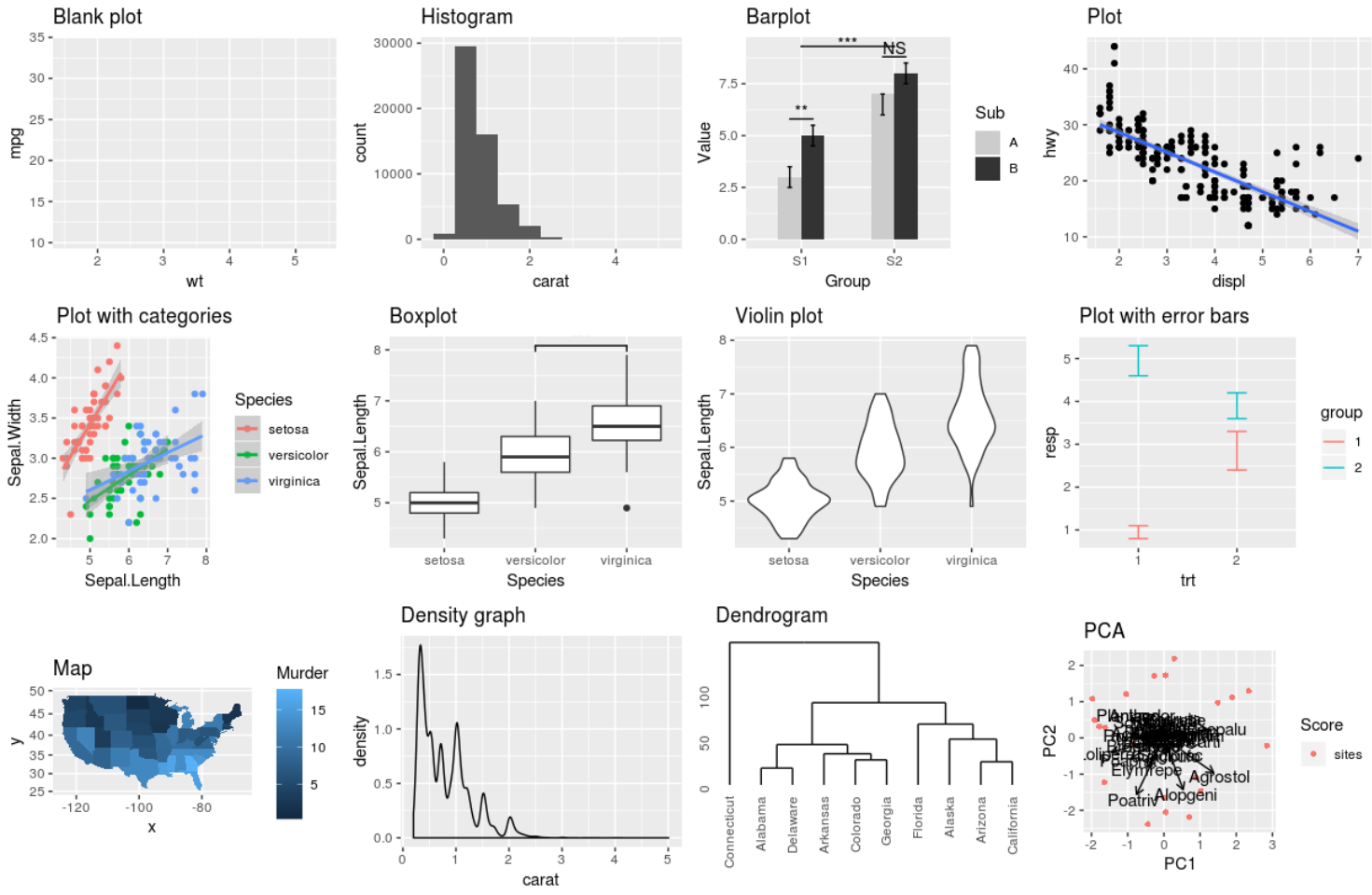
```
tips.gg <- tips.gg +
  theme_classic() +
  theme(axis.title = element_text(size = 16, colour = "navy"),
        axis.text = element_text(size = 12),
        plot.title = element_text(size = 16, colour = "orange3", face = "bold"),
        strip.text.x = element_text(size = 14, face = "bold"))
tips.gg
```



Fine-tuning your plots

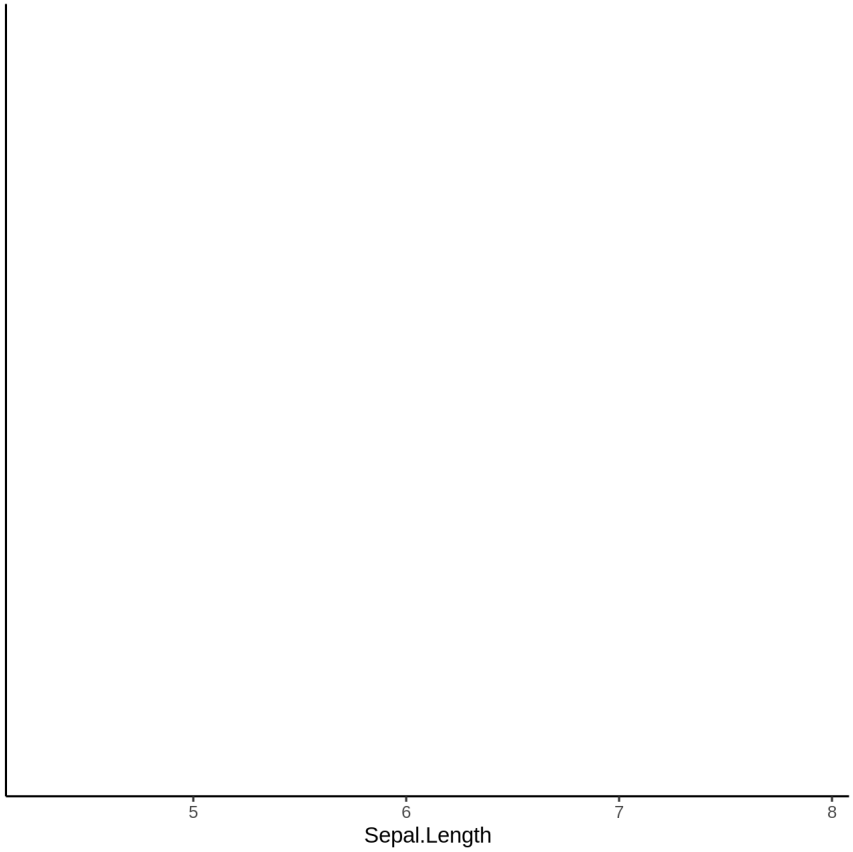
Using `geom_*()` to create different plots

ggplot2::geom_*()



ggplot2::ggplot()

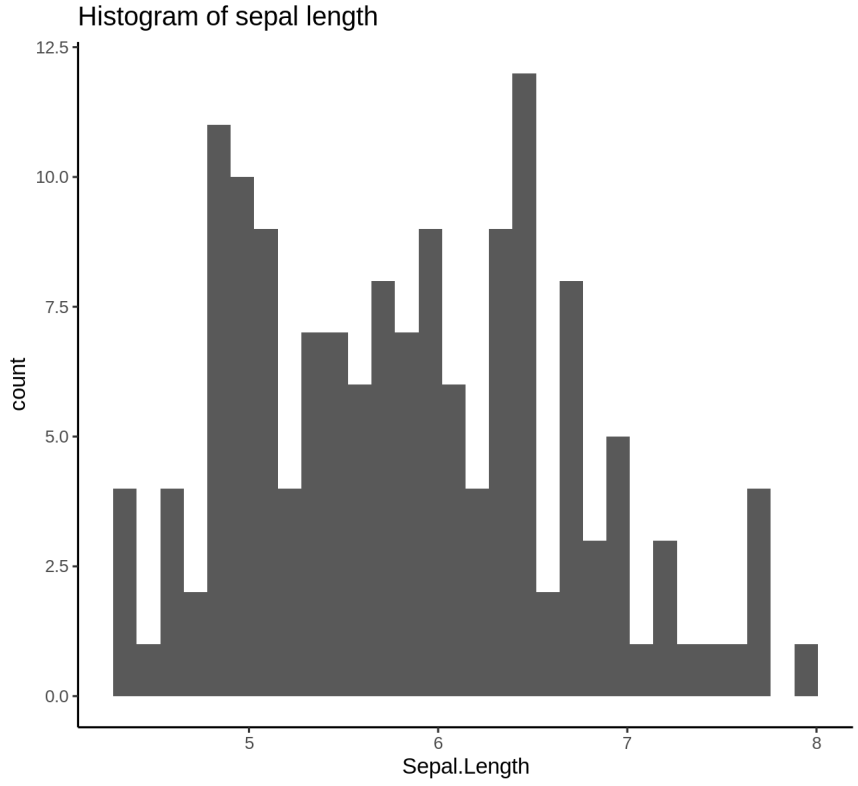
```
ggplot(iris, aes(Sepal.Length))
```



Histograms: `geom_histogram()`

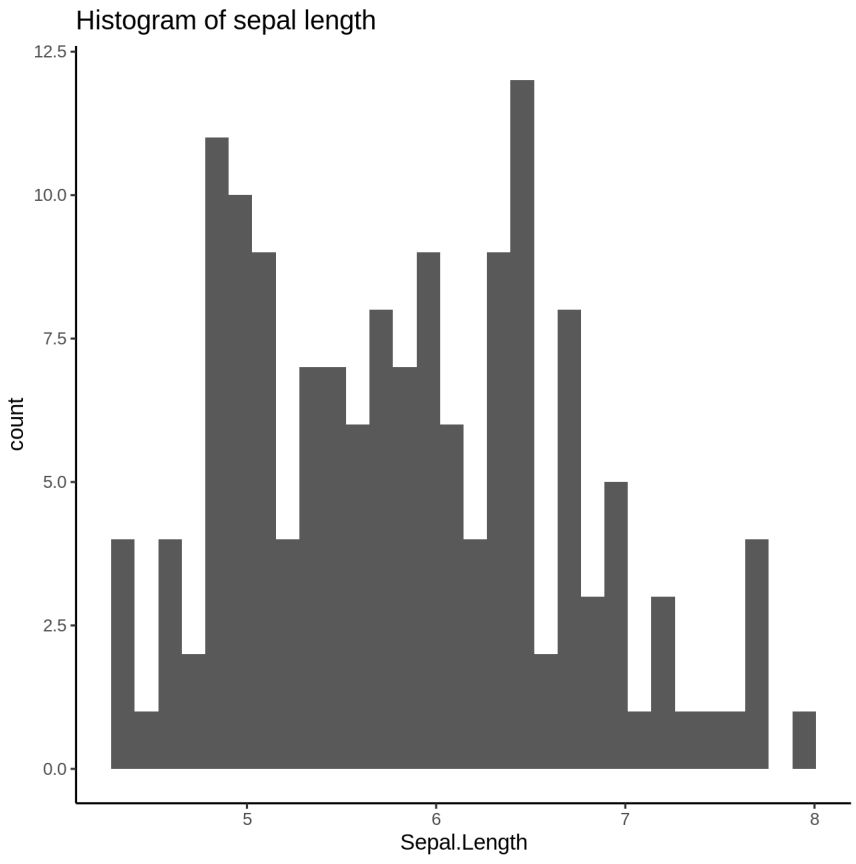
A **histogram** is an accurate graphical representation of the distribution of numeric data - only one aesthetic required

```
ggplot(iris, aes(Sepal.Length)) +
  geom_histogram() +
  ggtitle("Histogram of sepal length ")
```



`geom_histogram()` *versus* `graphics::hist()`

```
ggplot(iris, aes(Sepal.Length)) +
  geom_histogram() +
  ggtitle("Histogram of sepal length")
```




```
hist(iris$Sepal.Length,
     main = "Histogram of sepal length"
```

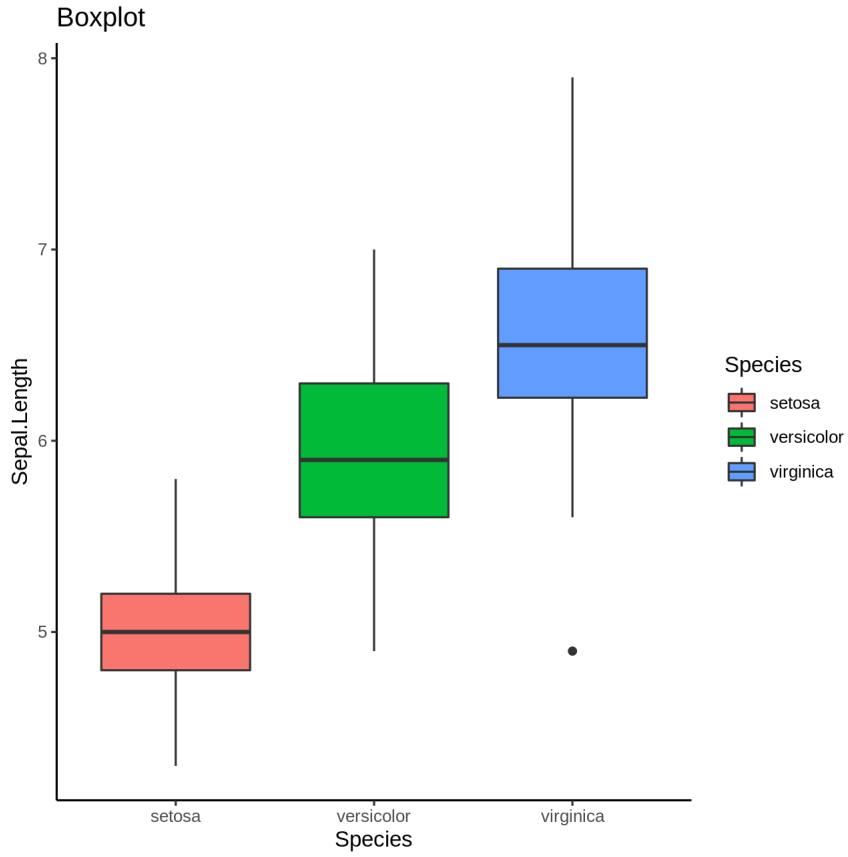
Scatterplot and linear-fit: `geom_point()` and `geom_smooth()`

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point() +
  labs(title = "Scatterplot")
```

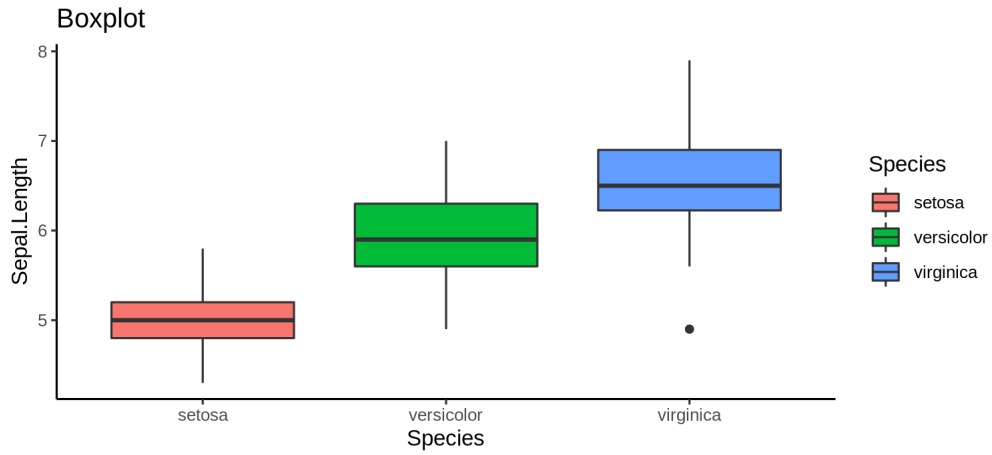
```
ggplot(mpg, aes(displ, hwy)) +
  geom_point() +
  labs(title = "Linear Regression") +
  geom_smooth(method = lm)
```

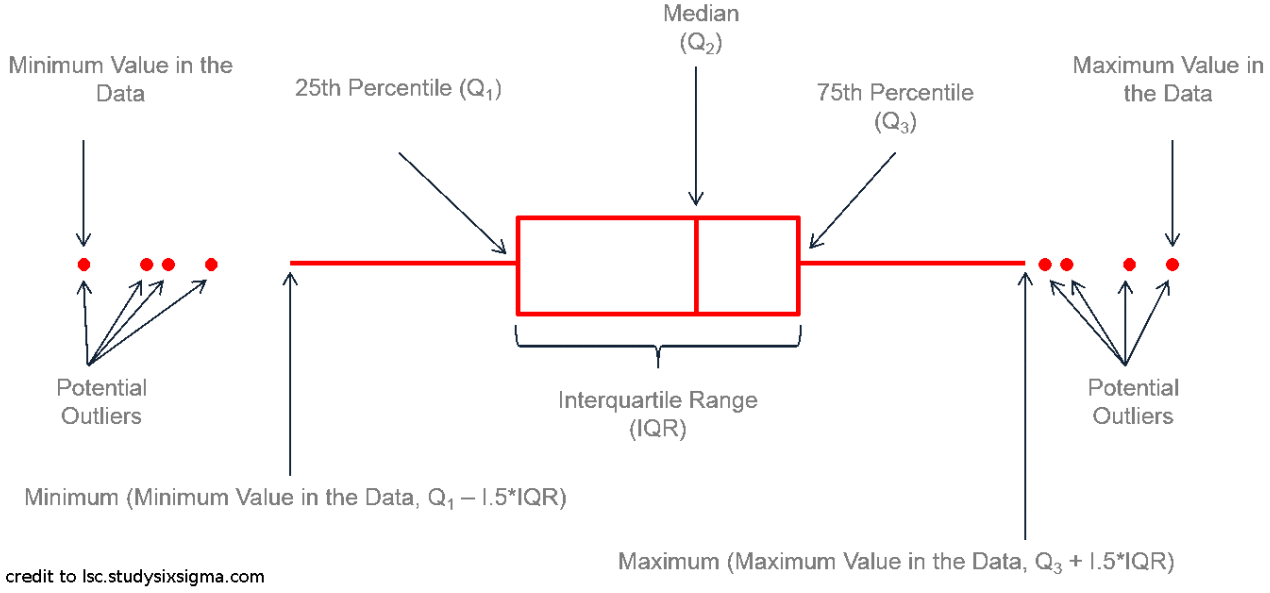
Boxplot: `geom_boxplot()`

```
ggplot(data = iris, aes(Species, Sepal.Length,
                        fill = Species)) +
  geom_boxplot() +
  labs(title = "Boxplot")
```



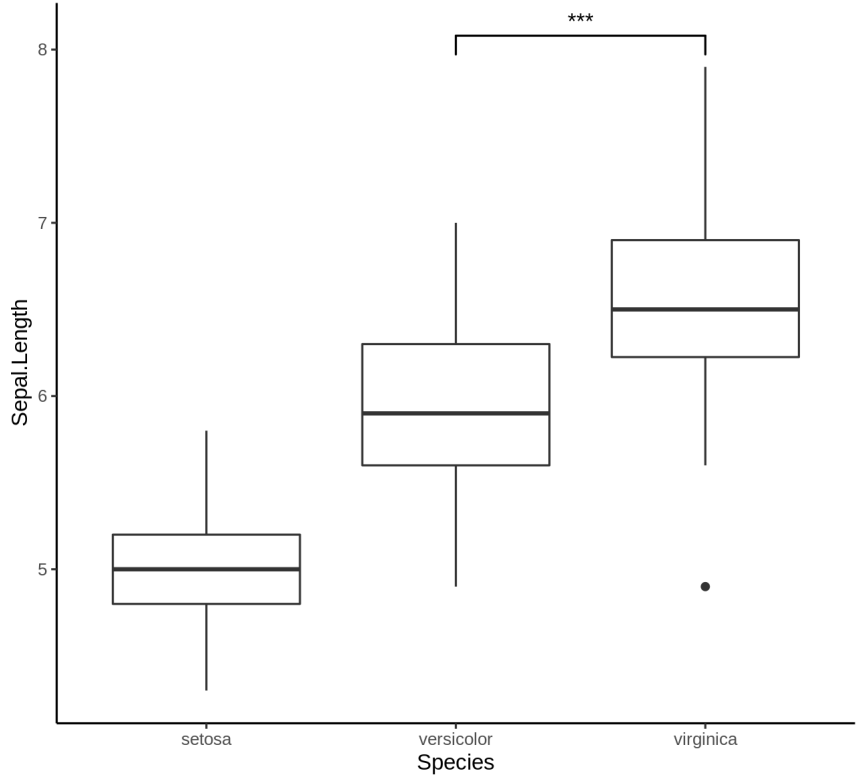
Boxplot: `geom_boxplot()`





Boxplot with annotations: `geom_boxplot()` and `geom_signif()`

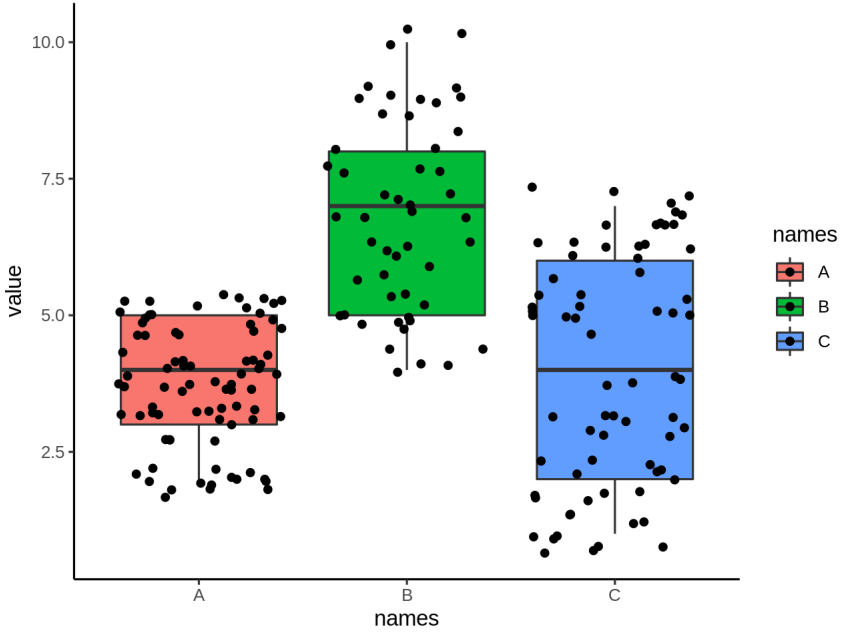
```
library(ggsignif)
ggplot(data = iris, aes(Species, Sepal.Length)) +
  geom_boxplot() +
  geom_signif(comparisons = list(c("versicolor", "virginica")),
              map_signif_level=TRUE)
```

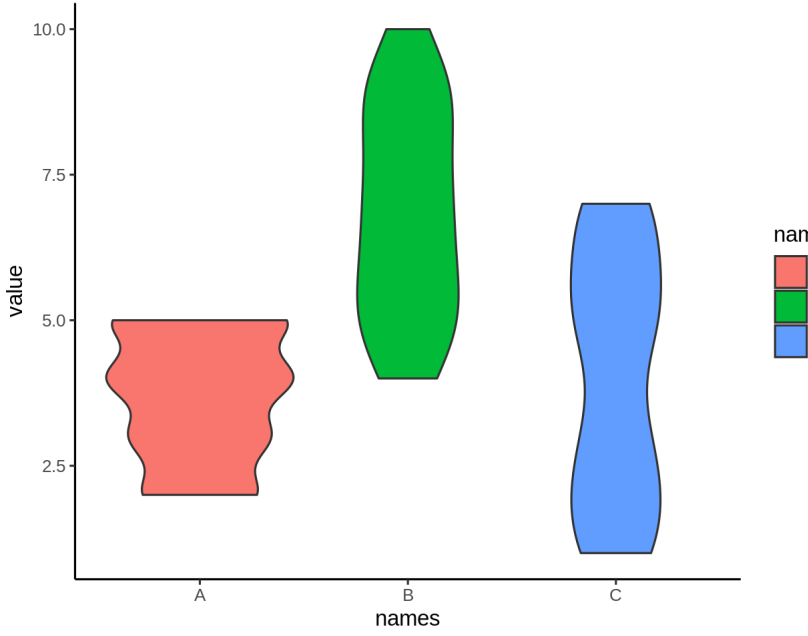


Violin plot: `geom_violin()`

As explained on https://www.data-to-viz.com/graph/violin.html

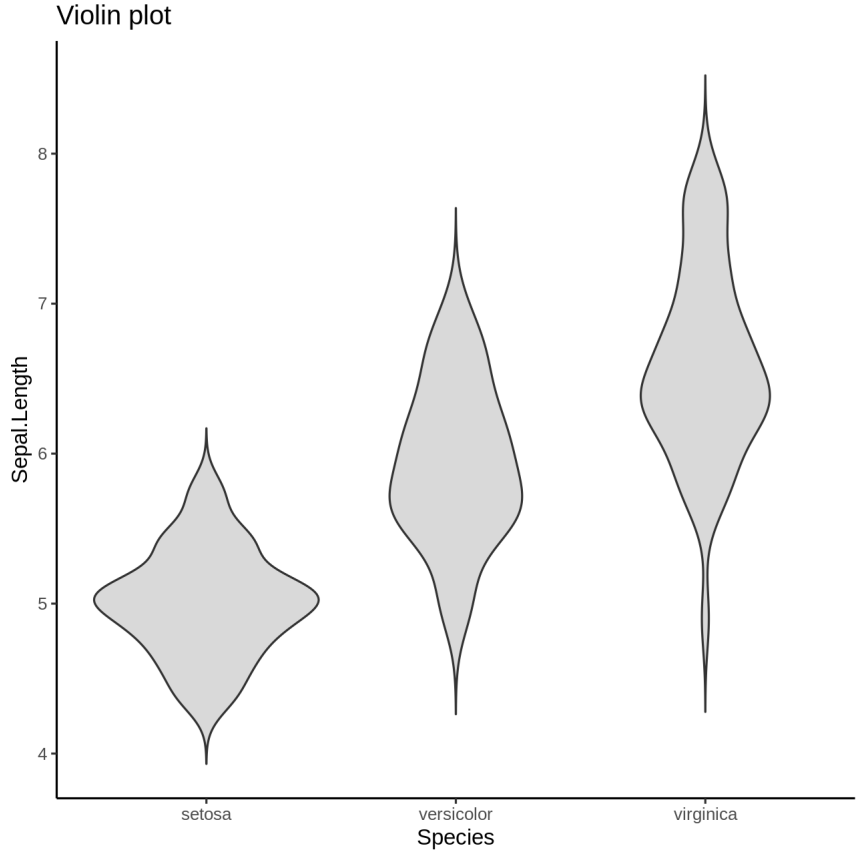
> Violin plot allows to visualize the distribution of a numeric variable for one or several groups. [...] It is really close to a boxplot, but allows a deeper understanding of the distribution.





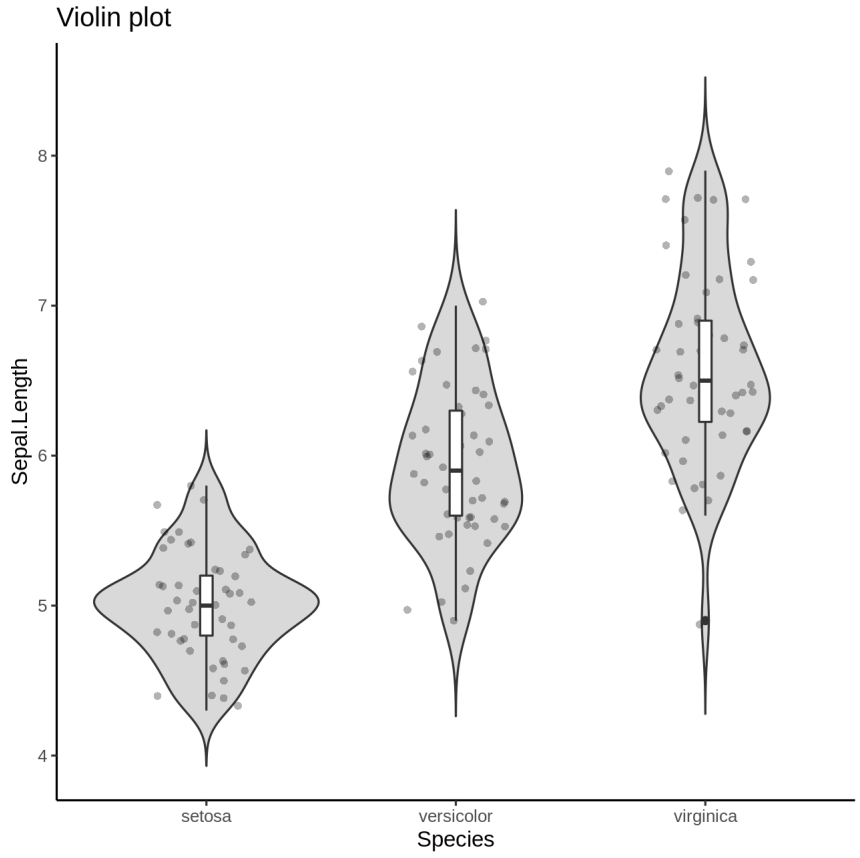
Violin plot: `geom_violin()`

```
violin <- ggplot(data = iris, aes(x=Species, y=Sepal.Length)) +
  geom_violin(trim=F,fill="grey70",alpha=.5) +
  labs(title = "Violin plot")
violin
```



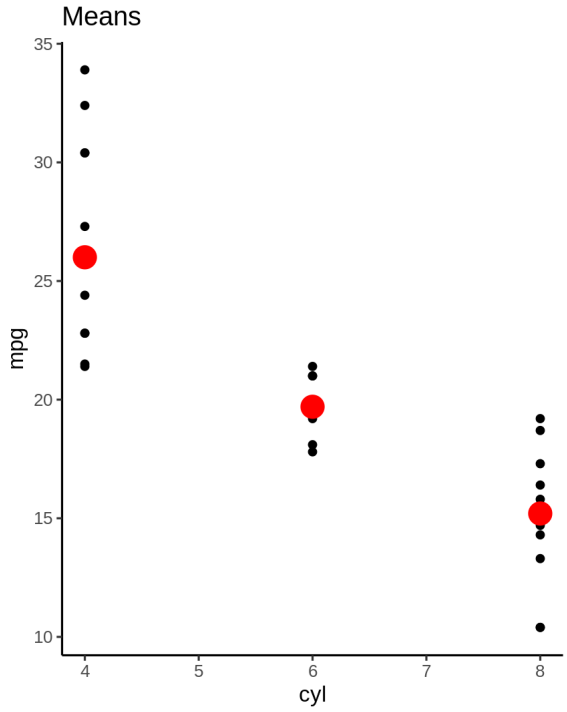
Violin plot: `geom_violin()` + `_boxplot()` + `_jitter()`

```
violin +
    geom_jitter(shape=16, position=position_jitter(0.2),
                alpha=.3)+
  geom_boxplot(width=.05)
```

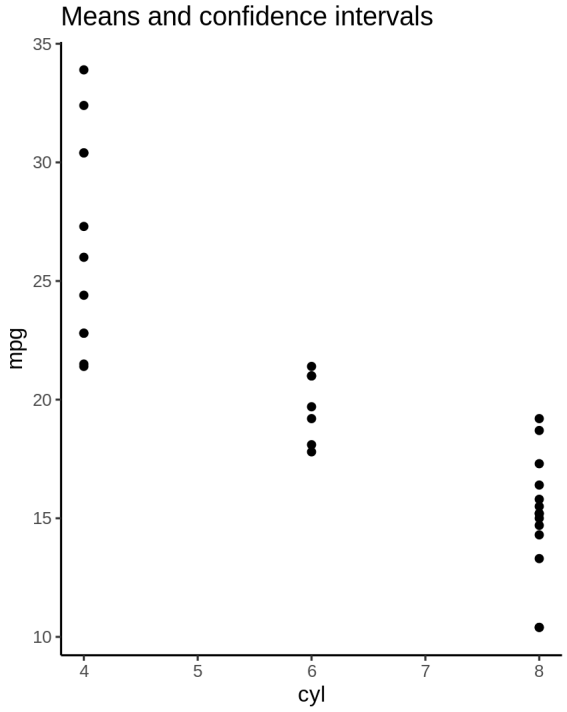


Summarise y values: `stat_summary()`

```
ggplot(mtcars, aes(cyl, mpg)) +
  geom_point() +
  stat_summary(fun.y = "median", geom =
               colour = "red",size=5) +
  labs(title = "Means")
```




```
ggplot(mtcars, aes(cyl, mpg)) +
  geom_point() +
  stat_summary(fun.data = "mean_cl_boot
               colour = "red",size=2) +
  labs(title = "Means and confidence in
```



Summarise values

See also `geom_errorbar()`, `geom_pointrange()`, `geom_linerange()`, `geom_crossbar()` for geoms to display summarised data.

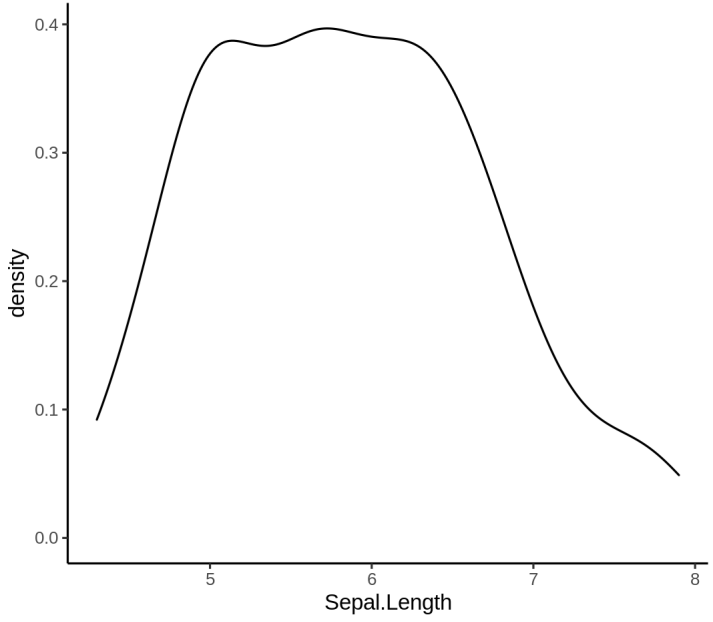
Representing maps: `geom_map()`

```
crimes <- data.frame(state = tolower(rownames(USArrests)), USArrests)
crimesm <- reshape2::melt(crimes, id = 1)

library(maps)
states_map <- map_data("state")

ggplot(crimes, aes(map_id = state)) +
  geom_map(aes(fill = Murder), map = states_map) +
  expand_limits(x = states_map$long, y = states_map$lat) +
  coord_map()
```

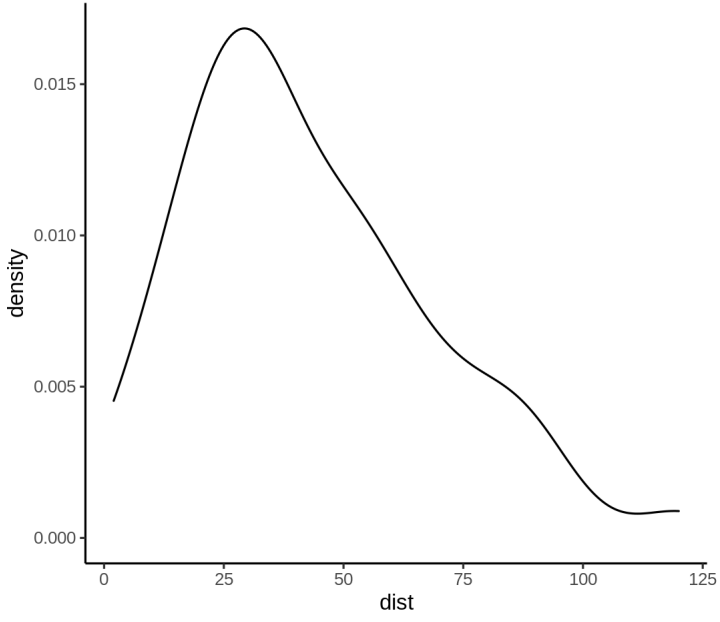
Density plots: `geom_density()`

A density plot shows the distribution of a numerical variable and it takes only set of numeric values as input.

```
iris.dens <- ggplot(iris, aes(Sepal.Le
  geom_density()
iris.dens
```

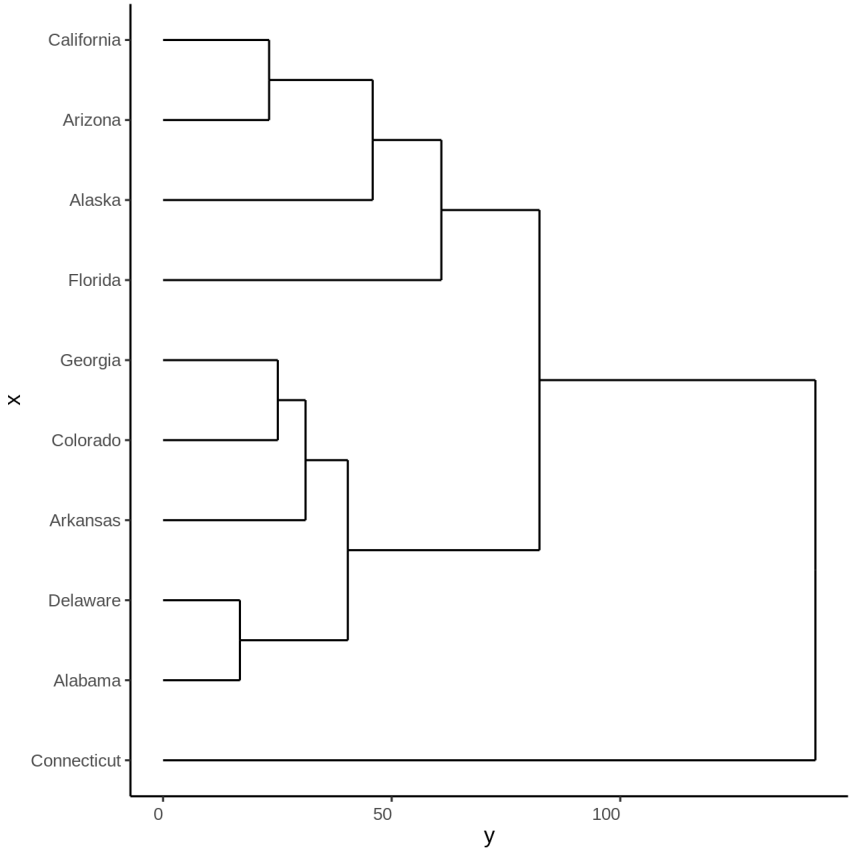



```
cars.dens <- ggplot(cars, aes(dist)) +
  geom_density()
cars.dens
```



Dendogram: `ggdendrogram()`

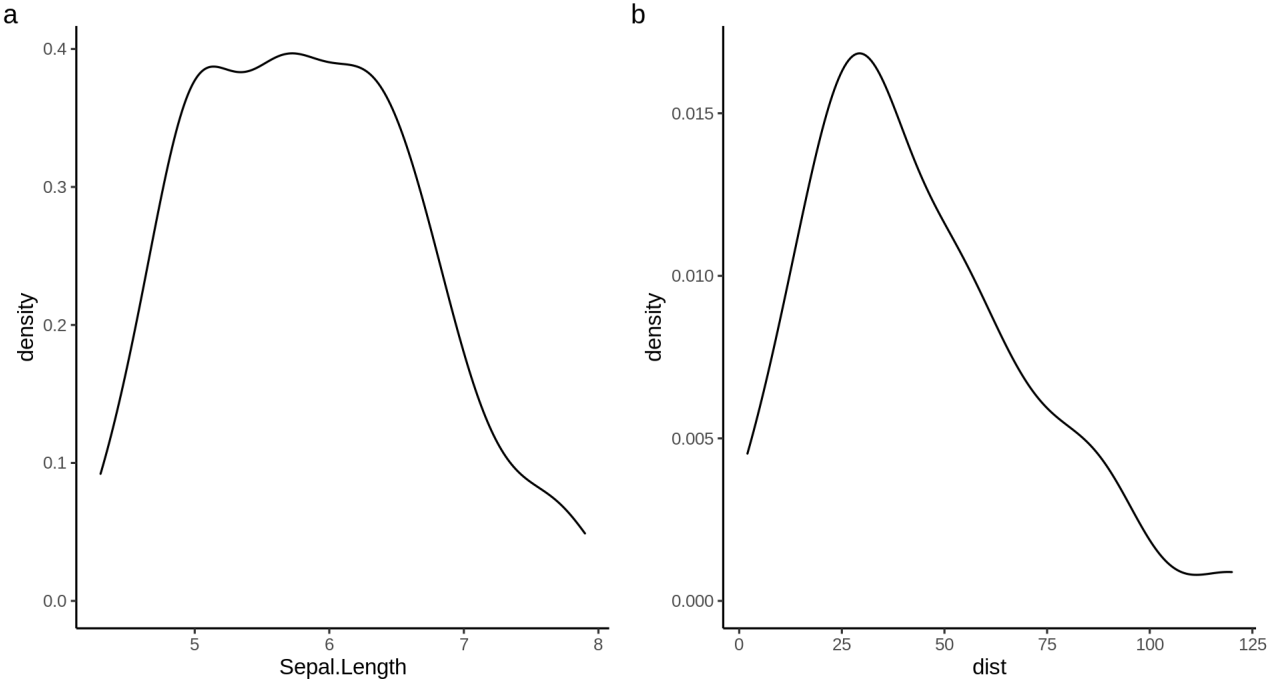
```
library(ggdendro)
USArrests.short = USArrests[1:10,]
hc <- hclust(dist(USArrests.short), "ave")

ggdendrogram(hc, rotate = TRUE, theme_dendro = FALSE)
```



Arrange plots: `patchwork`

Add multiple graphs on the same plot

```
install.packages("patchwork")
library(patchwork)
iris.dens + cars.dens +
  plot_annotation(tag_levels = 'a')
```



Final Challenge

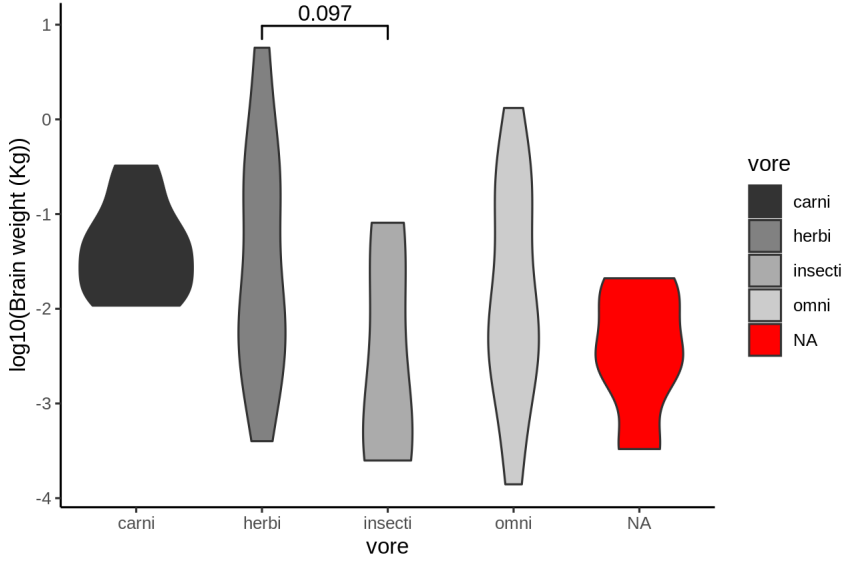
Create your own graph and follow these recommendations:

- Dataset: any (recommended: use your dataset)
- Explore a new geom_* and other plot elements

Use the following links for tips:
https://ggplot2.tidyverse.org/reference/index.html
http://shinyapps.stat.ubc.ca/r-graph-catalog/

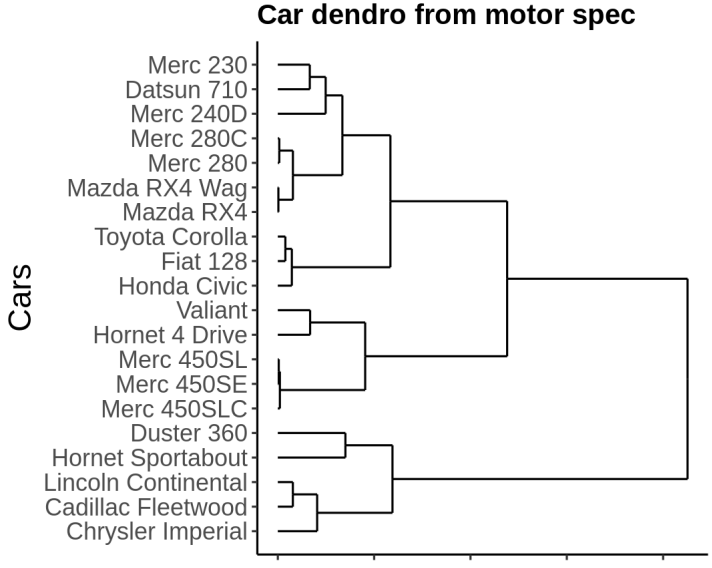
Final Challenge: Solution example #1

```
data(msleep)
msleep.challenge4 <- ggplot(msleep, aes(vore, log10(brainwt), fill=vore))
msleep.challenge4 + geom_violin() +
  geom_signif(comparisons = list(c("herbi", "insecti"))) +
  labs(main = "Brain weight among different vore", y = "log10(Brain weight (Kg))") +
  scale_fill_grey() +
  theme_classic()
```



Final Challenge: Solution example #2

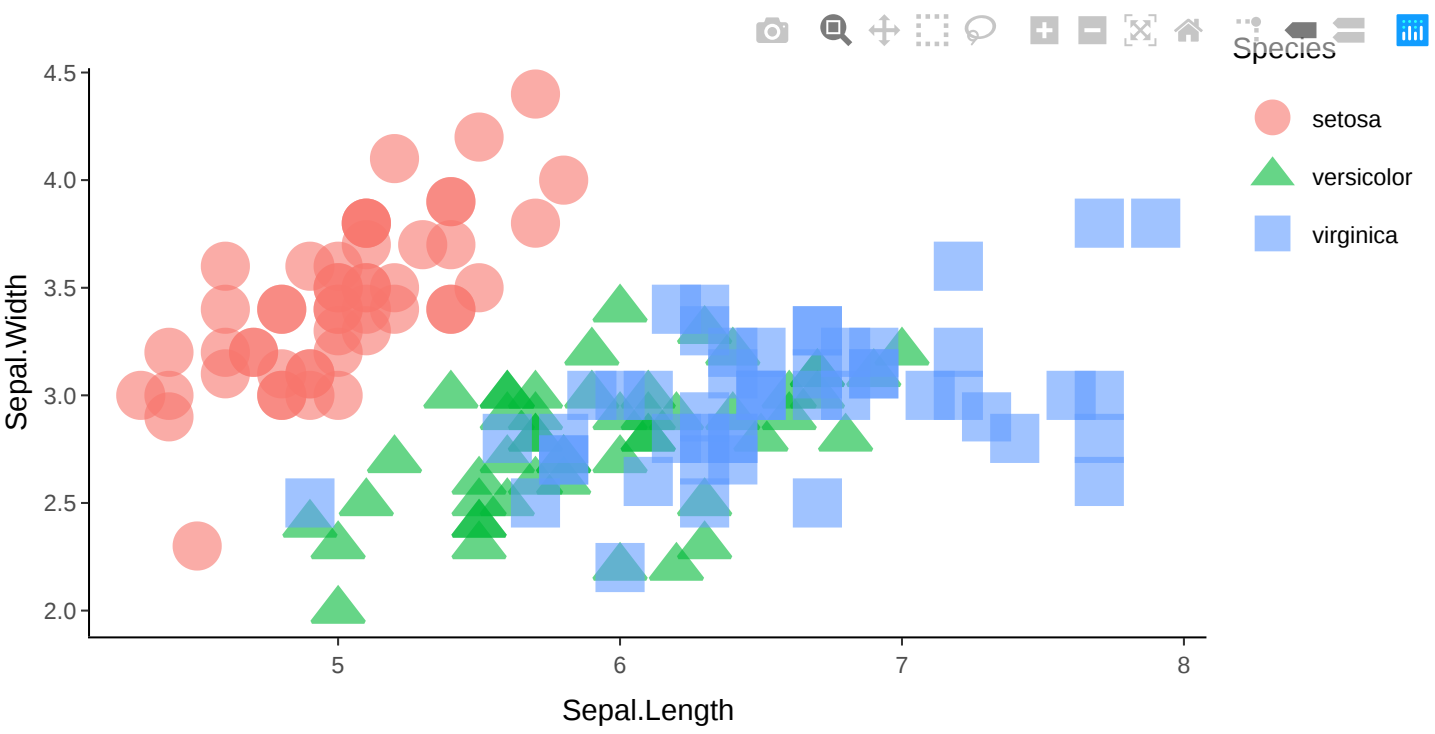
```
data(mtcars)
mtcars.short <- mtcars[1:20,]
mtcars.short.hc <- hclust(dist(mtcars.short), "complete")
dendro.challenge4 <- ggdendrogram(mtcars.short.hc, rotate = TRUE, theme_dendro = FAL
dendro.challenge4 + ggtitle("Car dendro from motor spec") +
  xlab("Cars") +
  theme(axis.title.y = element_text(size = 16),
        axis.title.x = element_blank(),
        axis.text.x = element_blank(),
        axis.text.y = element_text(size = 12),
        plot.title = element_text(size = 14, face="bold"))
```



Miscellaneous: interactive plots using `plotly()`

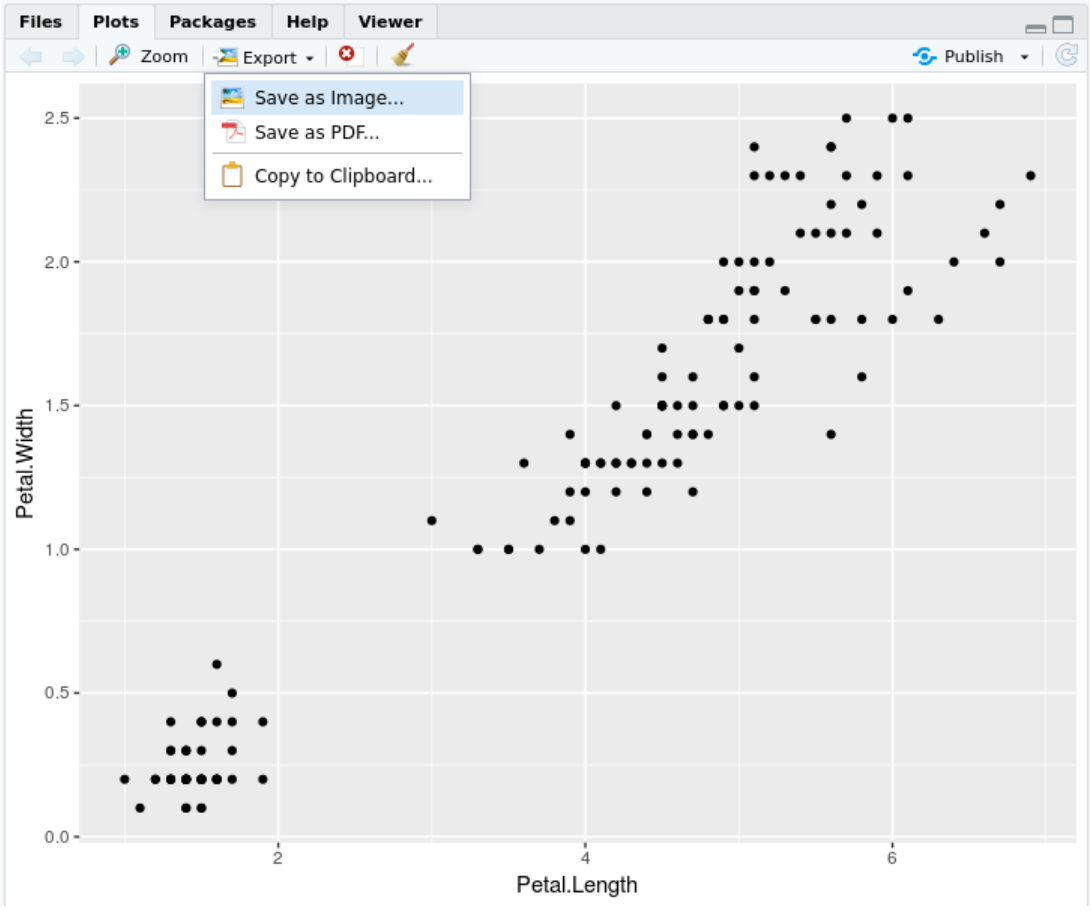
Select the species data to display directly from the legend

```
p = ggplot(iris,
           aes(x=Sepal.Length, y=Sepal.Width, colour=Species, shape=Species)) +
    geom_point(size=6, alpha=0.6)

plotly::ggplotly(p)
```



Saving your plots with ggplot2

Saving plots in RStudio



Think about the margin of the document you are using. If you resize the image after saving it, the labels and text will change size as well which could be hard to read.

Saving plots in code

`ggsave()` writes directly to your working directory and allows you to specify the name of the file, the dimensions of the plot, the resolution, etc.

```
my1rstPlot <- ggplot(iris, aes(Petal.Length, Petal.Width)) +
  geom_point()

ggsave("my1stPlot.pdf",
       my1rstPlot,
       height = 8.5, width = 11, units = "in", res = 300)
```

NB: Vectors (e.g., pdf, svg) format are more flexible than raster format (jpeg, png, ...) if the image needs modification afterwards.

Saving plots in code

Other methods to save image: see `?pdf` `?jpeg`

```
pdf("./graph_du_jour.pdf")
  print(my1rstPlot) # print function is necessary
graphics.off()
```

Saving plots in code

Tip: `quartz()` (mac) or `window()` (pc) functions make sizing easier before `ggsave()`!

Thank you for attending!