STAT3622 Data Visualization (Lecture 2)

R Graphics with ggplot2

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What's covered in this lecture?

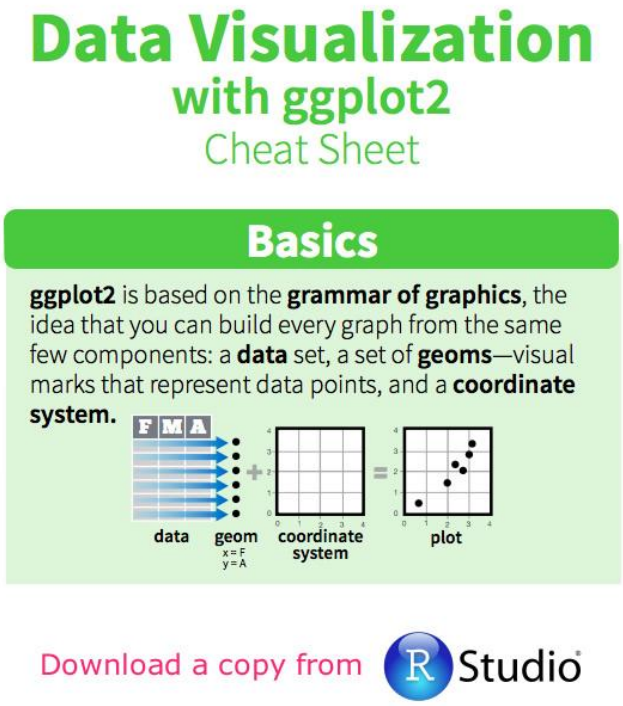
I. Grammar of Graphics

- Hadley Wickham and R:ggplot2
- Layer-by-Layer Graphics

II. Quick plots with qplot()

III. Layer-by-layer ggplot()

IV. Options and themes



I. Grammar of Graphics

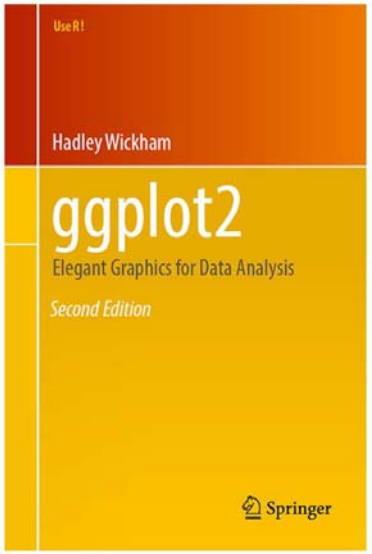
Hadley Wickham and R:ggplot2

- Chief scientist at RStudio, Creator of popular R packages: ggplot2, dplyr, tidyr, devtools, etc; “The man who r evolutionized R” according to Pricenomics (2015)
- R graphics: base -> lattice -> ggplot2

> "ggplot2, started in 2005, is an attempt to take the good things about base and lattice graphics and improve on them with a strong underlying model" (Hadley Wickham)

- R:ggplot2 is one of most commonly downloaded R packages
- Based on Grammar of Graphics by Wilkinson (2005; Springer 2ed)

http://hadley.nz/

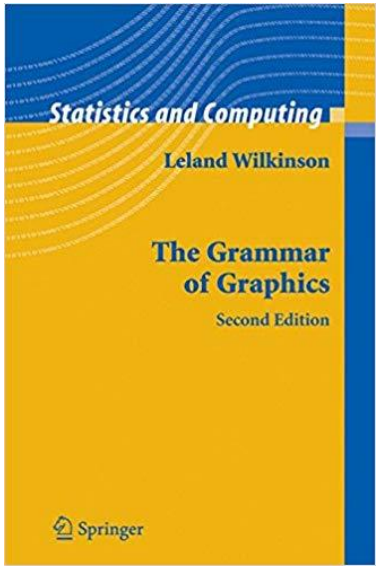


Springer (2016; 2ed)

Grammar of Graphics (GG)

Quote from the ggplot2 book that further quotes Wilkinson (2005):

> In brief, the grammar tells us that a statistical graphic is a mapping from data to aesthetic attributes (colour, shape, size) of geometric objects (points, lines, bars). The plot may also contain statistical transformations of the data and is drawn on a specific coordinate system. Facetting can be used to generate the same plot for different subsets of the dataset. It is the combination of these independent components that make up a graphic.



Keywords: mapping, aesthetic attributes, geometric objects, statistical transformations, coordinate system, facetting

R:ggplot2 package

ggplot2: An Implementation of the Grammar of Graphics

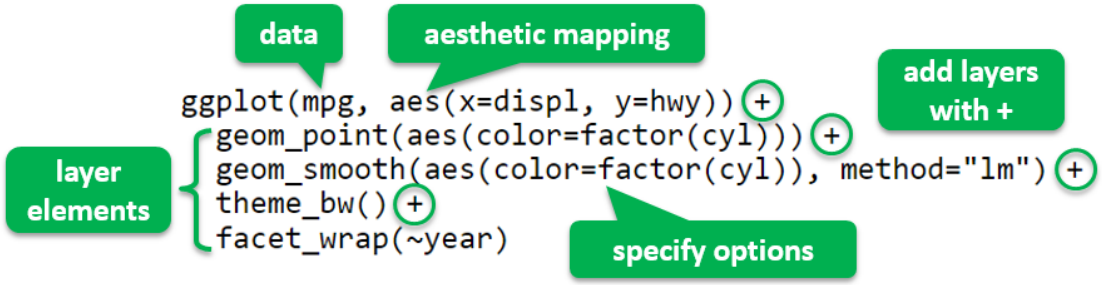
An implementation of the grammar of graphics in R. It combines the advantages of both base and lattice graphics: conditioning and shared axes are handled automatically, and you can still build up a plot step by step from multiple data sources. It also implements a sophisticated multidimensional conditioning system and a consistent interface to map data to aesthetic attributes. See http://ggplot2.org for more information, documentation and examples.

Version:	2.1.0
Depends:	R (≥ 3.1)

Source: https://cran.r-project.org/

- The most popular package for producing static visualizations in R; New upgrade to Version 3.2.1; See CRAN for updated information
- Online documentation at https://ggplot2.tidyverse.org/
- Download the useful cheatsheet created by Rstudio, Inc.
- Also available in Python: http://ggplot.yhathq.com/

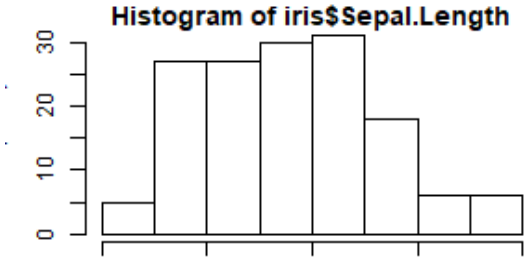
Layer-by-Layer Graphics



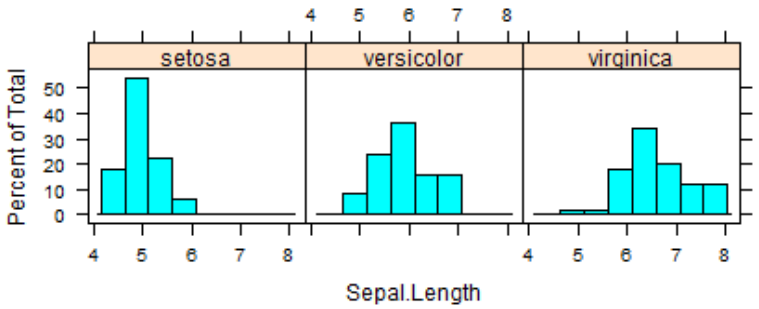
- **Aesthetics**: mapping data variables to aesthetic attributes (position, size, shape, color, ...)
- **Geometric objects**: point, line, polygon, histogram, quantile, bar, ...
- **Statistical transformations**: bin, boxplot, density, contour, function, ...
- Other components for ggplots: **scales** (mapping values of the data to visual values for each aesthetic, e.g. position, color, fill and shape scales), **coordinate system** (cartesian, polar, map projection, ..); **facet** (conditioning display split data in multi-panels; theme (control non-data visual elements (title, axes, tick, ...)

Base, Lattice and ggplot2 styles (first impression)

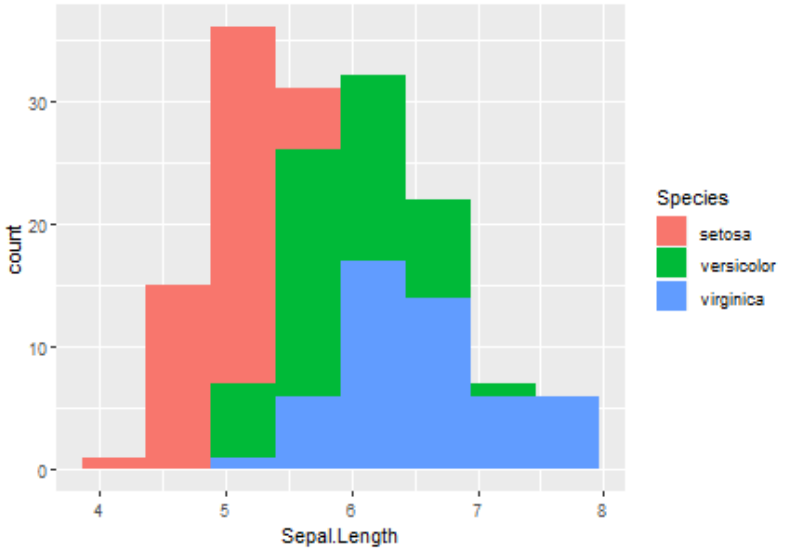
```
par(mar=c(1,3,1,0))
hist(iris$Sepal.Length) # Base graphics
```




```
library(lattice)
histogram(data=iris, ~Sepal.Length|Species)
```




```
library(ggplot2)
ggplot(data=iris,
       aes(x=Sepal.Length, fill=Species)) +
  geom_histogram(bins=8)
```



You Will Learn ...

- R:ggplot2 provides two ways/levels to build graphs:
  - qplot() - quick plot, supplies many defaults
  - ggplot() - grammar of graphics plot, with more controls
- Options and themes for making sophisticated ggplot2 graphs
- Later in this course, ggplot2 will also be used for animated/interactive plots

II. Quick plots with qplot()

Quick Plots with qplot()

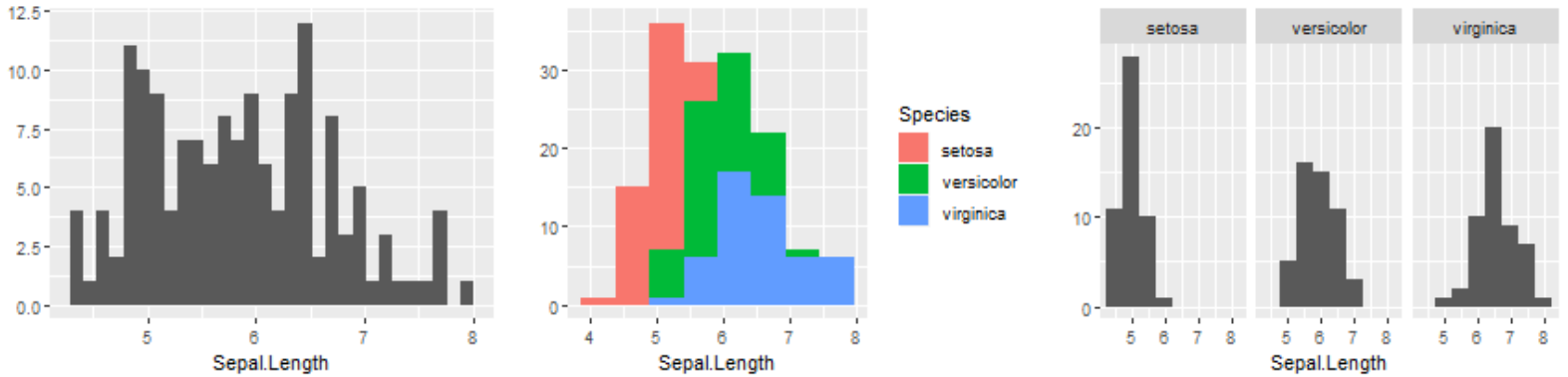
- qplot() is analog to base plot(), where "q" means quick
- qplot() may create a quick plot with minimum typing
- It defines a plot in a single call with the basic syntax:

qplot(dataframe, variables, [geom], options)

- Automatic use of default settings to make life easier.
- A sensible geom will be picked by default if it is not supplied.

Histogram

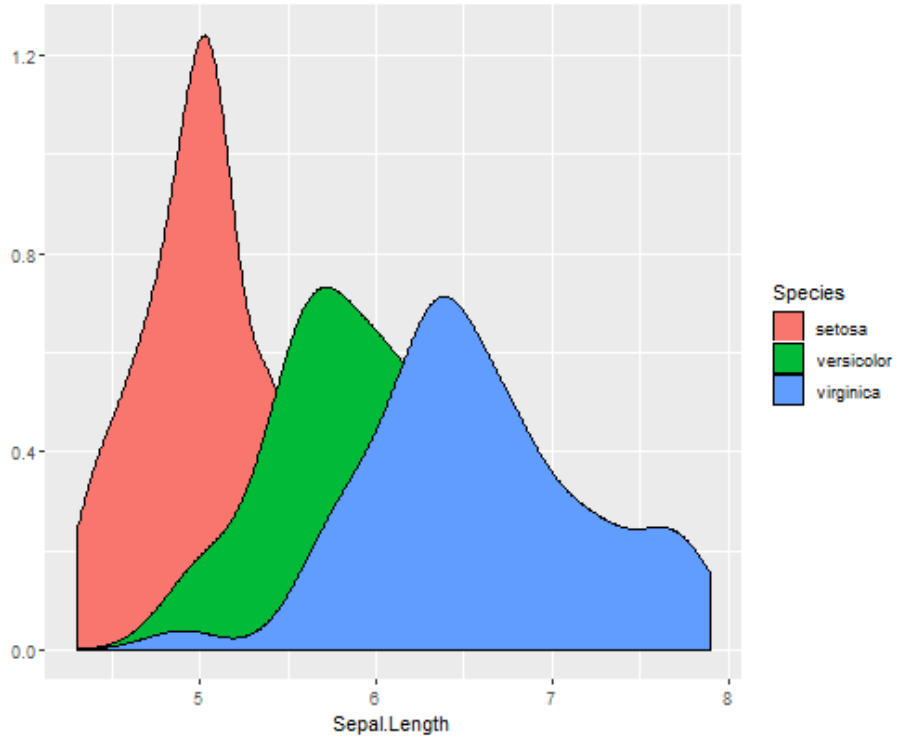
```
p1 = qplot(data = iris, Sepal.Length, geom="histogram")
p2 = qplot(data = iris, Sepal.Length, fill = Species, bins = 8)  # default geom
p3 = qplot(data = iris, Sepal.Length, facets = .~Species, binwidth = 0.5)
grid.arrange(p1,p2,p3, ncol=3)
```



- Histogram is the sensible geom for continuous variables
- Automatic color setting (color/fill are grouping variables in ggplot2)
- Faceting is similar to the conditioning function in Lattice

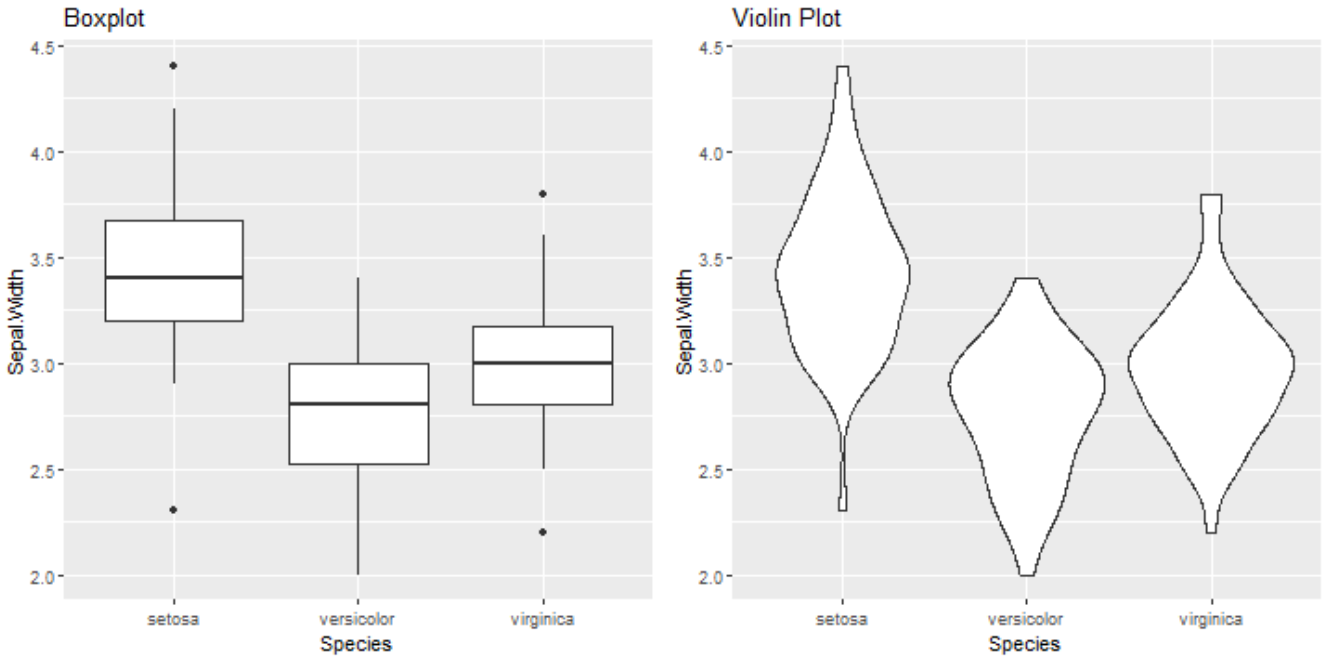
Density plot

```
qplot(data = iris, Sepal.Length, geom = "density",  fill = Species)
```



Boxplot with Grouping

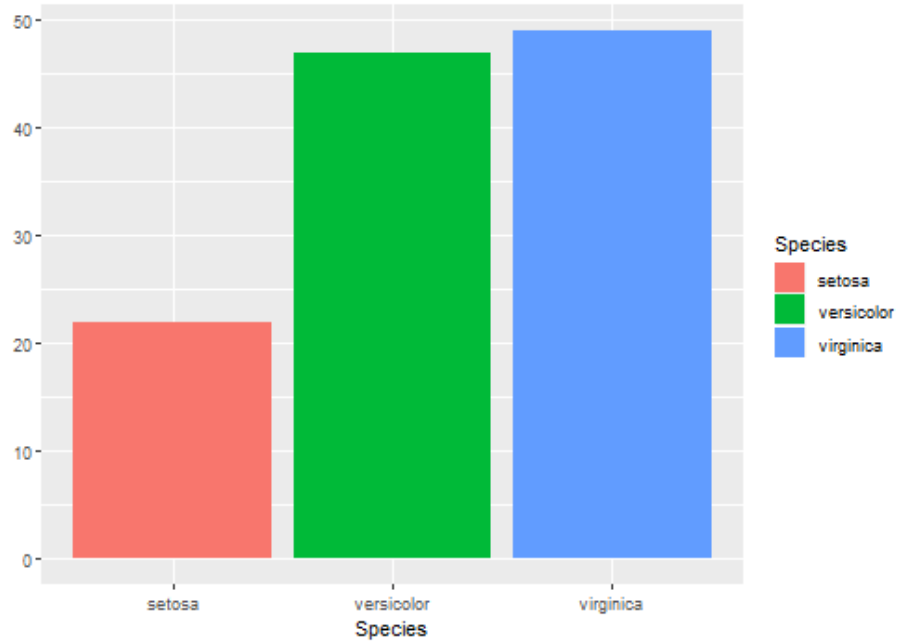
```
p1 = qplot(data = iris, Species, Sepal.Width, geom="boxplot", main="Boxplot")
p2 = qplot(data = iris, Species, Sepal.Width, geom="violin", main="Violin Plot")
grid.arrange(p1,p2,ncol=2)
```



- Following data are x (grouping) and y (response) variables

Bar plot for categoricla variables

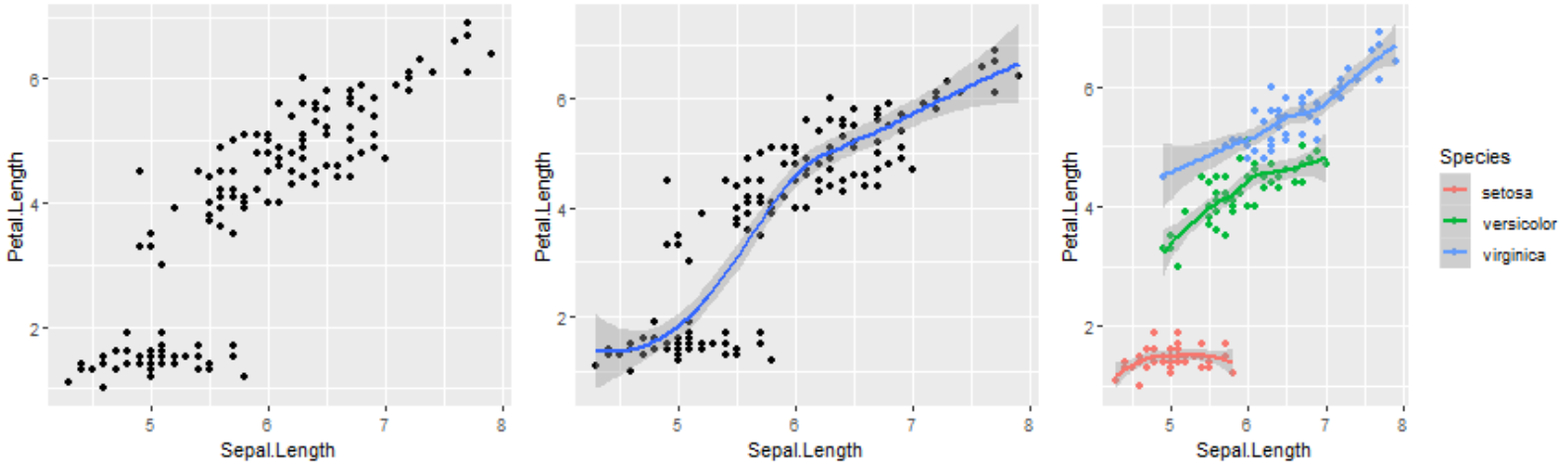
```
qplot(data = subset(iris, Sepal.Length>5), Species, geom="bar",  fill=Species)
```



- Bar is the sensible geom for categorical variables

Scatter plot

```
p1 = qplot(data = iris, Sepal.Length, Petal.Length, geom = "point")
p2 = qplot(data = iris, Sepal.Length, Petal.Length, geom = c("point", "smooth"))
p3 = qplot(data = iris, Sepal.Length, Petal.Length, geom = c("point", "smooth"),
           color = Species)  # Color as a grouping variable
grid.arrange(p1, p2, p3, ncol=3)
```



- Multiple geoms can be added together ...

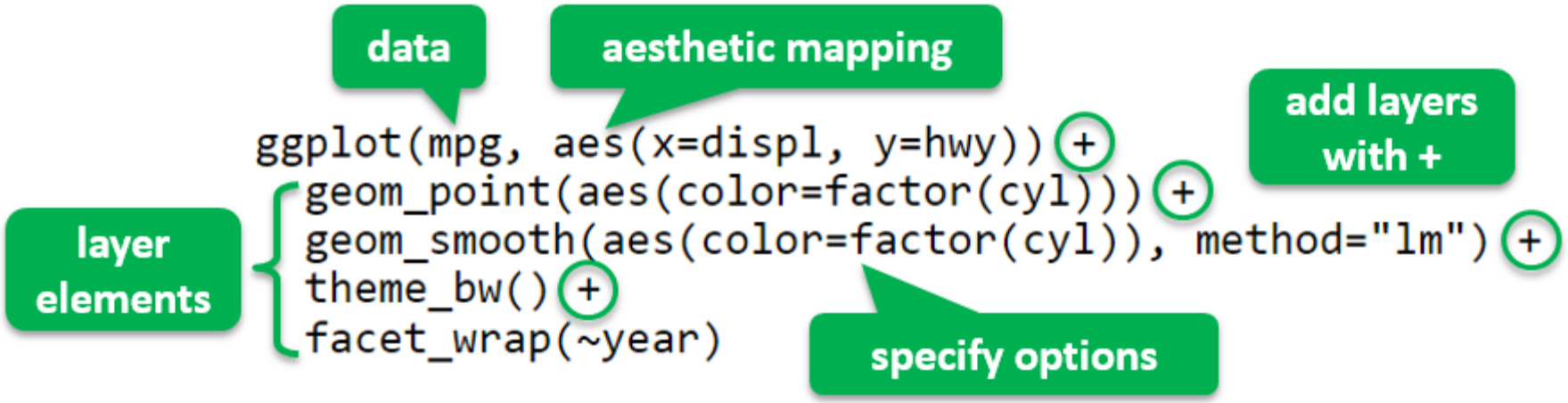
III. Layer-by-layer ggplot()

Key concepts/inputs for a ggplot graph:

- **Data**: a data.frame to visualize
- **Aesthetics**: mapping variables of the data to aesthetic attributes (position, size, shape, color, fill, transparency, ...)
- **Scales**: mapping values of the data to visual values for each aesthetic (e.g. position, color, fill and shape scales)
- **Geometric objects**: point, line, polygon, histogram, quantile, bar, ...
- **Statistical transformations**: bin, boxplot, density, contour, function, ...
- **Coordinate system**: Cartesian, polar, map projection, ...
- **Facet**: display split data in multi-panels (aka conditioning)
- **Theme**: control non-data visual elements (title, axes, tick, ...)

Layer-by-layer Syntax

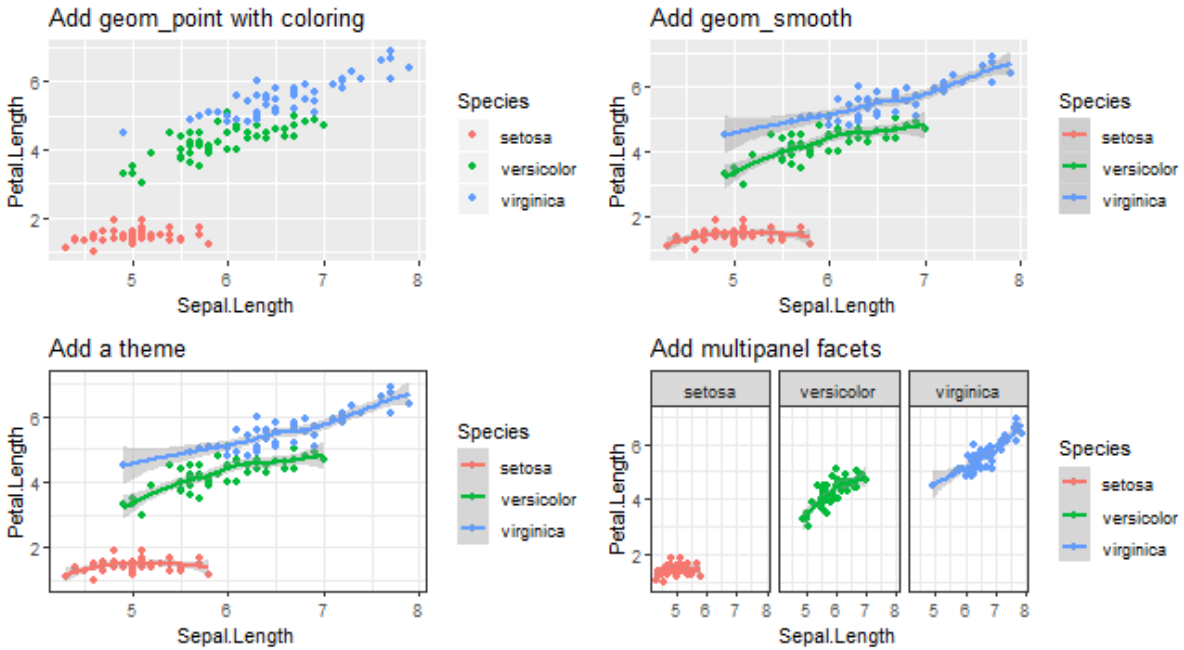
- ggplot() builds a plot layer by layer, with the syntax:



- ggplot() provides more control than qplot()
- ggsave() the last plot() with formats .png, .jpg, .pdf, ...

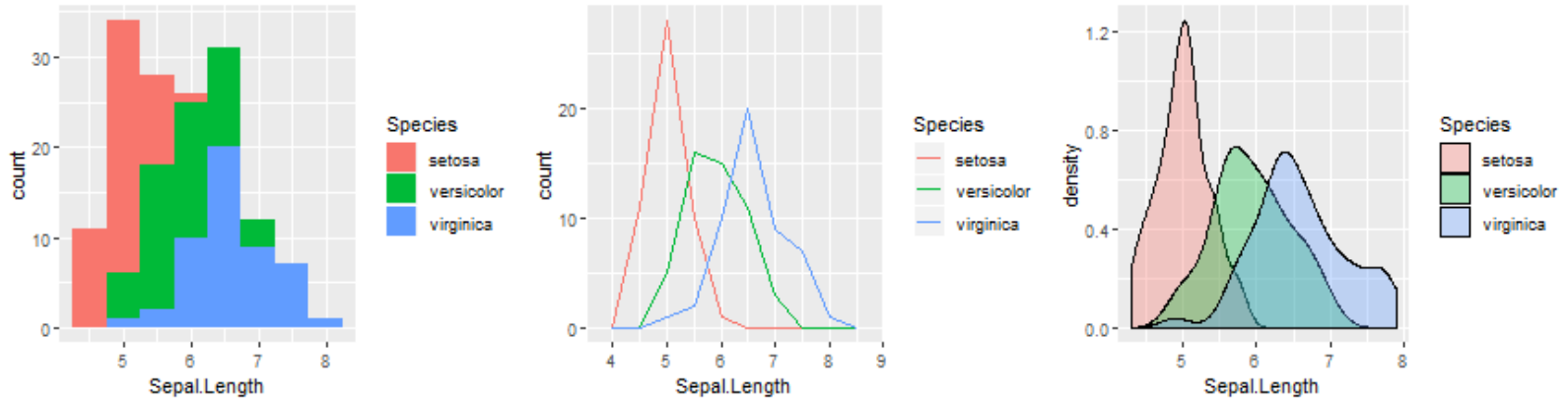
Layer-by-Layer Scatterplot

```
p0 = ggplot(iris, aes(x=Sepal.Length, y=Petal.Length))
p1 = p0 + geom_point(aes(color=Species)) + ggtitle("Add geom_point with coloring")
p2 = p1 + geom_smooth(aes(color=Species)) + ggtitle("Add geom_smooth")
p3 = p2 + theme_bw() + ggtitle("Add a theme")
p4 = p3 + facet_wrap(~Species) + ggtitle("Add multipanel facets")
grid.arrange(p1, p2, p3, p4, nrow=2, ncol=2)
```



Histogram, Freqpoly and Density plots

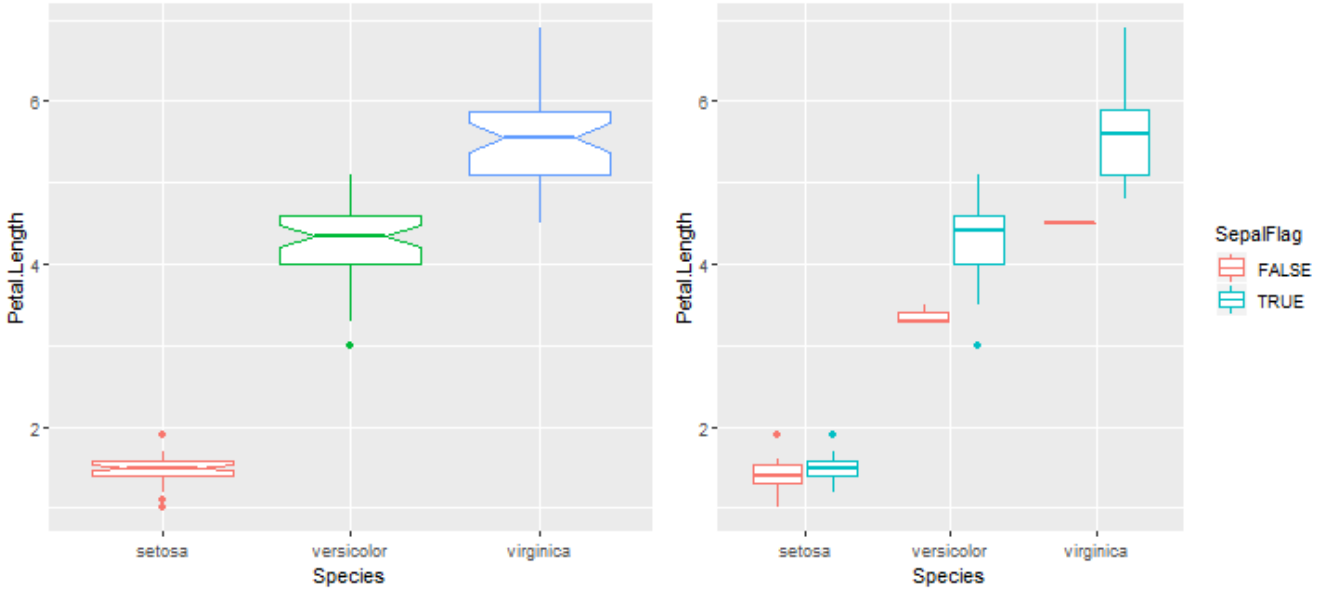
```
p1 = ggplot(iris, aes(Sepal.Length, fill=Species)) + geom_histogram(binwidth = 0.5)
p2 = ggplot(iris, aes(Sepal.Length, color=Species)) + geom_freqpoly(binwidth = 0.5)
p3 = ggplot(iris, aes(Sepal.Length, fill=Species)) + geom_density(alpha=1/3)
grid.arrange(p1, p2, p3, ncol=3)
```



- Differentiate between fill and color usages
- The option alpha in [0,1] sets the degree of transparency

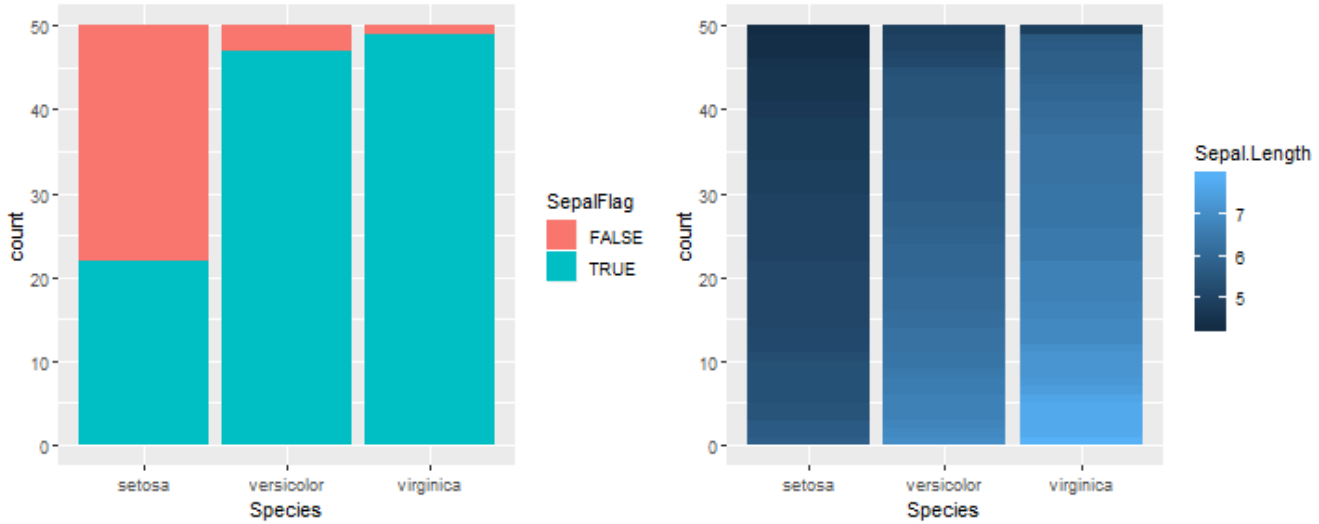
Boxplot

```
iris$SepalFlag = iris$Sepal.Length>5
p1 = ggplot(iris, aes(x=Species, y=Petal.Length, color=Species)) +
  geom_boxplot(notch = T, show.legend = F)
p2 = ggplot(iris, aes(x=Species, y=Petal.Length, color=SepalFlag)) + geom_boxplot()
grid.arrange(p1, p2, ncol=2)
```



Bar Chart

```
p1 = ggplot(iris, aes(Species, fill=SepalFlag)) + geom_bar(position = "stack")
p2 = ggplot(iris, aes(Species, fill=Sepal.Length, group=Sepal.Length)) + geom_bar()
grid.arrange(p1, p2, ncol=2)
```



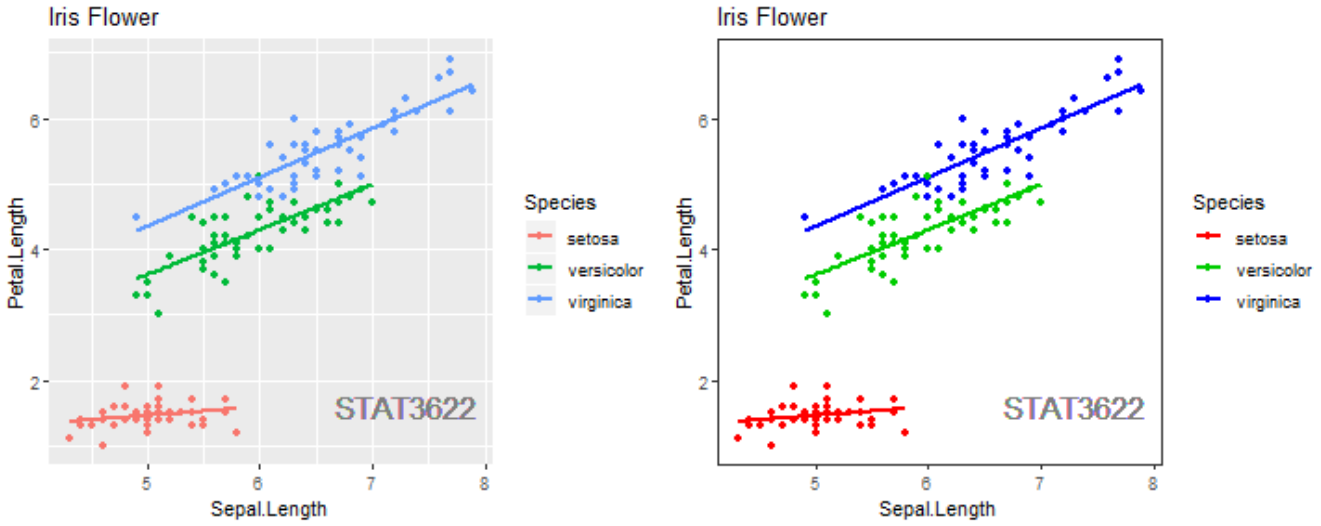
- geom_bar: position = "stack" (default), "fill", "dodge"
- Color bar is genrated for continuous grouping variable

IV. Options and themes

Options and Themes

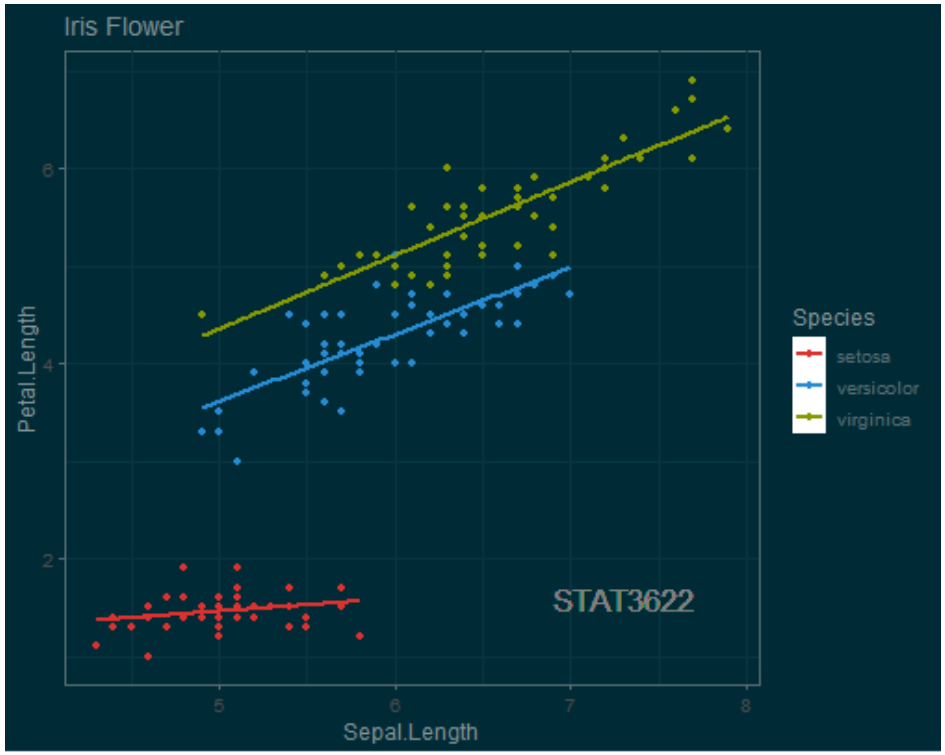
Many options are available for polishing the graphs and making them sophisticated.

```
p1 = ggplot(iris, aes(x=Sepal.Length, y=Petal.Length, colour=Species)) +
  geom_point() + stat_smooth(method="lm", se=F) +
  labs(title="Iris Flower") +
  geom_text(aes(7.3, 1.6), label="STAT3622", size=6, color="gray50")
p2 = p1 + geom_point() + theme_bw() +
  theme(panel.grid= element_blank()) + scale_color_manual(values = c(2,3,4))
grid.arrange(p1, p2, ncol=2)
```



Themes

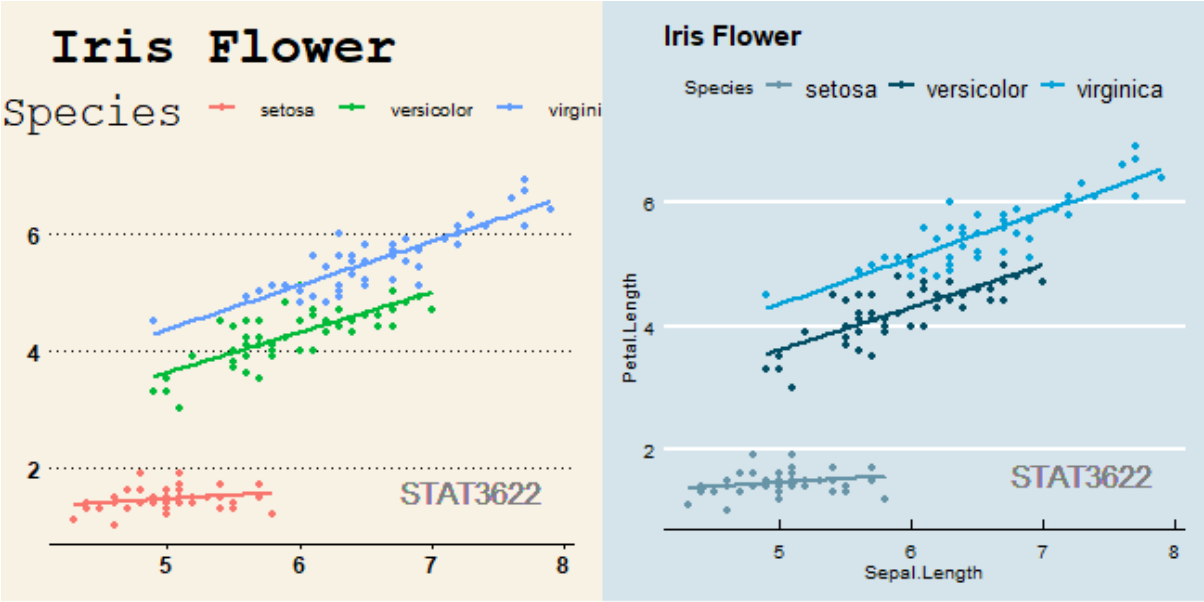
```
library(ggthemes)
p1 +  theme_solarized(light = F) + scale_colour_solarized("red")  # "Solarized Theme"
```



Themes (Continued)

- Wall Street Journal theme and Economist theme ...

```
p2 = p1 + theme_wsj()  #  "WSJ Theme"
p3 = p1 + theme_economist() + scale_colour_economist()  # "Economist Theme"
grid.arrange(p2, p3, ncol=2)
```



Thank you!