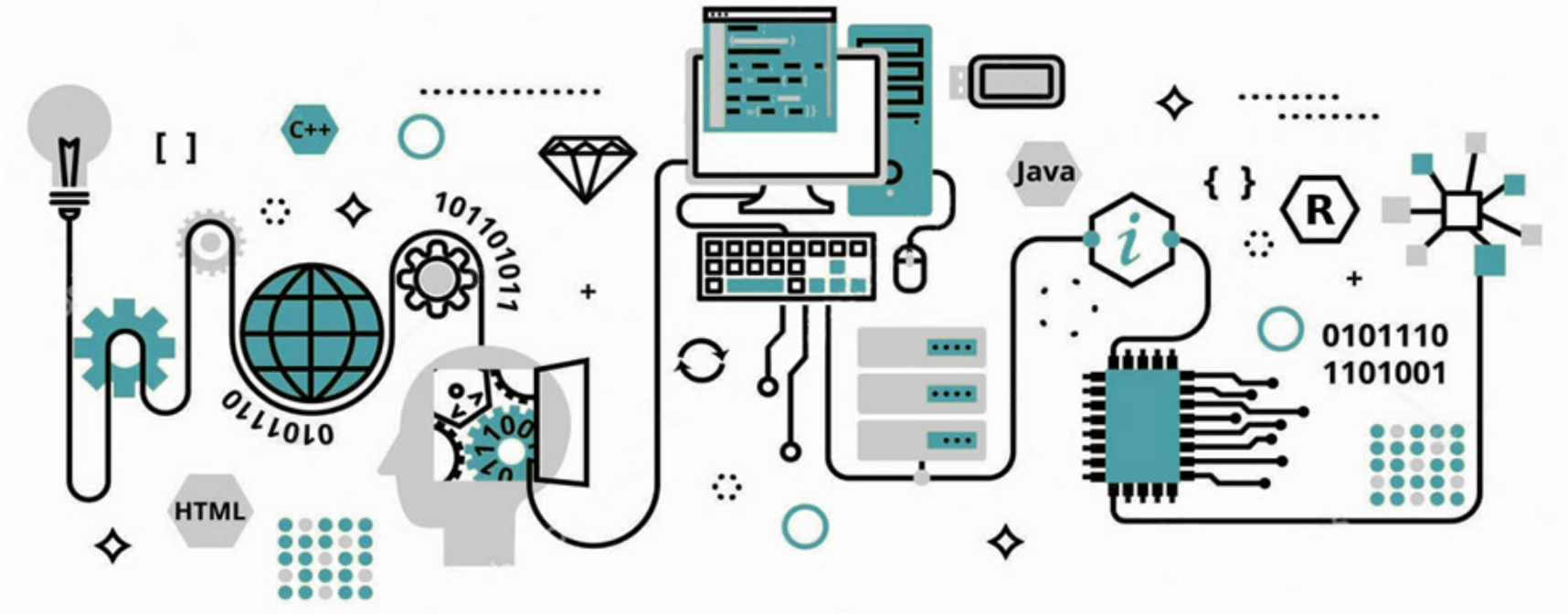


Visualisation with `ggplot2`

R Programming Foundation for Life Scientists

Roy Francis
NBIS, SciLifeLab

Why `ggplot2`?

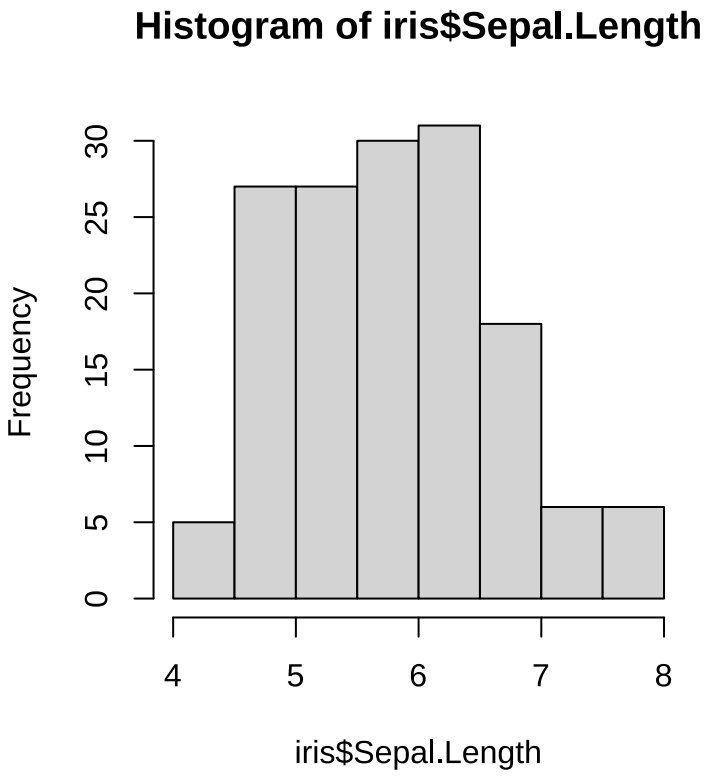
- Consistent code
- Flexible
- Automatic legends, colors etc
- Save plot objects
- Themes for reusing styles
- Numerous add-ons/extensions
- Nearly complete graphing solution

Not suitable for:

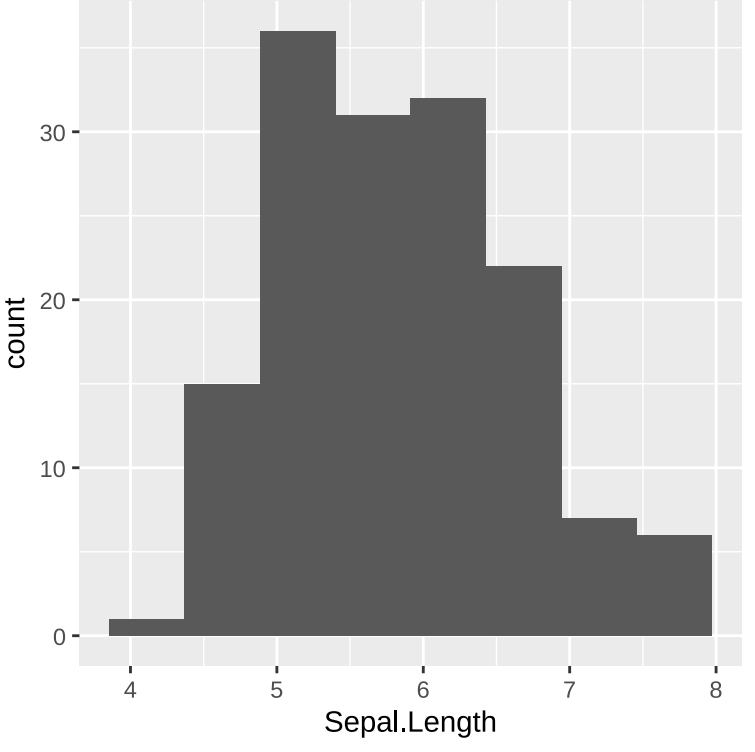
- 3D graphics

ggplot2 vs Base Graphics

```
hist(iris$Sepal.Length)
```



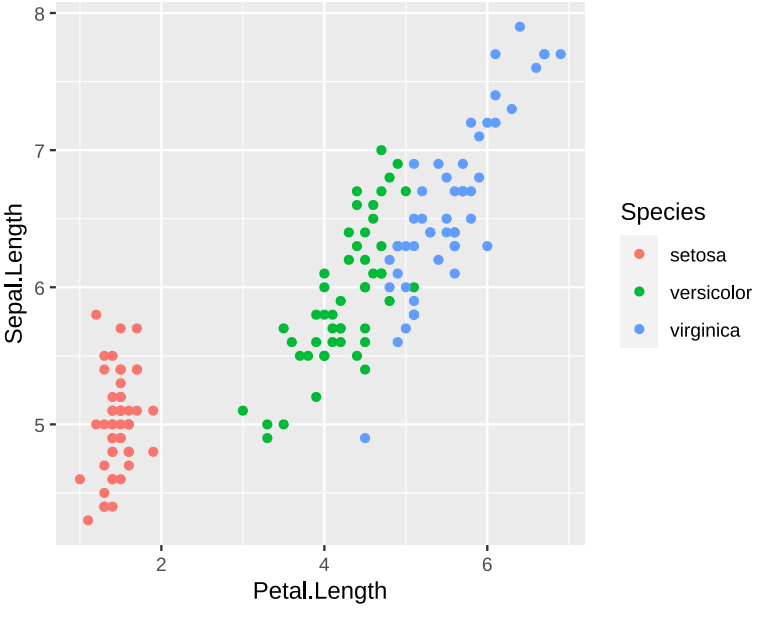

```
library(ggplot2)
ggplot(iris,aes(x=Sepal.Length))+
  geom_histogram(bins=8)
```



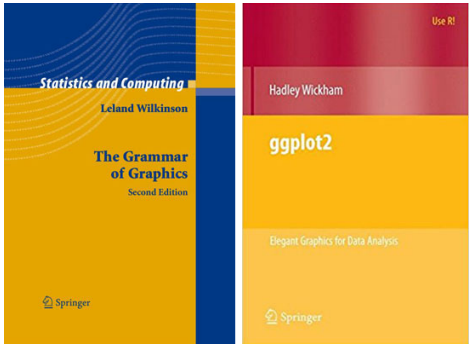
ggplot2 vs Base Graphics

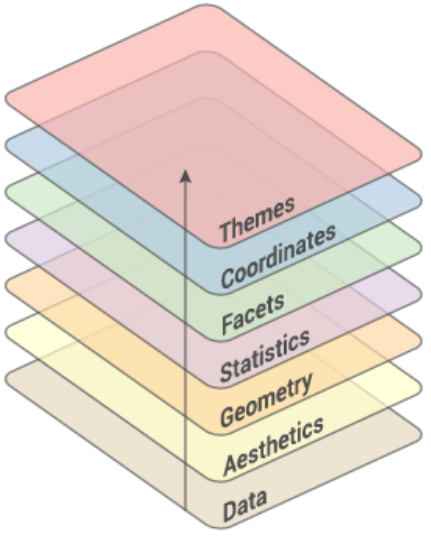
```
plot(iris$Petal.Length,iris$Petal.Width,
     col=c("red","green","blue")[iris$Speci
     pch=c(0,1,2)[iris$Species])
legend(x=1,y=2.5,
       legend=c("setosa","versicolor","virg
       pch=c(0,1,2),col=c("red","green","bl
```

```
ggplot(iris,aes(Petal.Length,Sepal.Length,c
  geom_point()
```



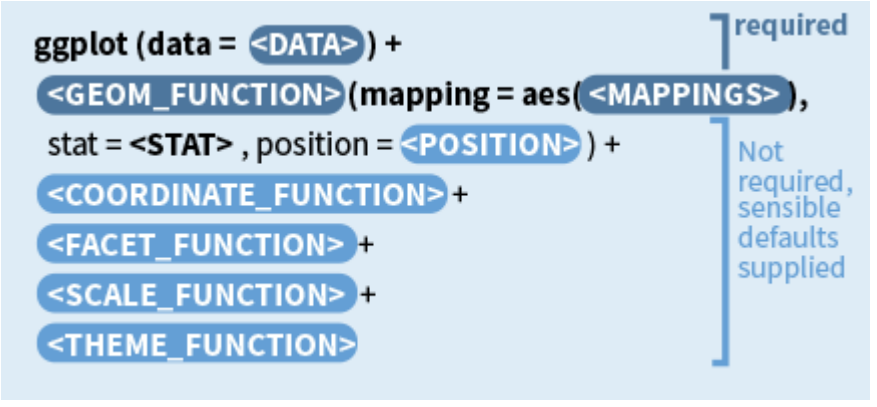
Grammar Of Graphics





- **Data**: Input data
- **Geom**: A geometry representing data. Points, Lines etc
- **Aesthetic**: Visual characteristics of the geometry. Size, Color, Shape etc
- **Scale**: How visual characteristics are converted to display values
- **Statistics**: Statistical transformations. Counts, Means etc
- **Coordinates**: Numeric system to determine position of geometry. Cartesian, Polar etc
- **Facets**: Split data into subsets

Building A Graph: Syntax

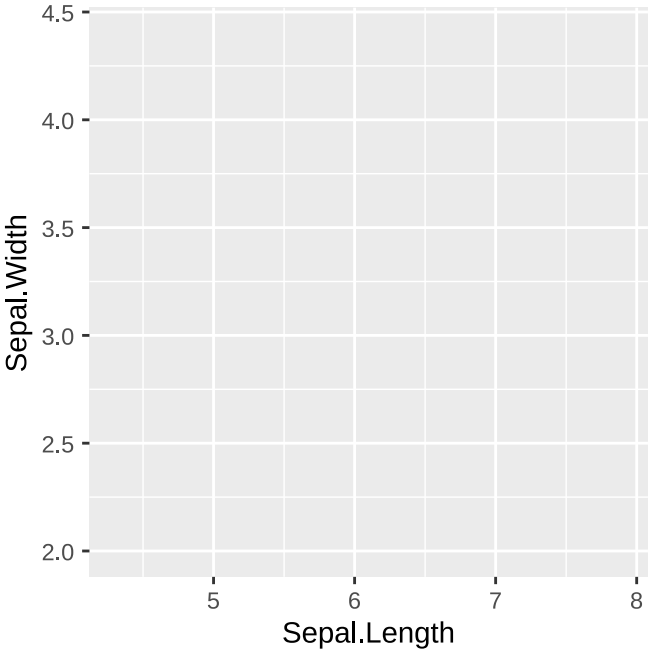


Building A Graph

```
ggplot(iris)
```

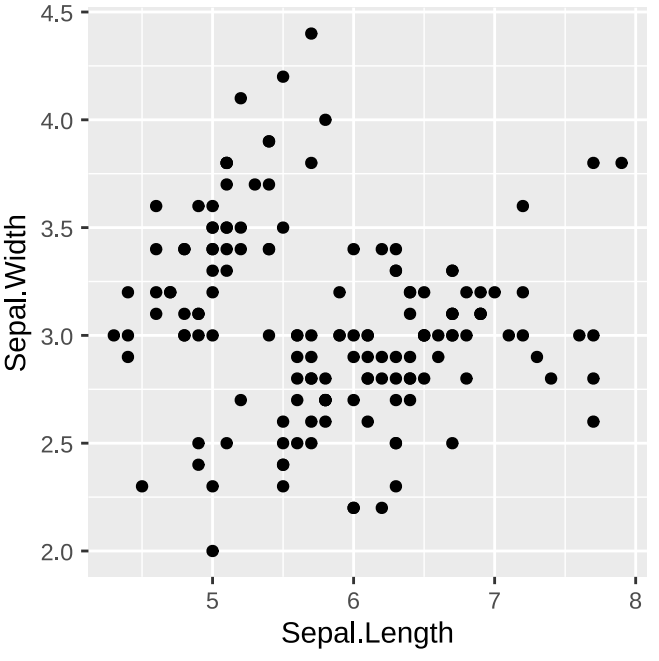
Building A Graph

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



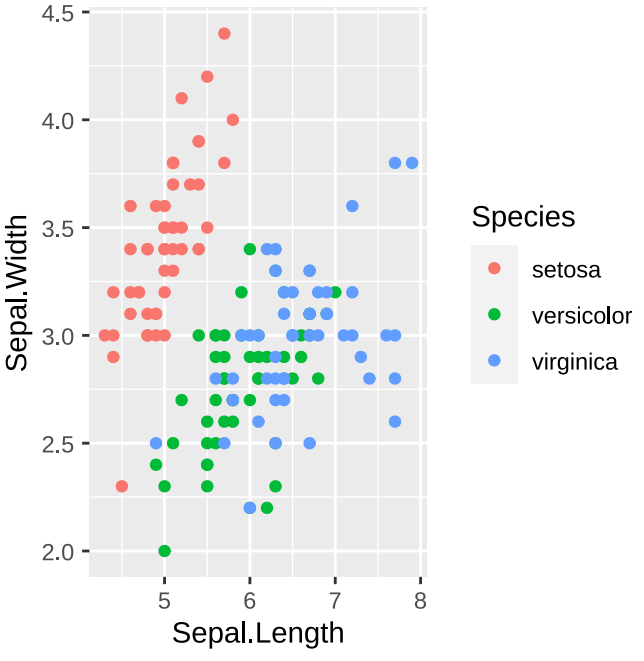
Building A Graph

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



Building A Graph

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



Data • `iris`

- Input data is always an R `data.frame` object

Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa

```
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 ...
```

Data • diamonds

carat	cut	color	clarity	depth	table	price	x	y	z
0.23	Ideal	E	SI2	61.5	55	326	3.95	3.98	2.43
0.21	Premium	E	SI1	59.8	61	326	3.89	3.84	2.31
0.23	Good	E	VS1	56.9	65	327	4.05	4.07	2.31

```
str(diamonds)
```

```
## tibble [53,940 × 10] (S3: tbl_df/tbl/data.frame)
##  $ carat  : num [1:53940] 0.23 0.21 0.23 0.29 0.31 0.24 0.24 0.26 0.22 0.23 ...
##  $ cut    : Ord.factor w/ 5 levels "Fair"<"Good"<..: 5 4 2 4 2 3 3 3 1 3 ...
##  $ color  : Ord.factor w/ 7 levels "D"<"E"<"F"<"G"<..: 2 2 2 6 7 7 6 5 2 5 ...
##  $ clarity: Ord.factor w/ 8 levels "I1"<"SI2"<"SI1"<..: 2 3 5 4 2 6 7 3 4 5 ...
##  $ depth  : num [1:53940] 61.5 59.8 56.9 62.4 63.3 62.8 62.3 61.9 65.1 59.4 ...
##  $ table  : num [1:53940] 55 61 65 58 58 57 57 55 61 61 ...
##  $ price  : int [1:53940] 326 326 327 334 335 336 336 337 337 338 ...
##  $ x      : num [1:53940] 3.95 3.89 4.05 4.2 4.34 3.94 3.95 4.07 3.87 4 ...
##  $ y      : num [1:53940] 3.98 3.84 4.07 4.23 4.35 3.96 3.98 4.11 3.78 4.05 ...
##  $ z      : num [1:53940] 2.43 2.31 2.31 2.63 2.75 2.48 2.47 2.53 2.49 2.39 ...
```

Data • Format

- Transforming data into long or wide formats

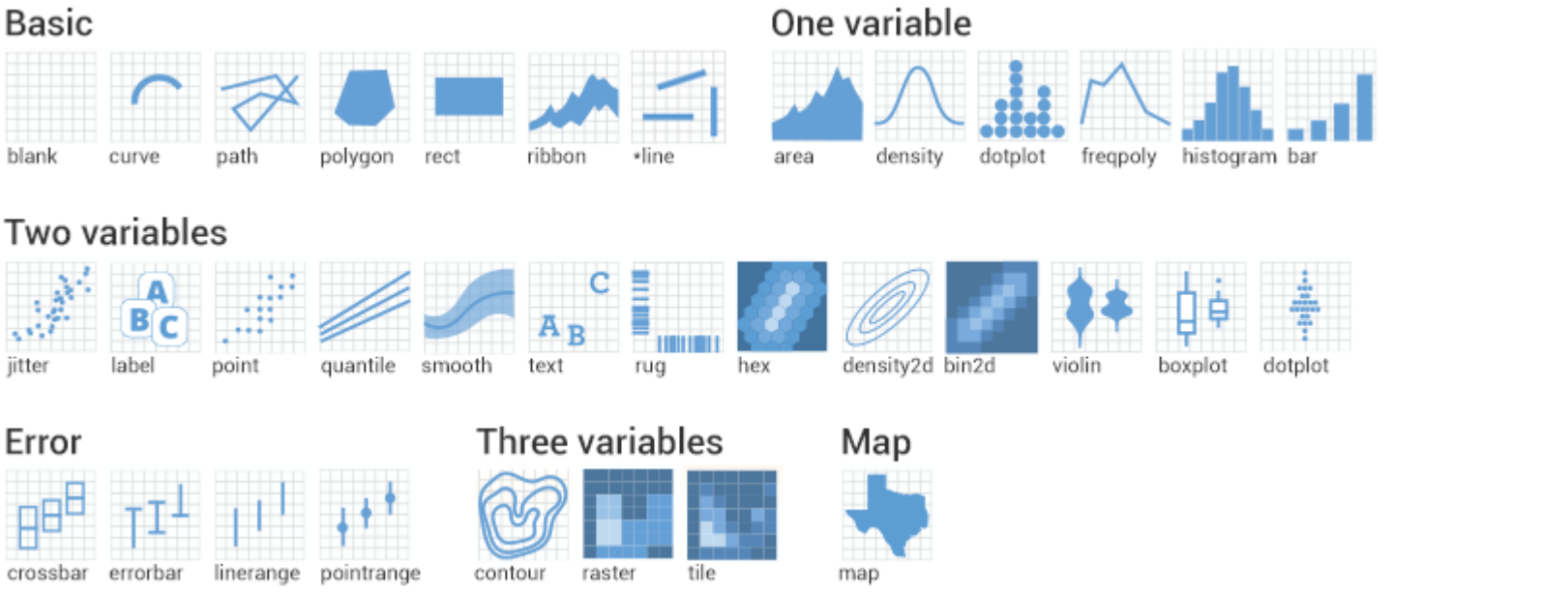
```
iris %>% head(n=4)
```

```
  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
```

```
iris %>% tidyr::pivot_longer(!Species,names_to="variable",values_to="value") %>%
         as.data.frame() %>% head(n=5)
```

```
  Species     variable value
1  setosa Sepal.Length   5.1
2  setosa  Sepal.Width   3.5
3  setosa Petal.Length   1.4
4  setosa  Petal.Width   0.2
5  setosa Sepal.Length   4.9
```

Geoms



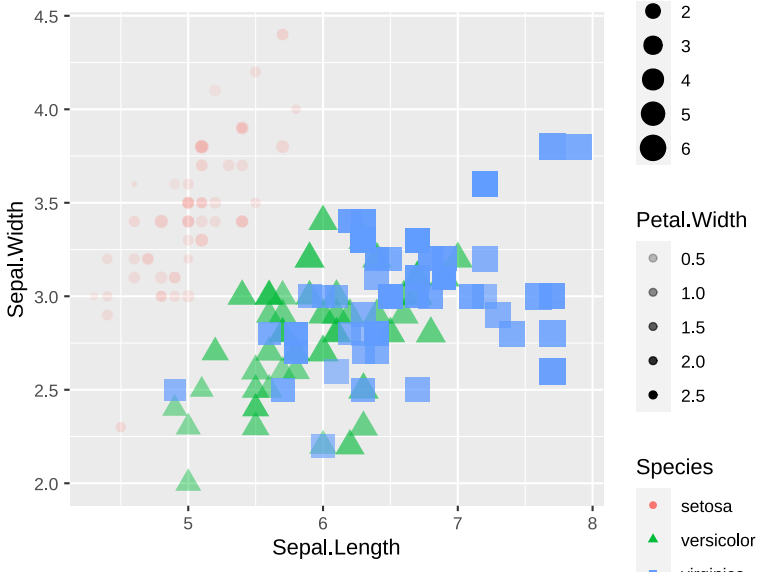

```
p <- ggplot(iris)
# scatterplot
p+geom_point(aes(x=Sepal.Length,y=Sepal.Width))
# barplot
p+geom_bar(aes(x=Sepal.Length))
# boxplot
p+geom_boxplot(aes(x=Species,y=Sepal.Width))
# search
help.search("^geom_",package="ggplot2")
```

Aesthetics

- Aesthetic mapping vs aesthetic parameter

```
ggplot(iris)+
  geom_point(aes(x=Sepal.Length,
                 y=Sepal.Width,
                 size=Petal.Length,
                 alpha=Petal.Width,
                 shape=Species,
                 color=Species))
```

```
ggplot(iris)+
  geom_point(aes(x=Sepal.Length,
                 y=Sepal.Width),
                 size=2,
                 alpha=0.8,
                 shape=15,
                 color="steelblue")
```

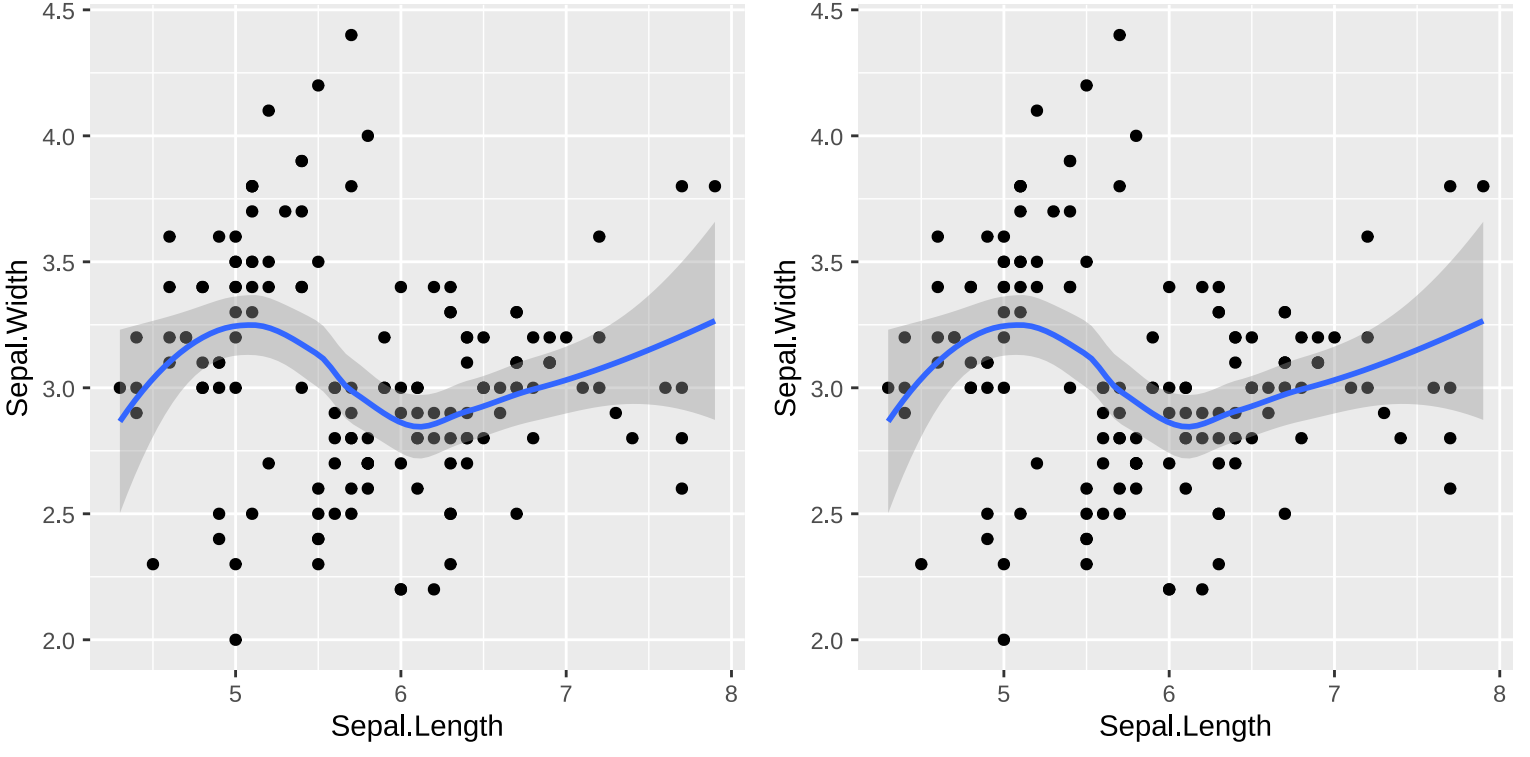


Aesthetics

```
x1 <- ggplot(iris) +
  geom_point(aes(x=Sepal.Length,y=Sepal.Width))+
  stat_smooth(aes(x=Sepal.Length,y=Sepal.Width))

x2 <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width))+
                      geom_point() + geom_smooth()

grid.arrange(x1,x2,nrow=1,ncol=2)
```

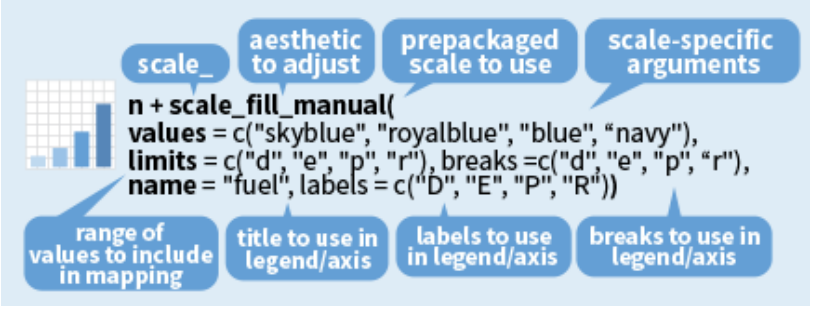


Multiple Geoms

```
ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width))+
      geom_point()+
      geom_line()+
      geom_smooth()+
      geom_rug()+
      geom_step()+
      geom_text(data=subset(iris,iris$Species=="setosa"),aes(label=Species))
```

Scales • Discrete Colors

- scales: position, color, fill, size, shape, alpha, linetype
- syntax: `scale_<aesthetic>_<type>`




```
p <- ggplot(iris)+geom_point(aes(x=Sepal.Le
                      y=Sepal.Width,color=Sp
p
```

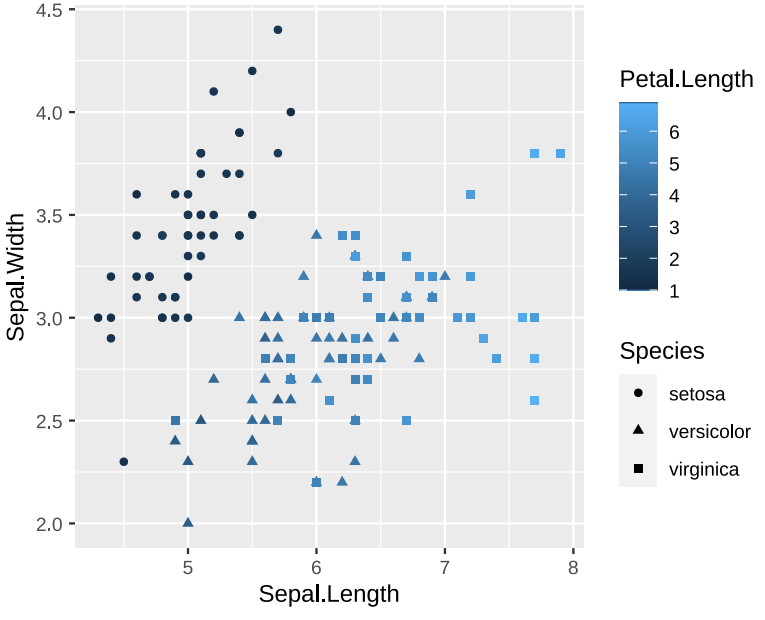
```
p + scale_color_manual(
     name="Manual",
     values=c("#5BC0EB","#FDE74C","#9BC53D"
```

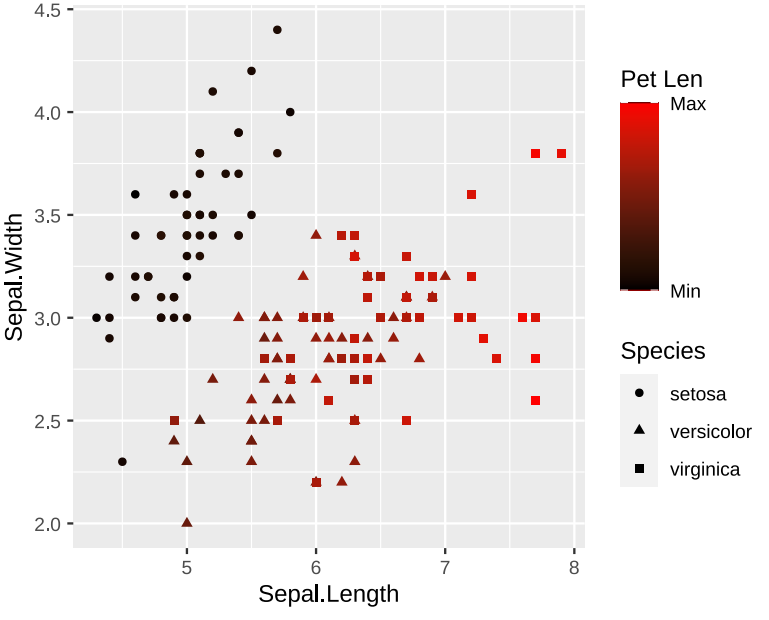
Scales • Continuous Colors

- In RStudio, type `scale_`, then press **TAB**

```
p <- ggplot(iris)+
      geom_point(aes(x=Sepal.Length,
                     y=Sepal.Width,
      shape=Species,color=Petal.Length))
p
```

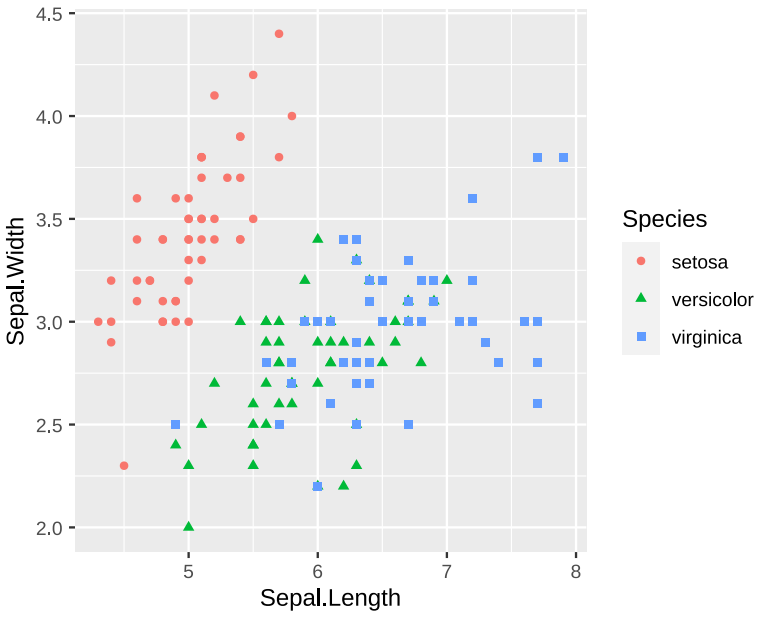
```
p +
scale_color_gradient(name="Pet Len",
  breaks=range(iris$Petal.Length),
  labels=c("Min","Max"),
  low="black",high="red")
```



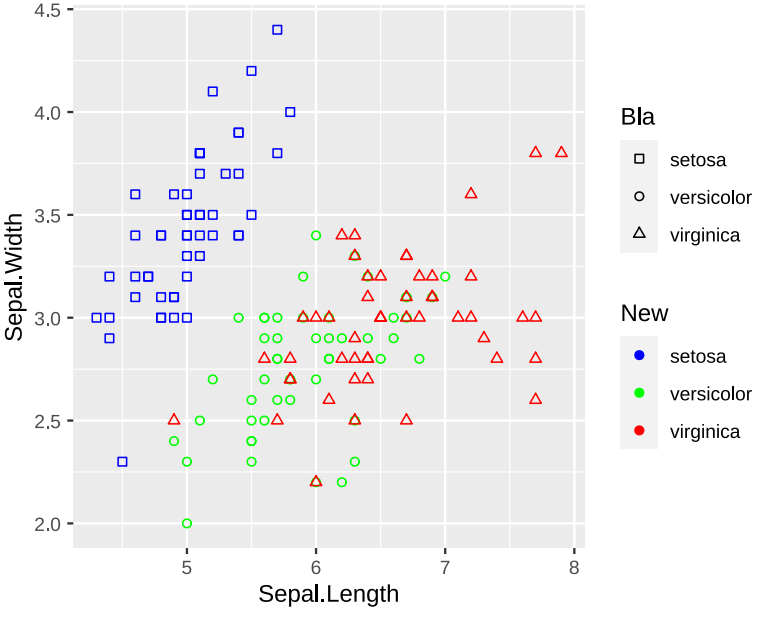


Scales • Shape

```
p <- ggplot(iris)+
      geom_point(aes(x=Sepal.Length,
                     y=Sepal.Width,
      shape=Species,color=Species))
p
```



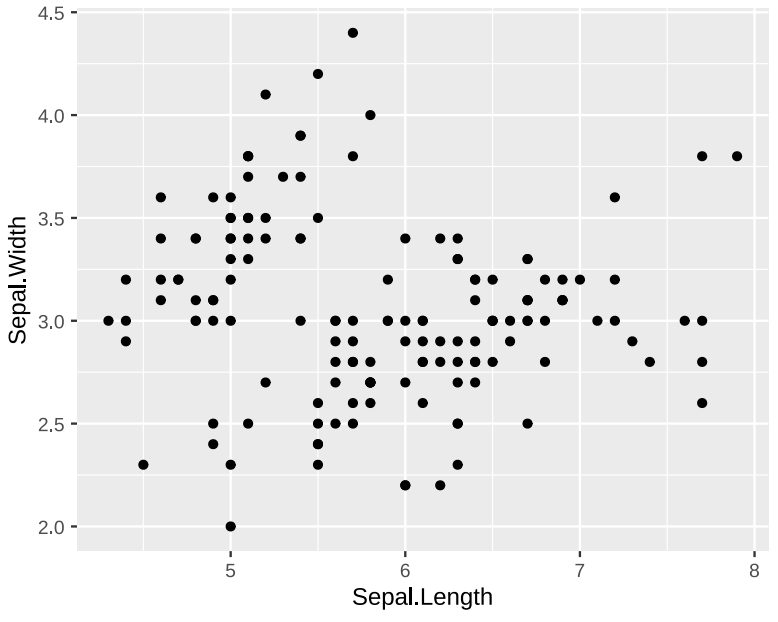

```
p +
scale_color_manual(name="New",
   values=c("blue","green","red"))+
scale_shape_manual(name="Bla",values=c(0,1,
```



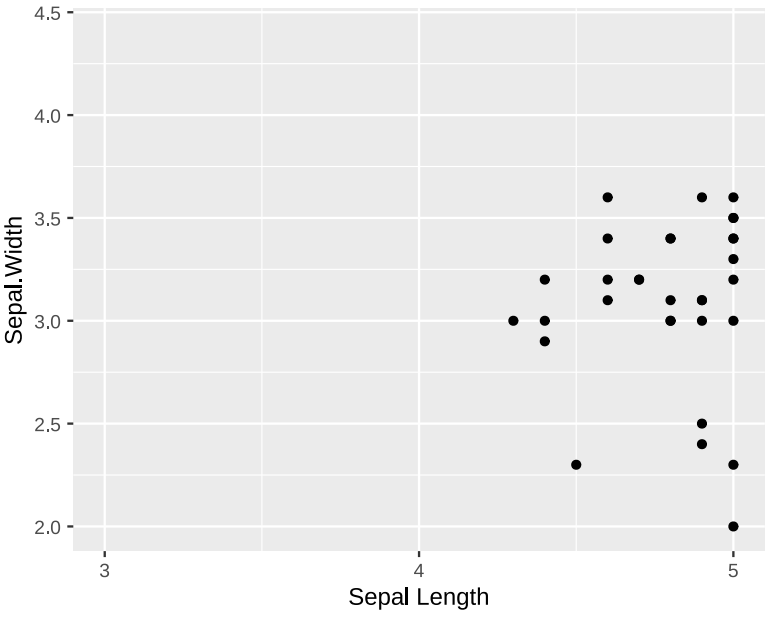
Scales • Axes

- scales: x, y
- syntax: `scale_<axis>_<type>`
- arguments: name, limits, breaks, labels

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



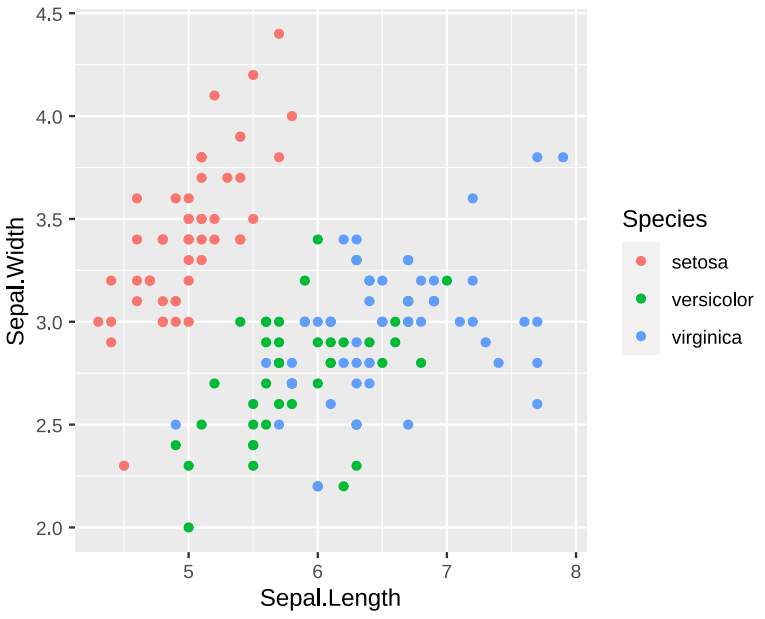

```
p + scale_color_manual(name="New",
   values=c("blue","green","red"))+
scale_x_continuous(name="Sepal Length",
        breaks=seq(1,8),limits=c(3,5))
```



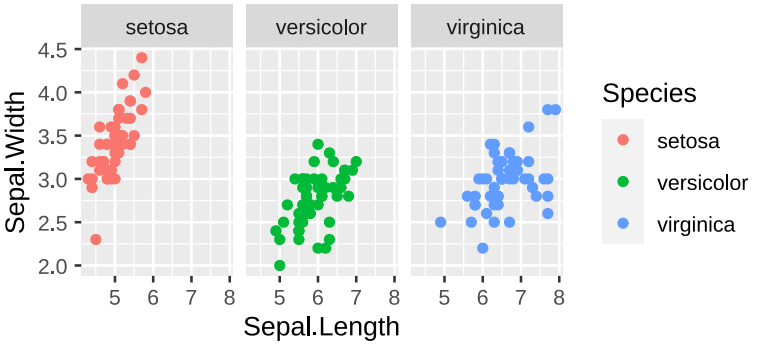
Facets • facet_wrap

- Split to subplots based on variable(s)
- Facetting in one dimension

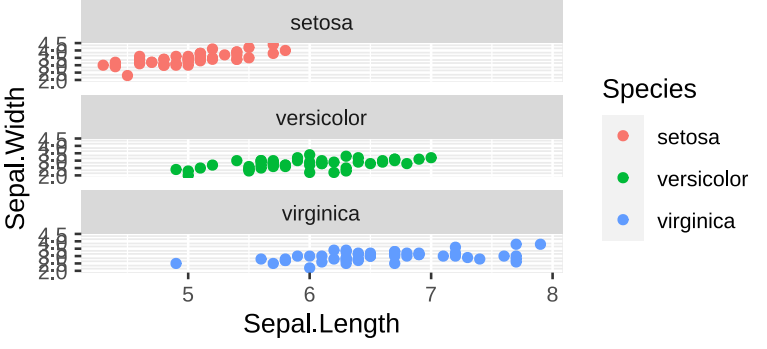
```
p <- ggplot(iris)+
     geom_point(aes(x=Sepal.Length,
                    y=Sepal.Width,
                    color=Species))
p
```




```
p + facet_wrap(~Species)
```



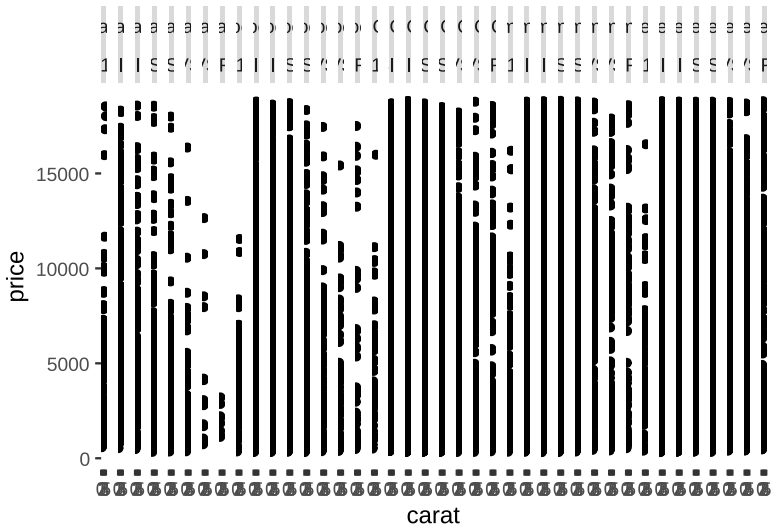

```
p + facet_wrap(~Species,nrow=3)
```



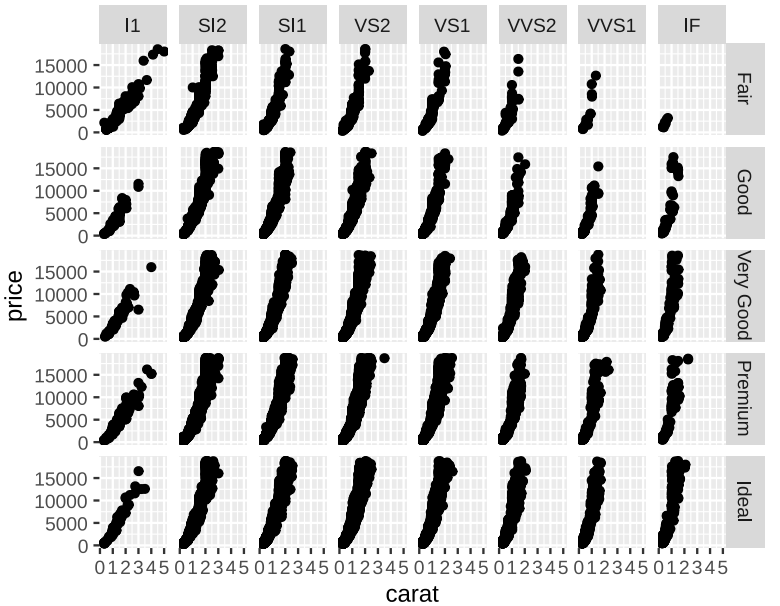
Facets • facet_grid

- Facetting in two dimensions

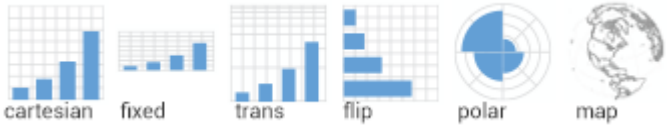
```
p <- diamonds %>%
     ggplot(aes(carat,price))+
     geom_point()
p + facet_grid(~cut+clarity)
```




```
p + facet_grid(cut~clarity)
```



Coordinate Systems



- `coord_cartesian(xlim=c(2,8))` for zooming in
- `coord_map` for controlling limits on maps
- `coord_polar`

```
p <- ggplot(iris,aes(x="",y=Petal.Length,fi
  geom_bar(stat="identity")
p
```

```
p+coord_polar("y",start=0)
```

Theme

- Modify non-data plot elements/appearance
- Axis labels, panel colors, legend appearance etc
- Save a particular appearance for reuse
- `?theme`

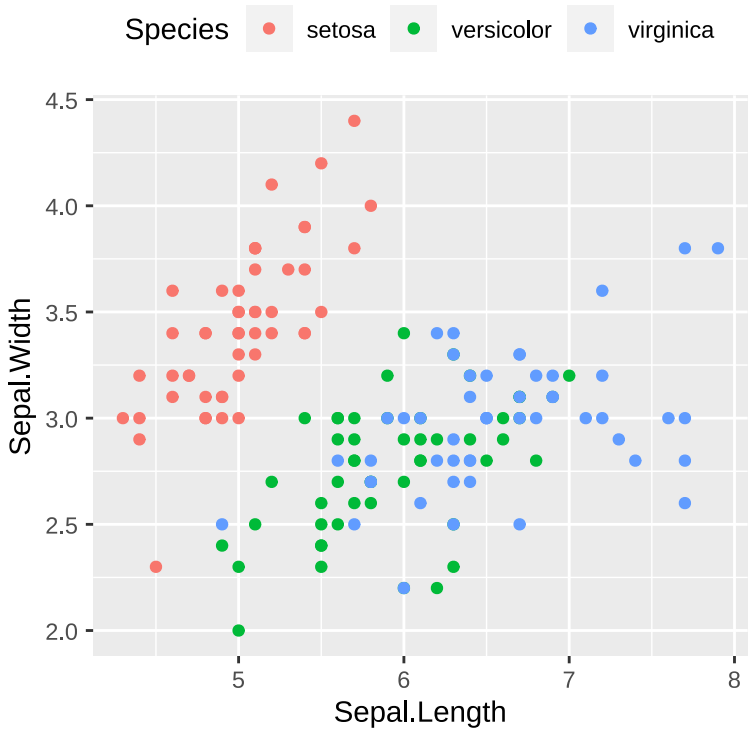
```
ggplot(iris,aes(Petal.Length))+
  geom_histogram()+
  facet_wrap(~Species,nrow=2)+
  theme_grey()
```

```
ggplot(iris,aes(Petal.Length))+
  geom_histogram()+
  facet_wrap(~Species,nrow=2)+
  theme_bw()
```

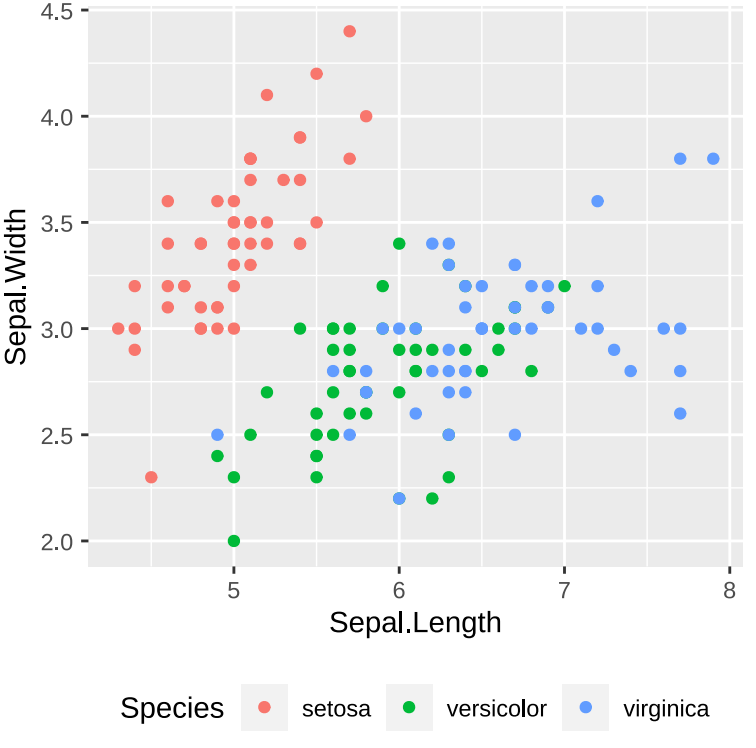
Theme • Legend

```
p <- ggplot(iris)+
      geom_point(aes(x=Sepal.Length,
                     y=Sepal.Width,
                     color=Species))
```

```
p + theme(legend.position="top")
```




```
p + theme(legend.position="bottom")
```



Theme • Text

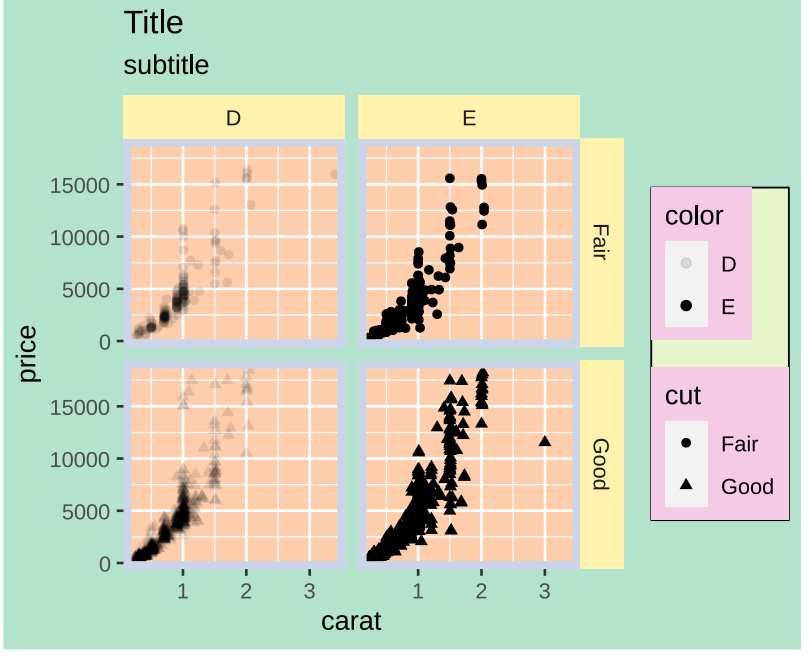
```
element_text(family=NULL,face=NULL,color=NULL,size=NULL,hjust=NULL,
             vjust=NULL, angle=NULL,lineheight=NULL,margin = NULL)
```

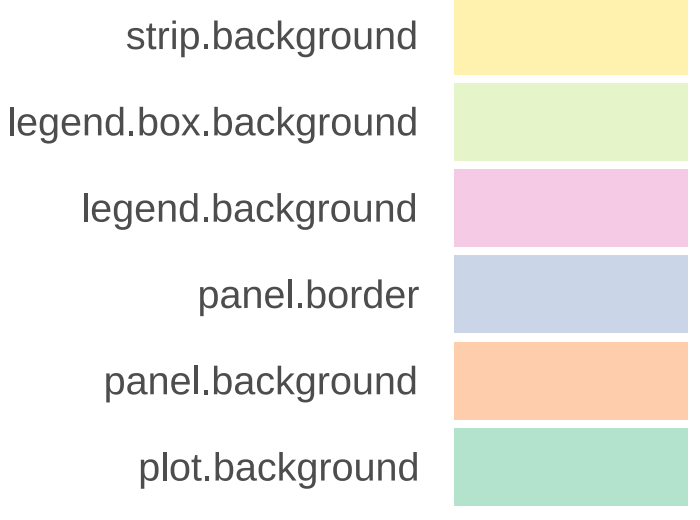
```
p <- p + theme(
    axis.title=element_text(color="#e41a1c"),
    axis.text=element_text(color="#377eb8"),
    plot.title=element_text(color="#4daf4a"),
    plot.subtitle=element_text(color="#984ea3"),
    legend.text=element_text(color="#ff7f00"),
    legend.title=element_text(color="#ffff33"),
    strip.text=element_text(color="#a65628")
)
```

Theme • Rect

```
element_rect(fill=NULL,color=NULL,size=NULL,linetype=NULL)
```

```
p <- p + theme(
    plot.background=element_rect(fill="#b3e2cd"),
    panel.background=element_rect(fill="#fdcdac"),
    panel.border=element_rect(fill=NA,color="#cbd5e8",size=3),
    legend.background=element_rect(fill="#f4cae4"),
    legend.box.background=element_rect(fill="#e6f5c9"),
    strip.background=element_rect(fill="#fff2ae")
)
```



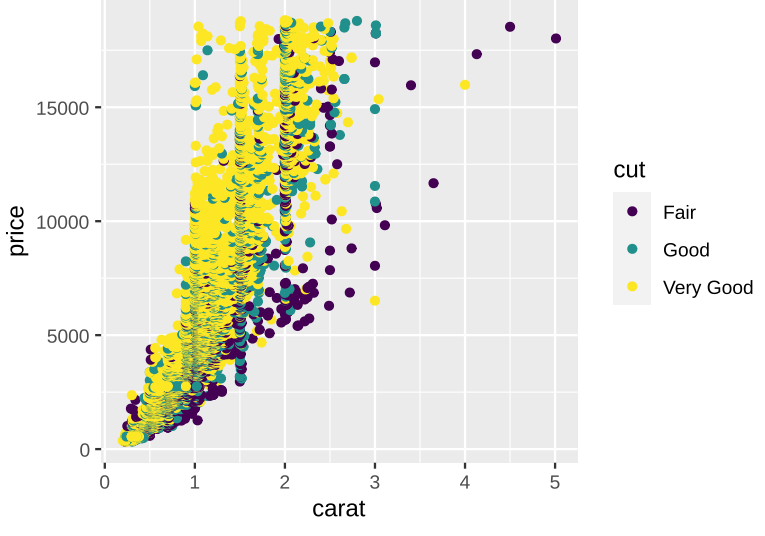


Theme • Reuse

```
newtheme <- theme_bw() + theme(
  axis.ticks=element_blank(),
  panel.background=element_rect(fill="white"),
  panel.grid.minor=element_blank(),
  panel.grid.major.x=element_blank(),
  panel.grid.major.y=element_line(size=0.3,color="grey90"),
  panel.border=element_blank(),
  legend.position="top",
  legend.justification="right"
)
```

```
p
```

```
p + newtheme
```



Position

```
##          Murder Assault UrbanPop Rape
## Alabama    13.2     236       58 21.2
## Alaska     10.0     263       48 44.5
## Arizona     8.1     294       80 31.0
```

```
us <- USArrests %>% mutate(state=rownames(.)) %>% slice(1:4) %>%
                    gather(key=type,value=value,-state)
p <- ggplot(us,aes(x=state,y=value,fill=type))
```

```
p + geom_bar(stat="identity",position="stac
```

```
p + geom_bar(stat="identity",position="dodg
```

Saving plots

```
p <- ggplot(iris,aes(Petal.Length,Sepal.Length,color=Species))+
  geom_point()
```

- `ggplot2` plots can be saved just like base plots

```
png("plot.png",height=5,width=7,units="cm",res=200)
print(p)
dev.off()
```

- `ggplot2` package offers a convenient function

```
ggsave("plot.png",p,height=5,width=7,units="cm",dpi=200,type="cairo")
```

- Use `type="cairo"` for nicer anti-aliasing
- Note that default units in `png` is pixels while in `ggsave` it's inches

Extensions

- gridExtra: Extends grid graphics functionality
- ggpubr: Useful functions to prepare plots for publication
- cowplot: Combining plots
- ggthemes: Set of extra themes
- ggthemr: More themes
- ggsci: Color palettes for scales
- ggrepel: Advanced text labels including overlap control
- ggmap: Dedicated to mapping
- ggraph: Network graphs
- ggiraph: Converting ggplot2 to interactive graphics

Thank you. Questions?

R version 4.0.3 (2020-10-10)

Platform: x86_64-pc-linux-gnu (64-bit)

OS: Ubuntu 18.04.5 LTS

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