Dynamic data visualization with R

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Overview

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  - visualize data, models and results of a statistical analysis
  - discover (and master) some R visualization packages
- Teacher: Laurent Rouvière, laurent.rouviere@univ-rennes2.fr
  - Research interests: nonparametric statistics, statistical learning
  - Teaching: statistics and probability (University and engineer school)
  - Consulting: energy (ERDF), banks, marketing, sport

Resources

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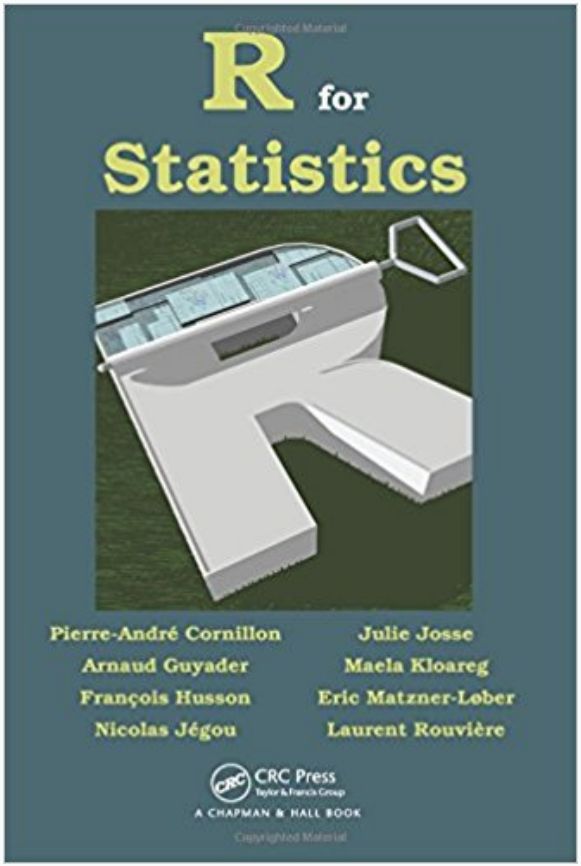
- Book: R for statistics, Chapman & Hall



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- Models are more and more complex
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Consequence

Visualization reveals crucial throughout a statistical study.

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- (at least) 2 ways to understand visualization:
  1. Statistical methods or algorithms: PCA, LDA, trees...
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  1. ggplot2: system for declaratively creating graphics $\Longrightarrow$ 3-4h.
  2. Mapping with ggmap, sf (static) leaflet (dynamic) $\Longrightarrow$ 3-4h.
  3. Dynamic or interactive tools
     - data with rAmCharts and plotly $\Longrightarrow$ 1h
     - dashboard with flexdashbard $\Longrightarrow$ 1h
     - web applications with shiny $\Longrightarrow$ 5h

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     - web applications with shiny $\Longrightarrow$ 5h

Remark

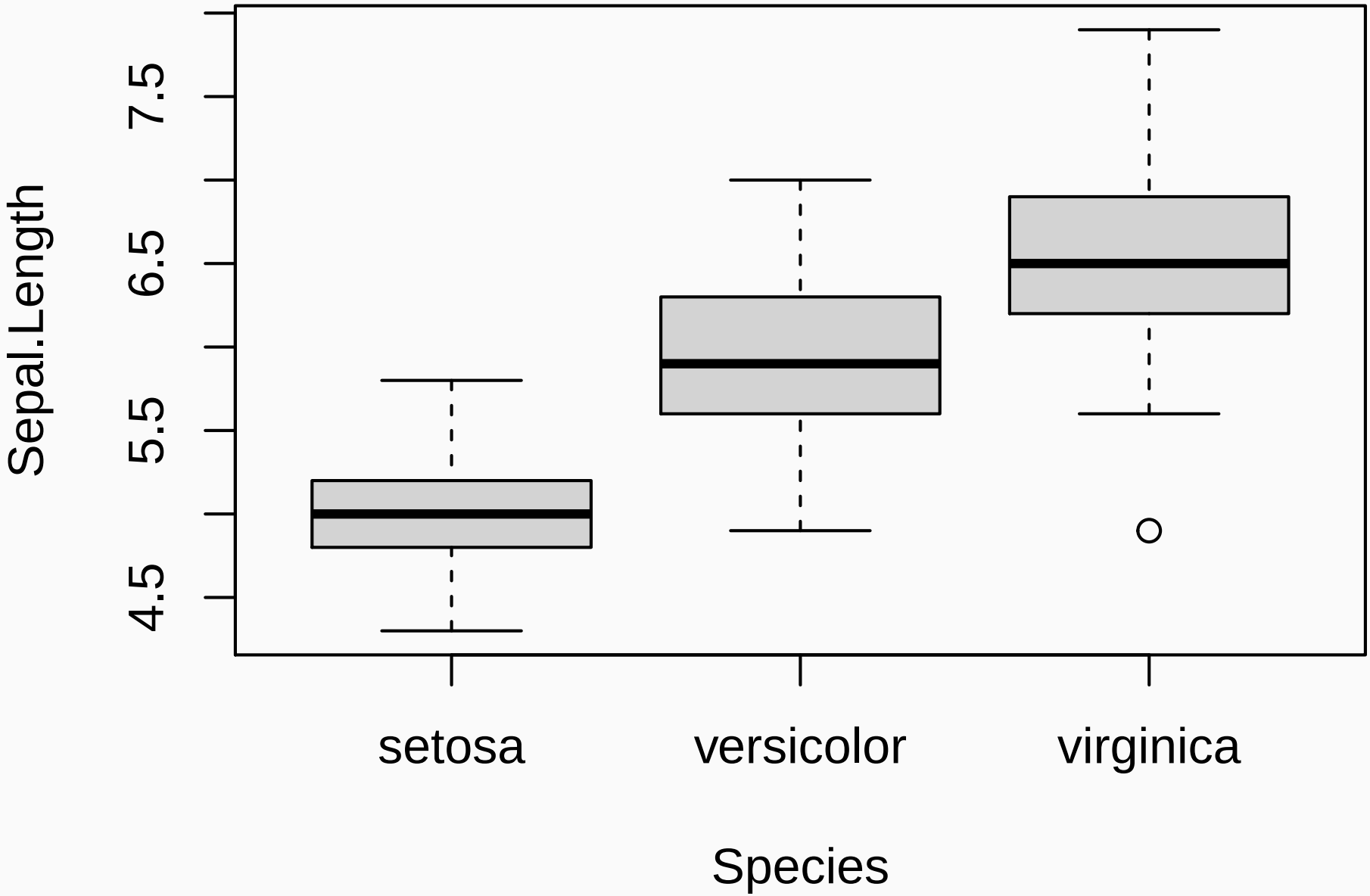
More and more R packages are dedicated to visualization.

Boxplot for the iris dataset

```
> data(iris)
> 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
```

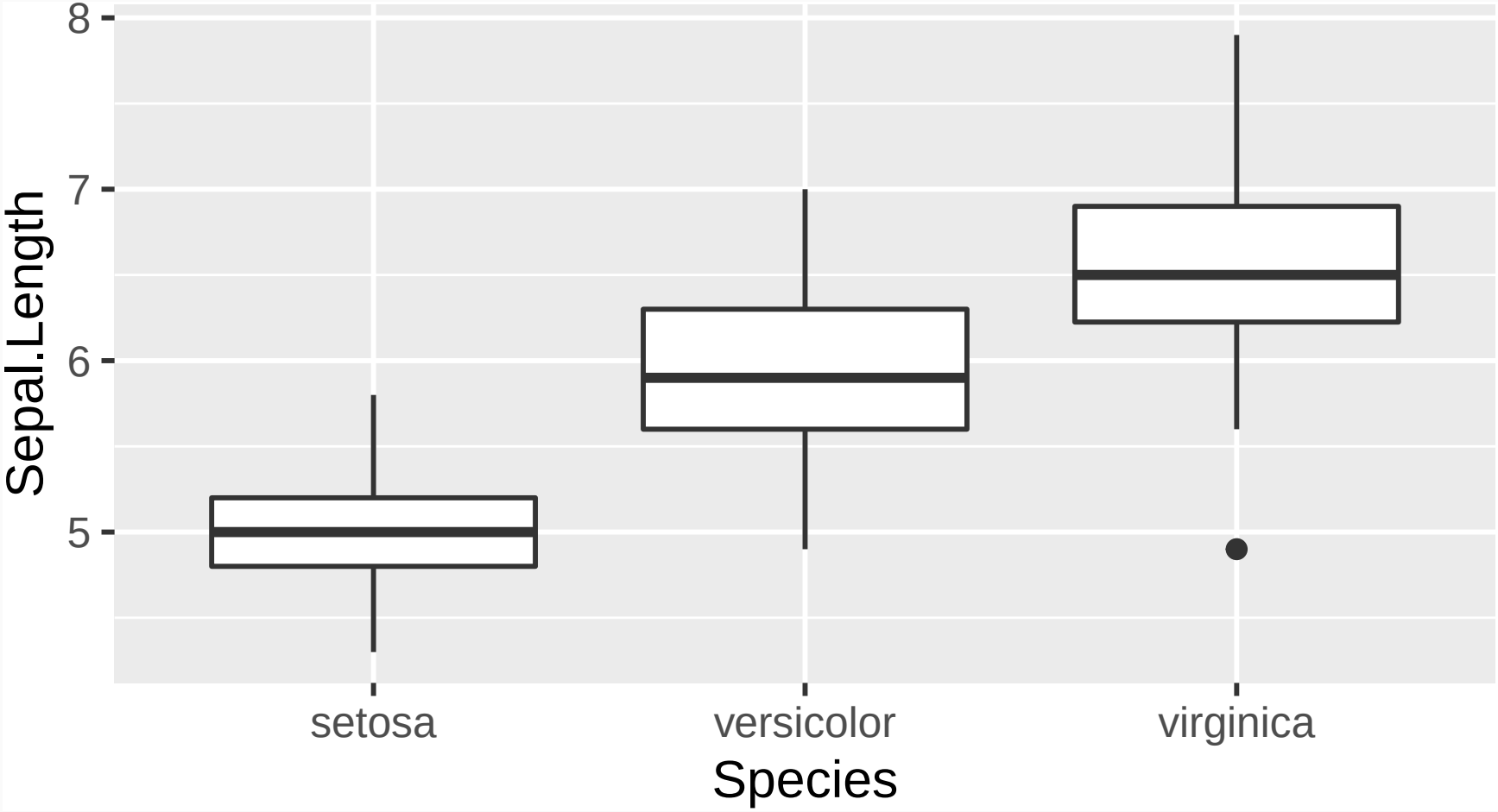
Classical tool

```
> boxplot(Sepal.Length~Species,data=iris)
```

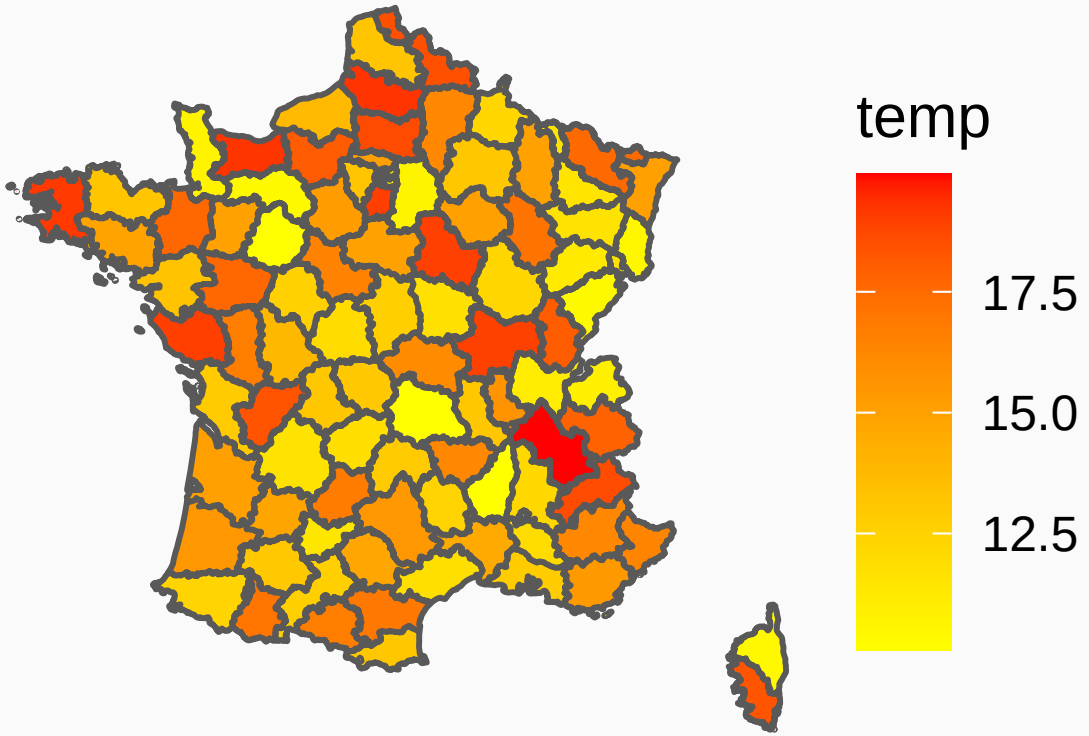


Ggplot tools

```
> library(tidyverse) #ggplot2 in tidyverse
> ggplot(iris)+aes(x=Species,y=Sepal.Length)+geom_boxplot()
```



A temperature map



Many informations

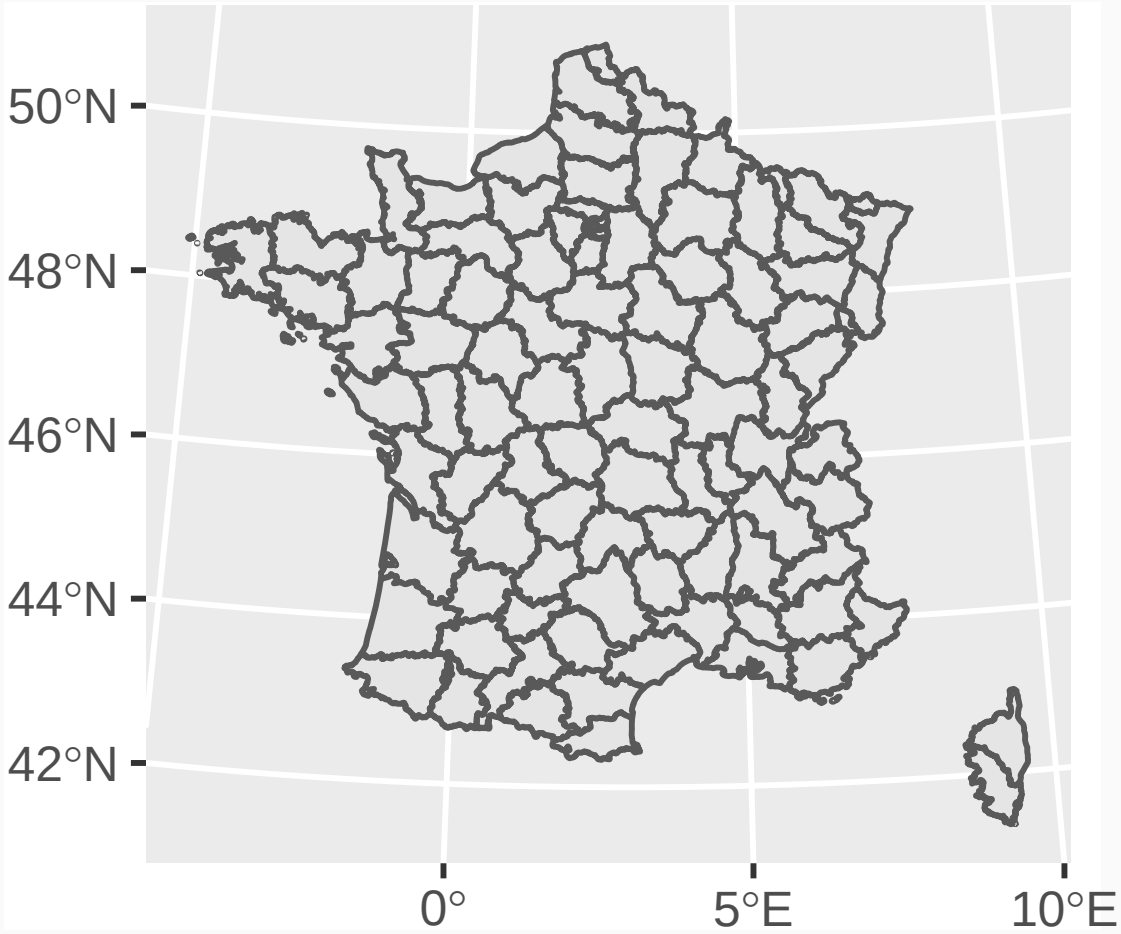
- Background map with boundaries of departments;
- Temperatures in each departments (meteofrance website).

Mapping with sf

```
> library(sf)
> dpt <- read_sf("./DATA/dpt")
> dpt %>% select(NOM_DEPT,geometry) %>% head()
Simple feature collection with 6 features and 1 field
geometry type:  MULTIPOLYGON
dimension:      XY
bbox:           xmin: 644570 ymin: 6272482 xmax: 1077507 ymax: 6997000
CRS:            2154
# A tibble: 6 x 2
  NOM_DEPT                                                    geometry
  <chr>                                                <MULTIPOLYGON [m]>
1 AIN                 (((919195 6541470, 918932 6541203, 918628 6540523~
2 AISNE               (((735603 6861428, 735234 6861392, 734504 6861270~
3 ALLIER              (((753769 6537043, 753554 6537318, 752879 6538099~
4 ALPES-DE-HAUTE-P~   (((992638 6305621, 992263 6305688, 991610 6306540~
5 HAUTES-ALPES        (((1012913 6402904, 1012577 6402759, 1010853 6402~
6 ALPES-MARITIMES     (((1018256 6272482, 1017888 6272559, 1016779 6272~
```

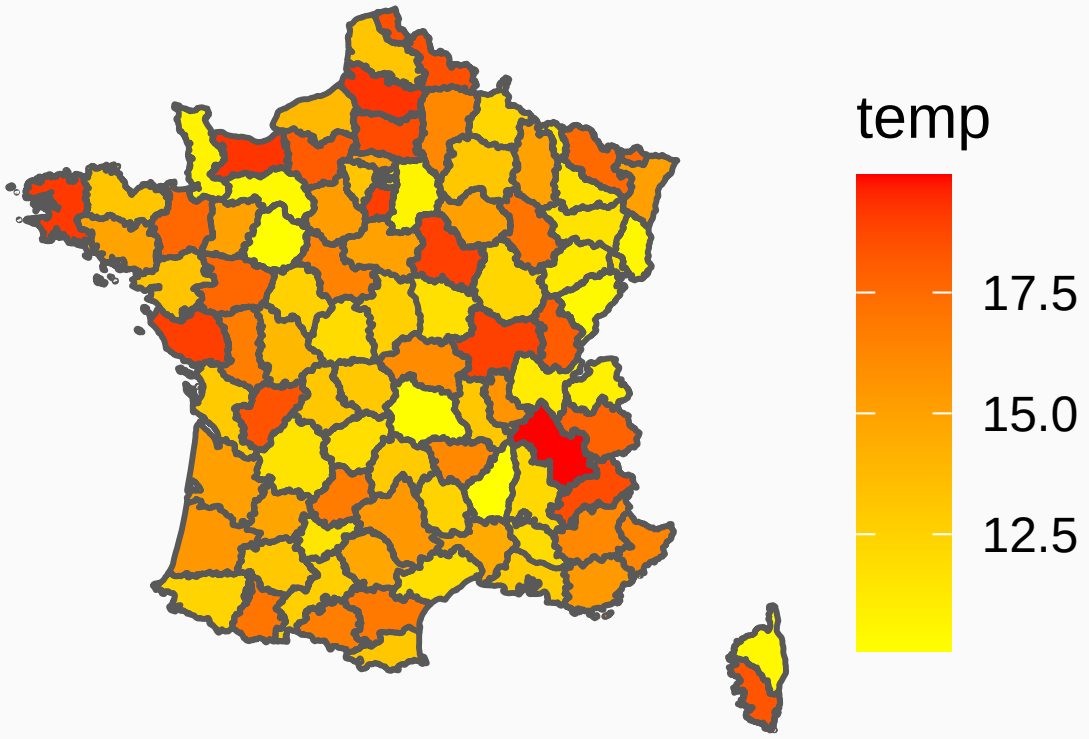
Background map

```
> ggplot(dpt)+geom_sf()
```



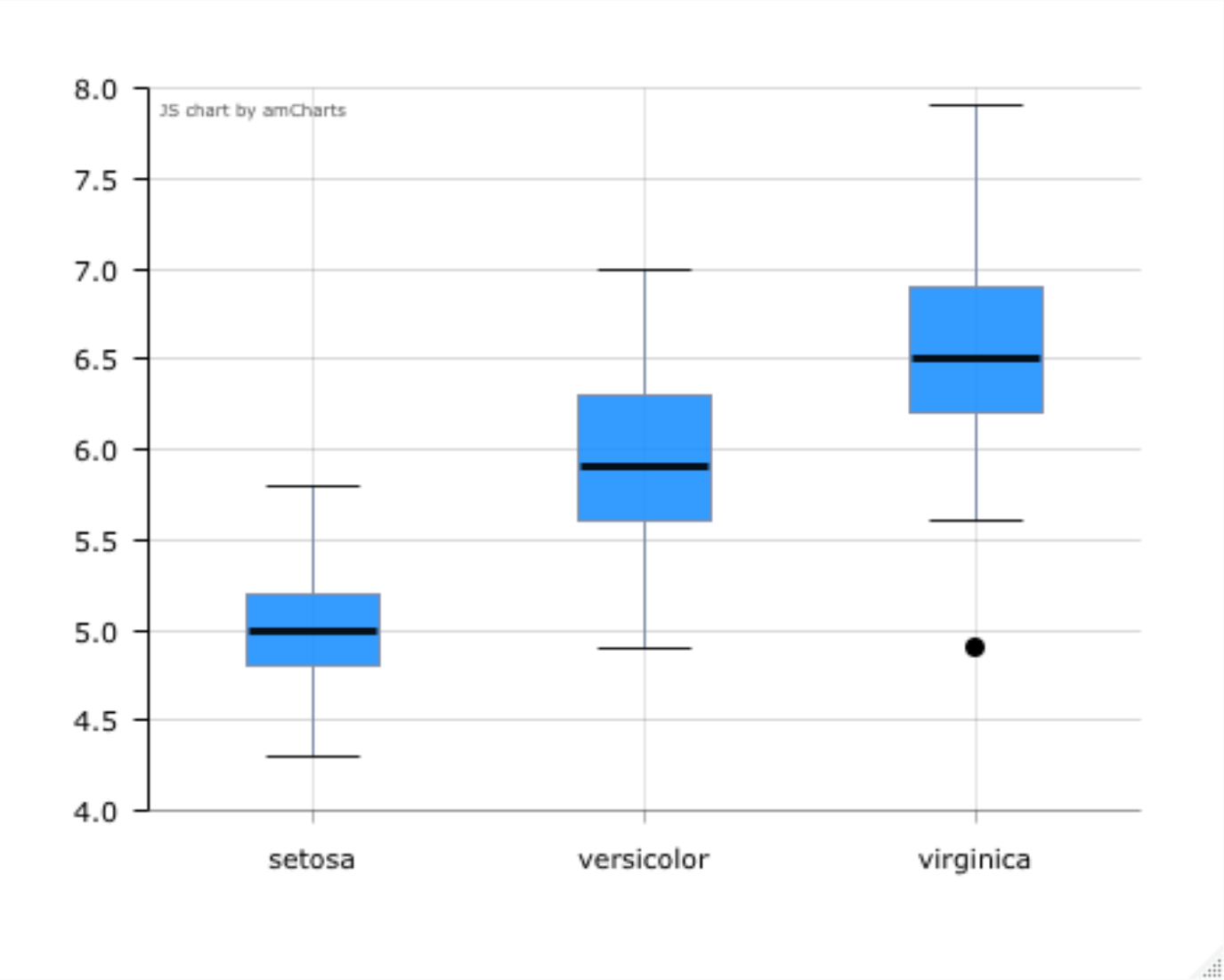
Temperature map

```
> ggplot(dpt) + geom_sf(aes(fill=temp)) +
+   scale_fill_continuous(low="yellow",high="red")+
+   theme_void()
```



Interactive charts with rAmCharts

```
> library(rAmCharts)
> amBoxplot(Sepal.Length~Species,data=iris)
```



Dashboard

- Useful to publish groups of related data visualizations (dataset, classical charts, simple models. . .)
- Package flexdahboard: https://rmarkdown.rstudio.com/flexdashboard/index.html

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- Package flexdahboard: https://rmarkdown.rstudio.com/flexdashboard/index.html
- Based on Rmarkdown syntax
- Example: https://lrouviere.shinyapps.io/dashboard/

Interactive web apps with shiny

- Shiny is a R package that makes it easy to build interactive web apps straight from R.
- Examples:
  - understand overfitting in machine learning: https://lrouviere.shinyapps.io/overfitting_app/
  - bike stations in Rennes: https://lrouviere.shinyapps.io/velib/

To summarize

- 15 hours for 3 (or 4) topics.
- 1 topic = slides + tutorial (supplement material + exercises).
- Require personal efforts.
- To Practice, to make mistakes and to correct these mistakes: only way to learn a computer tools.

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- 15 hours for 3 (or 4) topics.
- 1 topic = slides + tutorial (supplement material + exercises).
- Require personal efforts.
- To Practice, to make mistakes and to correct these mistakes: only way to learn a computer tools.
- You need to work alone between the sessions.
- Everyone can develop at its own pace (the goal is to progress), and ask questions during the sessions.
- I'm here to (try) to answer.

Outline

1. Data visualization with ggplot2
   - Conventional graphical functions (a reminder)
   - ggplot2 grammar
2. Mapping
   - ggmap
   - Shapefile contours with sf
   - Interactive maps with leaflet
3. Some Dynamic visualization tools

Data visualization with ggplot2

- Graphs are often the starting point for statistical analysis.
- One of the main advantages of **R** is how easy it is for the user to create many different kinds of graphs.
- We begin by a (short) review on conventional graphs,
- followed by an examination of some more complex representations, especially with ggplot2 package.

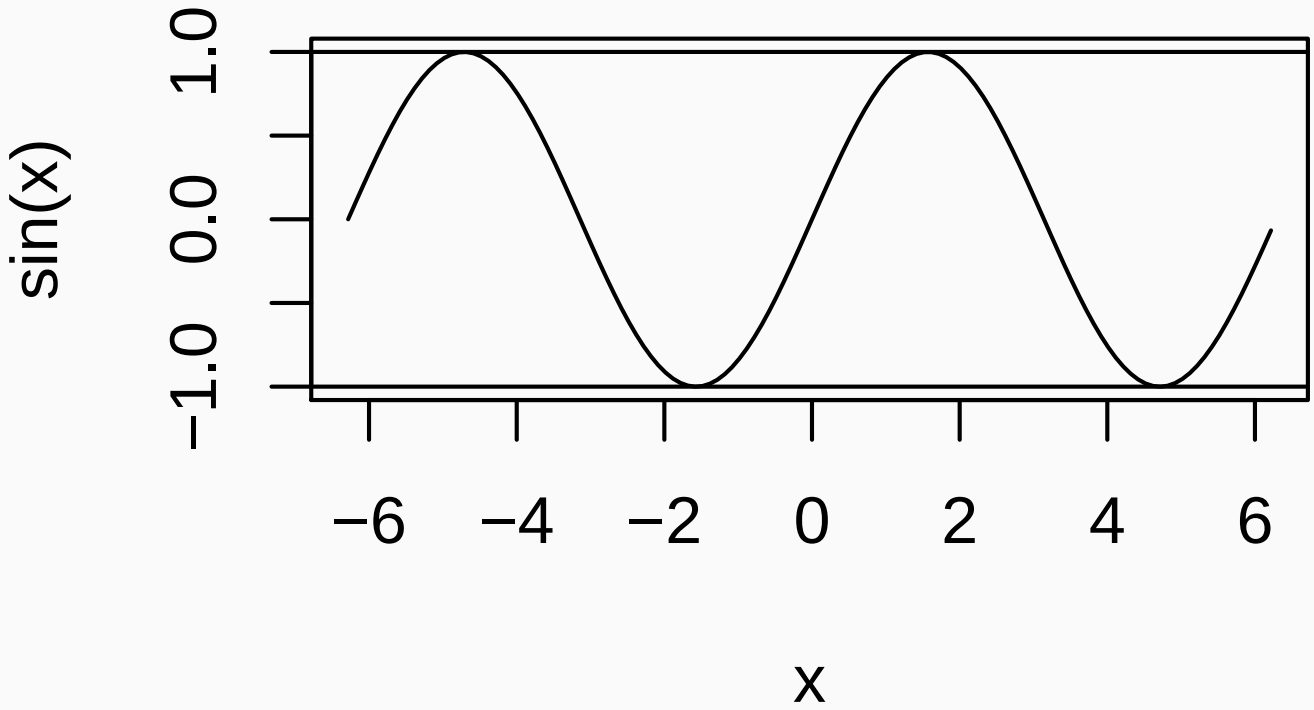
Data visualization with ggplot2

Conventional graphical functions (a reminder)

The plot function

- It is a generic function to represent all kind of data.
- For a scatter plot, we have to specify a vector for the x-axis and a vector for the y-axis.

```
> x <- seq(-2*pi,2*pi,by=0.1)
> plot(x,sin(x),type="l",xlab="x",ylab="sin(x)")
> abline(h=c(-1,1))
```



Graphs for datasets

- Many kind of representations are needed according to the variables we want to visualize.
- Histogram for continuous variables, barplot for categorical variables.
- Scatterplot for 2 continuous variables.
- Boxplot to visualize distributions.

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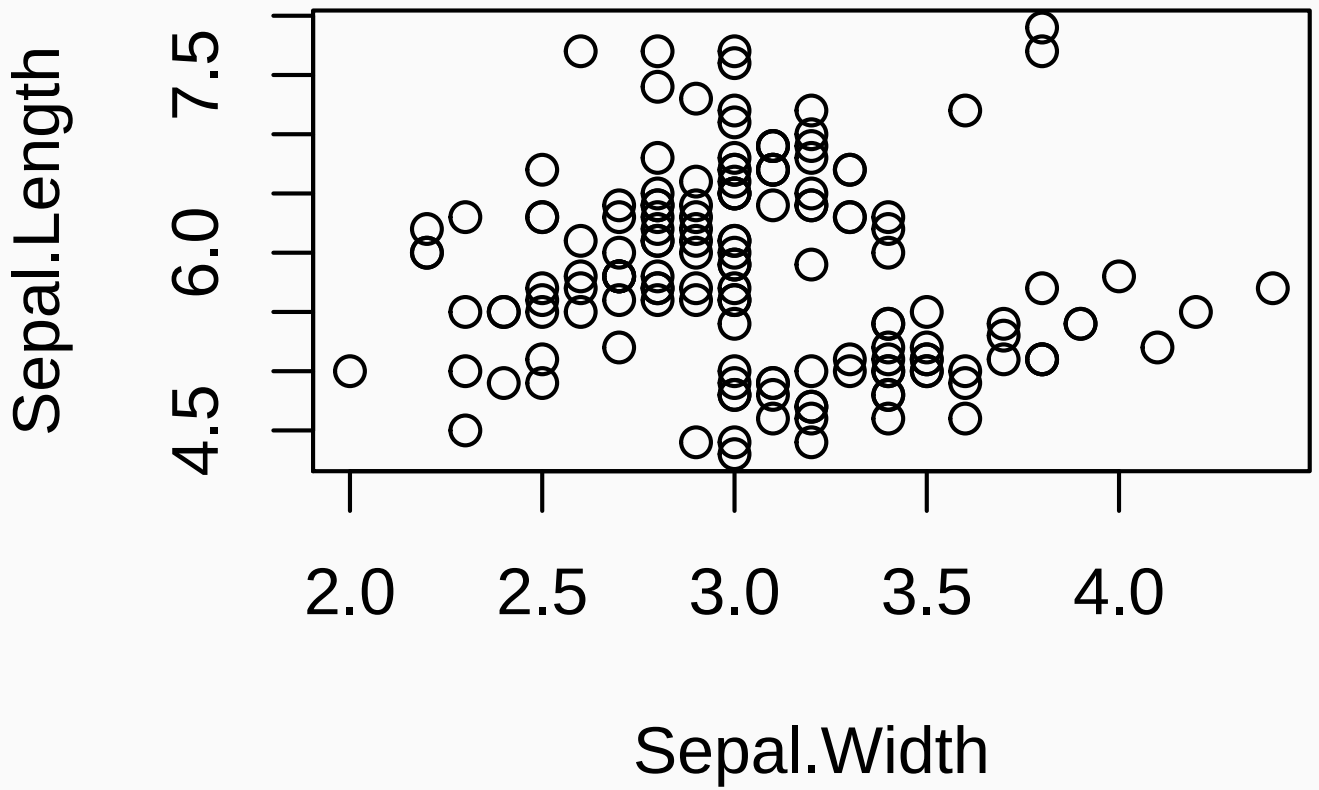
- Boxplot to visualize distributions.

Fortunately

There is a R function for all representations.

Scatterplot with dataset

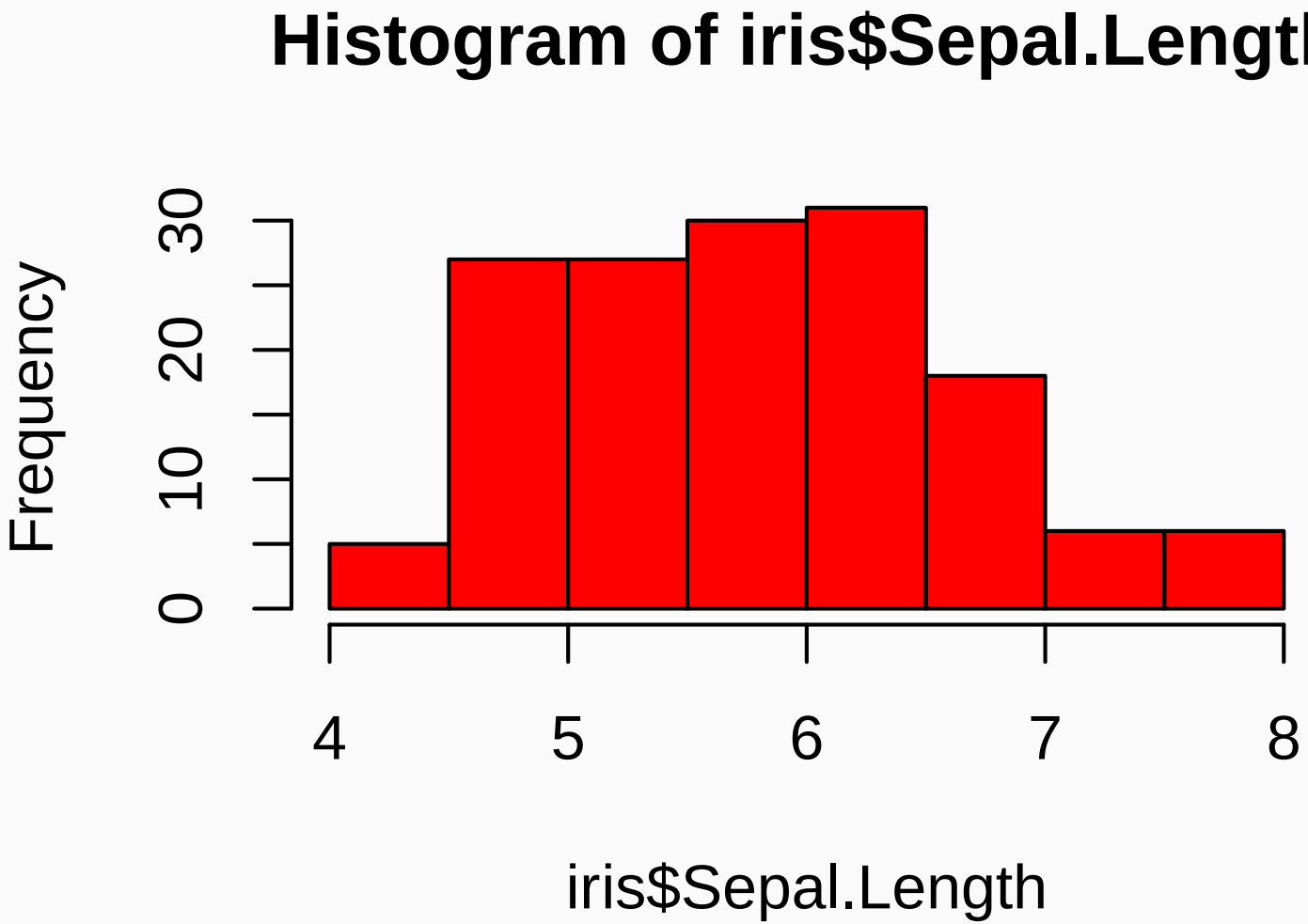
```
> plot(Sepal.Length~Sepal.Width,data=iris)
```




```
> #same as
> plot(iris$Sepal.Width,iris$Sepal.Length)
```

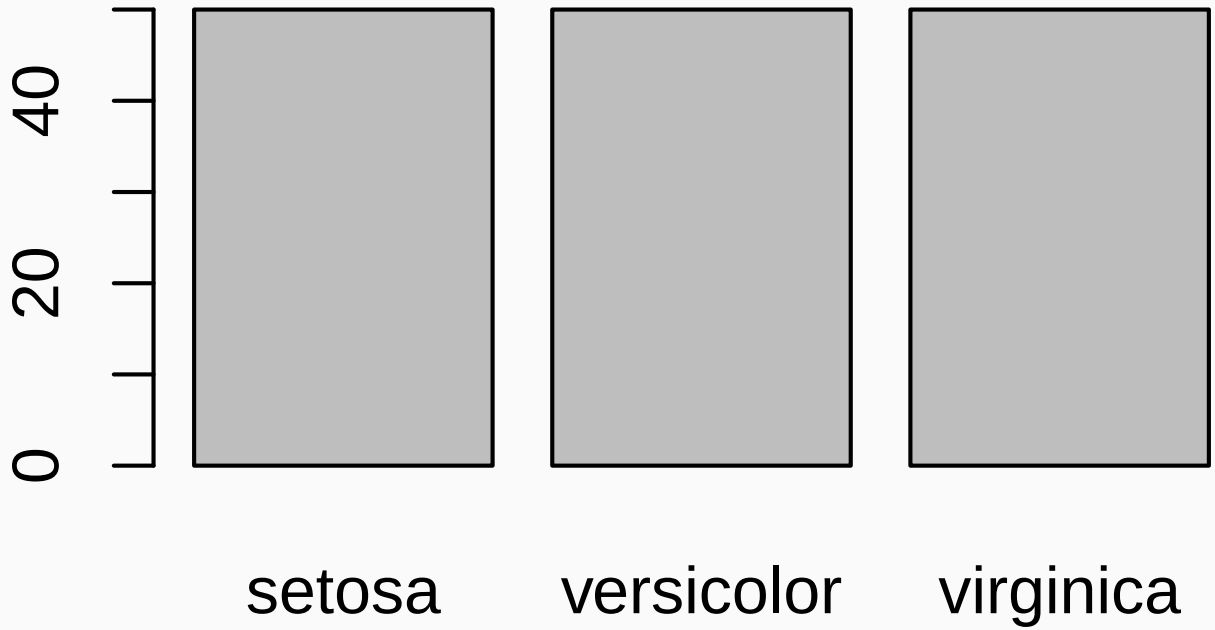
Histogram for continous variable

```
> hist(iris$Sepal.Length,col="red")
```



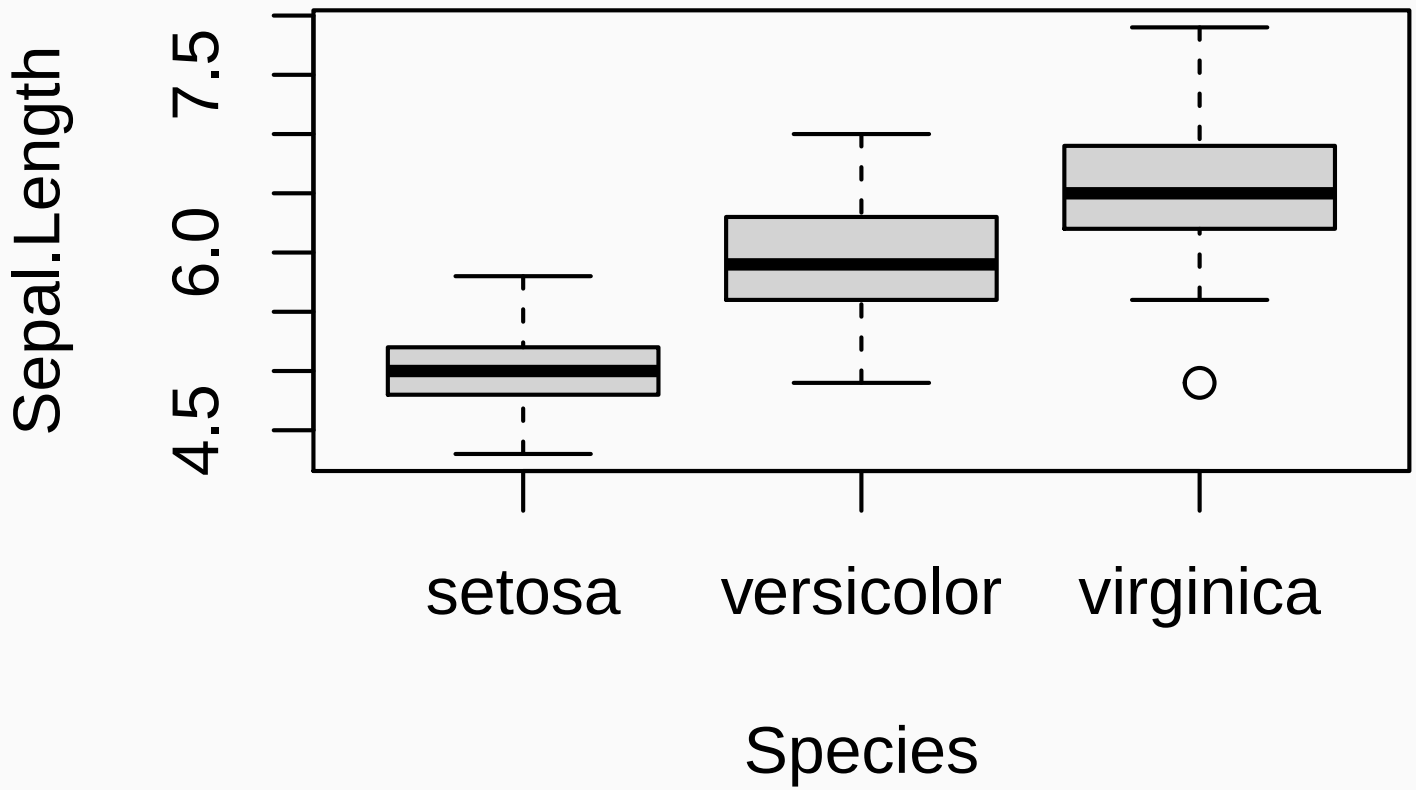
Barplot for categorical variables

```
> barplot(table(iris$Species))
```



Boxplot

```
> boxplot(Sepal.Length~Species,data=iris)
```



Data visualization with ggplot2

ggplot2 grammar

- ggplot2 is a plotting system for R based on the grammar of graphics (as **dplyr** to manipulate data).
- The goal is to provide a clear syntax for an efficient visualization.
- Ggplot provides "elegant" graphs (nor always the case for conventional R graphs).
- Documentation: tutorial, book

For a given dataset, a graph is defined from many **layers**. We have to specify:

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- the variables we want to plot
- the type of representation (scatterplot, boxplot...).

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Ggplot graphs are defined from these layers. We indicate

- the data with ggplot
- the variables with aes (aesthetics)
- the kind of representation with geom_...

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Main elements of the grammar are:

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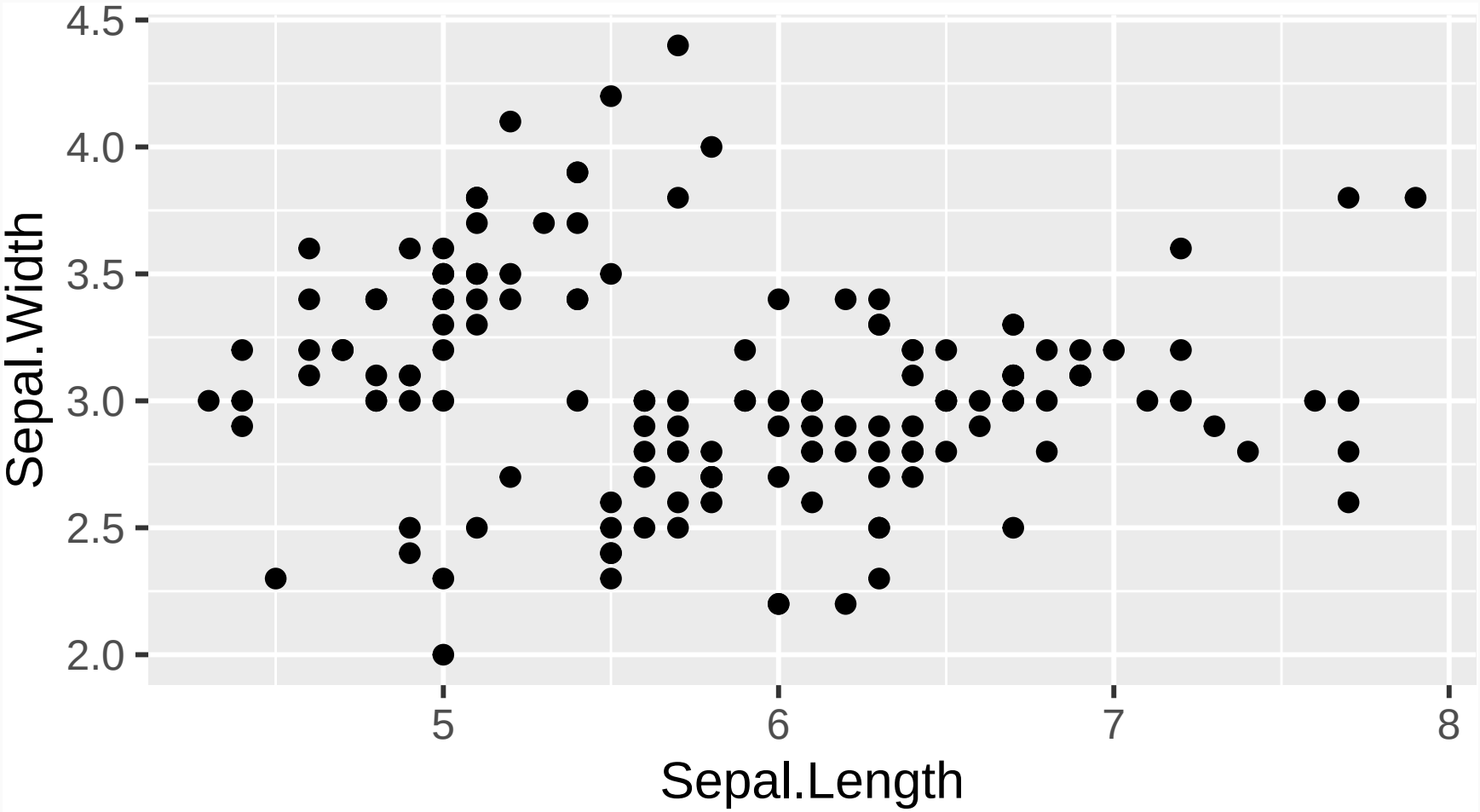
- Scales (scale_...): to control the mapping from data to aesthetic attributes (change colors, size...).

All these elements are gathered with the operator +.

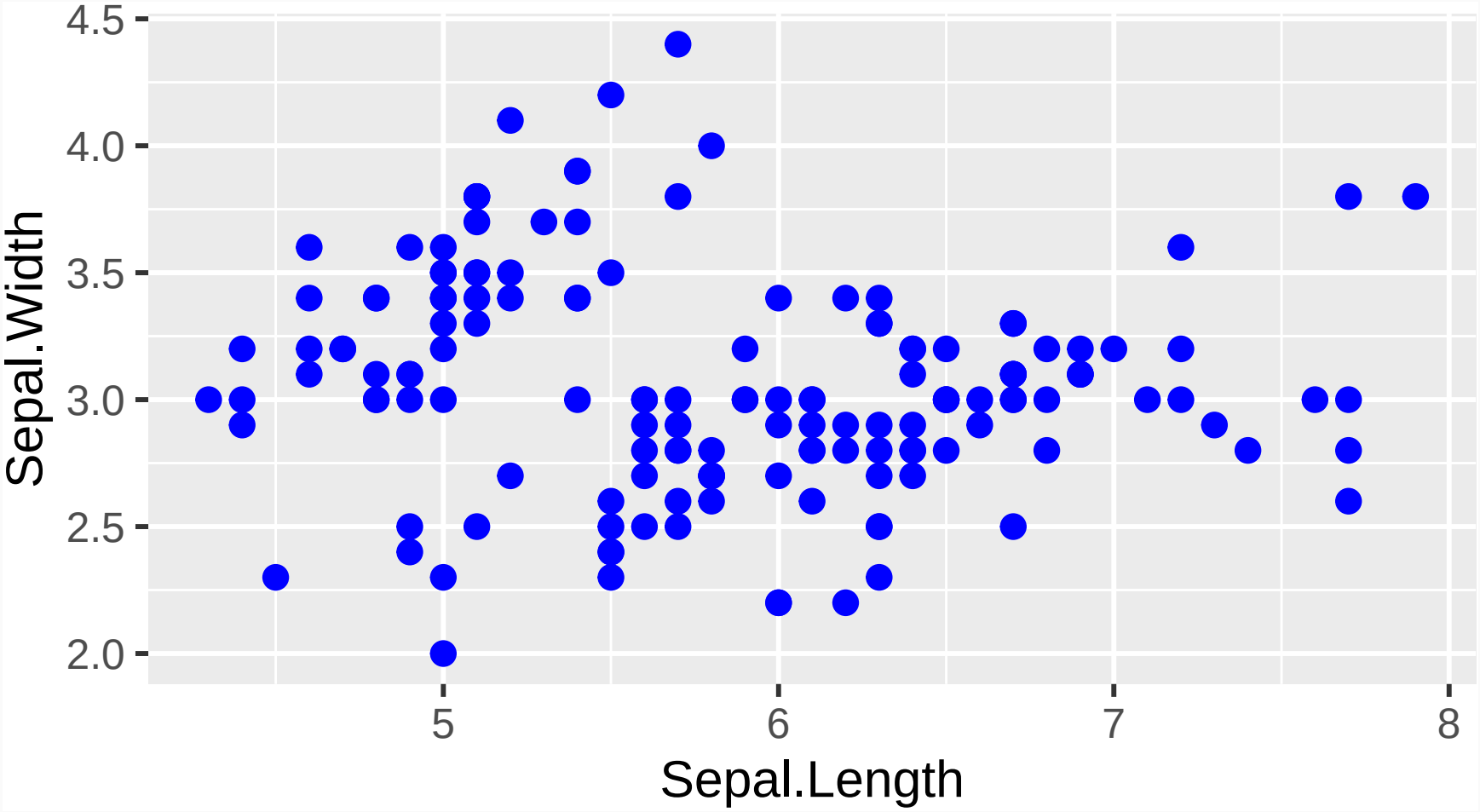
An example

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



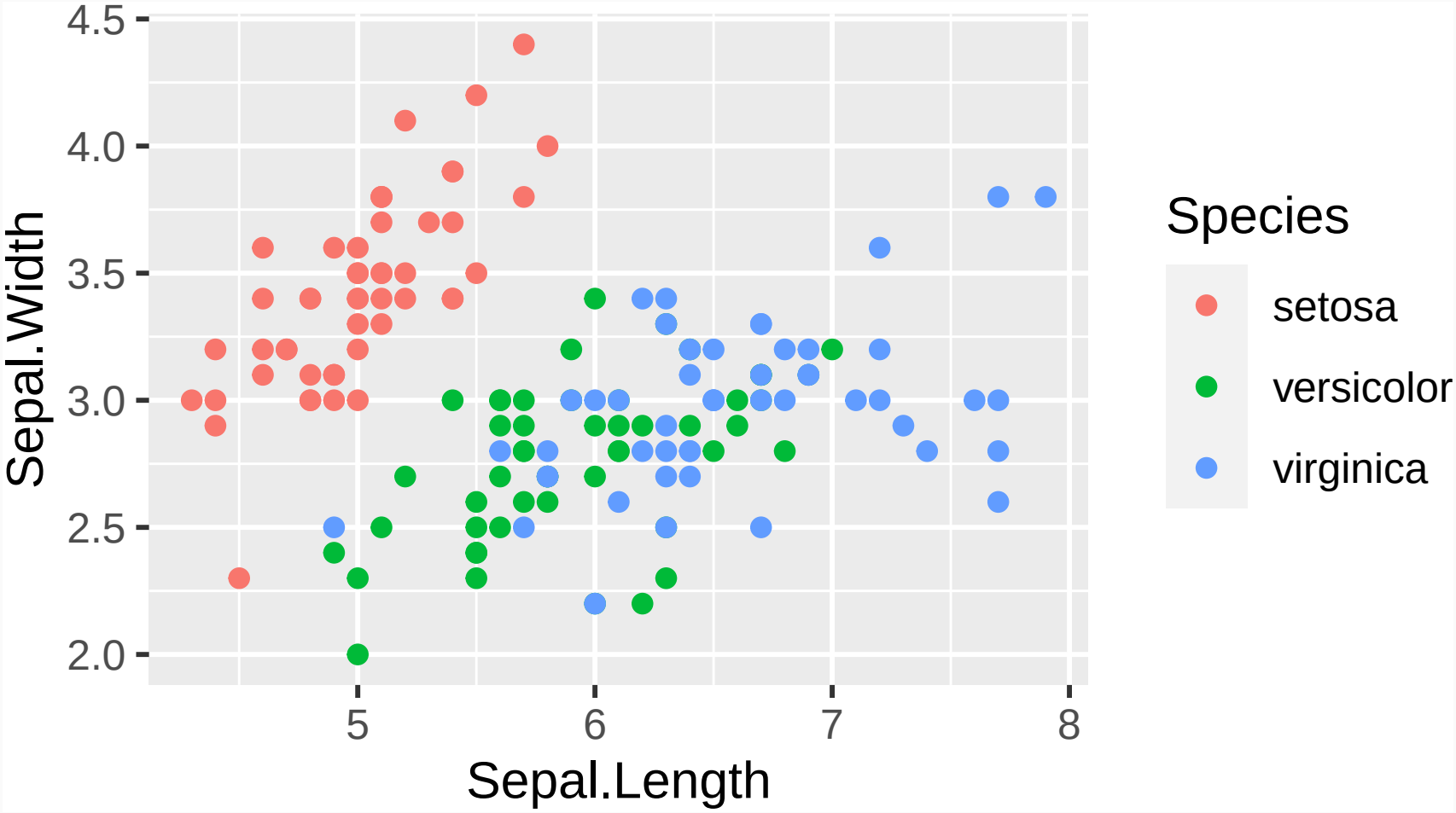
Color and size

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width)+
+   geom_point(color="blue",size=2)
```



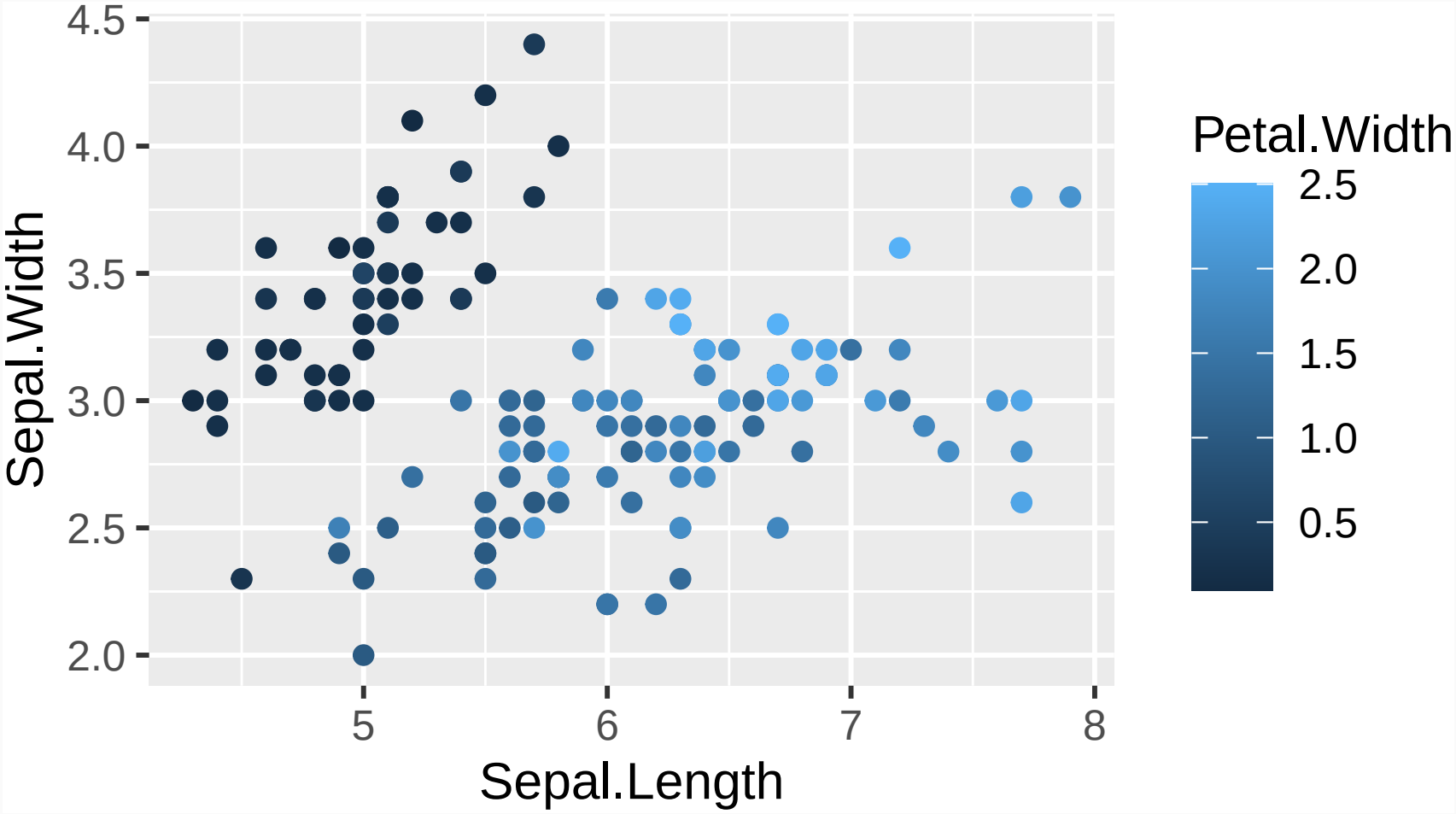
Color by (categorical) variable

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



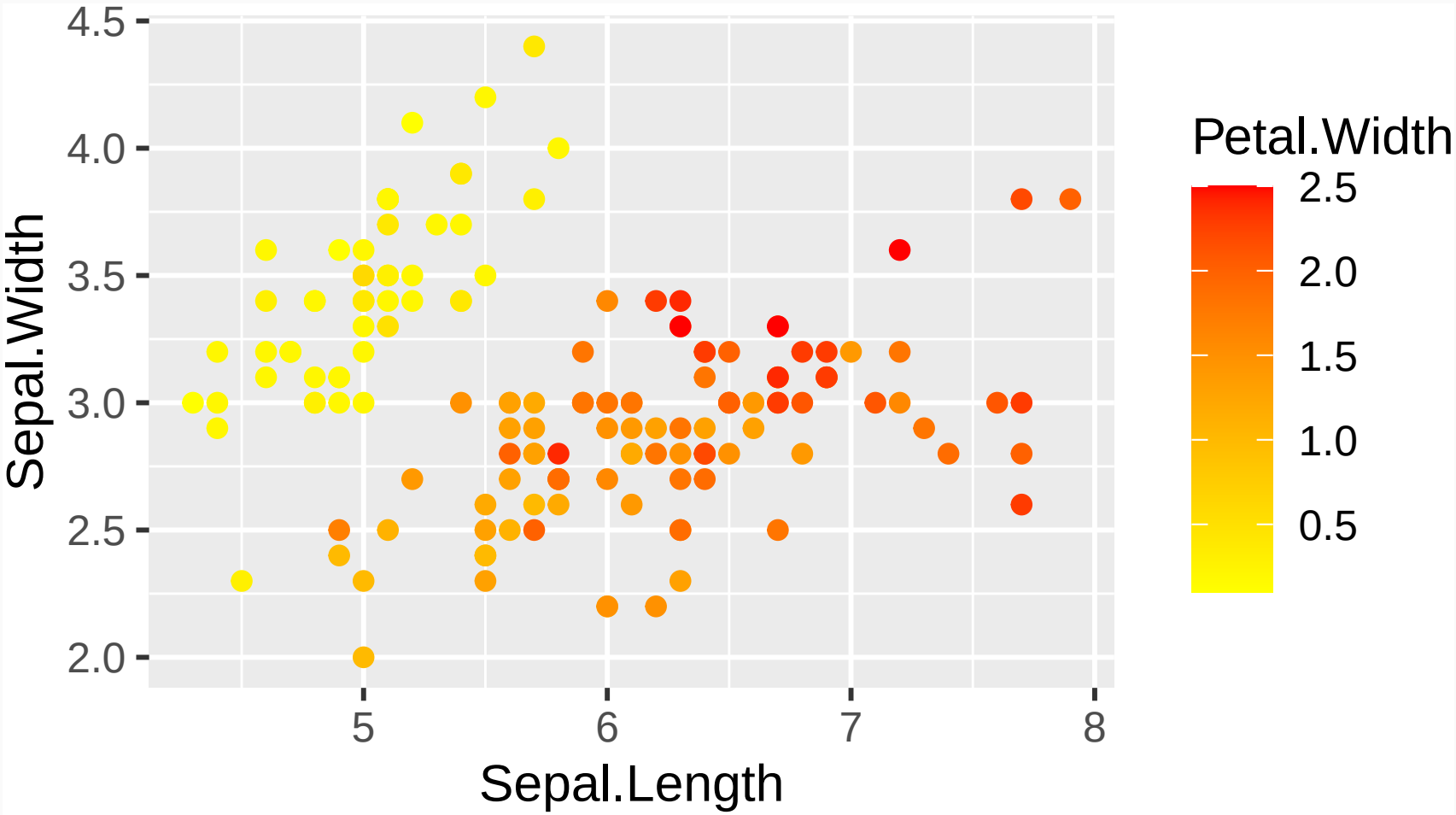
Color by (continous) variable

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



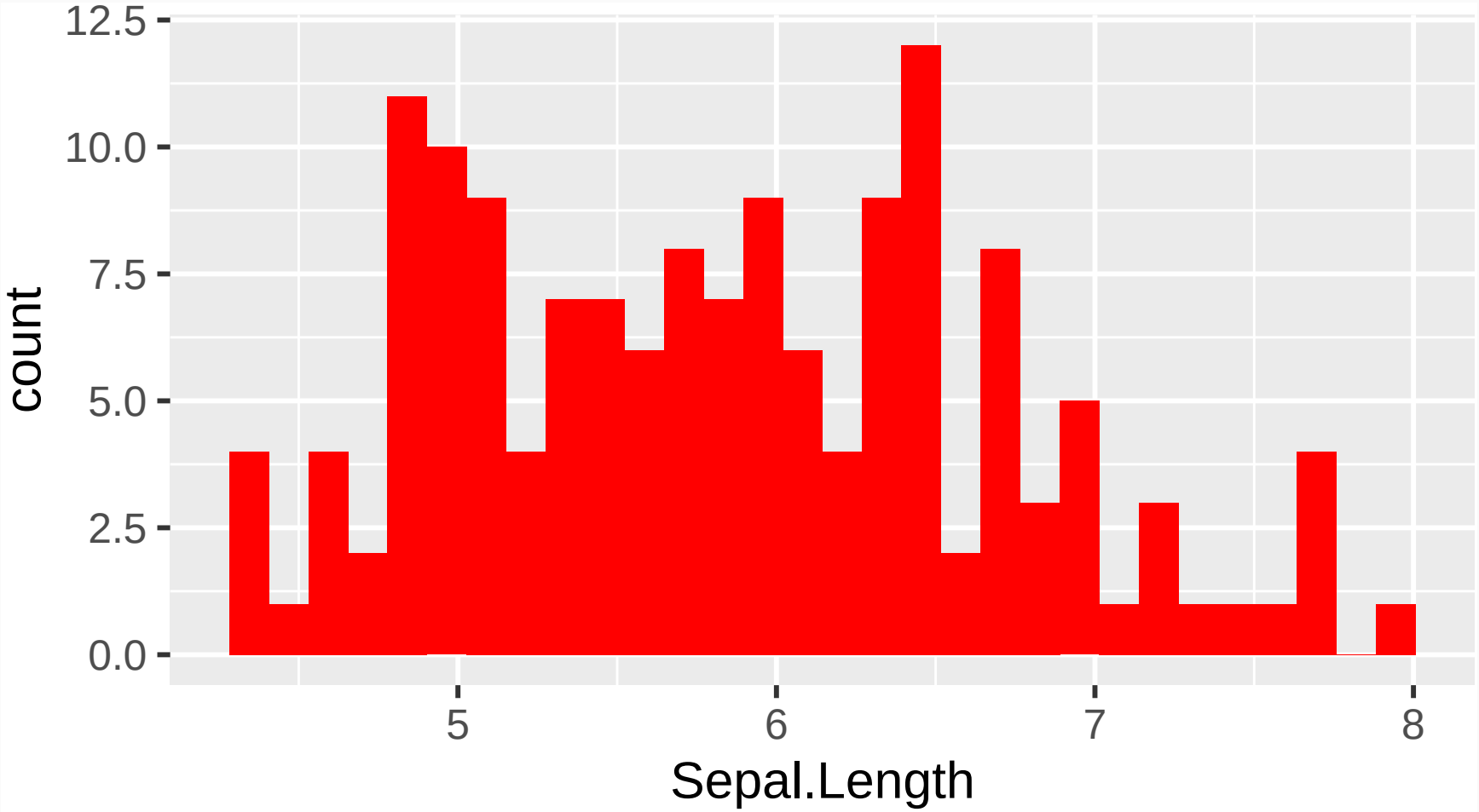
Color by (continous) variable

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width,
+                  color=Petal.Width)+geom_point()+
+            scale_color_continuous(low="yellow",high="red")
```



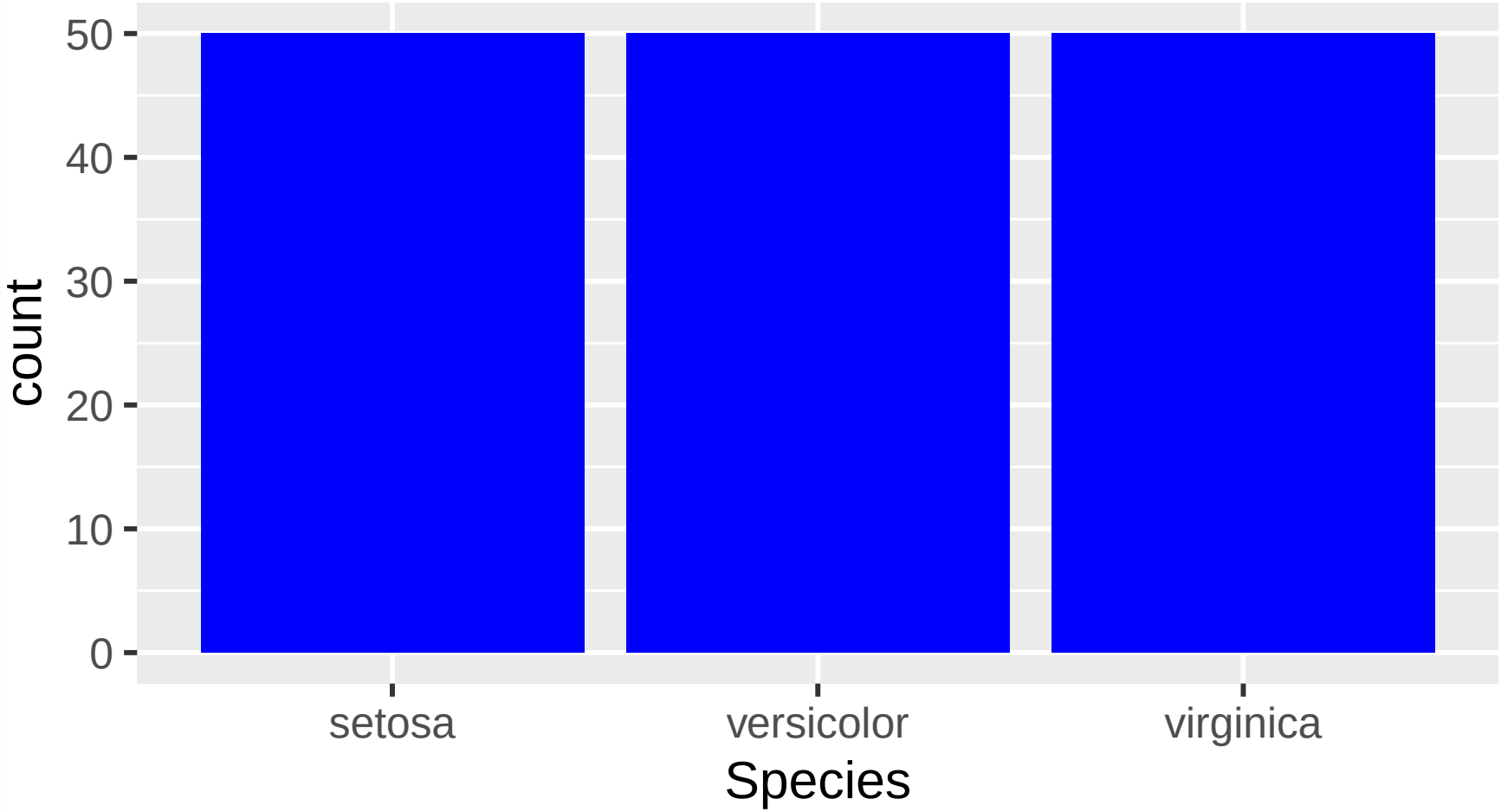
Histogram

```
> ggplot(iris)+aes(x=Sepal.Length)+geom_histogram(fill="red")
```



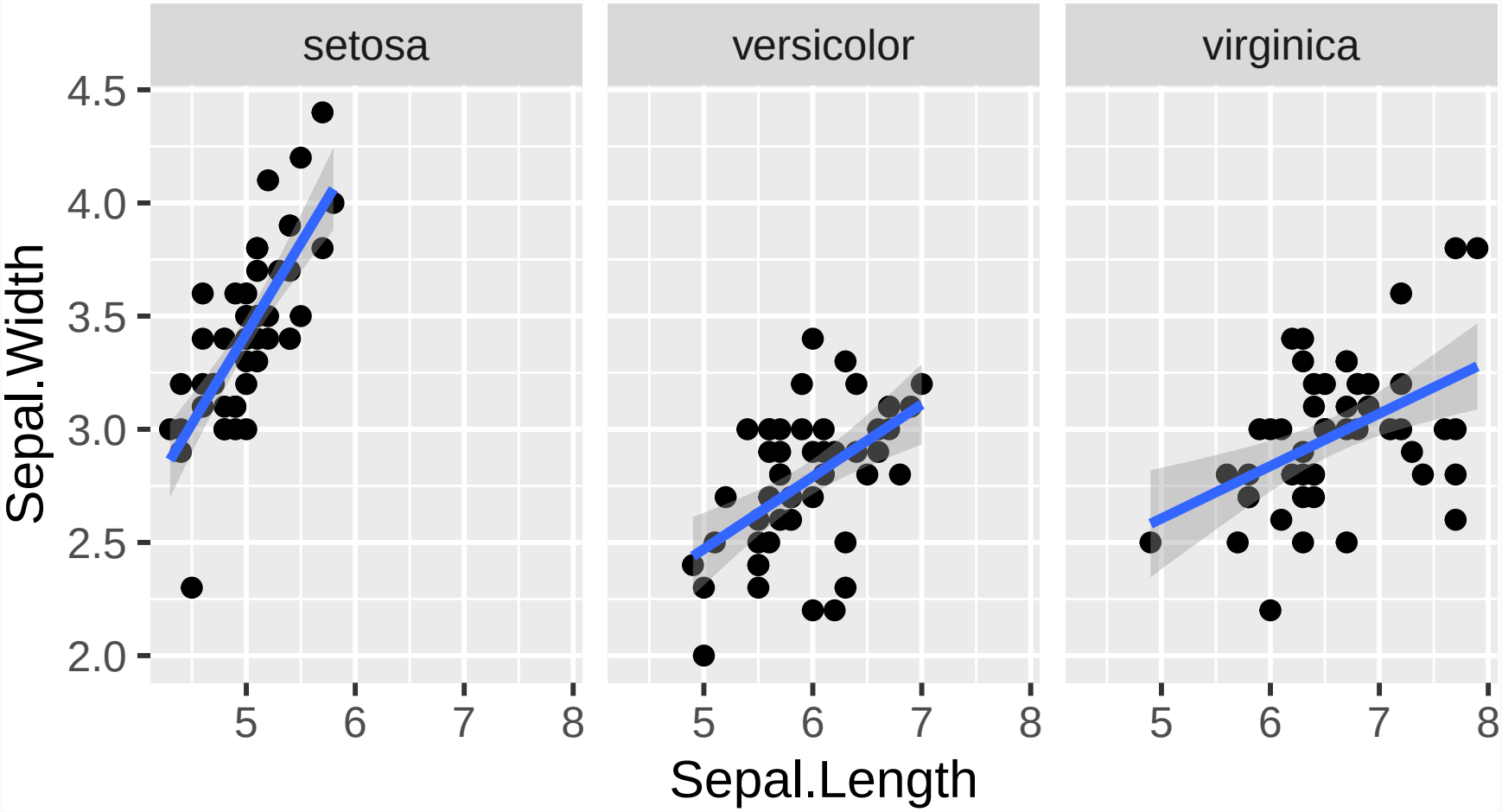
Barplot

```
> ggplot(iris)+aes(x=Species)+geom_bar(fill="blue")
```



Facetting (more complex)

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width)+geom_point()+
+       geom_smooth(method="lm")+facet_wrap(~Species)
```

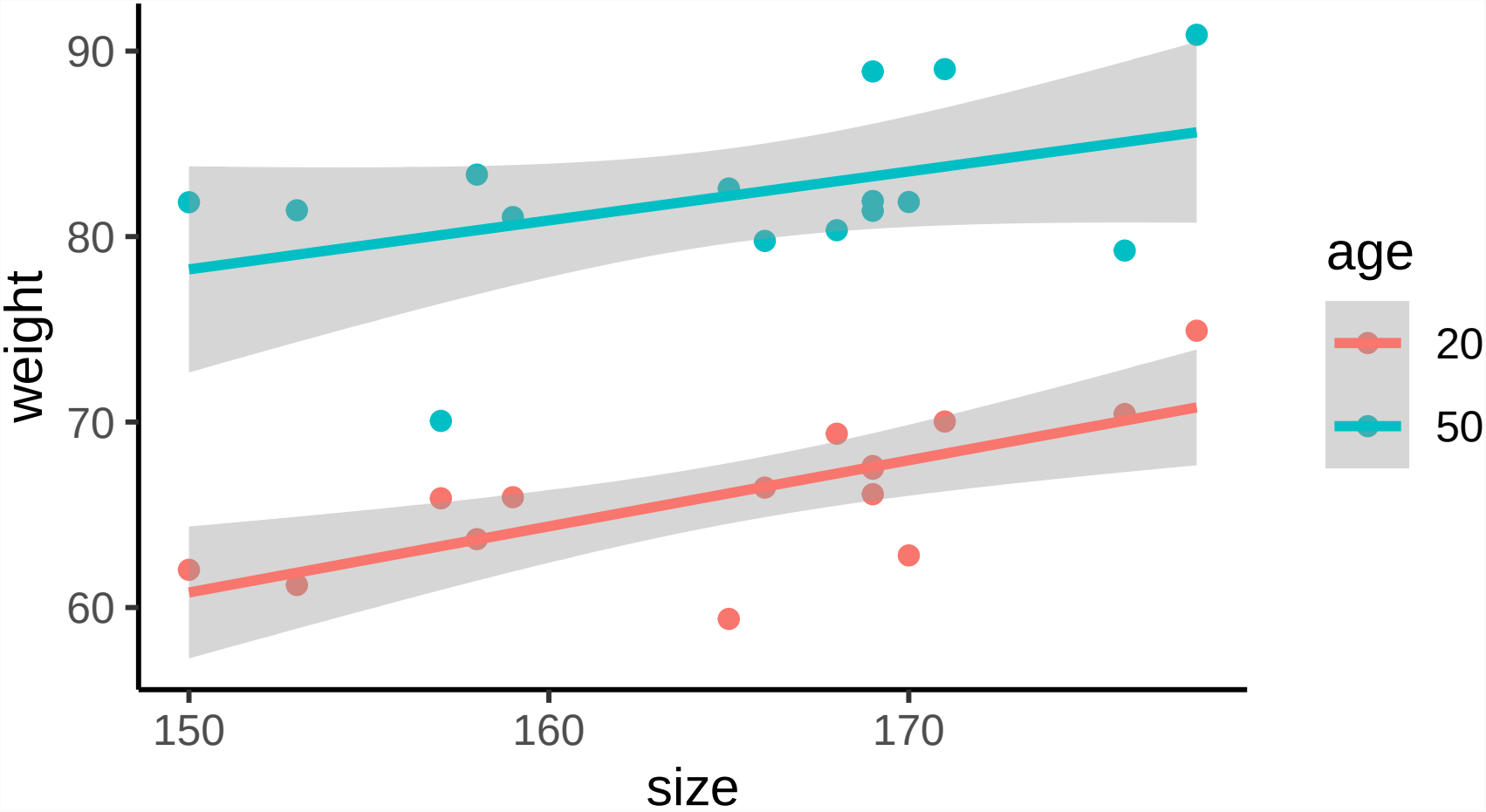


Combining ggplot with dplyr

- We often have to work on the dataframe to obtain an efficient ggplot syntax.
- For instance

```
> head(df)
# A tibble: 6 x 3
   size weight.20 weight.50
  <dbl>     <dbl>     <dbl>
1   153      61.2      81.4
2   169      67.5      81.4
3   168      69.4      80.3
4   169      66.1      81.9
5   176      70.4      79.2
6   169      67.6      88.9
```

Goal



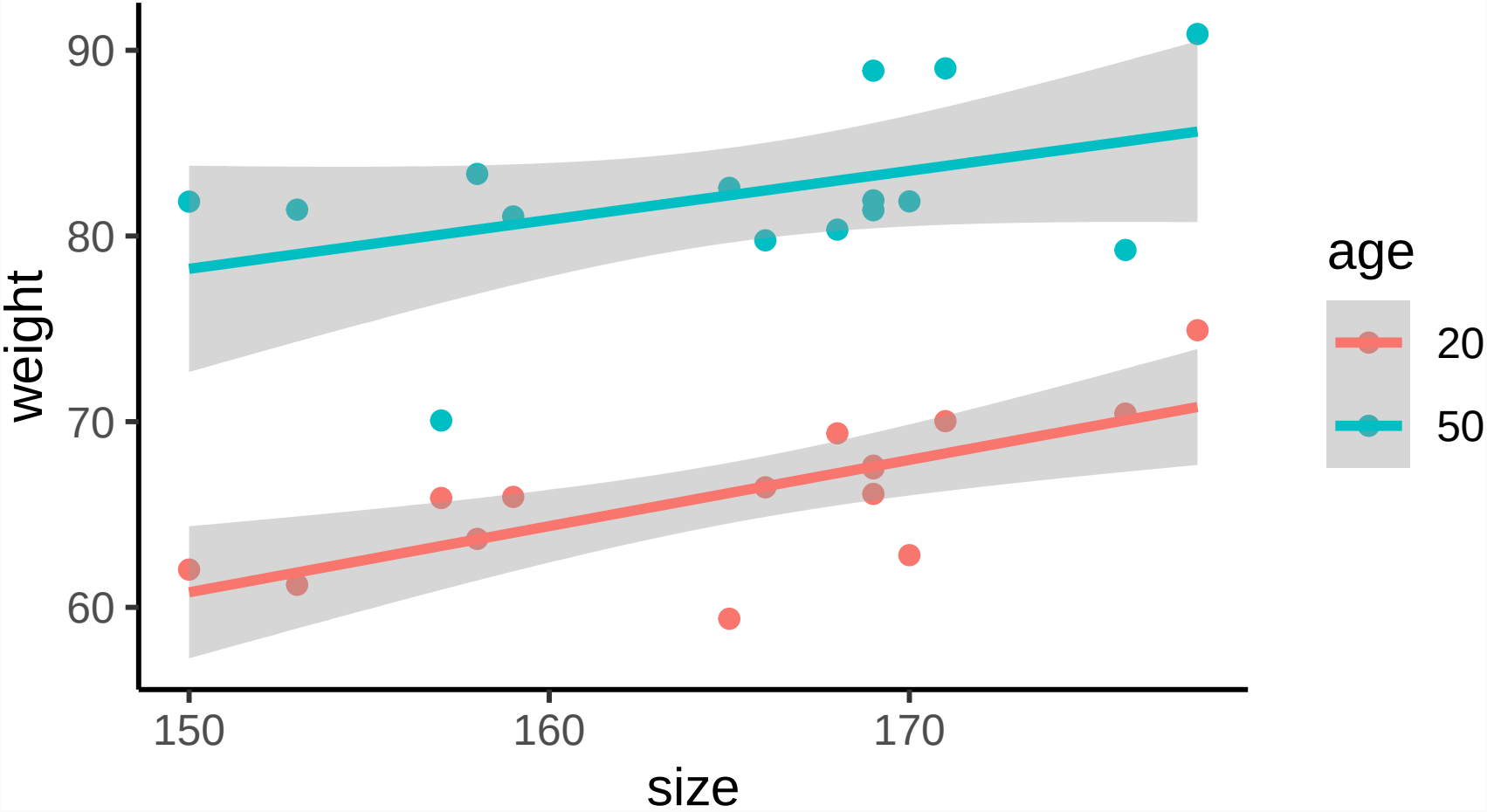
dplyr step

- Gather column weight.M and weight.W into one column weight with pivot_longer:

```
> df1 <- df %>% pivot_longer(-size,names_to="age",values_to="weight")
> df1 %>% head()
# A tibble: 6 x 3
   size age        weight
  <dbl> <chr>       <dbl>
1   153 weight.20    61.2
2   153 weight.50    81.4
3   169 weight.20    67.5
4   169 weight.50    81.4
5   168 weight.20    69.4
6   168 weight.50    80.3
> df1 <- df1 %>%
+   mutate(age=recode(age,"weight.20"="20","weight.50"="50"))
```

ggplot step

```
> ggplot(df1)+aes(x=size,y=weight,color=age)+
+   geom_point()+geom_smooth(method="lm")+theme_classic()
```



Complement: some demos

```
> demo(image)
> example(contour)
> demo(persp)
> library("lattice");demo(lattice)
> example(wireframe)
> library("rgl");demo(rgl)
> example(persp3d)
> demo(plotmath);demo(Hershey)
```

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```
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> example(persp3d)
> demo(plotmath);demo(Hershey)
```

$\Longrightarrow$ Work on this part of the tutorial.

Mapping

Introduction

- Many applications require maps to visualize data or results of a model;
- Many R packages: ggmap, RgoogleMaps, maps. . .
- In this part: ggmap, sf (static mapping) leaflet (interactive mapping).

Mapping

ggmap

Ggmap

- Similar to ggplot ;

Ggmap

- Similar to ggplot ;
- Instead of

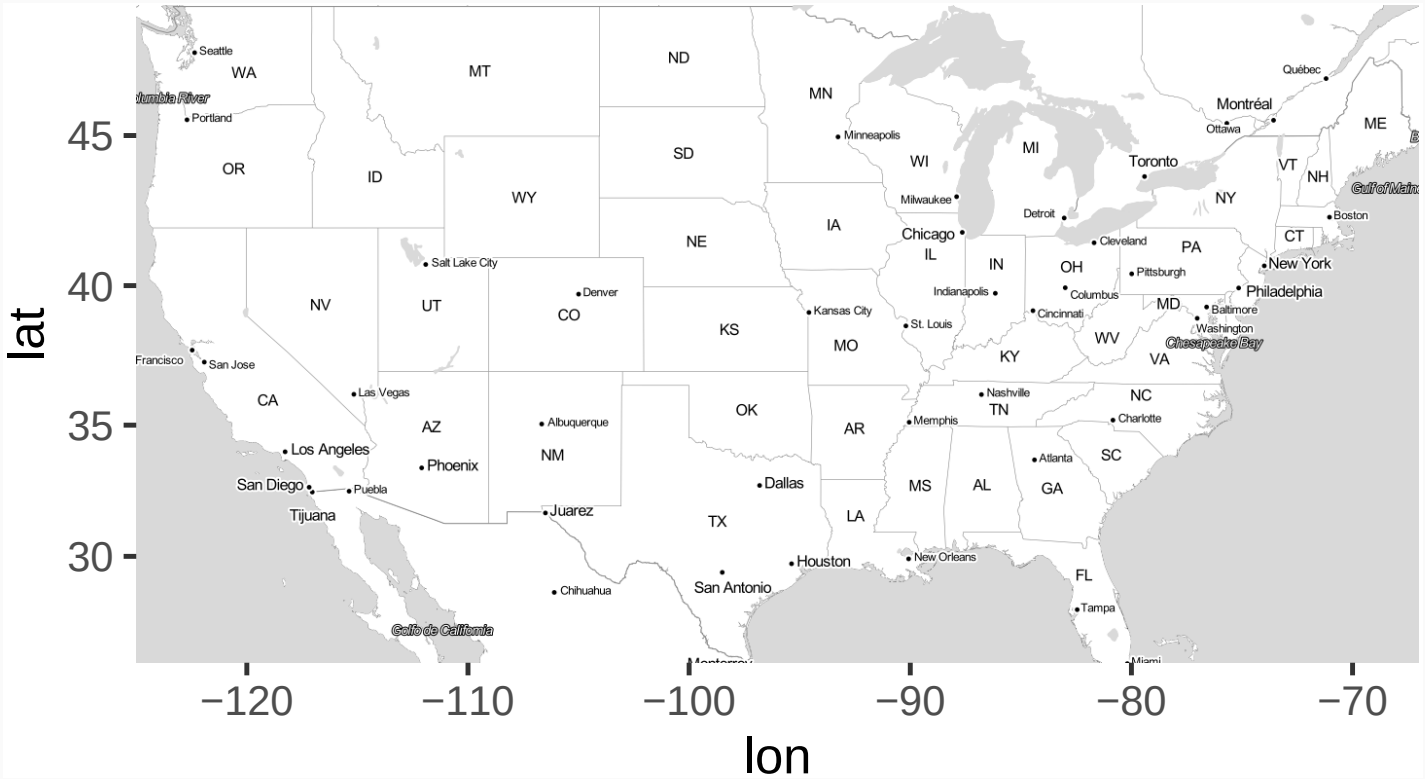
```
> ggplot(data)+...
```

- use

```
> ggmap(backgroundmap)+...
```

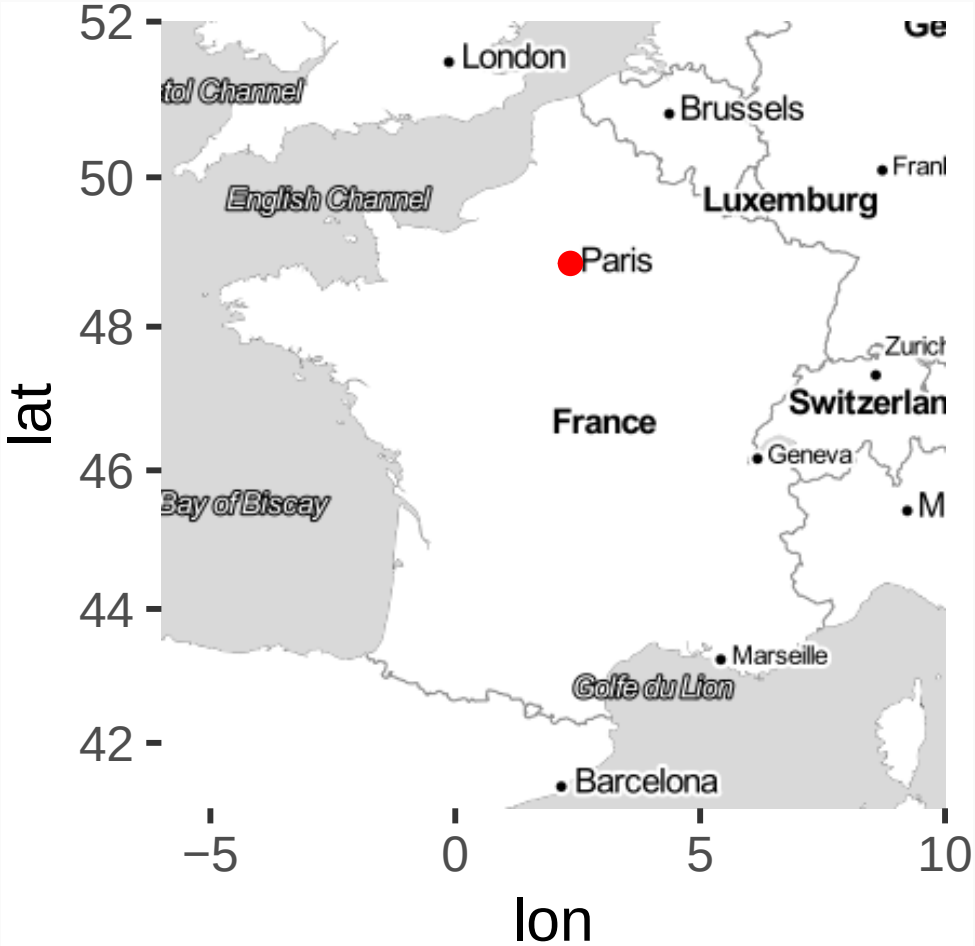
Background map

```
> library(ggmap)
> us <- c(left = -125, bottom = 25.75, right = -67, top = 49)
> map <- get_stamenmap(us, zoom = 5, maptype = "toner-lite")
> ggmap(map)
```



Adding informations with ggplot

```
> fr <- c(left = -6, bottom = 41, right = 10, top = 52)
> fond <- get_stamenmap(fr, zoom = 5,"toner-lite")
> Paris <- data.frame(lon=2.351499,lat=48.85661)
> ggmap(fond)+geom_point(data=Paris,aes(x=lon,y=lat),color="red")
```



Mapping

Shapefile contours with sf

sf package

- Ggmap: ok for easy maps (background with some points).
- Not sufficient for more complex representations (color countries according to variables).

sf package

- Ggmap: ok for easy maps (background with some points).
- Not sufficient for more complex representations (color countries according to variables).
- sf allows to manage specific tools for mapping: boundaries for countries or department, coordinate systems (latitudes-longitudes, World Geodesic System 84. . .)
- Background map with format shapefile (contours represented by polygons)
- Compatible with ggplot.

sf package

- Ggmap: ok for easy maps (background with some points).
- Not sufficient for more complex representations (color countries according to variables).
- sf allows to manage specific tools for mapping: boundaries for countries or department, coordinate systems (latitudes-longitudes, World Geodesic System 84. . .)
- Background map with format shapefile (contours represented by polygons)
- Compatible with ggplot.

References

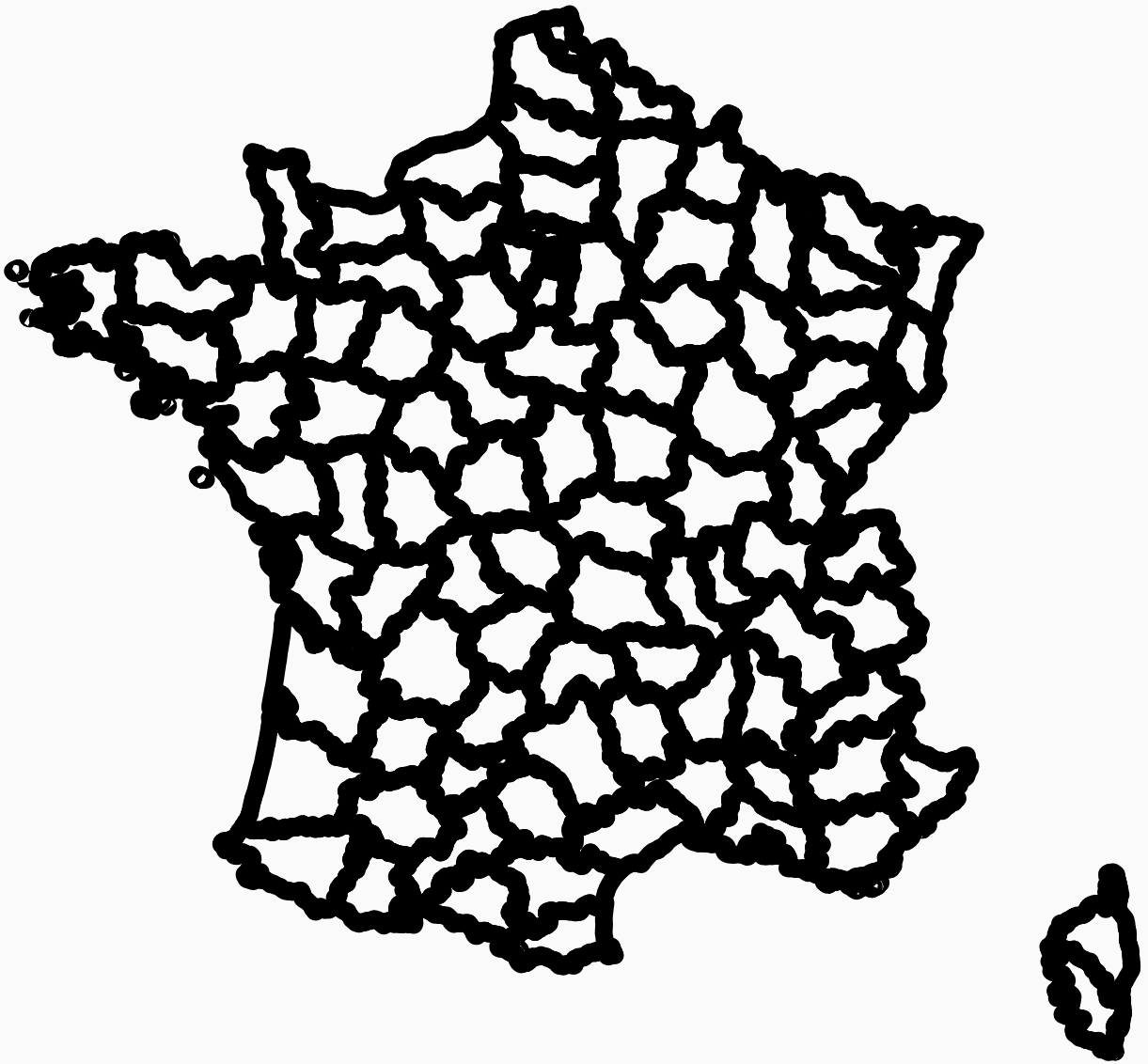
- https://statnmap.com/fr/2018-07-14-initiation-a-la-cartographie-avec-sf-et-compagnie/
- Vignettes on the cran :

Example

```
> library(sf)
> dpt <- read_sf("./DATA/dpt")
> dpt[1:5,3]
Simple feature collection with 5 features and 1 field
geometry type:  MULTIPOLYGON
dimension:      XY
bbox:           xmin: 644570 ymin: 6290136 xmax: 1022851 ymax: 6997000
CRS:            2154
# A tibble: 5 x 2
  NOM_DEPT                                                    geometry
  <chr>                                                <MULTIPOLYGON [m]>
1 AIN                 (((919195 6541470, 918932 6541203, 918628 6540523~
2 AISNE               (((735603 6861428, 735234 6861392, 734504 6861270~
3 ALLIER              (((753769 6537043, 753554 6537318, 752879 6538099~
4 ALPES-DE-HAUTE-P~ (((992638 6305621, 992263 6305688, 991610 6306540~
5 HAUTES-ALPES        (((1012913 6402904, 1012577 6402759, 1010853 6402~
```

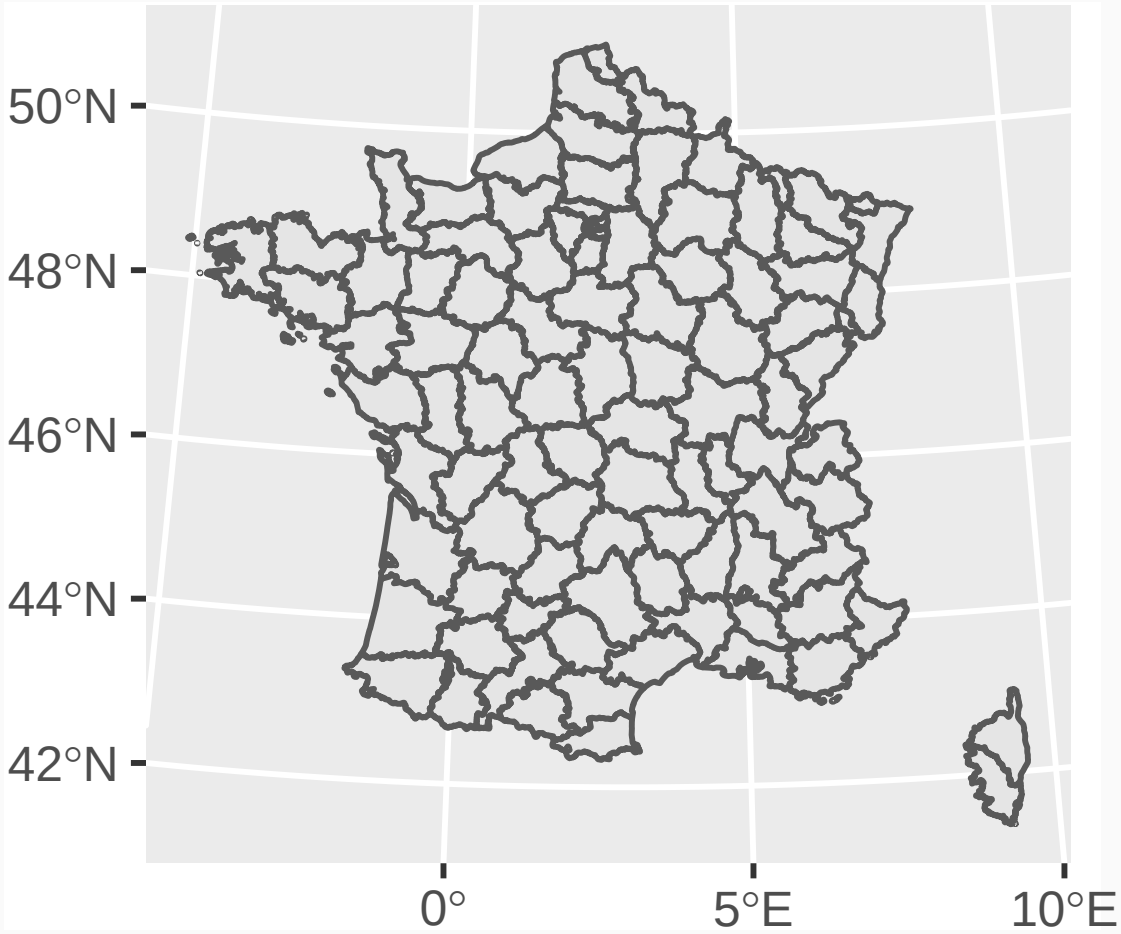
Visualize with plot

```
> plot(st_geometry(dpt))
```



Visualize with ggplot

```
> ggplot(dpt)+geom_sf()
```



Adding points on the map

- Define coordinates with st_point

```
> point <- st_sfc(st_point(c(2.351462,48.85670)),
+               st_point(c(4.832011,45.75781)),
+               st_point(c(5.369953,43.29617)))
```

Adding points on the map

- Define coordinates with st_point

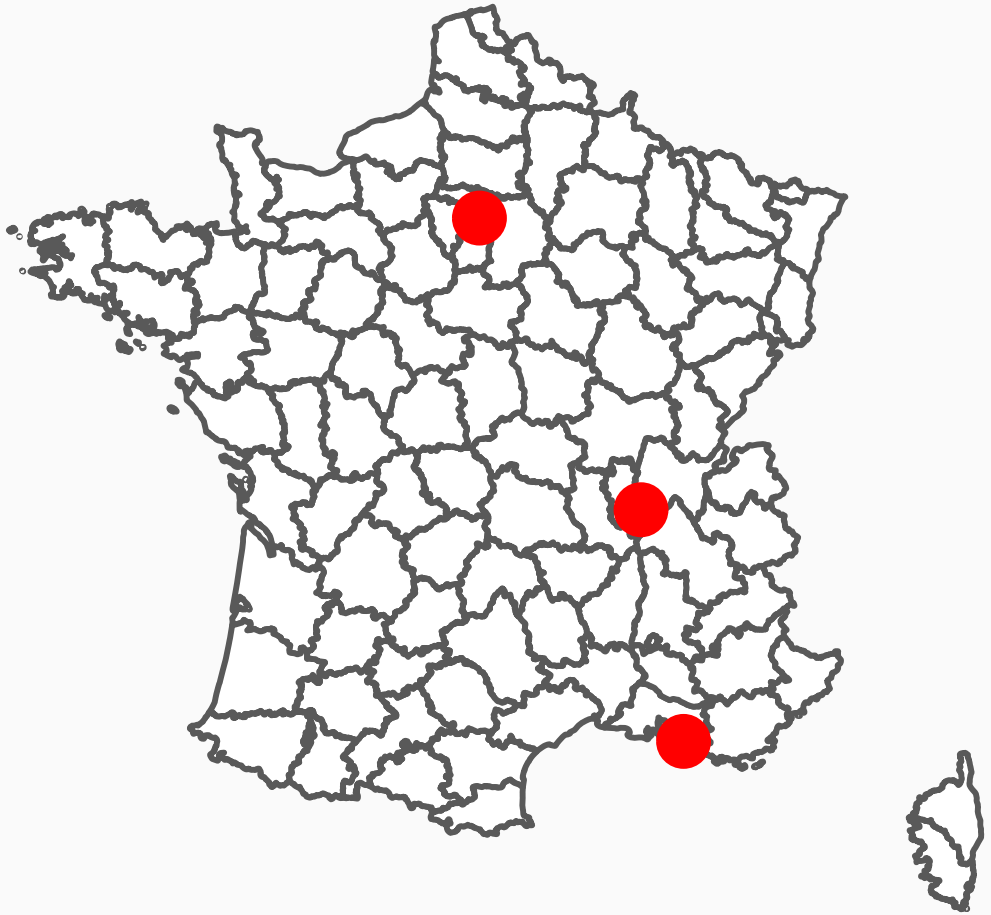
```
> point <- st_sfc(st_point(c(2.351462,48.85670)),
+               st_point(c(4.832011,45.75781)),
+               st_point(c(5.369953,43.29617)))
```

- Specify the coordinate system (4326 for lat-lon)

```
> st_crs(point) <- 4326 #lat-lon
> point
Geometry set for 3 features
geometry type:  POINT
dimension:      XY
bbox:           xmin: 2.351462 ymin: 43.29617 xmax: 5.369953 ymax: 48.85
CRS:            EPSG:4326
```

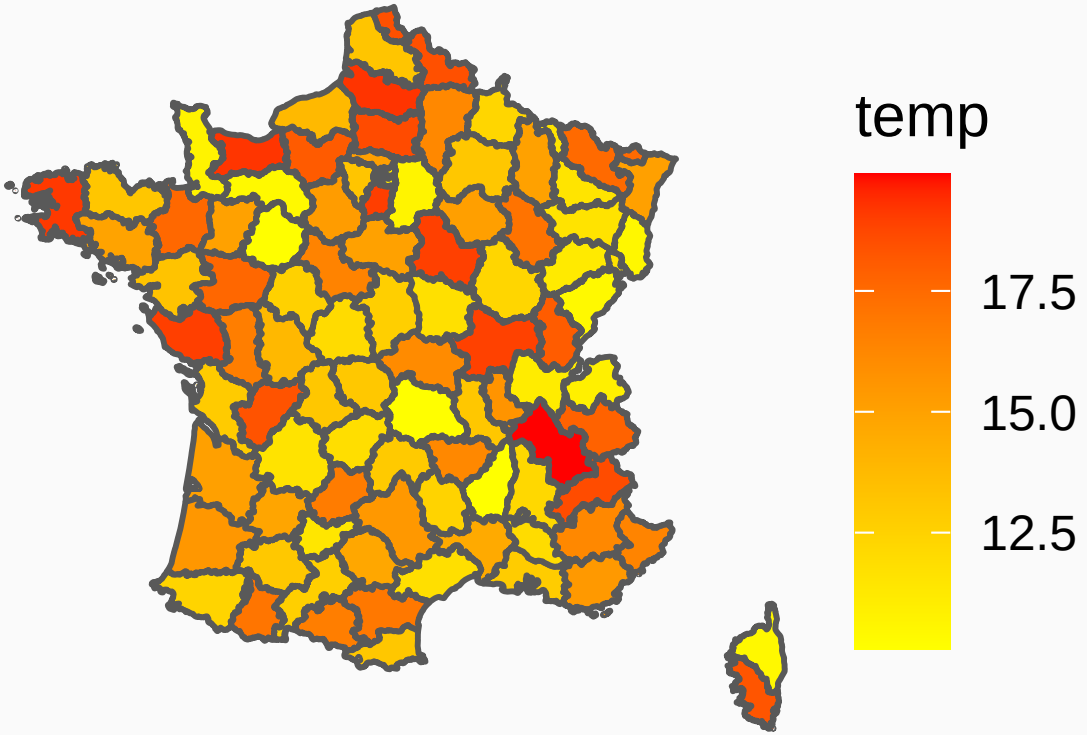
ggplot step

```
> ggplot(dpt) + geom_sf(fill="white")+
+   geom_sf(data=point,color="red",size=4)+theme_void()
```



Coloring polygons

```
> set.seed(1234)
> dpt1 <- dpt %>% mutate(temp=runif(96,10,20))
> ggplot(dpt1) + geom_sf(aes(fill=temp)) +
+   scale_fill_continuous(low="yellow",high="red")+
+   theme_void()
```



$\Longrightarrow$ Work on this part of the tutorial.

Mapping

Interactive maps with leaflet

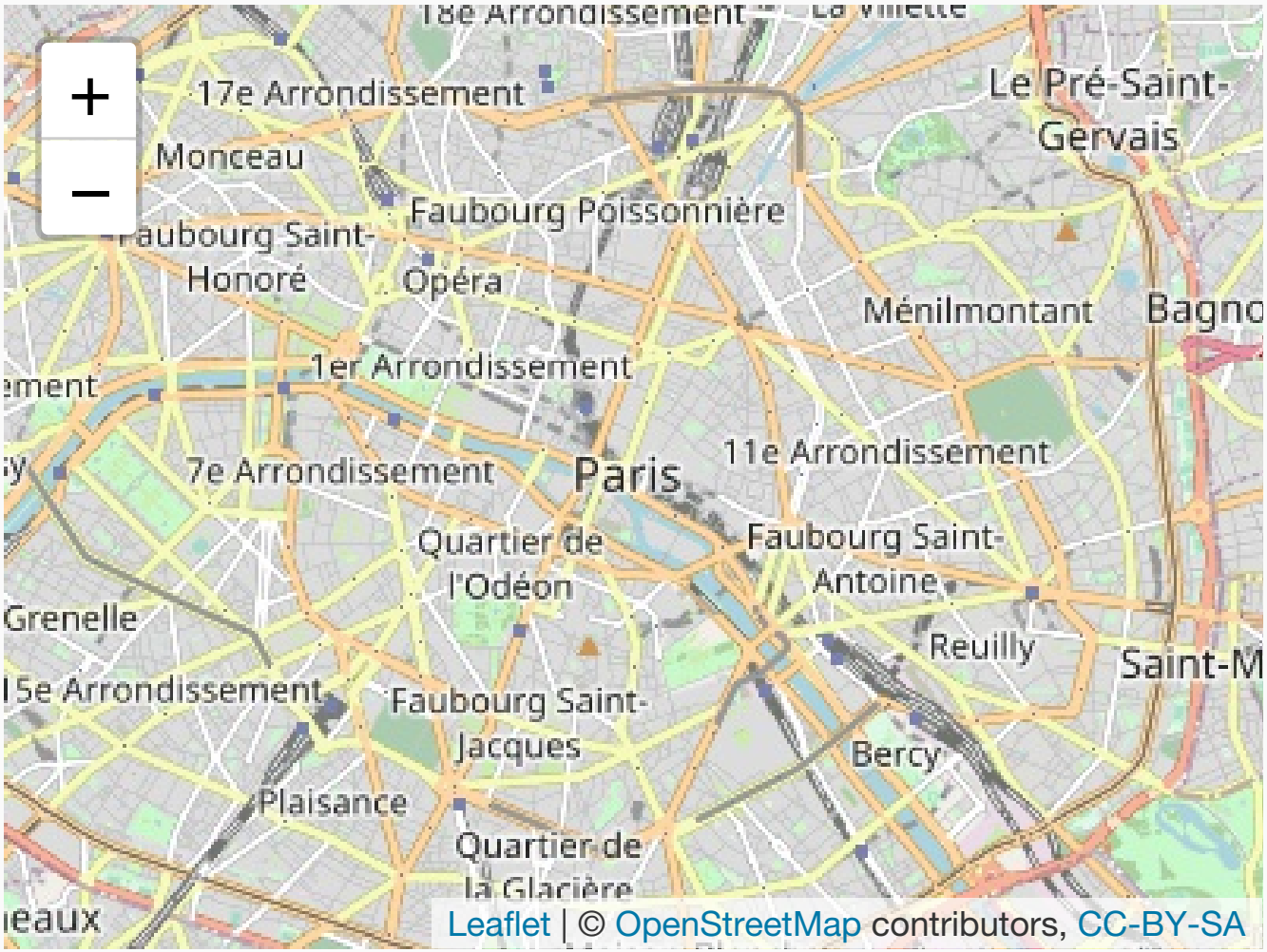
Background map

- Leaflet is one of the most popular open-source JavaScript libraries for interactive maps.
- Documentation: here

```
> library(leaflet)
> leaflet() %>% addTiles()
```

Many background styles

```
> Paris <- c(2.35222,48.856614)
> leaflet() %>% addTiles() %>%
+   setView(lng = Paris[1], lat = Paris[2],zoom=12)
```



```
> leaflet() %>% addProviderTiles("Stamen.Toner") %>%
+   setView(lng = Paris[1], lat = Paris[2], zoom = 12)
```

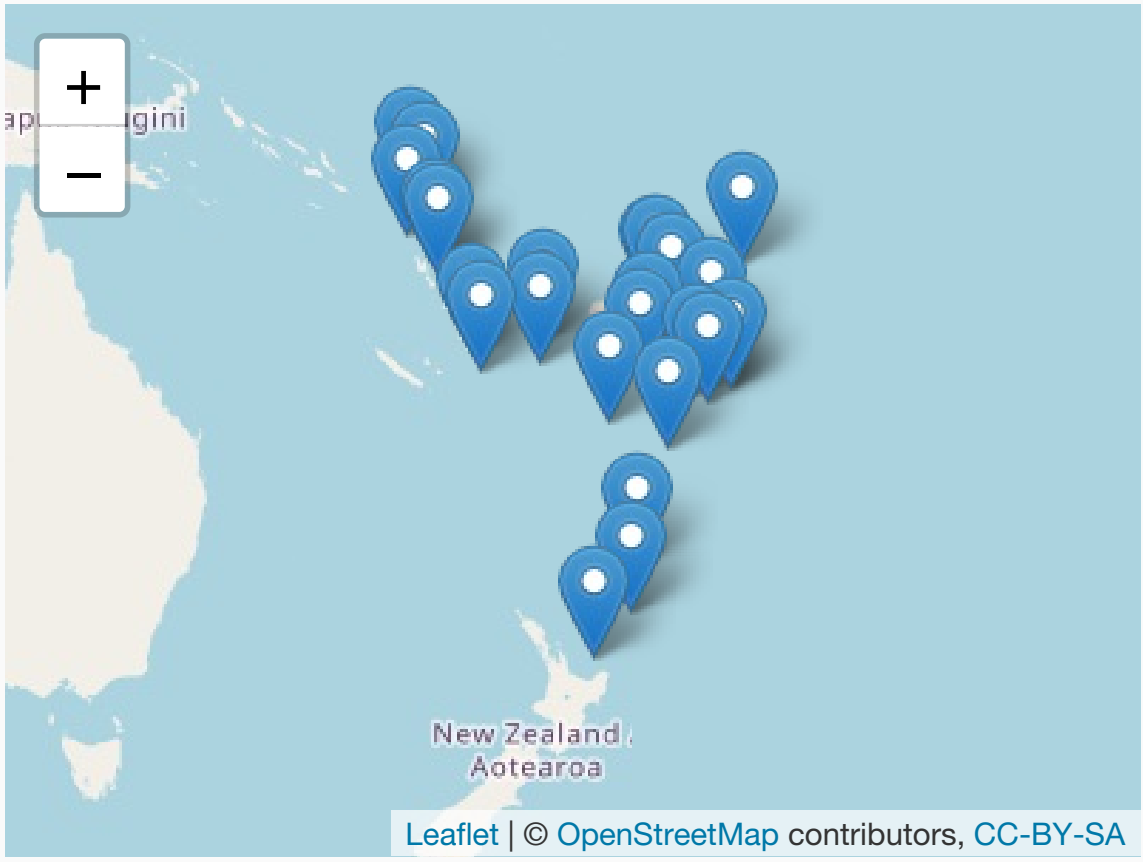
Leaflet with data

- Location of 1000 seismic events near Fiji

```
> data(quakes)
> head(quakes)
     lat   long depth mag stations
1 -20.42 181.62   562 4.8       41
2 -20.62 181.03   650 4.2       15
3 -26.00 184.10    42 5.4       43
4 -17.97 181.66   626 4.1       19
5 -20.42 181.96   649 4.0       11
6 -19.68 184.31   195 4.0       12
```

Visualize seismics with magnitude more then 5.5

```
> quakes1 <- quakes %>% filter(mag>5.5)
> leaflet(data = quakes1) %>% addTiles() %>%
+   addMarkers(~long, ~lat, popup = ~as.character(mag))
```

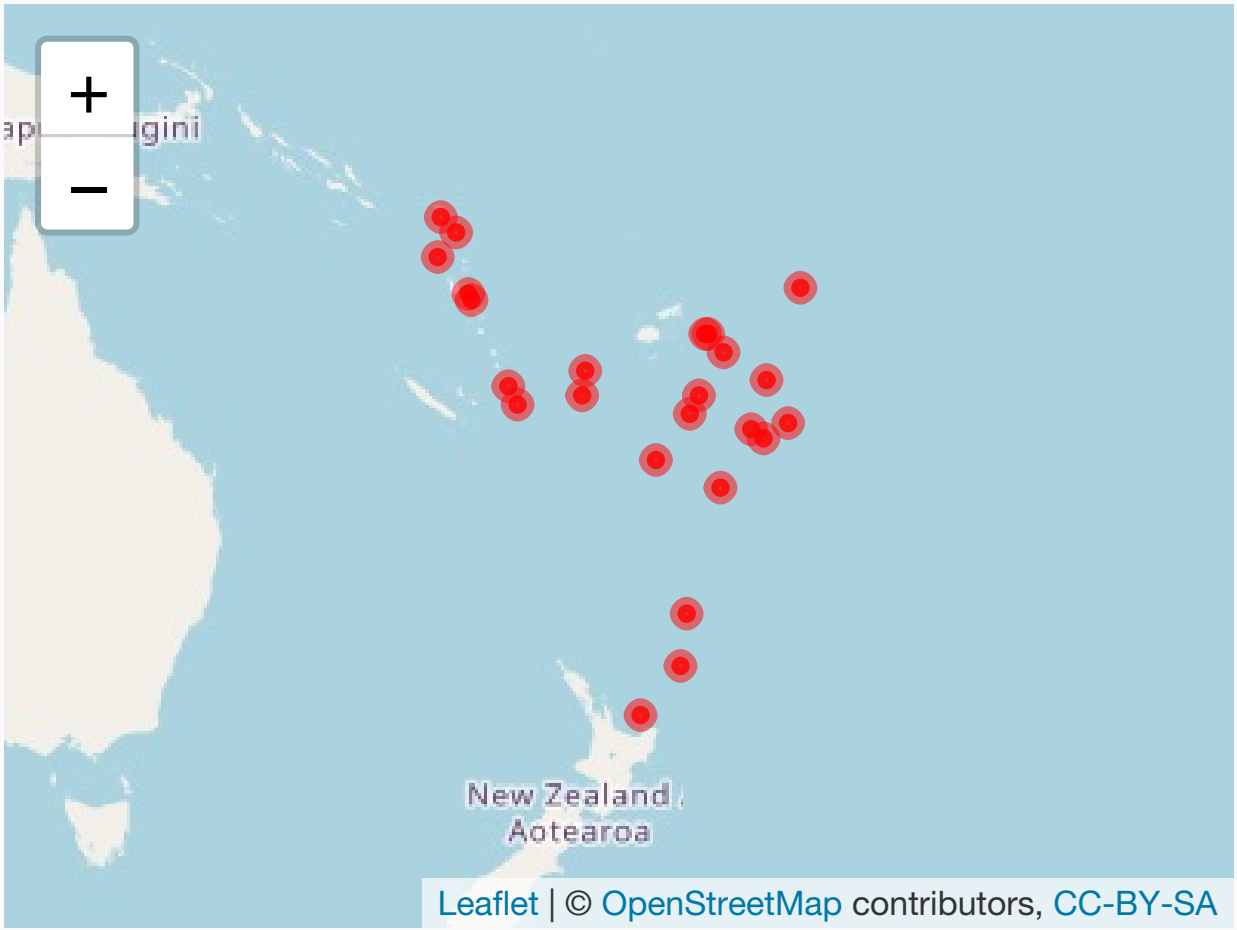


Remark

When you click on a marker, the magnitude appears.

addCircleMarkers

```
> leaflet(data = quakes1) %>% addTiles() %>%
+   addCircleMarkers(~long, ~lat, popup=~as.character(mag),
+                    radius=3,fillOpacity = 0.8,color="red")
```



Some Dynamic visualization tools

The tools

- Classical charts with rAmCharts and plotly.
- Graphs with visNetwork.
- Dashboard with flexdashboard.

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- Classical charts with rAmCharts and plotly.
- Graphs with visNetwork.
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Tutorial

Everything is here:
https://lrouviere.github.io/TUTO_DATAVIZ/dynamic.html