Data Visualisation Using R

Lecture-1

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Main objectives

- Identify the major issues and directions in contemporary data visualisation.
- Selecting appropriate visualisation techniques for the real world problem.
- Produce high quality figures for effective communication and scientific interpretation.

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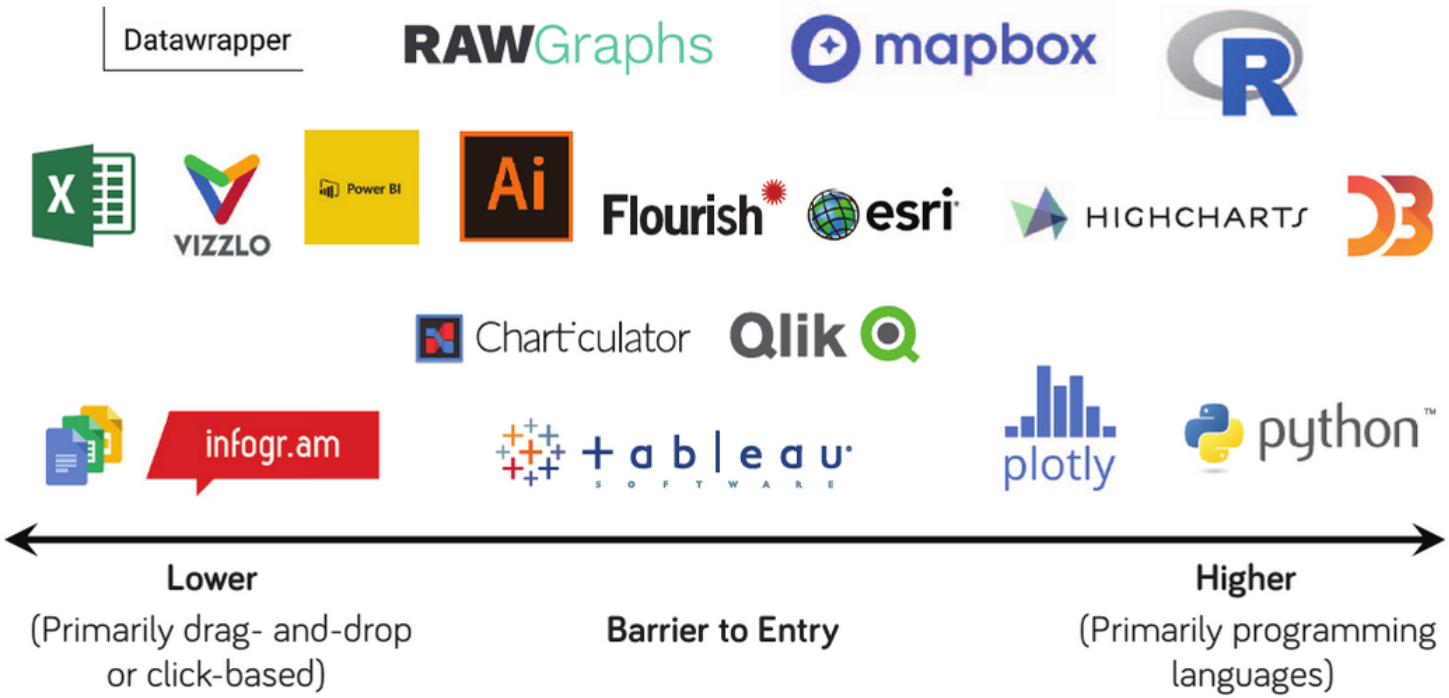
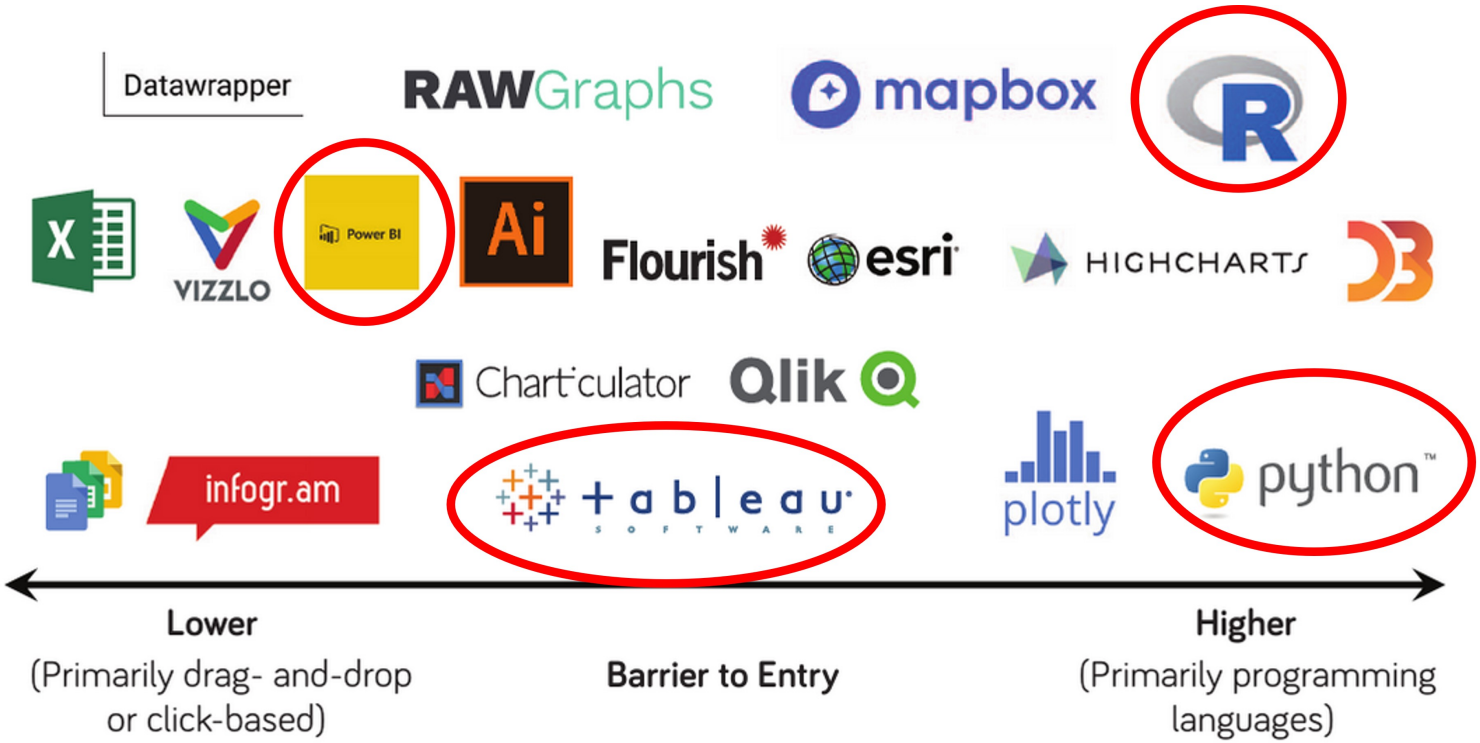
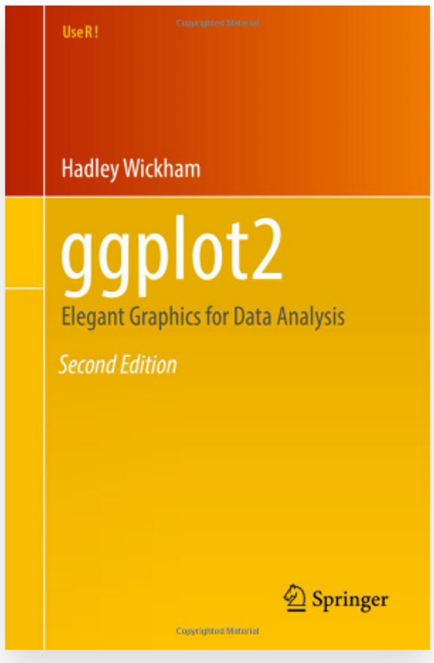
Data Visualisation Platforms

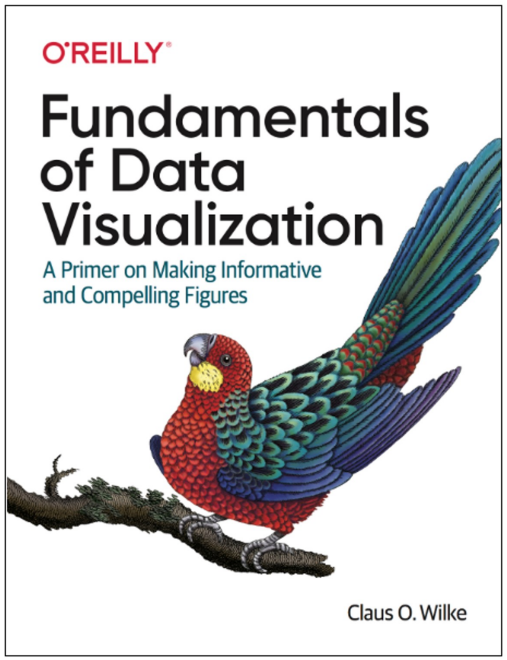


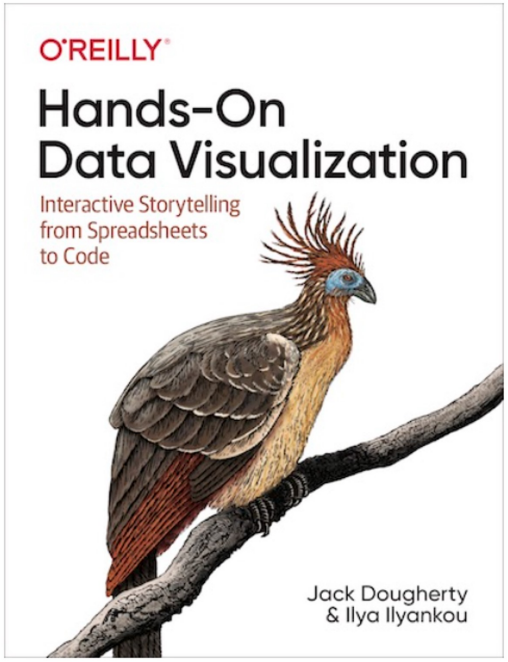
Visualisation Platforms taught in this Class



Books on Data Visualisation







Outline

1. Different Visualisations for different data types
2. Three most common data types: (i) proportions, (ii) point data, and (iii) distributions.
3. Proportions data examples and charts
4. Comparing Proportions for many categories
5. Point data examples and charts
6. Bar chart for point data (stacking principle)
7. Point chart for point data
8. Distributional data
9. Comparing distributional data of many categories
10. Summary

Different visualisations for different data

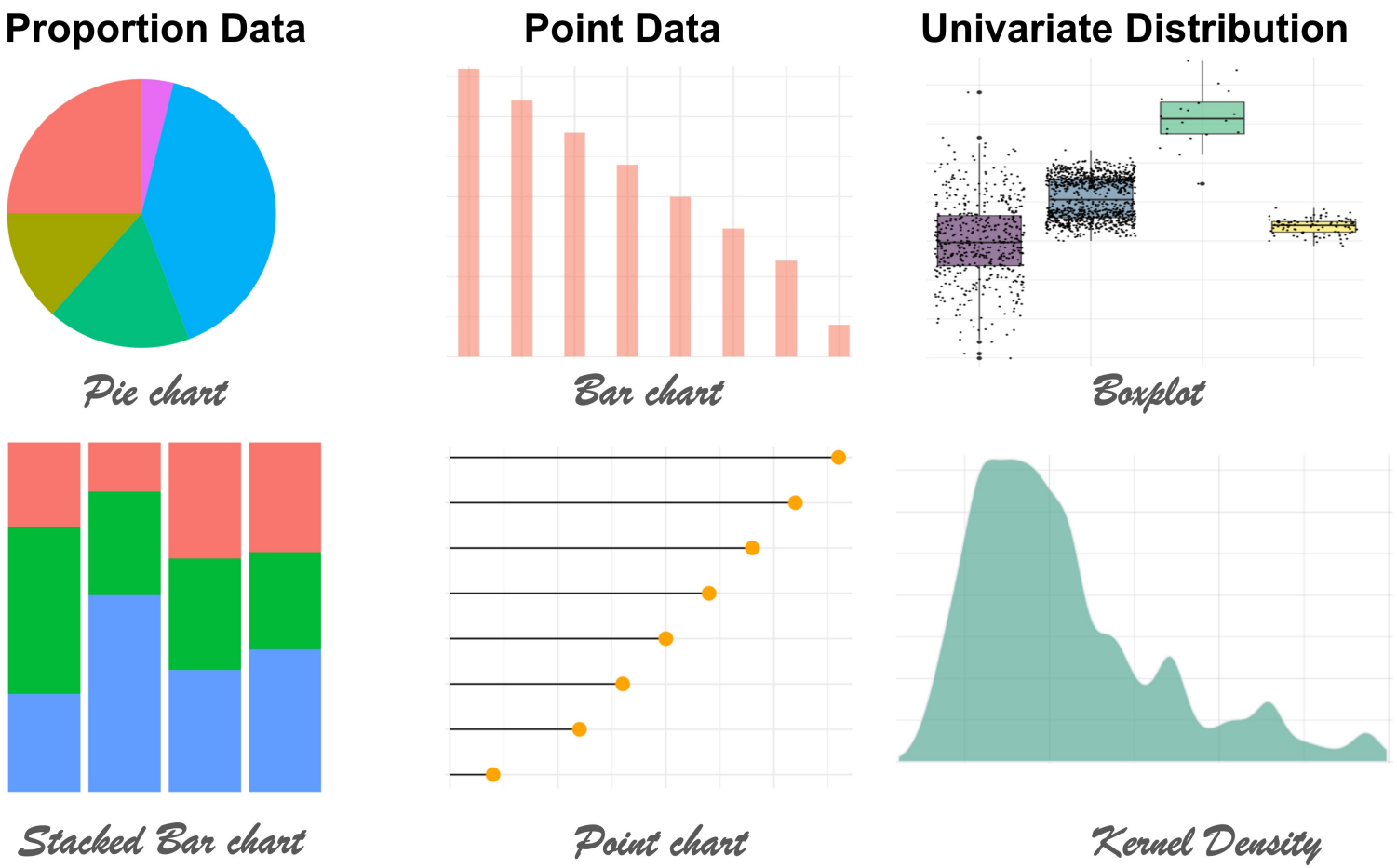


Figure 1: *Standard charts for three common data types.*

Examples of three data types

- Proportions (Percentage data): Data representing proportion (or percentage) of the whole population — all proportions (percentages) should add upto one (hundred). Examples: (i) *proportions of total revenue generated by different departments*, (ii) *percentages of total gun deaths for all states*, or (iii) *proportions of reported disease cases by the world health organisation (WHO) for different disease types*.
- Point data: Data representing a single summary. Examples: (i) *Total number of disease cases in a state*, (ii) *Risk of gun murder for each state in a year*, or (iii) *Median house prices in different suburbs*.
- Distributional data: Data representing many samples from a population. Examples: (i) *Blood sugar levels of patients after taking a new drug treatment*, (ii) *Samples from agricultural field trials to measure the risk of a fungal disease*, or (iii) *Exam marks of students*.

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USA state-wise gun murder data for 2010

```
> library(dslabs)
> data("murders")
> help(murders)
```

US gun murders by state for 2010

Description

Gun murder data from FBI reports. Also contains the population of each state.

Details

- state. US state
- abb. Abbreviation of US state
- region. Geographical US region
- population. State population (2010)
- total. Number of gun murders in state (2010)

Figure 2: *Description of murders dataset.*

Summary of murders data

```
> summary(murders)
     state               abb                 region
 Length:51          Length:51          Northeast     : 9
 Class :character   Class :character   South         :17
 Mode  :character   Mode  :character   North Central:12
                                       West          :13


   population            total
 Min.   :  563626   Min.   :   2.0
 1st Qu.: 1696962   1st Qu.:  24.5
 Median : 4339367   Median :  97.0
 Mean   : 6075769   Mean   : 184.4
 3rd Qu.: 6636084   3rd Qu.: 268.0
 Max.   :37253956   Max.   :1257.0
```

Figure 3: *Summary of gun violence deaths (total) for 51 states in 4 regions.*

Get a peek at murders dataset

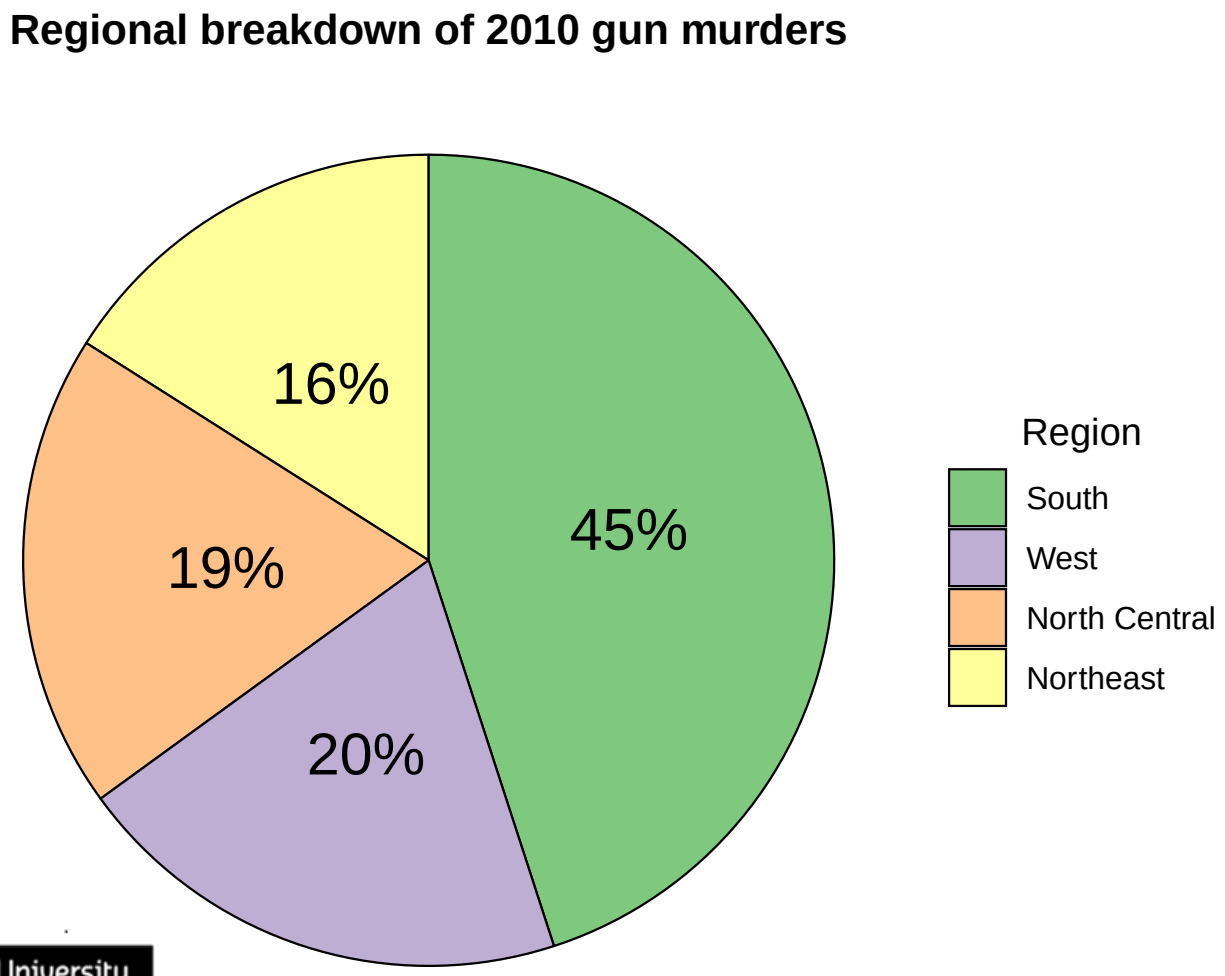
state	abb	region	population	total
Alabama	AL	South	4779736	135
Alaska	AK	West	710231	19
Arizona	AZ	West	6392017	232
Arkansas	AR	South	2915918	93
California	CA	West	37253956	1257
Colorado	CO	West	5029196	65
⋮	⋮	⋮	⋮	⋮
Vermont	VT	Northeast	625741	2
Virginia	VA	South	8001024	250
Washington	WA	West	6724540	93
West Virginia	WV	South	1852994	27
Wisconsin	WI	North Central	5686986	97
Wyoming	WY	West	563626	5

Figure 4: First and last six observations of the murders data.

Proportions data example

Suppose we are asked to show the percentages of total gun deaths in 2010 for four regions.

Pie chart is a standard tool to display this information.



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Pros and Cons of Pie chart

Pie charts have a really bad rap in the academic circle, but industry people love their pie charts.

1. Shortcomings
   - 1.1 Pie slices can be imprecise, as they are made using angles.
   - 1.2 Pie slices with similar percentages can be hard to distinguish.
   - 1.3 Human eyes are better suited to distinguish objects based on length or size than angles.
   - 1.4 Pie charts can be easily misused: (i) percentages not adding up to 100, (ii) too many slices of pie, (iii) creation of 3D pies.
2. Advantages
   - 2.1 Extremely intuitive to any audience if the number of classes used are small.
   - 2.2 Conveys the main message straightaway.

Cousins of Pie — Waffle and Donut charts

Waffle chart of murders data

- Use if one needs more precision than Pie chart.
- Encodes proportions in area, not in angles.
- Squares can be counted to compute the percentages — each waffle piece represents 1% of the total.

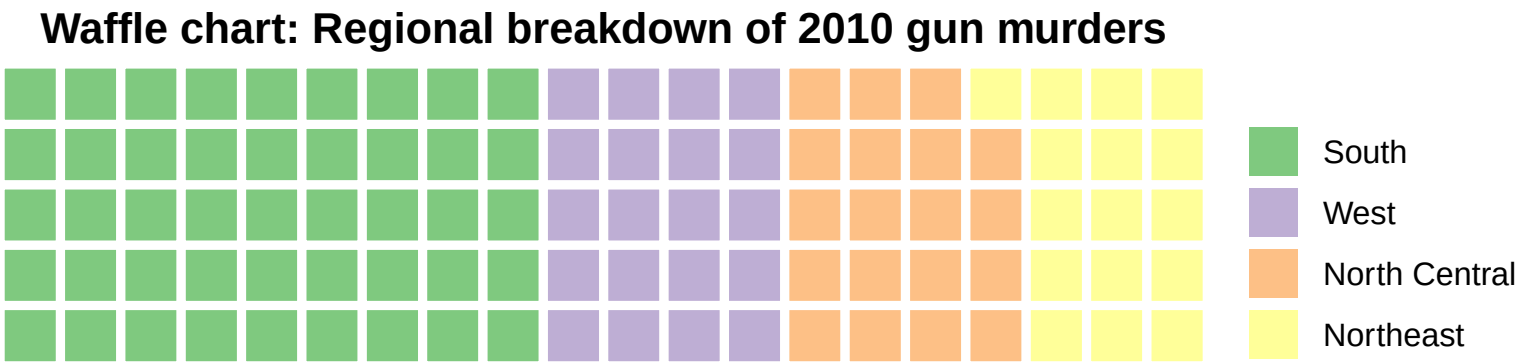


Figure 5: South: 45% ; West: 20% ; North Central: 19% ; Northeast: 16%.

Donut chart of murders data

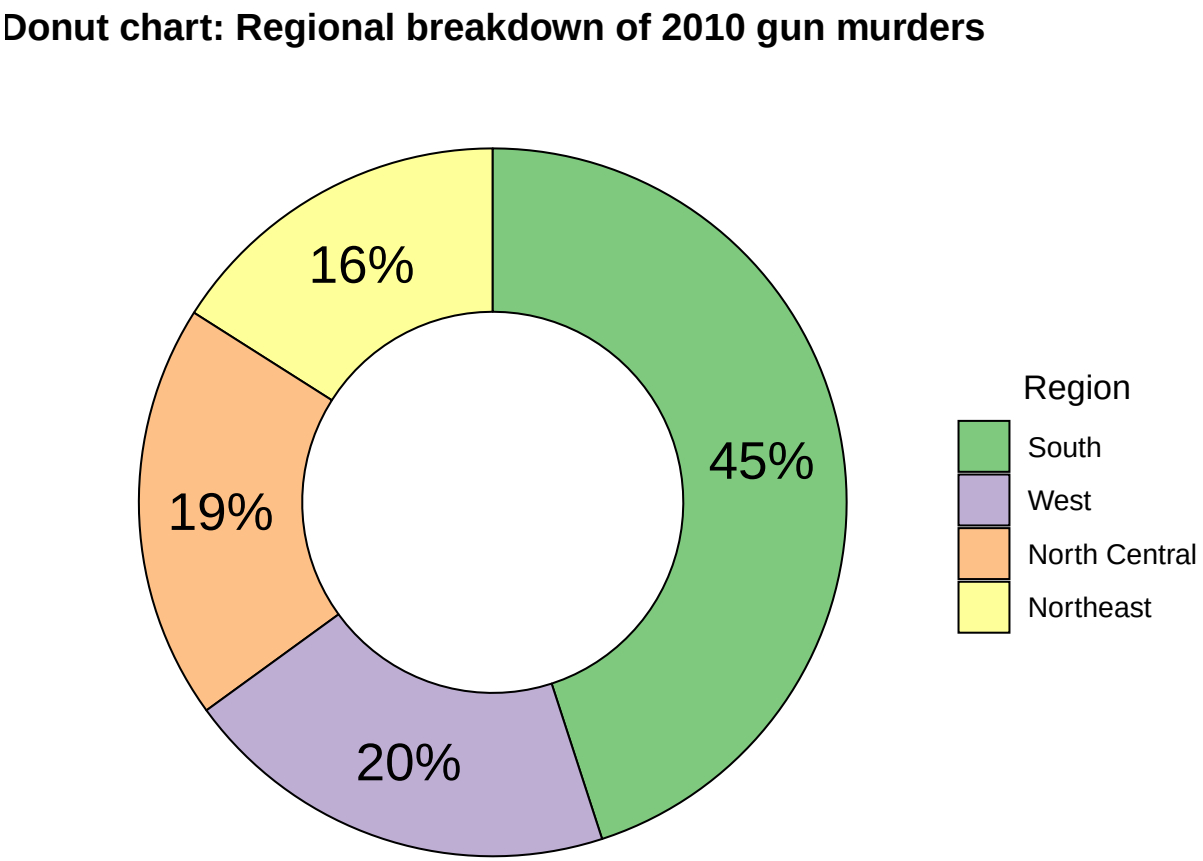
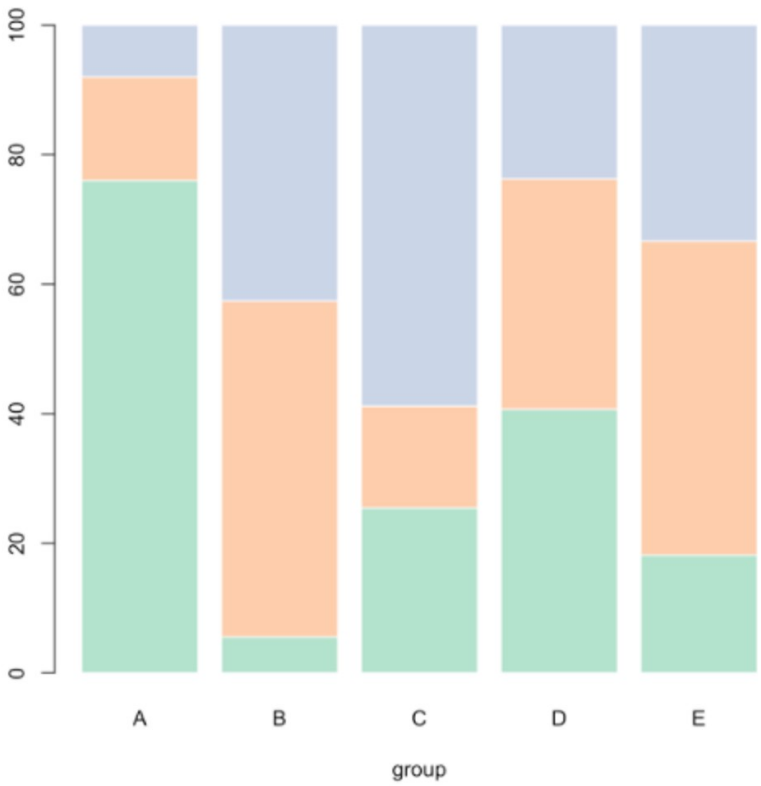


Figure 6: Donut chart is considered more aesthetically pleasing to eyes than its older cousin Pie chart.

Stacked bar plot

Stacked bar charts should be used to compare proportion data (e.g., revenues from three products blue, orange, green) amongst many populations/segments (e.g., five branches of the same company A, B, C, D, and E).



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Disease data from WHO

region	countryCode	country	disease	year	cases
EMR	AFG	Afghanistan	measles	2016	638
EUR	ALB	Albania	measles	2016	17
AFR	DZA	Algeria	measles	2016	41
EUR	AND	Andorra	measles	2016	0
AFR	AGO	Angola	measles	2016	53
AMR	ATG	Antigua and Barbuda	measles	2016	0
⋮	⋮	⋮	⋮	⋮	⋮
WPR	VUT	Vanuatu	yfever	1980	0
AMR	VEN	Venezuela (Bolivarian Republic of)	yfever	1980	4
WPR	VNM	Viet Nam	yfever	1980	0
EMR	YEM	Yemen	yfever	1980	0
AFR	ZMB	Zambia	yfever	1980	0
AFR	ZWE	Zimbabwe	yfever	1980	0

Figure 7: First and last six rows of the disease data published by World Health Organisation (WHO).

Summary of WHO's Disease data

```
 region          countryCode                      country
AFR :10481   AFG     :  223   Afghanistan             :  223
AMR : 7805   AGO     :  223   Albania                 :  223
EMR : 4683   ALB     :  223   Algeria                 :  223
EUR :11819   AND     :  223   Andorra                 :  223
SEAR: 2453   ARE     :  223   Angola                  :  223
WPR : 6021   ARG     :  223   Antigua and Barbuda     :  223
             (Other):41924   (Other)                 :41924
      disease           year          cases
diphtheria:7178   Min.   :1980   Min.   :      0
measles   :7178   1st Qu.:1991   1st Qu.:      0
mumps     :3686   Median :2001   Median :      0
pertussis :7178   Mean   :2000   Mean   :   1816
polio     :7178   3rd Qu.:2009   3rd Qu.:     35
rubella   :3686   Max.   :2016   Max.   :1122285
yfever    :7178
```

Figure 8: Incidences of seven diseases across six regions over the years between 1980 and 2016.

Disease distributions across Regions

Our aim is to compare the distributions of different diseases across the seven regions of the world for the year 2016.

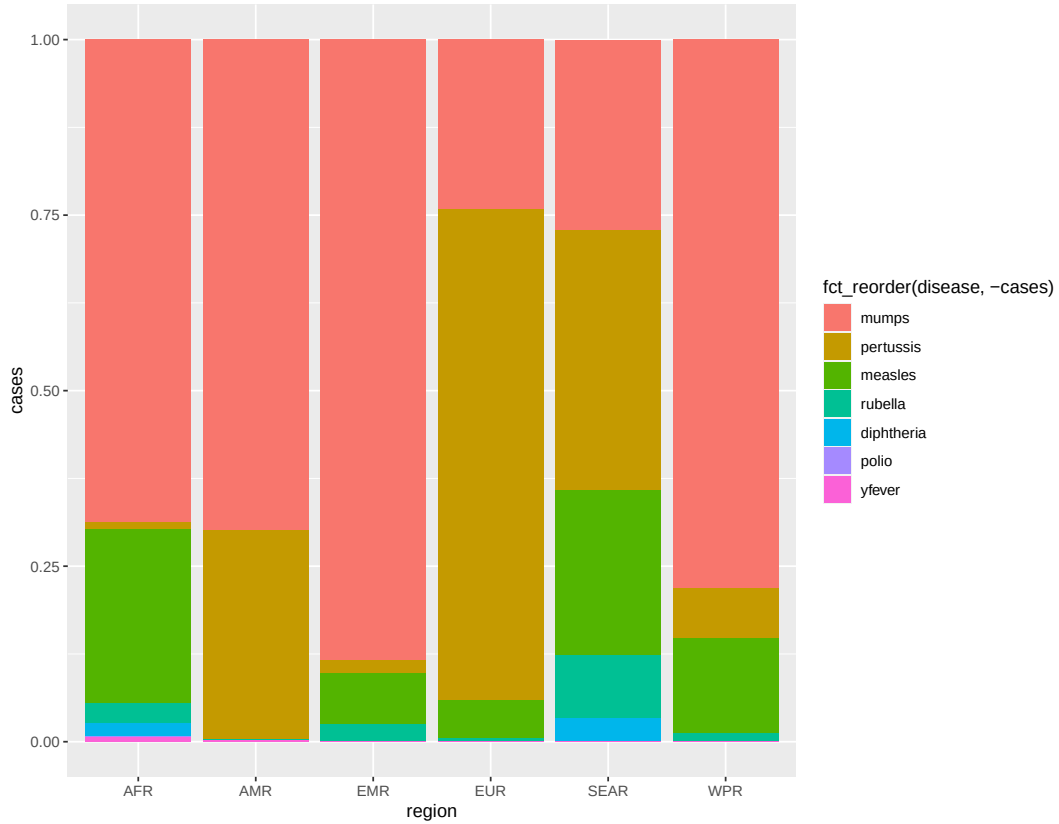


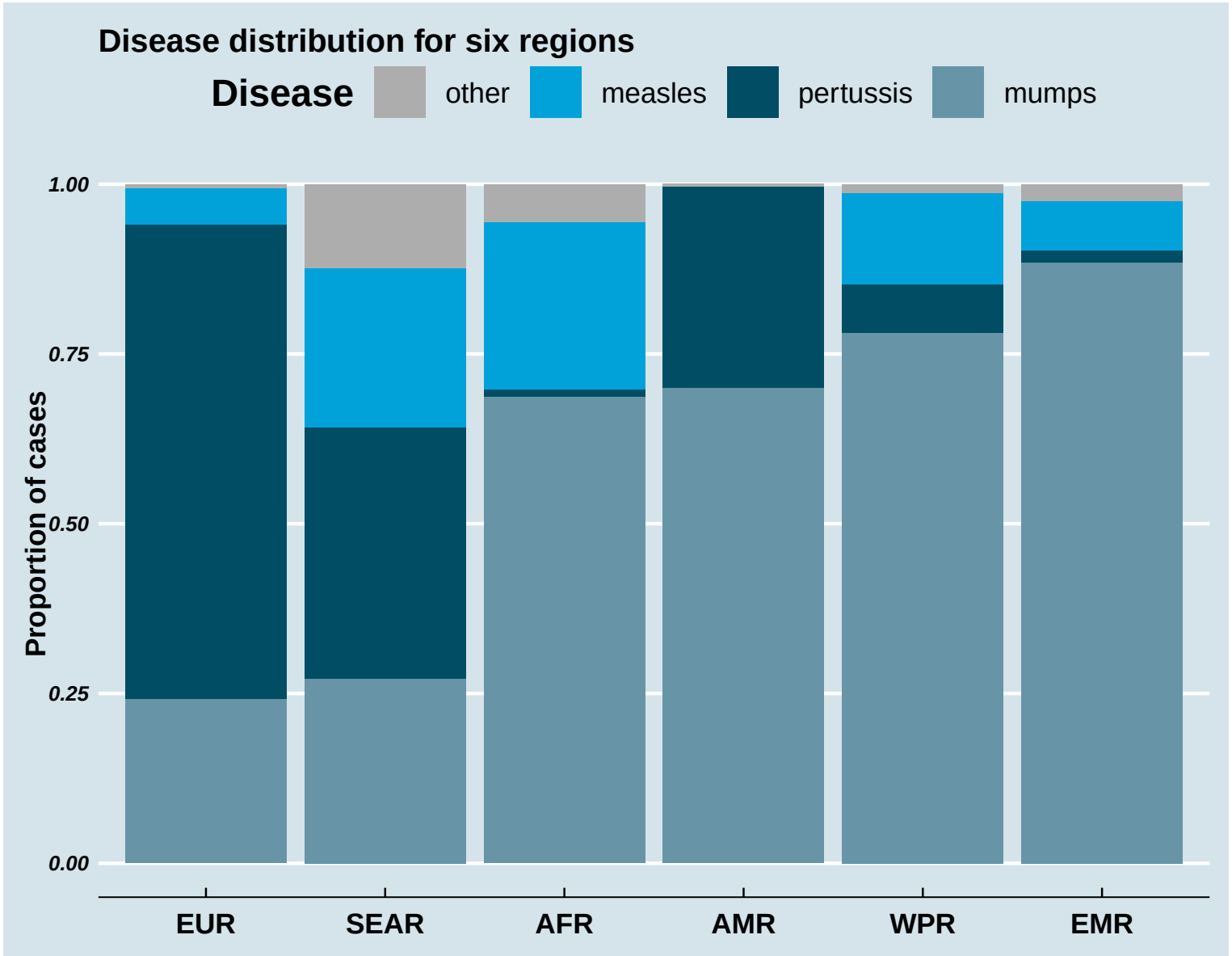
Figure 9: A barebone stacked barplot comparing diseases across regions.

Problems with our stacked barplot

There are several visualisation issues with our plot.

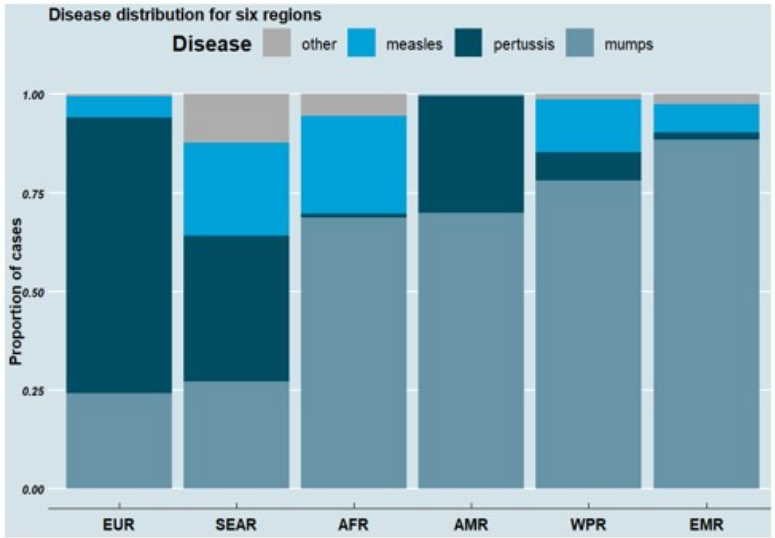
1. **Too many categories**
2. **No ordering of diseases**
3. **No ordering of regions**
4. **Poor theme and colour**
5. **No plot title/caption**
6. **Legend keys are small**
7. **Legend texts are small**

Enhanced stacked barplot



Changes made to enhance the plot

1. Reduced number of groups, and focused on most prevalent diseases.
2. Ordered diseases from most (mumps) to least prevalent (measles).
3. 'Other' category is of least importance --- put at the top of the bar.
4. The regions are ordered based on most proportion of mumps cases to least proportion mumps cases.
5. Selected a theme used in the famous Economist journal.
6. Increased the size of legend keys, legend texts, and axis texts.
7. Added an informative title to the plot.



Inspecting association between factors

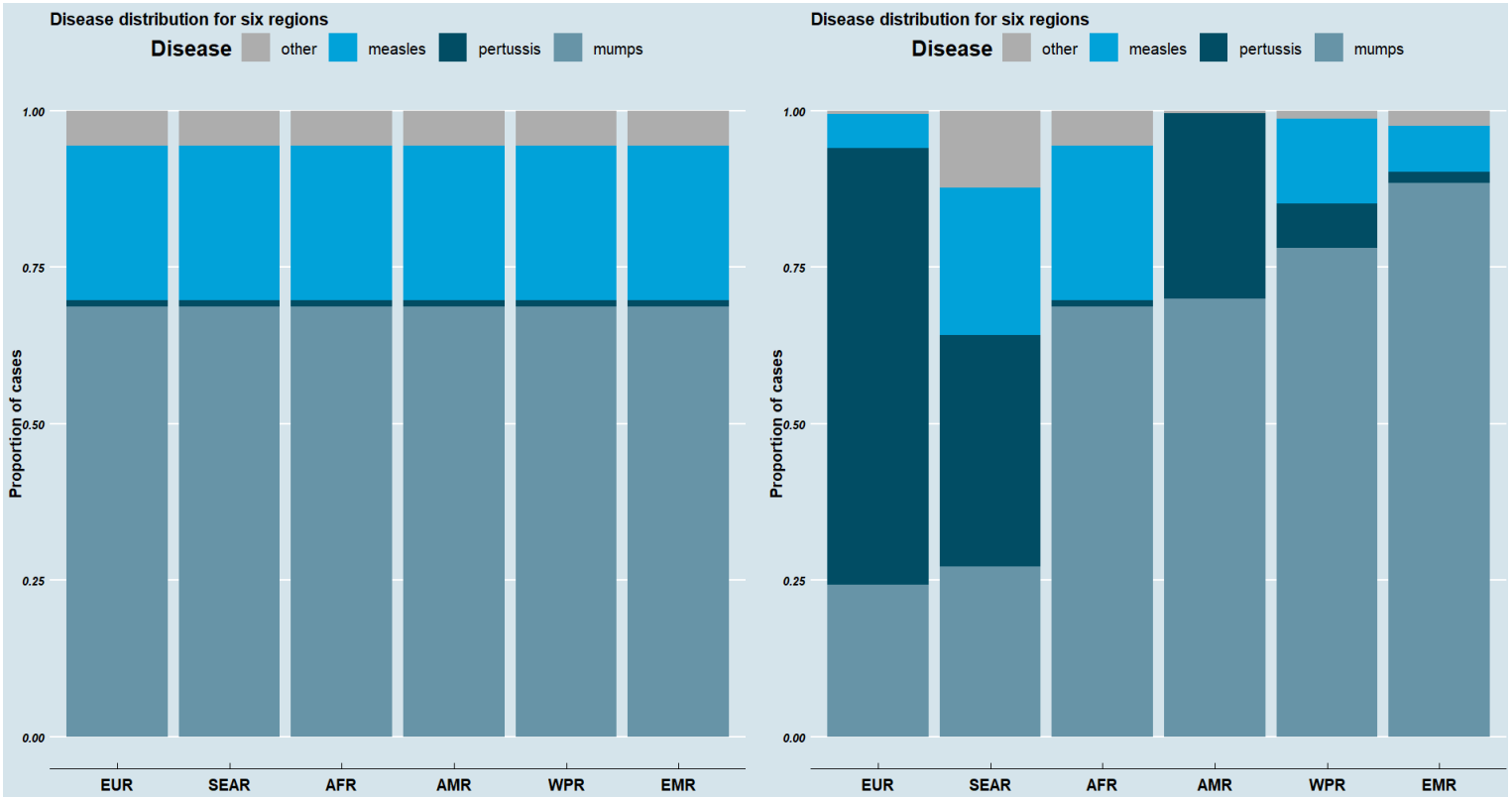


Figure 10: *Left*: The factors Disease and Region are not associated; *Right*: There is some relationship between factors Disease and Region — Disease prevalence does differ based on Region.

Point Data

- Point data represents **single observation** for each category. For example, (i) number of disease cases for each country, (ii) gun deaths per 1000 people in each state, or (iii) logarithm of GDP value for each country.
- Two charts are used typically to display such data — (i) Bar chart and (ii) Point chart.
- Bar charts are appropriate for variables that have some notion of stacking or accumulation. For example (i) the number of incidents of a particular disease or (ii) project expenditures in dollar amount.
- Bar charts are not appropriate for variables that do not have this property of addition or accumulation. For example, odds ratios, percentiles, or any non-linear transformations should be displayed using Point charts.

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Stacking Principle

Bar charts should be used to represent data that have some sort of accumulating property to them. You should ask yourself *if you could stack the units of the measure on top of each other*. For example, revenue (money) generated by different projects can be thought of as a *stack of dollar bills*.

Point Data Example from murders data

Question: Identify top 10 states based on USA gun murder deaths recorded in the murders dataset, and create an appropriate chart to present these data.

Horizontal Bar Plots are excellent

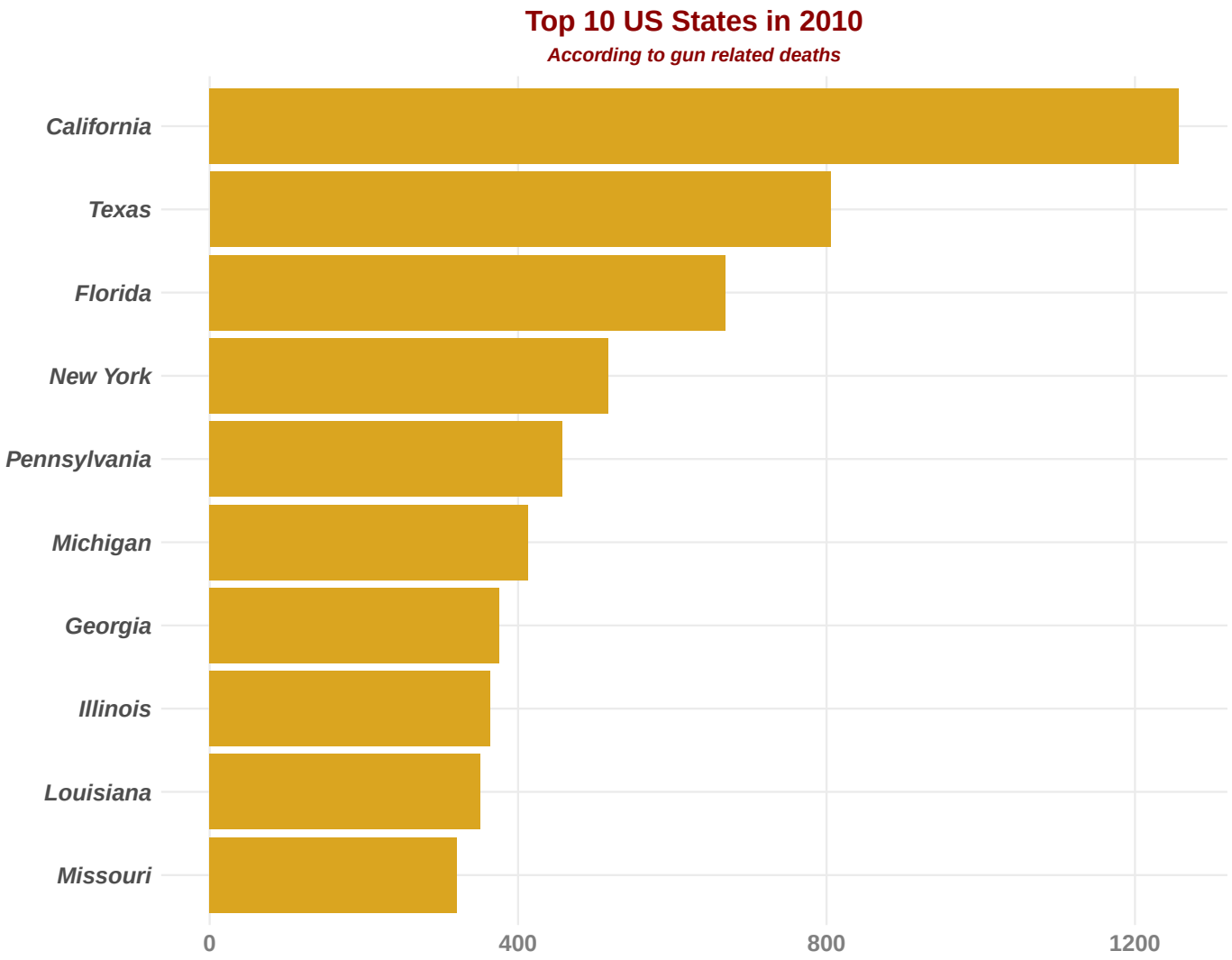
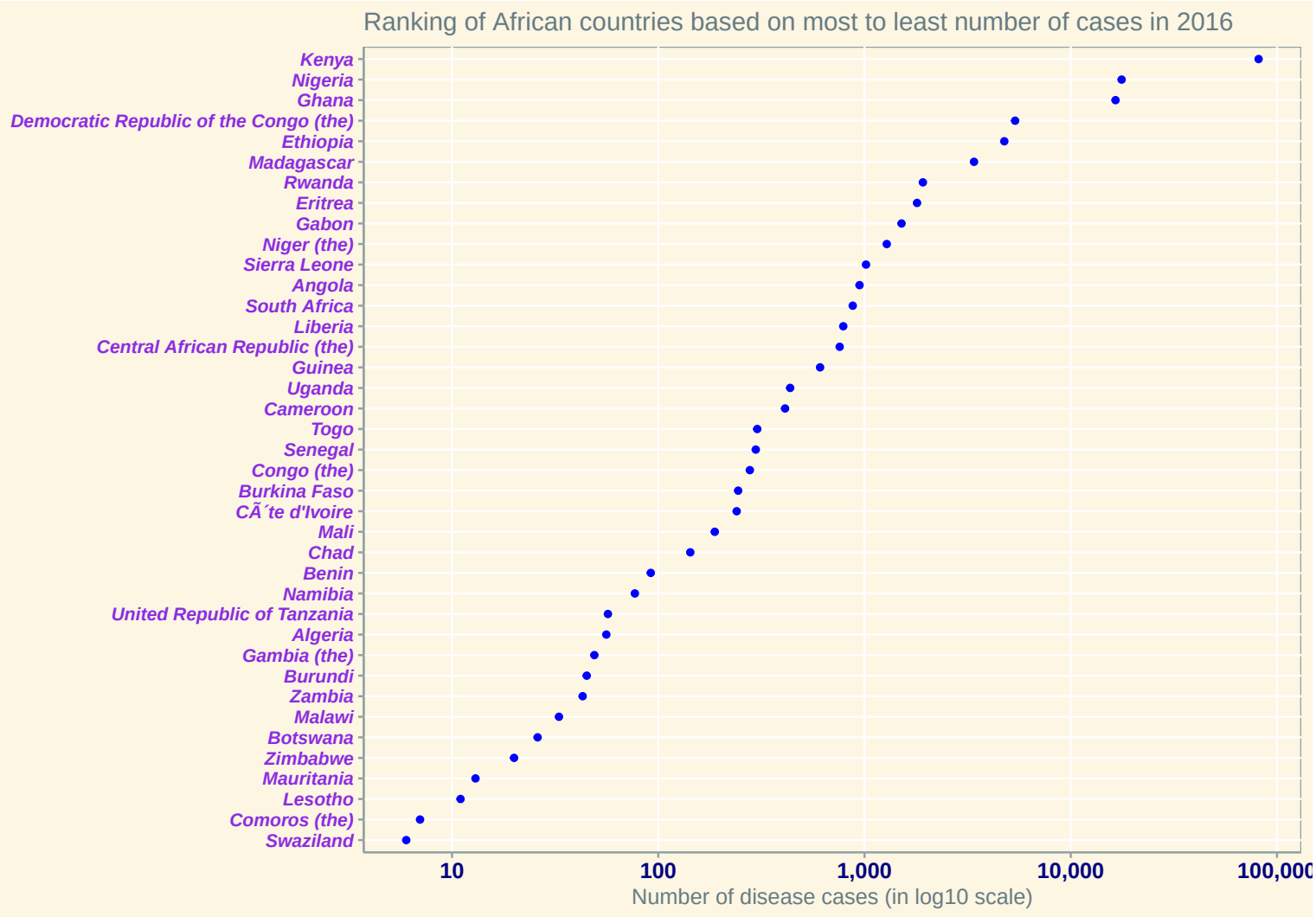


Figure 11: Axis of bar charts should start from zero.

Point Charts

- When we have point data that do not satisfy the stacking principle, we should use Point charts to illustrate these data.
- Many point data are not stackable, for example ratios, percentiles or different sensor measurements such as NDVI, soil moisture content, or temperature.
- Non-linear transformations such as logarithm, square-root or exponentially transformed data should be plotted using point charts.
- Easy to construct — simply remove the bar and replace the top of the bar with a point.

Point chart example ($\log_{10}(cases)$)



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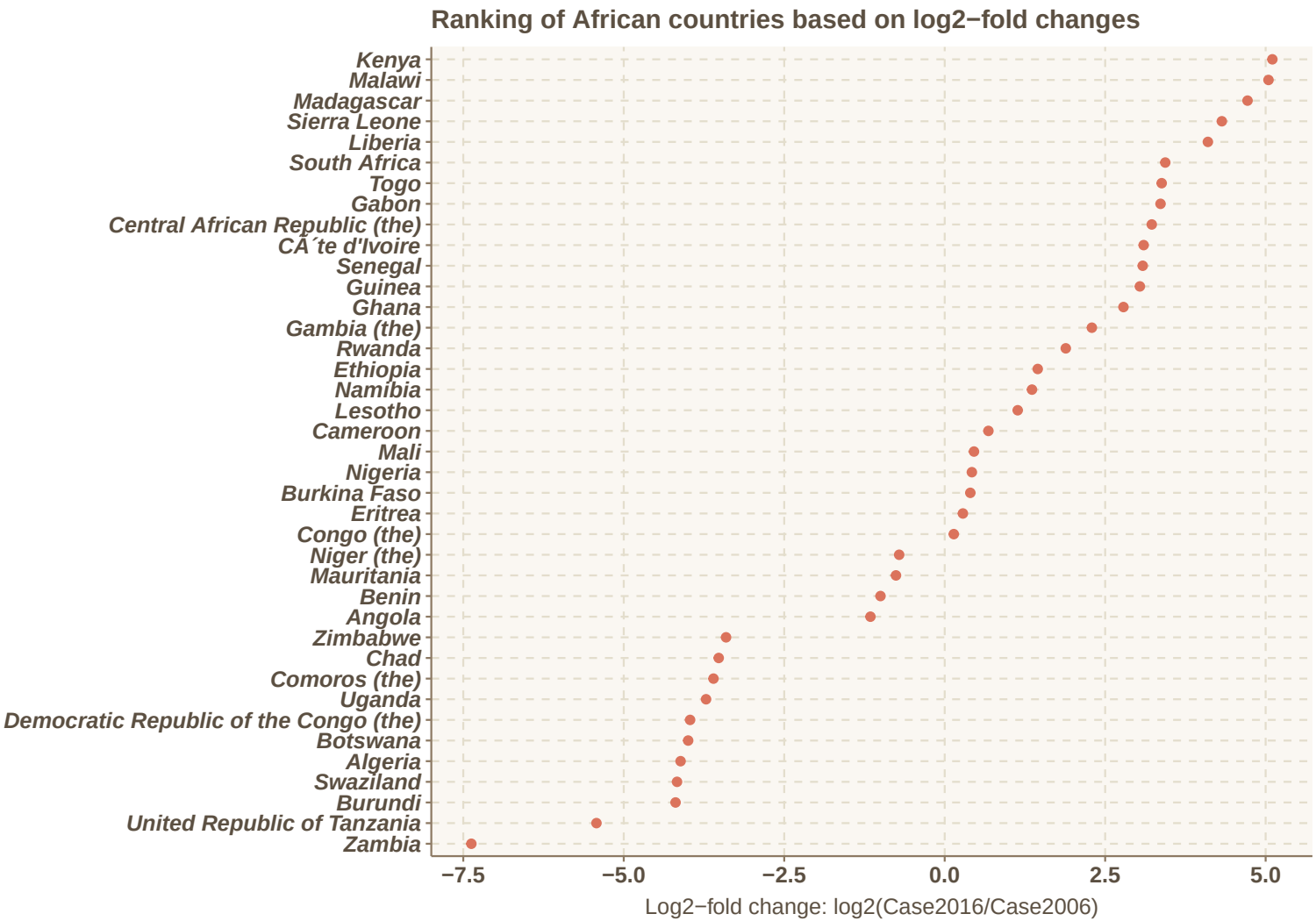
Point Data Example from disease data

Question: Rank countries from the AFR region based on the log_2-fold change in the number of cases from 2006 to 2016. The log_2-fold change is given by:

$$\log_2\left(\frac{\text{Case2016}}{\text{Case2006}}\right).$$

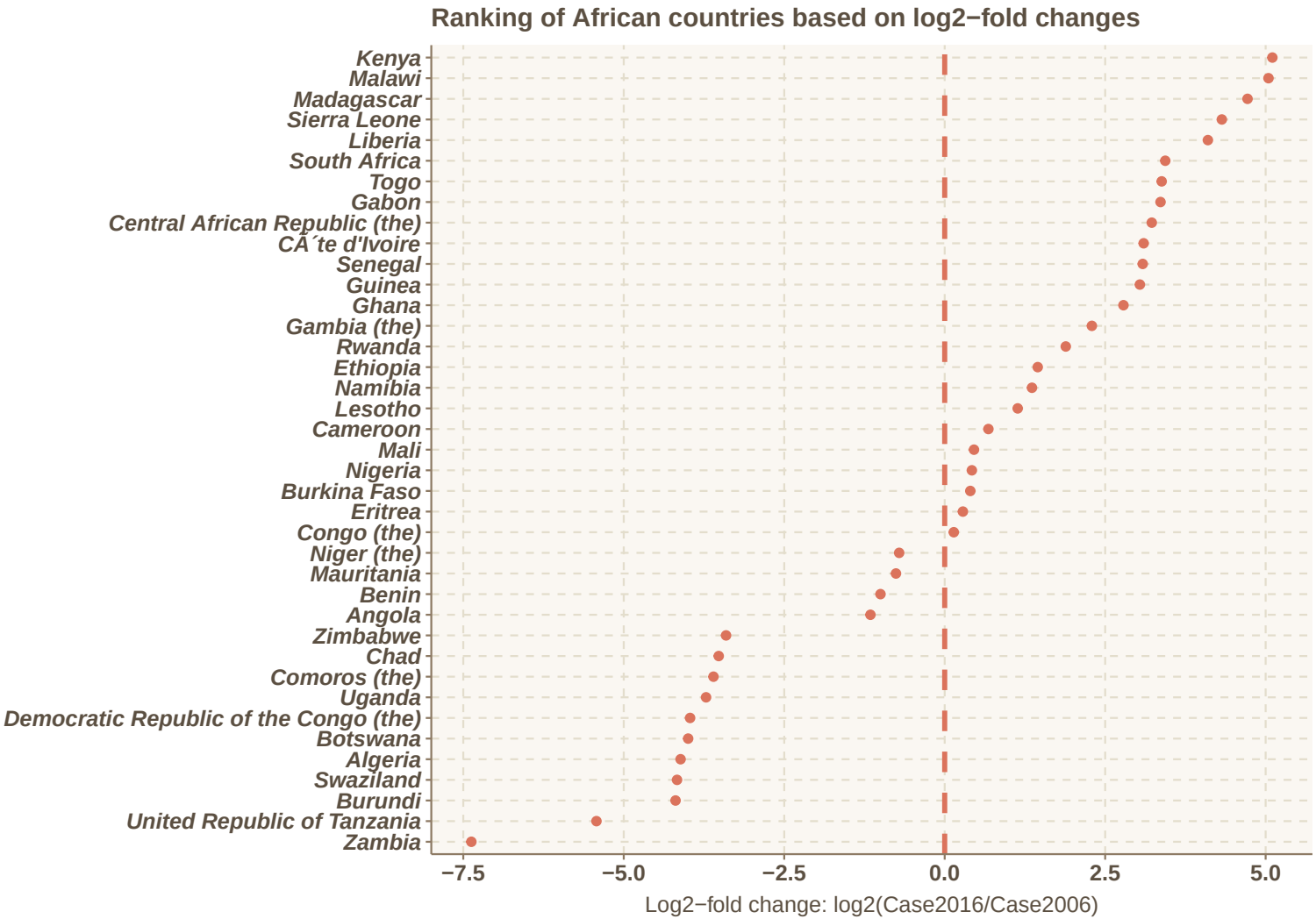
Log2-fold change of African nations



Properties of log2-fold changes

- Log-fold change is **symmetric around zero**.
- Value of log2-fold change of 1 means **two-times larger**, while the value of -1 means **two-times smaller**.
- The value of 0 is the **focal/turning point**, where the decreasing number of cases switches to increasing number of cases.
- **Adding a line at the 0** value would provide a visual aid to distinguish countries with declining number of disease cases from those with increasing number of disease cases.

Include an anchor at the focal point



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Data from a single distribution

The distributional data are observed when several samples are gathered from a population. The shape and percentiles of the distribution can often reveal very important and interesting facts about the population. For example (i) *age distribution of the supporters of a political party may help to design a targeted campaigning strategy*, (ii) *income distribution of a state may help to design various socio-economic programs by the state government*, or (iii) *age distribution of infected population may help to design an appropriate vaccination plan*.

Distributional data example: iris data

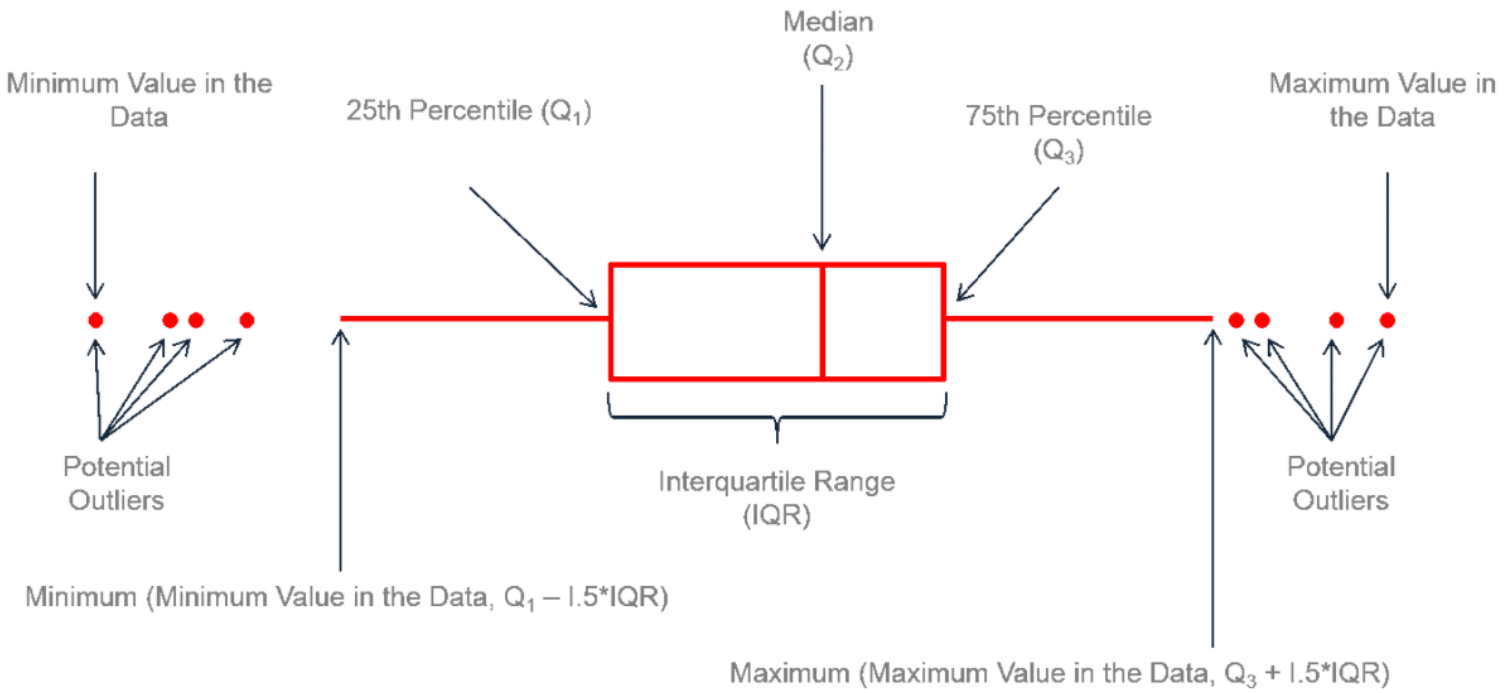
```
> head(iris)
Sepal.Length Sepal.Width Petal.Length Petal.Width Species
         5.1         3.5          1.4         0.2  setosa
         4.9         3.0          1.4         0.2  setosa
         4.7         3.2          1.3         0.2  setosa
         4.6         3.1          1.5         0.2  setosa
         5.0         3.6          1.4         0.2  setosa
         5.4         3.9          1.7         0.4  setosa
```

```
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width          Species
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100   setosa    :50
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300   versicolor:50
 Median :5.800   Median :3.000   Median :4.350   Median :1.300   virginica :50
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
```

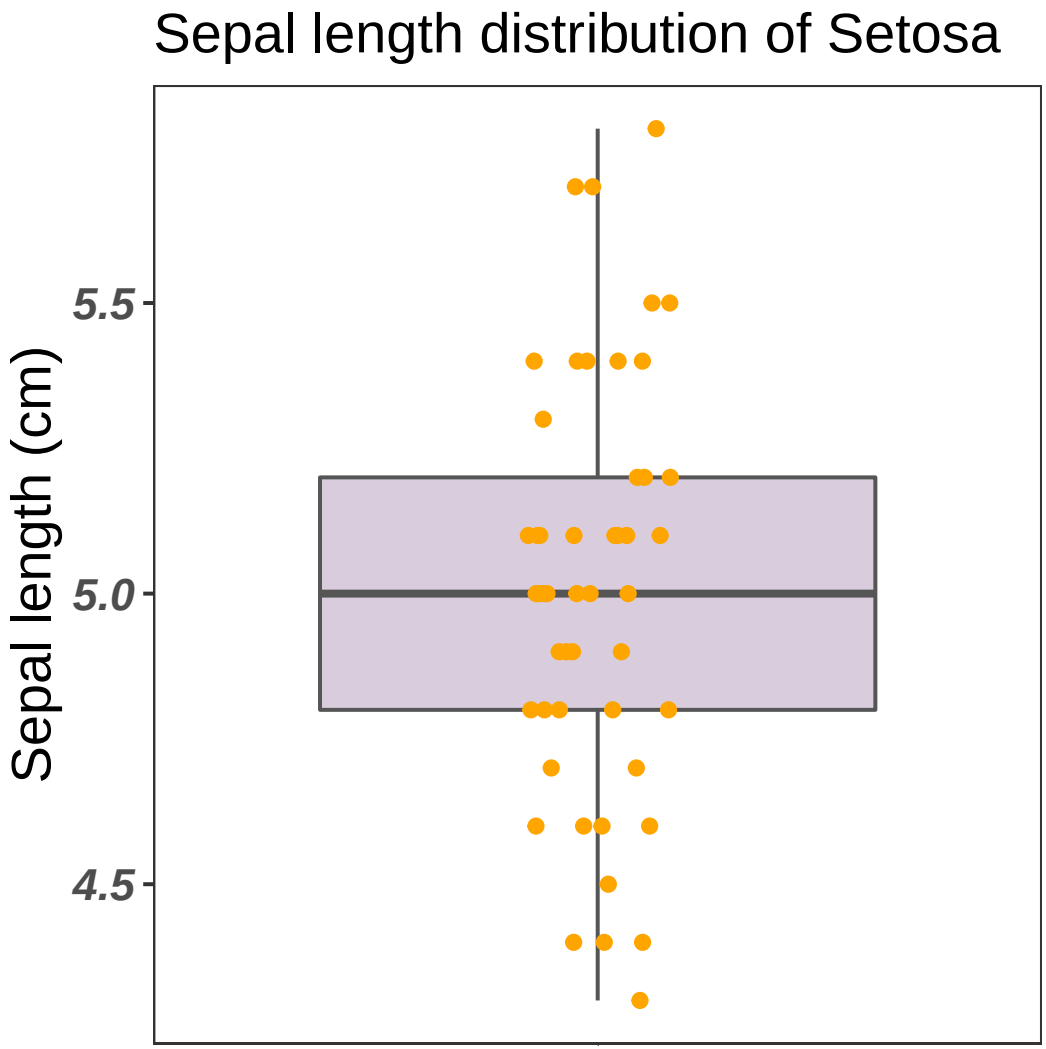
Figure 12: First six rows and summary of the iris dataset.

Boxplot for a quick distributional summary

Boxplot provides a concise visualisation of the distribution of the data. It shows the central tendency (median) and the (inter-quartile) range of the data.



Boxplot of Sepal.Length data



Beyond Boxplot

- Boxplot summarises the distribution using only five numbers: (i) median, (ii) first quartile, (iii) third quartile, (iv) 'minimum', and (v) 'maximum'.

- Boxplot does not indicate much about the peaks in the distribution — is the distribution bimodal?

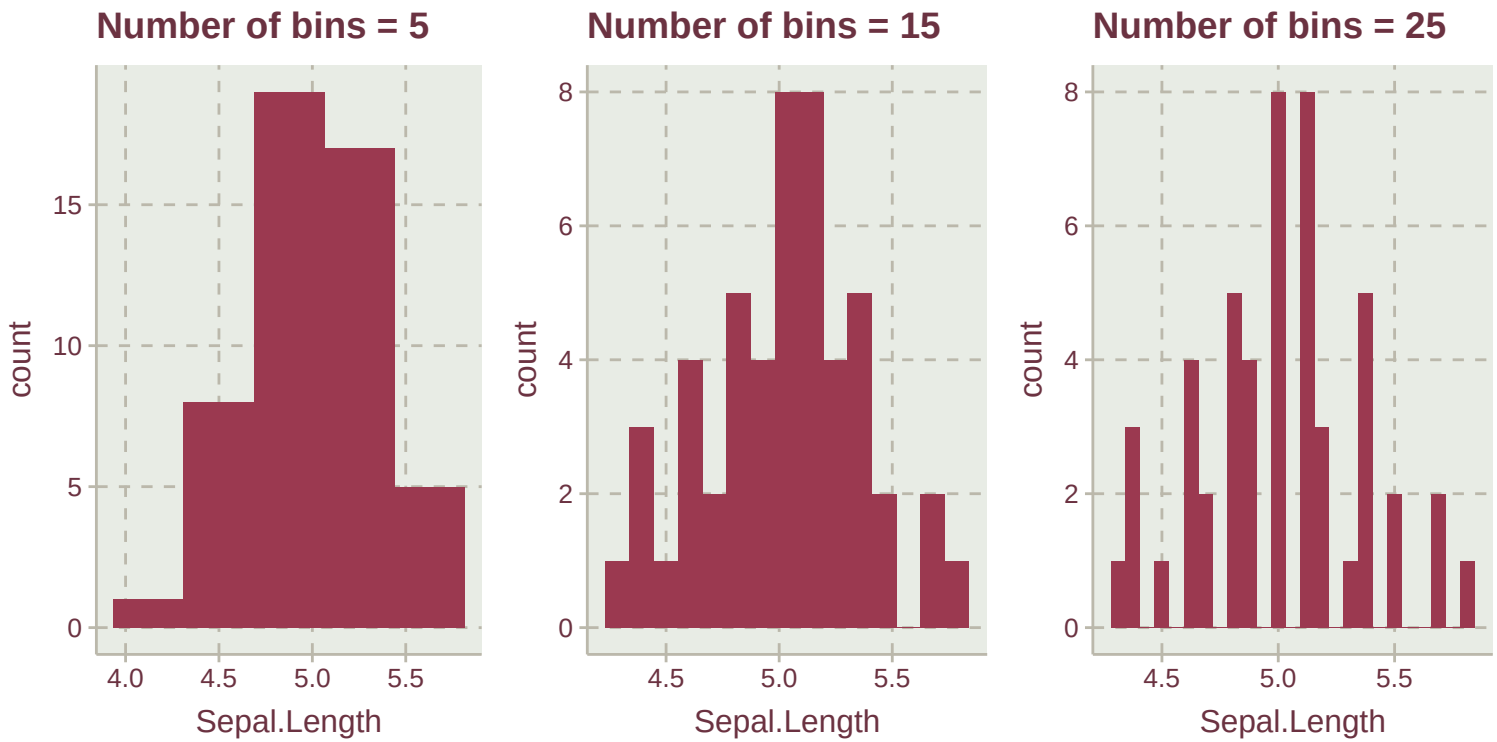
- To obtain more information about the distribution, we should use the histogram or the kernel density plot. However, boxplots are excellent tool for comparing distributions corresponding to many categories (we will come back to this point a bit later).

Histogram

Histograms are created by first binning the data and then counting the number of observations in each bin. As a data scientist, you should experiment with different binwidth values (or equivalently, with the number of bins).

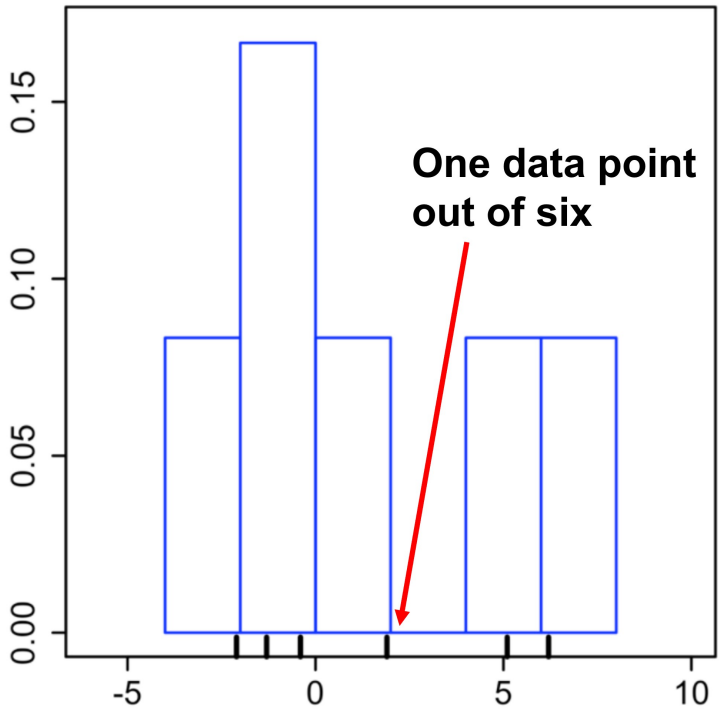
Histograms with different binwidths

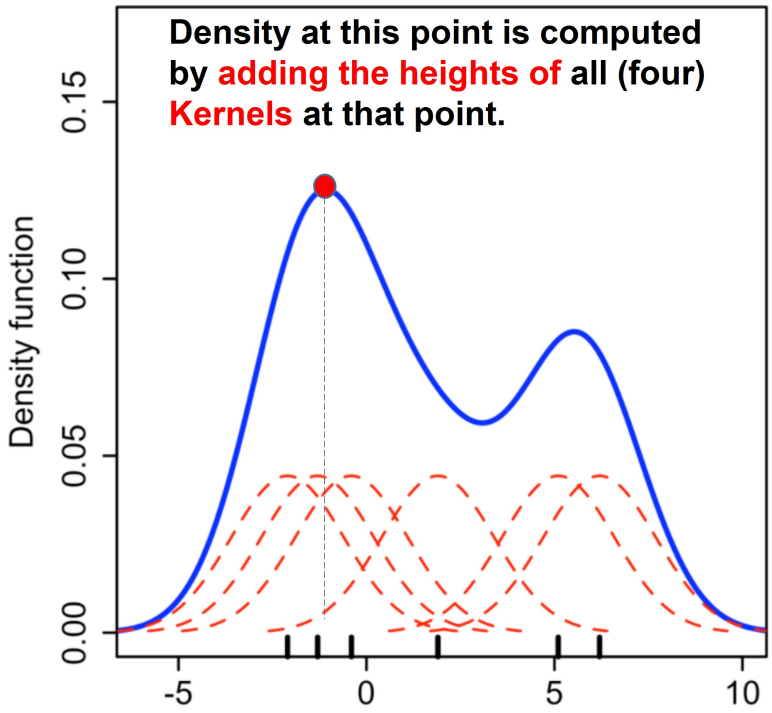
The distribution of Sepal length is fairly symmetric, with most values falling around 5.0 cm. in the middle of the distribution. The frequency declines very similarly as we move away from the centre toward the two ends.



Kernel Density Estimator (KDE)

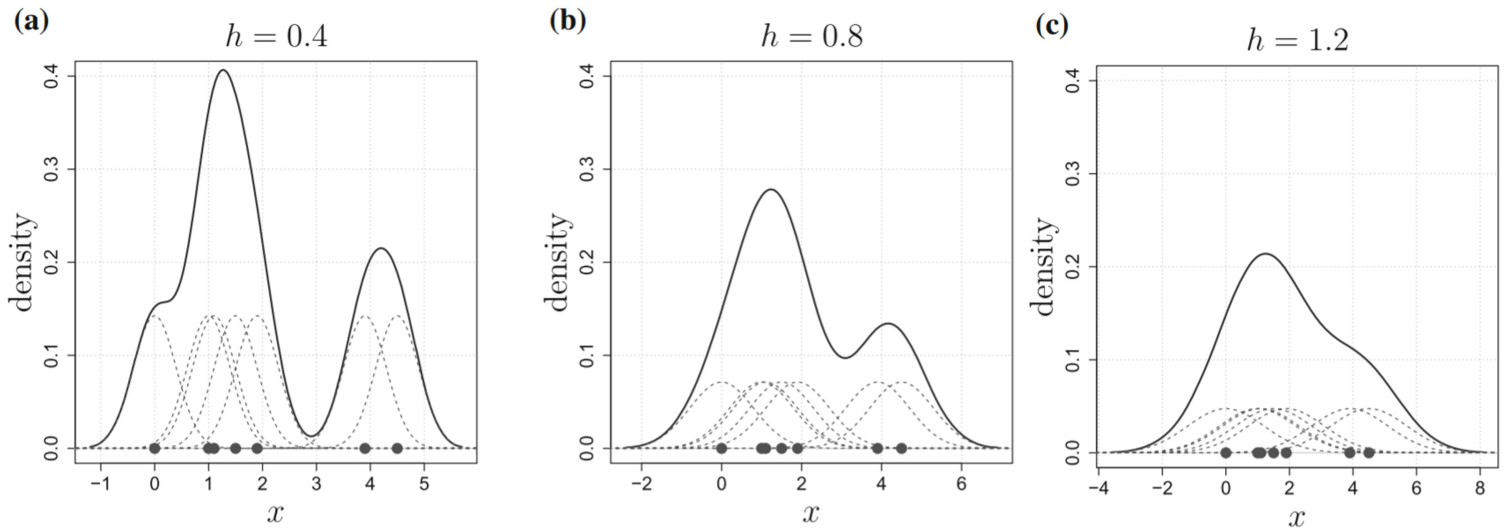
Kernel density estimator produces a smooth curve (a smoother version of density histogram) to represent the underlying density.





KDE with different bandwidths

- Bandwidth is crucial to determine the shape of the estimated density.
- Too smaller bandwidth will display many peaks (which may be due to sampling bias).
- Too larger bandwidth will smooth out many potential real peaks.



KDE of Petal.Length data

Kernel Density Estimates of the Petal.Length for three different bandwidth values.

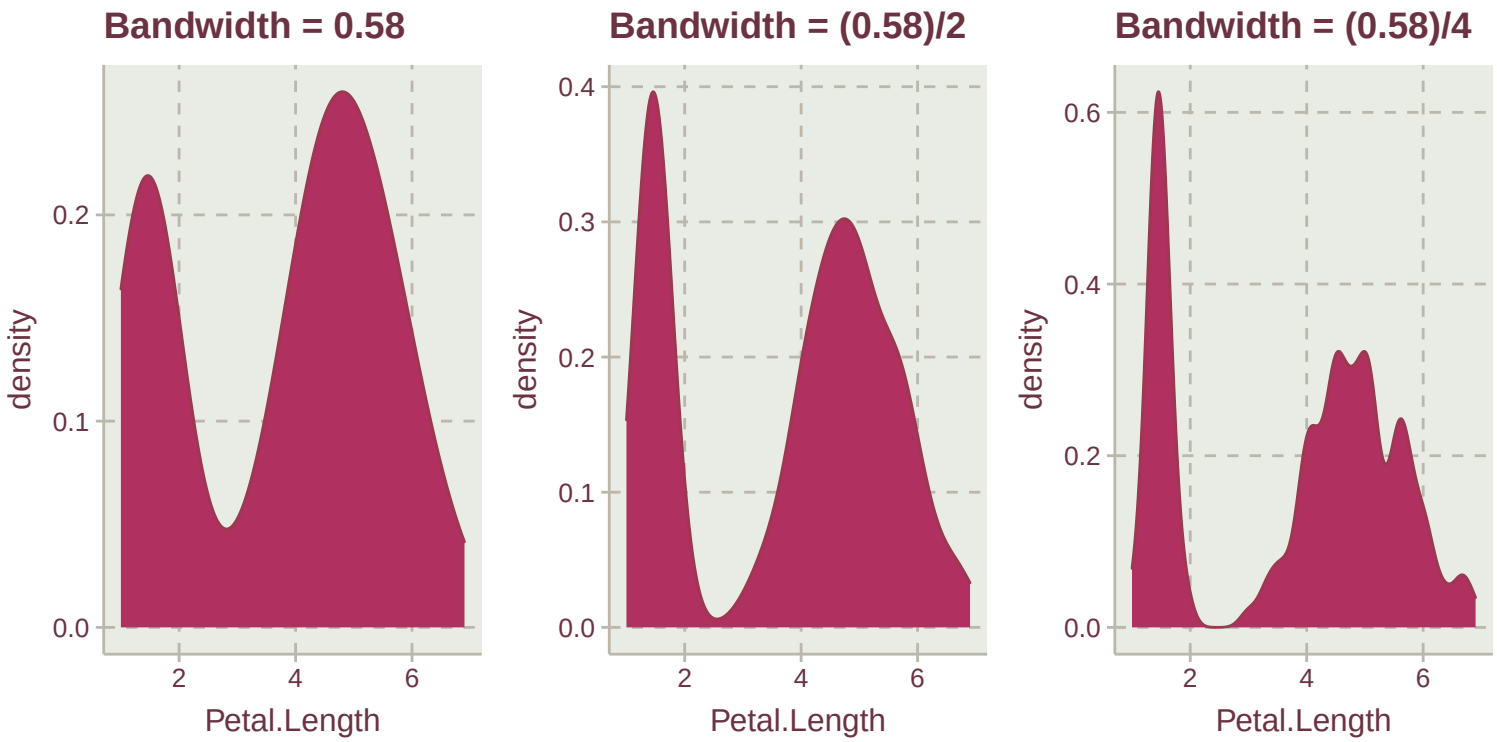


Figure 13: Default bandwidth of 0.58 is chosen in `geom_density()` and calculated using the function `bw.nrd0()`.

Petal Length Density

- Density of Petal length has two clear modes — one around 1.5 cm and the other around 5 cm.
- There could be a possible third peak around 5.5 cm, but it could be an artefact due to small bandwidth selection.
- Distinct peaks in the density may point to a missing factor.

Density peaks and missing factor

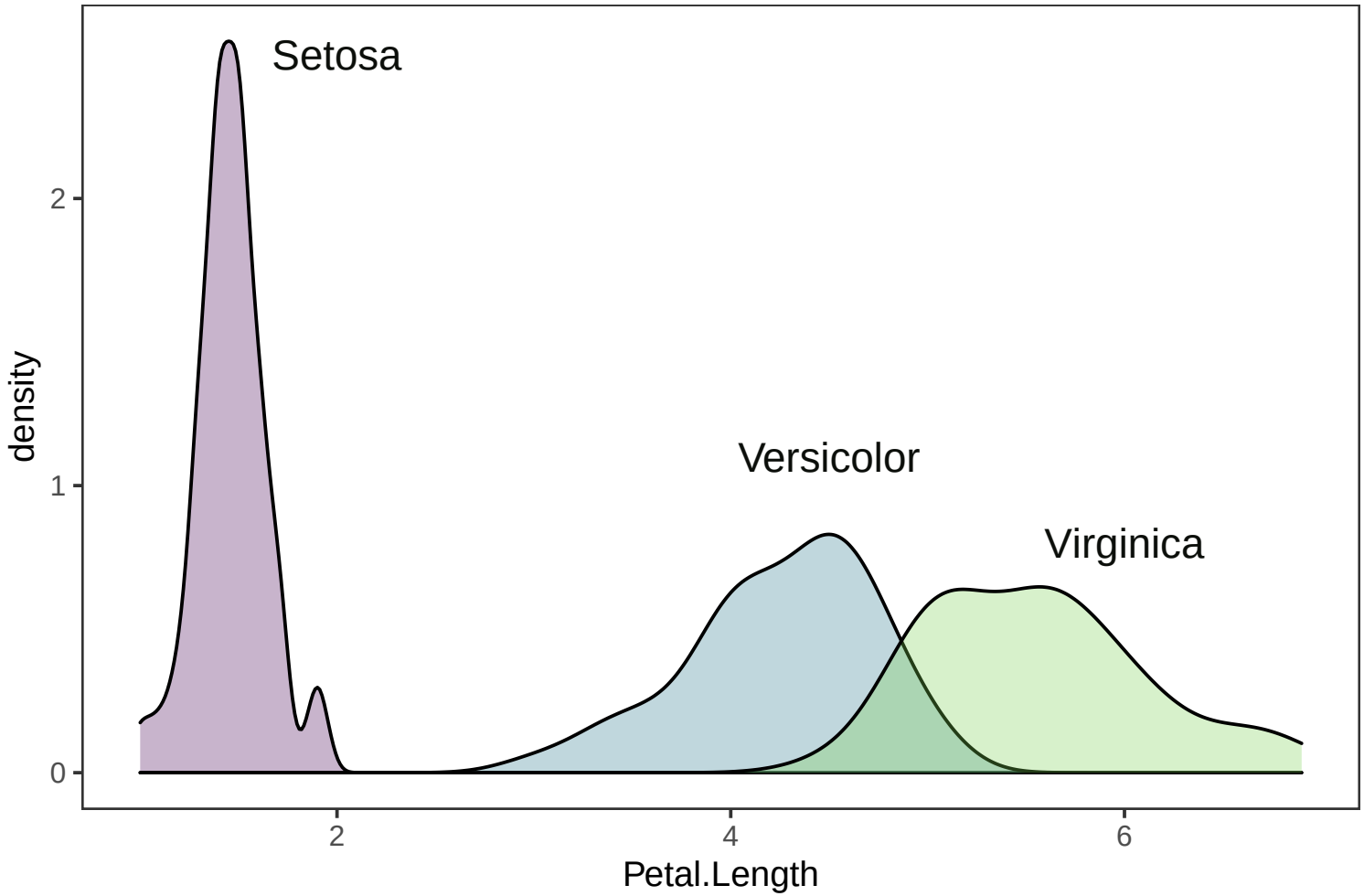
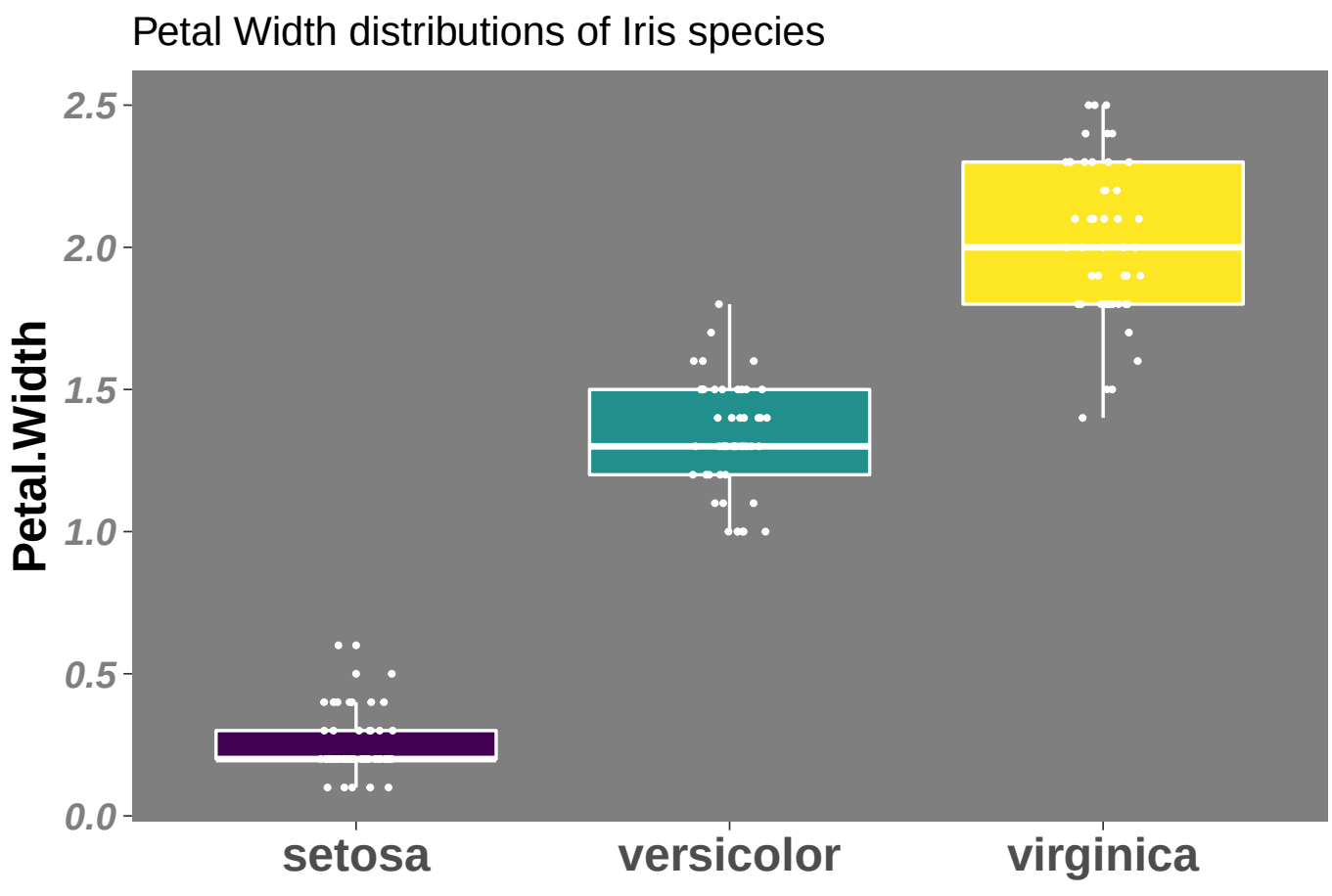


Figure 14: The missing factor is Species; however, it is hard to distinguish Versicolor and Virginica based on Petal Lengths.

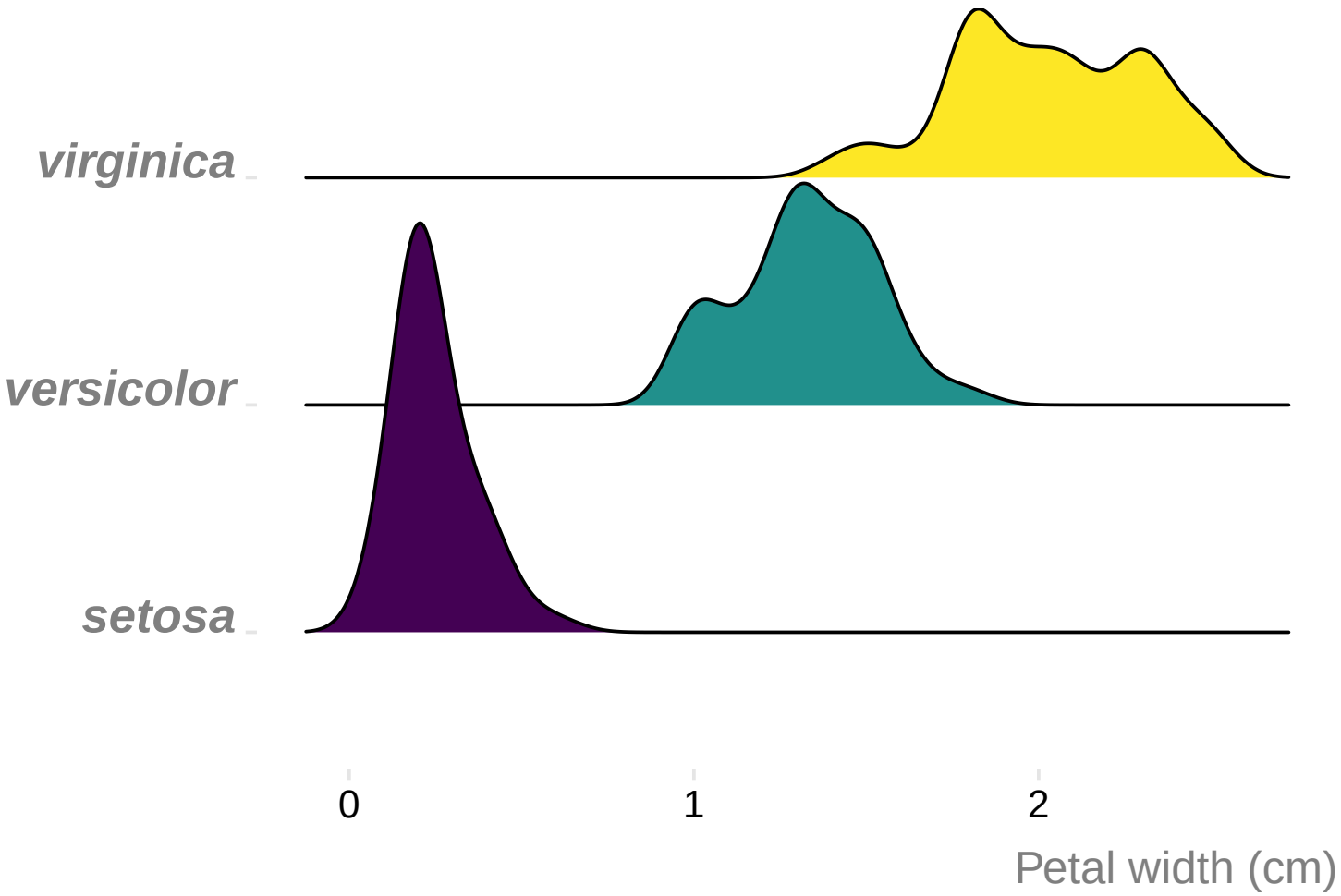
Comparing distributions of many categories

Compare the Petal Width distributions of three iris species — Boxplots are the most concise way to compare the three distributions.



KDE for Petal.Width distributions

We can also use KDE to compare the Petal Width distributions of three iris species.



Summary

- Use pie, waffle or donut charts for proportions data from a single population, but use Stacked Bar plot for comparing proportions data of many populations/categories.
- For point data satisfying stacking principle, use Bar charts. For other point data, use point charts instead.
- For distributional data, you can use boxplots, histograms or kernel density plots. You can also use a fancier plot, called the Violin plot, which works similarly as the kernel density plot.