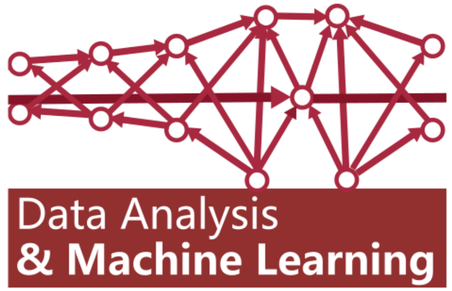


Data Analysis and Machine Learning 4 (DAML)

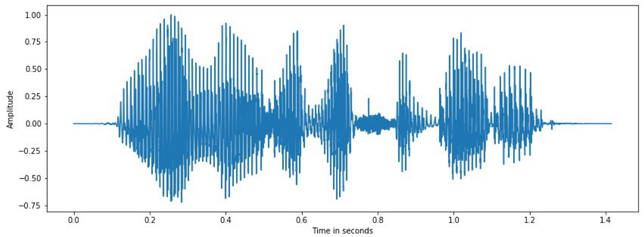
Week 2: Summarising and visualising data

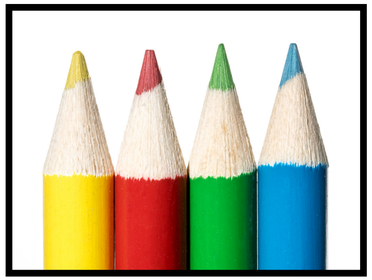
Elliot J. Crowley, 22nd January 2024

THE UNIVERSITY *of* EDINBURGH

Recap

- We looked at different modalities of data





	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)	species
0	5.1	3.5	1.4	0.2	setosa
1	4.9	3.0	1.4	0.2	setosa
2	4.7	3.2	1.3	0.2	setosa
3	4.6	3.1	1.5	0.2	setosa
4	5.0	3.6	1.4	0.2	setosa
...	...	...	...	...	...
145	6.7	3.0	5.2	2.3	virginica
146	6.3	2.5	5.0	1.9	virginica
147	6.5	3.0	5.2	2.0	virginica
148	6.2	3.4	5.4	2.3	virginica
149	5.9	3.0	5.1	1.8	virginica

- We considered variable types

iris species (nominal)

level of education (ordinal)

Tabular data

- We will focus on this modality in this course
- It crops up a lot in real life and it is straightforward to work with

	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)	species
0	5.1	3.5	1.4	0.2	setosa
1	4.9	3.0	1.4	0.2	setosa
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...	...	...	...	...	...
145	6.7	3.0	5.2	2.3	virginica
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147	6.5	3.0	5.2	2.0	virginica
148	6.2	3.4	5.4	2.3	virginica
149	5.9	3.0	5.1	1.8	virginica

Summarising Data

World Happiness Report

- Produced by a non-profit of the United Nations
- What do you want to know when you see this?

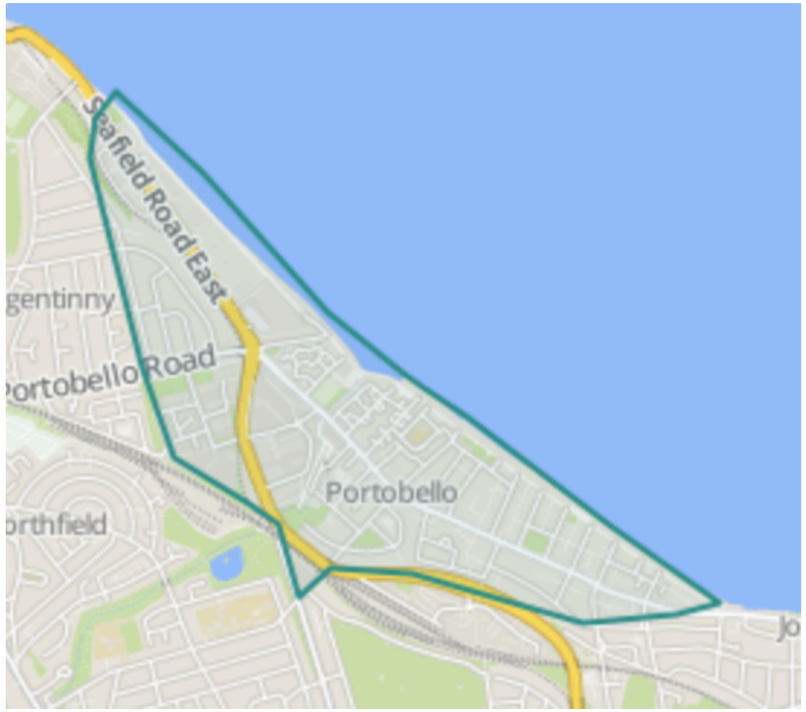
Country or region	Score	GDP per capita	Social support	Healthy life expectancy	Freedom to make life choices	Generosity	Perceptions of corruption
Guatemala	6.436	0.800	1.269	0.746	0.535	0.175	0.078
Yemen	3.380	0.287	1.163	0.463	0.143	0.108	0.077
Netherlands	7.488	1.396	1.522	0.999	0.557	0.322	0.298
...	...	...	...	...	...	...	...
Libya	5.525	1.044	1.303	0.673	0.416	0.133	0.152
Jamaica	5.890	0.831	1.478	0.831	0.490	0.107	0.028
United States	6.892	1.433	1.457	0.874	0.454	0.280	0.128

Extreme values

- Take **maximum** of score: Finland
- Take **minimum** of perceived corruption: Moldova

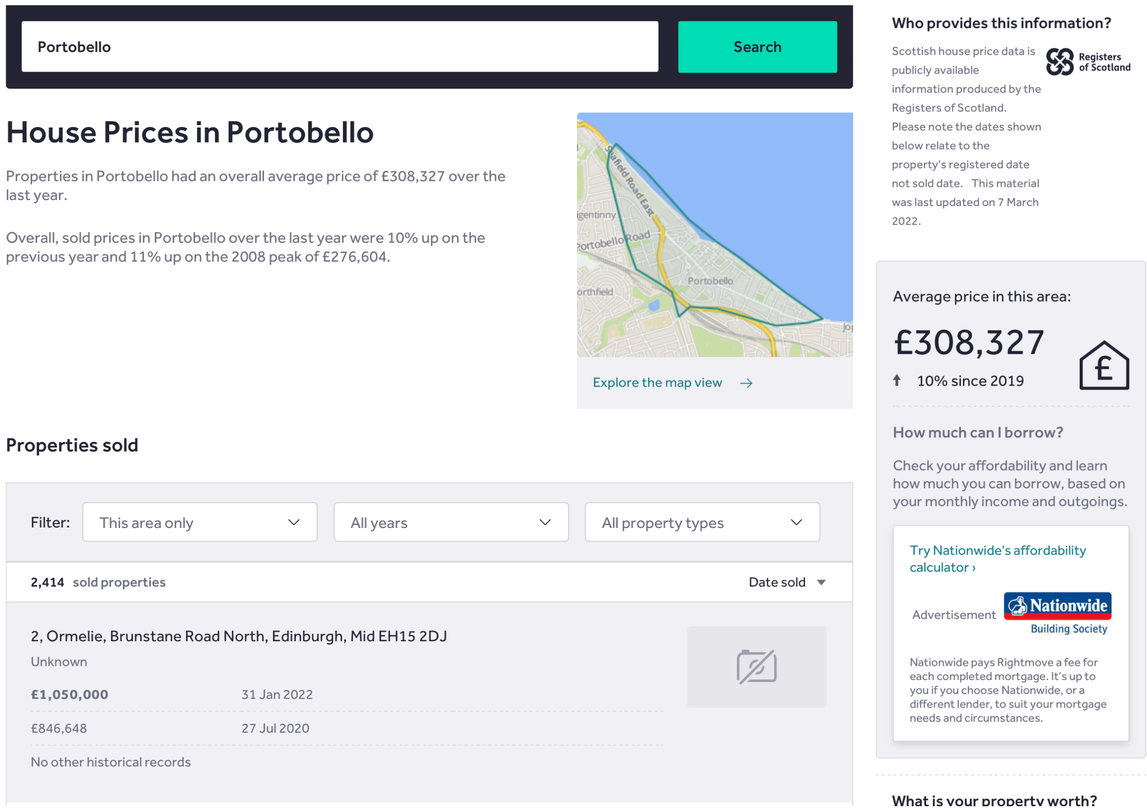
House buying

- Let’s say I’m considering buying a property in Portobello
- What do I need to know?



Central values

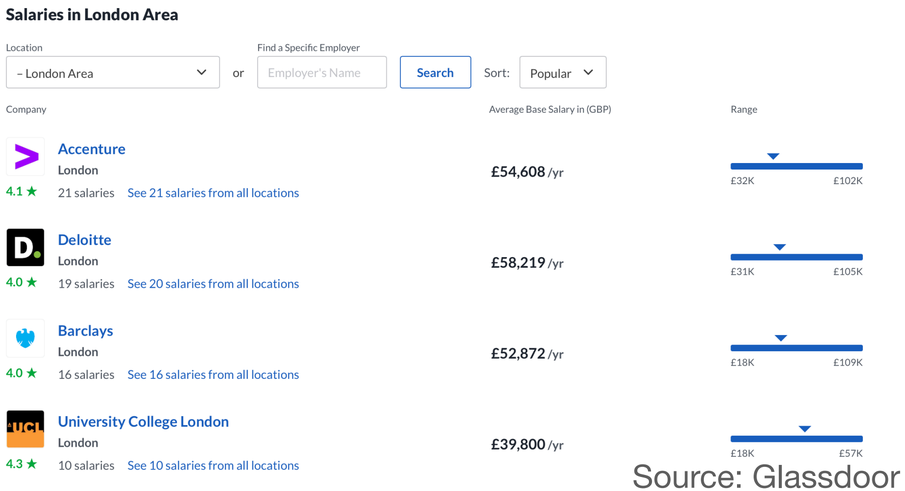
- Good to know the mean house price
- Or median?



Source: Rightmove

Summary statistics

- Most people will not scroll through a table!
- Summary statistics let us convey information as simply as possible
- We will now look at some (sample) statistics of (random) variables



Source: Glassdoor

Mode

- Suitable for summarising ordinal, nominal, and discrete variables
- Let's denote our (random) variable as X
- We have measurements of that variable
- The mode is the measurement that occurs the most

	Favourite Colour
0	red
1	blue
2	red
3	red
4	blue
5	yellow

3 red, 2 blue, 1 yellow

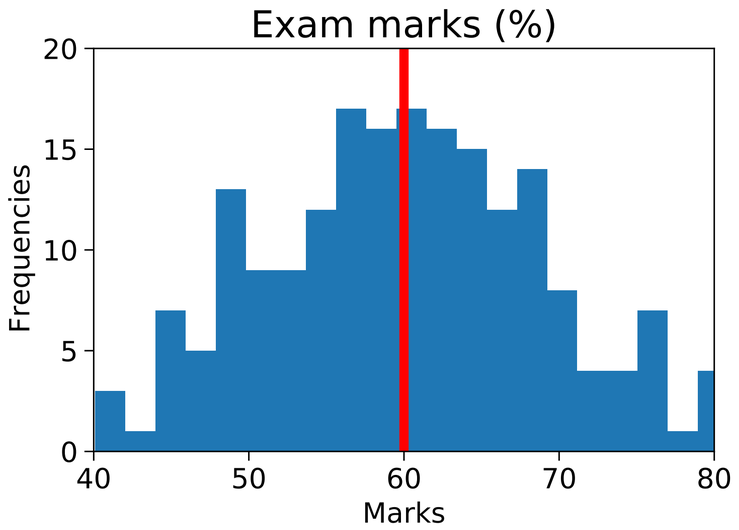
The mode is red

Mean

- Denote as μ. Suitable for summarising numerical variables
- For variable X we have N measurements $\{x^{(n)}\}_{n=1}^{N}$
- The measurements are just $x^{(1)}, x^{(2)}, \ldots, x^{(N)}$

$$\mu_x = \frac{1}{N}\sum_{n=1}^{N} x^{(n)}$$

	Mark (%)
0	60
1	40
2	45
...	...



Variance and Standard Deviation

- Let's denote variance as σ^2 and Standard deviation (SD) as σ
- For variable X we have N measurements $\{x^{(n)}\}_{n=1}^{N}$

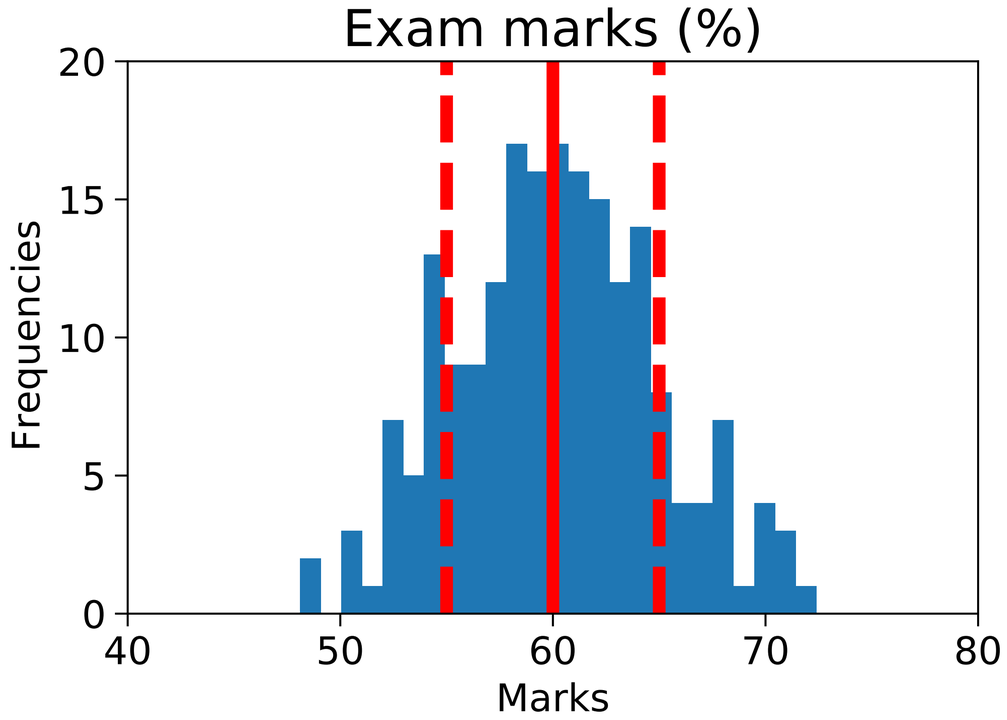
$$\sigma_x^2 = \frac{1}{N}\sum_{n=1}^{N}(x^{(n)} - \mu_x)^2$$

- Be aware that some definitions divide by $N-1$
- $N \approx N+1$ for large N so this isn't that important!

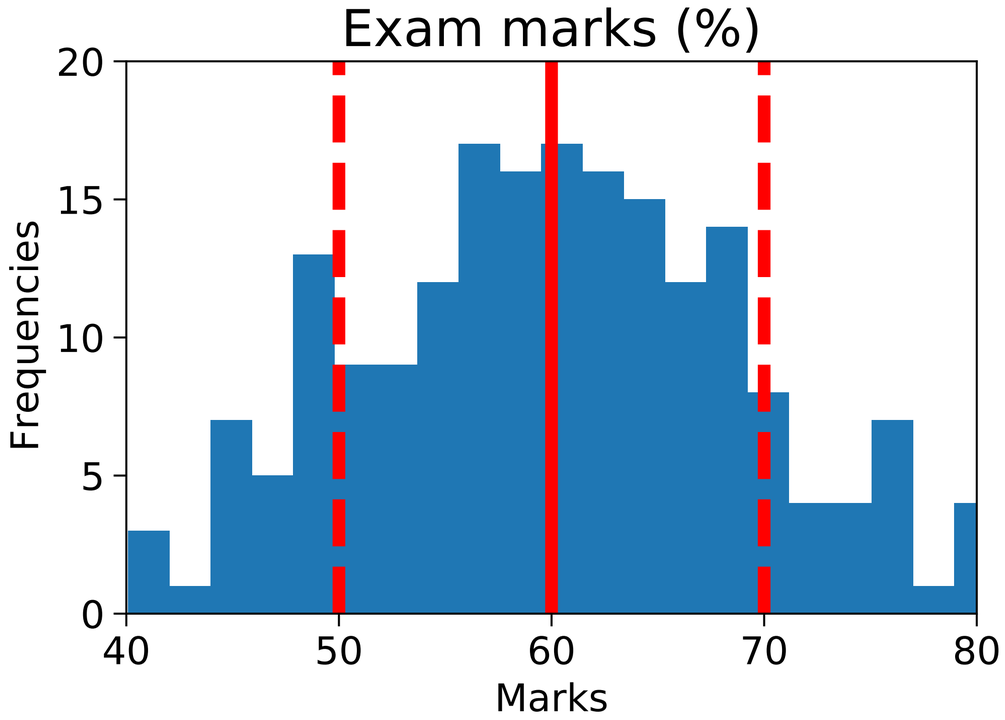
See https://towardsdatascience.com/the-reasoning-behind-bessels-correction-n-1-eeea25ec9bc9 for more info

Standard Deviation

SD measures the extent to which measurements deviate from the mean



$\sigma = 5$

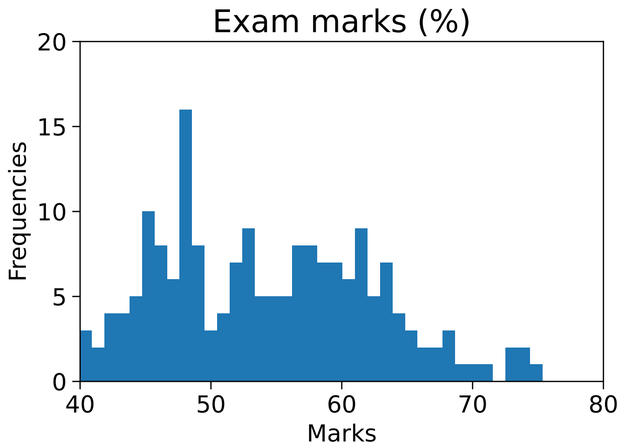


$\sigma = 10$

Skewness

- Denote using s. For variable X we have N measurements $\{x^{(n)}\}_{n=1}^{N}$

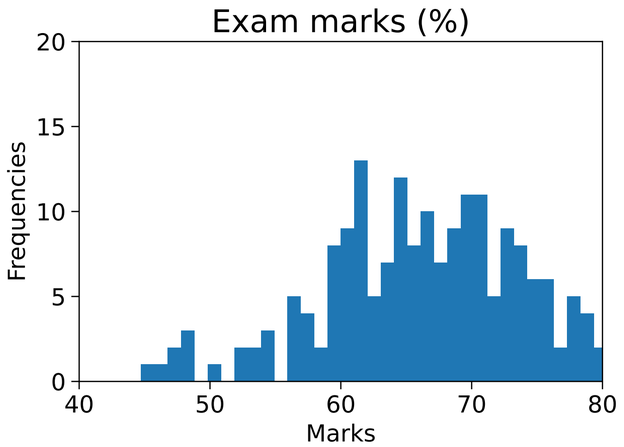
$$s_x = \frac{\frac{1}{N}\sum_{n=1}^{N}(x^{(n)} - \mu_x)^3}{\sigma_x^3}$$



Positive skew

Bulk of measurements on the left

Tail on the right



Negative skew

Bulk of measurements on the right

Tail on the left

Median

- Order measurements of a numerical variable from lowest to highest
- The median is the measurement in the middle

1 2 3 **5** 8 12 17

- The median is a **robust statistic**

1 2 3 **5** 8 12 1700000000

Medians are robust to outliers

Median salary is more meaningful than mean salary

Bet365 boss Denise Coates sees pay jump to £221m

8 January

By Lora Jones
Business reporter, BBC News

The boss of Bet365 was paid around £221m during its last financial year, despite the gambling giant reporting a significant loss.

https://www.bbc.co.uk/news/business-67912483

BUSINESS

FTSE 100 bosses earn average UK yearly pay after only three days

A typical boss of a company in London's top-flight stock market index makes £3.8 million a year

TAKEOVER DEALS DROP TO LOWEST SINCE FINANCIAL CRISIS (IAN WEST/PA)
PA ARCHIVE

DANIEL O'BOYLE @DAN_O_BOYLE
4 JANUARY 2024

https://www.standard.co.uk/business/ftse-100-bosses-ceo-salary-high-pay-centre-earnings-inequality-b1130313.html

Relating variables to each other

- We may be interested in the relationship between two variables
- Does GDP per capita relate to Healthy life expectancy?

Country or region	Score	GDP per capita	Social support	Healthy life expectancy	Freedom to make life choices	Generosity	Perceptions of corruption
Guatemala	6.436	0.800	1.269	0.746	0.535	0.175	0.078
Yemen	3.380	0.287	1.163	0.463	0.143	0.108	0.077
Netherlands	7.488	1.396	1.522	0.999	0.557	0.322	0.298
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United States	6.892	1.433	1.457	0.874	0.454	0.280	0.128

Covariance and correlation

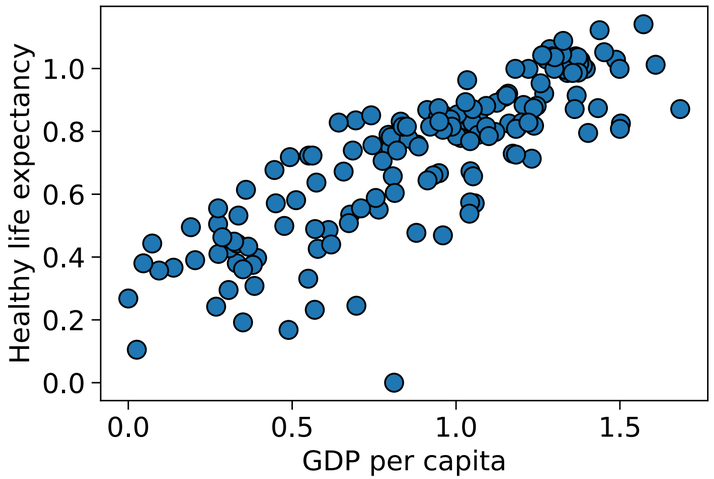
- We have two numerical variables X and Y each with N measurements
- Let's compute the means and SDs of each: $\mu_x, \mu_y, \sigma_x, \sigma_y$
- The covariance $\sigma_{x,y}$ and **Pearson correlation coefficient** $\rho_{x,y}$ are given by:

$$\sigma_{x,y} = \frac{1}{N} \sum_{n=1}^{N} (x^{(n)} - \mu_x)(y^{(n)} - \mu_y)$$

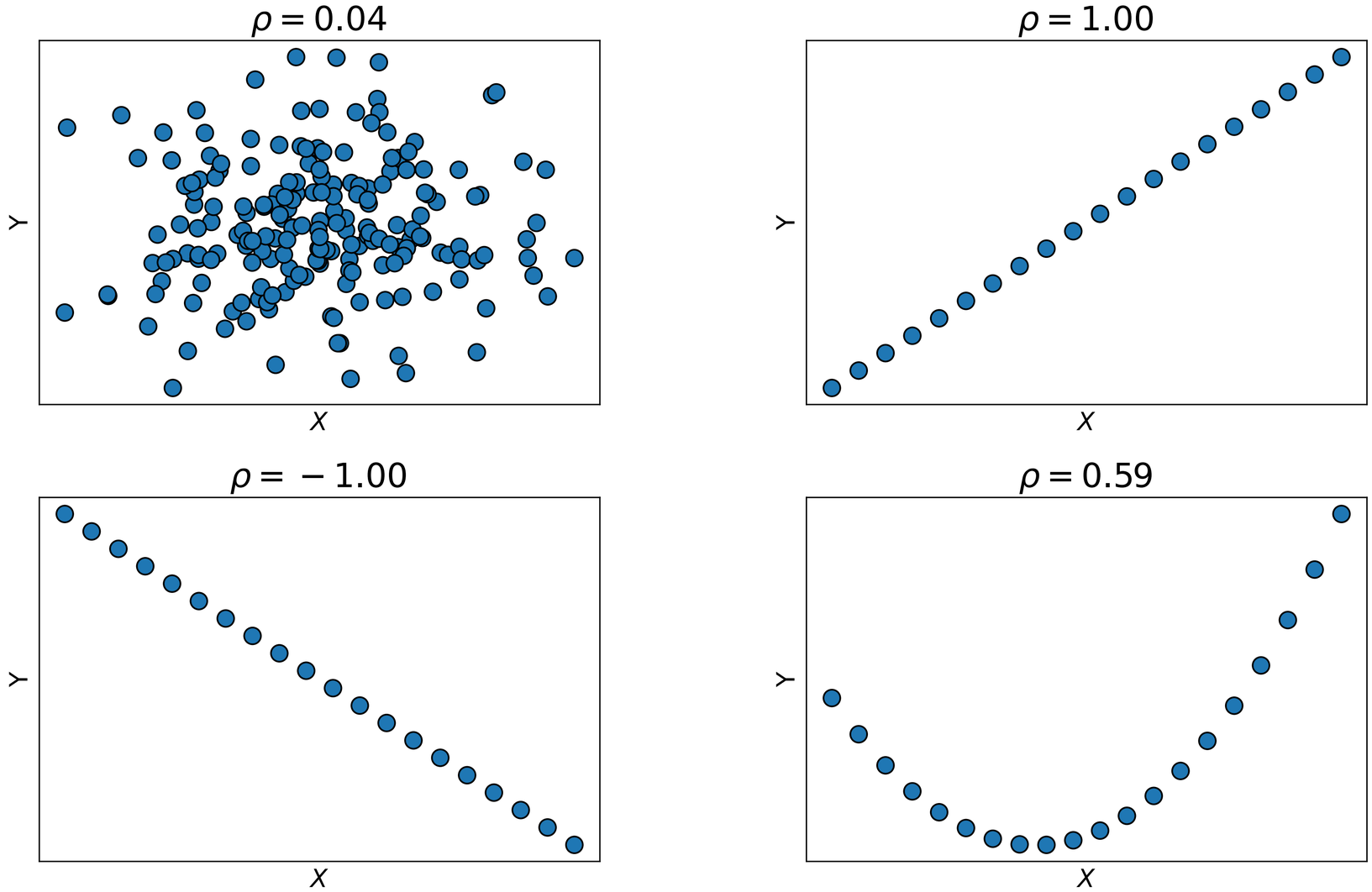
$$\rho_{x,y} = \frac{\sigma_{x,y}}{\sigma_x \sigma_y}$$

Pearson correlation coefficient

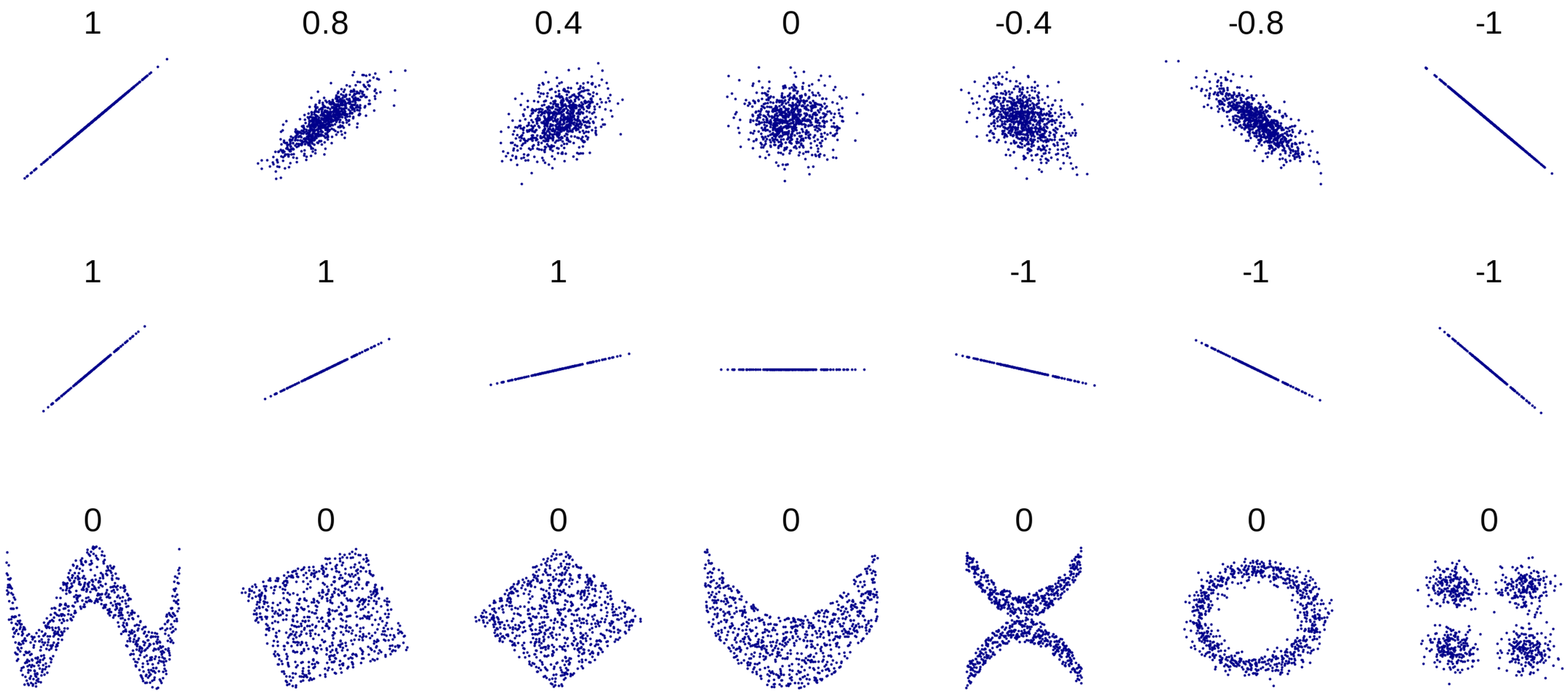
- $\rho_{x,y}$ has a value between -1 and $+1$
- It gives a measure of how linear the relationship between X and Y is
- That is, the extent to which we can use a line to map one to the other
- 0.84 for GDP per capita and Healthy life expectancy



Pearson correlation coefficient



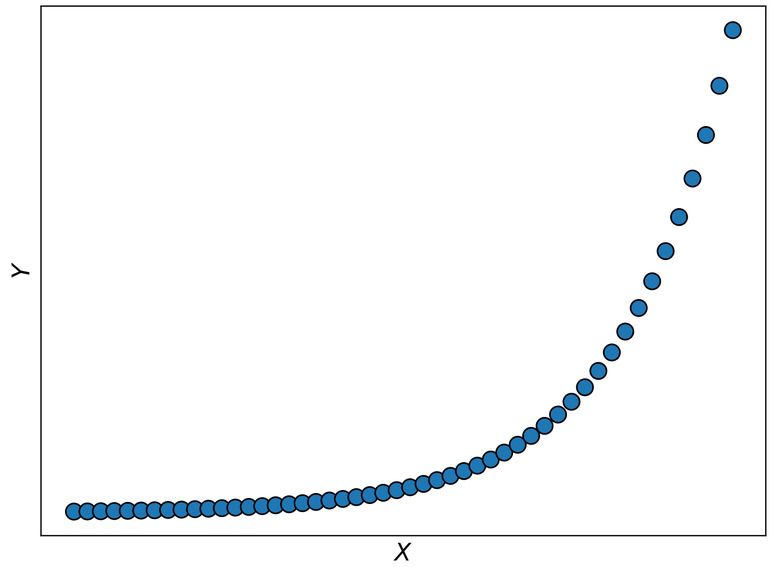
Pearson correlation coefficient

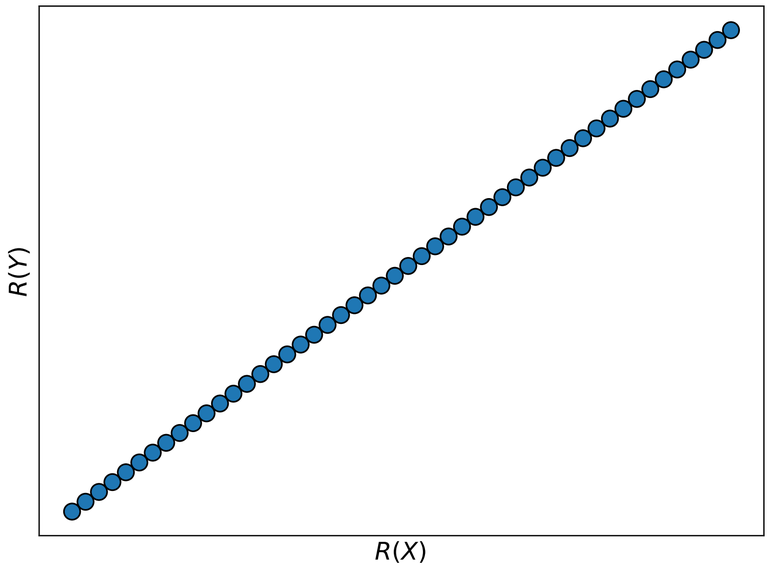


Source: https://en.wikipedia.org/wiki/Correlation#/media/File:Correlation_examples2.svg

Spearman's rank correlation coefficient r_s

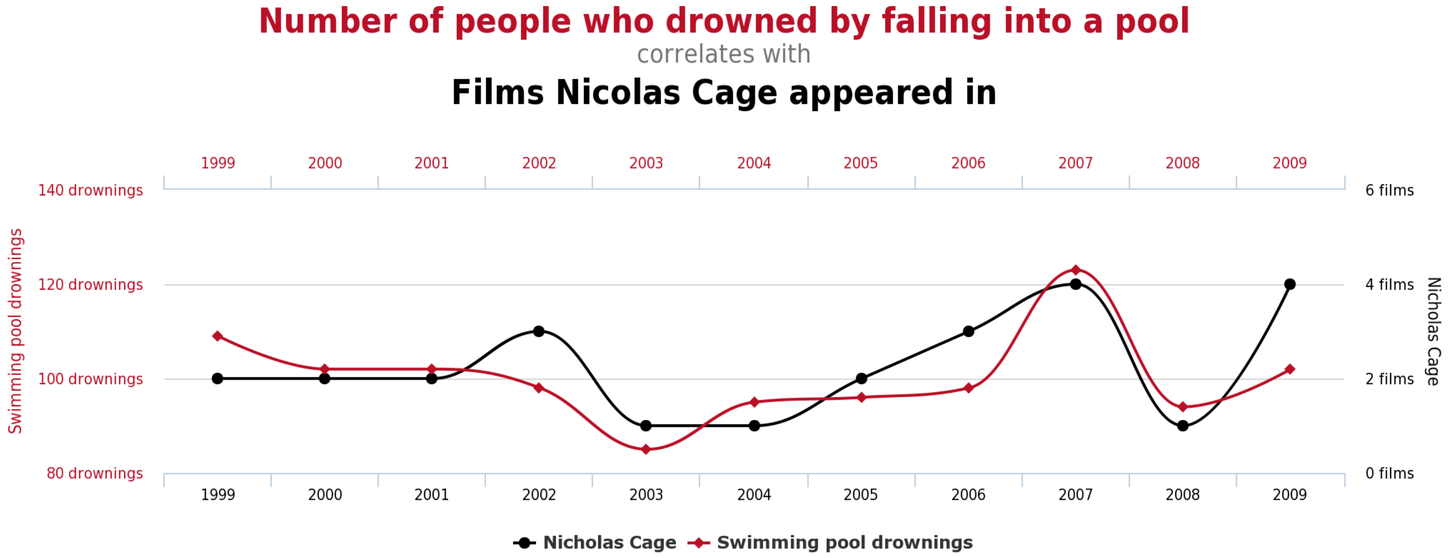
- This is the Pearson correlation coefficient of the **ranks** of two variables
- e.g. if $X = \{1,100,1000,10000\}$, $R(X) = \{4,3,2,1\}$
- It measures how monotonic the relationship between the variables is





The Pearson correlation here is 0.82
The Spearman correlation is 1

Correlation does not imply causation



Rubbish in, rubbish out

If your data is rubbish then anything you extract from it is also rubbish

- You might not have enough data points
- The process for collecting data might be flawed (e.g. biased)
- Measurements might be recorded incorrectly
- The variables chosen might not be useful

Misleading statistics

Can be nefarious, or just stupidity

BBC NEWS

LIVE BBC NEWS CHANNEL

News Front Page
World
UK
England
Northern Ireland
Scotland
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Business
Politics
Health
Education
Science & Environment
Technology
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Last Updated: Wednesday, 17 January 2007, 02:45 GMT

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Colgate warned over '80%' boast

The maker of Colgate toothpaste has been warned not to repeat its famous advertising claim that "more than 80% of dentists recommend Colgate".

Colgate's claim on posters was "misleading"

The Advertising Standards Authority concluded the claim on Colgate posters was "misleading" after investigating the phone survey behind the boast.

It found the dentists surveyed were allowed to name more than one brand.

But the ASA said the advertising claim implied 80% of dentists recommended Colgate to the exclusion of its rivals.

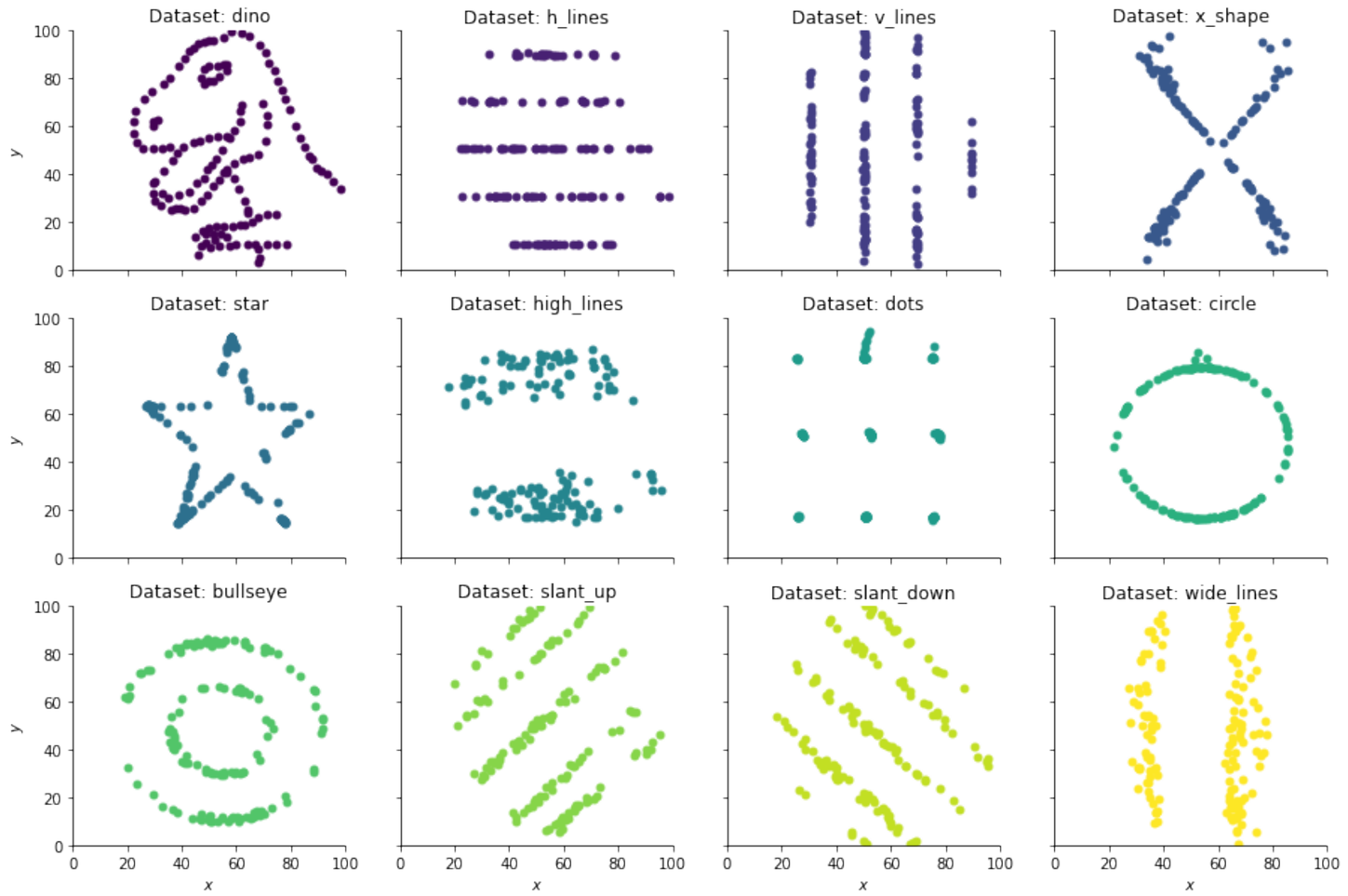
In fact, the ASA's inquiry found another competitor's brand was recommended almost as much as Colgate was by those dentists who were surveyed.

It added the survey "did not make clear the poll was on behalf of Colgate".

HANLON'S RAZOR

*Never attribute to **malice** that which is adequately explained by **stupidity***

The limitations of summary statistics



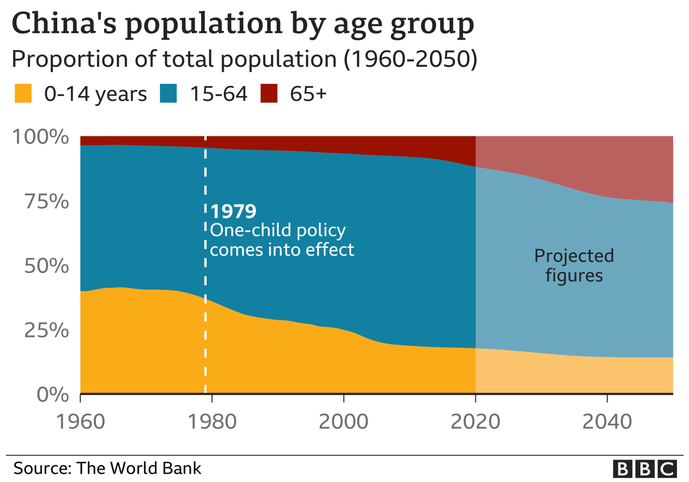
All 12 of these datasets have the same $\mu_x, \mu_y, \sigma_x, \sigma_y, \rho_{x,y}$

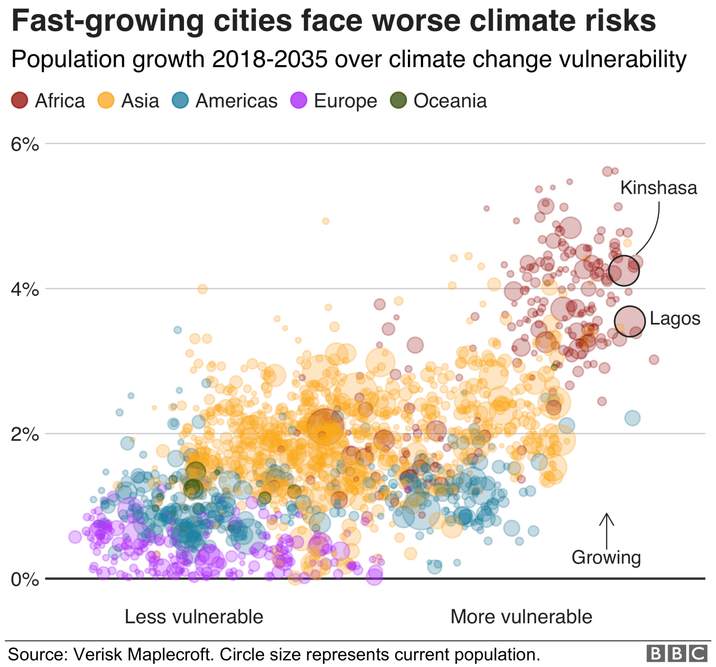
https://github.com/probml/pyprobml/blob/master/notebooks/book1/02/datasaurus_dozen.ipynb

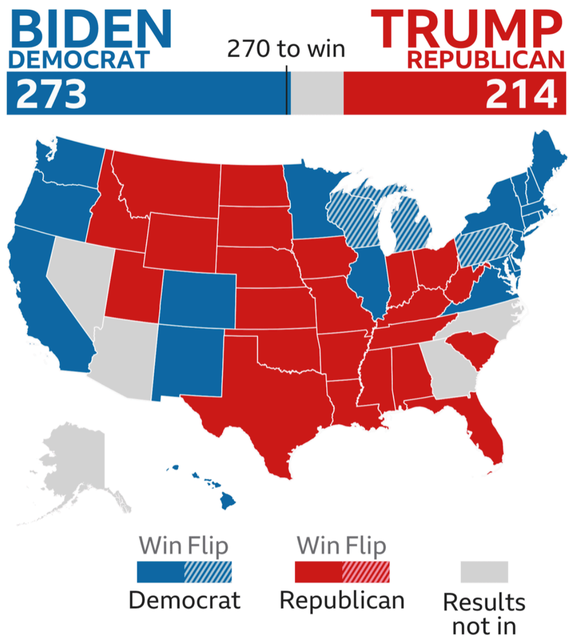
Visualising Data

Visualising data for presentation

- Conveying information as **simply**, and **clearly** as possible
- It is an art form, combining data analysis with graphic design



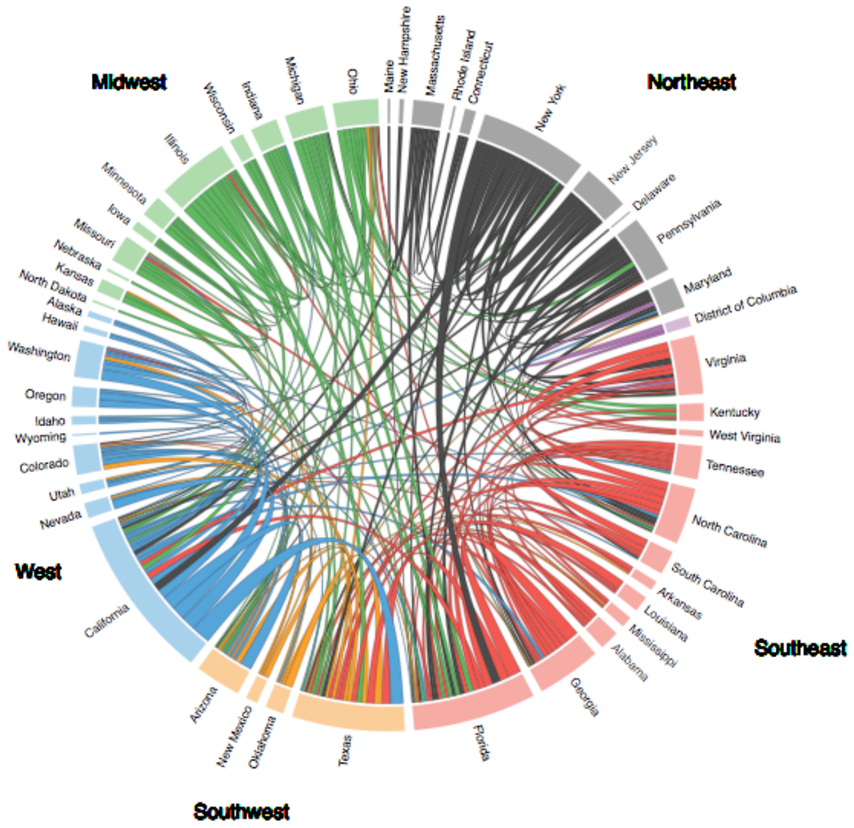




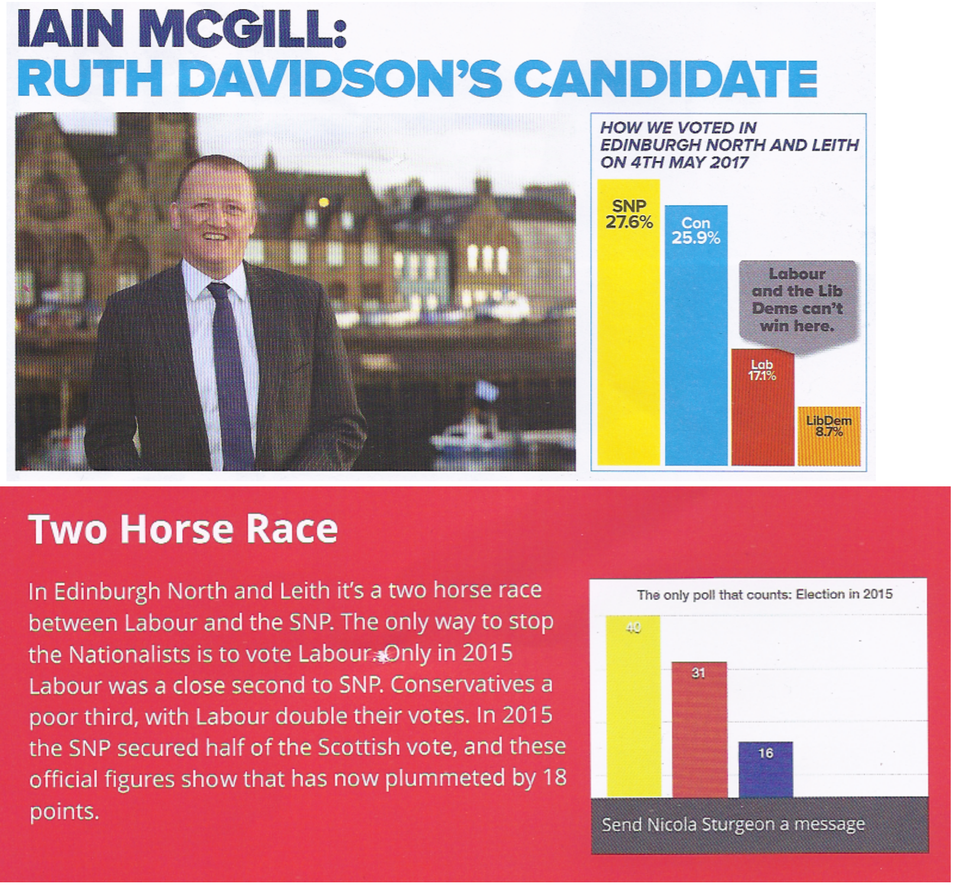
Source: BBC

Visualising data for presentation

Can be done badly e.g. overcomplicated or misleading



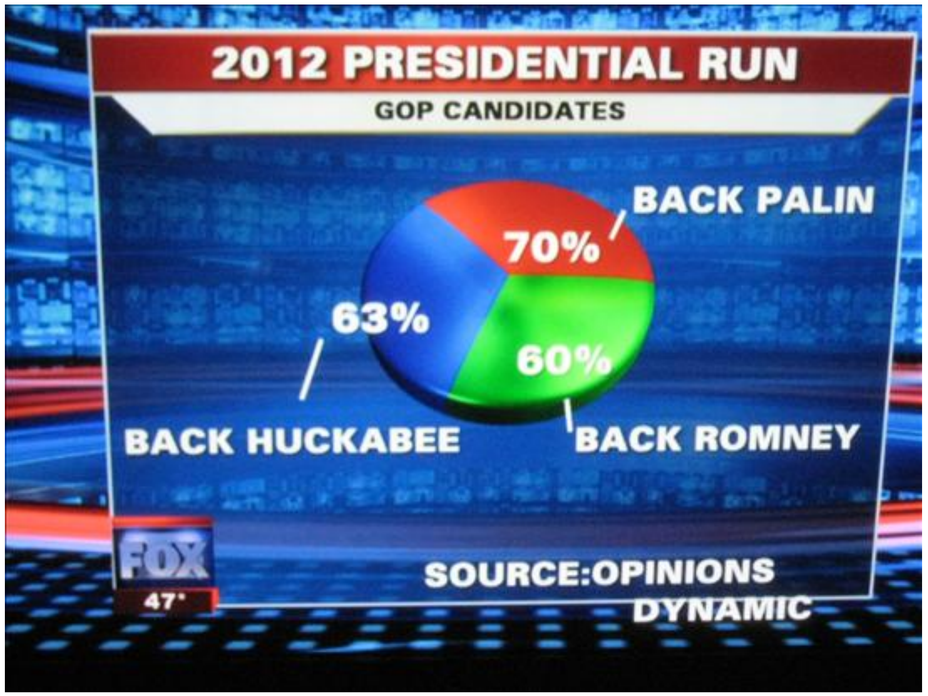
Source: https://junkcharts.typepad.com/junk_charts/2014/01/visualizing-movements-of-people.html

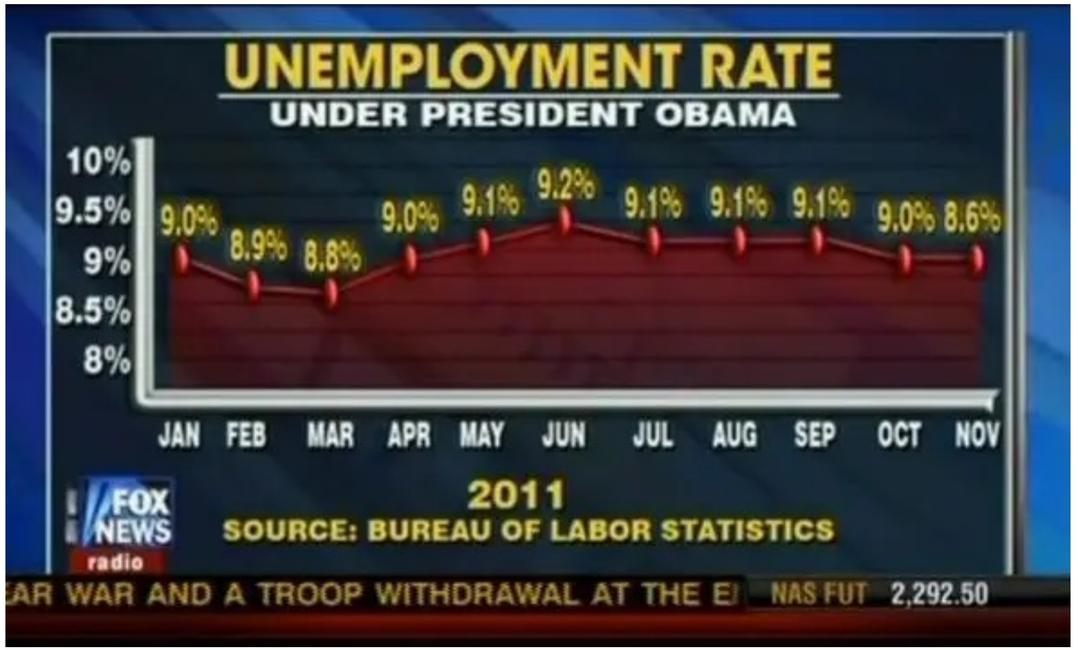


Source: https://www.broughtonspurtle.org.uk/news/dodgy-election-bar-charts-4

Visualising data for presentation

Or can just be completely wrong

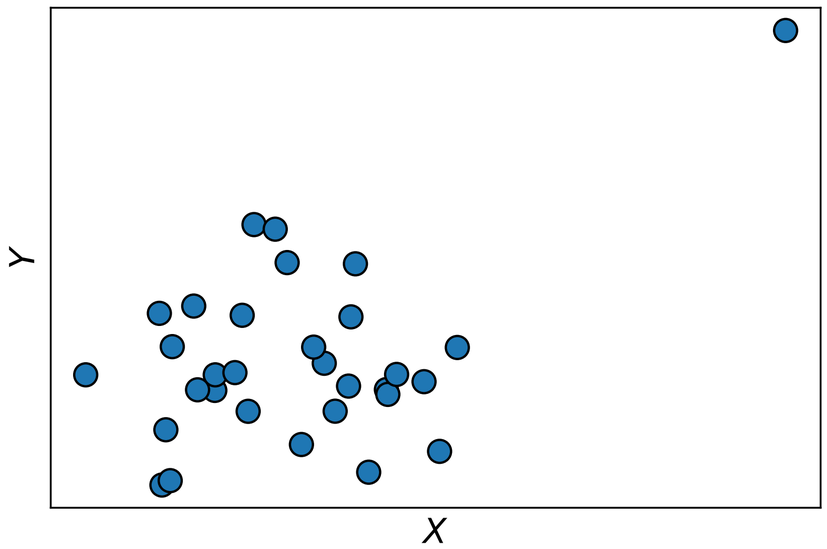


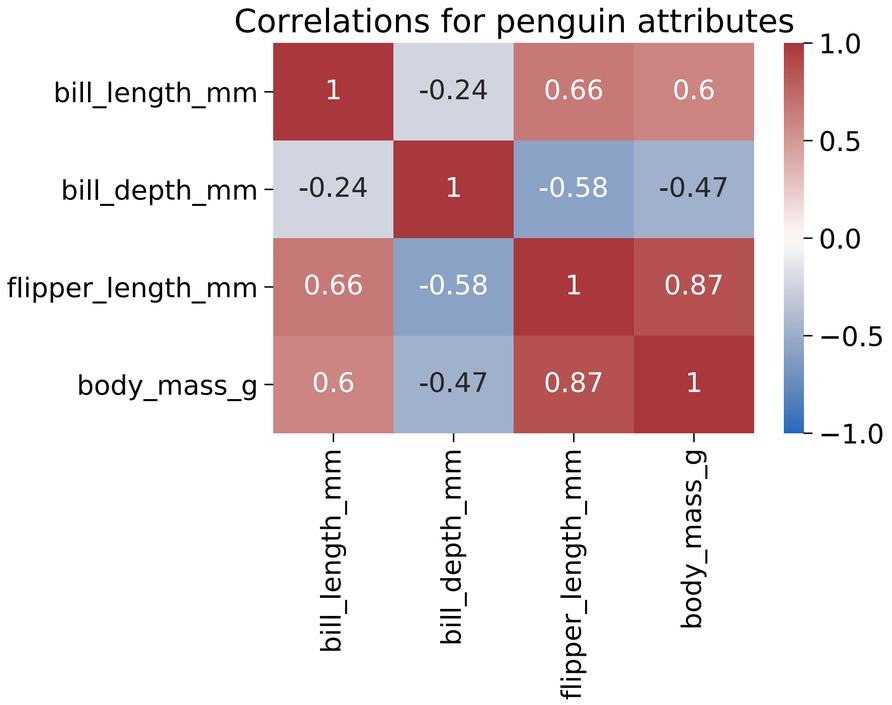


Source: https://www.businessinsider.com/fox-news-charts-tricks-data-2012-11?r=US&IR=T

Visualising data for exploration

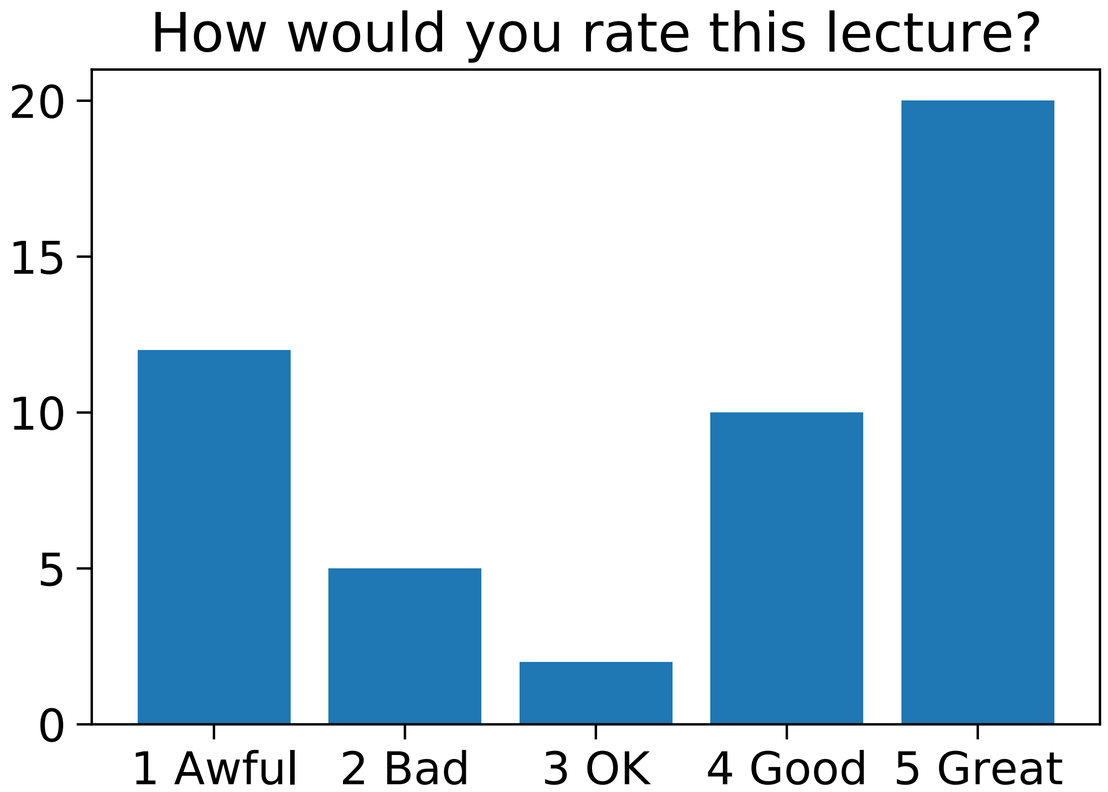
- This lets us find patterns, spot outliers/errors, identify important variables…
- It helps us decide which machine learning methods to use (if any!)
- **We want to know if the data makes sense and if it is meaningful**





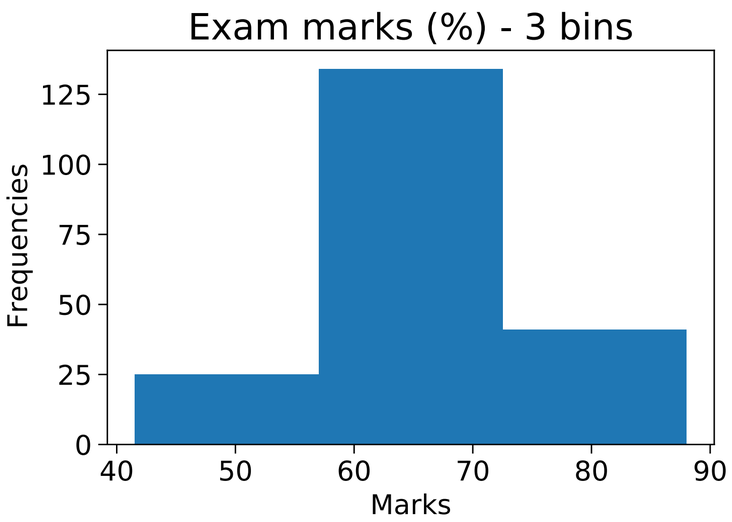
Bar plots

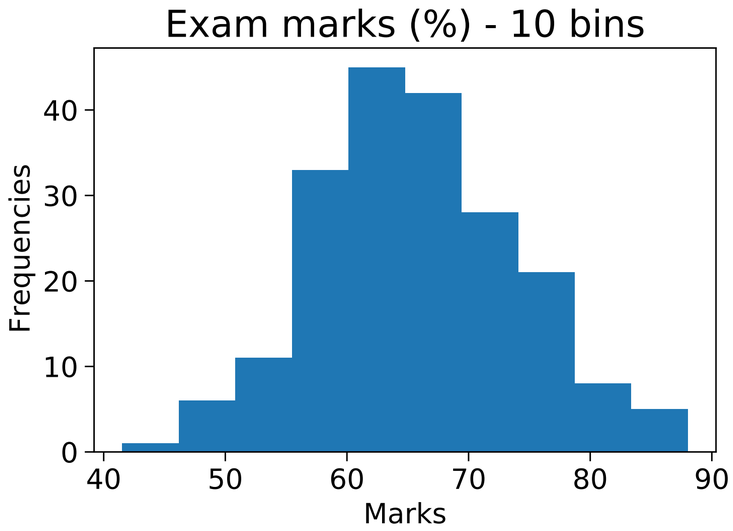
- Good for visualising categorical variables
- If the variable is ordinal then make sure that the columns are in order

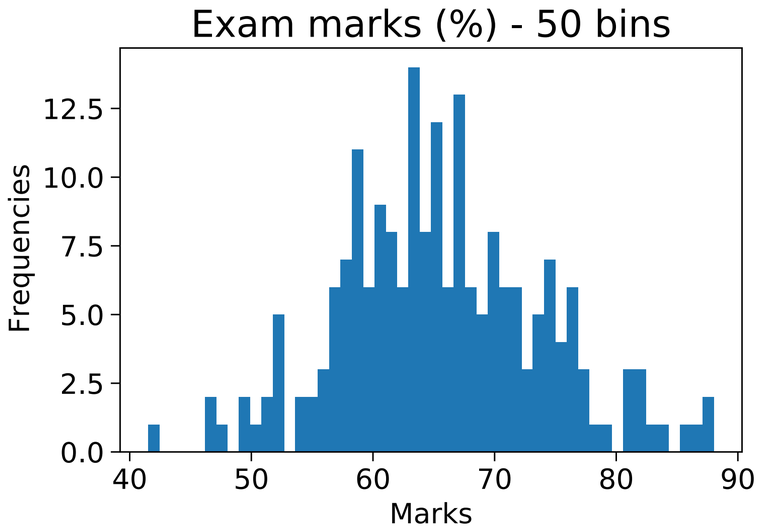


Histograms

- Sorts measurements for numerical variables into equal sized bins
- The number of bins (and/or bin width) may need tweaking depending on use



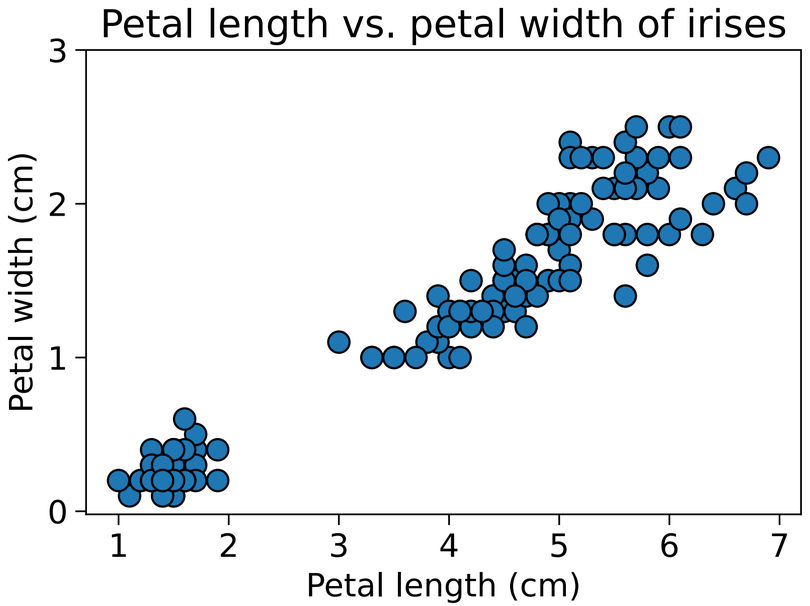


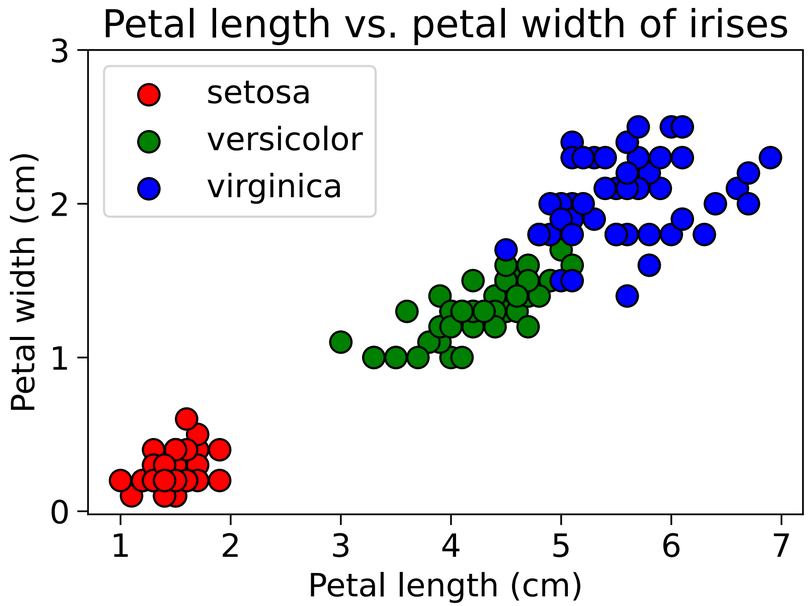


There are strange y ticks on this plot.
This can also be tweaked!

Scatter plots in 2D

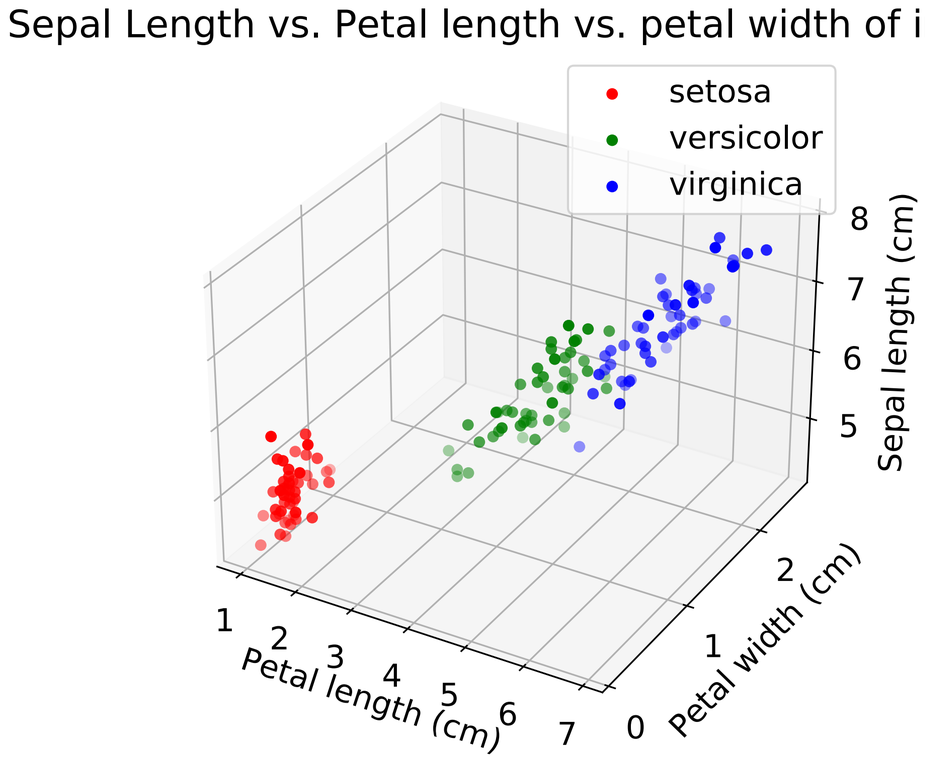
- Each point corresponds to a data item
- The x, y values for that point are measurements of two numerical variables
- We can also distinguish points by category by using different colours/shapes





Scatter plots in 3D

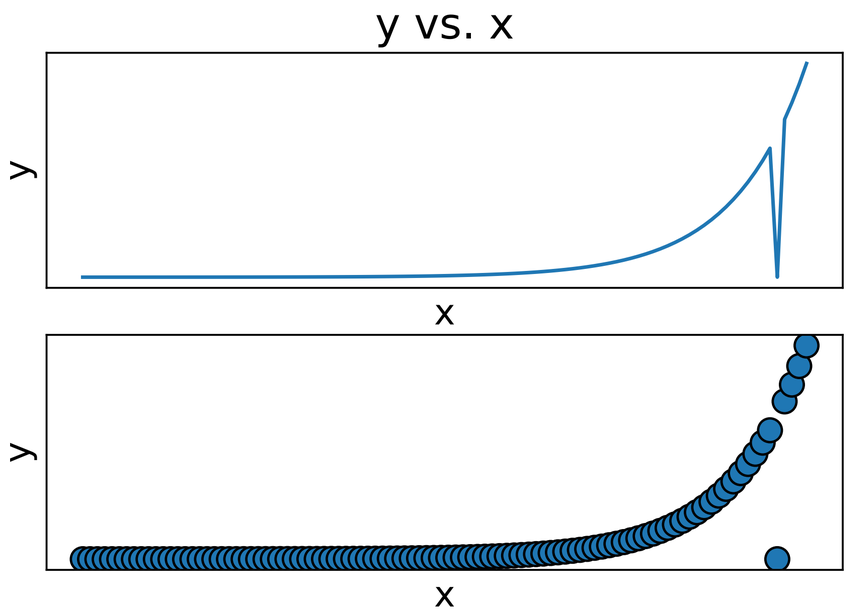
- We can have x, y, z values to show three measurements per point
- But beware: we can't see the space properly as its' only a 2D projection :(

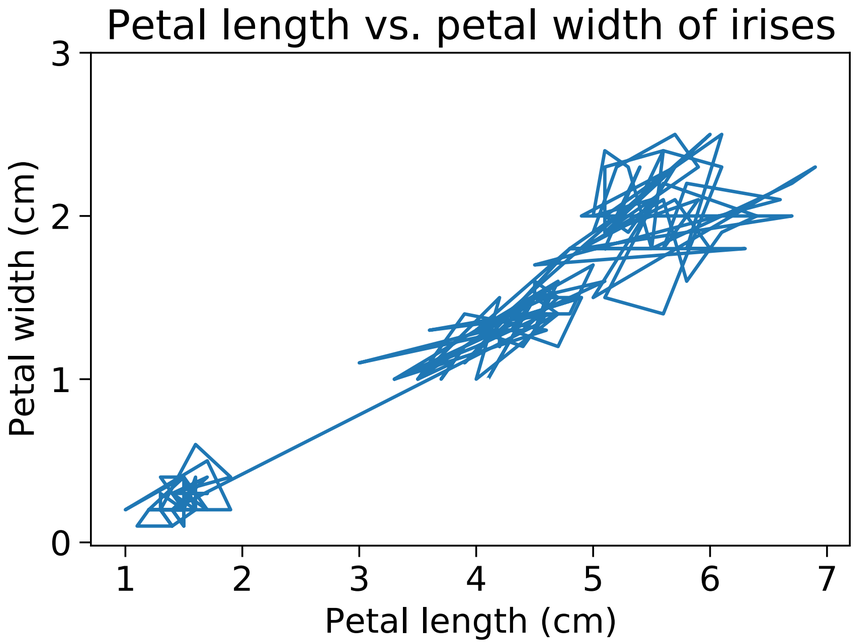


I tend to avoid 3D plots where possible

Line plots

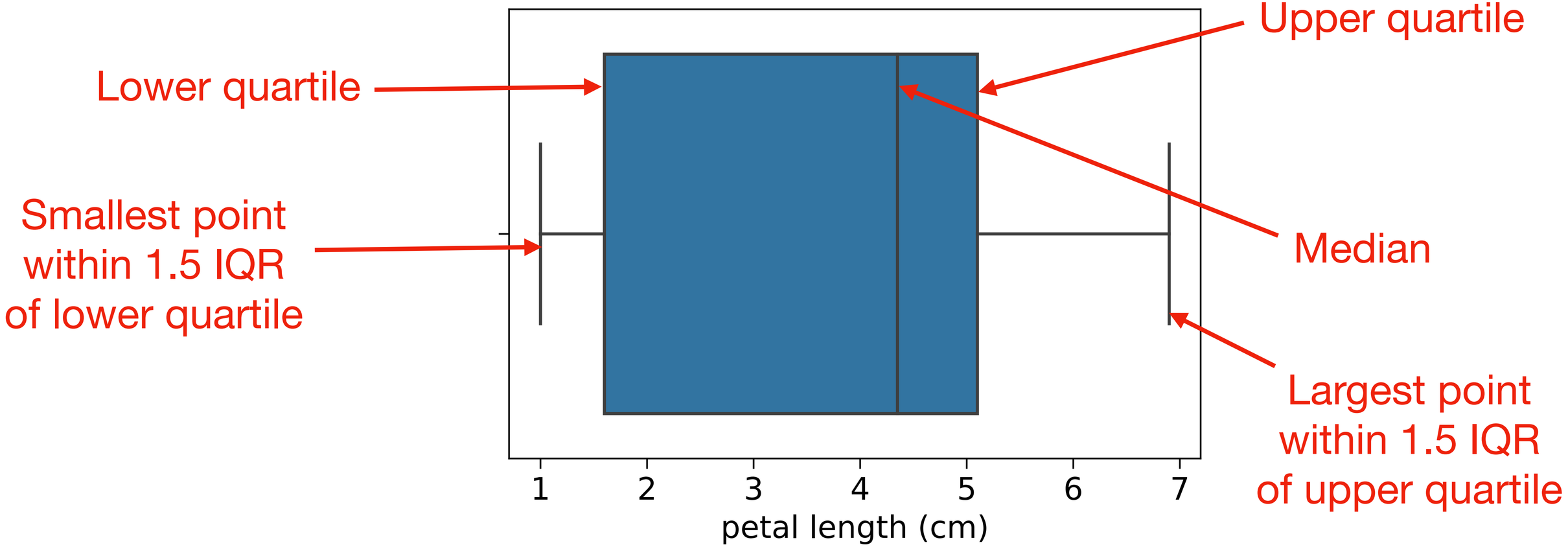
- Can be useful for interpolation
- But can depict a functional relationship that doesn't exist if used carelessly





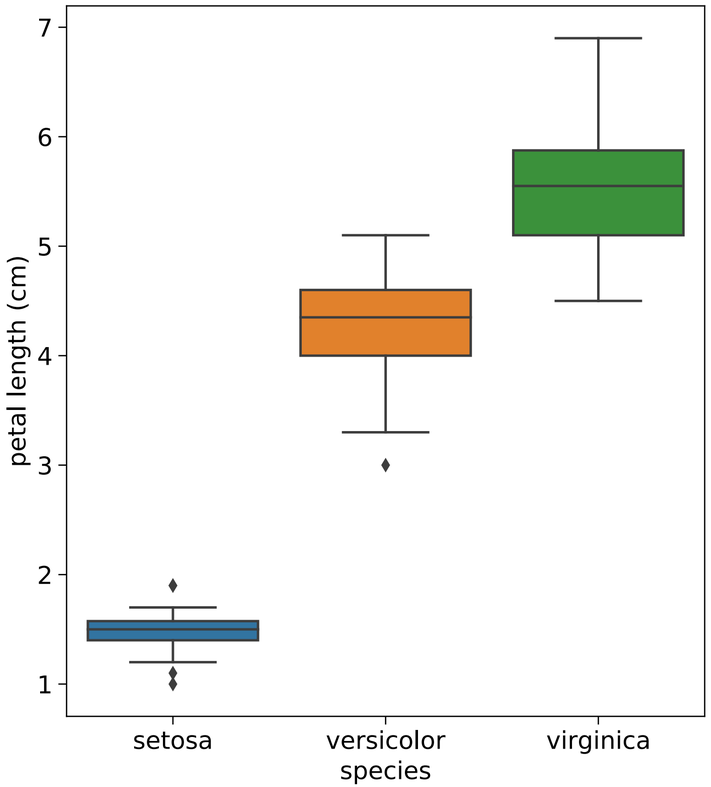
Box plots

- Shows 5 key statistics of a variable, each being an actual measurement
- Interquartile range (IQR) = upper quartile - lower quartile



Box plots

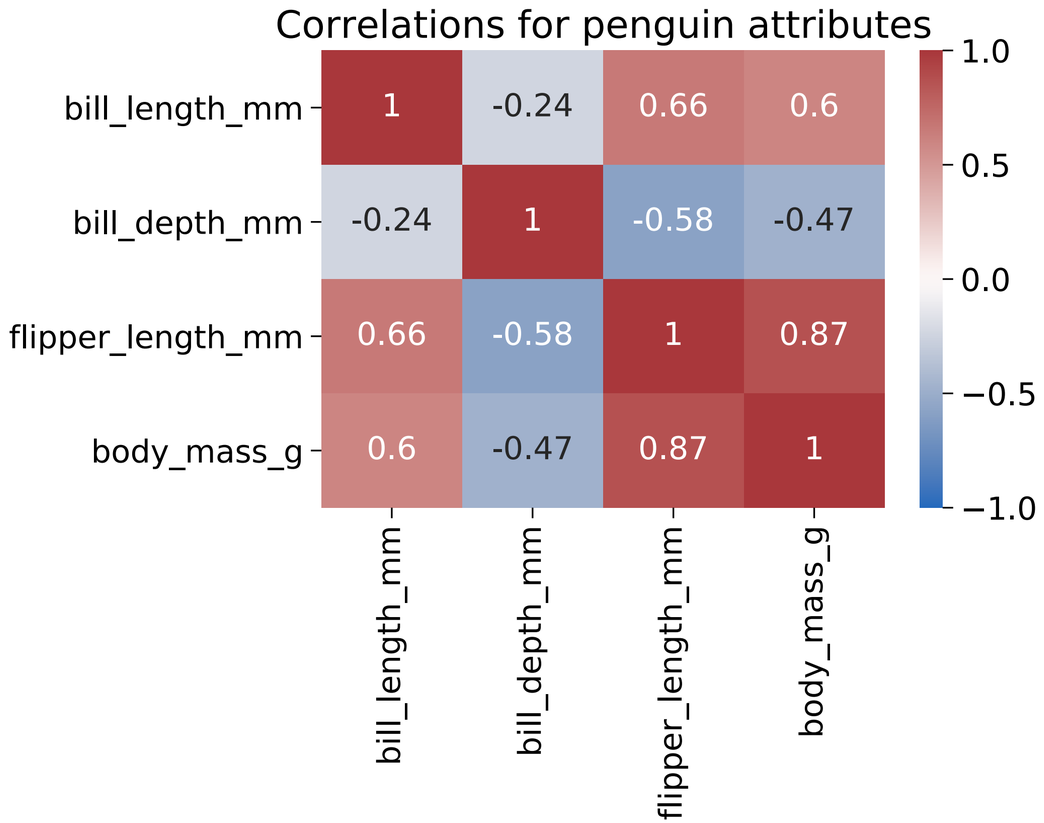
- We can view these statistics split by category
- Any points outside of the *whiskers* are plotted



Plot can be horizontal or vertical

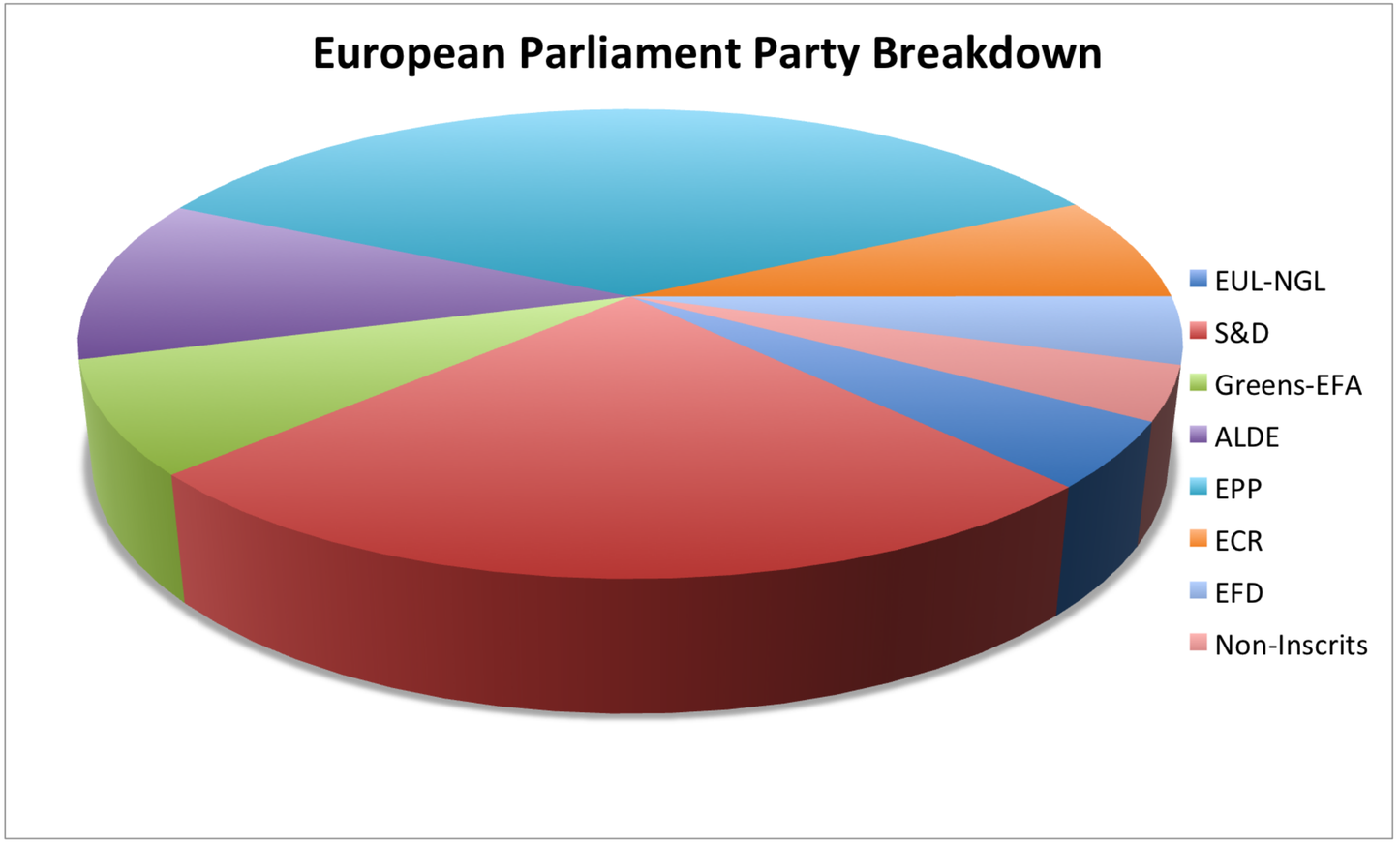
Heat maps

- A matrix of colours representing different magnitudes of some quantity
- Here we have Pearson correlation of different attributes of penguins



And of course … pie charts

Avoid!



Source: https://www.businessinsider.com/pie-charts-are-the-worst-2013-6?r=US&IR=T

Summary

- We have revised some statistics and seen how they can summarise data
- We have considered correlations for different pairs of variables
- We have seen examples of good and bad visualisations of data
- We have considered different ways of plotting data