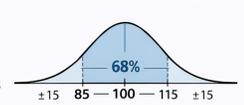


The CV as a measure of variability around the mean, i.e., the CV tells us how risky it is to use the mean as a predictor of individual observations.

CV = 0.15  
 Mean = 100  
 SD = 15  
 68% within 85 to 115



$$CV = \frac{s}{\bar{Y}} \times 100\%$$

Saying that a CV of 0.15 means that typical deviations are about 15% of the mean means that the standard deviation equals 0.15 x mean.

If the data are approximately normally distributed, about two-thirds (~68% to be exact) of the observations will fall within one standard deviation of the mean, that is, within 15 units of the mean (i.e., between 85 and 115).

A percentage such as 15% of the mean describe the scale of variation, not exact probabilities. Normality converts this scale into specific frequencies; non-normal distributions change the frequencies, not the relative amount of variation.

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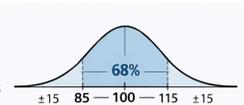
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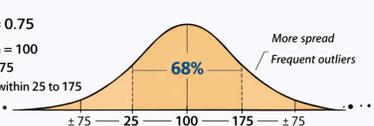
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The CV as a measure of variability around the mean, i.e., the CV tells us how risky it is to use the mean as a predictor of individual observations.

CV = 0.15  
 Mean = 100  
 SD = 15  
 68% within 85 to 115



CV = 0.75  
 Mean = 100  
 SD = 75  
 68% within 25 to 175



More spread  
 Frequent outliers

$$CV = \frac{s}{\bar{Y}} \times 100\%$$

In both examples above the mean is identical, but the relative spread of the data, and therefore the variability associated with using the mean as a predictor, is dramatically different.

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2

**Describing data**

Samples and populations are often made of lots of individual (observational) units and their associated information (observations, variables).

We need to be able to describe samples by summary statistics (mean, median, variance, etc) so that these summaries can serve as an estimate of the same summaries for their statistical populations.




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3

How do measures of location (mean versus median) and spread (standard deviation versus interquartile range) compare?

**Disarming fish**  
(protection against predation)



Threespine stickleback  
(*Gasterosteus aculeatus*)

**Plate Genotypes**  
Ectodysplasin (*Eda*) locus  
(3<sup>rd</sup> generation)

**MM (marine)**

**Mm (hybrid)**

**mm (freshwater)**

Variation is at the heart of biology! The diversity among individuals and species forms the foundation of biological science.

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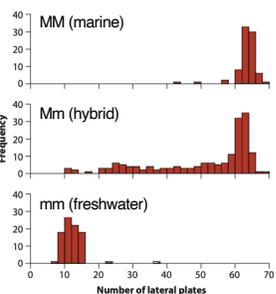
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4

How do measures of location (mean versus median) and spread (standard deviation versus interquartile range) compare?

**Disarming fish**  
(protection against predation)



Variation is at the heart of biology! The diversity among individuals and species forms the foundation of biological science.

**Which distribution is more asymmetric?**

Whitlock & Schluter, *The Analysis of Biological Data*, 3e © 2020 W. H. Freeman and Company

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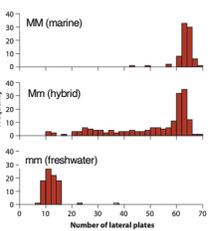
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5

How do measures of location (mean versus median) and spread (standard deviation versus interquartile range) compare?



**Which distribution is more asymmetric?**

Genotype	<i>n</i>	Mean	Median	Standard deviation	Interquartile range
<i>MM</i>	82	62.8	63	3.4	2
<i>Mm</i>	174	50.4	59	15.1	21
<i>mm</i>	88	11.7	11	3.6	3

Whitlock & Schluter, *The Analysis of Biological Data*, 3e © 2020 W. H. Freeman and Company

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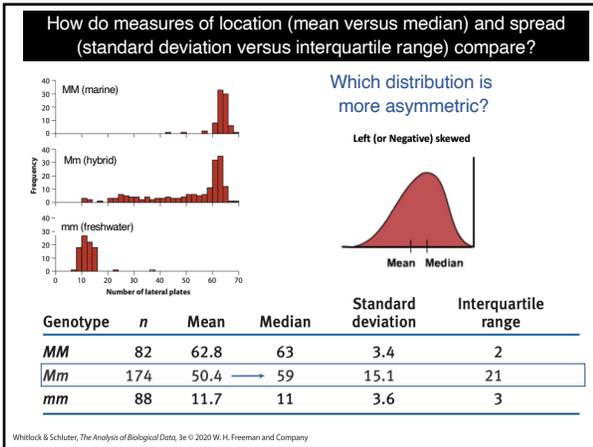
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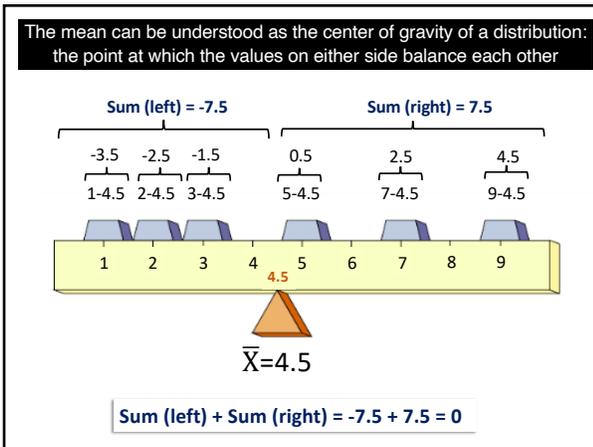
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Recall from lecture 5: the sum of deviations from the mean is always zero, making the mean the 'center of gravity' of a distribution.

Quantities needed to calculate the standard deviation and variance of snake undulation rate ( $Y = 1.375 \text{ Hz}$ ).

Observations ( $Y_i$ )	Deviations ( $Y_i - \bar{Y}$ )	Squared deviations ( $(Y_i - \bar{Y})^2$ )
0.9	-0.475	0.225625
1.2	-0.175	0.030625
1.2	-0.175	0.030625
1.3	-0.075	0.005625
1.4	0.025	0.000625
1.4	0.025	0.000625
1.6	0.225	0.050625
2.0	0.625	0.390625
Sum	0.000	0.735

Whitlock & Schluter, The Analysis of Biological Data, 3e © 2020 W. H. Freeman and Company

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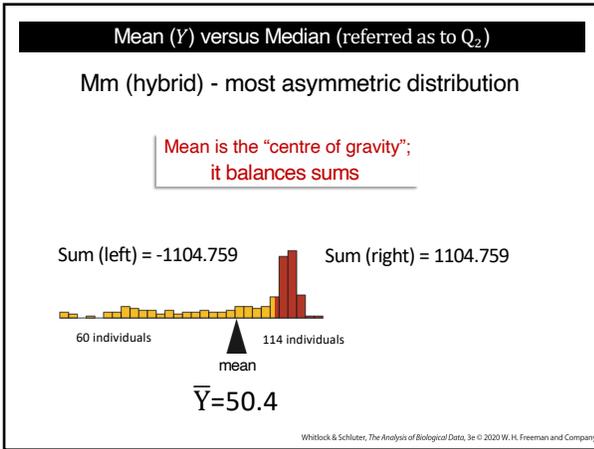
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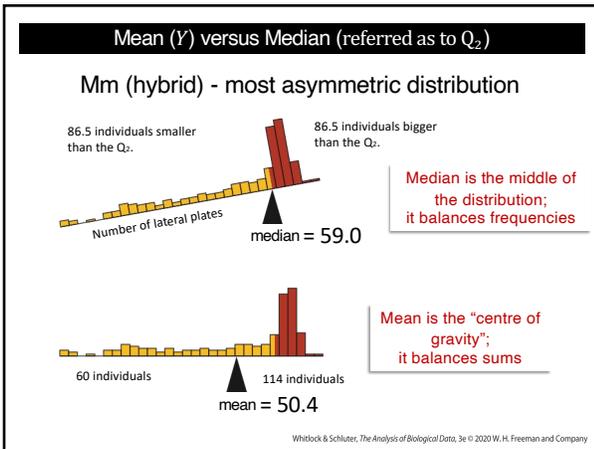
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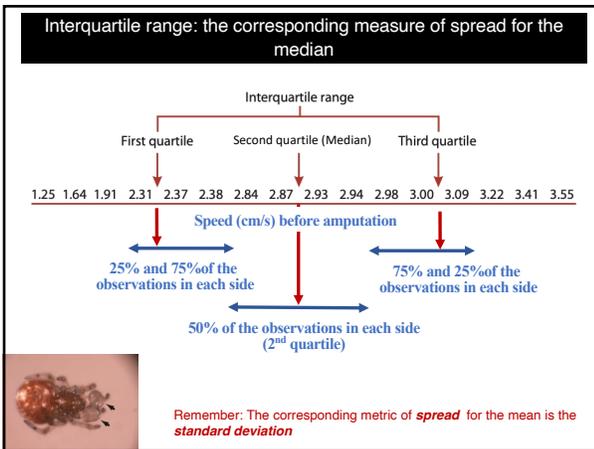
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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

25% and 75% of the observations in each side

75% and 25% of the observations in each side

50% of the observations in each side (2<sup>nd</sup> quartile)

It's important to understand what the first, second (median), and third quartiles represent, and how the median differs from the mean. While I don't expect you to calculate these values by hand, working through some examples helps develop numeracy and a better intuition for what these summaries actually mean.

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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

While the calculation of the median (2nd quartile or Q2) differs depending on whether the number of observations is odd or even, the calculations for the 1st (Q1) and 3rd (Q3) quartiles remain the same.

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**Interquartile range: the corresponding measure of spread for the median – first quartile  $Q_1$**

Speed (cm/s) before amputation

Positioning  $Q_1$ :  $j = 0.25n = (0.25)(16) = 4$

where  $n$  is the number of observations in the data (i.e., 16 male spiders).

Because here  $j$  is an integer (i.e., whole number, not a fraction), then the 1<sup>st</sup> quartile is the average of  $Y_{(j)}$  and  $Y_{(j+1)} = Y_{(4)}$  and  $Y_{(4+1)} = (2.31 + 2.37) / 2 = 2.340$  cm/s

**First quartile ( $Q_1$ ) = 2.340 cm/s**

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**Interquartile range: the corresponding measure of spread for the median – first quartile  $Q_1$**

Speed (cm/s) before amputation

This is not exactly the default rule in R, but the values are very similar. There are several different rules for calculating quartiles.

**First quartile ( $Q_1$ ) = 2.340 cm/s**

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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

If  $j$  was not an integer, round  $j$  (e.g., say  $j$  was 4.32 then round  $j = 4$ ). We would then have picked the 4<sup>th</sup> value in the ranked distribution (i.e., 2.31 cm/s)

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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

Positioning  $Q_3$ :  $j = 0.75n = (0.75)(16) = 12$

where  $n$  is the number of observations. If  $j$  is an integer (whole number, not a fraction), then the 3<sup>rd</sup> quartile is the average of  $Y_{(j)}$  and  $Y_{(j+1)} = Y_{(12)}$  and  $Y_{(12+1)} = (3.00 + 3.09) / 2 = 3.045$  cm/s

**Third quartile ( $Q_3$ ) = 3.045 cm/s**

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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

Positioning  $Q_3: j = 0.75n = (0.75)(16) = 12$

If  $j$  was not an integer (here 12), round  $j$  (e.g., say  $j$  was 12.72 then  $j = 13$ ). We would then have picked the 13<sup>th</sup> value in the ranked distribution (i.e., 3.09 cm/s). The same applies for  $j$  in  $Q_1$ .

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**Interquartile range: the corresponding measure of spread for the median**

Speed (cm/s) before amputation

The **interquartile range** (IQR) for the speed data before amputation is then  $Q_3 - Q_1 = 3.045 - 2.340 = 0.705$  cm/s

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**Remember: the mean reflects all values in a distribution but is influenced by extreme values. The median, while not as representative of the entire distribution, is resistant to the influence of extreme values.**

Mean is the "centre of gravity"; it balances sums	Median is the middle of the distribution; it balances frequencies
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$Y = 53, 58, 62, 64, 68, 72, 73, 77, 86, 87, 88, 92$

$\bar{Y} = 73.3$   
 $Q_2 = 72.5$

$Y = 53, 58, 62, 64, 68, 72, 73, 77, 86, 87, 88, 192$

$\bar{Y} = 81.7$   
 $Q_2 = 72.5$

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Let's take a "power break" – 1 minute



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The median is the middle measure of a set of observations (distribution)

If the number of observations ( $n$ ) is **even**, then the median is calculated differently:



It gives an "arm" (or a pedipalp) for a female spider.

Running speed (cm/s) of male *Tidarren* spiders before and after voluntary amputation of one pedipalp.

Spider	Speed before	Speed after	Spider	Speed before	Speed after
1	1.25	2.40	9	2.98	3.70
2	2.94	3.50	10	3.55	4.70
3	2.38	4.49	11	2.84	4.94
4	3.09	3.17	12	1.64	5.06
5	3.41	5.26	13	3.22	3.22
6	3.00	3.22	14	2.87	3.52
7	2.31	2.32	15	2.37	5.45
8	2.93	3.31	16	1.91	3.40



*Oxyopes salticus*

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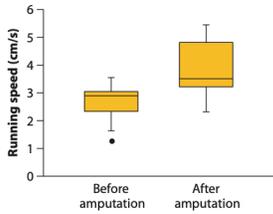
Representing data distributions by their quartiles:  
Boxplot (box-and-whisker plot)

What are the advantages of a box plot?

A boxplot quickly shows where most values lie (location) and how spread out the data are.

It helps reveal whether a distribution is symmetric or skewed.

It also stands out from many other graphs by clearly identifying potential outliers.



source - [www.netmba.com/statistics/plot/box/](http://www.netmba.com/statistics/plot/box/)

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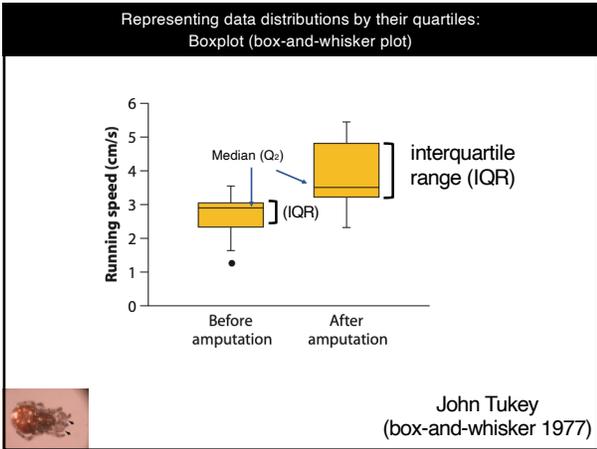
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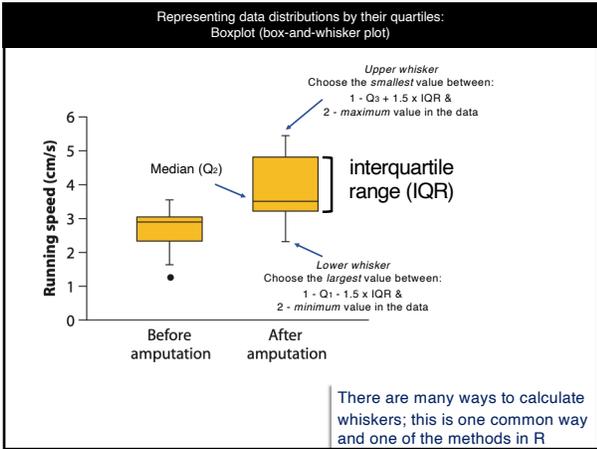
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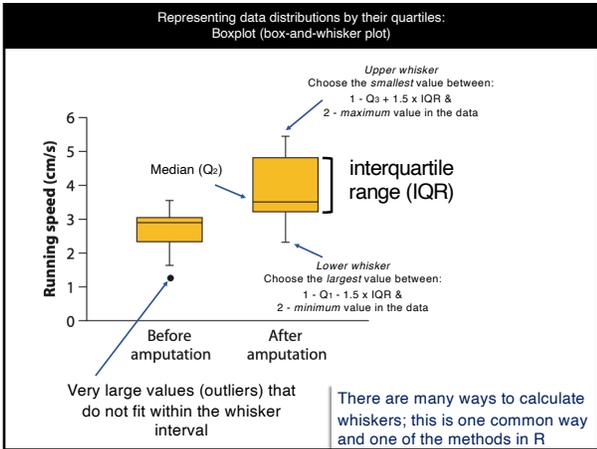
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Representing data distributions by their quartiles:  
Boxplot (box-and-whisker plot)

**What are the advantages of a box plot?**

A boxplot quickly shows where most values lie (location) and how spread out the data are.

It can often provide an indication of the data's symmetry and skewness, though this is not always the case.

median < mean    median = mean    median > mean  
right skewed    symmetric    left skewed

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Representing data distributions by their quartiles:  
Boxplot (box-and-whisker plot)

Three fictional data sets to illustrate the calculation and properties of distributions using their boxplot.

**Left-skewed distribution: 9,11,31,44,52,58,61,61,63,64,66**

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Representing data distributions by their quartiles:  
Boxplot (box-and-whisker plot)

Three fictional data sets to illustrate the calculation and properties of distributions using their boxplots.

**Right-skewed distribution: 1,2,3,4,5,6,7,10,20,30,40**

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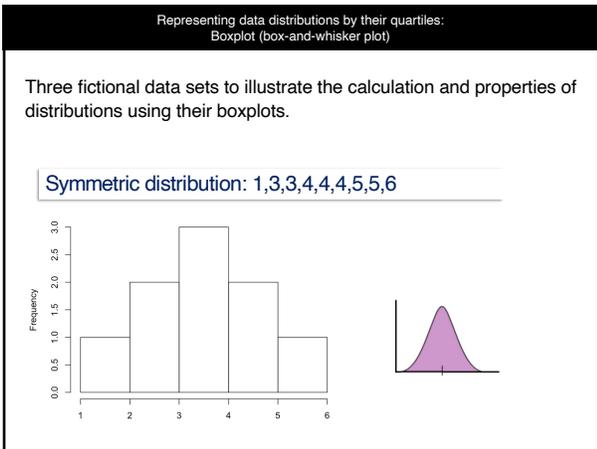
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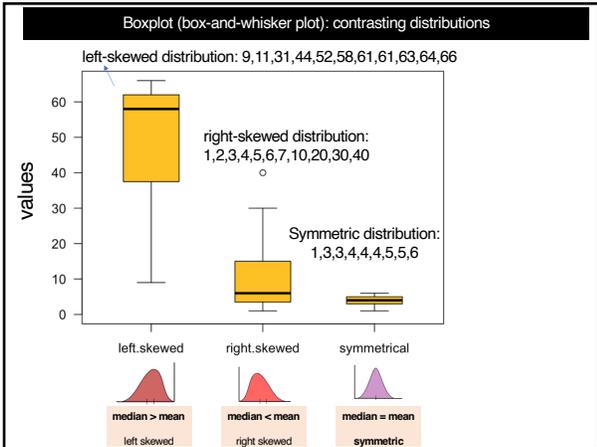
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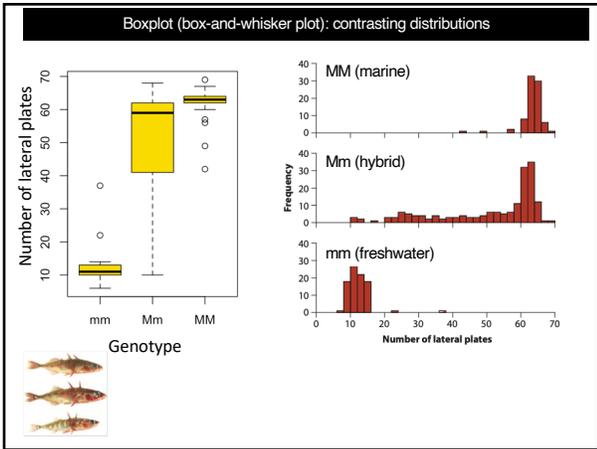
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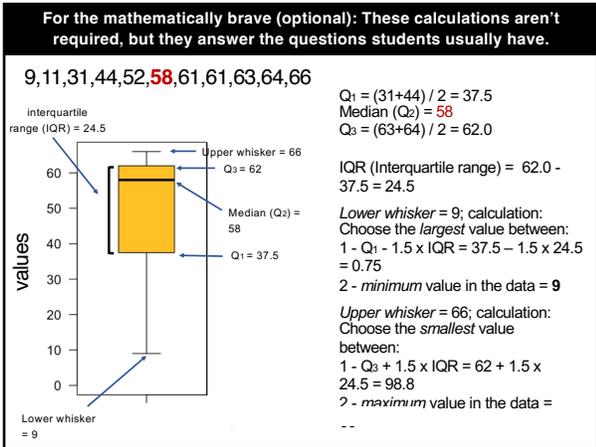
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**Statistics is based on samples!**

The main purpose of statistics is to learn about an entire population by studying a sample.

Statistics helps us make decisions when we don't have complete information, using samples to represent populations whose true features we don't fully know.

Since quantities calculated from samples (like the mean or standard deviation) change from sample to sample, uncertainty is always part of the process.

**Next lecture - Estimating with uncertainty**

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