

Unit 3: Science Investigation Skills

Mean and Standard deviation

A mean value is what is usually meant by “an average” in biology. Mean = sum of all measurements \div number of measurements.

Problems with the mean can occur when there are one or two unusually high (or low) values in the data (outliers) which can make the mean too high (or too low) to reflect any patterns in the data. For example, in an investigation to compare the mass of juice that can be extracted from two different types of apple:

Experimental repeats	Mass of juice extracted (g)	
	Jazz apples	Gala apples
1	102.0	141.0
2	95.0	160.0
3	134.0	155.0
4	115.0	130.0
5	97.0	120.0
6	132.0	191.0
7	119.0	154.0
8	107.0	203.0
9	126.0	170.0
10	111.0	176.0
Mean mass of juice extracted (g)		

Identify any values which are unusually high (or low) values in the data (outliers). How will they affect the mean?

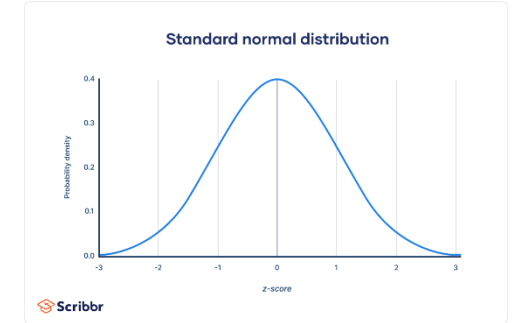
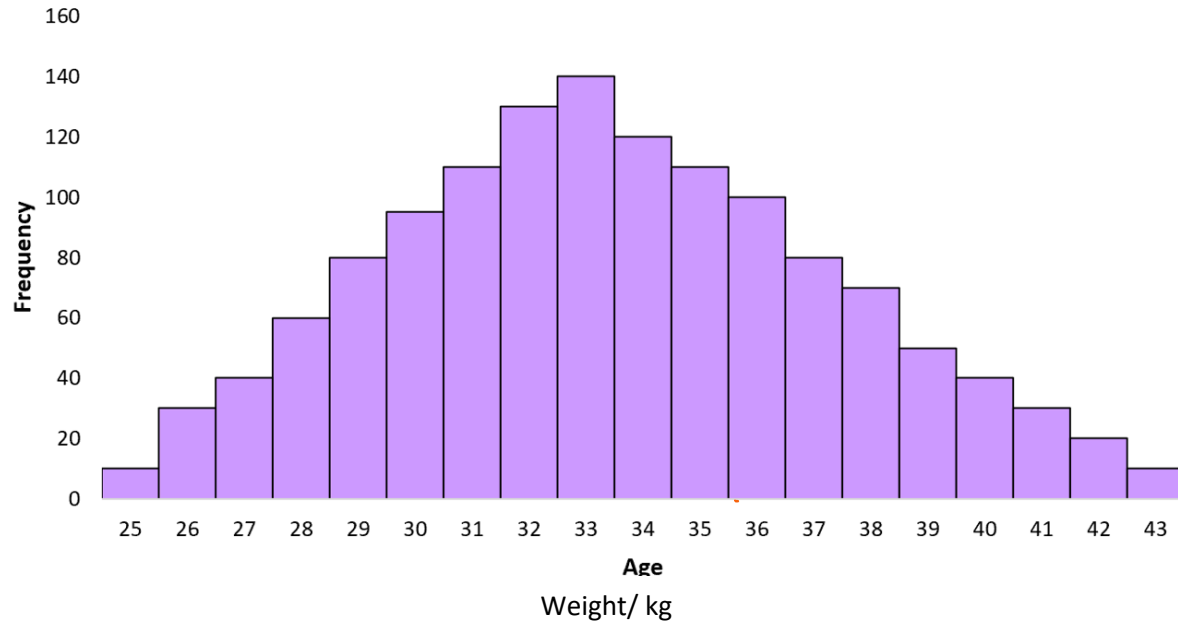
Standard deviation (σ)

Unit 3: Science Investigation Skills

The standard deviation shows the **average amount of variability in your dataset**. It tells you, on average, how far each value lies from the mean. A high standard deviation means that values are generally far from the mean, while a low standard deviation indicates that values are clustered close to the mean.

What is normal distribution?

Say we were plotting a histogram of the weights of students in a school. Here is the data



In a normal distribution of data, most values cluster around a central region, with values tapering off as they go further away from the centre.

A high standard deviation generally means that the data points are widely scattered from the average while a low standard deviation means that the data points are closer to the mean. This allows you to compare results within a population group.

Standard deviation is important because it measures the dispersion of data – or, in practical terms, volatility. It indicates how far from the average the data spreads. This helps you determine the limitations and risks inherent in decisions based on that data.

Unit 3: Science Investigation Skills

Calculating sample standard deviation (s)

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Σ = Sum of
 x = observation value
 \bar{x} = mean
 n = sample size

The steps to calculating the standard deviation are:

1. Calculate the mean of the data set
2. Subtract the mean from each value in the data set.
3. Square the differences found in step 2
4. Add up the squared differences found in step 3
5. Divide the total from step 4 by $(n - 1)$ for sample data
6. Take the square root of the result from step 5 to get the standard deviation.

Use the data in the table shown to calculate the standard deviation for the two data sources.

Experimental repeats	Mass of juice extracted (g)	
	Jazz apples	Gala apples
1	102.0	141.0
2	95.0	160.0
3	134.0	155.0
4	115.0	130.0
5	97.0	120.0
6	132.0	191.0
7	119.0	154.0
8	107.0	203.0
9	126.0	170.0
10	111.0	176.0
Mean mass of juice extracted (g)		

Unit 3: Science Investigation Skills

Practice question

Find the sample standard deviation for the 2 data sets

1. Jazz apples

Experimental repeats	Mass of juice extracted (g)	
	Jazz apples	Gala apples
1	102.0	141.0
2	95.0	160.0
3	134.0	155.0
4	115.0	130.0
5	97.0	120.0
6	132.0	191.0
7	119.0	154.0
8	107.0	203.0
9	126.0	170.0
10	111.0	176.0
Mean mass of juice extracted (g)	113.8	160.0
Standard deviation (s)		

Steps for calculation of the standard deviation

x	\bar{x}	$x - \bar{x}$	$(x - \bar{x})^2$
102.0	113.8		
95.0	113.8		
134.0	113.8		
115.0	113.8		
97.0	113.8		
132.0	113.8		
119.0	113.8		
107.0	113.8		
126.0	113.8		
111.0	113.8		
Sum			

$$S = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

Unit 3: Science Investigation Skills

2. Gala apples

Experimental repeats	Mass of juice extracted (g)	
	Jazz apples	Gala apples
1	102.0	141.0
2	95.0	160.0
3	134.0	155.0
4	115.0	130.0
5	97.0	120.0
6	132.0	191.0
7	119.0	154.0
8	107.0	203.0
9	126.0	170.0
10	111.0	176.0
Mean mass of juice extracted (g)	113.8	160.0
Standard deviation (s)		

Steps for calculation of the standard deviation			
x	\bar{x}	$x - \bar{x}$	$(x - \bar{x})^2$
141	160		
160	160		
155	160		
130	160		
120	160		
191	160		
154	160		
203	160		
170	160		
176	160		
Sum			

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Conclusion:

Unit 3: Science Investigation Skills

Exam practice

Filey Brigg is a long, narrow peninsula in North Yorkshire. It has one shore exposed to the ocean and the other shore sheltered by a bay as shown in the photograph.

Exposed shore

Sheltered shore



A limpet is an animal with a shell and is often found on these rocks. A limpet has a conical-shaped shell and a muscular foot that anchors it to the rock.

The diagrams show possible shapes formed by a limpet on a rock.



Unit 3: Science Investigation Skills

- (a) A study was carried out to investigate the effect of exposure on the shell height of limpets found on either side of Filey Brigg.

The table shows the data collected from the exposed shore.

Limpet	Shell Height / mm	$(x - \bar{x})$	$(x - \bar{x})^2$
1	9.0	0.7	0.45
2	5.9	-2.4	5.90
3	8.3	0.0	0.00
4	11.6	3.3	10.69
5	8.4	0.1	0.00
6	7.8	-0.5	0.28
7	9.2	0.9	0.76
8	9.1	0.8	0.59
9	10.0	1.7	2.79
10	7.9	-0.4	0.18
11	5.0	-3.3	11.09
12	9.3	1.0	0.94
13	9.1	0.8	0.59
14	7.8	-0.5	0.28
15	7.3	-1.0	1.06
16	8.6	0.3	0.07
17	6.9	-1.4	2.04
18	8.4	0.1	0.00
19	7.9	-0.4	0.18
20	9.1		
	$\bar{x} = 8.33$		

Unit 3: Science Investigation Skills

(i) Give a biotic factor that could affect the height of limpet shells.

(1)

(ii) Calculate the standard deviation of the exposed shore using the formula provided.

(2)

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Unit 3: Science Investigation Skills

Jun 2017

- 2 (a) Your colleague carried out a similar investigation on soil from three other areas in the small, inner city nature reserve.

Your colleague planted three seeds in each soil sample.

The table shows the height of the plants grown in these soil samples.

	height of plant (mm)			
	test 1	test 2	test 3	mean
area 1	7.0	9.0	8.0	8.0
area 2	22.0	24.0	26.0	
area 3	12.0	10.0	15.0	12.3

- (i) Calculate the mean for area 2.

Show your working.

(1)

Mean =

- (ii) Calculate the standard deviation for area 2.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

Show your working.

(5)

Unit 3: Science Investigation Skills

The following shows the data collected in an investigation into factors affecting enzyme activity.

How Substrate Concentration Affects the Reaction Rate of Catalase/Peroxide Reactions (Average Reaction Rates and Standard Deviation)

Concentration %	0	20	40	60	80	100
Reaction Rate Trial 1	0.00	10.00	11.50	12.61	14.40	14.48
Reaction Rate Trial 2	0.00	10.76	8.60	13.75	13.70	15.52
Reaction Rate Trial 3	0.00	11.81	11.90	14.00	15.00	15.00
Reaction Rate Trial 4	0.00	6.42	10.50	13.91	14.23	14.00
Average Reaction Rate (mm/sec)	0.00	9.75	10.63	13.57	14.33	14.75
Standard Deviation	0.00					

Complete the table to calculate the SD at each temperature.

What can you infer about the SD values at each temperature?

Unit 3: Science Investigation Skills

The ear lengths of a population of rabbits was measured.

Ear lengths (mm) data of 62, 60, 59, 61, 60, 58, 59, 60, 57, 56, 59, 58, 60, 59, 57, was grouped in the following categories (see the table).

Calculate the mean and standard deviation.

Difference between value and mean ($x - \bar{x}$)	Difference between value and mean squared ($(x - \bar{x})^2$)
$62 - 59 = 3$	9
$60 - 59 = 1$	1
$59 - 59 = 0$	0
$61 - 59 = 2$	4
$60 - 59 = 1$	1
$58 - 59 = -1$	1
$59 - 59 = 0$	0
$60 - 59 = 1$	1
$57 - 59 = -2$	4
$56 - 59 = -3$	9
$59 - 59 = 0$	0
$58 - 59 = -1$	1
$60 - 59 = 1$	1
$59 - 59 = 0$	0
$57 - 59 = -2$	4
Total $\sum(x - \bar{x})^2$	36