

HOW SCIENCE WORKS



- **INTERACTIVITY FEATURES THROUGHOUT**
- **SUITABLE FOR TEACHING AND STAFF TRAINING**
- **SUITABLE FOR INTERACTIVE WHITEBOARDS**
- **THE AS PACK OFFERS PROGRESSION FROM KS4**
- **COMPLEMENTS OUR CORE THEORY PRESENTATIONS**



The fundamental subject matter of 'How Science Works' is brought to life in an engaging way by powerful imagery, animations and interactivity. Pack AS covers 16 different elements of 'How Science Works' - including Presenting and Analysing Data, Opinions & Evidence and Science & Society. Pack A2 focuses on the statistical analysis of data and provides both explanatory presentations and associated xls spreadsheets. Both packs are perfect for class teaching and staff training purposes. The presentations can be used with an interactive whiteboard, digital projector or on standalone or networked PCs. You just need PowerPoint 2000 or later to run or personalise the original presentations. A low cost upgrade is available for schools/colleges who have purchased How Science Works for KS4 - see order form for further details.



Updates & Enhances AS How Science Works

Scientific Opinions

However, it is scientific to say,

"I think global warming is taking place because the polar ice sheet has melted substantially in the last ten years."

PACK - AS
16 PRESENTATIONS + GLOSSARY

Animated Graphics & Charts

The Use of Statistics

A Line Graph to Show Limpet Size Up a Shoreline

Analysing Evidence and Drawing Conclusions

Have you used an appropriate statistical test to analyse your data and given a full explanation of all your calculations? You must explain how your data fits the test you are using and state that you are carrying out this test at the 95% confidence limit. You must state a null hypothesis and state whether this is accepted or rejected at the 95% confidence limit.

Species Diversity in a River Ecosystem

A group of students used the kick sampling technique to collect, identify and count the invertebrates inhabiting a river

Calculating the Diversity Index

Multiply the number in each separate species (n) by n-1. Determine the total for all (n-1) values. Determine the total number of individuals (N) in the meadow. Substitute the calculated values in the Diversity Equation:

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

Example: $D = \frac{142(141)}{6246} = 3.21$

Standard Error of The Mean

The standard error of the mean provides an estimate of the likelihood that a sample mean is close to the true mean of a whole population.

The standard error is calculated using a formula that takes into account the standard deviation of the sample (s) and the sample size (n)

$$SE = \frac{s}{\sqrt{n}}$$

The formula shows that the larger the sample size, the smaller the standard error of the mean

PACK - A2
7 PRESENTATIONS + 11 SPREADSHEETS
50 PAGE STATISTICS WORKBOOK

Species Diversity in a Field

Species	Number (n)	n(n-1)
Pasture grass	72	6112
Field Scabious	23	506
Red Clover	19	342
Red Top	15	210
White Clover	8	56
Other	5	20
Total	142	6246

Simpson's Diversity Index (D)

Microsoft Excel - Spreadsheet

PACK - AS

16 PRESENTATIONS + GLOSSARY

PROVIDING PLENTY OF INTERACTIVITY AND FEEDBACK WHICH ACTIVELY ENGAGES STUDENTS IN THEIR OWN LEARNING

Presentations in AS Pack 'How Science Works'	Number of Slides
1. Opinions & Evidence	16
2. Hypothesis & Prediction	21
3. Types of Variable	22
4. Conducting a Fair Test	17
5. Accuracy, Precision & Sensitivity	21
6. Selecting & Using Apparatus	20
7. Reliability, Validity & Error	24
8. Presenting Data in Tables	20
9. Principles of Graph Drawing	19
10. Types of Graphs - 1 (Non Linear)	22
11. Types of Graphs - 2 (Linear)	22
12. Interpreting Data & Drawing Conclusions	37
13. Recognising Mathematical Relationships	14
14. Investigations & Practical Skills (AS)	27
15. Biological Drawings	22
16. Science & Society	28

Glossary (MS Word) - Colour & BW Versions supplied.



Precision - Data Set
 For: a **precise set** of repeat readings is one in which measurements are grouped closely together - there is very little spread around the mean value. *Now answer this question...*



Which of these sets of thermometer readings is the most precise?

30°C	31°C	30°C	33°C	<input type="checkbox"/>
30°C	31			<input type="checkbox"/>
30°C	30			<input type="checkbox"/>
30°C	31			<input type="checkbox"/>

The Difference Between Accuracy & Precision
 In this animation, the Ball's eye represents the true value of the variable, and the darts represent the measured values. Throw the darts, then drag the labels to the correct place...

Answer



WORLD NEWS

US Scientists Suggest Forests Act As Carbon 'Sink'

As growing concern exists amongst scientists around the world about global warming, scientists in the US have suggested that carbon dioxide levels may not rise as much as predicted. They suggest that plant growth will increase, helping to maintain a balance of carbon dioxide levels...

From this information, form a hypothesis, prediction and investigation...



Summary Questions

If you were able to compare your results with others in your class and all of the results were very similar, this would make your results:

more accurate	<input type="checkbox"/>
more precise	<input type="checkbox"/>
more reliable	<input type="checkbox"/>
more valid	<input type="checkbox"/>



Types of Variable

Independent & Dependent Variables - Example 1

In an investigation how temperature affects the germination of seeds, temperature is the independent variable and the number of seeds germinated is the dependent variable.

Controlled by temperature
 Independent variable → Dependent variable

The temperature is controlled in the experiment and the germination of the seeds is affected by the temperature.



Simplifying Tables

When presenting the mean in your final results table, you may want to modify your column headings.

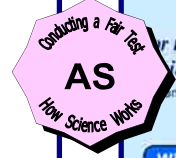
The following table appears rather cluttered...

Experiment Number	Volume of Oxygen Produced (mm ³)	Volume of Oxygen Produced (mm ³)	Volume of Oxygen Produced (mm ³)	Volume of Oxygen Produced (mm ³)	Average
1	0.0	0.0	0.0	0.0	0.0
2	1.8	1.0	1.0	1.0	1.2
3	2.0	2.4	2.4	2.4	2.2
4	2.6	2.5	2.5	2.5	2.5
5	2.5	2.6	2.6	2.6	2.5

This table contains the same data, but is less cluttered...

Experiment Number	Volume of Oxygen Produced (mm ³)				Average
	Reading 1	Reading 2	Reading 3	Reading 4	
1	0.0	0.0	0.0	0.0	0.0
2	1.8	1.0	1.0	1.0	1.2
3	2.0	2.4	2.4	2.4	2.2
4	2.6	2.5	2.4	2.5	2.5
5	2.5	2.6	2.4	2.5	2.5

How could you simplify this?



Identifying a Fair Test

For these investigations, identify the experiment which would make a fair test...

An investigation to see if water is needed for seeds to grow, this experiment was set up...

Which of the following experiments would make a fair test for this investigation?

10 seeds on compost	<input type="checkbox"/>
6 seeds on damp cotton wool	<input type="checkbox"/>
10 seeds on damp cotton wool	<input checked="" type="checkbox"/>
10 seeds on dry cotton wool	<input type="checkbox"/>

Correct! Click 'Next' to move on.

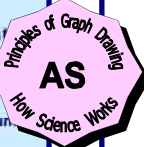


Keys and Legends for Multiple Sets of Data

If two sets of data are plotted on the same graph, each set of data should be clearly distinguishable, so use different coloured lines or different symbols. Always include a key or a legend...

A Line Graph to Show Transpiration and Water Absorption in Pelargonium

Rate of Transpiration (red line with triangles)
 Rate of Water Absorption (green line with squares)



PACK - AS

16 PRESENTATIONS + GLOSSARY

PROVIDING CLEAR EXPLANATIONS OF THE PRINCIPLES OF DESIGNING AND CONDUCTING SCIENTIFIC INVESTIGATIONS

Principles of Graph Drawing
AS
How Science Works

What's Wrong with These Graphs?

Look at the following graphs. Select the error that has been made in the choices provided.

Graph 2 - What is wrong with this graph?

Transpiration and Water Absorption in *Polygonum*.

A. No title
 B. Axes not labelled
 C. No scale shown
 D. Independent variable on the y-axis
 E. Wrong scale

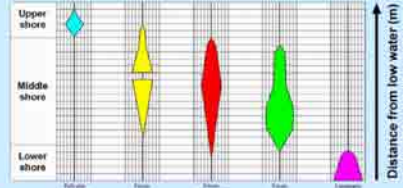
Correct - Well Done!

Interactive Diagrams

Types of Graph - 1
AS
How Science Works

Kite Diagrams

A kite diagram is commonly used for coastal marine ecology. The data plotted is usually an abundance scale (1-5) or % cover of a quadrat.



For a Kite Diagram:

- The data is plotted on both sides of a median line - thus kite diagrams always have a symmetrical aspect.
- The y-axis shows distance from a fixed reference such as low water mark.
- There can be gaps in the distribution of a species, e.g. this can be due to sandy outcrops amongst rocks as is the case for *F. spiralis* in the above chart. Therefore, care must be taken when interpreting kite diagrams - however they are good at showing zonation.

Types of Graph - 1
AS
How Science Works

Frequency Diagrams

A frequency diagram (or 'frequency chart') looks like a bar chart, but shows the frequency for binned data (discrete or continuous). A frequency diagram has no gaps between the columns.



Sometimes a frequency diagram is mistakenly referred to as a histogram. N.B. Many biological references still mistakenly use the terms histogram and frequency diagram as alternatives - which they are not.

For a Frequency Diagram...

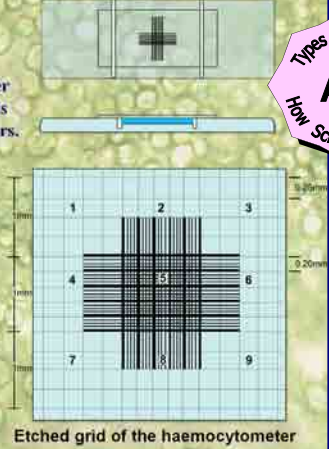
- A frequency diagram uses frequency on the y-axis. Frequency is simply indicated by the height on the vertical scale.
- The columns (and therefore the group intervals) must be of equal width.
- There are no gaps between the bars.
- The x-axis is either a continuous scale or a sequence of consecutive intervals. Intervals should be written centrally under the columns.

Types of Graph - 2
AS
How Science Works

Growth of a Yeast Cell Population

A student used a haemocytometer to count the number of yeast cells in a culture over a period of 5 hours.

Time (hours)	Number of yeast cells
0	30
1	86
2	240
3	657
4	1840
5	5158



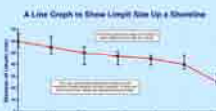
Etched grid of the haemocytometer

Types of Graph - 2
AS
How Science Works

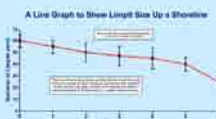
The Use of Error Bars

There are two main ways of showing error bars...

Plot the mean of the readings with the error bars above and below showing the range of the results. The error bars in this case indicate the maximum and minimum readings.



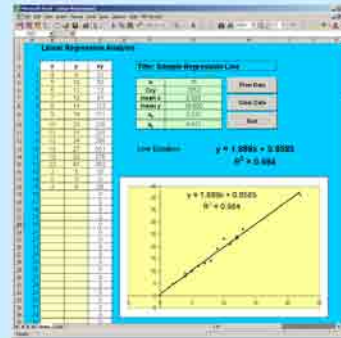
Plot the mean of the readings with the error bars showing the standard deviation of the results. The error bars in this case indicate the reliability of the results. (Two thirds of results are within 1 standard deviation of the mean).



Interpreting Data & Drawing Conclusions
AS
How Science Works

Line of Best Fit - Linear Regression

To find the precise line of best fit we can use a statistical process to calculate the equation for the line - this line is called the regression line...



Interpreting Data & Drawing Conclusions
AS
How Science Works

Line of Best Fit

Drag the line of best fit to the most appropriate place on the graph. 'Check Answer' to show the best position for this line...

Check Answer

Reset

Scatter Graph Showing Mass Against Resting Heart Rate

Interactive Diagrams

Recognising Mathematical Relationships
AS
How Science Works

Inverse Proportionality

The magnitude of a such a curve's gradient always decreases as x increases.

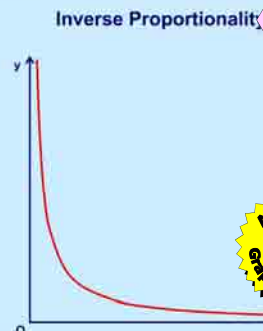
A graph of inverse proportionality is a symmetric curve.

The equation between x and y is of the form

$$y = \frac{k}{x}$$

where k is the constant of proportionality.

k can be estimated from points of data and then used to predict other values.



Animated Graphs & Charts

PACK - A2

7 PRESENTATIONS + 11 SPREADSHEETS
30 PAGE STATISTICS WORKBOOK

CLEARLY EXPLAINING THE PRINCIPLES OF STATISTICAL ANALYSIS AND PROVIDING THE NECESSARY TOOLS

Presentations & Spreadsheets in A2 'How Science Works'	
	Number of Slides
Presentations	
Investigations & Practical Skills A2	31
Statistics - Introduction	30
Statistics - Statistical Measures	34
Statistics Tests - Chi Squared	29
Statistics Tests - Spearman Rank Correlation Coefficient	14
Statistics Tests - Student's t-Test	12
Statistics - Simpson's Diversity Index	12
Statistical Spreadsheets	
General Statistical Measures (inc. Standard Error)	
Chi Squared	
Linear Regression	
Normal Distribution	
Ranking Data	
Spearman Rank Correlation Coefficient - One tailed	
Spearman Rank Correlation Coefficient - Two tailed	
t-test (One-tailed)	
t-test (Two-tailed)	
Simpson's Diversity Index	
Spearman Rank Correlation Coefficient - One tailed	
Statistics Workbook (MS Word) - 30 pages.	

Spearman Rank Correlation Coefficient

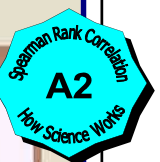
During an ecological survey of the distribution of invertebrates in a river ecosystem, students investigated the relationship between the *Biotic Index* and oxygen levels in the water; data was used to plot a scattergram and to calculate the value of the correlation coefficient (r_s)



✓ Nominal or interval data

✓ Continuously increasing or decreasing relationship reflected on a scattergram

✓ Sample size of between 7 and 30 pairs of measurements



Meadow Diversity

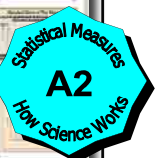
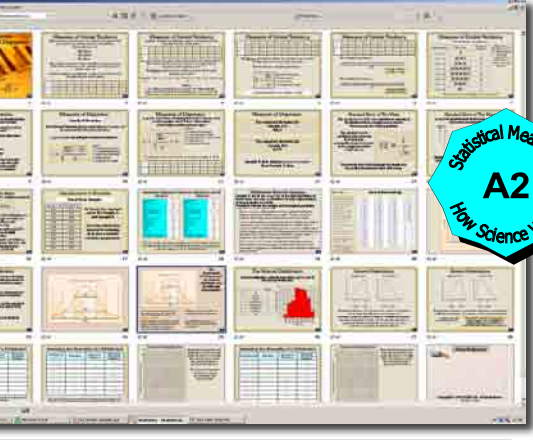
Species	Number
Festuca grass	72
Field Scabious	23
Buttercup	19
Dandelion	15
Clover	8
Mallow	5

These results were used to calculate the Simpson's Diversity Index.

t-test for Independent Samples

A group of students investigated the shell heights of dog whelms on a sheltered and rocky shore with a view to detecting any differences between them

- ✓ Interval level data
- ✓ Samples are independent
- ✓ Normally distributed populations
- ✓ Sample size less than 30 values



River Invertebrate Results

Organisms	Mean number of organisms per m ² of river bed	
	Site A	Site B
<i>Polycelis</i> (flatworm)	132	9
<i>Tubifex</i> (worm)	0	6
<i>Erpobdella</i> (leech)	3	26
<i>Limnaea</i> (snail)	9	0
<i>Thyas</i> (mite)	14	0
<i>Anabolia</i> (caddis larva)	15	1
<i>Simulium</i> (blackfly larva)	77	0
<i>Chironomus</i> (midge larva)	0	10
<i>Ecdyonurus</i> (mayfly nymph)	43	0

How Science Works - Pack A2 Statistics Workbook

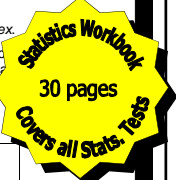
15) During an ecological survey of the distribution of invertebrates in a river ecosystem, students investigated the relationship between the *Biotic Index* and oxygen levels in the water. Data was used to plot a scattergram and to compute the value of the Spearman Rank Correlation Coefficient (r_s).

River site	1	2	3	4	5	6	7	8	9	10
Oxygen % saturation	110	120	75	73	102	105	109	70	63	77
Biotic Index	9	8	6	5	7	7	8	4	3	6

Null Hypothesis: There is no relationship between river oxygen levels and the *Biotic Index*.

Alternative Hypothesis: There is a correlation between river oxygen levels and the *Biotic Index*.

- Plot a scattergram of oxygen % saturation against the *Biotic Index*.
- Manually calculate the value of the Spearman rank correlation coefficient (r_s) and compare your value with that obtained from a stats package.
- Would you use the one-tailed or two-tailed test?
- Explain the output of the test.



Interval Data

Interval data consists of accurate measurements with units attached, e.g. seconds, minutes, centimetres, grams



The data obtained from the Laurel bush investigation is *interval* data

	12.5	13.1	14.5	15.2	11.9	8.3	11.4
Leaf lengths from shaded site (cm)							
Leaf lengths from sunny site (cm)	8.3	10.4	7.8	8.7	9.8	6.7	7.3

A characteristic of interval data is the *interval property* such that a leaf 8 cm is exactly twice that of a measurement of 4 cm; interval data is *numeric* and all the rules of arithmetic can be applied to such data



Phototaxis in Daphnia

Daphnia Distribution Results

Number of Daphnia	Group						Total
	1	2	3	4	5	6	
Illuminated area	8	7	10	8	6	8	
Dark area	4	5	3	4	6	5	

Category	O	E	(O-E)	(O-E) ²	(O-E)/E	(O-E)/E ²
	Illuminated area					
Dark area						

Chi-Squared: 2 x 2 contingency table

Calculate the absolute values of (O-E), i.e. convert negative values to positive, and then subtract 0.5 from each of the differences

[(O-E) - 0.5]² / E

[(O-E) - 0.5]² / E

Table showing expected and observed results

	Snail Type		Total
	Banded	Unbanded	
Illuminated	30	103	133
Dark	52	18	70
Total	82	121	203



Draw up a table and calculate [(O-E) - 0.5]² / E for each data cell. Sum together the values of [(O-E) - 0.5]² / E to obtain the χ^2 test value

PACK - A2

7 PRESENTATIONS + 11 SPREADSHEETS
30 PAGE STATISTICS WORKBOOK

STUDENTS CAN EASILY SELECT THE MOST APPROPRIATE
STATISTICAL TEST AND THEN APPLY IT TO THEIR DATA

Microsoft Excel - CHI_SQ1.T

CHI-SQUARED (χ^2) TEST - KNOWN RATIO 9:3:3:1

Observed (O)	Ratio	Expected (E)	(O - E) ²	(O - E) ² /E
400	9	386.438	183.941	0.47599
127	3	128.813	3.28516	0.0255
118	3	128.813	116.91	0.9076
42	1	42.9375	0.87891	0.02047

Degrees of Freedom: 3
Critical Value: 7.81
Null Hypothesis: accepted

$\chi^2 = \sum \frac{(O - E)^2}{E}$

Microsoft Excel - CHI_SQ1.T

Chi-Squared (χ^2) Test

Known Ratio 1:1: 1:1 1:1

Known Ratio 3:1: 3:1 3:1

Known Ratio 1:1:1:1: 1:1:1:1

Known Ratio 9:3:3:1: 9:3:3:1

Known Results - 2 variables: 2 Var 2 Var

Buttons: Save, Save At, Quit

Microsoft Excel - GEN_STAT1.T

General Statistical Data

Sample Size (n)	Sum (Σx)	Sum of Squares (Σx ²)	Mean	Standard Error	Confidence Limits (95%)	1.96 x Standard Error	Confidence Limits (95%)
20	654	24142	32.7	2.456	20.752 - 20.258	4.963	17.067 - 32.023

Buttons: Sort Data Ascending, Sort Data Descending, Clear Data, Print, Save At, Quit

Microsoft Excel - SPRMAS1.T

The Spearman Rank Correlation (r_s)
Oxygen % Saturation and Biotic Index

Site	Oxygen % saturation	Rank R ₁	Biotic Index	Rank R ₂	D = (R ₁ - R ₂)	D ²
1	110	9	10	10	-1	1
2	117	10	8	7.5	2.5	6.25
3	70	2	7	5.5	-3.5	12.25
4	73	3	5	3.5	-0.5	0.25
5	105	6	9	9	-3	9
6	107	7	7	5.5	1.5	2.25
7	109	8	8	7.5	0.5	0.25
8	74	4	4	2	2	4
9	63	1	3	1	0	0
10	76	5	5	3.5	1.5	2.25
11					0	0
12					0	0
13					0	0
14					0	0
15					0	0
16					0	0
17					0	0
18					0	0
19					0	0
20					0	0
21					0	0
22					0	0
23					0	0
24					0	0
25					0	0

Sort Order: 10, Sum: 0, D²: 37.5

Spearman Rank Correlation Coefficient (r_s): 0.77
Critical Value of r_s : 0.648
Correlation: significant positive correlation

How Science Works - Pack A2 - Using The Statistics Spreadsheets

THE CHI-SQUARED PROGRAMME

Opening Screen

The opening screen displays the various tests that can be performed using this programme. Select the ratio that you wish to test by clicking on the appropriate tab at the bottom of the page.

Microsoft Excel - CHI_SQ1.T

Chi-Squared (χ^2) Test

Known Ratio 1:1: 1:1 1:1

Known Ratio 3:1: 3:1 3:1

Known Ratio 1:1:1:1: 1:1:1:1

Known Ratio 9:3:3:1: 9:3:3:1

Known Results - 2 variables: 2 Var 2 Var

Known Results - 4 variables: 4 Var

Buttons: Save, Save At, Quit

Includes detailed help books, critical value tables, logarithmic graph paper, etc.

9 : 3 : 3 : 1

Microsoft Excel - CHI_SQ1.T

CHI-SQUARED (χ^2) TEST - KNOWN RATIO 9:3:3:1

Observed (O)	Ratio	Expected (E)	(O - E) ²	(O - E) ² /E
9	9	0	0	0
3	3	0	0	0
3	3	0	0	0
1	1	0	0	0

Degrees of Freedom: 3
Critical Value: 7.81
Null Hypothesis:

$\chi^2 = \sum \frac{(O - E)^2}{E}$

Data may be printed and saved under a different file name or deleted to undertake another test without saving the initial data

Microsoft Excel - T_TESTS

Two-tailed t-Test for Independent Samples


	Males	Females
n	45	45
sum	1167.600	1415.300
mean	25.947	31.451
Std. Dev.	3.850	3.767
Variance	14.825	14.191
deg. freedom	88	
t-value	6.855	
Two-tailed test 0.05 sig.	significant	

Simply enter your investigation data and process it with one click of a button.

Microsoft Excel - MANNWHITNEY

Mann-Whitney U Test

Field 1	Rank	Field 2	Rank
1	1.0	1	1.0
2	2.0	2	2.0
3	3.0	3	3.0
4	4.0	4	4.0
5	5.0	5	5.0
6	6.0	6	6.0
7	7.0	7	7.0
8	8.0	8	8.0
9	9.0	9	9.0
10	10.0	10	10.0
11	11.0	11	11.0
12	12.0	12	12.0
13	13.0	13	13.0
14	14.0	14	14.0
15	15.0	15	15.0
16	16.0	16	16.0
17	17.0	17	17.0
18	18.0	18	18.0
19	19.0	19	19.0
20	20.0	20	20.0
21	21.0	21	21.0
22	22.0	22	22.0
23	23.0	23	23.0
24	24.0	24	24.0
25	25.0	25	25.0



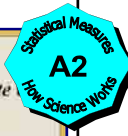
WORLD NEWS
2nd December 2006

Korean Scientist Clones Human Embryos

The Korean Scientist Dr Hwang Woo-Suk announced today that he and his team have successfully cloned human embryos. His announcement was made part of a worldwide media event planned to publicise this science. Although many teams around the world are trying to clone human embryos, Dr Hwang and his team are the first to succeed...

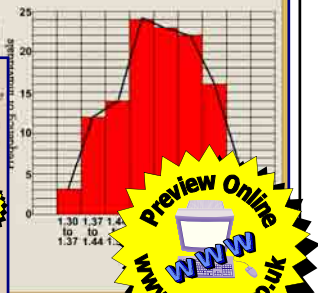
Editable, Curric. Discussion Points

AS
How Science Works



The Normal Distribution

Many investigations generate data which approximate the normal distribution



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www.sserltd.co.uk

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PRODUCT	STOCK CODE	DESCRIPTION (PC WINDOWS ONLY)	COST: (£) Ex. VAT	COST: (£) Inc. VAT	QTY	SUB TOTAL Inc. VAT
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	BHASST	How Science Works - AS Biology CD ROM + Full Site Licence	£140	£164.50		
BIOLOGY (A2) How Science Works	BHA2CD	How Science Works - A2 Biology (7 Presentations, 11 Spreadsheets, etc.) CD ROM + Single User Licence	£70	£82.25		
	BHA2ST	How Science Works - A2 Biology CD ROM + Full Site Licence	£140	£164.50		
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