Maths skills

In order to be able to develop your skills, knowledge and understanding in Biology, you will need to have developed your mathematical skills in a number of key areas. This section gives more explanation and examples of some key mathematical concepts you need to understand. Further examples relevant to your AS/A Level Biology studies are given throughout the book.

Arithmetic and numerical computation

Using standard form

Dealing with very large or small numbers can be difficult. To make them easier to handle, you can write them in the format $a \times 10^b$. This is called standard form.

To change a number from decimal form to standard form:

- Count the number of positions you need to move the decimal point by until it is directly to the right of the first number which is not zero.
- This number is the index number that tells you how many multiples of 10 you need. If the original number was a decimal, your index number must be negative.

Here are some examples:

Decimal notation	Standard form notation
0.000 000 012	1.2×10^{-8}
15	1.5×10^{1}
1000	1×10^{3}
3 700 000	3.7×10^{6}

Using ratios, fractions and percentages

Ratios, fractions and percentages help you to express one quantity in relation to another with precision. Ratios compare like quantities using the same units. Fractions and percentages are important mathematical tools for calculating proportions.

Ratios

A ratio is used to compare quantities. You can simplify ratios by dividing each side by a common factor. For example 12 : 4 can be simplified to 3 : 1 by dividing each side by 4.

EXAMPLE

Divide 180 into the ratio 3 : 2
Our strategy is to work out the total number of parts then divide 180 by the number of parts to find the value of one part.
total number of parts = 3 + 2 = 5
value of one part = 180 ÷ 5 = 36
answer = 3 × 36 : 2 × 36 = 108 : 72

Check your answer by making sure the parts add up to 180: 72 + 108 = 180

Fractions

When using fractions, make sure you know the key strategies for the four operators:

To add or subtract fractions, find the lowest common multiple (LCM) and then use the golden rule of fractions. The golden rule states that a fraction remains unchanged if the numerator and denominator are multiplied or divided by the same number.

EXAMPLE

$\frac{1}{2} + \frac{1}{5} = \frac{5}{10} + \frac{2}{10} = \frac{7}{10}$

To multiply fractions together, simply multiply the numerators together and multiply the denominators together.

EXAMPLE

$\frac{2}{7} \times \frac{4}{9} = \frac{8}{63}$

To divide fractions, simply invert or flip the second fraction and multiply.

EXAMPLE

$\frac{2}{3} \div \frac{7}{9} = \frac{2}{3} \times \frac{9}{7} = \frac{18}{21} = \frac{6}{7}$

Percentages

When using percentages, it is useful to recall the different types of percentage questions.

To increase a value by a given percentage, use a percentage multiplier.

EXAMPLE

Increase 30 mg by 23%.
If we increase by 23%, our new value will be 123% of the original value. We therefore multiply by 1.23.
answer = 30 × 1.23 = 36.9 mg

To decrease a value by a given percentage, you need to focus on the part that is left over after the decrease.

EXAMPLE

Decrease 30 mg by 23%.
If we decrease by 23%, our new value will be 100 − 23 = 77% of the original value. We therefore multiply by 0.77.
answer = 30 × 0.77 = 23.1 mg

To calculate a percentage increase, use the following equation:

$$\text{Percentage change} = \frac{\text{difference between values}}{\text{original value}} \times 100$$

To calculate percentage decrease, use the same equation but remember that your answer should be negative.

EXAMPLE

The volume of a solution increased from 40 ml to 50 ml. Calculate the percentage increase.
change in volume = 10 ml
percentage increase = $\frac{10}{40} \times 100 = 25\%$

Algebra

Using algebraic equations

Using algebraic equations is a very important skill for finding the value of an unknown quantity. In the real world, letters are used to symbolise important variables such as the blood sugar level of a diabetic or the irregular heartbeat of a patient.

The key rule to remember when using equations is that any operation that you apply to one side of the equation must also be applied to the other side.

EXAMPLE

Find the value of x in the following equation: 7x − 6 = 36
adding 6 to each side gives 7x = 42
dividing each side by 7 gives x = 6

Changing the subject of an equation

It can be very helpful to rearrange an equation to express the variable in which you are interested in terms of other variables. Always remember that any operation that you apply to one side of the equation must also be applied to the other side.

EXAMPLE

The diameter of a cell measured under the light microscope at magnification ×100 is 2 mm. Calculate the actual size.
You may remember the equation: image size = actual size × magnification. However, this question is asking us to find the actual size given the image size and magnification. We can rearrange the equation to suit our needs:
image size = actual size × magnification
$\frac{\text{image size}}{\text{magnification}} = \text{actual size}$
so actual size = $\frac{2}{100} = 0.02$ mm

Handling data

Using significant figures

Often when you do a calculation, your answer will have many more figures than you need. Using an appropriate number of significant figures will help you to interpret results in a more meaningful way.

Remember the 'rules' for significant figures:

- The first significant figure is the first figure which is not zero.
- Digits 1–9 are always significant.
- Zeros which come after the first significant figure are significant unless the number has already been rounded.

Here are some examples:

Exact number	To one s.f.	To two s.f.s.	To three s.f.s.
45 678	50 000	46 000	45 700
45 000	50 000	45 000	45 000
0.002 755	0.003	0.002 8	0.002 76

Principles of sampling and using Simpson's diversity index

When a scientist studies a population, it is not possible to study each organism in detail. Scientists therefore use sampling to estimate characteristics of the whole population by looking at a subset of individuals in the population. It is important that the sample chosen is representative of the habitat.

Once a suitable sample has been selected, it can be analysed. For example, Simpson's diversity index is a measure of biodiversity which takes into account both the species richness and the species abundance of an area. It is calculated by the formula:

$$D = 1 - [\Sigma(n/N)^2]$$

where n is the number of individuals of a particular species (or the percentage cover for plants), and N is the total number of all individuals of all species (or the total percentage cover for plants).

Graphs

Understand that $y = mx + c$ represents a linear relationship

Two variables are in a linear relationship if they increase at a constant rate in relation to one another. If you plotted a graph with one variable on the x-axis and the other variable on the y-axis, you would get a straight line. Any linear relationship can be represented by the equation $y = mx + c$ where the gradient of the line is m and the value at which the line crosses the y-axis is c. An example of a linear relationship is the relationship between degrees Celsius and degrees Fahrenheit, which can be represented by the equation $F = 9/5C + 32$ where C is temperature in degrees Celsius and F is temperature in degrees Fahrenheit.

Conversion of Celsius temperatures to Fahrenheit

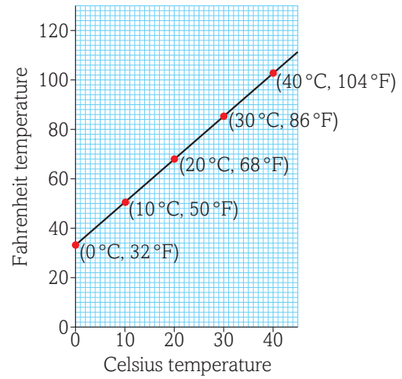


Figure 1

Calculate a rate of change from a graph showing a linear relationship

The rate of change from a graph showing a linear relationship is the gradient, or steepness, of the line. It is a measure of the rate of change of one variable, represented on the *x*-axis, in relation to the other variable, represented on the *y*-axis.

To calculate the rate of change:

1 Draw a right-angled triangle anywhere on the line.
2 Use the following equation to calculate the rate of change:

$$\text{gradient} = \frac{\text{difference on } y\text{-axis}}{\text{difference on } x\text{-axis}}$$

3 State the unit for your answer.

Draw and use the slope of a tangent to a curve as a measure of a rate of change

Sir Isaac Newton was fascinated by rates of change. He drew tangents to curves at various points to find the rates of change of graphs as part of his journey towards discovering calculus – an amazing branch of mathematics. He argued that the gradient of a curve at a given point is exactly equal to the gradient of the tangent of a curve at that point.

To calculate the rate of change:

1 Use a ruler to draw a tangent to the curve.
2 Calculate the gradient of the tangent using the technique given for a linear relationship. This is equal to the gradient of the curve at the point of the tangent.
3 State the unit for your answer.

Applying your skills

You will often find that you need to use more than one maths technique to answer a question. In this section, we will look at two example questions and consider which maths skills are required and how to apply them.

EXAMPLE

Hydrogen peroxide is a toxic by-product of respiration and is made in all living cells. Cells make the enzyme catalase in order to convert the toxin into water and oxygen. In order to study the effect of temperature on catalase activity, an experiment was set up using the equipment shown in Figure 2. The volume of oxygen released in 30 seconds was measured using the gas syringe. The results of the experiment are shown in the graph (Figure 3).

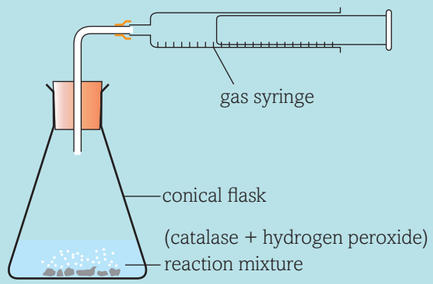


Figure 2

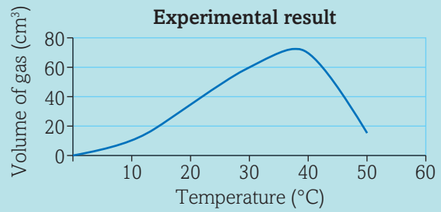


Figure 3

(a) *Calculate the percentage increase in volume of oxygen produced from 10 °C to 40 °C.*

(b) *Calculate the rates of each temperature test at 20, 40 and 50 °C and interpret the results.*

(c) *A further experiment is carried out where the volume of oxygen is recorded over the entire time of the reaction at 10 °C and 40 °C. The results are shown below:*

	Total volume of oxygen released (cm³)									
Temp.	0 s	10 s	20 s	30 s	40 s	50 s	60 s	70 s	80 s	90 s
10 °C	0	2	5	9	16	22	28	33	35	35
40 °C	0	7	15	27	33	35	35	35	35	35

Display both sets of results on an appropriately scaled graph.

(d) *Calculate the difference in rate between both reactions at 15 s.*

Answers

(a) The volume of gas at 10 °C = 10 cm³.
The volume of gas at 40 °C = 70 cm³.
The percentage increase = (70 − 10)/10 × 100 = 600% increase

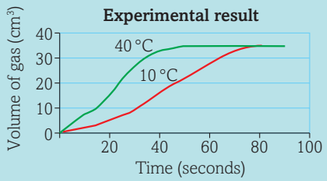
(b) $20\ °C = \frac{35}{30} = 1.17\ cm^3\ s^{-1}$

$40\ °C = \frac{70}{30} = 2.33\ cm^3\ s^{-1}$

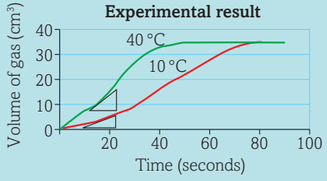
$50\ °C = \frac{15}{30} = 0.5\ cm^3\ s^{-1}$

The rate has doubled between 20 °C and 40 °C, but at 50 °C, the rate has decreased.

(c)



(d) We draw a tangent to each curve at 15 seconds so that we can use the gradient of the curve to calculate the rate.



We can then use the following equation to calculate gradient:

$$\text{gradient} = \frac{\text{difference on } x\text{-axis}}{\text{difference on } y\text{-axis}}$$

rate of reaction at 10 °C at 15 seconds = $\frac{3}{10} = 0.3\ cm^3\ s^{-1}$

rate of reaction at 40 °C at 15 seconds = $\frac{8}{10} = 0.8\ cm^3\ s^{-1}$

difference in rate between reactions at 15 seconds
= 0.8 − 0.3 = 0.5 cm³ s⁻¹

EXAMPLE

A photomicrograph of a T helper cell was taken using an electron microscope set at a magnification of ×50 000. In the image, several organelles were clearly identified and measured.

(a) *In the table below, calculate the actual object length of each organelle.*

Organelle	Image length (mm)	Object length (μm)
nucleus	240	
endoplasmic reticulum	360	
lysosome	10	
mitochondrion	120	

(b) *A lysosome is a spherical organelle. Calculate the surface area and volume of a lysosome.*

(c) *Calculate the surface area to volume ratio of a lysosome.*

Answers

(a) The question tells us that the magnification is ×50 000.
We know that image size = actual size × magnification
To make it easier to use, we can rearrange this equation as

$$\text{actual size} = \frac{\text{image size}}{\text{magnification}}$$

$$\text{actual length of nucleus} = \frac{240}{50\,000} = 0.004\,8\ mm$$

$$\text{actual length of endoplasmic reticulum} = \frac{360}{50\,000} = 0.007\,2\ mm$$

$$\text{actual length of lysosome} = \frac{10}{50\,000} = 0.000\,2\ mm$$

$$\text{actual length of mitochondrion} = \frac{120}{50\,000} = 0.002\,4\ mm$$

Before we can put these figures in the table, we need to convert to μm. 1 mm = 1000 μm so we need to multiply each figure by 1000.

Organelle	Image length (mm)	Object length (μm)
nucleus	240	4.8
endoplasmic reticulum	360	7.2
lysosome	10	0.2
mitochondrion	120	2.4

(b) You should be familiar with the following formulae, where *r* is radius:
surface area of sphere = $4\pi r^2$
volume of sphere = $\frac{4}{3}\pi r^3$
From (a) you know that the diameter of the lysosome is 0.2 μm.
This means that the radius must be 0.1 μm.
surface area of lysosome = $4\pi(0.1)^2 = 4\pi \times 0.01 = 0.125\,7\ \mu m^2$
to 4 d.p.
volume of lysosome = $\frac{4}{3}\pi(0.1)^3 = \frac{4}{3}\pi \times 0.001 = 0.004\,2\ \mu m^3$
to 4 d.p.

(c) It is simplest and most accurate to use the exact expressions from (b) involving π, rather than the final answers which have been rounded.
surface area-to-volume ratio = $4\pi \times 0.01 : \frac{4}{3}\pi \times 0.001$
We can simplify by multiplying each side by 1000 and dividing each side by π:
surface area-to-volume ratio = $40 : \frac{4}{3}$
Now we can divide each side by 4 and multiply each side by 3 to get:
surface area-to-volume ratio = 30 : 1

Preparing for your exams

Introduction

The way that you are assessed will depend on whether you are studying for the AS or the A Level qualification. Here are some key differences:

- AS students will sit two exam papers, each covering all of the content of the AS specification.
- A Level students will sit three exam papers, each covering content from both years of A Level learning. The third paper can include questions from all six modules covered during the two years of study.
- A Level students will also have their competence in key practical skills assessed by their teacher in order to gain the Science Practical Endorsement. The endorsement will not alter the overall grade but if you pass the endorsement this will be recorded on your certificate and can be used by universities as part of their conditional offer of a place on a course.

The tables below give details of the exam papers for each qualification.

AS exam papers

Paper	Paper 1: Breadth in Biology	Paper 2: Depth in Biology
Topics covered	Modules 1–4	Modules 1–4
% of the AS qualification	50%	50%
Length of exam	1 hour 30 minutes	1 hour 30 minutes
Marks available	70 marks	70 marks
Question types	20 marks multiple-choice followed by 50 marks short structured response	Structured questions and extended writing including two level of response questions
Experimental methods?	Yes	Yes
Mathematics	A minimum of 10% of the marks across both papers will be awarded for mathematics at GCSE higher tier level or above	

A Level exam papers

Paper	Paper 1: Biological processes	Paper 2: Biological diversity	Paper 3: Unified biology	Science Practical Endorsement
Topics covered	Modules 1,2,3 and 5	Modules 1,2,4 and 6	Modules 1–6	Assessed by teacher throughout course. Does not count towards A Level grade but a 'pass' result will be reported on A level certificate. It is likely that you will need to maintain a separate record of practical activities carried out during the course.
% of the A Level qualification	37%	37%	26%	
Length of exam	2 hours 15 minutes	2 hours 15 minutes	1 hour 30 minutes	
Marks available	100 marks	100 marks	70 marks	
Question types	15 marks multiple-choice followed by 85 marks structured response and extended writing including two level of response questions	15 marks multiple-choice followed by 85 marks structured response and extended writing including two level of response questions	Structured response and extended writing including two level of response questions	
Experimental methods?	Yes	Yes	Yes	
Mathematics	A minimum of 10% of the marks across all three papers will be awarded for mathematics at GCSE higher tier level or above			

Exam strategy

Arrive equipped

Make sure you have all of the correct equipment needed for your exam. As a minimum you should take:

- pen (black, ink or ball-point)
- pencil (HB)
- ruler (ideally 30 cm)
- rubber (make sure it's clean and doesn't smudge the pencil marks or rip the paper)
- calculator (scientific)

Ensure your answers can be read

Your handwriting does not have to be perfect but the examiner must be able to read it! When you're in a hurry it's easy to write key words that are difficult to decipher.

Plan your time

Note how many marks are available on the paper and how many minutes you have to complete it. This will give you an idea of how long to spend on each question. Be sure to leave some time at the end of the exam for checking answers. A rough guide of a minute a mark is a good start, but short answers and multiple-choice questions may be quicker. Longer answers might require more time.

Understand the question

Always read the question carefully and spend a few moments working out what you are being asked to do. The command word used will give you an indication of what is required in your answer.

Be scientific and accurate, even when writing longer answers. Use the technical terms you've been taught.

Always show your working for any calculations. Marks may be available for individual steps, not just for the final answer. Also, even if you make a calculation error, you may be awarded marks for applying the correct technique.

Plan your answer

Questions marked with a * are level of response questions. The examiners will be looking for a line of reasoning in your response. Here, marks will be awarded for your ability to logically structure your answer showing how the points that you make are related or follow on from each other where appropriate. Read the question fully and carefully (at least twice!) before beginning your answer.

Make the most of graphs and diagrams

Diagrams and sketch graphs can earn marks – often more easily and quickly than written explanations – but they will only earn marks if they are carefully drawn and fully annotated.

- If you are asked to read a graph, pay attention to the labels and numbers on the *x*- and *y*-axes. Remember that each axis is a number line.
- If asked to draw or sketch a graph, always ensure you use a sensible scale and label both axes with quantities and units. If plotting a graph, use a pencil and draw small crosses (×) or dots with a circle around them (⊙) for the points.
- Diagrams must always be neat, clear and fully labelled or annotated.

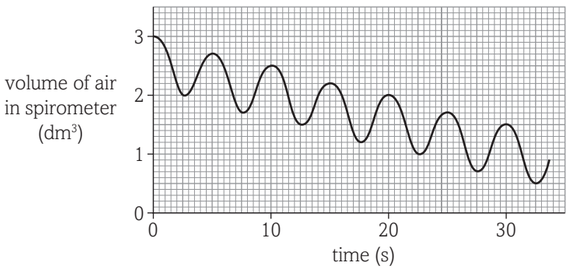
Check your answers

For open-response and extended writing questions, check the number of marks that are available. If three marks are available, have you made three distinct points? It can be helpful to number or bullet-point your response.

For calculations, read through each stage of your working. Substituting your final answer into the original question can be a simple way of checking that the final answer is correct. Another simple strategy is to consider whether the answer seems sensible. Pay particular attention to using the correct units.

Sample AS questions – multiple choice

The following spirometer trace shows the results of an experiment. Soda lime was used to extract carbon dioxide from exhaled air.



What is the rate of oxygen consumption in the experiment?

A 1.0 dm^3 **B** 3.0 dm^3 min^{-1}

C 5.0 dm^3 min^{-1} **D** 12 breaths min^{-1}

Your answer ☐

You *are* allowed to write on the exam paper, and in this case you would be advised to do exactly that. Start by drawing a horizontal line from the top of the trace at time 0 seconds across to 30 seconds. Then measure the distance between this line and the top of the peak on the trace at 30 seconds. This will give you the volume of oxygen consumed in 30 seconds. Remember that the answer is in dm^3 min^{-1} so you need to multiply the volume in 30 seconds by 2.

Multiple-choice questions always have one mark and the answer is given! For this reason students often make the mistake of thinking that they are the easiest questions on the paper. Unfortunately, this is not the case. These questions often require several answers to be worked out and error in one of them will lead to the wrong answer being selected. The three incorrect answers supplied (distractors) will feature the answers that students arrive at if they make typical or common errors. The trick is to answer the question before you look at any of the answers.

Question analysis

Multiple-choice questions look easy until you try to answer them. Very often they require some working out and thinking.

In multiple choice questions you are given the correct answer along with three incorrect answers (called distractors). You need to select the correct answer and write the appropriate letter in the box provided.

If you change your mind, put a line through the box and write your new answer next to it.

Average student answer

C

This question actually tests your understanding of the trace rather than your ability to measure from the graph. Answer A is achieved if you measure the tidal volume. Answer C can be achieved if you know what is meant by the oxygen absorbed per minute but select the wrong part of the trace to measure from. Answer D is achieved if you measure the number of breaths per minute rather than the oxygen absorbed per minute. This leaves answer B as the only correct response.

Verdict

This is a weak answer because:

- This candidate has probably made the mistake of measuring down to the bottom of the trough in the trace just after 30 seconds. That gives a reading of 2.5 dm^3 in about 30 seconds which gives the answer 5 dm^3 when multiplied by 2.
- The candidate has measured to the wrong part of the trace and has also been careless in not converting to dm^3 min^{-1} properly. The trough is actually at about 32 seconds so it is not accurate to simply multiply by 2 to get a figure per minute.

If you have any time left at the end of the paper go back and check your answer to each part of a multiple-choice question so that a slip like this does not cost you a mark.

Sample AS questions – short structured

Fig 1.1 is a diagram of a plant cell.

(a) (i) Name the cell components labelled A and B.

A .....

B .....

(ii) State the **functions** of the components labelled **C** and **D**

C .....

.....

.....

D .....

.....

.....

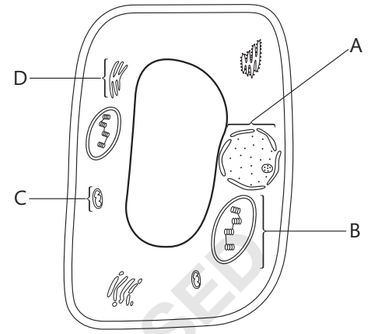


Fig 1.1

The command word in part (a) is 'name' and in part (b) it is 'state'. This indicates that all you need to do is write down the correct terms. You do not need to give further description or explanation. This would only waste your limited time in the examination.

Question analysis

- Generally one piece of information is required for each mark given in the question. There are two marks available for each part of this question so make sure you make two distinct points.
- The answer lines have been labelled to help you.
- Clarity and brevity are the keys to success on short structured questions. For one mark, it is often not necessary to write complete sentences.

Average student answer

In part (a)
A is the nuclear membrane
B is a chloroplast

In part (b)
Controls what enters and leaves the nucleus
Photosynthesis

Look closely at the label for A. It has a bracket on the end showing that the whole nucleus is being labelled. If a part of the nucleus were required as the answer then the label line would end on that part of the nucleus.

In part (b) it is important to read the question carefully and note that the question refers to different parts of the cell, not the same parts as used in part (a).

Verdict

- This is an average answer because:
- The student has recognised that the organelle is the nucleus but has given a name for only part of that organelle. The chloroplast has been correctly identified.
- The student has assumed that the functions required are for the components labelled in part (a). The functions given are accurate for the components named by the student in part (a). However, part (b) actually requires two steps: you need to identify organelles C and D and then write down their functions.

Sample AS questions – extended writing

Describe the arrangement and functions of two named components of a cell surface membrane. [4]

The command word in this question is 'describe'. This means that you need to provide a detailed account. The depth of the answer should be judged from the marks allocated for the question. You do not need to include any justifications or reasons. Four marks are available so four distinct points should be made. However, you are asked to describe something about the arrangement of two components and give the functions of the same two components of the membrane. Make sure that the arrangement and function do apply to the same component. This could be answered in the form of a small table in your examination paper.

Question analysis

- With any question worth four or more marks, think about your answer and the points that you need to make before you write anything down. It may be worth writing a few notes to help organise your thoughts – these could be written at the back of the examination paper.
- Keep your answer concise, and the information you write down relevant to the question. You will not gain marks for writing down biology that is not relevant to the question (even if correct) but it will cost you time.
- Remember that you can use bullet points or annotated diagrams in your answer.

Average student answer

A cell membrane is made up of a phospholipid bilayer. Within this bilayer there are some proteins that span the membrane and others that are free to move within the membrane. These form channels through which charged particles can pass across the membrane. Other features of the membrane include cholesterol, which sits within the bilayer and helps to stabilise the membrane structure. Glycoproteins and glycolipids provide binding sites for hormones.

At this level, your answers need technical terms and clarity in expression otherwise you will find yourself losing marks. It is also important to follow the rubric of the question.

Verdict

This is an average answer because:

- The student has made many good points.
- The question asks for the arrangement and function of two components. Therefore the examiner will mark the first two components named. That is phospholipid and protein in this response.
- The student has described an arrangement for phospholipids as a bilayer but has not given a function.
- The student has described both an arrangement and a function for proteins.
- The last two sentences go on to describe other components of the membrane. As these are the third and fourth components mentioned they will not be marked by the examiner – even though the candidate gave both an arrangement and a function for cholesterol. Writing these last two sentences was not a good use of time.

Sample AS questions – extended writing level of response

Haemoglobin is a protein that carries oxygen in the blood of all mammals. The structure of haemoglobin can vary slightly between species.

- Llamas live at high altitudes and camels live at low altitudes.
- At high altitudes the partial pressure of oxygen is low.
- Llama and camel haemoglobin consists of 2 α subunits and 2 β subunits.
- Each subunit contains a haem group and is able to bind to one molecule of oxygen.
- In the β subunits, one amino acid present in camel haemoglobin has been replaced by a different amino acid in llama haemoglobin.

Describe how the structure of llama haemoglobin is likely to be different from that of camel haemoglobin with reference to the four levels of protein structure. [6]

Six marks are available so six points need to be made. The command word is 'describe' but you are also told to refer to the four levels of protein structure.

You are given some hints in the stem of the question including a description of haemoglobin consisting of four polypeptides (two α and two β subunits) and that llama haemoglobin differs from camel haemoglobin by one amino acid.

You need to organise your answer so that it follows a logical line of reasoning.

Question analysis

- There will be two questions in your second examination which will test your ability to organise your response with a clear and logical structure.
- These questions will be allocated either 6 or 9 marks.
- Your response will be assessed for the level of organisation and whether the information presented is relevant.
  - For level 1 (1–2 marks or 1–3 marks) the information is basic and presented in an unstructured way.
  - For level 2 (3–4 marks or 4–6 marks) there is a line of reasoning and some structure is evident. The information is for the most part relevant and is supported by some evidence.
  - For level 3 (5–6 marks or 7–9 marks) there is a well-developed line of reasoning and a logical structure. The information is relevant and substantiated.
- It is vital to plan out your answer before you write it down. There is always space given on an exam paper to do this so just jot down the points that you want to make before you answer the question in the space provided. This will help to ensure that your answer is coherent and logical and that you don't end up contradicting yourself.
- It helps with longer extended writing questions to think about the number of marks available and how they might be distributed.

Average student answer

The primary structure is the sequence of amino acids in the polypeptide chain. One change in the amino acid sequence means that the primary structure has been changed.

This could cause a change in the secondary structure affecting the shape of the α helix or the β pleated sheet. This is because the hydrogen bonding that holds the secondary structure may have been altered by the presence of the different amino acid.

The different R-group on the new amino acid could also affect the bonding between nearby R groups. This might alter the three dimensional shape of the whole polypeptide chain – this is the tertiary structure.

You are given some hints in the stem of the question and you are reminded that proteins have four levels of structure – you need to write something about each level. To organise the answer it would be best to start at the primary structure and work through the levels of structure finishing with quaternary structure. Don't forget to substantiate your answer by explaining why each statement is true.

Verdict

This is an average to good answer because:

- The student has kept to relevant detail.
- The student has organised the information with a clear line of thought.
- Each statement about a change in structure has been explained by suggesting how the bonding within the molecule may be affected.
- However, the student has omitted to mention any possible effect on the quaternary structure. There may be no effect, but this should be clearly stated.

Sample AS questions – practical

Many enzymes are associated with non-protein molecules known as cofactors. Some cofactors are small inorganic ions.

Rennin is an enzyme that is involved in the digestion of milk. It converts soluble caseinogen in milk into insoluble casein. The cofactor Ca^{2+} is associated with this reaction.

A student wished to investigate the effect of Ca^{2+} on the action of rennin.

Describe how the student could carry out this investigation and produce valid results. [5]

Notice that the question says 'describe how the student could carry out this investigation to produce valid results'. The command word 'describe' requires a suitable level of detail. It is also important that the results must be valid. This means that the variables have been controlled well enough to make the results comparable with each other.

Question analysis

- There will be questions in your exams which assess your understanding of practical skills and draw on your experience of the core practicals. For these questions, think about:
  - how apparatus is set up
  - the method of how the apparatus is to be used
  - how readings are to be taken
  - how to make the readings reliable
  - how to control any variables
  - possible limitations and improvements.
- It helps with extended writing questions to think about the number of marks available and how they might be distributed. For example, if the question asked you to give the arguments for and against a particular case, then assume that there would be equal numbers of marks available for each side of the argument and balance the viewpoints you give accordingly. However, you should also remember that marks will also be available for giving an overall conclusion so you should be careful not to omit that.
- It is vital to plan out your answer before you write it down. There is always space given on an exam paper to do this so just jot down the points that you want to make before you answer the question in the space provided. This will help to ensure that your answer is coherent and logical and that you don't end up contradicting yourself.

Average student answer

Mix 10 cm^3 milk with 1 cm^3 rennin solution and 1 cm^3 of 1 M calcium ion solution.

Time how long the milk takes to form solids.

Dilute the calcium ion solution to form 0.1, 0.25, 0.5 and 0.75 M solutions.

Repeat with the same volumes of milk and rennin but use 1 cm^3 of each of the diluted calcium ion solutions each time.

A suitable level of detail means stating suitable volumes and concentrations. The results can be made valid by ensuring that the volumes and concentrations used are the same in all the readings. Some mention should be made of all the other possible variables.

Verdict

This is an average answer because:

- The student has quoted suitable volumes and concentrations to use.
- The student has kept the volumes the same in each test and has altered just one variable (the concentration of calcium ions).
- The student has used five different concentrations of calcium ions.
- However, there are some important details that have been missed. The student has not described carrying out the test with no calcium ions.
- The student does not mention repeating the experiment at each concentration of calcium ions enabling the reliability to be assessed, to check for anomalies and to calculate a mean.
- The student has not described controlling other variables, such as temperature and pH, to ensure the results are valid.
- The student has not detailed how the end point should be assessed – i.e. how to tell when solids have been formed.

Sample AS questions – calculation

On a biology field trip a pair of students collected some data about plant species in a area of ash woodland. Their results are shown in Table 4.1.

Species	Number of individuals (*n*)	*n*/*N*	$(n/N)^2$
Dog's mercury	40		
Wild strawberry	13	0.13	0.0169
Common avens	43		
Wood sorrel	4		
	N =		$\Sigma(n/N)^2$ =
			$1-(\Sigma(n/N)^2)$ =

Table 4.1

(a)(i) Use the information in the table to work out the Simpson's index of diversity (D) for the area of woodland sampled using the formula:

$$D = 1-(\Sigma(n/N)^2)$$

Where: n = number of individuals of a particular species.
N = total number of individuals in all species
Σ = sum of

Complete Table 4.1.

You may use the space below for your working.

The command here is 'calculate'. This means that you need to obtain a numerical answer to the question, showing relevant working. If the answer has a unit, this must be included.

Finding the numbers requires you to use the appropriate numbers from the table given.

Question analysis

- The important thing with calculations is that you must show your working clearly and fully. The correct answer on the line will gain all the available marks; however, an incorrect answer can gain all but one of the available marks if your working is shown and is correct.
- Show the calculation that you are performing at each stage and not just the result. When you have finished, look at your result and see if it is sensible.
- At some point during your answer you will need to do some kind of sum, and the skills are to decide
  - which numbers you need
  - which operation you need.

Average student answer

Species	Number of individuals (*n*)	*n*/*N*	$(n/N)^2$
Dog's mercury	40	40/100 = 0.40	$(0.4/100)^2$ = 0.1600
Wild strawberry	13	0.13	0.0169
Common avens	43	0.43	0.1849
Wood sorrel	4	0.4	0.16
	N = 100		$\Sigma(n/N)^2$ = 0.5218
			$1-(\Sigma(n/N)^2)$ = 0.4782

The student has not calculated *n*/*N* correctly for Wood sorrel. Therefore the value of $(n/N)^2$ is incorrect. This is an easy error to make if you use a calculator and do not think about the answer you have written. 4/100 is not 0.4, it is 0.04.

Verdict

This is an average answer because:

- The student has calculated most of the parts correctly.
- The working is shown in the top row of the table.
- The student has followed the calculation through appropriately.
- However, one part of the calculation is incorrect and this renders the final answer incorrect. AS students will sit two exam papers, each covering 50% of the content of the AS specification.

Glossary

α-glucose: glucose in which the hydrogen atom on carbon atom number one projects above the plain of the ring.

***ab initio* protein modelling:** a model is built based on the physical and electrical properties of the atoms in each amino acid in the sequence.

accuracy: how close a measured or calculated value is to the true value.

active immunity: where the immune system is activated and manufactures its own antibodies.

active site: an indented area on the surface of an enzyme molecule, with a shape that is complementary to the shape of the substrate molecule.

active transport: the movement of substances against their concentration gradient (from low to high concentration of that substance) across a cell membrane, using ATP and protein carriers.

adaptation: a characteristic that enhances survival in the habitat.

adhesion: the attraction between water molecules and the walls of the xylem vessel.

affinity: a strong attraction.

agglutination: the clumping of insoluble antigen molecules caused by crosslinking by antibodies that have a number of binding sites.

agglutinins: antibodies that cause pathogens to stick together.

allele: a version of a gene; also called gene variant.

alveoli: tiny folds of the lung epithelium to increase the surface area.

amino acids: monomers of all proteins, and all amino acids have the same basic structure.

amphiphilic: attracted to both water and fat – containing hydrophobic (lipophilic) and hydrophilic (lipophobic) parts.

amylopectin molecule: a molecule of polysaccharide with glycosidic bonds between carbon 1 and 4, and branches formed by glycosidic bonds between carbon 1 and 6. It is a constituent of starch.

amylose molecule: a molecule of polysaccharide with long straight chains of between 100 and 1000 α-glucose molecules. It is a constituent of starch. Like maltose, it has glycosidic bonds between carbon 1 and 4.

anatomical adaptations (anatomy): structural features.

anatomy: the branch of science concerned with studying the bodily structure of living organisms.

angina pectoris: a condition marked by severe pain in the chest, resulting from an inadequate blood supply, and therefore lack of oxygen, to the heart muscle that causes the coronary arteries to spasm (tighten).

anion: a negatively charged ion.

anomaly: result that does not fit the expected trend or pattern.

antibiotic: a chemical which prevents the growth of microorganisms. Antibiotics can be antibacterial or antifungal.

antibodies: specific proteins released by plasma cells that can attach to pathogenic antigens.

antigen-presenting cell: a cell that isolates the antigen from a pathogen and places it on the plasma membrane so that it can be recognised by other cells in the immune system.

antigen: a membrane-bound molecule used to recognise pathogens.

anti-toxins: antibodies that render toxins harmless.

aorta: the main artery of the body in mammals.

apoplast pathway: route by which water travels through the cell walls and in spaces between cells of plant tissue when travelling from roots to xylem and from xylem to leaves.

apoptosis: the death of cells which happens as a normal part of an organism's growth and development.

archaea: prokaryotic microorganisms of similar size to bacteria but having some differences of metabolism.

arithmetic mean: the average value of the numbers in a collection, found by dividing the sum of all the values by the number of values in the collection.

arteries: vessels that carry blood away from the heart.

arterioles: small blood vessels that distribute the blood from an artery to the capillaries.

artificial classification: a classification based on just one (or a few) characteristic(s).

artificial immunity: immunity that is achieved as a result of medical intervention.

artificial insemination: the medical or veterinary procedure of injecting semen, collected from a male animal, into the vagina or uterus of a female of the same species.

asexual reproduction: some multicellular organisms and single-celled protoctists such as *Amoeba* and *Paramecium* divide by mitosis to produce new individuals. They are genetically identical to the parent.

assimilates: substances that have become a part of the plant.

asymptomatic: not having any symptoms.

atria: thin-walled chambers of the heart that receive the blood from the veins, and then pass it to the ventricles.

atrio-ventricular node (AVN): a patch of tissue, in the heart, at the top of the septum that conducts the excitation wave from the atria to the ventricles.

atrio-ventricular valves: valves between the atria and the ventricles, which ensure that blood flows in the correct direction.

β-glucose: glucose in which the hydrogen atom on carbon atom number one projects below the plane of the ring.

B memory cells: cells that remain in the blood for a long time, providing long-term immunity.

bacteria: the plural of bacterium. Also see **prokaryotic microorganisms**.

bacterium: a member of a large group of unicellular microorganisms that have cell walls made of murein but lack membrane-bound organelles and a nucleus. Their DNA floats free in the cytoplasm.

behavioural adaptations: the ways that behaviour is modified for survival.

binary fission: a type of division found in prokaryotic cells and organelles such as chloroplasts and mitochondria.

binomial system: a system that uses the genus name and the species name to avoid confusion when naming organisms.

biodiversity: a measure of the variation found in the living world.

blood: the fluid used to transport materials around the body.

Bohr effect: the effect that extra carbon dioxide has on the haemoglobin, explaining the release of more oxygen.

Bohr shift: a change in the shape of the haemoglobin dissociation curve in the presence of carbon dioxide.

bordered pits: the part of plant cell walls which allow the exchange of fluids between tracheids or vessel elements.

bradycardia: a slow heart rhythm.

breathing rate: the number of breaths per minute.

bronchi and **bronchioles:** smaller airways leading into the lungs.

buccal cavity: the mouth.

buffer: a solution that resists changes in pH, so keeps the pH stable.

callose: a large polysaccharide deposit that blocks old or damaged phloem sieve tubes.

canker: a sunken lesion in tree bark caused by necrosis.

capillaries: very small vessels with very thin walls.

carbaminohaemoglobin: a compound of haemoglobin and carbon dioxide, and is one of the forms in which carbon dioxide exists in the blood, within red blood cells. 10% of carbon dioxide is carried in blood this way.

carbohydrates: a group of molecules containing C, H and O.

carbonic acid: a very weak acid formed when carbon dioxide reacts with water.

carbonic anhydrase: the enzyme that catalyses the combination of carbon dioxide and water.

cardiac cycle: the sequence of events in one full beat of the mammalian heart.

cardiac muscle: specialised muscle found in the walls of the heart chambers.

cartilage: a form of connective tissue.

Casparian strip: an impermeable, waterproof substance (suberin) in the walls of the endodermal cells of plant roots. It creates a water tight seal between the cells, preventing water entering the xylem via the apoplast pathway.

catalyst: chemical that speeds up the rate of a reaction and remains unchanged and reusable at the end of the reaction.

cation: a positively charged ion.

chloride shift: the movement of chloride ions into the erythrocytes to balance the charge as hydrogencarbonate ions leave the cell.

chromatids: replicates of chromosomes.

chromatography: a technique for the separation of a mixture by passing it in solution or suspension through a medium in which the components of the mixture move at different rates.

circulatory system (double): one in which the blood flows through the heart twice for each circuit of the body.

circulatory system (single): one in which the blood flows through the heart once for each circuit of the body.

ciliated epithelium: a layer of cells that have many hair-like extensions called cilia.

CITES: Convention on International Trade in Endangered Species.

class: a taxonomic group of organisms that all possess the same general traits, e.g. the same number of legs.

classification: the process of placing living things into groups.

climate change: significant, long-lasting changes in weather patterns.

clonal expansion: an increase in the number of cells by mitotic cell division.

clonal selection: selection of a specific B or T cell that is specific to the antigen.

closed circulatory system: one in which the blood is held in vessels.

coenzymes: small organic non-protein molecules that bind *temporarily* to the *active site* of enzyme molecules, either just before or at the same time that the substrate binds.

cofactor: a substance that has to be present to ensure that an enzyme-catalysed reaction takes place at the appropriate rate. Some cofactors (**prosthetic groups**) are part of the enzyme structure, and others (mineral ion cofactors and organic **coenzymes**) form temporary associations with the enzyme.

cohesion: the attraction between water molecules caused by hydrogen bonds.

collenchyma cells: cells that have thick cellulose walls and strengthen vascular bundles and outer parts of stems, whilst also allowing some flexibility in these regions.

colorimeter: an instrument for measuring the absorbance of different wavelengths of light in a solution.

common ancestor: the most recent individual from which a set of organisms in a group are directly descended.

companion cells: plant cells that help to load sucrose into the sieve tubes.

comparative protein modelling: one approach is protein threading, which scans the amino acid sequence against a database of solved structures and produces a set of possible models which would match that sequence.

competitive inhibition: inhibition of an enzyme, where the inhibitor molecule has a similar shape to that of the substrate molecule and competes with the substrate for the enzyme's active site. It blocks the active site and prevents formation of enzyme-substrate (ES) complexes.

computer modelling: a model of a process which is created on a computer, often used for processes that can need the increased calculation speed.

concentration: the abundance of molecules per unit volume.

concentration gradient: a measurement of how the concentration of a substance changes from one place to another, often across a membrane.

condensation: the conversion of a vapour or gas to a liquid.

condensation reaction: reaction that occurs when two molecules are joined together with the removal of water.

conformational change: a change in the shape of a macromolecule.

conjugated protein: a protein associated with a non-protein compound..

connective tissue: a widely distributed animal/mammalian tissue consisting of cells in an extracellular matrix of protein and polysaccharide; includes bone, cartilage and blood; areolar and adipose tissue.
conservation *ex situ*: conservation outside the normal habitat of the species.
conservation *in situ*: carrying out active management to maintain the biodiversity in the natural environment.
continuous variation: variation where there are two extremes and a full range of values in between.
convergent evolution: the process whereby organisms not closely related independently evolve similar traits as a result of being adapted to similar environments or ecological niches.
coronary arteries: arteries supplying blood to the heart muscle.
correlation coefficient: a measure of how closely two sets of data are correlated. A value of 1 means perfect correlation.
cotransport: transport across a cell membrane, using a carrier or channel protein, of two substances, both moving in the same direction – for example, both moving into the cell.
countercurrent flow: where two fluids flow in opposite directions.
Countryside Stewardship Scheme: a scheme to encourage farmers and other land owners to manage parts of their land in a way that promotes conservation.
covalent bonds: formed when electrons are shared between atoms. These bonds are very strong.
crenated: a shrivelled animal cell that has lost water by osmosis.
cytochrome *c*: a type of cytochrome; an iron-containing protein found within inner mitochondrial membranes and that forms part of the electron transport chain.
cytokines: hormone-like molecules used in cell signalling to stimulate the immune response.
cytokinesis: cytoplasmic division following nuclear division, resulting in two new daughter cells.
cytolysis: the process in animal cells where, if a lot of water molecules enter, the cell will swell and burst as the plasma membrane breaks.
cytology: the study of cell structure and function.
cytoskeletal motor proteins: molecular motors such as myosins, kinesins and dyneins.

datalogger: an electronic device that records data over time or in relation to location either with a built-in instrument or sensor or via external instruments and sensors.
denaturation: a process in which proteins lose their tertiary structure and can no longer function. Their shape unravels due to extremes of pH or heat.
denatured: the irreversible change of shape/loss of tertiary structure of proteins; caused by high temperatures or extremes of pH.
deoxyribose: a five-carbon sugar derived from the five-carbon sugar ribose by replacement of a hydroxyl group by hydrogen, at carbon atom 2.
diaphragm: a layer of muscle beneath the lungs.
dicotyledonous plants: plants with two seed leaves and a branching pattern of veins in the leaf.
diastole: the relaxing phase of the cardiac (heartbeat) cycle.
differential staining: stains that bind to specific cell structures, staining each structure differently so the structures can be easily identified within a single preparation.
differentiation: process by which stem cells become specialised into different types of cell.
diffusion: movement of molecules from an area of high concentration of that molecule to an area of low concentration; it may or may not be across a membrane; it does not involve metabolic energy (ATP).
digestive system: the organs and glands in the body that are responsible for digestion beginning with the mouth and extending through the oesophagus, stomach, small intestine, and large intestine, ending with the rectum and anus.
dilate: to make or become wider, larger, or more open.
diploid: cell in which the nucleus has two complete sets of chromosomes.
direct transmission: passing a pathogen from host to new host, with no intermediary.
disaccharides: any of a class of sugars whose molecules contain two monosaccharide residues joined by a condensation reaction.
discontinuous variation: where there are distinct categories and nothing in between.
dissection: to cut apart tissues, organs or organisms for visual or microscopic study of their structure.
dissociation: releasing the oxygen from oxyhaemoglobin.
disulfide links: also called disulfide bridges or disulfide bonds; strong covalent bond (where electrons are shared) between two sulfur atoms, within a (protein) molecule. These bonds are not broken by heat but can be broken by reducing agents.
DNA polymerase: enzyme that catalyses formation of DNA from activated deoxyribose nucleotides, using single-stranded DNA as a template.
domain: the highest taxonomic rank. There are three domains: Archaea, Eubacteria and Eukaryotae.
double helix: shape of DNA molecule, due to coiling of the two sugar–phosphate backbone strands into a right-handed spiral configuration.

ecosystem a community of interacting organisms and their physical environment.
ectopic heartbeat: an extra or an early beat of the ventricles.
elastic fibres: protein fibres that can deform and then recoil to their original size.
elastin: a type of protein made by cross-linking a polypeptide called tropoelastin. Tropoelastin has a coiled structure. The cross-linking and coiling make elastin a strong and extensible protein. It is found in structures in living organisms, such as elastic cartilage and ligaments, where they need to stretch or adapt their shape as part of life processes.
electrocardiogram: a trace that records the electrical activity of the heart.
electron micrograph: a photograph of an image seen using an electron microscope.
elliptocytosis: cells being more elliptical in shape than they usually are.
electrophoresis: the movement of charged particles/molecules in a fluid or gel under the influence of an electric field.
embryo-transfer: a step in the process of assisted reproduction in which embryos are placed into the uterus of a female with the intent to establish a pregnancy.
endemicity: refers to degree of a condition being endemic – always present in an area/community.
endocytosis: bulk transport of molecules, too large to pass through a cell membrane even via channel or carrier proteins, into a cell.
endothelium: the inner layer or lining of a blood vessel, made of a single layer of cells.
environmental variation: variation caused by response to environmental factors such as light intensity.
endodermis: a layer of cells surrounding the vascular tissue in the root of a plant.
enzyme cascade: a sequence of successive activation reactions involving enzymes, which is characterised by a series of amplifications stemming from an initial stimulus. The product of each preceding reaction catalyses the next reaction.
enzyme-product complex: enzyme molecule with product molecule(s) in its active site. The two are joined temporarily by non-covalent forces.
enzyme-substrate complex: enzyme molecule with substrate molecule(s) in its active site. The two are joined temporarily by non-covalent forces.
epidemic: a rapid spread of disease through a high proportion of the population.
epidermal tissue: tissue consisting of epidermal cells – cells that form the outer layer of cells of a multicellular organism. Usually has a protective function.
epithelial cells: cells that constitute lining tissue in animals.
epithelial tissues: lining or covering tissue, consisting of epithelial cells.
erythrocyte: a red blood cell.
ester bond: a bond formed by condensation reaction between the –OH group of a carboxylic acid and the –OH group of an alcohol, to produce an ester
ES complex: see **enzyme-substrate complex**
Eubacteria: taxonomic domain, consisting of true bacteria – prokaryotic microorganisms not archaea.
Eukaryotae: taxonomic domain consisting of organisms that have eukaryotic cells.
eukaryotic: cells having a true nucleus/organisms with eukaryotic cells.
eukaryotic cell cycle: series of events in a eukaryotic cell leading to its replication to produce two daughter cells; consists of interphase, mitosis and cytokinesis.
evaporation: the change of state of a liquid into a vapour at a temperature below the liquid's boiling point. Evaporation occurs at the surface of a liquid where some molecules of liquid with high kinetic energy escape.
evolution: the gradual process by which the present diversity of living organisms has developed from earlier forms during the last 3000 million years of the history of the Earth.
exocytosis: the bulk transport of molecules, too large to pass through a cell membrane even via channel or carrier proteins, out of a cell.
extant still in existence; surviving.
extinction: when the last living member of a species dies and the species ceases to exist.
extracellular: outside the cell.
eyepiece graticule: a measuring device. It is placed in the eyepiece of a microscope and acts as a ruler when you view an object under the microscope.

facilitated diffusion: movement of molecules from an area of high concentration of that molecule to an area of low concentration, across a partially permeable membrane via protein channels or carriers; it does not involve metabolic energy (ATP).
family: a group of closely related genera, e.g. within the order Carnivora we might recognise the 'dog' family and the 'cat' family.
fatty acids: have a carboxyl group (–COOH) on one end, attached to a hydrocarbon tail, made of only carbon and hydrogen atoms. This may be anything from 2 to 20 carbons long.
fertilisation: the fusion of male and female gamete nuclei.
fetal haemoglobin: the type of haemoglobin usually found only in the fetus.
fibrillation: uncoordinated contraction of the atria and ventricles.
fibrous protein: has a relatively long, thin structure, is insoluble in water and metabolically inactive, often having a structural role within an organism.
filaments: slender branches of tissue that make up the gill. They are often called primary lamellae.
flaccid: plant tissue where there is no turgor – the tissue is soft.
fluid mosaic model: theory of cell membrane structure with proteins embedded in a sea of phospholipids.

gamete: sex cell, e.g. ovum/spermatozoon.
gene: a length of DNA that codes for a polypeptide or for a length of RNA that is involved in regulating gene expression.
genetic erosion: a process whereby an already limited gene pool of an endangered species of plant or animal diminishes even more when individuals from the surviving population die off without getting a chance to meet and breed with others in their endangered low population.
genetic variation: variation caused by possessing a different combination of alleles.
genome: the total DNA content of a cell or an individual.
genus: a group of closely related species.
gill filaments: slender branches of tissue that make up the gill of a fish. They are often called primary lamellae.
glucose: a 6-carbon monosaccharide sugar.
glycerol: has three carbon atoms. It is an alcohol, which means it has free –OH groups.
globular protein: has molecules of a relatively spherical shape, which are soluble in water, and often have metabolic roles within the organism.
glycocalyx: all the carbohydrate molecules on the exterior of a cell surface membrane.
glycogen molecule: the energy store in humans; large polysaccharide molecule made of many glucose residues joined by condensation reactions and like amylopectin, has glycosidic bonds between carbon atoms 1 and 4, and branches formed by glycosidic bonds between carbon atoms 1 and 6.

glycolipid: lipid/phospholipid with a chain of carbohydrate molecules attached.
glycoprotein: protein with a chain of carbohydrate molecules attached.
glycosidic bond: a bond formed between two monosaccharides by a hydrolysis reaction.
growth factors: a substance, such as a vitamin, hormone or cytokinin, which is required for the stimulation of growth in living cells.
goblet cells: cells that secrete mucus.
guard cell: in leaf epidermis, two of these cells surround stomata.

habitat: where an organism lives.
haemoglobin: the red pigment used to transport oxygen in the blood.
haemoglobinic acid: the compound formed by the buffering action of haemoglobin as it combines with excess hydrogen ions.
haemolysis: lysis of animal cells, in this case it is referring to lysis of red blood cells.
haemolytic anaemia: anaemia with chronic premature destruction of red blood cells.
haploid: having only one set of chromosomes; represented by the symbol '*n*'.
helicase: enzyme that catalyses the breaking of hydrogen bonds between the nitrogenous pairs of bases in a DNA molecule.
hazard: a factor that has the potential to cause harm.
herd vaccination: using a vaccine to provide immunity to all or almost all of the population at risk.
heterotropic ossification: overgrowth of bone, often in the wrong place, e.g. muscle tissue.
high-power drawing: a drawing showing detail of some individual cells.
histamine: a compound which is released by mast cells in response to injury and in allergic and inflammatory reactions, causing contraction of smooth muscle and dilation of capillaries.
homologous chromosomes: matching chromosomes, containing the same genes at the same places (loci). They may contain different alleles for some or all of the genes.
homozygosity: in a diploid cell or organism the state where both copies of a given gene are the same allele.
hormone: a chemical produced in glands and that travels to its target cells via the blood. Later broken down in the liver. Involved with communication and control.
hydathodes: Structures in plants that can release water droplets which may then evaporate from the leaf surface.
hydrocarbon: a compound consisting of only hydrogen and carbon.
hydrogen bond: a weak interaction that can occur wherever molecules contain a slightly negatively charge bonded to a slightly positively charged hydrogen.
hydrogencarbonate ion: HCO_3^-.
hydrolysis reaction: reaction that occurs when a molecule is split into two smaller molecules with the addition of water.
hydrophilic: attracted to water.
hydrophobic: repelled by water.
hydrophyte: a plant adapted to living in water or where the ground is very wet.
hydrostatic pressure: the pressure that a fluid exerts when pushing against the sides of a vessel or container.
hypertension: long term high blood pressure.
hyphae each of the branching filaments that make up the mycelium of a fungus.

immune response: the reaction of the cells and fluids of the body to the presence of a substance which is not recognised as a constituent of the body itself.
immune system: the organs and processes of the body that provide resistance to infection and toxins. Organs include the thymus, bone marrow, and lymph nodes.
***in vitro* fertilisation:** a process where an egg is surgically removed from the ovaries and fertilised with sperm in a laboratory.
indirect transmission: passing a pathogen from host to new host, via a vector.
inflammation: swelling and redness of tissue caused by infection.
inhibitor: a substance that reduces or stops a reaction.
inorganic ions: charged particles of inorganic (not carbon-based) substances, e.g. Mg^{2+}, Ca^{2+}.
integumentary system: the organ system that protects the body from various kinds of damage, such as loss of water or abrasion from outside. The system comprises the skin and its appendages (including hair, scales, feathers, hooves and nails).
intercalated discs: gap junctions between muscle cells in the heart muscle. They enable the heart muscle cells to fit tightly together and help to facilitate synchronised contraction of the heart muscle.
intercostal muscles: muscles between the ribs. Contraction of the external intercostal muscles raises the rib cage.
interleukins: signalling molecules that are used to communicate between different white blood cells.
interphase: phase of cell cycle where the cell is not dividing; it is subdivided into growth and synthesis phases.
interspecific variation: the differences between species.
intracellular: inside the cell.
intraspecific variation: the variation between members of the same species.
ionic bond: a type of chemical bond that involves the electrostatic attraction between oppositely charged ions.

karyotype: a photomicrograph of chromosomes in a cell.
keratin: a fibrous protein forming the main structural constituent of hair, feathers, hooves, nails, claws, horns.
keratinocytes: an epidermal cell that produces keratin.
keystone species: one that has a disproportionate effect upon its environment relative to its abundance.
kinetic energy: the energy of motion.
kingdom: taxonomic group; traditionally there are five main kingdoms: Plantae, Animalia, Fungi and Protoctista are all Eukarya whose cells possess a nucleus. All those single celled organisms that do not possess a nucleus are grouped into the kingdom Prokaryota.

lamellae: folds of the filament to increase surface area. They are also called secondary lamellae or gill plates.
leucocyte: a white blood cell.
lignification: the deposition of lignin in the walls of xylem vessels.
lignin: the waterproof substance that impregnates the walls of xylem vessels. When plant xylem vessels are lignified they are woody.
limiting factor: an environmental factor that limits the rate of a biological process. When a process is controlled by a number of factors, the factor that is in least supply will limit the process. If this factor is increased then the process will proceed at a faster rate. If it is decreased the process will proceed at a slower rate.
lipids: a group of substances that are soluble in alcohol rather than water. They include triglycerides, phospholipids, glycolipids and cholesterol.
lipophilic: attracted to fat (lipids).
lipophobic: repelled by fat (lipids).
locus: the position of a gene on a chromosome.
longitudinal section: a section cut lengthways.
low-power plan: a drawing showing distribution of cells but no individual cells shown.
lymph: the fluid held in the lymphatic system, which is a system of tubes that returns excess tissue fluid to the blood system.
lymphatic system: a network of vessels and organs that help maintain the internal fluid environment of the body; also transports fat and proteins and makes some blood cells. Receives tissue fluid that has passed out of blood capillaries and bathed cells. Lymph drains into blood vessels in neck region. Lymph organs include the tonsils, thymus, spleen and lymph nodes.

macromolecule: a very large, organic molecule.
macrophages: large phagocytic cells that ingest and digest pathogens and present the pathogen's antigens to other cells of the immune system.
magnification: the number of times larger an image appears, compared to the size of the object.
marine conservation zones: areas of the sea set aside to conserve the diversity of species and habitats.
median: the number that separates a data set into two halves; half the set is above the median value and the other half is below the median value. In a sample there may be no specimen that actually has the median value.
meiosis: type of nuclear division that results in the formation of cells containing half the number of chromosomes of the parent cell.
meristem: an area of unspecialised cells, in plants, that can divide and differentiate into other cell types.
mesenchyme: connective tissue.
mesoderm: the middle of the three layers in the early embryo; gives rise to connective tissue, muscles and part of the gonads (ovaries and testes).
mesophyll: a type of cell found in plant leaves.
metabolic/metabolism: the chemical reactions that take place inside living cells or organisms.
micrometer: a precise measuring device and not a unit of measurement. Note the difference in spelling. It is a small scale on a microscope slide that can be viewed under a microscope and used to calibrate the value of eyepiece divisions at different magnifications.
micrometre: equal to one millionth (10^{-6}) of a metre. It is the standard unit for measuring cell dimensions. Note the difference in spelling between micrometre and micrometer.
microscopy: the use of the microscope to study small organisms/objects.
mitosis: type of nuclear division that produces daughter cells genetically identical to each other and to the parent cell.
mode: the most common value amongst a group/data set.
monoculture: a crop consisting of one strain of one species.
monocytes: the largest white blood cells usually have a large kidney-shaped nucleus.
monomer: a small molecule which binds to many other identical molecules to form a polymer.
monosaccharide: any of the class of sugars (e.g. glucose) that cannot be hydrolysed to give a simpler sugar.
mucous membrane: specialised epithelial tissue that is covered by mucus.
muscle tissue: highly cellular, well vascularised (has many blood vessels) tissues responsible for most types of body movement. Muscle cells are called fibres, contain the proteins actin and myosin, and can contract. Three types of muscle tissue: smooth, skeletal and cardiac.
musculo-skeletal system: the combination of the skeletal muscles and skeleton working together, includes the bones, muscles, tendons and ligaments of the body.
mutation: a change to the genetic material of an organism, either to a gene or to a chromosome. The changing of the structure of a gene, resulting in a variant allele that may be transmitted to subsequent generations; caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes. May involve loss of a portion of a chromosome, or an abnormal chromosome number.
mycelium the vegetative part of a fungus, consisting of a network of fine white filaments (hyphae).
myocardial infarction: a heart attack.
myofibrils: microscopic fibres that make up the larger fibres of skeletal (striated) muscle.
myogenic muscle: muscle that can initiate its own contraction.

nanometre: one thousandth (10^{-3}) of a micrometre. It is therefore one thousand millionth (10^{-9}) of a metre. It is a useful unit for measuring the sizes of small organelles within cells and for measuring the size of large molecules.
natural classification: a classification that reflects the evolutionary relationships between organisms.
natural immunity: immunity achieved through normal life processes.
natural selection: the term used to explain how features of the environment apply a selective force on the reproduction of individuals in a population.
necrosis: cell death cell death disease or injury; it may subsequently limit the spread of a pathogen.
nervous system: the central nervous system (brain and spinal cord) and the peripheral nervous system – the network of nerve cells (neurones) that transmit nerve impulses between parts of the body and the central nervous system. Fast acting control system to detect stimuli and to bring about responses in muscles and glands.

nervous tissue: the main component of the nervous system. Consists of neurones and supporting cells.
neutrophil: a type of white blood cell that engulfs foreign matter and traps it in a large vacuole (phagosome), which fuses with lysosomes to digest the foreign matter.
non-competitive inhibition: the inhibition of an enzyme where the competitor molecule attaches to a part of the enzyme molecule but NOT the active site. It changes the shape of the active site and prevents ES complexes forming as the enzyme active site is no longer complementary in shape to the substrate molecule.
nucleotide: molecule consisting of a five-carbon sugar, a phosphate group and a nitrogenous base.

oncotic pressure: the pressure created by the osmotic effects of the solutes in a solution.
open circulatory system: one in which the blood is not held in vessels .
operculum: a bony flap that covers and protects the gills.
opsonins: proteins that bind to the antigen on a pathogen and then allow phagocytes to bind.
optimum: best.
optimum pH: the pH at which an enzyme works best, at its fastest rate.
optimum temperature: the temperature at which an enzyme works best, at its fastest rate.
order: taxonomic group; a subdivision of the class using additional information about the organisms, e.g. the class Mammalia is divided into meat-eating mammals (order Carnivora) and vegetation-eating mammals (order Herbivora).
organ: collection of tissues working together to perform a function/related functions.
organ system: a number of organs working together to carry out an overall life function.
organelles: small structures within cells, each of which carries out a specific function.
osmosis: passage of water molecules down their water potential gradient, across a partially permeable membrane.
ossification: process of changing cartilage to bone by depositing calcium phosphate.
ostia: pores in the heart of an insect that allow blood from the body to enter the heart.
ovalocytosis: cells being more oval in shape than they usually are.
oxygen tension: measured in units of pressure (kPa). See partial pressure.
oxygen uptake: the volume of oxygen absorbed by the lungs in one minute.
oxyhaemoglobin: a molecule of haemoglobin with oxygen molecules loosely bound to it. When haemoglobin takes up oxygen, it becomes oxyhaemoglobin.

palisade cells: closely-packed photosynthetic cells within leaves.
pandemic: an infectious disease which spreads rapidly across continents.
partial pressure: the concentration of oxygen is measured by the relative pressure that it contributes to a mixture of gases. This is called the partial pressure of oxygen or pO_2.
parenchyma: a packing tissue in plants which fills spaces between other tissues. In roots parenchyma cells may store starch. In leaves some (called chlorenchyma) have chloroplasts and can photosynthesise. In aquatic plants aerenchyma tissue is parenchyma with air spaces to keep the plant buoyant.
partially permeable: allows some, but not all, substances to pass through.
passive immunity: immunity achieved when antibodies are passed to the individual through breast feeding or injection.
pathogen: a microorganism that causes disease.
penicillin: an antibiotic or group of antibiotics produced naturally by certain mould fungi, now usually prepared synthetically.
pepsin: an enzyme that digests protein in the stomach of mammals.
peptide bond: a bond formed when two amino acids are joined by a condensation reaction.
pericycle: a thin layer of meristem tissue between the endodermis and the phloem in plant roots.
peristalsis: the involuntary contraction and relaxation of the muscle layers of the intestine or another canal within the body, creating wave-like movements which push the contents of the canal forward.
personalised medicine: the development of designer medicines for individuals.
phagocytosis: a type of endocytosis where large solid particles or small organisms are taken into a cell.
phloem: tissue that carries products of photosynthesis, in solution, within plants.
phospholipid: molecule consisting of glycerol, two fatty acids and one phosphate group.
photomicrograph: a photograph of an image seen using an optical microscope.
phylogeny: the study of the evolutionary relationships between organisms.
phylum: a major subdivision of the kingdom. A phylum contains all the groups of organisms that have the same body plan, e.g. possession of a backbone.
physiological adaptations (physiology): affect the way that processes work.
pinoendocytosis: if cells ingest liquids by endocytosis, this is called pino(endo)cytosis.
pinocytosis: a type of endocytosis where liquid is taken into a cell.
plasma: the fluid portion of the blood.
plasma cells: derived from the B lymphocytes, these are cells that manufacture antibodies.
plasma membrane: the cell surface membrane.
plasmodesmata: gaps in the cell wall containing cytoplasm that connects two cells.
plasmolysed: plant cell where the contents have shrunk due to loss of water by osmosis and the plasma membrane has separated from the cell wall.

plasmolysis: the process in which the protoplast of a plant cell shrinks as a result of water loss and the plasma membrane detaches from the cell wall.
platelets: small colourless disc-shaped cell fragments without a nucleus, found in large numbers in blood and involved in clotting.
pluripotent: able to differentiate into any type of cell.
polar: where the charge is not evenly distributed across the particle.
polymer: a large molecule made from many smaller molecules called monomers.
polymorphic gene locus: a locus that has more than two alleles.
polynucleotide: a large molecule consisting of many nucleotides.
polypeptide: polymer made of many amino acid units joined together by peptide bonds. Insulin is a polypeptide of 51 amino acids.
polysaccharides: polymers of monosaccharides that are made of hundreds or thousands of monosaccharide monomers bonded together.
potometer: a device that can measure the rate of water uptake as a leafy stem transpires.
precision: the closeness of agreement between measured values obtained by repeated measurements.
primary defences: those that prevent pathogens entering the body.
primary immune response: the initial response caused by a first infection.
primary structure: the sequence of amino acids found in a protein molecule.
prokaryotic microorganisms: unicellular microorganisms which have cell walls made of murein but lack membrane-bound organelles and an organised nucleus.
product: molecule produced from substrate molecules, by an enzyme-catalysed reaction.
prosthetic group: a non-protein component that forms a permanent part of a functioning protein molecule.
proteins: large polymers comprised of long chains of amino acids.
protoctista: phylum containing many eukaryotic organisms that cannot be classed as fungi, animals or plants.
pulmonary artery: the artery carrying blood from the right ventricle of the heart to the lungs for oxygenation.
pulmonary vein: the vein carrying oxygenated blood from the lungs to the left atrium of the heart.
Purkyne tissue: consists of specially adapted muscle fibres that conduct the wave of excitation from the AVN down the septum to the ventricles.

Q_{10}: temperature coefficient, calculated by dividing the rate of reaction at (T + 10) °C by rate of the reaction at T °C.
quadrat: a simple square frame used to define the sample area.
qualitative testing: test that shows the presence or absence of a substance but does not indicate how much of the substance is present.
qualitative data: data that does not involve quantity (numbers).
quantitative data: data that does involve quantity (numbers).
quaternary structure: protein structure where a protein consists of more than one polypeptide chain. For example, insulin has a quaternary structure.

random error: statistical fluctuations in the measured data due to the precision limitations of the measurement device.
regenerative medicine: stem cells may be used to populate a bioscaffold of an organ, and then directed to develop and grow into specific organs for transplanting.
reproductive system: a collection of organs that work together for the purpose of producing a new organism, including gonads (ovaries and testes) and uterus.
residual volume: the volume of air that remains in the lungs after forced expiration.
resolution: the clarity of an image; the higher the resolution the clearer the image.
respiration: a process in living organisms involving the release of energy from food; aerobic respiration occurs in the presence of oxygen and involves the release of carbon dioxide; anaerobic respiration occurs in the absence of oxygen and may involve the production of carbon dioxide and ethanol, or the production of lactic acid; both aerobic and anaerobic respiration involve the oxidation of complex organic substances, such as glucose or fatty acids.
respiratory system: a biological system consisting of specific organs and structures used for the process of breathing, gaseous exchange and respiration in an organism.
ribose: a five-carbon sugar which occurs widely in nature as a constituent of nucleosides, RNA and several vitamins and coenzymes.
ribosome: a small organelle consisting of RNA and associated proteins found in large numbers in the cytoplasm of prokaryotic and eukaryotic cells, and on rough endoplasmic reticulum of eukaryotic cells. Each ribosome consists of two subunits. Amino acids are assembled into polypeptides at ribosomes, during a process called translation, where the ribosome moves along and reads instructions from a length of messenger RNA.
ring vaccination: used when a new case of a disease is reported. All people who have been in contact with/live close to, the patient are vaccinated.
risk: the level of exposure to a hazard.
risk assessment: a way of managing risks by reducing exposure to hazards.
root hair cells: epidermal cells of young roots with long hair-like projections.

sampling techniques: techniques used to collect samples, for example random sampling, systematic sampling and stratified sampling.
sarcomere: the smallest contractile unit of a muscle.
sclerenchyma cells: plant cells that have lignified walls and are used to strengthen stems and leaf midribs.
secondary defences: defences which attack pathogens that have entered the body.
secondary immune response: a more rapid and vigorous response caused by a second or subsequent infection by the same pathogen.

secondary structure: the coiling or folding of an amino acid chain, which arises often as a result of hydrogen bond formation between different parts of the chain. The main forms of secondary structure are the helix and the pleated sheet.
selective breeding: the selection of specific traits in plants or animals through breeding programmes.
semi-conservative replication: how DNA replicates, resulting in two new molecules, each of which contains one old strand and one new strand. One old strand is conserved in each new molecule.
semilunar valves: valves that prevent blood re-entering the heart from the arteries.
septum: the wall that separates two chambers.
sieve plates: the perforated end walls of the sieve tube elements in phloem.
sieve tube elements: make up the tubes in phloem tissue that carry sap up and down the plant. The sieve tube elements are separated by sieve plates.
significant figures: the digits of a number that have a meaning and contribute to the number's precision.
Simpson's index of diversity: a measure of the diversity of a species in a habitat.
sink: a part of the plant where materials are removed from the transport system; for example, the roots receive sugars and store them as starch. At another time of year, the starch may be converted back to sugars and transported to a growing stem – so the roots can also be a source!
sino-atrial node (SAN): the heart's pacemaker. It is a small patch of tissue that sends out waves of electrical excitation at regular intervals in order to initiate contractions.
sister chromatids: when a chromosome has replicated, the resulting two identical chromatids produced are sister chromatids.
smooth muscle: involuntary muscle that contracts without the need for conscious thought.
soil depletion: the loss of soil fertility caused by removal of minerals by continuous cropping.
source: a part of the plant that loads materials into the transport system; for example, the leaves photosynthesise and the sugars made are moved to other parts of the plant.
species: a group of organisms that can freely interbreed to produce fertile offspring.
species evenness: a measure of how evenly represented the species are.
species richness: a measure of how many different species are present.
spherocytosis: cells being more spherical in shape than they usually are.
spiracle: an external opening or pore that allows air in or out of the tracheae.
spirometer: a device that can measure the movement of air into and out of the lungs.
squamous epithelial cells: flattened epithelial cells arranged in a layer.
stage graticule: a precise measuring device. It is a small scale that is placed on a microscope stage and used to calibrate the value of eyepiece divisions at different magnifications.
standard deviation: a measure of the spread around a mean.
statins: chemicals that competitively inhibit an enzyme that catalyses the production of cholesterol in the liver.
stem cell: unspecialised cell able to express all of its genes and divide by mitosis.
stomata: minute pores in the epidermis of the leaf or stem of a plant, which allow movement of gases in and out of the intercellular spaces.
Student's *t*-test: a test used to compare two means.
substrate: molecule that is altered by an enzyme-catalysed reaction.
succulents: a plant that stores water in it stem which becomes fleshy and swollen.
surface area to volume ratio: the surface area of an organism divided by its volume, expressed as a ratio.
symbiosis: the relationship where two organisms coexist for their mutual benefit.
symplast pathway: the route taken by water as it moves from cell to cell via the cell cytoplasm.
synthesis: making large molecules from smaller ones.
synthetic biology: the re-engineering of biology. This could be the production of new molecules that mimic natural processes, or the use of natural molecules to produce new biological systems that do not exist in nature.
systematic error: errors that may be inherent in the equipment and are repeated at every replicate. However, if the percentage error is known, a calculation can be made to find the margin of error.
systemic circulation: the part of the cardiovascular system which carries oxygenated blood away from the heart to the body, and returns deoxygenated blood back to the heart.
systole: the phase of the heartbeat when the heart muscle contracts and pumps blood from the chambers e.g. from atria to ventricles or from ventricles into the arteries.

T helper cells: cells that release signalling molecules to stimulate the immune response.
T killer cells: cells that attack and destroy our own body cells that are infected by a pathogen.
T memory cells: cells that remain in the blood for a long time, providing long-term immunity.
T regulator cells: cells that are involved with inhibiting or ending the immune response.
tachycardia: a rapid heart rhythm.
temperature: the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale.
tendinous cords: cord-like tendons in heart ventricles that connect the papillary muscles in the ventricle walls to the tricuspid valve or to the bicuspid valve in the heart, to prevent the valves turning inside out.
tertiary structure: the overall three-dimensional shape of a protein molecule. Its shape arises due to interactions including hydrogen bonding, disulfide bridges, ionic bonds and hydrophobic interactions.
tidal volume: the volume of air inhaled or exhaled in one breath, usually measured at rest.
tissue: group of cells that work together to perform a specific function/set of functions.
tissue fluid: the fluid surrounding the cells and tissues.
toxin: a substance that is poisonous to living cells/organisms.
trachea: the main airway leading from the back of the mouth to the lungs in mammals.
tracheal fluid: the fluid found at the ends of the tracheoles in the tracheal system in insects.
tracheal system: a system of air-filled tubes in insects.
transcription: the process of making messenger RNA from a DNA template.
transect: a line across a habitat.
translation: formation of a protein, at ribosomes, by assembling amino acids into a particular sequence according to the coded instructions carried from DNA to the ribosome by mRNA.
translocation: the transport of assimilates through a plant.
transmission: passing a pathogen from an infected individual to an uninfected individual.
transpiration: the loss of water vapour from the aerial parts of a plant, mostly through the stomata in the leaves.
transport: the movement of substances such as oxygen, nutrients, hormones, waste and heat around the body.
transverse section: a section cut crossways.
triglycerides: lipid molecules consisting of glycerol, and three fatty acids.
turgid: a swollen state of plant cells that have taken in water by osmosis and reached their maximum state of swelling. The cell wall now exerts a pressure and prevents any more water entering the cell.
tylose: an outgrowth from parenchyma cells into xylem vessels (vascular tissue used for water and mineral transport throughout a plant) which can block the vessel.
ultrastructure: structures within cells.
unsaturated fatty acid: fatty acid lacking the full complement of hydrogens. There are double bonds between some of the adjacent carbon atoms, giving a kink in the long hydrocarbon chain.
urinary system: also known as the renal system. Consists of the two kidneys, ureters, the bladder, and the urethra. Each kidney consists of millions of functional units called nephrons. This system deals with removal of nitrogenous waste and with osmoregulation.

vaccination: a way of stimulating an immune response so that immunity is achieved.
vacuolar pathway: the route taken by water as it passes from cell to cell via the cytoplasm and vacuoles.
validity: if an investigation provides the answer to the research question it is valid. It is measuring what it says it is measuring. For an investigation to be valid control variables have to be controlled so that only the independent variable is causing the change.
variation: the presence of variety – the differences between individuals.
vascular tissue: consists of cells specialised for transporting fluids by mass flow.
vasodilation: an increase in the diameter of the lumen of arteries allowing increased blood flow to specific regions of the body.
vector: an organism that carries a pathogen from one host to another.
veins: vessels that carry blood back to the heart.
vena cava: a large vein carrying deoxygenated blood into the heart. There are two in humans, the inferior vena cava (carrying blood from the lower body) and the superior vena cava (carrying blood from the head, arms, and upper body).
venom: a harmful secretion injected into a victim by a venomous organism such as a snake, insect or spider.
ventilation: the refreshing of the air in the lungs, so that there is a higher oxygen concentration than in the blood, and a lower carbon dioxide concentration .
ventricles: the lower chambers of the heart, their walls create high pressure to pump the blood out of the heart and into arteries.
venules: small blood vessels that collect blood from capillaries and lead into the veins.
viable: capable of surviving or living successfully, especially under particular environmental conditions, relating to a plant, animal, or cell.
vital capacity: the greatest possible volume of air that can be expelled from the lungs after taking the deepest possible breath.
water potential: measure of the tendency of water molecules to diffuse from one region to another.
water vapour potential gradient: a difference in the concentration of water (vapour) molecules inside the leaf compared to outside.
waxy cuticles: these prevent water collecting on the cell surfaces. Since pathogens collect in water and need water to survive, the absence of water is a passive defence.
wildlife reserves: areas set aside for the conservation of species or habitats.

xerophyte: a plant adapted to living in dry conditions.
xylem: tissue that carries water and mineral ions from the roots to all parts of the plant.
xylem vessels: the tubes which carry water up the plant.

zygote: cell produced after fertilisation of two gametes during sexual reproduction.

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