Microscopes and magnification

Specification reference

- *2.1.1 (b)*
- *2.1.1 (e)*
- *2.1.1 (f)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the different units of measurement involved in microscopy, and be able to convert from one to another
- perform calculations using a formula to obtain the magnification or the actual size of an object as seen by any type of microscope.

Introduction

Microscopes are a basic and fundamental piece of biological equipment. They function by producing a magnified image of the object, such as a cell or tissue, which allows a biologist to examine the object in more detail.

It is important to know how much an object has been magnified, and to be able to calculate the actual size of the object. This allows us to make more accurate descriptions of a structure and to give comparisons with other structures visible.

There is a formula which we can use, which allows us to calculate the magnification and real size of objects. This sheet will give you a clear guide as to how to tackle a question on calculations involving the microscope.

Background

Microscopes are used to enlarge images of small objects. They are a major piece of equipment used by the biologist. There are many different types of microscopes. You need to know about the four most commonly used. You can read about the differences between these types of microscopes in Topic 2.1 and 2.2.

Below is a summary of the types of microscopes giving their uses, advantages, and disadvantages.

microscope	uses	advantages	disadvantages
light microscope	Uses light rays to observe object.	Can observe living things Does not use harsh chemicals Easy to set up and use Cheap and portable	Low magnification (up to 2000 times) Low resolution

microscope	uses	advantages	disadvantages
Electron microscopes (EM)			
Transmission EM	Uses focused beams of electrons through sections of tissues.	High magnification (up to 5000 000 times) High resolution Can see details inside cells	Can only see dead material Harsh chemicals used in preparation which can cause artefacts Expensive
Scanning EM	Uses focused beams of electrons reflected off the tissues.	High magnification (up to 5000 000 times) High resolution Can see details of the surfaces of structures	
Laser scanning confocal microscope	Uses a laser beam of light to illuminate chemical stains within the specimen. These then fluoresce.	Can see living cells. Can observe cell processes by tracking molecules. Higher resolution than light microscopes.	More expensive than light microscope. More complex than light microscope.

You could be given images of objects like cells, organelles, or organs, photographed, or drawn using either a light microscope or the different types of electron microscopes. Images photographed using a microscope of any type will have very small sizes, usually smaller than a millimetre.

There are three units you may encounter in microscopy:

- a millimetre (mm)
- a micrometre (μm)
- and, less commonly, a nanometre (nm).

You might find it difficult to convert a measurement taken in one unit to a different unit. Try the rule of thousands.

1 metre = 1000 mm

1 mm = 1000 μm

1 μm = 1000 nm

If you need to convert down the size range, multiply the larger size by 1000.

If you need to convert up the size range, divide by 1000.

Here are some examples.

1 The diameter of an arteriole is 1.5 mm, how many μm is it?
You are converting down the size range, so multiply by 1000.

$1.5 \times 1000 = 1500$ μm

2 A mitochondrion is 2 μm long, how many nm is it?

You are converting down the size range, so multiply by 1000.

$2 \times 1000 = 2000$ nm

3 A chloroplast is 10 500 nm, what size is it in μm?

You are converting up the size range, so divide by 1000.

$\frac{10\,500}{1000} = 10.5$ μm

Now try questions 1 and 2 in the task. Once you feel confident with the conversion of units look at the next section on the use of a formula to calculate size.

Using a formula to calculate size

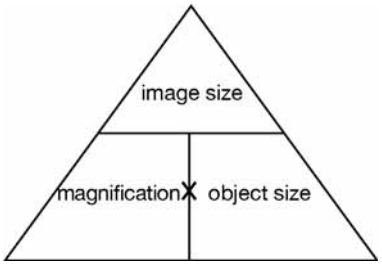
You may be asked to calculate the magnification used for a specimen or to calculate the actual size of a specimen.

The formula for these calculations is:

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

or $$\text{Object size} = \frac{\text{image size}}{\text{magnification}}$$

You should be able to manipulate the formula. Some students find this triangle helpful:



2.2 Magnification and calibration
Support worksheet

When attempting these questions try using the following step by step approach:

Step 1 – measure the object or scale bar in mm.

Step 2 – If you have two measurements of size, convert them to the same units.

Step 3 – Select the correct version of the formula.

Step 4 – Substitute the figures into the formula.

Step 5 – Use your calculator to calculate the unknown.

Step 6 – Check you answer is in the correct units and is the correct number of decimal places.

Task

1 If the width of a mitochondrion is 0.5 µm, what is the width in nm?

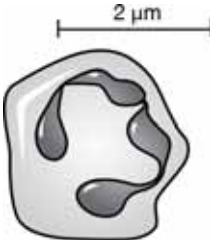
2 A student measured the maximum width of an open stomata and found it to be 3.5 µm. what was the width in mm?

3 A student drew a picture of a palisade cell from a leaf. The drawing measured 100 mm and the real size of the cell was 0.2 mm. Use the formula to calculate the magnification of the drawing.

4 A student saw a diagram of an artery in a text book that was magnified 15 times. The image size in the book was 75 mm. Calculate the actual size of the real artery.

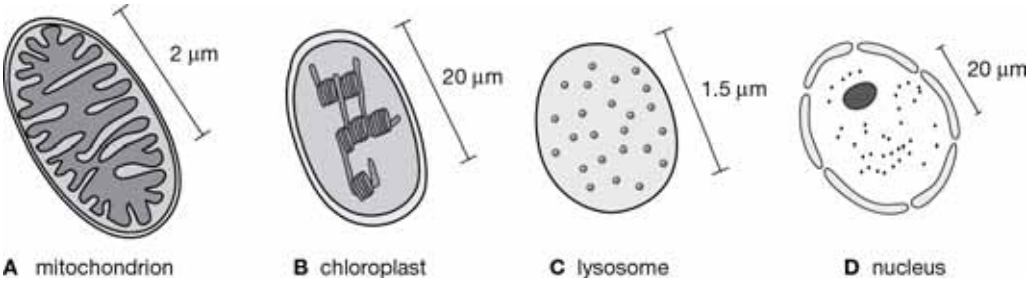
5 A student made a drawing of a red blood cell from the microscope. The cell was 7.5 µm in diameter and the drawing was 60 mm in diameter. Calculate the magnification the student had used for the drawing.

6 Below is a drawing of a phagocyte. Use the scale bar to calculate the magnification of the image.



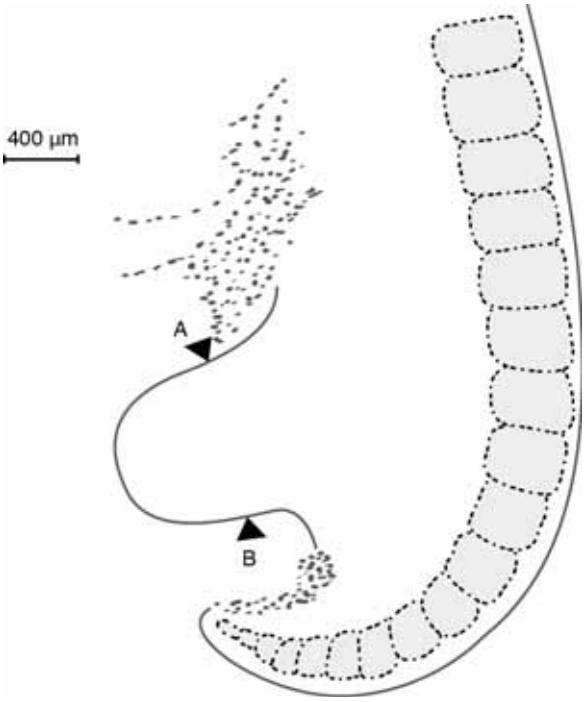
Questions

1 Below are four diagrams of different organelles in the animal cell. Each drawing has been made the same size. Study the diagrams and the information given and state which drawing has been most magnified.



(*1 mark*)

2 The figure below shows the leg bud of a chick embryo at about four days of incubation.



a Calculate the magnification of the image. Show your working. (*2 marks*)

b Calculate the actual size of the limb bud from A to B. Give your answer in µm. (*2 marks*)

Answers

Task

1 Width of the mitochondrion:
$0.5 \times 1000 = 500$ nm

2 Width of the stomata is:
$\frac{3.5}{1000} = 0.0035$ mm

3 The formula used was:

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

palisade cell was:

$$\text{magnification} = \frac{100}{0.2} = \times 500$$

4 The formula used was:

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

So the artery size was:

$$\text{Object size} = \frac{75}{15} = 5 \text{ mm.}$$

5 Step 1 convert the values to μm
Image of red blood cell was 60 mm
Now follow rule of thousands. $60 \times 1000 = 60\,000$
Now use the formula

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

$$\text{Magnification} = \frac{60\,000}{7.5} = \times 8000 \text{ magnified.}$$

6 Scale bar length = 20 mm.
Rule of thousands $20 \times 1000 = 20\,000$ μm
Now use the formula:

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

$$\text{Magnification} = \frac{20\,000}{20} = \times 1000 \text{ magnification}$$

Questions

1 C (*1 mark*)

2 **a** Scale bar length = 10 mm.

Rule of thousands 10 × 1000 = 10 000 µm (*1 mark*)

Now use the formula:

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

$$\text{Magnification} = \frac{10\,000}{400} = \times 25 \text{ magnification}$$ (*1 mark*)

b Measure the distance between A and B as 25 mm.

Convert to µm

25 × 1000 = 25 000 µm (*1 mark*)

Now use the formula

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

$$\text{Object size} = \frac{25\,000}{25} = 1000 \text{ µm}.$$ (*1 mark*)

Protein synthesis

Specification reference

- *2.1.3 (f)*
- *2.1.3 (g)*

Learning outcomes

After completing the worksheet you should be able to:

- identify the different types of nucleic acid and their roles in protein synthesis
- be more confident with the process of complementary base pairing
- understand and be able to describe the codon/anticodon interaction
- become more proficient at writing extended answers involving sequences.

Introduction

This subject requires a knowledge of the structure of DNA and how a section of that molecule, a gene, is copied into RNA, and how that message is interpreted by the cell to produce a protein.

The aim of this sheet is to review the processes of transcription and translation.

Background

Before attempting this sheet, you should be familiar with the structure of the nucleic acids, DNA and RNA, as described in Topic 3.8 'Nucleic acids'.

The process of protein synthesis consists of two main steps:

Transcription – the process where a copy of the gene is made inside the nucleus, and sent to the ribosome. The gene is a section of DNA which opens up and is copied into a messenger molecule. The copy of the gene is mRNA.

Translation – the process where the copy of the gene is used to make the protein at the ribosome. The mRNA arrives at the ribosome from the nucleus. It brings the code from the gene. At the ribosomes the amino acids from the cytoplasm are brought together. The order of the amino acids is determined by the order of the bases on the mRNA.

Look at this table for a simple summary of the different types of nucleic acid and the roles they have in the process

Nucleic acid	Role	Tip to help
DNA	This is the information molecule which does not leave the nucleus.	**D**NA **d**oesn't move.
mRNA	Copy of the gene which moves from the nucleus to the ribosome.	This is the **message**, like an e-mail it moves.
rRNA	Forms part of the ribosome.	Only found in the **ribosome**.

Nucleic acid	Role	Tip to help
tRNA	Brings the specific amino acid from the cytoplasm to the ribosome.	This **transfers** the amino acid.

These molecules appear in the order of the table, which is alphabetical. Try questions 1 and 2 in the task.

Remember you have learnt about complementary base pairing during Topic 3.9 'DNA replication and the genetic code'. The base pairing in protein synthesis is similar, but has one major difference. In DNA replication the base adenine (A) combines with thymine (T). However, in protein synthesis, the DNA is copied into RNA not DNA. So here the adenine of the DNA combines with a uracil (U) instead of thymine (T).

e.g.	DNA	mRNA	tRNA
	A	U	A
	C	G	C
	T	A	U
	G	C	G

Now try question 3 in the task.

A codon (or triplet) is three base pairs, which codes for the amino acid. An anticodon is the complementary triplet of bases.

In *transcription* the codon on the DNA is copied by complementary base pairing into the anticodon on the mRNA.

In *translation* the mRNA now becomes the codon, which forms a temporary link with the anticodon on the tRNA. Here the anticodon is a complementary copy of the mRNA which allows the two to pair up.

Now try questions 4 and 5 in the task.

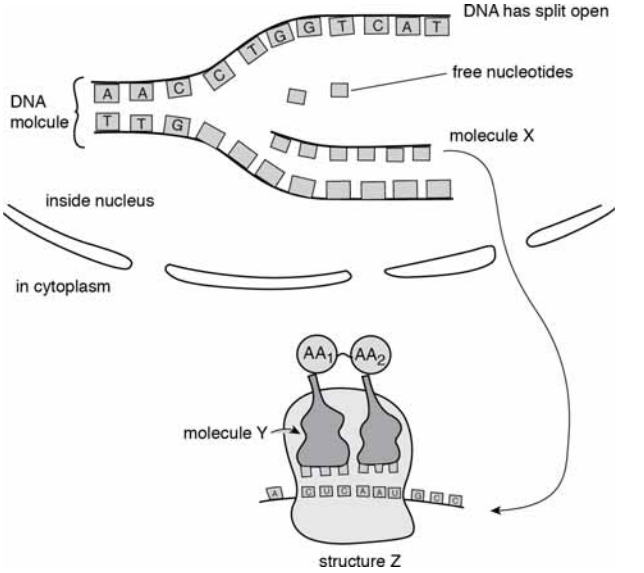
You may be asked to write extended responses to questions about protein synthesis. Try this tip:

- break the process into two processes – transcription and translation
- break each process into 5–7 steps
- colour code them using the colours of the rainbow in order – it helps to be able to remember the red step or the orange step.

Then in any answer you should write out your statements (red, orange, yellow, etc.) Now try question 5 in the task again.

Task

The diagram below represents the process of protein synthesis in a cell.



1 **a** Name the molecules X and Y.

b Name the structure Z.

2 **a** Name the process occurring inside the nucleus.

b Name the process occurring at structure Z.

3 Write in the boxes on the diagram the initial letters of the bases on:

a the DNA strand

b molecule X

c molecule Y.

4 The following events occur when mRNA is made during the process of transcription.

a The enzyme RNA polymerase attaches to one strand of the DNA.

b The DNA molecule opens up in the region of a gene.

c The RNA polymerase runs along the strand.

d Free RNA nucleotides are paired up opposite the DNA template using complementary base pairing.

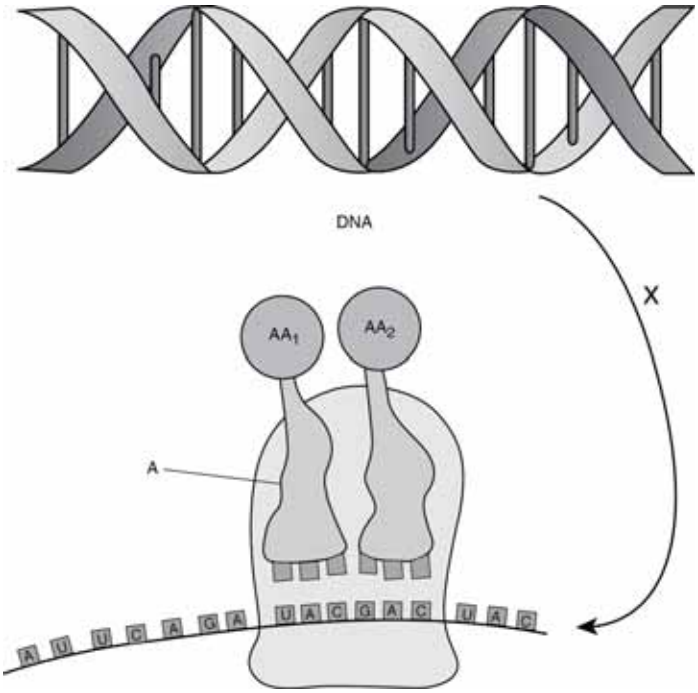
In which sequence do these steps occur?

	First step → final step			
A	1	3	2	4
B	2	1	3	4
C	1	4	2	3
D	2	4	1	3

5 Describe how a specific amino acid is brought into structure Z during the process of protein synthesis.

Exam-style question

1 The diagram represents the flow of information in the process of protein synthesis.



a Name the process labelled X. (*1 mark*)

b What is the name of the molecule produced by process X? (*1 mark*)

c Write in the boxes of molecule A the initial letters of the bases. (*1 mark*)

d What is the name given to this triplet of bases on molecule A? (*1 mark*)

e Describe how specific amino acids are assembled at the ribosome to form a protein. (*5 marks*)

Answers

Tasks

1 **a** X = mRNA
Y = tRNA
b ribosome

2 **a** transcription
b translation

3 **a** GACCAGTA
b GGUCAU
c GAG

4 B

5 Each tRNA molecule has a specific amino acid molecule attached.
The tRNA molecule also has an exposed triplet of bases called an anticodon.
The anticodon is complementary to the codon of mRNA exposed at the ribosome.
Only the correct tRNA molecule can link to the mRNA at that point.

Exam-style question

1 **a** transcription (*1 mark*)
b mRNA (*1 mark*)
c AUG (*1 mark*)
d anticodon (*1 mark*)
e Any five in a correct sequence from:
the mRNA arrives at the ribosome (*1 mark*)
three bases/codon are exposed inside the ribosome (*1 mark*)
the tRNA molecule also has an exposed triplet of bases called an anticodon (*1 mark*)
the anticodon is complementary to the codon of mRNA exposed at the ribosome (*1 mark*)
only the correct tRNA molecule can link to the mRNA at that point (*1 mark*)
each tRNA molecule has a specific amino acid molecule attached (*1 mark*)
a second codon is exposed inside the ribosome, a second tRNA molecule brings in a second amino acid (*1 mark*)
the two amino acids bond together/form a peptide bond/condensation reaction occurs. (*1 mark*)
(*maximum 5 marks*)

Transport across plasma membranes

Specification reference

- *2.1.5 (d) (i)*
- *2.1.5 (e) (i)*

Learning outcomes

After completing the worksheet you should be able to:

- describe the structure of the plasma membrane
- describe diffusion, osmosis, and active transport.

Introduction

In order to understand how materials enter and leave cells, you need a sound knowledge of the structure of plasma membranes and to be familiar with the processes of diffusion, osmosis, and active transport. This activity is designed to consolidate your knowledge as the processes involved are fundamental to the physiology of living organisms. It is also important that you use the correct terminology when describing these processes.

Questions

1 Draw a labelled diagram to show the arrangement of molecules in the fluid-mosaic model of the membrane structure. Indicate the outside and the inside of the cell on your diagram.

2 Explain why this model of the membrane structure is known as the fluid-mosaic model.

3 What are the functions of the components of plasma membranes?

4 Diffusion is the net movement of molecules or ions from an area of higher concentration to an area of lower concentration.

a Explain what is meant by ‘net movement’.

b Explain how each of the following factors affects the rate of diffusion.

1. The concentration gradient.
2. The area of the exchange surface.
3. The thickness of the exchange surface.
4. The size and nature of the diffusing molecules.

5 Facilitated diffusion is a special type of diffusion enabling molecules, such as glucose; and amino acids, and charged particles, such as sodium ions, to diffuse into and out of cells.

a Explain how facilitated diffusion differs from simple diffusion.

b In what ways are the two processes similar?

c By means of labelled diagrams, show how large molecules enter cells by facilitated diffusion.

6 Osmosis is the diffusion of water molecules through partially permeable membranes. It is defined in terms of water potential.

a Complete the following passage by filling in the missing words or phrases.

Osmosis is the diffusion of water from an area of ..... or ..... water potential to an area of ..... or ..... water potential through a partially permeable membrane.

Pure water has a water potential of .....

Adding a solute to pure water ..... the water potential.

The more solute that is added, the more ..... the solution becomes and the value of the water potential is more .....

Two solutions that have the same water potential are said to be .....

b Explain what happens when (i) red blood cells and (ii) discs of potato tuber tissue are placed in pure water.

7 Explain how active transport differs from passive forms of transport.

8 Describe how energy from ATP is used in active transport.

Answers

1 Accept diagrams which show a phospholipid bilayer with the molecules represented accurately with their heads and tails oriented correctly. There should be proteins in the membrane – look for extrinsic and intrinsic proteins, cholesterol molecules, glycolipid and glycoproteins attached to the extrinsic proteins. Credit some attempt to represent channel proteins and carrier proteins. The outside and the inside of the cell should be labelled.

2 The 'fluid' property is due to the fact that the phospholipid molecules move relative to each other, providing the membrane with flexibility. The protein molecules form the 'mosaic'. The protein molecules vary in size and shape.

3 Phospholipid bilayer allows lipid-soluble molecules through but prevents entry of water-soluble ones. It also makes the membrane flexible.

Membrane (intrinsic) proteins span the membrane and allow the passage of larger molecules or ions that are water-soluble. Some act as carrier proteins to transport the water-soluble substances across the membrane. Others are channel proteins, facilitating the active transport of sodium and potassium ions, for example, across the membrane.

Glycolipids and glycoproteins attached to some extrinsic proteins act as receptors and enable cell recognition.

Proteins provide structural support.

Cholesterol molecules reduce the fluidity and give strength.

4 Diffusion is the net movement of molecules or ions from an area of higher concentration to an area of lower concentration.

a Molecules in a gas or liquid are moving randomly all the time and will diffuse both ways. Where there is a difference in concentration, however, there will be a tendency for more molecules to move away from the higher concentration to where they are in a lower concentration, i.e. down a concentration gradient, until equilibrium is reached and there is an even distribution.

Note: Reference should be to 'down' the concentration gradient, not 'along' or 'across'.

b Explain how each of the following factors affects the rate of diffusion:

The concentration gradient: the greater the concentration gradient, the faster the rate of diffusion. As the difference in concentration becomes less, the rate will slow down.

The area of the exchange surface: the larger the surface area, the faster the rate of diffusion. In the human body, microvilli increase the surface area of the cell-surface membranes of cells involved in absorption.

The thickness of the exchange surface: the thicker the exchange surface, the slower the rate of diffusion as the particles have a longer distance to travel. Thin exchange surface membranes are the most efficient.

The size and nature of the diffusing molecules: small molecules diffuse faster than large ones. Fat-soluble molecules diffuse faster than water-soluble ones. Polar molecules diffuse faster than non-polar molecules. Oxygen, however, is non-polar and diffuses quickly. As the degree of polarity increases, the rate of diffusion decreases. Water is polar and small enough, however, to get through quickly. So size and polarity are not mutually exclusive.

5 Facilitated diffusion is a special type of diffusion enabling molecules, such as glucose and amino acids, and charged particles, such as sodium ions, to diffuse into and out of cells.

a Simple diffusion is the movement of substances through a plasma membrane. Facilitated diffusion enables larger molecules and charged particles to diffuse through plasma membranes. It involves the carrier proteins and protein channels.

b Both processes are passive, i.e. do not use energy. In both, movement is down a concentration gradient. The rates of both depend on the surface area of the exchange surface, the thickness of the exchange surface and the nature of the diffusing molecules.

c Accept suitable diagrams showing proteins which span the plasma membrane, higher concentration of molecules outside the cell and lower concentration inside. Credit diagrams of channel proteins and carrier proteins.

6 Osmosis is the diffusion of water molecules through partially permeable membranes. It is defined in terms of water potential.

a Osmosis is the diffusion of water from an area of **higher** or **less negative** water potential to an area of **lower** or **more negative** water potential through a partially permeable membrane. Pure water has a water potential of **zero**. Adding a solute to pure water **lowers** the water potential. The more solute that is added, the more **concentrated** the solution becomes and the value of the water potential is more **negative**. Two solutions that have the same water potential are said to be **isotonic**.

b **i** Red blood cells burst because they have a lower or more negative water potential and water is taken up by osmosis. The cells swell and burst because the plasma membrane cannot stretch to accommodate the water.

ii Discs of potato tuber become turgid but the cells do not burst. Water enters the cells by osmosis because the cells have a lower or more negative water potential. The cell contents swell and push up against the cellulose cell walls which then exert an inward pressure preventing the cells from bursting and from taking up any more water.

7 In active transport, molecules are moved from a lower concentration to a higher concentration against a concentration gradient. This process requires energy. It involves the use of carrier proteins in a similar way to facilitated diffusion, in that the molecules attach to the carrier protein, the protein changes shape and the molecule moves across the membrane into the cell. Energy from ATP is needed to move the molecule against the concentration gradient.

8 ATP attaches to the carrier protein on the inside of the cell causing it to change shape or position in the membrane and to allow molecules passage into the cell. ADP and P are released from the carrier protein which then reverts to its original receptive shape or position.

Accept from suitably annotated diagrams.

Chromosomes and chromatids

Specification reference

- *2.1.6 (a)*
- *2.1.6 (c)*
- *2.1.6 (g)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the differences between chromosomes and chromatids
- identify the amount of DNA in the nucleus at each stage of the cell cycle
- identify the key points in the cycle where the amount of DNA changes in the cell.

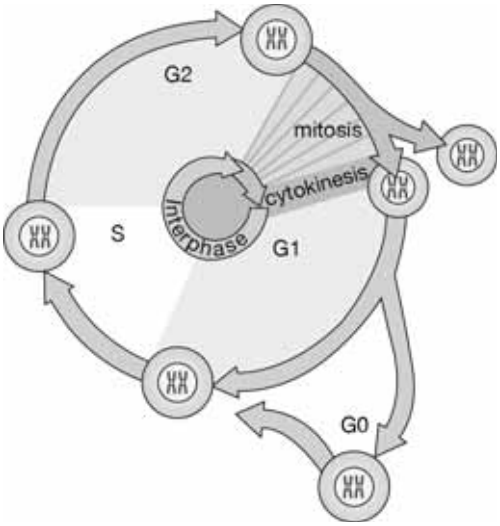
Introduction

Cells constantly follow a cycle of events of growth and division. When a cell divides it is vital that the genetic information in the chromosomes can be copied and passed to the daughter cells. The process of copying the chromosomes leads to a doubling of the amount of DNA at key points in the cycle, followed by halving during division. This changing amount of DNA during the cell cycle often leads to misconceptions for students.

The aim of this sheet is to help to clarify the differences between the terms chromosomes and chromatids. It will also identify the amount of DNA at each stage in the cycle.

Background

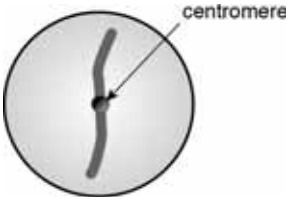
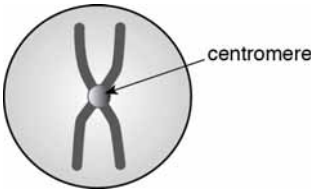
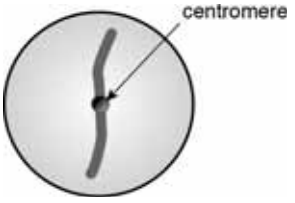
The cell cycle is a sequence of events which occurs in the cell as it grows and divides into two new daughter cells. The cell cycle is explained in detail in Topic 6.1 ‘The cell cycle’. The cycle is divided into a number of stages. A specific series of events occur in each stage. The table below summaries the events.



6.1 The cell cycle
Support worksheet

	Stage	Main events
Interphase	**G_1**	Phase of growth Organelles replicate The cell reaches a checkpoint, and has two options here: • the cell can pass the checkpoint of it is too large and divide • or the cell can enter G_0 as a differentiated cell or a stem cell.
	S	Here the DNA is duplicated in the nucleus.
	G_2	Increases the amount of stored energy. The cell reaches a second checkpoint where the DNA is checked for errors.
Division	**M**	The cell divides. There are two types of nuclear division: • mitosis – producing two genetically identical daughter cells. • meiosis – producing four cells with half the amount of DNA. Following nuclear division, cytokinesis occurs – this is cytoplasmic division.

During S phase the DNA duplicates in the process of DNA replication (See Topic 3.9 'DNA replication and the genetic code'). This creates the more characteristic 'X' shaped chromosome now made of two chromatids. However, you may find it difficult to remember the difference between a chromosome and a chromatid. Try this simple summary:

G_1 of cell cycle		**G_2 of cell cycle**		**G_1 of new cell cycle**
	S Phase		Mitosis	
1 chromosome Made of: 1 strand of DNA Or 1 chromatid		1 chromosome Made of: 2 identical strands of DNA Or 2 chromatids		1 chromosome Made of: 1 strand of DNA Or 1 chromatid

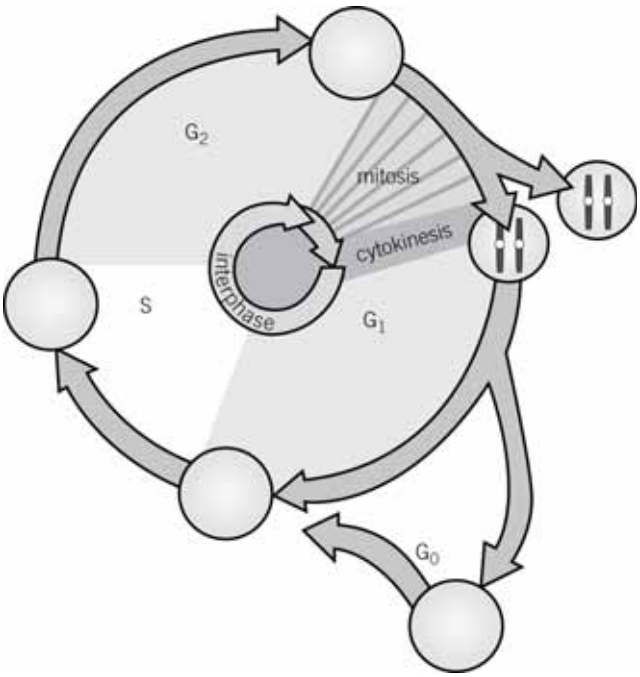
The second problem that you may encounter with the DNA molecule is during the division itself. It can be difficult to remember how much DNA the cell has at the various points during division. The details of all the events of mitosis and meiosis have been covered in Topics 6.3 'Mitosis' and 6.4 'Meiosis'. Here is a very brief summary of those events, but the emphasis has been placed on the amount of DNA at the different phases.

6.1 The cell cycle
Support worksheet

Mitosis		Meiosis	
Interphase	Remember that **DNA doubles** during S phase	Interphase	Remember that **DNA doubles** during S phase
Prophase	Nucleus disrupts, chromosomes become visible. **Chromosomes have two chromatids.**	Prophase I	Nucleus disrupts, chromosomes become visible. Homologous chromosomes pair up. **Chromosomes have two chromatids.**
Metaphase	Spindle forms, chromosomes line up on equator. **Chromosomes still have two chromatids.**	Metaphase I	Spindle forms, chromosome pairs line up on equator. **Chromosomes still have two chromatids.**
Anaphase	Chromatids pulled to opposite poles. **Each chromatid now becomes a chromosome.**	Anaphase I	Homologous chromosomes are pulled to opposite poles. **Each chromosome still has two chromatids.**
Telophase	Nucleus reforms, chromosomes condense. **Each chromosome has one chromatid.** **The DNA content of the nucleus has halved.**	Telophase I	Nucleus reforms, chromosomes condense. **Each chromosome has two chromatids.** **The DNA content of the nucleus has halved.**
		Interphase II	There may be a short interphase, but the cell does not go through the phases of the cell cycle. **No DNA replication**.
		Prophase II	Nucleus disrupts, chromosomes become visible. **Chromosomes have two chromatids.**
		Metaphase II	Spindle forms, chromosomes line up on equator. **Chromosomes still have two chromatids.**
		Anaphase II	Chromatids pulled to opposite poles. **Each chromatid now becomes a chromosome.**
		Telophase II	Nucleus reforms, chromosomes condense. **Each chromosome has one chromatid.** **The DNA content of the nucleus has halved again.**

Task

1 Complete the drawing of the cell cycle, by adding the correct chromosome drawings in each of the cells.



2 Complete the following sentences by adding the most appropriate word in the blanks.

The cell undergoes a sequence of events as it grows and divides. The cell after division enters a phase called G_1 during which time the cell grows and its …….. replicate.

At a key checkpoint in this phase the cell can differentiate, remain dormant in …….. or go on to divide.

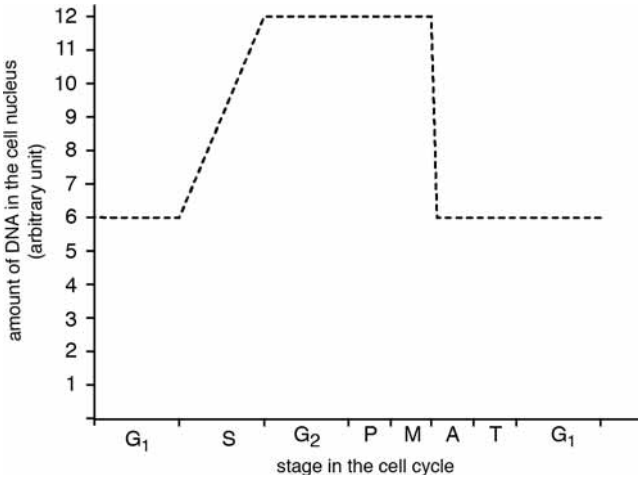
If the cell passes the checkpoint, it enters the second phase called S phase. During S phase the DNA……...

Here a single strand of DNA doubles. The chromosomes now have …… chromatids.

Following S phase the cell passes through a short G_2 phase, where the DNA is checked and the cell builds up a store of……

The cell then divides by …… to form two daughter cells.

3 Below is a graph showing the amount of DNA at various stages in the cell cycle of a cell undergoing mitosis.



a Describe what has happened to the amount of DNA in the cell nucleus during S phase.

b Explain why this change in the DNA has occurred.

c Name one phase on the graph when the chromosome would have:

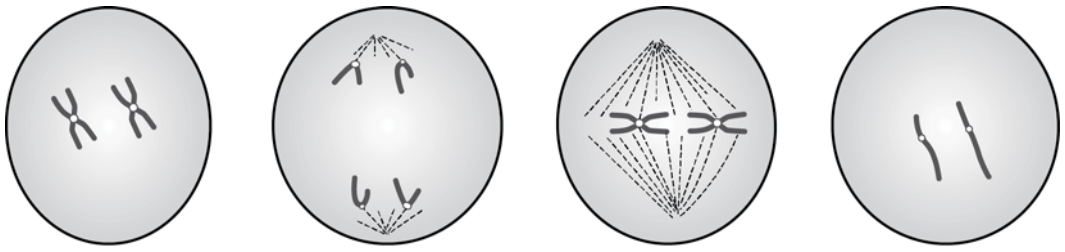
i one chromatid

ii two chromatids.

d Explain how the amount of DNA has halved between metaphase and anaphase.

Questions

1 The drawings below show various stages in the mitotic division of a cell.



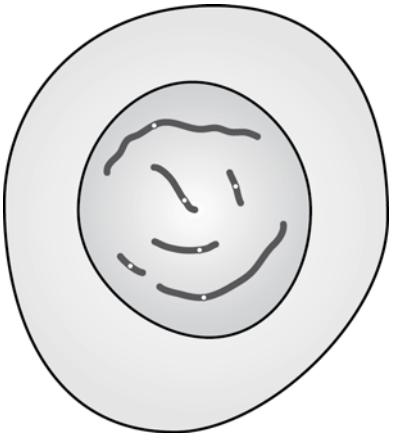
a In which sequence do these steps occur?

	First step → final step			
A	A	B	C	D
B	D	A	C	B
C	D	B	C	A
D	D	B	A	C

(*1 mark*)

b Which of the drawings shows the cell in metaphase? (*1 mark*)

2 The drawing below shows an animal cell.



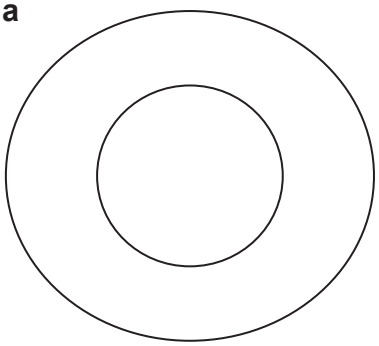
In the circles below show:

a The nucleus of the cell after it has passed through S phase. (*2 marks*)

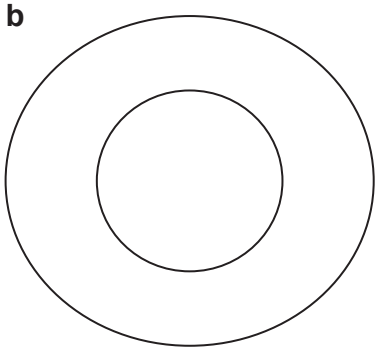
b The nucleus after the cell has divided by mitosis. (*2 marks*)

c The nucleus after the cell has divided by meiosis. (*3 marks*)

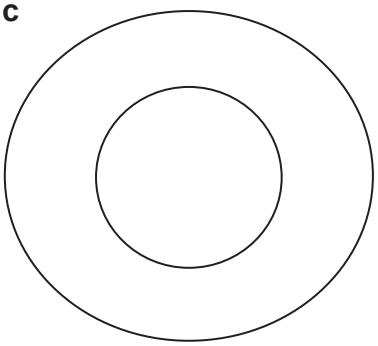
a



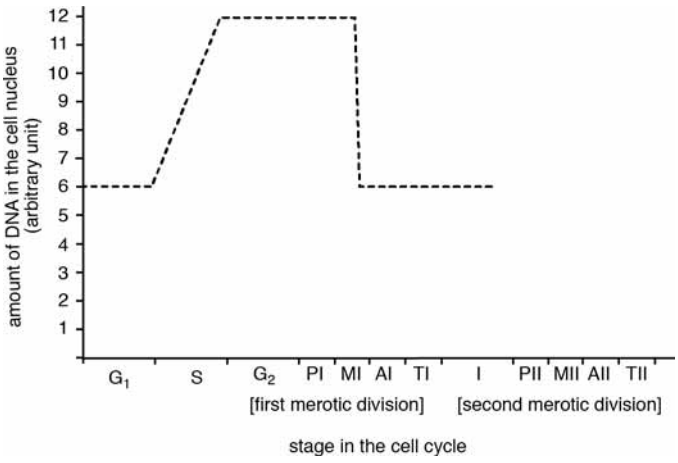
b



c



3 Below is a graph showing the amount of DNA in a cell undergoing meiosis.



a Complete the graph to show what happens to the amount of DNA during the rest of the division. (*1 mark*)

b Explain what has happened to the chromosomes during the second meiotic division. (*2 marks*)

Answers

Task

1 The drawings should have two 'X' shaped chromosomes in the cells shown at S and G_2 , all the rest should have two single stranded chromosomes.

2 organelles
G_0
duplicates
two
energy
mitosis

3 **a** the amount doubles

b the DNA has replicated
The chromosome now has two strands of DNA or chromatids.

c **i** G_1 or A or T (anaphase or telophase)
ii S or G_2 or P or M (prophase or metaphase)

d chromatids split apart at the centromere;
the chromatids move to opposite poles;
each new cell only has one chromatid as a chromosome, or half the original DNA.

Questions

1 **a** B (*1 mark*)

b C (*1 mark*)

2 **a** 6 chromosomes: 2 long, 2 short, 2 medium; (*1 mark*)
each with two chromatids (*1 mark*)

b 6 chromosomes: 2 long, 2 short, 2 medium; (*1 mark*)
each with one chromatid (*1 mark*)

c three chromosomes; (*1 mark*)
each with one chromatid (*1 mark*)
1 long, 1 medium, and 1 short (*1 mark*)

3 **a** The amount of DNA should drop to 3 units between MII and AII. (*1 mark*)

b The chromosomes are pulled apart/split at the centromere; (*1 mark*)
each chromatid goes to opposite poles. (*1 mark*)

Measuring breathing – spirometry

Specification reference

- *3.1.1 (e)*

Learning outcomes

After completing the worksheet you should be able to:

- identify steps in the method for using a spirometer, and know the reasons for each step
- interpret the trace produced from a spirometer
- perform calculations based in a spirometer trace.

Introduction

Measuring lung volumes and breathing rates is an important technique, used by clinicians and sports physiologists amongst others. The principle piece of equipment used for measuring breathing is called a spirometer. Although there are many different designs for this piece of equipment, the basic functioning is the same.

Spirometry is technique which can present a number of issues. There are a number of points in the methods for spirometry that students tend to forget in any answer or description of the process. Secondly interpreting the trace produced from spirometry can cause problems.

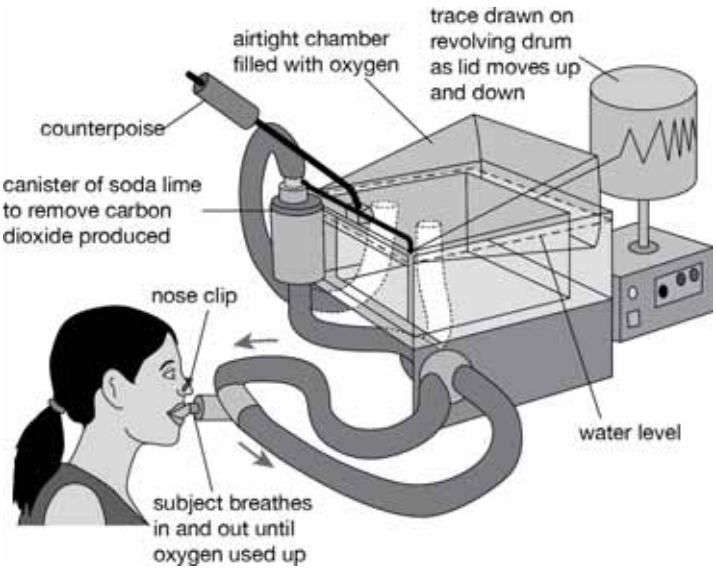
The aim of this sheet is to reinforce the basic steps in the method for the use of a spirometer. In addition the sheet will offer support in analysing a trace.

Background

The structure and function of the human respiratory system has been covered in Topic 7.2 ‘The Mammalian Gaseous Exchange System.’ This topic describes the various organs in the system and how they are adapted for their function, it also explains how humans ventilate their lungs.

The volumes of air breathed in or out of the lungs can vary depending on the activity or health of a person. Measuring these volumes has considerable use to doctors, when concerned by respiratory problems, or sports physiologists, when analysing fitness levels. The spirometer is the piece of equipment used by scientists to measure lung volumes. The most common type of spirometer in school laboratories is shown in Figure 1.

It is important to know the major steps in the method for using a spirometer. Examiners like to ask experimental questions. It could be the whole method or more commonly just one or two steps. An aid for remembering the steps is to number the steps, and also to know the reason for each step. Look at the table below showing the main steps in the method.



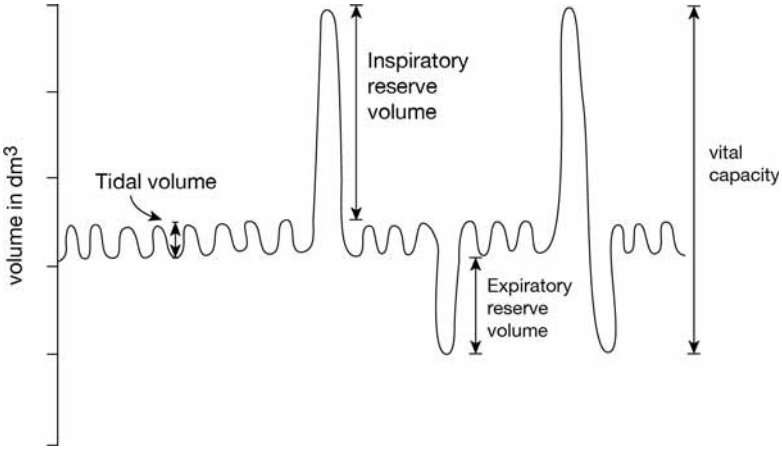
Step	Reason
Calibrate the spirometer. The details vary from machine to machine, but you need to know how to measure a litre and a minute on the trace.	This allows us to calculate the actual volumes breathed.
Fill the drum with fresh air.	To ensure normal levels of oxygen in the air to be breathed by the subject.
Subject should be in good health.	To avoid any medical problems during the experiment.
Subject wears a noseclip.	To stop air moving through nose. This allows valid measurements.
Subject breathes normally into the machine through the mouthpiece.	To record the volume of air being breathed.
Use a sterile mouthpiece.	To avoid infection.
The subjects exhaled air passes through a canister of soda lime.	To absorb carbon dioxide.
Turn on the kymograph.	To start the recording of the trace.
Subject breathes normally for at least three full breaths.	To record resting breathing rate.
The drum will move up and down.	Up as the subject breathes out, down as they breath in.

There are a number of important lung volumes.

- *Tidal volume* – the volume of air that we breathe in and out during a normal breath. This is usually about 500 cm^3.
- *Inspiratory reserve volume* – the maximum volume (in excess of the tidal volume) we can breathe in during one forced breath.

- *Expiratory reserve volume* – the maximum volume (in excess of the tidal volume) we can breathe out in one forced breath.
- *Vital capacity* – the maximum volume of air that can be breathed during a forced breath in and then out.

Residual volume is the amount of air left in the lungs after a forced breath out. You cannot measure this using a spirometer.



You may be asked to analyse a trace produced by a spirometer.

First you need to be able to identify the four different volumes. Look at the trace in the diagram above, and memorise the different traces. This is not usually too difficult to remember. There are a number different calculations that could be taken from the trace. The most common values that examiners expect you to be able to calculate are:

- breathing rate
- tidal volume
- vital capacity
- oxygen uptake.

Task

1 Spirometers are used to measure lung volumes.

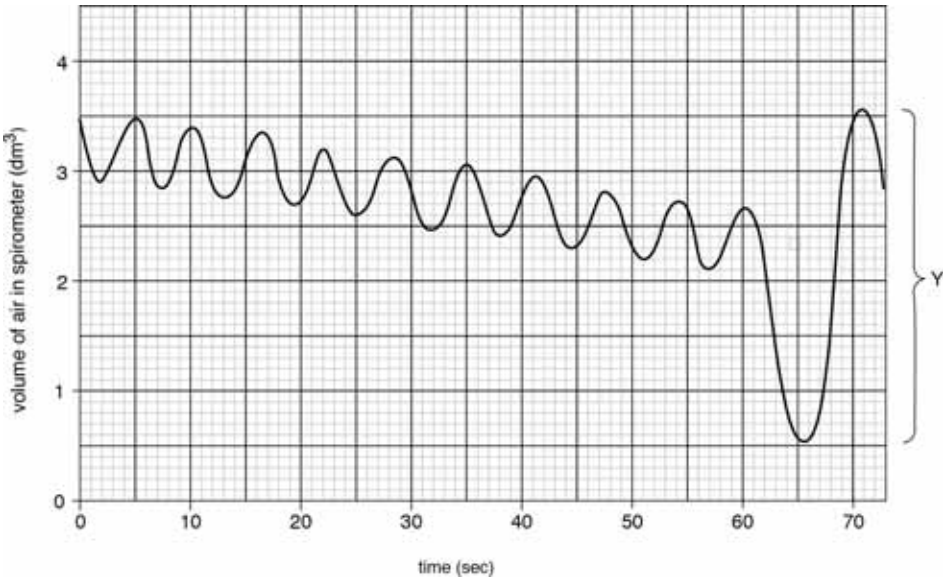
a Give one reason why scientists might record lung volumes.

b State two precautions taken when using a spirometer.

c State the purpose of soda lime in the canister attached to the breathing tubes.

d In which direction does the drum move during inspiration?

2 Here are some examples of how to calculate lung volumes. Look at the trace below, and then look at how it is used in the following calculations.



a Breathing rate

Step 1: Count the number of breaths taken per minute on the time trace.

Tip – you need to count full breaths, so count the number of peaks (or troughs) in 1 minute.

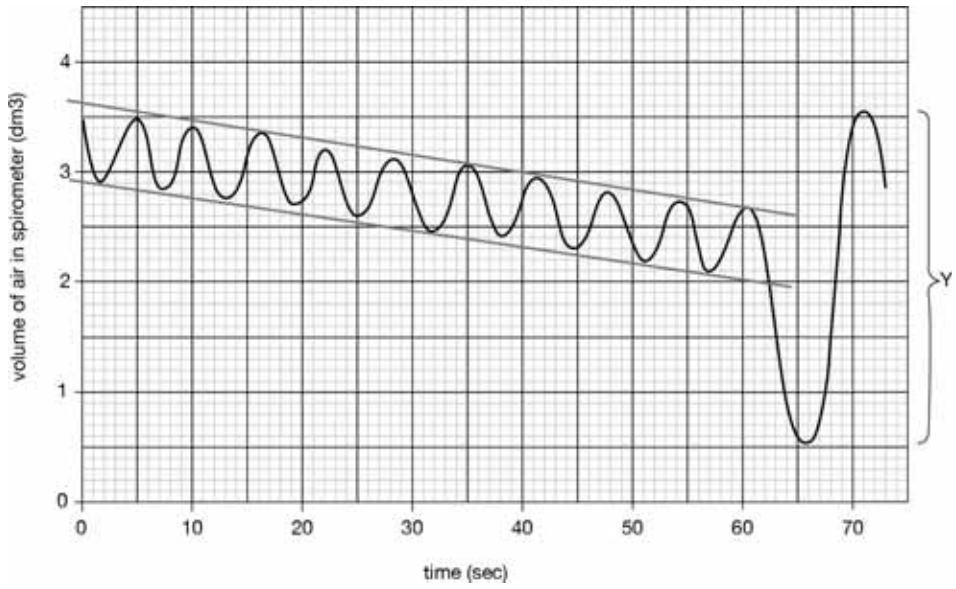
Answer: In this trace there are 10 peaks during the 60 seconds, so the breathing rate is 10 breaths per minute.

b Tidal volume

Step 1: Draw two lines on the trace, one above, and one below the trace of tidal volume.

Step 2: Measure about 3 or 4 volumes (between the top and bottom line).

Step 3: Take the mean.



Answer: In this trace the distance between the lines can be measured for three peaks:

- at the first peak the volume is = 0.65 dm^3
- at the fourth peak the volume is = 0.65 dm^3
- at the eighth peak the volume is = 0.60 dm^3

The mean volume is 0.63 dm^3

c Vital capacity

Step 1: Measure the height of the vital capacity indicated by the letter 'Y' on the trace.

Step 2: Convert this to a volume using the axis.

Answer: The height is 41 mm. This is equivalent to 3 dm^3.

d Oxygen uptake

Step 1: The reason why the trace slopes downward is that the oxygen is being used up by the subject. (Although the subject is breathing out carbon dioxide in replacement, it is being absorbed by the soda lime and does not play any part in the trace.)

Step 2: If we measure the drop of the slope in a period of time we get a value of the oxygen uptake.

Step 3: Draw a line across the top of the trace (use the drawing above).

Step 4: In one minute this line has fallen 8.5 squares on the axis. This is 0.85dm^3. This is the volume of oxygen used in one minute.

Questions

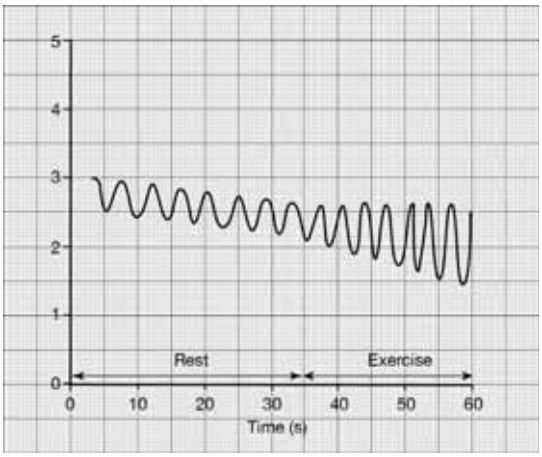
1 The spirometer is a piece of apparatus used to investigate lung function.

a Name the gas absorbed by the soda lime in the canister in the spirometer. (*1 mark*)

b Explain why the subject using a spirometer to measure their tidal volume wears a nose clip. (*2 marks*)

c Explain how you would use the spirometer to measure a subject's tidal volume. (*3 marks*)

2 The following trace from a spirometer was recorded from a male athlete.



a State the name of the lung volume being measured by the athlete during the period of rest. (*1 mark*)

b Label on the trace, using the letter 'E' a point where the athlete is exhaling. (*1 mark*)

c Describe the changes which occur to the athlete's breathing shown on the trace during exercise. (*2 marks*)

d Calculate the breathing rate per minute of the athlete during rest. (*1 mark*)

e Calculate the oxygen uptake in dm^3 per minute for the athlete during the rest period. Show your working. (*2 marks*)

Answers

Task

1 **a** measure fitness/respiratory health/specific respiratory condition

b sterilise mouthpiece;
check subject's health;
fill spirometer with fresh air

c absorb carbon dioxide

d down

Questions

1 **a** carbon dioxide (*1 mark*)

b stops air moving into spirometer through the nose / ensures all air is breathed out through the mouth; (*1 mark*)
allows valid measurements. (*1 mark*)

c ensure that the subject does not breathe through the nose; (*1 mark*)
subject breathes normally; (*1 mark*)
measure the height/amplitude of waves from the trace; (*1 mark*)
measure a number of times between two lines to calculate a mean; (*1 mark*)
details of how spirometer works (e.g. movement of drum/use of kymograph, etc.) (*1 mark*)
(*maximum 3 marks*)

2 **a** tidal volume (*1 mark*)

b E placed on a line that is sloping downward. (*1 mark*)

c increased volume; (*1 mark*)
faster breathing rate. (*1 mark*)

d 16 breaths per minute. (*1 mark*)

e 0.9 $dm^3\ min^{-1}$ (*1 mark for working, 1 mark for correct answer*)

8.4 Transport of oxygen and carbon dioxide in the blood Support worksheet

Oxygen dissociation curves

Specification reference

- *3.1.2 (j)*

Learning outcomes

After completing the worksheet you should be able to:

- understand and be able to explain the oxygen dissociation curve for haemoglobin.
- understand and be able to explain the effect of carbon dioxide on the dissociation curve.
- understand and be able to explain the significance of the difference between adult and fetal haemoglobin dissociation curves.

Introduction

The transport of oxygen is perhaps one of the most important functions of the blood, and certainly one of the best known functions. However, the mechanisms involved in the uptake and release of oxygen by the haemoglobin can be hard to understand.

The aim of this support sheet is to take you through the interpretation of the oxygen dissociation curve. It will also give you some tips for approaching questions involving oxygen dissociation curves.

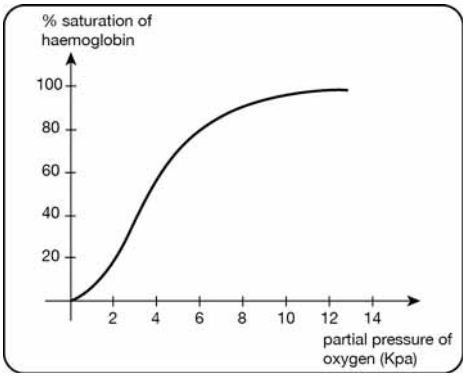
Background

The transport of oxygen is a major function for the blood. The oxygen is carried inside the red blood cell or erythrocyte, attached to a molecule called haemoglobin. Haemoglobin is a protein made of four polypeptide chains. Each chain has a prosthetic haem group that contains iron. An oxygen molecule can bind loosely to each of the haem groups forming oxy-haemoglobin in the lungs. The oxy-haemoglobin releases the oxygen in the tissues.

$$Hb + 4O_2 \rightarrow HbO_8$$

haemoglobin + oxygen → oxy-haemoglobin

It is possible to measure the uptake of oxygen by the haemoglobin at different oxygen partial pressures (KPa). This produces an oxygen dissociation curve.



8.4 Transport of oxygen and carbon dioxide in the blood Support worksheet

Physiological significance of the dissociation curve

The partial pressure of oxygen in the body varies from place to place. The graph shows what happens to the oxygen carriage by haemoglobin at different partial pressures. Therefore, the graph indicates what is happening in different parts of the body. Remember the lungs are at the top of the graph and the tissues are at the bottom.

1 In the lungs:

- the partial pressure of oxygen in the lungs is between 10 and 12 KPa
- the blood has a high affinity for oxygen at these high partial pressures in the lungs
- the blood becomes about 95% saturated with oxygen at this point.

2 In the tissues:

- when the blood arrives in the tissues, the partial pressure of oxygen is between 2–4 KPa.
- at this point the haemoglobin has a low affinity for oxygen
- the haemoglobin will offload or release oxygen to the tissues readily.

Now try questions 1 to 5. For all of these questions make reference to the graph shown above.

1 What is the partial pressure of oxygen in the lungs?

2 What is the partial pressure of the oxygen in the tissues?

Some questions about oxygen dissociation curves tend to ask you explain the significance of the dissociation curve to the functioning of the haemoglobin in an area of the body. Here is a tip for approaching any such question. Use this writing frame with three points to create a standard type of response:

1 Location	Describe where in the body you are talking about, and what the partial pressure is from the graph.
2 Effect	Explain the effect of this partial pressure on the haemoglobin's affinity for oxygen.
3 Consequence	Explain what happens to the oxygen molecule, is it taken up by haemoglobin or released.

Now look at how to apply this frame to a question:

3 Explain the significance of the oxygen dissociation curve to oxygen uptake in the lungs.

Your answer should include statements like these:

Location: The partial pressure of oxygen in the lungs is high at about 10 to 12 KPa.

Effect: At this high partial pressure the haemoglobin has a high affinity for oxygen.

Consequence: This causes the haemoglobin to bind with the oxygen from the lungs becoming saturated.

4 The graph above shows the oxygen dissociation curve for adult human haemoglobin. What is the significance of the shape of the curve at high values of partial pressure of oxygen?

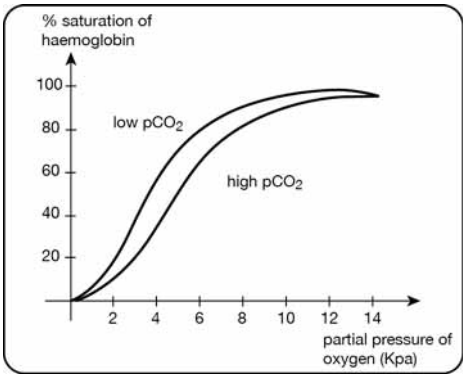
5 Between 2 and 4 KPa the oxygen dissociation curve for adult human haemoglobin is very low. Explain the significance of this in the body.

Physiological significance of carbon dioxide on the dissociation curve

So far we have only considered the effect of oxygen partial pressure on its uptake, and assumed all other factors are constant. However, there is a second gas, carbon dioxide, that is produced in the tissues and will affect the dissociation curve. If carbon dioxide concentrations are increased, the oxygen dissociation curve moves downwards and to the right. This is called the Bohr effect or Bohr shift.

The graph below shows the effect of increasing the carbon dioxide concentration on the dissociation curve. There are two important features to note here:

- the curve is shifted down and to the right compared to the first graph
- the curve starts and finishes at the same point.



The carbon dioxide has little significance in the lungs, as the carbon dioxide is diffusing out of the blood and into the alveolus. As such the normal dissociation curve applies when considering the lungs. However, respiring tissues produce carbon dioxide that diffuses into the blood, as a result the Bohr effect has a significant effect in the tissues.

In the tissues:

- the partial pressure of CO_2 is high due to respiration in the tissues
- the partial pressure of oxygen is between 2–4 KPa
- haemoglobin has an even lower affinity for oxygen with high carbon dioxide levels present
- it more readily offloads or releases its oxygen to the tissues.

Now try question 6.

6 Read the following question and a sample student answer. Identify three things that make this a poor answer.

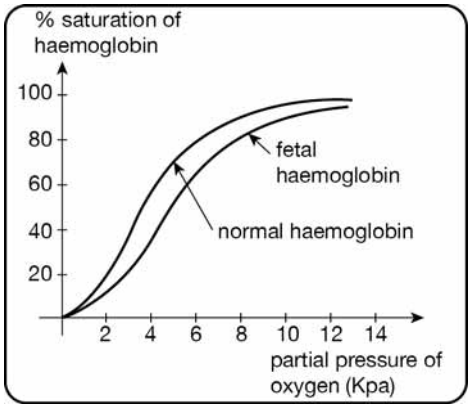
Explain how increasing the carbon dioxide partial pressure will increase the amount of oxygen reaching the tissues.

In the tissues the oxygen levels are low and the carbon dioxide levels are high. This is because the tissues are respiring and producing lots of carbon dioxide. The blood will release oxygen to the tissues, for increased respiration. So increasing the carbon dioxide levels increases the amount of oxygen available.

Physiological significance of the fetal haemoglobin on the dissociation curve

Finally, you need to understand the difference between adult and fetal haemoglobin. Fetal haemoglobin has a slightly different structure to adult haemoglobin, which gives it a higher affinity for oxygen at low partial pressures of oxygen. This means that fetal haemoglobin is able to saturate with oxygen at lower partial pressures than the adult.

This has a few more points to explain than before, because you need to explain about both the mother's haemoglobin and the babies. However, you can use the same format – location, effect, and consequence statements – to explain what is happening.



1 The mother's haemoglobin:

- when the blood arrives in the placenta, the partial pressure of oxygen is between 2–4 KPa
- at this point the haemoglobin has a low affinity for oxygen
- the haemoglobin will offload or release oxygen to the tissues readily.

2 The baby's haemoglobin:

- the partial pressure of oxygen in the placenta is between 2–4 KPa
- at this point the fetal haemoglobin still has a high affinity for oxygen
- fetal haemoglobin will bind to oxygen released by the mother across the placenta.

Now try question 7 in the task.

7 Complete the sentences below about the role of haemoglobin in the transport of oxygen to the fetus.

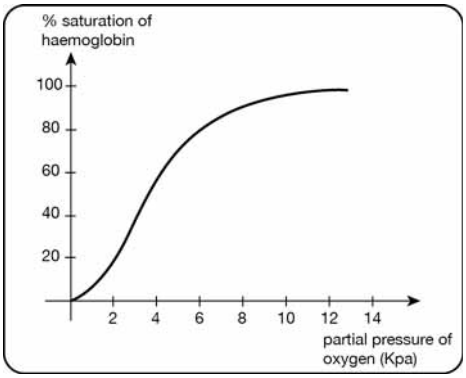
When the mother's blood arrives in the placenta, the partial pressure of oxygen is between……... At this point her haemoglobin has a ……... affinity for oxygen. The oxy-haemoglobin will dissociate. The haemoglobin will ……... oxygen to the placenta readily. At the same low partial pressure of oxygen in the placenta of between 2–4 KPa. the fetal haemoglobin still has a ……... affinity for oxygen. The oxygen …… across the placenta. The fetal haemoglobin will ……... to oxygen released by the mother's haemoglobin.

Exam-style questions

1 Which of the following gives the partial pressure of oxygen in the lungs?

a 2–4KPa
b 4–6KPa
c 8–10KPa
d 10–12KPa. (*1 mark*)

2 Below is a graph showing the oxygen dissociation curve for adult haemoglobin. Carbon dioxide has an effect on the dissociation curve.



a Draw a line on the graph to show the effect of increasing the amount of carbon dioxide (partial pressure) on the dissociation curve. (*2 marks*)
b Name the effect of the increase of carbon dioxide. (*1 mark*)
c Explain how the effect of increasing the partial pressure of carbon dioxide results in a greater supply of oxygen to exercising muscle tissue. (*3 marks*)

3 Fetal haemoglobin has a dissociation curve to the left of adult haemoglobin.

a Explain how the fetal haemoglobin ensures that the fetus gets a supply of oxygen. (*4 marks*)
b Explain why humans change from fetal to adult haemoglobin after birth. (*2 marks*)

8.4 Transport of oxygen and carbon dioxide in the blood Support worksheet

Answers

1 Between 10 and 12 KPa

2 Between 2 and 4 KPa

3 Answer supplied on task sheet

4 The partial pressure of oxygen in the lungs is high at about 10 to 12 KPa.

At this high partial pressure the haemoglobin has a high affinity for oxygen.

This causes the haemoglobin to bind with the oxygen from the lungs becoming saturated.

5 The partial pressure of oxygen in the tissues is low at about 2 to 4 KPa.

At this low partial pressure the haemoglobin has a low affinity for oxygen.

This causes the haemoglobin to release/offload the oxygen to the tissues for respiration.

6 The answer:

a doesn't give the location in terms of partial pressure of oxygen

b doesn't refer to the affinity of haemoglobin for oxygen

c spends too much time talking about carbon dioxide when the question is about oxygen

d repeats the question in the answer

7 2–4KPa; low; release/offload; high; diffuses; bind

Exam-style questions

1 D 10–12 KPa

2 **a** line drawn which is moved down or to the right.

Starts and finishes at the same points.

b Bohr (shift/effect)

c In the tissues, the p.p. of oxygen is between 2–4 KPa.

The haemoglobin has an even lower affinity for oxygen with high carbon dioxide levels present.

It more readily offloads or releases its oxygen to the tissues.

3 **a** *Any four from:*

When the blood arrives in the placenta, the p.p. of oxygen is between 2–4 KPa.

At this point the haemoglobin has a low affinity for oxygen.

The haemoglobin will offload or release oxygen to the tissues readily.

At the same low p.p. of oxygen in the placenta between 2–4 KPa.

At this point the fetal haemoglobin still has a high affinity for oxygen.

The fetal haemoglobin will bind to oxygen released by the mother across the placenta.

b the fetal haemoglobin would have too high affinity for oxygen

there would not be enough oxygen released to adult tissues

Translocation

Specification reference

- *3.1.3 (f)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the process of translocation
- state all the cellular structures involved
- state all the molecules involved in the movement
- describe the processes by which each molecule moves.

Introduction

There are two transports systems in plants. Water is transported in the xylem, and sucrose and other assimilates are transported in the phloem.

The aim of this sheet is to take you through the process of the transport of sucrose as a sequence of steps, and to use the sequence to develop a memory aid in the form of a poster.

Background

There are two transport systems in plants, the transpiration stream and translocation.

Transpiration stream – this is the movement of water and solutes from the roots to the leaves. It occurs in tissues called xylem. You will have encountered process in Topic 9.3 'Transpiration'.

Translocation – this is the movement of assimilates, like sucrose, from the site where they are made (source) to the places where they are used or stored (sinks). This process occurs in tissues called the phloem. You will have covered in Topic 9.4 'Translocation'.

Translocation is a complicated topic for many reasons:

- it is difficult to recall the cells in which it occurs
- lots of different molecules or ions are involved
- you need to remember the different processes by which the molecules move.

Below is a step-by-step sequence of events for this process. Read the following statements and highlight all the keywords.

Loading at the source

1 Phloem consists of two main cell types, sieve tube elements and companion cells.
2 Hydrogen ions are pumped out of the companion cells into the neighbouring mesophyll cells.
3 The hydrogen ions move by active transport.
4 Companion cells contain many mitochondria to provide the ATP needed for the active transport of hydrogen.
5 A high concentration of hydrogen ions builds up in the mesophyll cells.
6 The hydrogen move back into the companion cells, down a concentration gradient using a co-transporter protein.
7 Sucrose is transported with the hydrogen ions.
8 These two move by facilitated diffusion.
9 This results in a build-up in sucrose inside the companion cells.
10 Sucrose moves by diffusion into the sieve tube elements.
11 This increases the concentration inside the sieve tube element.
12 The water potential inside the sieve tube now lowers.
13 Water moves (from high water potential to low water potential) into the sieve tube elements by osmosis from surrounding cells such as the xylem.
14 The increase in water inside the elements increases the turgor pressure inside the elements.
15 This causes the movement of water and assimilates by mass flow from source to sink.

Unloading at the sink

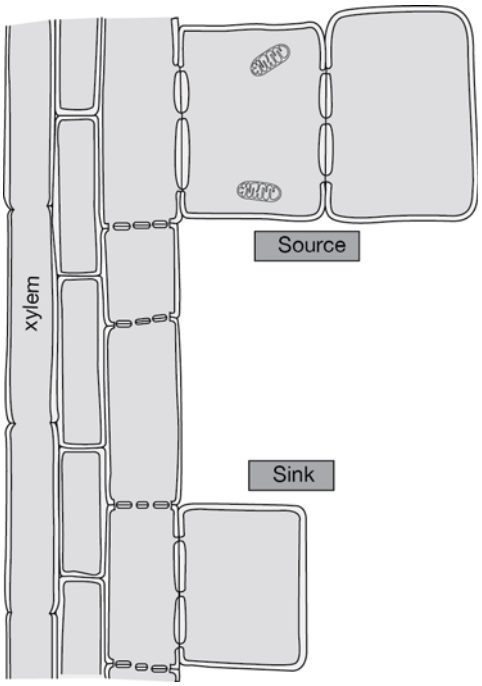
1 Water and assimilates like sucrose arrive in the sieve tube elements in the sink.
2 Sucrose diffuses into the cells surrounding the sieve tube elements.
3 These cells convert the sucrose into other substances like starch for storage, or glucose and fructose for respiration.
4 This lowers the concentration and creates a concentration gradient, causing more sucrose to diffuse out of the sieve tube.
5 The reduced sucrose in the sieve tube leads to an increase in the water potential.
6 Water moves out of the sieve tube into surrounding cells by osmosis.
7 This reduces the turgor pressure inside the sieve tubes.
8 This maintains the mass flow inside the phloem.

Task

Use the information above to make an annotated diagram to explain translocation. Make the diagram as big as possible, (perhaps use flip chart paper or bigger) and include as much information as possible, but do not copy any statement. Try to rewrite the statements to see if you have understood each one.

9.4 Translocation
Support worksheet

Use colours to distinguish the cell types, processes, and molecules involved. You could copy this template to create your diagram.



Questions

1 Give one piece of evidence which shows that companion cells carry out active transport. (*1 mark*)

2 Name the process by which:

a water is transported from the roots to the leaves (*1 mark*)

b sucrose is transported from the leaves to the roots. (*1 mark*)

3 Complete these sentences about the loading of sucrose into phloem.

Translocation is the process of transport of the products of ……Sucrose and other …… are loaded into the phloem at the source. …… ions are pumped from the companion cell into surrounding …… cells, by active transport. Hydrogen ions and …… move back into the companion cells by co-transport. The sucrose concentration now builds in the companion cell, causing it to …… into the sieve tube elements. This increase in sucrose in the sieve tube lowers the water potential, causing water to move in by …….. The result is that the ……. pressure is raised causing the mass flow of the water and sucrose to the sink. (*8 marks*)

4 Explain how the movement of sucrose out of the sieve tube element is brought about at the sink. (*3 marks*)

Answers

1 Presence of large numbers of mitochondria. (*1 mark*)

2 **a** transpiration (*1 mark*)

b translocation (*1 mark*)

3 photosynthesis (*1 mark*)

assimilates (*1 mark*)

hydrogen (*1 mark*)

mesophyll (*1 mark*)

sucrose (*1 mark*)

diffuse (*1 mark*)

osmosis (*1 mark*)

turgor (*1 mark*)

4 *Any three of:* *(3 marks maximum)*

Sucrose is broken down in the cells at the sink.

Glucose is used for respiration/starch is used for storage.

This creates a concentration gradient for sucrose.

Sucrose diffuses out of the sieve tube into the cells at the sink.

Comparing two populations – a statistical approach

Specification reference

- *4.2.2 (f)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the reasons for selecting statistical routines to analyse data
- carry out one statistical analysis (*t*-test) with confidence.

Introduction

Variation between individuals provides many opportunities for experimental studies. These experimental approaches often generate large amounts of data that need to be analysed. There are a range of methods, graphical and statistical, that can be used in such an analysis. Selecting the correct approach is often an area which causes difficulties.

The aim of this sheet is to explain where each test might be most appropriate, and to give a detailed explanation of one of the tests.

Background or worked examples

Variation is the difference in characteristics between individuals of the same species (intraspecific variation) or between individuals of different species (interspecific variation). There are two major causes of variation, genetic causes and environmental causes. You will have looked at these in Topic 10.5 ‘Types of variation’.

Many investigations of variation involve recording large amounts of data about a characteristic, such as height, from a large numbers of organisms. The data may be collected from different groups of organisms, for example populations on different sides of a mountain. Once the data has been collected it must be analysed. Once analysed, we need to look for trends in the data, or relationships between the data sets collected. This could involve a number of possible steps:

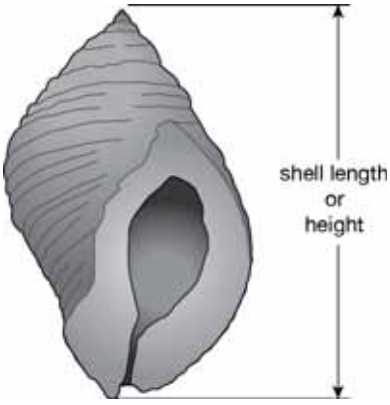
- processing the data, perhaps to produce a mean and standard deviation, to give a central value and a measure of spread to compare
- graphing the data to illustrate any relationship or trend
- statistical tests looking for relationships or significance between the data sets.

It can be difficult to know which form of statistical analysis to use. Use this table as a summary of when to use each test.

Test	Reason for selection	Examples of use
standard deviation	This is a **measure of spread** in the data. This value gives an indication of the amount of spread.	The effect of an environmental factor on a characteristic, for example sunlight on plant height.
student's *t*-test	This looks for **significant difference** between **two sets** of data for **one characteristic** between two sub-groups.	Comparing mean fruit weight for two crops grown in different fields.
Spearman's rank correlation co-efficient	This looks for a **relationship between** the data for two variables.	Height and width of limpets on a seashore.
Chi-squared (χ^2) test	This looks for **significant difference** between **observed** results and what you might **expect**, where the data fits into categories.	Comparing results of an actual genetic cross with the predicted ratio.

Task

The dogwhelk (*Nucella lapillus)* is a common organism found on rocky shores. A student investigated the variation in shell height for two groups of dogwhelks found on two different beaches, one exposed and one sheltered. The student wanted to know if there was any significant difference between the two populations of dogwhelks.



10.6 Representing variation graphically Support worksheet

Below is the data collected.

Sheltered beach	
Animal number	**Shell height (cm)**
1	1.98
2	3.25
3	3.11
4	2.98
5	2.67
6	2.39
7	2.49
8	2.53
9	2.24
10	2.78
11	3.20
12	2.89
13	3.39
14	2.42
15	2.97
16	2.99
17	2.73

Exposed beach	
Animal number	**Shell height (cm)**
1	1.92
2	1.78
3	2.11
4	1.58
5	2.23
6	2.08
7	2.58
8	2.45
9	2.39
10	1.98
11	2.20
12	2.98
13	2.28
14	2.51
15	2.87
16	
17	

Analysing the data

1 Graphing the data

Re-arrange the data from the tables above into the frequency table below.

Shell Height (cm)	Sheltered beach population	Exposed beach population
1.51 – 1.75		
1.76 – 2.00		
2.01 – 2.25		
2.26 – 2.50		
2.51 – 2.75		
2.76 – 3.00		
3.01 – 3.25		
3.26 – 3.50		

Now plot a graph of the data – use a frequency diagram or histogram.

When the graph is drawn you should be able to see that the two populations are distributed at slightly different points on the graph. This is easier to notice from a graph than it is from the tables of data.

We now have the suggestion that there is a difference between the two populations, but this is based on our judgement of the graph shapes. To obtain more convincing evidence of any difference, we can carry out a statistical test to look for significant difference. But which test?

What have we got?

- We have two sets of data (one from two different populations).
- The sets of data are for the same characteristic.

What do we want to know?

- We are looking for significant difference.

By looking at the table above we can select the student's *t*-test.

Step 1

Calculate the mean and standard deviations for each population. Do this and add the answers to the table below. Use the following equation to calculate the standard deviation.

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

σ = **standard deviation**

Σ = **sum of**

x = **each value in the data set**

$\bar{x}$ = **mean of all values in the data set**

n = **number of value in the data set**

Sheltered beach	
Number of animals tested (n_1)	
Mean ($\bar{x}_1$)	
Standard deviation(σ_1)	
Standard deviation squared (σ_1^2)	

Exposed beach	
Number of animals tested (n_2)	
Mean ($\bar{x}_2$)	
Standard deviation(σ_2)	
Standard deviation squared (σ_2^2)	

Step 2

State a null hypothesis. As with all significance testing, it is first necessary to state a null hypothesis. This is a statement which always suggests that there is *'no significant difference between the two sets of data'.* In this case the null hypothesis could be fully stated as below:

'There is no significant difference between the data for height from the two beaches. Any difference in the results is due to chance.'

Step 3

Perform the calculation. Use the formula below.

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\left(\frac{\sigma_1^2}{n_1}\right) + \left(\frac{\sigma_2^2}{n_2}\right)}}$$

Where:

$\sqrt{}$ = The square root of

σ_1^2 = The variance of data 1 (sheltered beach population)

σ_2^2 = The variance of data 2 (exposed beach population)

n_1 = The number of results for data 1 (sheltered beach population)

n_2 = The number of results for data 2 (exposed beach population)

Substitute the figures into the equation, and calculate a value of 't'. The value of 't' does not have a meaning in itself. It can be used to produce a probability of the significant difference or similarity between the two sets of data.

Step 4

Calculate the degrees of freedom. The greater the number of data points, the greater the potential spread of results. Therefore it is necessary to take into account the potential spread of results by calculating the degrees of freedom, which is based on the number of results. The formula for calculating the degrees of freedom in the *t*-test is the number of results of population 1 minus one, plus the number of results of population 2 minus one.

Degrees of freedom = $(n_1 - 1) + (n_2 - 1)$

Calculate the degrees of freedom for the data above.

Step 5

Armed with the 't' statistic and the degrees of freedom, it is now possible to determine the probability value (*p*). The probability will indicate the likelihood of no significant difference between the two sets of results, or the likelihood of the null hypothesis being true. In significance tests of this sort, it is necessary to have a probability above which the Null hypothesis is always accepted. Such a threshold of probability is called a confidence limit. It is set at $p = 0.05$ (5%) by convention.

- If $p \geq 0.05$ (5%) this means the null hypothesis must be accepted. There is no significant difference between the two sets of results. The spread of data could have occurred due to chance alone in more than 5% of the times of performing this experiment.
- If $p < 0.05$ (5%) this means the null hypothesis must be rejected. There is a significant difference between the two sets of results. The spread of data could not have occurred due to chance.

It is now necessary to refer to probability tables. Scan down the column for the degrees of freedom, to the value closest to the calculated degree of freedom, in this case 30. Read across the row to find the figure closest to the calculated value of *t*. The column headings will then determine the probability range for the statistic.

Degrees of freedom	Probability (*p*) values.				Degrees of freedom
	0.1	0.05	0.01	0.001	
30	1.70	2.04	2.75	3.65	30

Questions

1 In an investigation a student wanted to have an idea about the spread of the data. Which of the following statistics would they calculate?

a student *t*-test
b Chi-squared test
c standard deviation
d mean

(*1 mark*)

2 A student investigated the difference in the length of the middle digit in two groups of fossil birds, to see if they were the same species or not. Below is a summary of the results he obtained.

Species 1	
Number of animals recorded (n_1)	29
Mean ($\bar{x}_1$)	6.1 cm
Standard deviation (σ_1)	0.5
Standard deviation squared (σ_1^2)	0.25

Species 2	
Number of animals recorded (n_2)	48
Mean ($\bar{x}_2$)	5.7 cm
Standard deviation (σ_2)	1.2
Standard deviation squared (σ_2^2)	1.44

They decided to calculate the student's *t*-test on the data to look for significant difference.

a State the null hypothesis for this test. (*1 mark*)

b Use the formula to calculate the value of *t*.

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\left(\frac{\sigma_1^2}{n_1}\right) + \left(\frac{\sigma_2^2}{n_2}\right)}}$$

(*2 marks*)

c How many degrees of freedom would there be in this test? (*1 mark*)

d When the student looked at the probability for the *t*-test value in this case they found a value of *p* being smaller than 0.05. What does this indicate about the two populations? (*2 marks*)

10.6 Representing variation graphically Support worksheet

Answers

Task

Graphing the data.

Shell Height (cm)	Sheltered beach population	Exposed beach population
1.51 – 1.75	0	1
1.76 – 2.00	1	3
2.01 – 2.25	1	4
2.26 – 2.50	3	3
2.51 – 2.75	3	2
2.76 – 3.00	5	2
3.01 – 3.25	3	0
3.26 – 3.50	1	0

Graph should show two distinct populations.

Table of values.

Sheltered beach	
Number of animals tested (n_1)	17
Mean ($\bar{x}_1$)	2.76
Standard deviation(σ_1)	0.374
Standard deviation squared (σ_1^2)	0.140

Exposed beach	
Number of animals tested (n_2)	15
Mean ($\bar{x}_2$)	2.26
Standard deviation(σ_2)	0.370
Standard deviation squared (σ_2^2)	0.137

$t = 3.76$

degrees of freedom = 30

probability of less than 0.001

Questions

1 C: standard deviation (*1 mark*)

2 **a** There is no significant difference between the digit size for the two populations of birds. Any difference is due to chance. (*1 mark*)

b $t = 2.036$ (*2 marks*)

c degrees of freedom = 75 (*1 mark*)

d *Any two of:*

the probability is less than 0.05, reject the null hypothesis (*1 mark*)

there is a significant difference between the bird populations (*1 mark*)

the differences are not due to chance. (*1 mark*)

Maintaining biodiversity

Specification reference

- *4.2.1 (g)*
- *4.2.1 (h)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the reasons for maintaining biodiversity
- understand the methods of maintaining biodiversity
- construct detailed and wide ranging responses to questions on biodiversity.

Introduction

Biodiversity is a measure of the numbers and types of organisms in our environment. In this support sheet we consider the reasons for maintaining biodiversity in our environment, and some of the methods by which we maintain biodiversity.

One area that can be tricky when considering biodiversity is how comprehensive your answers to questions should be. The aim of this support sheet is to suggest strategies to help you provide greater depth and breadth to any response to questions on this topic.

Background

Biodiversity is a measure of the numbers and types of organisms in the environment. You will have already considered a number of important concepts relating to biodiversity:

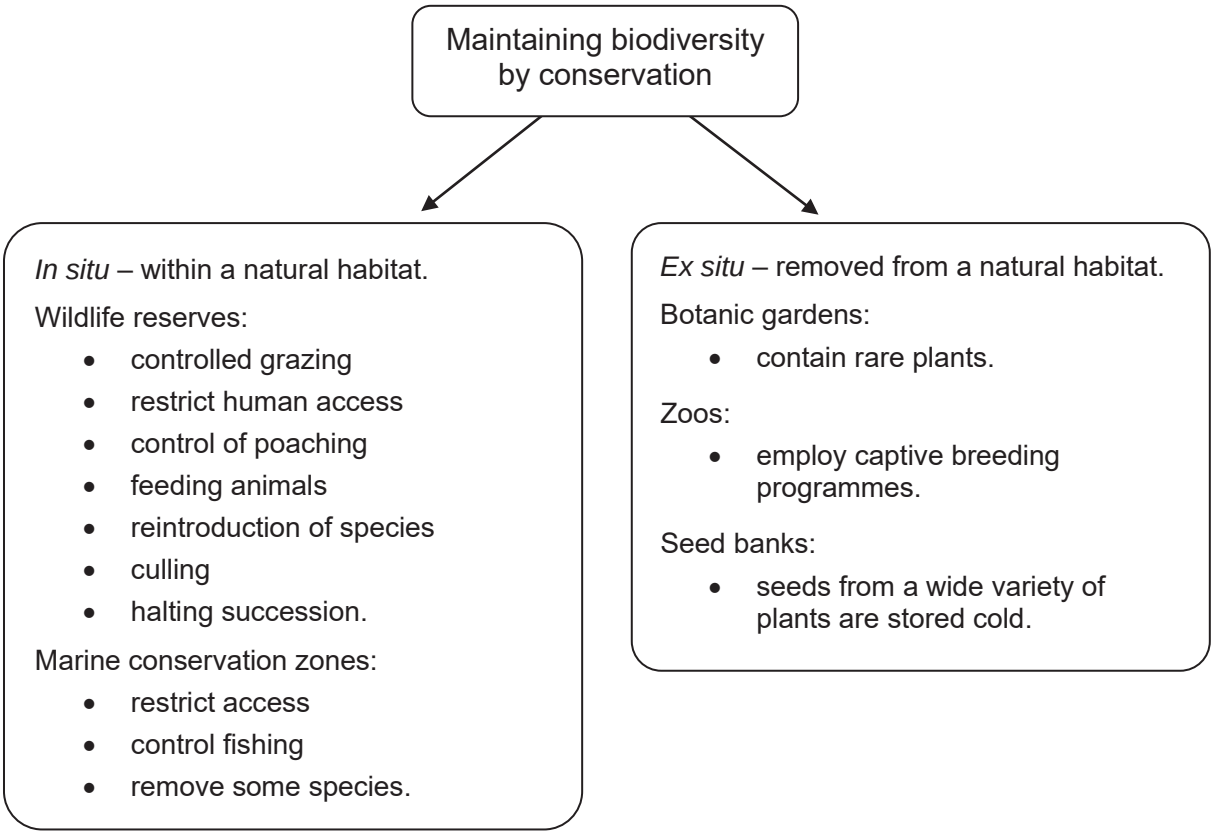
- the concept of biodiversity and the different levels of biodiversity which we can study.
- the different sampling methods used to calculate biodiversity of sampling
- how to calculate species diversity
- factors affecting biodiversity.

There are a number of reasons for maintaining biodiversity which are summarized below.

Reason for maintaining biodiversity	Explanation
aesthetic	• providing beautiful environment for people to live in • it would be wrong to destroy natural beauty
economic	• reducing soil erosion • reducing the mineral depletion that occurs in monoculture • sustainability – using natural resources without their loss • avoiding the loss of potentially economically valuable species • avoiding the rapid spread of disease seen in monoculture • promoting tourism to an area • giving greater potential for the manufacture of products • giving greater genetic diversity that could be useful in genetic engineering

ecological	• individuals are interdependent upon each other for survival:
	  • in food chains
	  • for pollination
	• keystone species are individuals that have a disproportionate impact on a habitat and its biodiversity

There are a range of methods for maintaining biodiversity.



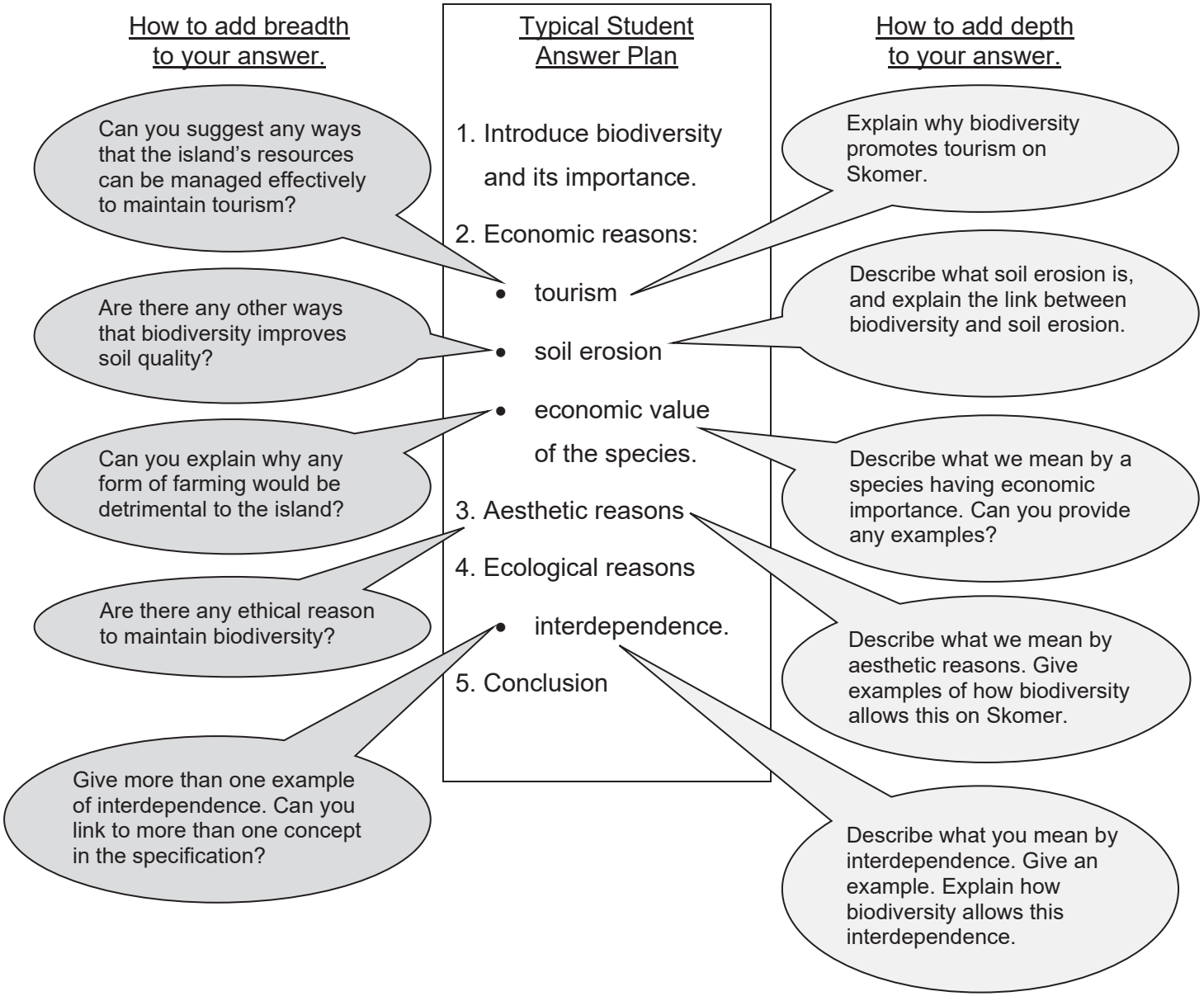
Task

Try this approach as a method for answering a longer answer question on the topic of biodiversity. You are given a typical student answer plan, however, you need to add depth and breadth.

- Use the bubbles to the right ask you to find information which will give your depth in the answer.
- Use the bubbles to the left ask you to find information which will give your breadth in the answer.

The island of Skomer off the coast of Wales is a natural nature reserve and a site of special scientific interest (SSSI). The island has, amongst other wildlife, the largest colony of Atlantic Puffins in southern Britain and a large diverse population of wild flowers.

Suggest why it is important to maintain the biodiversity of Skomer Island.



Questions

1 Define what is meant by the terms:

a biodiversity (*1 mark*)

b conservation (*1 mark*)

c sustainability (*1 mark*)

2 One method for maintaining biodiversity is the use of seed banks.

a Describe how a seed bank could be used to maintain biodiversity. (*1 mark*)

b Give two economic reasons why maintaining biodiversity using seed banks is important. (*2 marks*)

3 Beavers are common animals in North America. They build dams in the rivers, which create ponds behind the dams. Within the ponds new habitats are quickly established.

Beavers cut down large trees to help construct the dams. This results in a natural thinning of the woodlands, which allow different woodland plants to grow.

Beaver ponds contain a wide variety of insects, amphibians, molluscs, birds, and plant life that would not normally be found in fast-flowing rivers. The dams also contain the fish that the beavers and other carnivores feed off.

a Suggest why the beaver is considered a keystone species. (*1 mark*)

b Beavers have an impact on their environment.

i Describe one way in which the beaver physically changes its environment. (*1 mark*)

ii Explain how this change brought about by the beaver increases biodiversity in an area. (*2 marks*)

c Environmental biologists have been constructing arguments to persuade hunters not to kill beavers. Suggest two reasons, one economic and one ecological, to help support the environmentalist's case. (*2 marks*)

4 The African savannah is of great ecological importance, because it has a wide variety wildlife. Environmental biologists have worked tirelessly to conserve the wildlife of the savannah.

a Describe and explain the methods used to conserve wildlife *in situ*. (*3 marks*)

b Suggest how zoos could help maintain biodiversity in the African savannah. (*2 marks*)

Answers

Task

Credit depth (D) marks and breadth (B) marks in the response.

Economic:

D1 – idea that biodiversity provides a great range of species which will be of scientific interest.

D2 – more species make the area more attractive to tourists.

B1 – concept of sustainable management to maintain biodiversity in the environment.

D3 – soil erosion due to lack of tree roots to retain particles.

D4 – soil erosion due to lack of humus in soil from decomposing plant material.

B2 – soil mineral depletion due to monoculture removes minerals, whereas a diverse community reduces mineral depletion.

D5 – economic species are those from which humans can obtain useful product.

D6 – examples.

B3 – removal of species which might be useful in the future, idea of unidentified useful drugs, or useful genes for genetic engineering.

Aesthetic:

D7 – range of wildlife provides aesthetically pleasing environment.

D8 – examples range of wildflowers or sea birds.

B4 – ethical issues - humans should not be responsible for the loss of species.

Ecological:

D9 – interdependence is where the survival of one group/population of species is dependent upon another group.

D10 – food chains.

B5 – pollination.

Questions

1 a (A measure of) the number and variety of organisms in an area. (*1 mark*)

b The preservation and careful management of the environment and natural resources. (*1 mark*)

c The use of resources that meets the needs of people today without limiting the ability of future generations to meet their needs. (*1 mark*)

2 a Seeds are stored so that new plants could be grown in the future, for reintroduction or research. (*1 mark*)

b *Any two from:*

- possible use in breeding programmes; (*1 mark*)
- use in genetic engineering; (*1 mark*)
- use in production of economically important products/drugs. (*1 mark*)

3 a Beavers have a disproportional effect upon their environment. (*1 mark*)

b i Building dams or cutting down trees. (*1 mark*)

ii dams create different habitats; (*1 mark*)

new species can now live there, increasing biodiversity. (*1 mark*)

OR

cutting down trees thins the woods/creates clearings; (*1 mark*)

leaves room for new woodland plants to establish. (*1 mark*)

c *Economic:* diverse woodland, avoids mineral depletion / diverse community might contain economically valuable species / beavers and diverse community promotes tourism / some species might have desirable genes for use in genetic engineering. (*1 mark*)

Ecological: loss of beavers will reduce biodiversity which will affect food chains in the habitats / reduce ability for pollination due to loss of insect life. (*1 mark*)

4 a *Any three from:*

create reserves; (*1 mark*)

which reduces human access; (*1 mark*)

reduces poaching; (*1 mark*)

controlled reintroduction of species to reserves; (*1 mark*)

controlled culling to remove species exceeding their natural numbers. (*1 mark*)

b breeding programmes can produce new individuals; (*1 mark*)

some of which can be reintroduced into the savannah. (*1 mark*)

Pathogens

Specification reference

- *4.1.1 (a)*
- *4.1.1 (b)*

Learning outcomes

After completing the activity you should be able to:

- describe how different pathogens are transmitted
- consider experimental design when investigating pathogens.

Tasks

In this activity, you will consider different types of pathogenic microorganisms, how they gain access to human beings and the effects they have on the body. This activity is designed to build on your knowledge of pathogens gained at GCSE and to remind you of investigative skills.

Pathogenic microorganisms

During a discussion on how infectious diseases were transmitted, some students decided to set up experiments to show that there were microorganisms present in the air and that washing your hands reduced the number of microorganisms you could pass on to someone else. Individual microorganisms are too small to be seen with the naked eye, but if they are given a food source and the right conditions they will form colonies that can be seen. The apparatus they used included sterile agar plates, adhesive tape and an incubator set at 25 °C.

Questions

1 Describe how the students would use the apparatus to show that there were microorganisms present in the air in the laboratory. Remember to think carefully about experimental design and how to make the results reliable.

2 Describe the method the students would use to show that washing your hands reduces the number of microorganisms present on them. Remember to think carefully about experimental design and how to make the results reliable.

3 How would you present the results of these investigations?

4 The second experiment supports the work of Semmelweis who pioneered the control of infection in hospitals. Explain why hand washing is still so important in hospitals today.

Types of pathogens

Pathogenic microorganisms cause diseases and include bacteria, fungi and viruses.

Questions

5 Make a list of the differences between bacteria and viruses with reference to their size, their structure and their method of reproduction.

6 Complete the following table by filling in the blank spaces with the appropriate information:

Type of pathogen	Disease caused	Name of organism
Bacterium		*Escherichia coli*
	Thrush	
Virus	Common cold	
		Clostridium botulinum
	Cold sores	
Fungus		*Trichophyton rubrum*
Bacterium	Tuberculosis	

How pathogens enter the body and cause disease

Pathogenic microorganisms can gain entry to the body in three main ways: through the skin, via the gas-exchange system and into the digestive system in our food and drink.

Questions

7 What happens to prevent pathogenic microorganisms gaining entry to the body through a cut in the skin?

8 Explain why not all the pathogenic organisms that enter the body via the gas-exchange system and the digestive system cause disease.

9 What effects do pathogenic microorganisms have when they get into our bodies?

Answers

1 The students would expose a number of sterile agar plates (more than one) to the air in the laboratory for a specified length of time and then seal them with the adhesive tape. They would keep a similar number of plates unexposed (as a control), sealed with adhesive tape. Both sets of plates would then be incubated for 2–3 days at 25° C. The two sets of plates would then be scored for the number of colonies present.

Note: It is important to have a control and to expose the plates for a set length of time.

2 A student would touch the surface of an agar plate with unwashed fingers then seal the plate with adhesive tape. The student would then wash their hands thoroughly with soap and water, dry them and touch the surface of another agar plate with their washed fingers, sealing the plate with adhesive tape as before. Both plates would be incubated at 25° C. For reliability, this could be done more than once or by several members of the group. After 2–3 days, the plates would be scored for the number of colonies present.

3 The results could be presented as bar charts or in tables. If several plates are used, then the average number of colonies per plate can be used.

4 Doctors and nurses go from one patient to another and could transmit infections. Washing hands is particularly important in the prevention of the spread of MRSA and other bacteria which are resistant to antibiotics. It is also important that visitors wash their hands as they could bring in pathogenic bacteria from outside.

Note: These investigations could be extended to investigate the presence of microorganisms in different parts of the school or the use of different hand washing techniques.

5 Make a list of the differences between bacteria and viruses with reference to their size, their structure and their method of reproduction.

- Bacteria are smaller than the cells of plants and animals but larger than viruses.
- Bacteria are single-celled organisms with a cell wall, plasma membrane, cytoplasm, plasmids, food reserves and nuclear material. Viruses consist of a protein coat surrounding nucleic acid.
- Bacteria reproduce by dividing into two. Viruses can only replicate in a host cell where their nucleic acid causes the host cell to make new viruses which are released when the host cell breaks down.

6 Complete the following table by filling in the blank spaces with the appropriate information.

Type of pathogen	Disease caused	Name of organism
Bacterium	Food poisoning	*Escherichia coli*
Fungus	Thrush	*Candida albicans*
Virus	Common cold	*Rhinovirus*
Bacterium	Botulism	*Clostridium botulinum*
Virus	Cold sores	*Herpes simplex (type 1)*
Fungus	Athlete's foot	*Trichophyton rubrum*
Bacterium	Tuberculosis	*Mycobacterium tuberculosis*

7 When the skin is cut, tiny blood vessels are broken and the blood clots, sealing up the wound. The clot dries and forms a scab preventing the entry of pathogens. The scab falls off when the skin has regrown underneath.

8 Pathogens entering via the gas-exchange system (nose, nasal passages) may be trapped in the mucus lining of the nasal passages and the trachea. The mucus is moved by cilia on the epithelial cells of these regions to the back of the mouth and throat and removed.

Many of the pathogens which are ingested with food and drink are killed by the extremely acidic conditions in the stomach.

9 Many pathogenic microorganisms, especially bacteria, produce poisonous substances called toxins. Bacteria can reproduce rapidly in the conditions inside the body (suitable temperature, food) and the toxins cause disease symptoms, such as headaches, aches and pains and a raised temperature. Some of these symptoms are caused by the response of the body to the presence of the pathogen and the toxins.

Viruses take over the cells causing damage and destroying them. Viruses rarely produce toxins.