Support those students who build investigative and experimental skills to support the development of Biology specification (9201), for first teaching from September 2016. The Oxford AQA International GCSE textbook that fully supports the Oxford AQA International GCSE includes:

- Biology
- Chemistry
- Mathematics

The plant will remain wilted until the temperature drops, the sun goes in, or the plant can get the water they need. How to get in touch:

How will transpiration in a plant be affected if the top leaf surfaces are a) sealed with an airproof film, or b) damaged? Describe how water moves up a plant in the transpiration stream.

The loss of water vapour from the xylem to the atmosphere is known as transpiration. This occurs because more stomata are opened up to let in carbon dioxide for photosynthesis. However, when the stomata are open, plants lose water by evaporation and diffusion through the open stomata. Warm, sunny conditions increase the rate of transpiration.

Evaporation is more rapid as the water moves up the stem through open stomata. This is because it is easier to get water from the xylem to the atmosphere when the stomata are open. The stomata on the surface of plant leaves can be opened and closed by the guard cells that surround them. Plants open their stomata to take in carbon dioxide for photosynthesis. However, when the stomata are open, plants lose water loss. In very hot environments, the cuticle may be very thick and shiny. Most leaves have a waxy, waterproof layer (the cuticle) to prevent uncontrolled water loss. The leaves all collapse and hang down. This greatly reduces the photosynthesis.

Conditions that increase the rate of evaporation and diffusion of water when the stomata are open include:

- Low humidity
- High temperatures
- Windy conditions
- Sunlight

The stomata close, which stops photosynthesis and risks overheating. If a plant begins to lose water faster than it is replaced by the roots, it can take measures water uptake, which is almost the same as lost by the plant in transpiration. A potometer is used to show the water uptake of a plant. This gives you a good idea of the amount of water the plant is taking up from the soil.

There are a number of experiments which can be done to show the amount of water uptake. One method is to use a piece of paper towel. The paper towel is placed under the plant and the amount of water lost is measured. Another method is to use a potometer. The potometer is a device which measures the amount of water lost by transpiration. Many of them use a piece of paper towel which is placed under the plant. The amount of water lost is measured and recorded.

The effect of the environment on transpiration can be studied by observing how the plants respond to different conditions. For example, how will transpiration in a plant be affected if the top leaf surfaces are a) sealed with an airproof film, or b) damaged? How will transpiration in a plant be affected if the top leaf surfaces are a) sealed with an airproof film, or b) damaged? Explain how the plants will cope with this situation.

Describe how water moves up a plant in the transpiration stream. Water moves up through the xylem from the roots to the leaves. The water vapour evaporates from the cells of the plant and rises up the xylem. As the water moves up the stem, it is drawn up by transpiration. This causes the water to move up the stem.

After this topic, you should be able to:

1. Understand the process of transpiration
2. Describe how water moves up in the transpiration stream
3. Explain how the environment affects transpiration
4. Predict how plants will respond to changes in the environment

Water loss from the leaves can pull litres of water many metres above the ground. The water moves up the stem and into the leaves to replace the water lost by evaporation. The water is then used by the plant for photosynthesis. The plant will remain wilted until the temperature drops, the sun goes in, or the plant can get the water they need.

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How to use this book

This book has been written for you by experienced teachers and subject experts. It covers what you need to know for your exams and is packed full of features to help you achieve the very best that you can.

Figure 1  Many diagrams are as important for you to learn as the text, so make sure you revise them carefully

Key words are highlighted in the text. You can look them up in the glossary at the back of the book if you are not sure what they mean.

Required practical
This feature helps you to become familiar with key practicals. It may be a simple introduction, a reminder, or the basis for a practical in the classroom.

Summary questions
These questions give you the chance to test whether you have learnt and understood everything in the topic. If you get any wrong, go back and have another look. They are designed to be increasingly challenging.

And at the end of each chapter you will find …

Chapter summary questions
These will test you on what you have learnt throughout the whole chapter, helping you to work out what you have understood and where you need to go back and revise.

Practice questions
These questions are examples of the types of questions that you will answer in your actual exam, so you can get lots of practice during your course.

Key points
At the end of the topic are the important points that you must remember. They can be used to help with revision and summarising your knowledge.
Practical skills

During this course, you will develop your understanding of the scientific process and the skills associated with scientific enquiry. Practical work is an important part of the course as it develops these skills and in addition it reinforces concepts and knowledge developed during the course. As part of this course, you are expected to undertake practical work in many topics and must carry out the five required practicals listed below:

**Required practicals**

1. Investigating the effect of different concentrations of solutions separated by a partially permeable membrane.
2. Investigating how variables affect the rate of photosynthesis.
3. Investigating how different temperatures and pH affect the rate of digestion.
5. Investigating the effect of disinfectants and antibiotics on uncontaminated cultures of microorganisms.

In Paper 2, you will be assessed on aspects of the practical skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations, and evaluate information that is presented to you.

**Designing a practical procedure**

- Design a practical procedure to answer a question, solve a problem, or test a hypothesis.
- Comment on/evaluate plans for practical procedures.
- Select suitable apparatus for carrying out experiments accurately and safely.

**Control**

- Appreciate that, unless certain variables are controlled, experimental results may not be valid.
- Recognise the need to choose appropriate sample sizes, and study control groups where necessary.

**Risk assessment**

- Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.

**Collecting data**

- Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart, or graph).

**Analysing data**

- Recognise and identify the cause of anomalous results and suggest what should be done about them.
- Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results, and recognise when it is appropriate to ignore anomalous results in calculating a mean.
- Recognise and identify the causes of random errors and systematic errors.
- Recognise patterns in data, form hypotheses, and deduce relationships.
- Use and interpret tabular and graphical representations of data.

**Making conclusions**

- Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.

**Evaluation**

- Evaluate data, considering its repeatability, reproducibility, and validity in presenting and justifying conclusions.
- Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.
- Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.
Earth is covered with a great variety of living things. However, they all have one thing in common – they are all made up of cells. Most cells are very small and you can only see them using a microscope. Eggs are the biggest animal cells. Unfertilised ostrich eggs are the biggest of all – they have a mass of around 1.3kg and you certainly don’t need a microscope to see them! The light microscopes in schools may magnify things several hundred times. Scientists have found out even more about cells using electron microscopes. These can magnify objects more than a hundred thousand times.

Most of the organisms you see around you are eukaryotes. This includes all animals and plants. Many microorganisms are prokaryotes. You will compare eukaryotic cells and prokaryotic cells on page 5.

**Animal cells – structure and function**

All eukaryotic cells have some features in common. You can see these clearly in animal cells. Human cells have the same features as other animal cells, and so do the cells of most other living things.

- **The nucleus** – controls all the activities of the cell. It contains the genes on the chromosomes that carry the instructions for making the proteins needed to build new cells or new organisms.
- **The cytoplasm** – a liquid gel in which most of the chemical reactions needed for life take place, for example, the first stages of respiration.
- **The cell membrane** – controls the passage of substances such as glucose and mineral ions into the cell. It also controls the movement of substances such as urea or hormones out of the cell.
- **The mitochondria** – structures in the cytoplasm where oxygen is used and where most of the energy is released during respiration.
- **Ribosomes** – where protein synthesis takes place, making all the proteins needed in the cell.

**Plant cells – structure and function**

Plants are very different organisms from animals. They make their own food by photosynthesis. They stay in one place, and do not move their whole bodies about from one place to another.

Plant cells have all the features of a typical animal cell, but they also contain features that are needed for their very different way of life. Algae are simple aquatic organisms. They also make their own food and have many similar features to plant cells. For centuries they were classified as plants, but now they are part of a different kingdom.
Animal and plant cells

Key points

Most human cells are similar to most other animal cells and contain features common to all cells – a nucleus, cytoplasm, cell membrane, mitochondria, and ribosomes.

Plant and algal cells contain all the structures seen in animal cells as well as a cellulose cell wall. Many plant cells also contain chloroplasts and a permanent vacuole filled with sap.

All plant and algal cells have:

- a cell wall made of cellulose that strengthens the cell and gives it support.

Many (but not all) plant cells also have these other features:

- Chloroplasts are found in all the green parts of the plant. They are green because they contain the green substance chlorophyll. Chlorophyll absorbs light energy to make food by photosynthesis. Root cells do not have chloroplasts because they are underground and do not photosynthesise.
- A permanent vacuole is a space in the cytoplasm filled with cell sap. This is important for keeping the cells rigid to support the plant.

Summary questions

1. a List the main structures you would expect to find in an animal cell.
   b You would find all the things that are present in animal cells in a plant cell or algal cell, too. There are three extra features that may be found in plant cells but not in animal cells. What are they?
   c What are the main functions of these three extra structures?
2. Why are the nucleus and the mitochondria so important in all cells?
3. Chloroplasts are found in many plant cells but not in all of them. Give an example of plant cells without chloroplasts, and explain why they have none.
Eukaryotes and prokaryotes

Bacteria are single-celled living organisms that are much smaller than animal and plant cells. Most bacteria are less than 1 μm in length. They are prokaryotic cells. You could fit hundreds of thousands of bacteria onto the full stop at the end of this sentence, so you can’t see individual bacteria without a powerful microscope.

When you culture bacteria on an agar plate, you grow many millions of bacteria. This enables you to see the bacterial colony with your naked eye.

Bacterial cells

Each bacterium is a single cell. It is made up of cytoplasm surrounded by a membrane and a cell wall. Inside the bacterial cell is the genetic material. Unlike animal, plant, and algal cells, the genes are not contained in a nucleus. The long strand of DNA (the bacterial chromosome) is usually circular and is found free in the cytoplasm.

Many bacterial cells also contain plasmids, which are small, circular bits of DNA. These carry extra genetic information. Plasmids are widely used by scientists in the process of genetic engineering.

Some bacteria have specialised structures. A slime, capsule around the outside of the cell wall protects some bacteria from your immune system. Others have tiny whip-like threads called flagella to help them move around.

Although some bacteria cause disease, many are harmless. Some are actually really useful to humans. People use them to make foods like yoghurt and cheese. Others are used in sewage treatment and to make medicines. Bacteria are vital as decomposers in food chains and webs, and in natural cycles such as the carbon and nitrogen cycles. They are also an important part of a healthy gut.
Comparing eukaryotic cells with prokaryotic cells

As you have seen, all living things are made of cells. Prokaryotic organisms such as bacteria are often made of single cells. Eukaryotic organisms are often multicellular, including plants, fish, and people.

- **Prokaryotic cells** are smaller and simpler than eukaryotic cells. They are often an order of magnitude smaller than plant cells, for example. They do not have a nucleus or any other membrane-bound organelles. They have a cell wall, but it is not made of cellulose.

- **Eukaryotic cells** are larger and more complex than prokaryotic cells. They all have a nucleus, although a few types, such as red blood cells, lose their nucleus as they grow and mature. They have many different cell organelles, all surrounded by membranes. Plant cells have cell walls made of cellulose.

The main similarities and differences are summarised in the following table:

<table>
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<tr>
<th>Prokaryotic cells</th>
<th>Eukaryotic cells</th>
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<tbody>
<tr>
<td>Very small cells often less than 5 μm</td>
<td>Bigger cells usually between 10 and 100 μm</td>
</tr>
<tr>
<td>No nucleus – loop of DNA</td>
<td>Membrane-bound nucleus containing DNA</td>
</tr>
<tr>
<td>No membrane-bound organelles</td>
<td>Membrane-bound organelles</td>
</tr>
<tr>
<td>Cell wall not made of cellulose</td>
<td>Animal cells have no cell wall, plant cells have cellulose cell wall</td>
</tr>
<tr>
<td>Some genes may be in separate circular structures called plasmids</td>
<td>No plasmids</td>
</tr>
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</table>

Figure 3 These scanning electron micrographs show prokaryotic bacterial cells on the right and eukaryotic human cells on the left, balanced on the end of a pin. The bacteria are magnified more than ×1500, but the human cells are only magnified around ×300 – yet they are still much bigger.

Summary questions

1. **a** What is unusual about the genetic material in bacterial cells?
   **b** Which are bigger, bacterial cells or human cells?
   **c** What is the difference between the cell walls of plant cells and the cell walls of bacteria?

2. Explain how bacteria are both useful and/or damaging to people.

3. Make a table to compare the structures in animal, plant, algal, and bacterial cells.

**Key points**

- A bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall. The genes are not in a distinct nucleus. Some of the genes are in circular structures called plasmids.

- Animal and plant cells are eukaryotic cells and bacterial cells are prokaryotic cells.
Learning objectives

After this topic, you should know:
- that cells may be specialised to carry out a particular function.

1.3 Specialised cells

The smallest living organisms are single cells. They can carry out all of the functions of life. These functions range from feeding and respiration to excretion and reproduction.

Most organisms are bigger and are made up of lots of cells. Some of these cells become specialised in order to carry out particular jobs.

When a cell becomes specialised, its structure is adapted to suit the particular job it does. As a result, specialised cells often look very different to a typical plant or animal cell. Sometimes cells become so specialised that they only have one function within the body. Examples of this include sperm cells, egg cells, red blood cells, and nerve cells. Some specialised cells, such as egg and sperm cells, work individually. Others are adapted to work as part of a tissue, an organ, or a whole organism.

Fat cells

If you eat more food than you need, your body makes fat and stores it in fat cells. The fat can be broken down and used to transfer energy when it is needed. Fat cells help animals, including humans, to survive when food is in short supply. Thousands of fat cells together form adipose tissue.

Fat cells have three main adaptations:
- They have a small amount of cytoplasm and large amounts of fat.
- They have few mitochondria as the cell needs very little energy.
- They can expand – a fat cell can end up 1000 times its original size as it fills up with fat.

Cone cells from human eye

There are cone cells in the light-sensitive layer of your eye (the retina). They make it possible for you to see in colour.

Cone cells have three main adaptations:
- The outer segment contains a special chemical, a visual pigment, which changes chemically in coloured light. It needs energy to change back to its original form. The visual pigments are based on the vitamin A in your diet.
- The middle segment is packed full of mitochondria. The mitochondria transfer the energy needed to reform the visual pigment. This lets you see continually in colour.
- The final part of the cone cell is made up of specialised synapses that connect to the optic nerve. When coloured light makes your visual pigment change, a nerve impulse is triggered. This makes its way along the optic nerve to your brain.

Did you know ... ?

An adult human who is not overweight will typically have 30 to 50 billion fat cells in their body.

links

You can find out much more about the organisation of specialised cells into tissues, organs, and organ systems in 1.4 Tissues and organs and 1.5 Organ systems.
**Root hair cells**

You find root hair cells close to the tips of growing roots. Plants need to take in lots of water (and dissolved mineral ions). The root hair cells help them to take up water and mineral ions more efficiently. The water and mineral ions then pass easily across the root to the xylem tissue. The xylem tissue carries water and mineral ions up into the rest of the plant. Mineral ions are moved into the cell by active transport.

Root hair cells have two main adaptations:
- The root hairs increase the surface area for water to move into the cell.
- The root hair cells have a large permanent vacuole that speeds up the movement of water by osmosis from the soil across the root hair cell.

**Sperm cells**

Sperm cells are usually released a long way from the egg they are going to fertilise. They contain the genetic information from the male parent. Depending on the type of animal, sperm cells need to move through water or the female reproductive system to reach an egg. Then they have to break into the egg.

Sperm cells have several adaptations to make all this possible:
- A long tail whips from side to side and helps move the sperm towards the egg.
- The middle section is full of mitochondria, which provide the energy for the tail to work.
- The acrosome stores digestive enzymes for breaking down the outer layers of the egg.
- A large nucleus contains the genetic information to be passed on.

**Summary questions**

1. Make a table to explain how the structure of each cell discussed in this topic is adapted to its function.
2. **a** Muscle cells can contract (shorten) and are used to move the body around and also to move substances around your body. Muscle cells usually contain many mitochondria. Explain why this is an important adaptation.
   **b** The palisade cells are found near the top surface of a leaf. They contain many chloroplasts. Why is this an important adaptation?
3. Explain the types of features you would look for to decide on the function of an unknown specialised cell.

**Key points**

- Cells may be specialised to carry out a particular function.
- Examples of specialised cells are fat cells, cone cells, root hair cells, and sperm cells.
- Cells may be specialised to work as tissues, organs, or whole organisms.

**Practical**

**Observing specialised cells**

Try looking at different specialised cells under a microscope.

When you look at a specialised cell, there are two useful questions you can ask yourself:
- How is this cell different in structure from a generalised cell?
- How does the difference in structure help the cell to carry out its function?
Large **multicellular organisms** have to overcome problems linked to their size. They develop different ways of exchanging materials. During the development of a multicellular organism, cells **differentiate**. They become specialised to carry out particular jobs. For example, in animals, muscle cells have a different structure to blood cells and nerve cells. In plants, the cells where photosynthesis takes place are very different to root hair cells.

However, the adaptations of multicellular organisms go beyond specialised cells. Similar specialised cells are often found grouped together to form a tissue.

## Tissues

A **tissue** is a group of cells with similar structure and function working together. **Muscular tissue** can contract to bring about movement. **Glandular tissue** contains secretory cells that can produce and **secrete** (release) substances such as enzymes and hormones. **Epithelial tissue** covers the outside of your body as well as your internal organs.

Plants have tissues too. **Epidermal tissues** cover the surfaces and protect them. **Palisade mesophyll** contains lots of chloroplasts and can carry out photosynthesis, whilst **spongy mesophyll** has some chloroplasts for photosynthesis but also has big air spaces and a large surface area to make the diffusion of gases easier. **Xylem** and **phloem** are the transport tissues in plants. They carry water and dissolved mineral ions from the roots up to the leaves and transport dissolved food from the leaves around the plant.

## Organs

**Organs** are made up of tissues. One organ can contain several tissues, all working together. For example, the stomach is an organ involved in the digestion of your food. It contains:

- muscular tissue, to churn the food and **digestive juices** together and move the contents through the digestive system
- glandular tissue, to produce the digestive juices that break down food
- epithelial tissue, which covers the inside and the outside of the organ.

---

**Figure 1** Muscle tissue contracts to move your skeleton around

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**Figure 2** The stomach contains several different tissues, each with a different function in the organ
The pancreas is an organ that has two important functions. It makes hormones to control our blood glucose, as well as some of the enzymes that digest our food. It contains two very different types of glandular tissue to produce these different secretions.

### Plant organs

Animals are not the only organisms to have organs – plants do, too.

Plants have differentiated cells that form specialised tissues. Within the body of a plant, tissues such as the palisade and spongy mesophyll, xylem, and phloem are arranged to form organs. Each organ carries out its own particular functions.

Plant organs include the leaves, stems, and roots, each of which has a very specific job to do (Figure 3).

![Figure 3](image)

**Figure 3** Plants have specific tissues to carry out particular functions. They are arranged in organs such as **a** the leaf, **b** the stem, and **c** the roots

To summarise, whether in a plant or an animal, an organ is a collection of different tissues working together to carry out important functions for the organism.

### Summary questions

1. **a** What is a tissue?  
   **b** What is an organ?

2. State whether each of the following is a specialised cell, a tissue, or an organ and explain your answer:  
   **a** sperm  
   **b** kidney  
   **c** stomach.

3. **a** Explain how the tissues in a leaf are arranged to form an effective organ for photosynthesis.  
   **b** Explain how the stomach is adapted for its role in the digestion of food.

### Key points

- A tissue is a group of cells with similar structure and function.
- Organs are made of tissues. One organ may contain several types of tissue.
- Animal organs include the stomach and the heart.
- Plant organs include stems, roots, and leaves.
Organ systems

A whole multicellular organism is made up of a number of organ systems working together. Organ systems are groups of organs that all work together to perform a particular function. The way one organ functions often depends on other organs in the system. The human digestive system is a good example of an organ system.

The digestive system

The digestive system is one of several organ systems that make it possible for mammals and other animals to exchange substances with the environment. The food you eat is made up of large insoluble molecules. Your body cannot take these molecules in and use them. They need to be digested (broken down) into smaller, soluble molecules that can be absorbed into your bloodstream and used by your cells. This is the function of your digestive system. The digestive system is made up of many different organs that all work together. They include:

- Mouth (containing teeth, tongue, and salivary glands)
- Oesophagus
- Stomach
- Pancreas
- Gall bladder
- Duodenum
- Bile duct
- Liver
- Small intestine
- Large intestine
- Diaphragm
- Anus
Organ systems

Organ systems are groups of organs that perform a particular function. The digestive system in a mammal is an example of a system where substances are exchanged with the environment.

**Key points**

- Organ systems are groups of organs that perform a particular function.
- The digestive system in a mammal is an example of a system where substances are exchanged with the environment.

---

**Part of the digestive system**

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glands (e.g. salivary glands, the pancreas)</td>
</tr>
<tr>
<td>Stomach</td>
</tr>
<tr>
<td>Liver</td>
</tr>
<tr>
<td>Small intestine</td>
</tr>
<tr>
<td>Large intestine</td>
</tr>
</tbody>
</table>

---

**Did you know ... ?**

The human digestive system is between 6 m and 9 m long. That is about 9 million times longer than an average human cell!

You will learn a lot more about the human digestive system and how it works in Chapter 5. Other human organ systems include:
- the breathing system, which allows the body to exchange the gases oxygen and carbon dioxide with the environment
- the cardiovascular system (the heart and the blood vessels), which carries substances to and from the cells of the body.

**Plant organ systems**

In small plants, the whole body works as an organ system with the roots, stems, and leaves working together to allow the plant to exchange substances with the environment. For example, water comes into the plant through the roots, is carried through the plant in the stems, and is lost into the environment again through the leaves. You will learn more about how plant organ systems work in Chapter 9.

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**Summary questions**

1. Match each organ (A–D) to its correct function (1–4):

| A | Stem | 1 | Breaking down large insoluble molecules into smaller soluble molecules |
| B | Root | 2 | Photosynthesising in plants |
| C | Small intestine | 3 | Providing support in plants |
| D | Leaf | 4 | Anchoring plants and obtaining water and minerals from soil |

2. Explain the difference between organs and organ systems, giving two examples.

3. Using the human digestive system as an example, explain how the organs in an organ system rely on each other to function properly.
Diffusion

Your cells need to take in substances such as glucose and oxygen for respiration. Cells also need to get rid of waste products and release chemicals that are needed elsewhere in your body. Dissolved substances and gases can move into and out of your cells across the cell membrane. One of the main ways in which they move is by diffusion.

Diffusion

Diffusion is the spreading out of the particles of a gas, or of any substance in solution (a solute). This results in the net movement (overall movement) of particles. The net movement is from an area of high concentration to an area of lower concentration. It takes place because of the random movement of the particles. The motion of the particles causes them to bump into each other, and this moves them all around.

Imagine a room containing a group of boys and a group of girls. If everyone closes their eyes and moves around briskly but randomly, children will bump into each other. They will scatter until the room contains a mixture of boys and girls. This gives you a good model of diffusion (Figure 1).

Rate of diffusion

If there is a big difference in concentration between two areas, diffusion will take place quickly. Many particles will move randomly towards the area of low concentration. Only a few will move randomly in the other direction.

However, if there is only a small difference in concentration between two areas, the net movement by diffusion will be quite slow. The number of particles moving into the area of lower concentration by random movement will only be slightly more than the number of particles that are leaving the area.

\[ \text{net movement} = \text{particles moving in} - \text{particles moving out} \]

In general, the greater the difference in concentration, the faster the rate of diffusion. This difference between two areas of concentration is called the concentration gradient. The bigger the difference, the steeper the concentration gradient and the faster the rate of diffusion. In other words, diffusion occurs down a concentration gradient (Figure 2).

Temperature also affects the rate of diffusion. An increase in temperature means the particles in a gas or a solution move around more quickly. When this happens, diffusion takes place more rapidly as the random movement of the particles speeds up.
Diffusion

Key points

- Diffusion is the net movement of particles from an area where they are at a high concentration to an area where they are at a lower concentration, down a concentration gradient.
- The greater the difference in concentration, the faster the rate of diffusion.
- Dissolved substances such as glucose and gases such as oxygen move in and out of cells by diffusion.

1 Explain the process of diffusion in terms of the particles involved.
2 a Explain why diffusion takes place faster when there is an increase in temperature.
   b Explain in terms of diffusion why so many cells have folded membranes along at least one surface.
3 Explain the following statements in terms of diffusion:
   a Digested food products move from the inside of your gut into the bloodstream.
   b Carbon dioxide moves from the blood in the capillaries in your lungs to the air in the lungs.
   c Male moths can track down a mate from up to 3 miles away because of the special chemicals produced by the female.
Learning objectives
After this topic, you should know:
- what happens in osmosis
- why osmosis is so important in cells.

**Study tip**
Remember, all particles can diffuse from an area of high concentration to an area of lower concentration, provided they are soluble and small enough to pass through the membrane. Osmosis refers only to the diffusion of water through a partially permeable membrane.

Osmosis
Diffusion takes place when particles can spread freely from one place to another. However, the solutions inside cells are separated from those outside by the cell membrane. This membrane does not let all types of particles through. Membranes that only let some types of particles through are called partially permeable membranes.

**The process of osmosis**
Partially permeable cell membranes let water move across them. Remember:
- A *dilute* solution of sugar contains a *high* concentration of water (the solvent). It has a *low* concentration of sugar (the solute).
- A *concentrated* sugar solution contains a relatively *low* concentration of water and a *high* concentration of sugar.

The cytoplasm of a cell is made up of chemicals dissolved in water inside a partially permeable bag of cell membrane. The cytoplasm contains a fairly concentrated solution of salts and sugars. Water moves from a dilute solution (with a high concentration of water molecules) to a concentrated solution (with fewer water molecules) across the membrane of the cell.

This special type of diffusion, where water moves across a partially permeable membrane, is called osmosis.

The concentration inside your body cells needs to stay the same for them to work properly. However, the concentration of the solutions outside your cells may be very different to the concentration inside them. This concentration gradient can cause water to move into or out of the cells by osmosis.

- If the concentration of solutes in the solution outside the cell is *lower* than the concentration inside the cell, the solution is hypotonic to the cell.
- If the concentration of solutes in the solution outside the cell is *the same* as the concentration inside the cell, the solution is isotonic to the cell.
- If the concentration of solutes in the solution outside the cell is *higher* than the concentration inside the cell, the solution is hypertonic to the cell.

**Osmosis in animals**
If a cell uses up water in its chemical reactions, the cytoplasm becomes more concentrated. The surrounding fluid becomes hypotonic and more water immediately moves in by osmosis.

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**Investigating osmosis**
You can make model cells using bags made of partially permeable membrane (Figure 1). You can see what happens to them if the concentrations of the solutions inside or outside the ‘cells’ change.

- Sugar molecules
- Water molecules

*Figure 1* A model of osmosis in *a* cell. In *a* the ‘cell’ contents are more concentrated than the surrounding solution. In *b* the ‘cell’ contents are less concentrated than the surrounding solution.
If the cytoplasm becomes too dilute because more water is made in chemical reactions, the surrounding fluid becomes hypertonic and water leaves the cell by osmosis. So osmosis restores the balance in both cases.

However, osmosis can also cause big problems in animal cells. If the solution outside the cell becomes much more dilute than the cell contents (hypotonic), a lot of water will move into the cell by osmosis. The cell will swell and may burst.

If the solution outside the cell becomes more concentrated than the cell contents (hypertonic), water will move out of the cell by osmosis. The cytoplasm will become too concentrated and the cell will shrivel up. Then it can no longer survive.

Once you understand the effect osmosis can have on cells, the importance of maintaining constant internal conditions in the human body becomes clear.

**Osmosis in plants**

Plants rely on osmosis to support their stems and leaves. Water moves into plant cells by osmosis. This causes the vacuole to swell and press the cytoplasm against the plant cell walls. The pressure builds up until no more water can physically enter the cell – this pressure is known as **turgor**. Turgor pressure makes the cells hard and rigid, which in turn keeps the leaves and stems of the plant rigid and firm.

Plants need the fluid surrounding the cells to always be hypotonic to the cytoplasm, with a lower concentration of solutes and a higher concentration of water than the plant cells themselves. This keeps water moving by osmosis in the right direction and the cells are turgid. If the solution surrounding the plant cells is hypertonic to (more concentrated than) the cell contents, water will leave the cells by osmosis. The cells will no longer be firm and swollen – they become flaccid (soft) as there is no pressure on the cell walls. At this point, the plant wilts as turgor no longer supports the plant tissues.

If more water is lost by osmosis, the vacuole and cytoplasm shrink, and eventually the cell membrane pulls away from the cell wall. This is **plasmolysis**. Plasmolysis is usually only seen in laboratory experiments. Plasmolysed cells die quickly unless the osmotic balance is restored.

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**Study tip**

When writing about osmosis, be careful to specify whether it is the concentration of water or solutes you are referring to. Simply saying ‘higher concentration outside cell’ will gain no marks!

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**Summary questions**

1. **a** What is the difference between osmosis and simple diffusion?  
   **b** How does osmosis help to maintain the cytoplasm of plant and body cells at a specific concentration?

2. **a** Define the following terms:  
   i isotonic solution  
   ii hypotonic solution  
   iii hypertonic solution.  
   **b** Why is it so important for the cells of the human body that the solute concentration of the fluid surrounding the cells is kept as constant as possible?

3. Explain why osmosis is so important in the support systems of plants.

4. Animals that live in fresh water have a constant problem with their water balance. The single-celled organism called **Amoeba** has a special vacuole in its cell. It fills with water and then moves to the outside of the cell and bursts. A new vacuole starts forming straight away. Explain in terms of osmosis why the **Amoeba** needs one of these vacuoles.
Support those students who don't speak English as a first language with clear language, an extensive glossary and highlighted.