



EDEXCEL INTERNATIONAL GCSE (9–1)

BIOLOGY

Student Book

Philip Bradfield and Steve Potter



PEARSON EDEXCEL INTERNATIONAL
GCSE (9–1)

BIOLOGY

Student Book

Phil Bradfield
Steve Potter

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ABOUT THIS BOOK

This book is written for students following the Pearson Edexcel International GCSE (9–1) Biology specification and the Edexcel International GCSE (9–1) Science Double Award specification. You will need to study all of the content in this book for your Biology examinations. However, you will only need to study some of it if you are taking the Double Award specification. The book clearly indicates which content is in the Biology examinations and not in the Double Award specification. To complete the Double Award course you will also need to study the Physics and Chemistry parts of the course.

In each unit of this book, there are concise explanations and worked examples, plus numerous exercises that will help you build up confidence. The book also describes the methods for carrying out all of the required practicals.

The language throughout this textbook is graded for speakers of English as an additional language (EAL), with advanced Biology-specific terminology highlighted and defined in the glossary at the back of the book. A list of command words, also at the back of the book, will help you to learn the language you will need in your examination.

You will also find that questions in this book have Progression icons and Skills tags. The Progression icons refer to Pearson's Progression scale. This scale – from 1 to 12 – tells you what level you have reached in your learning and will help you to see what you need to do to progress to the next level. Furthermore, Edexcel have developed a Skills grid showing the skills you will practise throughout your time on the course. The skills in the grid have been matched to questions in this book to help you see which skills you are developing. Both skills and Progression icons are not repeated where they are same in consecutive questions. You can find Pearson's Progression scale at www.pearsonglobalschools.com/igscienceprogression along with guidelines on how to use it.

Learning Objectives show what you will learn in each lesson.

Key Point boxes summarise the essentials.

104 ANIMAL PHYSIOLOGY HOMEOSTASIS AND EXCRETION

8 HOMEOSTASIS AND EXCRETION

The kidneys have major roles to play in both homeostasis and excretion. This chapter is mainly concerned with the structure and function of the kidneys. It also deals with another important aspect of homeostasis – maintaining a steady body temperature.

LEARNING OBJECTIVES

- Understand that homeostasis is the maintenance of a constant internal environment
- Understand that control of body water content and body temperature are examples of homeostasis
- Know the excretory products of the lungs, kidneys and skin
- Understand the origin of carbon dioxide and oxygen as waste products of metabolism and their loss from the stomata of a leaf

BIOLOGY ONLY

- Understand that urine contains water, urea and ions
- Understand how the kidney carries out its roles of excretion and osmoregulation
- Describe the structure of the urinary system, including the kidneys, ureters, bladder and urethra

BIOLOGY ONLY

- Describe the structure of a nephron, including the Bowman's capsule and glomerulus, convoluted tubules, loop of Henle and collecting duct
- Describe ultrafiltration in the Bowman's capsule and the composition of the glomerular filtrate
- Understand why selective reabsorption of glucose occurs at the proximal convoluted tubule
- Understand how water is reabsorbed into the blood from the collecting duct
- Describe the role of ADH in regulating the water content of the blood
- Describe the role of the skin in temperature regulation, with reference to sweating, vasoconstriction and vasodilation

Inside our bodies, conditions are kept relatively constant. This is called **homeostasis**. The kidneys are organs which have a major role to play in both homeostasis and in the removal of waste products, or **excretion**. They filter the blood, removing substances and controlling the concentration of water and solutes (dissolved substances) in the blood and other body fluids.

KEY POINT

The meaning of 'homeostasis' is 'keeping the conditions in the internal environment of the body relatively constant'. One aspect of homeostasis is the maintenance of the water and salt content of the internal environment. This is called **osmoregulation**.

HOMEOSTASIS

If you were to drink a litre of water and wait for half an hour, your body would soon respond to this change by producing about the same volume of urine. In other words, it would automatically balance your water input and water loss. Drinking is the main way that our bodies gain water, but there are other sources (Figure 8.1). Some water is present in the food that we eat, and a small amount is formed by cell respiration. The body also loses water, mostly in urine, but also smaller volumes in sweat, faeces and exhaled air. Every day, we gain and lose about the same volume of water, so that the total content of our bodies stays more or less the same. This is an example of homeostasis. The word 'homeostasis' means 'steady state', and refers to keeping conditions inside the body relatively constant.

The inside of the body is known as the **internal environment**. You have probably heard of the 'environment', which means the 'surroundings' of an organism. The internal environment is the surroundings of the cells inside the body. It particularly means the blood, together with another liquid called **tissue fluid**.

Looking Ahead tells you what you would learn if you continued your study of Biology to a higher level, such as International A Level.

Biology only features show the content that is on the Biology specification only and not the Double Award specification. All other content in this book applies to Double Award students.

136 PLANT PHYSIOLOGY PLANTS AND FOOD

ACTIVITY 1

PRACTICAL: TESTING LEAVES FOR STARCH

You can test for starch in food by adding a few drops of yellow-brown iodine solution (see Chapter 4). If the food contains starch, a blue-black colour is produced.

Leaves that have been in sunlight also contain starch, but you can't test for it by adding iodine solution to a fresh leaf. The outer waxy surface of the leaf will not absorb the solution, and besides, the green colour of the leaf would hide the colour change. To test for starch in a leaf, the outer waxy layer needs to be removed and the leaf decolourised. This is done by placing the leaf in boiling ethanol (see Figure 10.2).

The Bunsen burner is turned off (this is important because ethanol is highly flammable), the leaf is placed in a boiling tube containing ethanol, and the tube is placed in the beaker of hot water. The boiling point of ethanol (about 78 °C) is lower than that of water (100 °C) so the ethanol will boil for a few minutes, until the water cools down. This is long enough to remove most of the chlorophyll from the leaf.

When the leaf has turned colourless or pale yellow, it is removed and washed in cold water to soften it, then spread out on a tile and covered with a few drops of iodine solution. After a few minutes, any parts of the leaf that contain starch will turn a dark blue-black colour. This only works if the plant has had plenty of light for some hours before the test.

Safety Note: Wash your hands after handling the leaves. Take care not to splash boiling water. Do not treat the ethanol directly with any flame as a beaker of hot water. Iodine solution will badly stain everything – including skin.

TURN OFF BUNSEN BURNER

Figure 10.2 How to test a leaf for starch

Practicals describe the methods for carrying out all of the practicals you will need to know for your examination.

PLANT PHYSIOLOGY CHEMICAL COORDINATION IN PLANTS 171

Experiment 3

tip removed and placed on agar block for several hours

tip discarded and agar block placed on one side of decolourized coleoptile

bending occurs in absence of unidirectional light

Figure 12.6 Experiments on coleoptiles that helped to explain the mechanism of phototropism.

In experiment 1, it was shown that the phototropic response could be brought about, even without unidirectional light, by removing a coleoptile tip (decapitating the coleoptile) and placing the tip on one side of the decapitated stalk.

In experiment 2, it was found that the phototropic response could be collected in another water-absorbing material (a block of agar jelly). Placing the agar block on one side of the decapitated coleoptile stalk caused it to bend.

Investigations like experiments 2 and 3 led scientists to believe that the hormone caused bending by stimulating growth on the side of the coleoptile furthest from the light. The theory is that the hormone is produced in the tip of the shoot, and diffuses back down the shoot. If the shoot is in the dark, or if light is all around the shoot, the hormone diffuses at equal rates on each side of the shoot, so it stimulates the shoot equally on all sides. However, if the shoot is receiving light from one direction, the hormone moves away from the light as it diffuses downwards. The higher concentration of hormone on the 'dark' side of the shoot stimulates cells there to grow, making the shoot bend towards the light (Figure 12.7).

EXTENSION WORK

'Auxin' should really be 'auxins', since there are a number of chemicals with very similar structures making up a group of closely related plant hormones.

EXTENSION WORK

As well as auxins, there are four other main groups of plant hormones, called gibberellins, cytokinins, abscisic acid and ethene. They control many aspects of plant growth and development, apart from tropisms. These include growth of buds, leaves and fruit, fruit ripening, seed germination, leaf fall and opening of stomata, to name just a few.

USING A CLIMATAT TO SHOW TROPISMS

A climatostat is a piece of apparatus consisting of an electric motor turning a cork disc. Germinating seeds are attached to the disc. The motor turns the disc and seeds around very slowly, so that the movement eliminates the effect of any directional stimulus that may be acting on the seeds. The climatostat can be turned through 90°, so that the disc rotates either horizontally or vertically.

Extension work boxes include content that is not on the specification and which you do not have to learn for your examination. However, the content will help to extend your understanding of the topic.

300 MICROORGANISMS AND GENETIC MODIFICATION GENETIC MODIFICATION

SKILLS ANALYSIS

5 The diagram shows the main stages in transferring the human insulin gene to a bacterium.

SKILLS CRITICAL THINKING

a Name the enzymes used at stages 1 and 2.

b What is the role of the plasmid in this procedure?

c How would the insulin-producing bacteria be used to produce significant amounts of insulin?

SKILLS REASONING

d Why is the insulin produced this way preferred to insulin extracted from other animals?

SKILLS INTRAPERSONAL

6 Carry out some research to find out more about the use of transgenic animals for organ transplantation. What are the arguments for and against its use? What are the ethical objections?

SKILLS CRITICAL THINKING

7 Producing genetically modified plants and animals is more complex than producing genetically modified bacteria.

a Describe two ways in which genes can be introduced into plant cells.

b How are these genetically modified cells used to produce whole organisms?

c What sort of animal cell is genetically modified and then used to produce the whole organism?

SKILLS INTRAPERSONAL

8 Write an essay about the importance of genetic engineering. In your essay you should make reference to:

a important potential benefits resulting from genetic engineering in animals and plants

b concerns about the risks resulting from genetic engineering in animals and plants.

Skills tags tell you which skills you are practising in each question.

Chapter Questions test your knowledge of the topic in that chapter.

Progression icons show the level of difficulty according to the Pearson International GCSE Science Progression Scale.

Unit Questions test your knowledge of the whole unit and provide quick, effective feedback on your progress.

MICROORGANISMS AND GENETIC MODIFICATION UNIT QUESTIONS 301

UNIT QUESTIONS

SKILLS CRITICAL THINKING

1 Some experimental sheep were genetically modified, using a human gene. The gene codes for a protein involved in blood clotting, called factor IX. The gene for factor IX was cut from human DNA and injected into a sheep body cell. The nucleus of this body cell was transferred to an enucleated sheep ovum. The ovum was cultured in a dish and then implanted in the uterus of a surrogate sheep to complete its development.

Two lambs produced by this method grew to maturity. They produced milk from which Factor IX could be extracted.

a Name an enzyme that can be used to cut DNA. (1)

b What is an enucleated ovum? (2)

c The sheep produced by this method are called transgenic. What is meant by this term? (1)

SKILLS REASONING

d The transgenic sheep were reproduced by cloning. What are the advantages of producing the sheep in this way? (3)

SKILLS CRITICAL THINKING

e Factor IX can be used to treat people with a blood clotting disorder called haemophilia. Why is important to have blood that clots? (2)

f Blood contains plasma, white blood cells, red blood cells and platelets. Which two components of the blood are involved with blood clotting? (2)

Total 11 marks

SKILLS CRITICAL THINKING

2 Some genes are transferred from one plant species to another. These genes are called 'jumping genes'. Environmentalists are concerned that genetically modified plants may transfer some of their genes to wild species. Explain their concern about genetically modified plants that:

a have genes that make them resistant to herbicides (weedkillers) (2)

b have genes that make them resistant to pests (2)

c have genes that increase the yield of the crop they can produce. (2)

Total 6 marks

ASSESSMENT OVERVIEW

The following tables give an overview of the assessment for this course.

We recommend that you study this information closely to help ensure that you are fully prepared for this course and know exactly what to expect in the assessment.

PAPER 1	SPECIFICATION	PERCENTAGE	MARK	TIME	AVAILABILITY
Written examination paper Paper code 4BI1/1B and 4SD0/1B Externally set and assessed by Edexcel	Biology Science Double Award	61.1%	110	2 hours	January and June examination series First assessment June 2019
PAPER 2	SPECIFICATION	PERCENTAGE	MARK	TIME	AVAILABILITY
Written examination paper Paper code 4BI1/2B Externally set and assessed by Edexcel	Biology	38.9%	70	1 hour 15 mins	January and June examination series First assessment June 2019

If you are studying Biology then you will take both Papers 1 and 2. If you are studying Science Double Award then you will only need to take Paper 1 (along with Paper 1 for each of the Physics and Chemistry courses).

ASSESSMENT OBJECTIVES AND WEIGHTINGS

ASSESSMENT OBJECTIVE	DESCRIPTION	% IN INTERNATIONAL GCSE
AO1	Knowledge and understanding of biology	38%–42%
AO2	Application of knowledge and understanding, analysis and evaluation of biology	38%–42%
AO3	Experimental skills, analysis and evaluation of data and methods in biology	19%–21%

EXPERIMENTAL SKILLS

In the assessment of experimental skills, students may be tested on their ability to:

- solve problems set in a practical context
- apply scientific knowledge and understanding in questions with a practical context
- devise and plan investigations, using scientific knowledge and understanding when selecting appropriate techniques
- demonstrate or describe appropriate experimental and investigative methods, including safe and skilful practical techniques
- make observations and measurements with appropriate precision, record these methodically and present them in appropriate ways
- identify independent, dependent and control variables
- use scientific knowledge and understanding to analyse and interpret data to draw conclusions from experimental activities that are consistent with the evidence
- communicate the findings from experimental activities, using appropriate technical language, relevant calculations and graphs
- assess the reliability of an experimental activity
- evaluate data and methods taking into account factors that affect accuracy and validity.

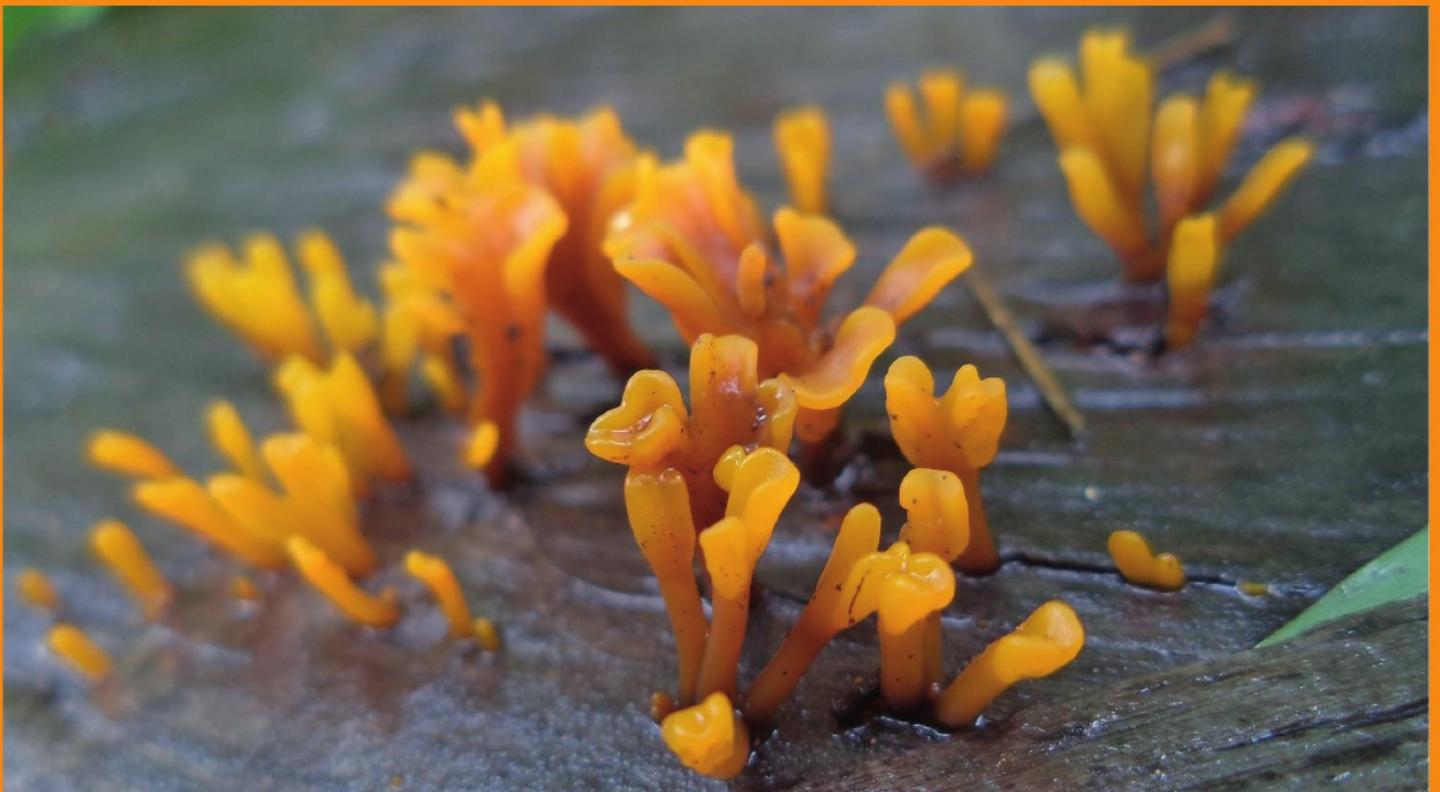
CALCULATORS

Students are permitted to take a suitable calculator into the examinations. Calculators with QWERTY keyboards or that can retrieve text or formulae will not be permitted.

UNIT 1

ORGANISMS AND LIFE PROCESSES

All living organisms are composed of microscopic units known as cells. These building blocks of life have a number of features in common, which allow them to grow, reproduce, and generate more organisms. In Chapter 1 we start by looking at the structure and function of cells, and the essential life processes that go on within them. Despite the fact that cells are similar in structure, there are many millions of different species of organisms. Chapter 2 looks at the diversity of living things and how we can classify them into groups on the basis of the features that they show.



1 LIFE PROCESSES

There are structural features that are common to the cells of all living organisms. In this chapter you will find out about these features and look at some of the processes that keep cells alive.

LEARNING OBJECTIVES

- Understand the characteristics shared by living organisms
 - Describe cell structures and their functions, including the nucleus, cytoplasm, cell membrane, cell wall, mitochondria, chloroplasts, ribosomes and vacuole
 - Know the similarities and differences in the structures of plant and animal cells
 - Understand the role of enzymes as biological catalysts in metabolic reactions
 - Understand how temperature changes can affect enzyme function, including changes to the shape of the active site
 - Understand how enzyme function can be affected by changes in pH altering the active site
 - Investigate how enzyme activity can be affected by changes in temperature
- BIOLOGY ONLY**
- Investigate how enzyme activity can be affected by changes in pH
- Describe the differences between aerobic and anaerobic respiration
 - Understand how the process of respiration produces ATP in living organisms
- Know that ATP provides energy for cells
 - Know the word equation and balanced chemical symbol equation for aerobic respiration
 - Know the word equations for anaerobic respiration
 - Investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms
 - Understand the processes of diffusion, osmosis and active transport by which substances move into and out of cells
 - Understand how factors affect the rate of movement of substances into and out of cells
 - Investigate diffusion in a non-living system (agar jelly)
- BIOLOGY ONLY**
- Explain the importance of cell differentiation in the development of specialised cells
- Describe the levels of organisation within organisms – organelles, cells, tissues, organ systems
- BIOLOGY ONLY**
- Understand the advantages and disadvantages of using stem cells in medicine.

All living organisms are composed of units called **cells**. The simplest organisms are made from single cells (Figure 1.1) but more complex plants and animals are composed of millions of cells. In many-celled (**multicellular**) organisms, there may be hundreds of different types of cells with different structures. They are specialised so that they can carry out particular functions in the animal or plant. Despite all the differences, there are basic features that are the same in all cells.



▲ Figure 1.1 Many simple organisms have 'bodies' made from single cells. Here are four examples.

There are eight life processes which take place in most living things.

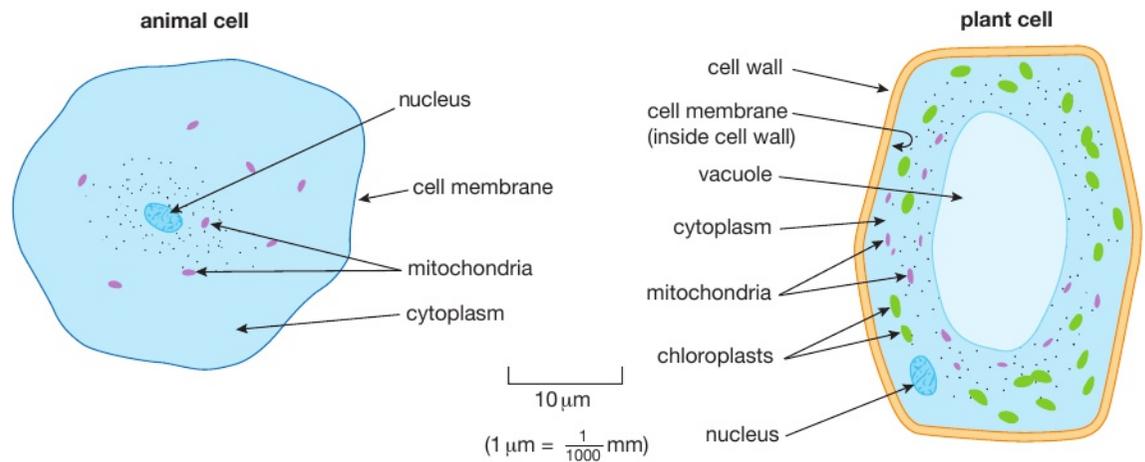
Organisms:

- require nutrition – plants make their own food, animals eat other organisms
- respire – release energy from their food
- excrete – get rid of waste products
- respond to stimuli – are sensitive to changes in their surroundings
- move – by the action of muscles in animals, and slow growth movements in plants
- control their internal conditions – maintain a steady state inside the body
- reproduce – produce offspring
- grow and develop – increase in size and complexity, using materials from their food.

CELL STRUCTURE

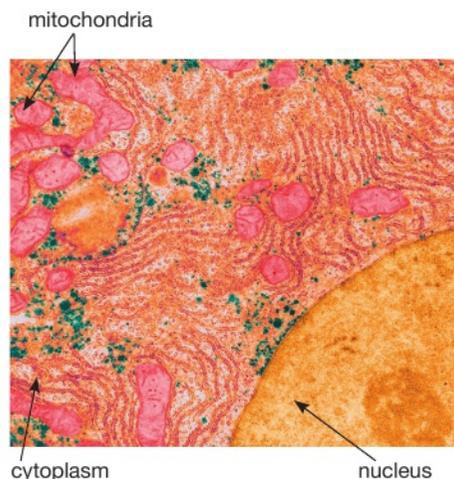
This part of the book describes the cell structure of ‘higher’ organisms such as animals, plants and fungi. The cells of bacteria are simpler in structure and will be described in Chapter 2.

Most cells contain certain parts such as the nucleus, cytoplasm and cell membrane. Some cells have structures missing, for instance red blood cells are unusual in that they have no nucleus. The first chapter in a biology textbook will usually present diagrams of ‘typical’ plant and animal cells. In fact, there is really no such thing as a ‘typical’ cell. Humans, for example, are composed of hundreds of different kinds of cells – from nerve cells to blood cells, skin cells to liver cells. What we really mean by a ‘typical’ cell is a general diagram that shows all the features that you will find in most cells (Figure 1.2). However, not all these are present in *all* cells – for example the cells in the parts of a plant that are not green do not contain chloroplasts.



▲ Figure 1.2 The structure of a ‘typical’ animal and plant cell.

The living material that makes up a cell is called **cytoplasm**. It has a texture rather like sloppy jelly, in other words somewhere between a solid and a liquid. Unlike a jelly, it is not made of one substance but is a complex material made of many different structures. You can’t see many of these structures under an ordinary light microscope. An electron microscope has a much higher magnification and can show the details of these structures, which are called **organelles** (Figure 1.3).



▲ Figure 1.3 The organelles in a cell can be seen using an electron microscope.

The largest organelle in the cell is the **nucleus**. Nearly all cells have a nucleus. The few types that don't are usually dead (e.g. the xylem vessels in a stem, Chapter 11) or don't live for very long (e.g. red blood cells, Chapter 5). The nucleus controls the activities of the cell. It contains **chromosomes** (46 in human cells) which carry the genetic material, or **genes**. Genes control the activities in the cell by determining which proteins the cell can make. The DNA remains in the nucleus, but the instructions for making proteins are carried out of the nucleus to the cytoplasm, where the proteins are assembled on tiny structures called **ribosomes**. A cell contains thousands of ribosomes, but they are too small to be seen through a light microscope.

One very important group of proteins found in cells are **enzymes**. Enzymes control the chemical reactions that take place in the cytoplasm.

All cells are surrounded by a **cell membrane**, sometimes called the cell *surface* membrane to distinguish it from other membranes inside the cell. This is a thin layer like a 'skin' on the surface of the cell. It forms a boundary between the cytoplasm of the cell and the outside. However, it is not a complete barrier. Some chemicals can pass into the cell and others can pass out. We say that the membrane is **partially permeable**. The membrane can go further than this and actually *control* the movement of some substances – it is **selectively permeable**.

One organelle that is found in the cytoplasm of all living cells is the **mitochondrion** (plural mitochondria). In cells that need a lot of energy such as muscle or nerve cells, there are many mitochondria. This gives us a clue to their function. They carry out some of the reactions of **respiration** (see page 12) releasing energy that the cell can use. Most of the energy from respiration is released in the mitochondria.

PLANT CELLS

All of the structures you have seen so far are found in both animal and plant cells. However, some structures are only ever found in plant cells. There are three in particular – the cell wall, a permanent vacuole and chloroplasts.

The **cell wall** is a layer of non-living material that is found outside the cell membrane of plant cells. It is made mainly of a carbohydrate called **cellulose**, although other chemicals may be added to the wall in some cells. Cellulose is a tough material that helps the cell keep its shape and is one reason why the 'body' of a plant has a fixed shape. Animal cells do not have a cell wall and tend to be more variable in shape. Plant cells absorb water, producing an internal pressure that pushes against adjacent cells, giving the plant support (see Chapter 11). Without a cell wall strong enough to resist these pressures, this method of support would be impossible. The cell wall is porous, so it is not a barrier to water or dissolved substances. We call it *freely permeable*.

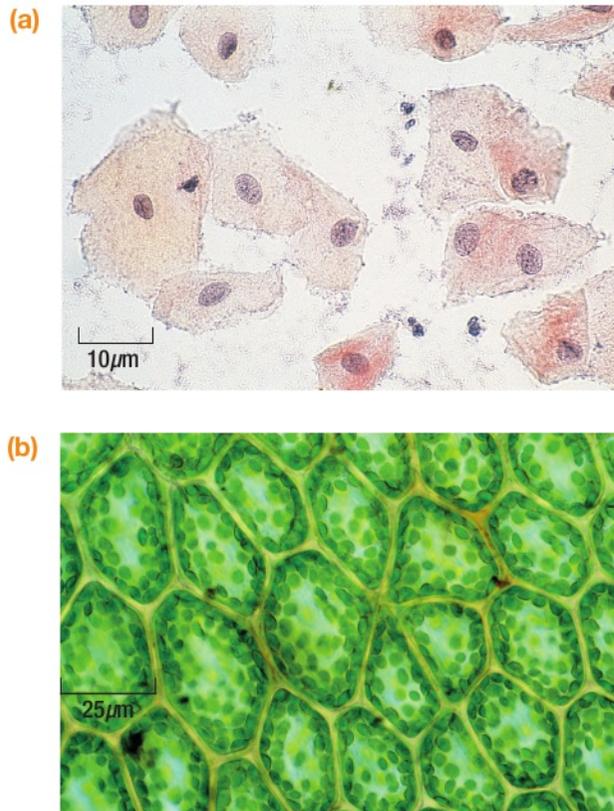
Mature (fully grown) plant cells often have a large central space surrounded by a membrane, called a **vacuole**. This vacuole is a permanent feature of the cell. It is filled with a watery liquid called cell sap, which is a store of dissolved sugars, mineral ions and other solutes. Animal cells do contain vacuoles, but they are only small, temporary structures.

Cells of the green parts of plants, especially the leaves, contain another very important organelle, the **chloroplast**. Chloroplasts absorb light energy to make food in the process of photosynthesis (see Chapter 10). They contain a green pigment called **chlorophyll**. Cells from the parts of a plant that are not green, such as the flowers, roots and woody stems, have no chloroplasts.

KEY POINT

Nearly all cells contain cytoplasm, a nucleus, a cell membrane and mitochondria. As well as these structures, plant cells have a cell wall and a permanent vacuole, and plant cells that photosynthesise contain chloroplasts.

Figure 1.4 shows some animal and plant cells seen through the light microscope.



▲ Figure 1.4 (a) Cells from the lining of a human cheek. (b) Cells from the photosynthetic tissue of a leaf.

KEY POINT

The chemical reactions taking place in a cell are known as metabolic reactions. The sum of all the metabolic reactions is known as the **metabolism** of the cell. The function of enzymes is to catalyse metabolic reactions.

KEY POINT

You have probably heard of enzymes being involved in digestion of food. In the intestine enzymes are secreted onto the food to break it down. These are called *extracellular* enzymes, which means they function 'outside cells'. However, most enzymes stay inside cells and carry out their function there; they are *intracellular*. You will find out about digestive enzymes in Chapter 4.

KEY POINT

Secretion is the release of a fluid or substances from a cell or tissue.

ENZYMES: CONTROLLING REACTIONS IN THE CELL

The chemical reactions that take place in a cell are controlled by a group of proteins called enzymes. Enzymes are biological **catalysts**. A catalyst is a chemical which speeds up a reaction without being used up itself. It takes part in the reaction, but afterwards is unchanged and free to catalyse more reactions. Cells contain hundreds of different enzymes, each catalysing a different reaction. This is how the activities of a cell are controlled – the nucleus contains the genes, which control the production of enzymes, which then catalyse reactions in the cytoplasm:

genes → proteins (enzymes) → catalyse reactions

Everything a cell does depends on which enzymes it can make, which in turn depends on which genes in its nucleus are working.

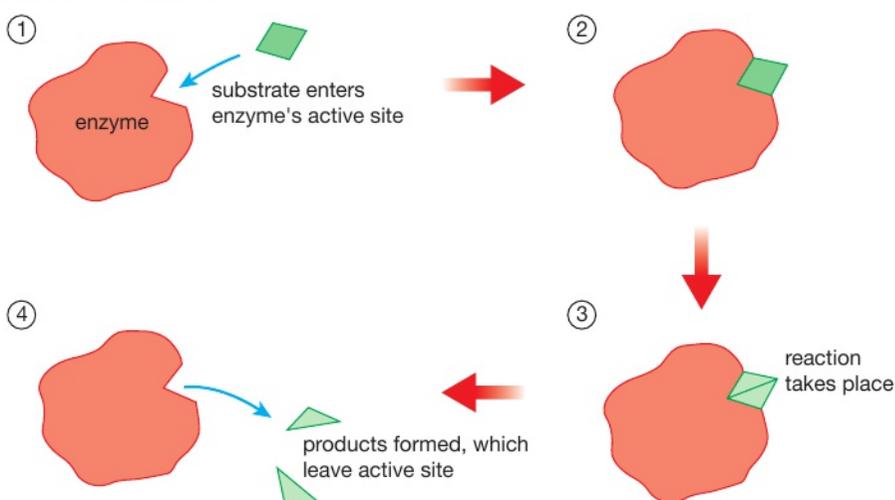
What hasn't been mentioned is why enzymes are needed at all. They are necessary because the temperatures inside organisms are low (e.g. the human body temperature is about 37 °C) and without catalysts, most of the reactions that happen in cells would be far too slow to allow life to go on. The reactions can only take place quickly enough when enzymes are present to speed them up.

It is possible for there to be thousands of different sorts of enzymes because they are proteins, and protein molecules have an enormous range of structures and shapes (see Chapter 4).

The molecule that an enzyme acts on is called its **substrate**. Each enzyme has a small area on its surface called the **active site**. The substrate attaches to the active site of the enzyme. The reaction then takes place and products are formed. When the substrate joins up with the active site it lowers the energy needed for the reaction to start, allowing the products to be formed more easily.

Enzymes also catalyse reactions where large molecules are built up from smaller ones. In this case, several substrate molecules attach to the active site, the reaction takes place and the larger product molecule is formed. The product then leaves the active site.

The substrate fits into the active site of the enzyme like a key fitting into a lock. Just as a key will only fit one lock, a substrate will only fit into the active site of a particular enzyme. This is known as the **lock and key model** of enzyme action. It is the reason why enzymes are *specific*, i.e. an enzyme will only catalyse one reaction.



▲ Figure 1.5 Enzymes catalyse reactions at their active site. This acts like a 'lock' to the substrate 'key'. The substrate fits into the active site, and products are formed. This happens more easily than without the enzyme – so enzymes act as catalysts.

After an enzyme molecule has catalysed a reaction, the product is released from the active site, and the enzyme is free to act on more substrate molecules.

FACTORS AFFECTING ENZYMES

KEY POINT

'Optimum' temperature means the 'best' temperature, in other words the temperature at which the reaction takes place most rapidly.

DID YOU KNOW?

Kinetic energy is the energy an object has because of its movement. The molecules of enzyme and substrate are moving faster, so they have more kinetic energy.

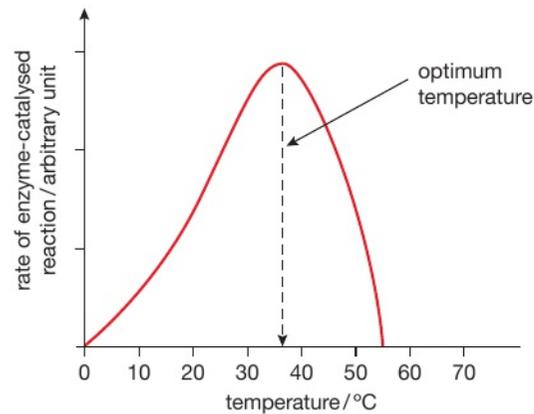
A number of factors affect the activity of enzymes. The rate of reaction may be increased by raising the concentration of the enzyme or the substrate. Two other factors that affect enzymes are temperature and pH.

TEMPERATURE

The effect of temperature on the action of an enzyme is easiest to see as a graph, where we plot the rate of the reaction against temperature (Figure 1.6).

Enzymes in the human body have evolved to work best at body temperature (37 °C). The graph in Figure 1.6 shows a peak on the curve at this temperature, which is called the *optimum temperature* for the enzyme.

As the enzyme is heated up to the optimum temperature, the rise in temperature increases the rate of reaction. This is because higher temperatures give the molecules of the enzyme and the substrate more kinetic energy, so they collide more often. More collisions means that the reaction will take place more frequently.



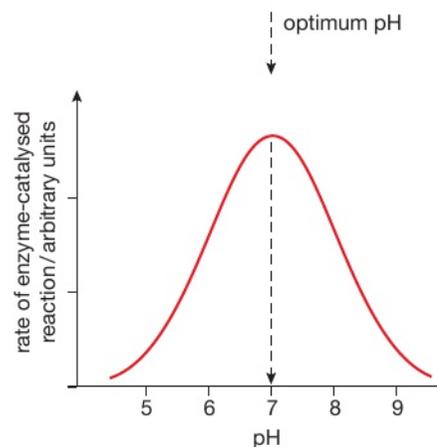
▲ Figure 1.6 Effect of temperature on the action of an enzyme.

However, above the optimum, temperature starts to have another effect. Enzymes are made of protein, and proteins are broken down by heat. From 40 °C upwards, the heat destroys the enzyme. We say that it is **denatured**. You can see the effect of denaturing when you boil an egg. The egg white is made of protein, and turns from a clear runny liquid into a white solid as the heat denatures the protein. Denaturing changes the shape of the active site so that the substrate will no longer fit into it. Denaturing is permanent – the enzyme molecules will no longer catalyse the reaction.

Not all enzymes have an optimum temperature near 37 °C, only those of animals such as mammals and birds, which all have body temperatures close to this value. Enzymes have evolved to work best at the normal body temperature of the organism. Bacteria that always live at an average temperature of 10 °C will probably have enzymes with an optimum temperature near 10 °C.

pH

The pH around the enzyme is also important. The pH inside cells is neutral (pH 7) and most enzymes have evolved to work best at this pH. At extremes of pH either side of neutral, the enzyme activity decreases, as shown in Figure 1.7. The pH at which the enzyme works best is called its *optimum pH*. Either side of the optimum, the pH affects the structure of the enzyme molecule and changes the shape of its active site, so that the substrate will not fit into it so well.



▲ Figure 1.7 Most enzymes work best at a neutral pH.

KEY POINT

Although most enzymes work best at a neutral pH, a few have an optimum below or above pH 7. The stomach produces hydrochloric acid, which makes its contents very acidic (see Chapter 4). Most enzymes stop working at a low pH, but the stomach makes an enzyme called pepsin which has an optimum pH of about 2, so that it is adapted to work well in these unusually acidic surroundings.



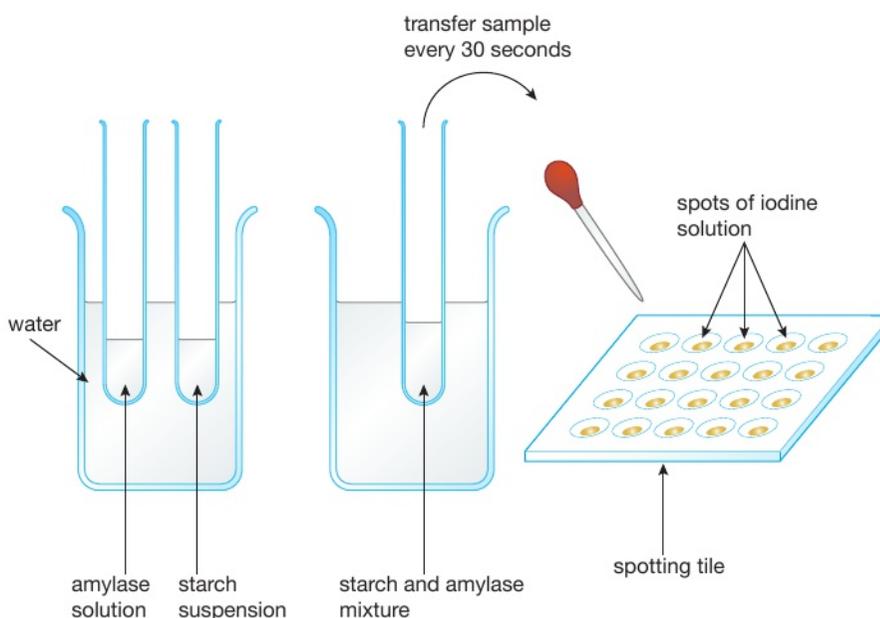
Safety Note: Wear eye protection and avoid skin contact with the liquids. Amylase is hazardous to the eyes.

ACTIVITY 1

▼ PRACTICAL: AN INVESTIGATION INTO THE EFFECT OF TEMPERATURE ON THE ACTIVITY OF AMYLASE

The digestive enzyme amylase breaks down starch into the sugar maltose. If the speed at which the starch disappears is recorded, this is a measure of the activity of the amylase.

Figure 1.8 shows apparatus which can be used to record how quickly the starch is used up.



▲ Figure 1.8 Investigating the breakdown of starch by amylase at different temperatures.

Spots of iodine solution are placed into the dips on the spotting tile. Using a syringe, 5 cm^3 of starch suspension is placed in one boiling tube, and 5 cm^3 of amylase solution in another tube, using a different syringe. The beaker is filled with water at 20°C . Both boiling tubes are placed in the beaker of water for 5 minutes, and the temperature recorded.

The amylase solution is then poured into the starch suspension, leaving the tube containing the mixture in the water bath. Immediately, a small sample of the mixture is removed from the tube with a pipette and added to the first drop of iodine solution on the spotting tile. The colour of the iodine solution is recorded.

A sample of the mixture is taken every 30 seconds for 10 minutes and tested for starch as above, until the iodine solution remains yellow, showing that all the starch is used up.

The experiment is repeated, maintaining the water bath at different temperatures between 20°C and 60°C . A set of results is shown in the table below.

Time / min	Colour of mixture at different temperatures / (°C)				
	20	30	40	50	60
0.0	Blue-black	Blue-black	Blue-black	Blue-black	Blue-black
0.5	Blue-black	Blue-black	Brown	Blue-black	Blue-black
1.0	Blue-black	Blue-black	Yellow	Blue-black	Blue-black
1.5	Blue-black	Blue-black	Yellow	Blue-black	Blue-black
2.0	Blue-black	Blue-black	Yellow	Brown	Blue-black
2.5	Blue-black	Blue-black	Yellow	Brown	Blue-black
3.0	Blue-black	Blue-black	Yellow	Brown	Blue-black
3.5	Blue-black	Blue-black	Yellow	Yellow	Blue-black
4.0	Blue-black	Blue-black	Yellow	Yellow	Blue-black
5.5	Blue-black	Blue-black	Yellow	Yellow	Blue-black
6.0	Blue-black	Brown	Yellow	Yellow	Blue-black
6.5	Blue-black	Brown	Yellow	Yellow	Blue-black
7.0	Blue-black	Yellow	Yellow	Yellow	Blue-black
7.5	Blue-black	Yellow	Yellow	Yellow	Brown
8.0	Blue-black	Yellow	Yellow	Yellow	Brown
8.5	Brown	Yellow	Yellow	Yellow	Yellow
9.0	Brown	Yellow	Yellow	Yellow	Yellow
9.5	Yellow	Yellow	Yellow	Yellow	Yellow
10.0	Yellow	Yellow	Yellow	Yellow	Yellow

The rate of reaction can be calculated from the time taken for the starch to be fully broken down, as shown by the colour change from blue-black to yellow. For example, at 50 °C the starch had all been digested after 3.5 minutes. The rate is found by dividing the volume of the starch (5 cm³) by the time:

$$\text{Rate} = \frac{5.0 \text{ cm}^3}{3.5 \text{ min}} = 1.4 \text{ cm}^3 \text{ per min}$$

Plotting a graph of rate against temperature should produce a curve similar to the one shown in Figure 1.6. Try this, using the results in the table. Better still, you may be able to do this experiment and provide your own results.

If the curve doesn't turn out quite like the one in Figure 1.6, can you suggest why this is? How could you improve the experiment to get more reliable results?

BIOLOGY ONLY

ACTIVITY 2

▼ PRACTICAL: AN INVESTIGATION INTO THE EFFECT OF pH ON THE ACTIVITY OF CATALASE

!
Safety Note: Wear eye protection and avoid contact with the mixture. Catalase is hazardous to the eyes.

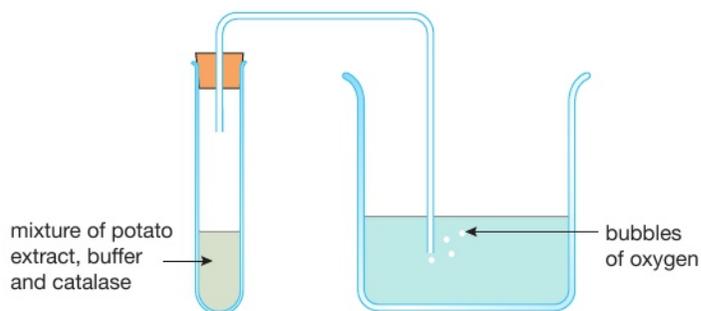
Buffer solutions are solutions of salts that resist changes in pH. Different buffer solutions can be prepared for maintaining different values of pH. Buffer solutions are useful for finding the effect of pH on enzyme activity.

Hydrogen peroxide (H_2O_2) is a product of metabolism. Hydrogen peroxide is toxic (poisonous), so it must not be allowed to build up in cells. The enzyme catalase protects cells by breaking down hydrogen peroxide into the harmless products water and oxygen:



Potato cells contain a high concentration of catalase. A large potato is chopped into small pieces and placed in a blender with an equal volume of distilled water. The blender is switched on to mince up the potato tissue and release the catalase from the cells. The potato debris is allowed to settle to the bottom and the liquid extract above the debris removed.

The extract is tested for catalase activity at different values of pH. Using a graduated syringe, 5 cm^3 of extract is placed in a boiling tube and 5 cm^3 of pH 7 buffer solution added from another syringe. The tube is shaken gently to mix the buffer with the potato extract. The mixture is left for 5 minutes, then 5 cm^3 of 5% hydrogen peroxide solution is added to the tube from a third syringe. A bung and delivery tube is quickly inserted in the boiling tube and the end of the delivery tube placed in a beaker of water (Figure 1.9).



▲ Figure 1.9 Apparatus to investigate the effect of pH on catalase activity.

The bubbles of oxygen gas produced in the first minute after adding the hydrogen peroxide are counted. The number of bubbles per minute is a measure of the initial reaction rate.

The experiment is repeated, using different buffers. Some results are shown in the table below.

pH	Rate of reaction / bubbles per minute
5	6
6	39
7	47
8	14

Plot a bar chart of the results.

Which pH gives the fastest rate of reaction?

How could you modify this experiment to find a more precise value of the optimum pH for the enzyme catalase?

Think – are four values of pH enough? Is there a better way than counting bubbles of gas?

How could you control the temperature during the experiment?

How could you modify the experiment to make the results more reliable?

Think – is one set of results enough?

END OF BIOLOGY ONLY

HOW THE CELL GETS ITS ENERGY

A cell needs a source of energy in order to be able to carry out all the processes needed for life. It gets this energy by breaking down food molecules to release the stored chemical energy that they contain. This process is called respiration. Many people think that respiration means the same as ‘breathing’, but although there are links between the two processes, the biological meaning of respiration is very different.

Respiration happens in all the cells of our body. Oxygen is used to oxidise food, and carbon dioxide (and water) are released as waste products. The main food oxidised is a sugar called **glucose**. Glucose contains stored chemical energy that can be converted into other forms of energy that the cell can use. It is rather like burning a fuel to get the energy out of it, except that burning releases most of the energy as heat. Respiration releases some heat energy, but most is used to make a substance called **ATP** (see below). The energy stored in the ATP molecules can then be used for a variety of purposes, such as:

- contraction of muscle cells, producing movement
- active transport of molecules and ions (see page 18)
- building large molecules, such as proteins
- cell division.

The energy released as heat is also used to maintain a constant body temperature in mammals and birds (see Chapter 8).

The overall reaction for respiration is:



This is called **aerobic respiration**, because it uses oxygen. Aerobic respiration happens in the cells of humans and those of animals, plants and many other organisms. It is important to realise that the equation above is only a *summary* of the process. It actually takes place gradually, as a sequence of small steps, which release the energy of the glucose in small amounts. Each step in the process is catalysed by a different enzyme. The later steps in the process are the aerobic ones, and these release the most energy. They happen in the mitochondria of the cell.

KEY POINT

Respiration is called an *oxidation* reaction, because oxygen is used to break down food molecules.

DID YOU KNOW?

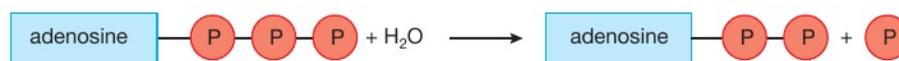
Carbon from the respired glucose passes out into the atmosphere as carbon dioxide. The carbon can be traced through this pathway using a radioactive form of carbon called carbon-14.

ATP – THE ENERGY ‘CURRENCY’ OF THE CELL

Respiration releases energy while other cell processes use it up. Cells have a way of passing the energy from respiration to the other processes that need it. They do this using a chemical called **adenosine triphosphate** or **ATP**. ATP is present in all living cells.

ATP is composed of an organic molecule called adenosine attached to three phosphate groups. In a cell, ATP can be broken down losing one phosphate group and forming adenosine diphosphate or ADP (Figure 1.10 (a)).

(a) When energy is needed ATP is broken down into ADP and phosphate (P):



(b) During respiration ATP is made from ADP and phosphate:



▲ Figure 1.10 ATP is the energy ‘currency’ of the cell.

When this reaction takes place, chemical energy is released and can be used to drive metabolic processes that need it.

During respiration the opposite happens – energy from the oxidation of glucose is used to drive the reverse reaction and a phosphate is added onto ADP (Figure 1.10 (b)).

ATP is often described as the energy ‘currency’ of the cell. It transfers energy between the process that releases it (respiration) and the processes in a cell that use it up.

ANAEROBIC RESPIRATION

There are some situations where cells can respire *without* using oxygen. This is called **anaerobic respiration**. In anaerobic respiration, glucose is not completely broken down, so less energy is released. The advantage of anaerobic respiration is that it can occur in situations where oxygen is in short supply. Two important examples of this are in yeast cells and muscle cells.

Yeasts are single-celled fungi. They are used in processes such as baking bread. When yeast cells are prevented from getting enough oxygen, they stop respiring aerobically and start to respire anaerobically instead. The glucose is partly broken down into ethanol (alcohol) and carbon dioxide:



This process is described in more detail in Chapter 21.

Think about the properties of ethanol – it makes a good fuel and will burn to produce a lot of heat, so it still has a lot of chemical energy ‘stored’ in it.

Muscle cells can also respire anaerobically when they are short of oxygen. If muscles are overworked, the blood cannot reach them fast enough to deliver

DID YOU KNOW?

It was once thought that lactate was toxic and caused muscle fatigue. We now know that this is *not* true. In fact physiologists have shown that lactate actually *delays* muscle fatigue. Fatigue is caused by other changes that happen in the muscles during exercise.

DID YOU KNOW?

Lactate is sometimes called lactic acid.



Safety Note: Wear eye protection, treat all living organisms with care and avoid skin contact.

enough oxygen for aerobic respiration. This happens when a person does a 'burst' of activity, such as a sprint, or quickly lifting a heavy weight. This time the glucose is broken down into a substance called **lactate**:



Anaerobic respiration provides enough energy to keep the overworked muscles going for a short period. During the exercise, the level of lactate rises in the muscle cells and bloodstream.

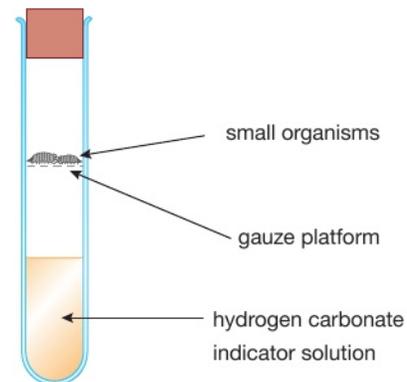
After the exercise the lactate is respired aerobically in the mitochondria. The volume of oxygen needed to completely oxidise the lactate that builds up in the body during anaerobic respiration is called the **oxygen debt**.

ACTIVITY 3

▼ PRACTICAL: DEMONSTRATION OF THE PRODUCTION OF CARBON DIOXIDE BY SMALL LIVING ORGANISMS

Hydrogen carbonate indicator solution is normally orange, but turns yellow if carbon dioxide is added to it. The indicator is sensitive to small changes in carbon dioxide concentration, and can be used to show production of carbon dioxide by small organisms such as woodlice, maggots (fly larvae) or germinating seeds.

The organisms are placed in a stoppered boiling tube with the indicator, as shown in Figure 1.11. The gauze platform supports the organisms above the hydrogen carbonate indicator solution and stops them from coming into contact with the chemical.



▲ Figure 1.11 Testing for carbon dioxide production by small organisms.

Of the three species of organisms mentioned above, which do you think would change the colour of the indicator most quickly? If you are able to observe each of the organisms, this might help with your prediction.

When you have made your prediction (called a 'hypothesis'), plan an investigation to test it. Take care to consider the variables that need to be controlled, and don't forget to include a description of a fourth tube that you would need to set up as the experimental Control (see Appendix A for an explanation of these terms).

It may be possible for you to carry out the investigation using similar apparatus and organisms.

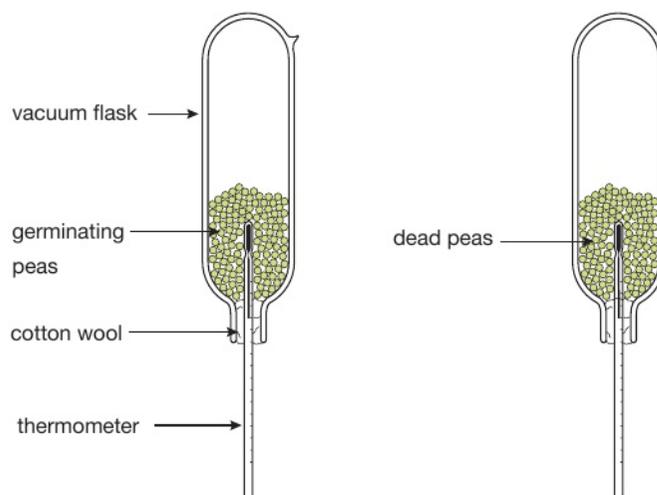
! Safety Note: Eye protection should be worn when using bleach to wash the peas and skin contact avoided.

ACTIVITY 4

▼ PRACTICAL: DEMONSTRATION THAT HEAT IS PRODUCED BY RESPIRATION

Some peas are soaked in water for 24 hours, so that they start to germinate. A second batch of peas is boiled, to kill them. Each set of peas is washed in a 1% bleach solution, which acts as a disinfectant, killing any bacteria present on the surface of the peas. The peas are then rinsed twice in distilled water to remove any traces of bleach.

Each batch of peas is placed in an inverted vacuum flask as shown in Figure 1.12, leaving some air in each flask. A vacuum flask insulates its contents, so that any small temperature change inside the flask can be measured.



▲ Figure 1.12 Experiment to show that heat is produced during respiration in germinating peas.

The seeds produce carbon dioxide gas, which is denser than air. The inverted flasks and cotton wool allow this to escape. It might otherwise kill the peas.

The apparatus is left set up for a couple of days, and the temperature inside each flask measured at the start and end of the experiment.

The following results were obtained from this experiment:

Temperature in both flasks at the start = 21 °C

Temperature in flask with dead peas at the end = 21 °C

Temperature in flask with living peas at the end = 24 °C

Can you explain these results? Why is it necessary to kill any microorganisms on the surface of the peas? Explain the importance of the flask containing dead peas.

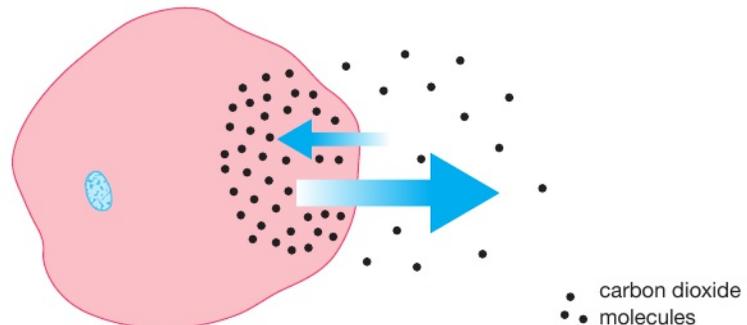
MOVEMENT OF MATERIALS IN AND OUT OF CELLS

Cell respiration shows the need for cells to be able to take in certain substances from their surroundings, such as glucose and oxygen, and get rid of others, such as carbon dioxide and water. As you have seen, the cell surface membrane can control which chemicals can pass in and out – it is described as selectively permeable.

There are three main ways that molecules and ions can move through the membrane. They are diffusion, active transport and osmosis.

DIFFUSION

Many substances can pass through the membrane by **diffusion**. Diffusion happens when a substance is more concentrated in one place than another. For example, if the cell is making carbon dioxide by respiration, the concentration of carbon dioxide inside the cell will be higher than outside. This difference in concentration is called a concentration gradient. The molecules of carbon dioxide are constantly moving about because of their kinetic energy. The cell membrane is permeable to carbon dioxide, so the molecules can move in either direction through it. Since there is a higher concentration of carbon dioxide molecules inside the cell than outside, over time, more molecules will move from inside to outside than move in the other direction. We say that there is a *net* movement of the molecules out of the cell (Figure 1.13).



▲ Figure 1.13 Carbon dioxide is produced by respiration, so its concentration builds up inside the cell. Although the carbon dioxide molecules diffuse in both directions across the cell membrane, the overall (net) movement is out of the cell, down the concentration gradient.

KEY POINT

Diffusion is the net movement of particles (molecules or ions) from a region of high concentration to a region of low concentration, i.e. down a concentration gradient.

The opposite happens with oxygen. Respiration uses up oxygen, so there is a concentration gradient of oxygen from outside to inside the cell. There is therefore a net movement of oxygen *into* the cell by diffusion.

The rate of diffusion is affected by various factors.

- The concentration gradient. Diffusion happens more quickly when there is a steep concentration gradient (i.e. a big difference in concentrations between two areas).
- The surface area to volume ratio. A larger surface area in proportion to the volume will increase the rate.
- The distance. The rate is decreased if the distance over which diffusion has to take place is greater.
- The temperature. The rate is greater at higher temperatures. This is because a high temperature provides the particles with more kinetic energy.



Safety Note: Wear eye protection and avoid all skin contact with the acid and the dyed agar blocks.

ACTIVITY 5

▼ PRACTICAL: DEMONSTRATION OF DIFFUSION IN A JELLY

Agar is a jelly that is used for growing cultures of bacteria. It has a consistency similar to the cytoplasm of a cell. Like cytoplasm, it has a high water content. Agar can be used to show how substances diffuse through a cell.

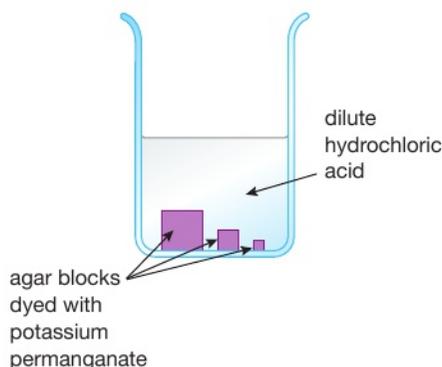
This demonstration uses the reaction between hydrochloric acid and potassium permanganate solution. When hydrochloric acid comes into contact with potassium permanganate, the purple colour of the permanganate disappears.

A Petri dish is prepared which contains a 2 cm deep layer of agar jelly, dyed purple with potassium permanganate. Three cubes of different sizes are cut out of the jelly, with side lengths 2 cm, 1 cm and 0.5 cm. The cubes have different volumes and total surface areas. They also have a different surface area to volume ratio, as shown in the table below.

Length of side of cube / cm	Volume of cube / cm ³ (length × width × height)	Surface area of cube / cm ² (length × width of one side) × 6	Ratio of surface area to volume of cube (surface area divided by volume)
2	$(2 \times 2 \times 2) = 8$	$(2 \times 2) \times 6 = 24$	$24/8 = 3$
1	$(1 \times 1 \times 1) = 1$	$(1 \times 1) \times 6 = 6$	$6/1 = 6$
0.5	$(0.5 \times 0.5 \times 0.5) = 0.125$	$(0.5 \times 0.5) \times 6 = 1.5$	$1.5/0.125 = 12$

Notice that the smallest cube has the largest surface area to volume ratio. The same is true of cells – a small cell has a larger surface area to volume ratio than a large cell.

The cubes are carefully dropped, at the same time, into a beaker of dilute hydrochloric acid (Figure 1.14).



► Fig 1.14 Investigating diffusion in a jelly.

The time taken for each cube to turn colourless is noted.

Which cube would be the first to turn colourless and which the last? Explain the reasoning behind your prediction.

If the three cubes represented cells of different sizes, which cell would have the most difficulty in obtaining substances by diffusion?

It may be possible for you to try this experiment, using similar apparatus.

ACTIVE TRANSPORT

Diffusion happens because of the kinetic energy of the particles. It does not need an 'extra' source of energy from respiration. However, sometimes a cell needs to take in a substance when there is very little of that substance outside the cell, in other words *against* a concentration gradient. It can do this by another process, called **active transport**.

During active transport a cell uses energy from respiration to take up substances, rather like a pump uses energy to move a liquid from one place to another. In fact, biologists speak of the cell 'pumping' ions or molecules in or out. The pumps are large protein molecules located in the cell membrane, and they are driven by the breakdown of ATP. An example of a place where this happens is in the human small intestine, where some glucose in the gut is absorbed into the cells lining the intestine by active transport. The roots of plants also take up certain mineral ions in this way. Cells use active transport to control the uptake of many substances.

KEY POINT

Active transport is the movement of substances against a concentration gradient, using energy from respiration.

OSMOSIS

Water moves across cell membranes by a special sort of diffusion, called **osmosis**. Osmosis happens when the total concentrations of all dissolved substances inside and outside the cell are different. Water will move across the membrane from the more dilute solution to the more concentrated one. Notice that this is still obeying the rules of diffusion – the water moves from where there is a higher concentration of *water* molecules to a lower concentration of *water* molecules. Osmosis can only happen if the membrane is permeable to water but not to some other solutes. We say that it is **partially permeable**.

Osmosis is important for moving water from cell to cell, for example in plant roots. You will find out more about osmosis in Chapter 11.

KEY POINT

Osmosis in cells is the net movement of water from a dilute solution to a more concentrated solution across the partially permeable cell membrane.

SPECIALISED EXCHANGE SURFACES

KEY POINT

'Adapted' or 'an **adaptation**' means that the structure of a cell or an organism is suited to its function. It is a word that is very commonly used in biology, and will appear again in many of the chapters of this book. We also use it when we say that organisms are adapted to their environment.

All cells exchange substances with their surroundings, but some parts of animals or plants are specially adapted for the exchange of materials because they have a very large surface area in proportion to their volume. In animals, two examples are the alveoli (air sacs) of the lungs (Chapter 3) and the villi of the small intestine (Chapter 4). Diffusion is a slow process, and organs that rely on diffusion need a large surface over which it can take place. The alveoli allow the exchange of oxygen and carbon dioxide to take place between the air and the blood during breathing. The villi of the small intestine provide a large surface area for the absorption of digested food. In plants, exchange surfaces are also adapted by having a large surface area, such as the spongy mesophyll of the leaf (Chapter 10) and the root hairs (Chapter 11).

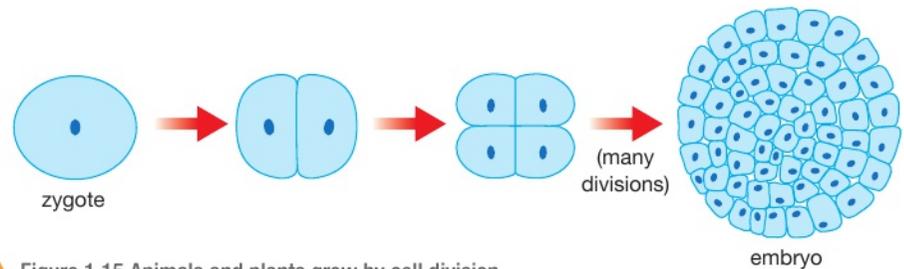
BIOLOGY ONLY

CELL DIVISION AND DIFFERENTIATION

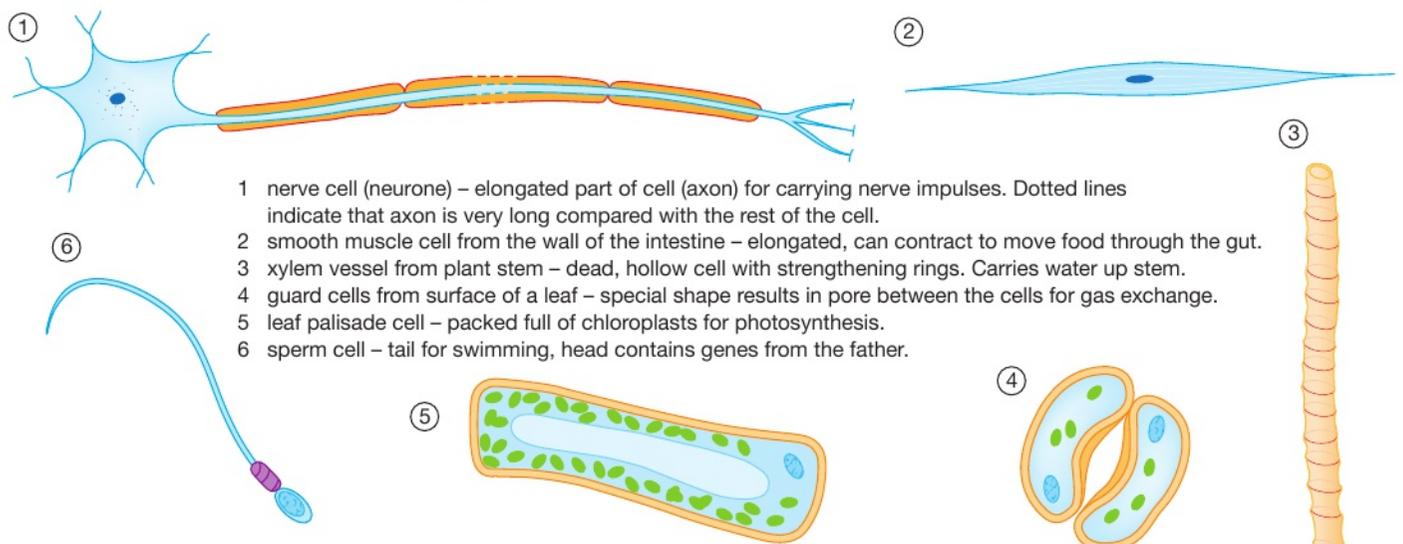
Multicellular organisms like animals and plants begin life as a single fertilised egg cell, called a **zygote**. This divides into two cells, then four, then eight and so on, until the adult body contains countless millions of cells (Figure 1.15).

This type of cell division is called **mitosis** and is under the control of the genes. You can read a full account of mitosis in Chapter 17, but it is worthwhile considering an outline of the process now. First of all the chromosomes in the nucleus are copied, then the nucleus splits into two, so that the genetic information is shared equally between the two 'daughter' cells. The cytoplasm then divides (or in plant cells a new cell wall develops) forming two smaller

cells. These then take in food substances to supply energy and building materials so that they can grow to full size. The process is repeated, but as the developing embryo grows, cells become specialised to carry out particular roles. This specialisation is also under the control of the genes, and is called **differentiation**. Different kinds of cells develop depending on where they are located in the embryo, for example a nerve cell in the spinal cord, or an epidermal cell in the outer layer of the skin (Figure 1.16). Throughout this book you will read about cells that have a structure adapted for a particular function.



▲ Figure 1.15 Animals and plants grow by cell division.



- 1 nerve cell (neurone) – elongated part of cell (axon) for carrying nerve impulses. Dotted lines indicate that axon is very long compared with the rest of the cell.
- 2 smooth muscle cell from the wall of the intestine – elongated, can contract to move food through the gut.
- 3 xylem vessel from plant stem – dead, hollow cell with strengthening rings. Carries water up stem.
- 4 guard cells from surface of a leaf – special shape results in pore between the cells for gas exchange.
- 5 leaf palisade cell – packed full of chloroplasts for photosynthesis.
- 6 sperm cell – tail for swimming, head contains genes from the father.

▲ Figure 1.16 Some cells with very specialised functions. They are not drawn to the same scale.

What is hard to understand about this process is that through mitosis all the cells of the body have the *same* genes. For cells to function differently, they must produce different proteins, and different genes code for the production of these different proteins. How is it that some genes are ‘switched on’ and others are ‘switched off’ to produce different cells? The answer to this question is very complicated, and scientists are only just beginning to work it out.

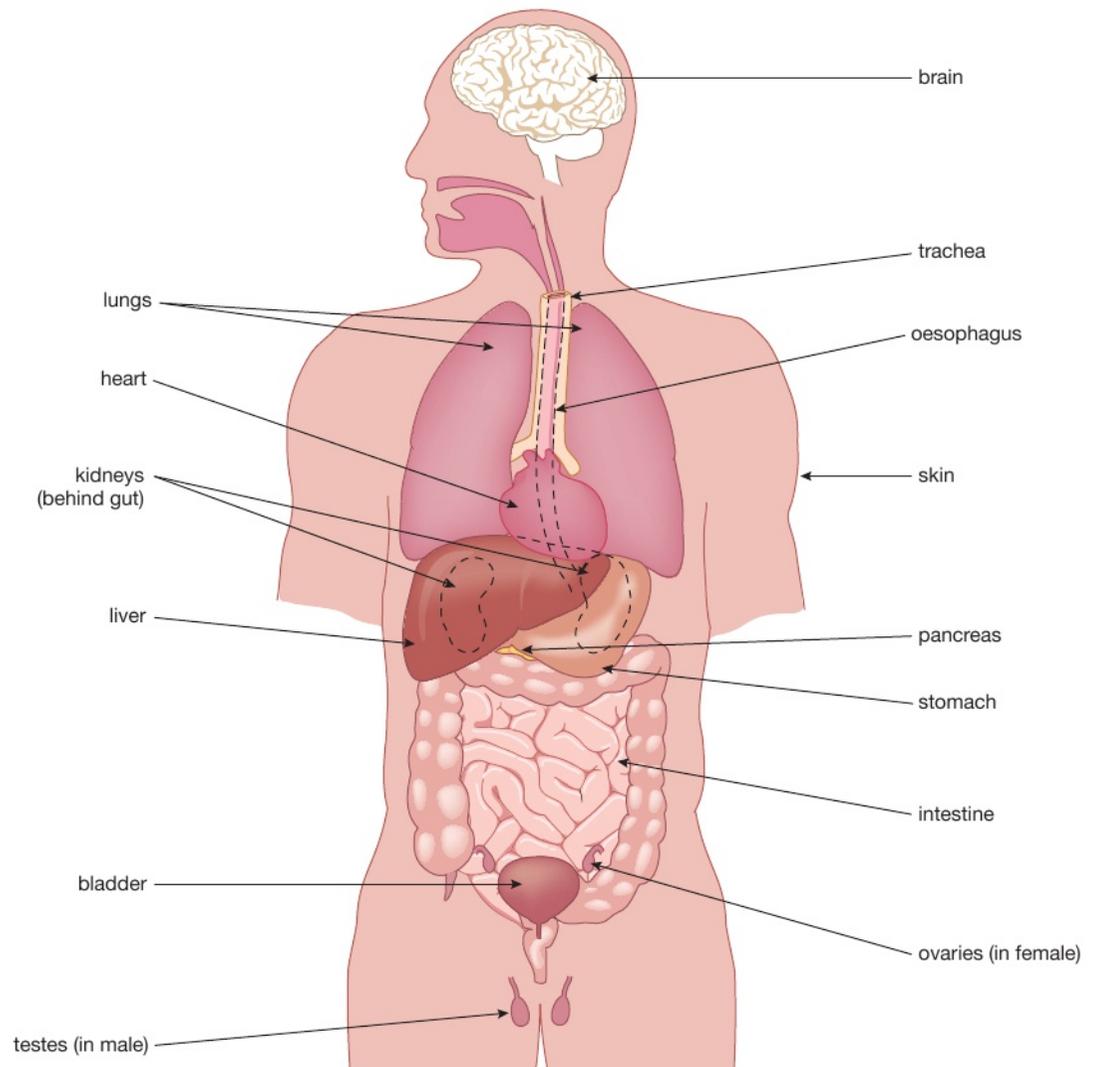
END OF BIOLOGY ONLY

CELLS, TISSUES AND ORGANS

Cells with a similar function are grouped together as **tissues**. For example, the muscle of your arm contains millions of similar muscle cells, all specialised for one function – contraction to move the arm bones. This is muscle tissue. However, a muscle also contains other tissues, such as blood, nervous tissue and epithelium (lining tissue). A collection of several tissues carrying out a particular function is called an **organ**. The main organs of the human body are shown in Figure 1.17. Plants also have tissues and organs. Leaves, roots, stems and flowers are all plant organs.

In animals, jobs are usually carried out by several different organs working together. This is called an **organ system**. For example, the digestive system consists of the gut, along with glands such as the pancreas and gall bladder. The function of the whole system is to digest food and absorb the digested products into the blood. There are seven main systems in the human body. These are the:

- digestive system
- gas exchange system – including the lungs, which exchange oxygen and carbon dioxide
- circulatory system – including the heart and blood vessels, which transport materials around the body
- excretory system – including the kidneys, which filter toxic waste materials from the blood
- nervous system – consisting of the brain, spinal cord and nerves, which coordinate the body's actions
- endocrine system – glands secreting hormones, which act as chemical messengers
- reproductive system – producing sperm in males and eggs in females, and allowing the development of the embryo.



▲ Figure 1.17 Some of the main organs of the human body.

BIOLOGY ONLY**STEM CELLS**

A **stem cell** is a cell that has the ability to divide many times by mitosis while remaining undifferentiated. Later, it can differentiate into specialised cells such as muscle or nerve cells. In humans there are two main types of stem cells:

- *Embryonic stem cells* are found in the early stage of development of the embryo. They can differentiate into any type of cell.
- *Adult stem cells* are found in certain adult tissues such as bone marrow, skin, and the lining of the intestine. They have lost the ability to differentiate into any type of cell but can form a number of specialised tissues. For example, bone marrow cells can divide many times but are only able to produce different types of red and white blood cells.

The use of stem cells to treat (or prevent) a disease, or to repair damaged tissues is called *stem cell therapy*. At present, the most common form of stem cell therapy is the use of bone marrow transplants. Bone marrow transplants are used to treat patients with conditions such as leukaemia (a type of blood cancer). Some cancer treatments use chemicals that kill cancer cells (chemotherapy) but this also destroys healthy cells. Bone marrow transplants supply stem cells that can divide and differentiate, replacing cells lost from the body during chemotherapy. Bone marrow transplants are now a routine procedure and have been used successfully for over 30 years. Bone marrow and other adult stem cells are readily available, but they have limited ability to differentiate into other types of cell.

Scientists are able to isolate and culture embryonic stem cells (Figure 1.18). These are obtained from fertility clinics where parents choose to donate their unused embryos for research. In the future, it is hoped that we will be able to use embryonic stem cells to treat many diseases such as diabetes along with brain disorders such as Parkinson's disease. Stem cells could also be used to repair damaged nerve tissue. Until now, treatments using embryonic stem cells have not progressed beyond the experimental stage. Stem cell research can also present problems. Many people object morally to using cells from embryos for medical purposes despite the fact that they might one day be used to cure many diseases.



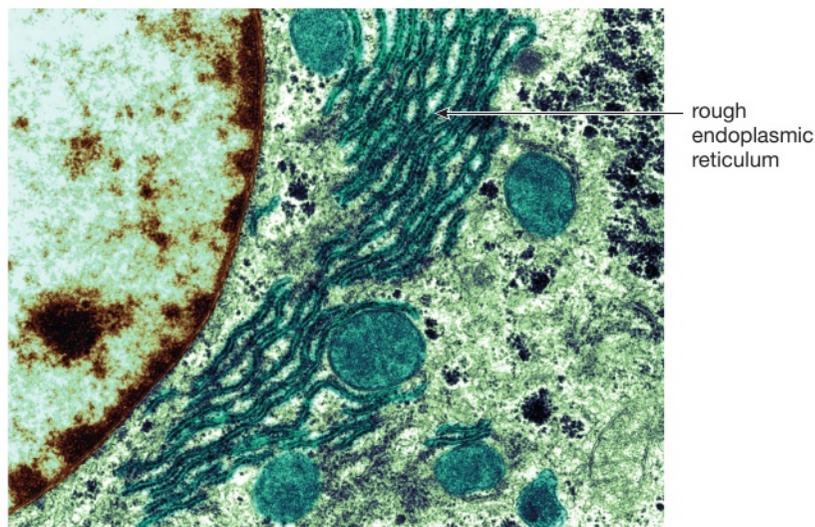
▲ Figure 1.18 Extracting a stem cell from an embryo at an early stage of its development. The embryo consists of a ball of about 20 cells. A single cell is removed by drawing it into a fine glass capillary tube.

LOOKING AHEAD – MEMBRANES IN CELLS

If you continue to study biology beyond International GCSE, you will learn more about the structure and function of cells. You might like to look on the Internet for some electron micrographs and carry out some further research into cells.

Electron micrographs allow us to see cells at a much greater magnification than by using a light microscope. They also reveal more detail. The image produced by a light microscope can only distinguish features about the size of a mitochondrion. The electron microscope has a much greater *resolution*. Resolution is the ability to distinguish two points in an image as being separate. The maximum resolution of a light microscope is about 200 nanometres (nm), whilst with an electron microscope we can distinguish structures less than 1 nm in size. That is why ribosomes are only visible using an electron microscope – they are about 25 nm in diameter. A nanometre (nm) is 10^{-9} m, or one millionth of a millimetre.

Electron microscopy reveals that much of the cytoplasm is made up of membranes. As well as the cell surface membrane, there are membranes around organelles such as the nucleus, mitochondria and chloroplasts. In addition, there is an extensive system of membranes running throughout the cytoplasm, called the endoplasmic reticulum (ER). Some ER is covered in ribosomes, and is called rough ER (Figure 1.19).



▲ Figure 1.19 Rough endoplasmic reticulum is a system of membranes extending throughout the cytoplasm of a cell. It is covered with ribosomes the (tiny dots). Ribosomes are the site of protein synthesis.

There are thousands of different chemical reactions that take place inside cells. A key function of a cell membrane is to separate cell functions into different compartments so they don't take place together. For example, the reactions and enzymes of aerobic respiration are kept inside the mitochondria, separate from the rest of the cytoplasm.

CHAPTER QUESTIONS

SKILLS CRITICAL THINKING



More questions on life processes can be found at the end of Unit 1 on page 32.

1 Which of the following comparisons of animal and plant cells is *not* true?

	Animal cells	Plant cells
A	do not have chloroplasts	have chloroplasts
B	have mitochondria	do not have mitochondria
C	have temporary vacuoles	have permanent vacuoles
D	do not have cellulose cell walls	have cellulose cell walls

2 Which of the following descriptions is correct?

- A The cell wall is freely permeable and the cell membrane is partially permeable
- B The cell wall is partially permeable and the cell membrane is freely permeable
- C Both the cell wall and the cell membrane are freely permeable
- D Both the cell wall and the cell membrane are partially permeable



3 What are the products of anaerobic respiration in yeast?

- A ethanol and carbon dioxide
- B lactate and carbon dioxide
- C carbon dioxide and water
- D ethanol and water

BIOLOGY ONLY

4 Which of the following is the best definition of 'differentiation'?

- A The organisation of the body into cells, tissues and organs
- B A type of cell division resulting in the growth of an embryo
- C The adaptation of a cell for its function
- D The process by which the structure of a cell becomes specialised for its function

END OF BIOLOGY ONLY

SKILLS INTERPRETATION



5 a Draw a diagram of a plant cell. Label all of the parts. Alongside each label write the function of that part.

SKILLS CRITICAL THINKING



b Write down three differences between the cell you have drawn and a 'typical' animal cell.

SKILLS INTERPRETATION



6 Write a short description of the nature and function of enzymes. Include in your description:

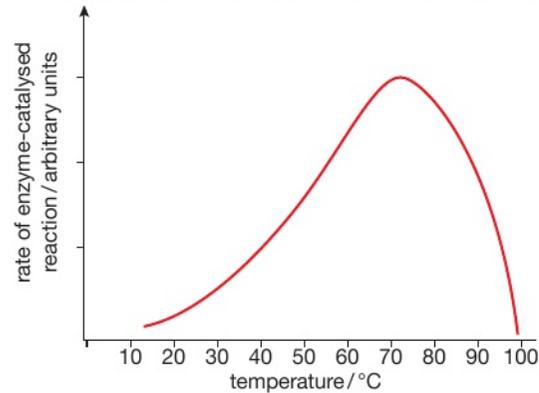
- a definition of an enzyme
- a description of the 'lock and key' model of enzyme action
- an explanation of the difference between intracellular and extracellular enzymes.

Your description should be about a page in length, including a labelled diagram.

SKILLS ANALYSIS

6

- 7 The graph shows the effect of temperature on an enzyme. The enzyme was extracted from microorganism that lives in hot mineral springs near a volcano.



- What is the optimum temperature of this enzyme?
- Explain why the activity of the enzyme is greater at 60 °C than at 30 °C.
- The optimum temperature of enzymes in the human body is about 37 °C. Explain why this enzyme is different.
- What happens to the enzyme at 90 °C?

8

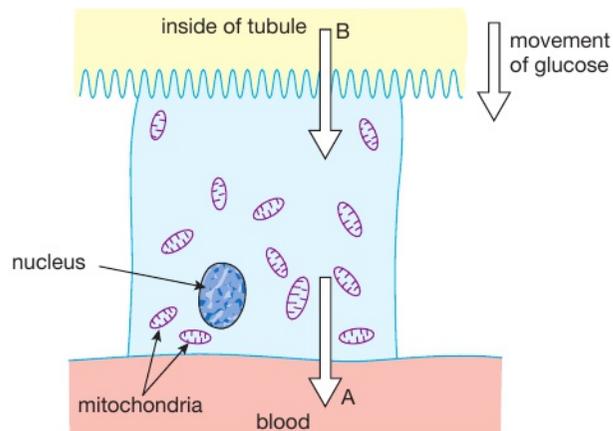
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- 8 Explain the differences between diffusion and active transport.
- 9 The nerve cell called a **motor neurone** (page 19) and a **palisade** cell of a leaf (page 19) are both very specialised cells. Read about each of these and explain very briefly (three or four lines) how each is adapted to its function.
- 10 The diagram shows a cell from the lining of a human kidney tubule. A major role of the cell is to absorb glucose from the fluid passing along the tubule and pass it into the blood, as shown by the arrow on the diagram.



- What is the function of the mitochondria?
- The tubule cell contains a large number of mitochondria. They are needed for the cell to transport glucose across the cell membrane into the blood at 'A'. Suggest the method that the cell uses to do this and explain your answer.
- The mitochondria are *not* needed to transport the glucose into the cell from the tubule at 'B'. Name the process by which the ions move across the membrane at 'B' and explain your answer.
- The surface membrane of the tubule cell at 'B' is greatly folded. Suggest how this adaptation helps the cell to carry out its function.

SKILLS INTERPRETATION

SKILLS CRITICAL THINKING, INTERPRETATION

SKILLS ANALYSIS, INTERPRETATION

5

7

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7

2 THE VARIETY OF LIVING ORGANISMS

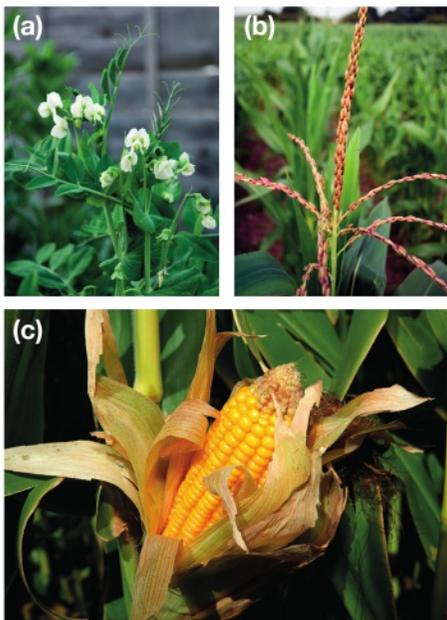
There is an enormous variety of living organisms. Biologists put them into groups according to their structure and function. The members of each group have certain features in common.

LEARNING OBJECTIVES

- Understand the difference between eukaryotic and prokaryotic organisms
- Describe the features common to plants and recognise examples of flowering plants such as maize, peas and beans
- Describe the features common to animals and recognise examples such as mammals and insects
- Describe the features common to fungi and recognise examples such as *Mucor* and yeast
- Describe the features common to protoctists and recognise examples such as *Amoeba*, *Chlorella* and *Plasmodium*
- Describe the features common to bacteria and recognise examples such as *Lactobacillus bulgaricus* and *Pneumococcus*
- Describe the features common to viruses and recognise examples such as the influenza virus, the HIV virus and the tobacco mosaic virus
- Understand the term 'pathogen' and know that pathogens may include fungi, bacteria, protoctists or viruses.

There are more than ten million species of organisms alive on Earth today, and many more that once lived on Earth but are now extinct. In order to make sense of this enormous variety biologists classify organisms, putting them into groups. Members of each group are related – they are descended from a common ancestor by the process of evolution (see Chapter 19). This common ancestry is reflected in the similarities of structure and function of the members of a group.

The five major groups of living organisms are plants, animals, fungi, protoctists and bacteria.



▲ Figure 2.1 (a) A pea plant. Its leaves and stem cells contain chloroplasts, giving them their green colour. The white flowers are pollinated by insects. (b) Maize plants are pollinated by wind. These are the male flowers, which make the pollen. (c) The female maize flowers produce seeds after pollination.

PLANTS

You will be familiar with flowering plants, such as those shown in Figure 2.1. This group, or **kingdom**, also contains simpler plants, such as mosses and ferns. All plants are **multicellular**, which means that their 'bodies' are made up of many cells. Their main distinguishing feature is that their cells contain chloroplasts and they carry out photosynthesis – the process that uses light energy to convert simple inorganic molecules such as water and carbon dioxide into complex organic compounds (see Chapter 10). One of these organic compounds is the carbohydrate **cellulose**, and all plants have cell walls made of this material.

Plants can make many other organic compounds as a result of photosynthesis. One of the first to be made is the storage carbohydrate **starch**, which is often found inside plant cells. Another is the sugar **sucrose**, which is transported around the plant and is sometimes stored in fruits and other plant organs. The structure and function of flowering plants is dealt with in Unit 3 of this book.

ANIMALS

You will be even more familiar with this kingdom, since it contains the species *Homo sapiens*, i.e. humans! The variety of the animal kingdom is also enormous, including organisms such as sponges, molluscs, worms, starfish, insects and crustaceans, through to larger animals such as fish, amphibians, reptiles, birds and mammals (Figure 2.2). The last five groups are all **vertebrates**, which means that they have a vertebral column, or backbone. All other animals lack this feature, and are called **invertebrates**.



▲ Figure 2.2 (a) A housefly. (b) A mosquito, feeding on human blood. Houseflies and mosquitoes are both insects, which make up the largest sub-group of all the animals. About 60% of all animal species are insects. (c) This high jumper's movement is coordinated by a complex nervous system.

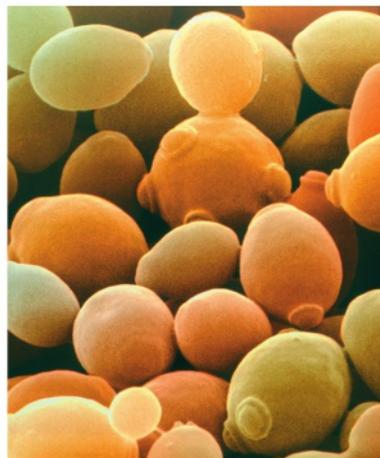
Animals are also multicellular organisms. Their cells never contain chloroplasts, so they are unable to carry out photosynthesis. Instead, they gain their nutrition by feeding on other animals or plants. Animal cells also lack cell walls, which allows their cells to change shape, an important feature for organisms that need to move from place to place. Movement in animals is achieved in various ways, but often involves coordination by a nervous system (see Chapter 6). Another feature common to most animals is that they store carbohydrate in their cells as a compound called **glycogen** (see Chapter 4). The structure and function of animals is dealt with in Unit 2 of this book.

FUNGI

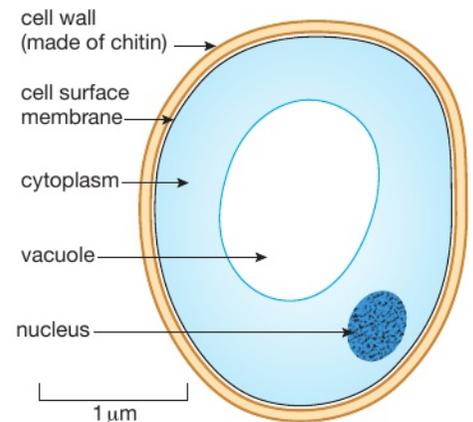
Fungi include mushrooms and toadstools, as well as moulds. These groups of fungi are multicellular. Another group of fungi is the yeasts, which are **unicellular** (made of single cells). Different species of yeasts live everywhere – on the surface of fruits, in soil, water, and even on dust in the air. The yeast powder used for baking contains millions of yeast cells (Figure 2.3). The cells of fungi never contain chloroplasts, so they cannot photosynthesise. Their cells have cell walls, but they are not composed of cellulose (Figure 2.4).

EXTENSION WORK

Because fungi have cell walls, they were once thought to be plants that had lost their chlorophyll. We now know that their cell wall is not made of cellulose as in plants, but of a different chemical called **chitin** (the same material that makes up the outside skeleton of insects). There are many ways that fungi are very different from plants (the most obvious is that fungi do not photosynthesise) and they are not closely related to plants at all.



▲ Figure 2.3 Yeast cells, highly magnified



▲ Figure 2.4 Structure of a yeast cell