Chapter 1: Life Processes

The cells of all living organisms have common features, and the organisms themselves share common processes. In this chapter you will read about these features and look at some of the processes that keep cells alive.

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, like ourselves, are multicellular, composed of millions of cells. In a **multicellular** organism there are many 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 are common to most living things. Organisms:

- **require nutrition** either they make their own food, as in plants, or eat other organisms, as animals do
- excrete get rid of toxic waste products
- move by the action of muscles in animals, and slow growth movements in plants
- grow and develop increase in size and mass, using materials from their food
- **respire** get energy from their food
- respond to stimuli are sensitive to changes in their surroundings
- reproduce produce offspring
- **control** their internal conditions.

Cell structure

For over 160 years scientists have known that animals and plants are made from cells. All cells contain some common parts, such as the nucleus, cytoplasm and cell membrane. Some cells have structures missing, for instance red blood cells lack a nucleus, which is unusual. The first chapter in a biology textbook usually shows 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 might find in most cells, without them being too specialised. Figure 1.2 shows the features you would expect to see in many animal and plant cells. However not all these are present in all cells – the parts of a plant which are not green do not have chloroplasts, for example.



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. mature 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**. You will find out much more about genes and inheritance later in the book. Genes control the activities in the cell by determining which proteins the cell can make. One very important group of proteins found in cells is **enzymes** (see below). Enzymes control chemical reactions that go on in the cytoplasm.

All cells are surrounded by a **cell surface membrane** (often simply called the cell membrane). 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 (the membrane is **permeable** to them). In fact, the cell membrane *controls* which substances pass in either direction. We say that it is **selectively** permeable.

One organelle that is found in the cytoplasm of all living cells is the **mitochondrion** (plural **mitochondria**). There are many mitochondria in cells that need a lot of energy, such as muscle or nerve cells. This gives us a clue to the role of mitochondria. They carry out some of the reactions of **respiration** (see page 6) to release energy that the cell can use. In fact, most of the energy from respiration is released in the mitochondria.

All of the structures we 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. This is why plant cells have a fairly fixed shape. Animal cells, which lack a cell wall, tend to be more variable in shape. Plant cells absorb water, producing internal pressure which pushes against other cells of the plant, giving them support. Without a cell wall to withstand these pressures, this method of support would be impossible. The cell wall has large holes in it, so it is not a barrier to water or dissolved substances. In other words it is **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**, a store of dissolved sugars, mineral ions and other solutes. Animal cells can have small vacuoles, but they are only temporary structures.

Cells of the green parts of plants, especially the leaves, have another very important organelle, the **chloroplast**. Chloroplasts absorb light energy to make food in the process of photosynthesis (see Chapter 10). The chloroplasts are green because 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.

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

Enzymes: controlling reactions in the cell

The chemical reactions that go on 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 catalyse reactions in the cytoplasm:







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

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

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. So the function of enzymes is to catalyse metabolic reactions. You have probably heard of the enzymes involved in digestion of food. They are secreted by the intestine onto the food to break it down. They are called **extracellular** enzymes, which means 'outside cells'. However, most enzymes stay *inside* cells – they are **intracellular**. You will read about digestive enzymes in Chapter 4. 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. This is 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. Only when enzymes are present to speed them up do the reactions take place quickly enough.

It is possible for there to be thousands of different sorts of enzymes because they are made of 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.

The substrate fits into the active site of the enzyme rather like a key fitting into a lock. That is why this is called the 'lock and key' model of enzyme action (Figure 1.5).



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.

Notice how, after it has catalysed the reaction once, the enzyme is free to act on more substrate molecules.

Factors affecting enzymes

Temperature affects the action of enzymes. This is easiest to see as a graph, where we plot the rate of the reaction controlled by an enzyme against the temperature (Figure 1.6).

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



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

'Optimum' temperature means the 'best' temperature, in other words the temperature at which the reaction takes place most rapidly. As the enzyme is heated up to the optimum temperature, increasing temperature speeds up the rate of reaction. This is because higher temperatures give the molecules of enzyme and substrate more energy, so they collide more often. More collisions mean that the reaction will take place more frequently. However, above the optimum temperature another factor comes into play. 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.

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

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

Not all enzymes have an optimum temperature near 37 °C, just 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 of 10 °C.

Experiment 1



Figure 1.8 Steps 1-6.

the amylase.

Spots of iodine are placed into the depressions on the spotting tile. 5 cm³ of starch suspension is placed in one boiling tube, using a syringe, and 5 cm³ of amylase solution in another tube, using a different syringe. The beaker is filled with water at room temperature. 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 on the spotting tile. The colour of the iodine is recorded.

Temperature is not the only factor that affects an enzyme's activity. The rate of reaction may also be increased by raising the concentration of the enzyme or the substrate. The pH of the surroundings is also important. The pH inside cells is around neutral (pH 7) and not surprisingly, most enzymes have evolved to work best at this pH. At extremes of pH either side of neutral, the enzyme activity decreases, as shown by Figure 1.7. The pH at which the enzyme works best is called the **optimum pH** for that enzyme. 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.

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 like this, 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.

A sample of the mixture is taken every 30 seconds for 10 minutes and tested for starch as above, until the iodine 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.

| | Colour of mixture at different temperatures | | | | | | |
|------------|---------------------------------------------|------------|------------|------------|------------|--|--|
| Time (min) | 20°C | 30°C | 40°C | 50°C | 60°C | | |
| 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 used up. For example, at 50 °C the starch was all gone after 3.5 minutes. The rate is found by dividing the volume of the starch (5 cm³) by the time:

Rate = 5/3.5 = 1.4 cm³/min

Plotting a graph of rate against temperature should produce a curve something like the one shown in Figure 1.6. Try this, either using the results in the table, or you may be able to provide your own results, by carrying out a similar experiment yourself.

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

How the cell gets its energy

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

The process of 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 glucose (a sugar). 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 all its energy as heat, whereas respiration releases some heat energy, but most is trapped as energy in other chemicals. This chemical energy can be used for a variety of purposes, such as:

- contraction of muscle cells, producing movement
- active transport of molecules and ions (see page 10)
- building large molecules, such as proteins
- cell division.

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

The overall reaction for respiration is:

| glucose | + | oxygen | \rightarrow | carbon dioxide | + | water | (+ energy) |
|--------------------|---|--------|---------------|------------------|---|-------|------------|
| $C_{6}H_{12}O_{6}$ | + | 60, | \rightarrow | 6CO ₂ | + | 6H,0 | (+ energy) |

This is called **aerobic** respiration, because it uses oxygen. It is not just carried out by human cells, but by all animals and plants and many other organisms. It is important to realise that the equation above is just 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 cell's mitochondria.

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, and less energy is released. However, 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 commercial processes such as making wine and beer, and 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:

| glucose | \rightarrow | ethanol | + | carbon dioxide | (+ some energy) |
|--------------------|---------------|-------------|---|----------------|-----------------|
| $C_{6}H_{12}O_{6}$ | \rightarrow | $2C_2H_5OH$ | + | $2CO_2$ | |

This process is looked at in more detail in Chapter 21. The ethanol from this respiration is the alcohol in wine and beer. The carbon dioxide is the gas that makes bread rise when it is baked. 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 'stored' chemical energy 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 enough oxygen for aerobic respiration. This happens when a person does a 'burst' activity, such as a sprint, or quickly lifting a heavy weight. This time the glucose is broken down into a substance called **lactic acid**:

 $\begin{array}{rcl} {\rm glucose} & \rightarrow & {\rm lactic \ acid} & (+ \ {\rm some \ energy}) \\ {\rm C_6H_{12}O_6} & \rightarrow & {\rm 2C_3H_6O_3} \end{array}$

In respiration, carbon passes from glucose out into the atmosphere as carbon dioxide. The carbon can be traced through this pathway using radioactive C^{14} .

Anaerobic respiration has two main disadvantages over aerobic respiration. It converts much less of the energy stored in food into a form of chemical energy that cells can use. It also produces toxic waste products, such as lactic acid or ethanol.

Anaerobic respiration provides enough energy to keep the overworked muscles going for a short period, but continuing the 'burst' activity makes lactic acid build up in the bloodstream, producing muscle cramps. The person then has to rest, to oxidise the lactic acid fully. This uses oxygen. The volume of oxygen needed to completely oxidise the lactic acid that builds up in the body during anaerobic respiration is called the **oxygen debt**.

Experiment 2





Experiment 3

Demonstration of the production of carbon dioxide by small living organisms

Hydrogencarbonate 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 or germinating seeds.

The organisms are placed in a stoppered boiling tube with the indicator, as shown in Figure 1.9. The gauze platform supports the organisms above the hydrogencarbonate indicator solution and stops them from coming into contact with the chemical.

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. You will need to ensure that your plan means that the comparison between the three organisms is 'fair'. Don't forget to include a description of a control that you would set up.

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

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, surface-sterilising them and killing any bacteria present. 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 1.10, 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 1.10 Experiment to show that heat is produced during respiration in germinating peas.

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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 end of the experiment.

The following results were obtained from this experiment:

Temperature in flask with dead peas = 21 °C

Temperature in flask with living peas = 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.

Movements 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 is selective about which chemicals can pass in and out. There are three main ways that molecules and ions can move through the membrane. They are diffusion, active transport and osmosis.

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 they can move in either direction through it. Because there is a higher concentration of carbon dioxide molecules inside the cell than outside, over time more molecules will move from inside the cell to outside than move in the other direction. We say that there is a *net* movement of the molecules from inside to outside (Figure 1.11).



Figure 1.11 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.

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.

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 rate of diffusion of a substance is greater at higher temperatures. The reason for this is that a higher temperature will give the diffusing particles more kinetic energy. Active transport is the movement of particles against a concentration gradient, using energy from respiration.

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**. The cell uses energy from respiration to take up the particles, rather like a pump uses energy to move a liquid from one place to another. In fact, biologists usually speak of the cell 'pumping' ions or molecules in or out. The pumps are large protein molecules located in the cell membrane. 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 (Chapter 11).

Experiment 4

Demonstration of diffusion in a jelly

Agar jelly 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 are carefully dropped, at the same time, into a beaker of dilute hydrochloric acid (Figure 1.12)

The time is taken for each cube to turn colourless.

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.



Earlier in this chapter we called the cell membrane 'selectively' permeable. This term is sometimes used when describing osmosis. It means that the membrane has control over which molecules it lets through (e.g. by active transport). 'Partially' permeable just means that small molecules such as water and gases can pass through, while larger molecules cannot. Strictly, the two words are not interchangeable, but they are often used this way in biology books. 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 can read about osmosis in much more detail in Chapter 11.

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 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 (air sacs) allow 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) or the root hairs (Chapter 11).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 1.13).

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 1.14). Throughout this book you will read about cells that have a structure adapted for a particular function.



Figure 1.13 Animals and plants grow by cell division.

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

The rate of diffusion of a substance is increased by:

- a steep concentration gradient
- high temperatures
- a large surface area to volume ratio.



Figure 1.14 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. 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.

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 1.15. 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
- **respiratory** system including the lungs, which exchange oxygen and carbon dioxide
- **circulatory** system including the heart and blood vessels, which transport materials around the body



Figure 1.15 Some of the main organs of the human 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.

You should now be able to:

- recall the eight characteristics of living organisms
- recognise cell structures, including the nucleus, cytoplasm, cell membrane, cell wall, chloroplast and vacuole, and describe their functions
- describe the differences between plant and animal cells
- understand the role of enzymes as biological catalysts in metabolic reactions
- ✓ understand how the functioning of enzymes can be affected by changes in temperature and pH
- describe how to carry out simple controlled experiments to illustrate how enzyme activity can be affected by changes in temperature
- understand the processes of aerobic and anaerobic respiration; recall word equations for these reactions, and the chemical symbol equation for aerobic respiration
- describe simple experiments to demonstrate the production of carbon dioxide and heat from suitable living organisms
- understand the movement of substances into and out of cells by diffusion, osmosis and active transport, and the factors that can affect the rate of movement
- / describe a simple experiment to demonstrate diffusion in agar jelly
- describe the levels of organisation within organisms: organelles, cells, tissues, organs and organ systems.

Questions

More questions on life processes can be found at the end of Section A on page 23.

- 1 *a*) Draw a diagram of a plant cell. Label all of the parts. Alongside each label write the function of that part.
 - *b*) Write down three differences between the cell you have drawn and a 'typical' animal cell.
- 2 Write a short description of the nature and function of enzymes. It would be easier if you worked on a computer. 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.

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



- a) What is the optimum temperature of this enzyme?
- *b*) Explain why the activity of the enzyme is greater at 60 °C than at 30 °C.
- *c*) The optimum temperature of enzymes in the human body is about 37 °C. Explain why this enzyme is different.
- d) What happens to the enzyme at 90 °C?
- 4 Explain the differences between diffusion and active transport.
- 5 The nerve cell called a **motor neurone** (page 67) and a **palisade** cell of a leaf (page 113) 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.
- 6 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.



- a) What is the function of the mitochondria?
- b) 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.
- *c*) 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.
- *d*) The surface membrane of the tubule cell at 'B' is greatly folded. Explain how this adaptation helps the cell to carry out its function.