

How the ideas in this topic link together

Large organisms need systems to take in and transport substances to and from every cell in the body. For example, oxygen and glucose must be delivered for cellular respiration, and waste products such as carbon dioxide must be carried away. Specialised surfaces have evolved to import and export such substances, and networks transport them within the organism.

Transport systems in an organism are rather like a bus route – they carry a range of substances, and there are particular places within the organism where materials are taken on board and off-loaded.

In animals like humans, transport and exchange processes are monitored and controlled by nervous and hormonal communications. This is similar to the way that bus and rail transport systems are coordinated by a control centre.

draft, sample map

Working Scientifically Focus

- Using models and diagrams to represent processes
- Analysing experimental data



2

Transport over larger distances

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SYSTEMS IN THE HUMAN BODY

IDEAS YOU HAVE MET BEFORE:

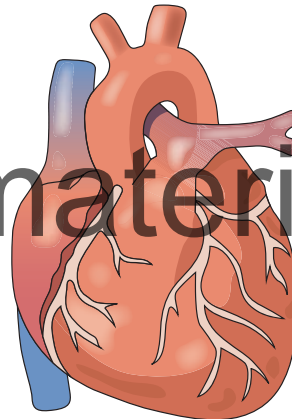
ORGANISMS OBTAIN ENERGY BY THE PROCESS OF RESPIRATION.

- The energy released in respiration drives all the processes necessary for life.
- Most organisms respire by aerobic respiration, using oxygen.
- Some cells or organisms can survive without oxygen. They respire anaerobically.



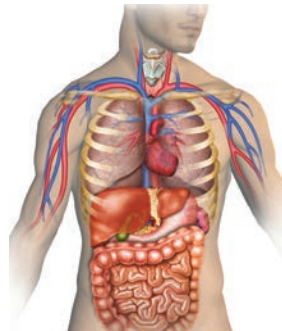
BLOOD IS USED TO TRANSPORT SUBSTANCES TO AND FROM BODY TISSUES.

- The circulatory system moves substances around the body in the blood.
- The function of the heart is to pump blood around the body.
- Blood is made up of red blood cells, white blood cells, plasma and platelets.
- Products of digestion are carried to cells and used to build carbohydrates, lipids and proteins.
- Glucose is required by all cells for respiration; carbon dioxide and water are waste products.
- Oxygen is taken from the lungs to the body. Carbon dioxide is returned from the body to the lungs, where it is excreted.
- Excess protein is converted to urea and transported in the blood to be excreted by the kidneys.



ORGANS WORK TOGETHER AS SYSTEMS.

- Organs are aggregations of tissues.
- Organ systems work together to form organisms.
- Glands in the digestive system produce digestive enzymes.



IN THIS CHAPTER YOU WILL FIND OUT ABOUT:

ANAEROBIC RESPIRATION IS RESPIRATION WITHOUT OXYGEN.

- In animals such as mammals, the muscles can respire anaerobically for short periods during intense activity.
- Anaerobic respiration involves incomplete breakdown of glucose and therefore releases much less energy than aerobic respiration.

WHY DO SOME ORGANISMS NEED ORGAN SYSTEMS?

- Size affects the ability and efficiency of diffusion alone to supply cells with nutrients.
- Small organisms do not have specialised organs for gas exchange or transport of some materials.
- Membrane surfaces and organ systems are specialised for exchanging materials to ensure that all body cells get the nutrients that they need.
- Mammals have transport systems – for example, the heart works as a pump for the transport system in humans.

HOW ARE CONDITIONS IN THE BODY, PROCESSES AND ORGAN SYSTEMS COORDINATED AND CONTROLLED?

- The nervous and endocrine systems are involved in coordination and control.
- The nervous system works using electrical impulses, transmitted using nerves.
- The endocrine system uses chemicals called hormones, which are secreted by endocrine glands.
- The control of hormone secretion by many glands is by negative feedback.

2.1a Cellular respiration

KEY WORDS

aerobic respiration
cellular respiration
exothermic

Learning objectives:

- explain the need for energy
- describe aerobic respiration as an exothermic reaction
- write a balanced symbol equation for respiration, given the formula of glucose.

This runner is using energy to run a marathon. But we all need a continuous supply of energy – 24 hours a day – just to stay alive.

We need energy to live

Organisms need energy:

- to drive the chemical reactions needed to keep them alive, including building large molecules
- for movement
- to keep warm.

Energy is needed to make our muscles contract and to keep our bodies warm. It's also needed to transport substances around our bodies.

In other sections of the book, you will also find out that energy is needed:

- for cell division
- to maintain a constant environment within our bodies
- for active transport. Plants use active transport to take up mineral ions from the soil, and to open and close their stomata
- to transmit nerve impulses.

- 1 List four uses of energy in animals.



Figure 2.1.1 An average runner uses around 13 000 kJ of energy for a marathon

Aerobic respiration

Cellular respiration is the process used by all organisms to release the energy they need from food.

Cellular respiration using oxygen is called **aerobic respiration**. This type of respiration takes place in animal and plant cells, and in many microorganisms.

Glucose is a simple sugar. It is the starting point of cellular respiration in most organisms. The food that organisms take in is, therefore, converted into glucose.

This chemical reaction is **exothermic**. A reaction is described as exothermic when it releases energy. Some of the energy transferred is released as thermal energy.



Figure 2.1.2 Birds and mammals use heat energy to maintain a constant body temperature

2 What is the purpose of cellular respiration?

3 How do birds and mammals make use of the waste thermal energy?

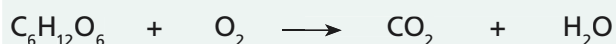
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Bioenergetics

This is the equation for aerobic respiration:

glucose + oxygen → carbon dioxide + water (energy released)

HIGHER TIER ONLY



This equation describes the overall change brought about through each of a series of chemical reactions. A small amount of energy is actually released at each stage in the series.

The first group of steps occurs in the cytoplasm of cells, but most of the energy is transferred by chemical reactions in mitochondria.

4 When and where does respiration occur?

5 Give one characteristic feature of actively respiring cells.

6 Why do we often get hot when we exercise?.



Figure 2.1.3 Insect flight muscles have huge numbers of well-developed mitochondria

DID YOU KNOW?

The muscle an insect uses to fly is the most active tissue found in nature.

COMMON MISCONCEPTIONS

Don't forget that *all* organisms respire. The equation is the reverse of photosynthesis, but don't confuse the two. Photosynthesis is the way in which plants make their food.

2.1b Comparing aerobic and anaerobic respiration

KEY WORDS

anaerobic
respiration
lactic acid
oxygen debt

Learning objectives:

- describe the process of anaerobic respiration in humans
- compare the processes of aerobic and anaerobic respiration.

Without oxygen, you would die. But when your muscles are actively contracting, they run short of oxygen. When this happens, muscle cells can respire without oxygen for short periods of time. This is anaerobic respiration – respiration without oxygen. Lactic acid is produced.

Anaerobic respiration

If there is not enough oxygen available for aerobic respiration, anaerobic respiration takes place in the cytoplasm of muscle cells. It is represented by the equation:



- 1 What is meant by 'anaerobic respiration'?
- 2 When does anaerobic respiration happen in muscle cells?
- 3 Write down the word equation for anaerobic respiration in muscles.

Incomplete oxidation

Anaerobic respiration in muscles is exothermic (a chemical reaction that releases energy), but it is much less efficient than aerobic respiration. Unlike in aerobic respiration, glucose molecules are not completely broken down (oxidised), which means that much less energy is released – only around 5% of the energy released by aerobic respiration, per molecule of glucose. However, in situations where muscles are running short of oxygen, the amount of energy produced is enough to keep cells running for a while longer. The waste product is lactic acid rather than carbon dioxide and water.

- 4 Explain why anaerobic respiration releases much less energy than aerobic respiration.
- 5 Why is anaerobic respiration important in muscle cells?

Oxygen debt

2.1b

During long periods of vigorous activity, our muscles become tired. This is partly because the lactic acid from anaerobic respiration builds up in the muscles and stops them from contracting efficiently.

We say that anaerobic respiration creates an **oxygen debt**. This is the amount of extra oxygen the body needs to react with the accumulated lactic acid and remove it from the cells. The oxygen oxidises the lactic acid to carbon dioxide and water.

Oxygen debt explains why, after exercise, we carry on breathing deeply and quickly for a while – the body is taking in extra oxygen, and transporting it to the muscles in the blood, to remove the build-up of lactic acid from anaerobic respiration.

	Aerobic respiration, in humans	Anaerobic respiration, in humans
Where	in all cells	in muscle cells
When	all the time	during vigorous exercise
By-products	carbon dioxide + water	lactic acid
Energy produced	a great deal	much less – only 5% of that from aerobic respiration
Oxygen needed	yes	no
Oxygen debt produced	no	yes



Figure 2.1.4 This athlete is breathing deeply to help clear the lactic acid build-up in her muscles

- 6 Using the term ‘oxygen debt’, explain why a sprinter continues to breathe deeply after running a 100 m race.

KEY SKILL

You must be able to compare aerobic and anaerobic respiration: the need for oxygen, the products and the amount of energy transferred.

KEY CONCEPT

2.1c The need for transport systems in multicellular organisms

Learning objectives:

- explain why multicellular organisms need a transport system, in terms of surface area : volume ratio.

KEY WORDS

diffusion
organs
organ systems
surface area:
volume ratio
tissues

A single-celled organism has a relatively large surface area : volume ratio, so substances can diffuse quickly into and out of all parts of the cell. Larger, multicellular organisms have a smaller surface area : volume ratio and cannot rely on diffusion alone. Instead, they need specialised organ systems to carry materials to and from every cell in the body.

Cells, tissues and organ systems

In multicellular organisms, most cells work together in tissues. A **tissue** is a group of cells with a particular function. Many tissues have a number of similar types of cell to enable the tissues to carry out their function.

Tissues are grouped into **organs**. Organs also carry out specific functions.

Different organs are arranged into **organ systems** – for example the circulatory system, digestive system, respiratory system and reproductive system.

Many chemical reactions happen inside living cells. Substances such as nutrients and oxygen must enter the cell to fuel these reactions. The waste products of the reactions, such as carbon dioxide, need to be removed. The circulatory system, digestive system and respiratory system work together to transport these substances to and from all cells in the body.

- 1 Arrange the following in ascending order of size:
system cell human body organ tissue
- 2 Name two types of cell and two types of tissue in the circulatory system.

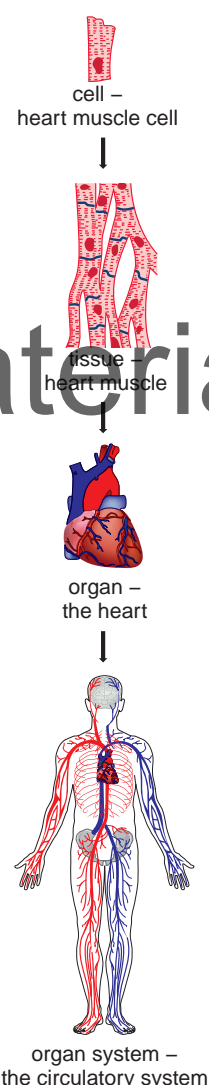


Figure 2.1.5 The organisation of the human circulatory system

Size matters

Most cells are no more than 1 mm in diameter. This is because nutrients, oxygen and waste substances can diffuse quickly in and out of small cells. However, as the volume of a cell increases, the distance increases between the cytoplasm at the centre of the cell and the cell membrane. In addition, larger cells have greater chemical activity, and so need substances to be moved in and out at a greater rate. In cells bigger than 1 mm diameter, the rate of exchange with the surroundings by diffusion may be too slow to meet the cell's needs. The cell would probably not survive.

- 3 How does the size of a cell affect the chemical activity inside the cell?
- 4 Describe one chemical activity that takes place in cells.

Looking at surface area : volume ratios

The surface area of a cell affects the rate at which particles can enter and leave the cell. It also affects the rate at which energy is lost or gained.

The volume of the cell affects the rates of chemical reactions within the cell (how quickly materials are used in reactions and how fast the waste products are made).

Look at Figure 2.1.6. The cubes represent cells.

- Cubes have six sides, so the surface area = length \times width \times 6.
- The volume of a cube = length \times width \times height.
- Surface area : volume ratio = surface area \div volume.

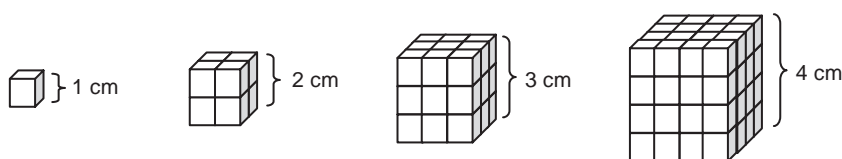


Figure 2.1.6 Cubes of increasing size

- 5 What do you think will happen to surface area and volume as size increases?
- 6 What do you think will happen to surface area : volume ratio as size increases?
- 7 What does a decrease in surface area : volume ratio make it more difficult to do?
- 8 Why do multicellular organisms need a transport system?

MATHS SKILLS

2.1d Surface area:volume ratio

Learning objectives:

- be able to calculate surface area and volume
- calculate and compare surface area:volume ratios
- know how to apply ideas about surface area and volume
- use SI units (e.g. m, mm)
- use prefixes and powers of ten for orders of magnitude (e.g. centi, milli, micro)
- interconvert units.

KEY WORDS

ratio
sphere

The ratio of surface area to volume is very important in living things. In science we use mathematical skills to calculate the surface area:volume ratio, which helps us to understand how organisms work.

Finding the area of a surface

Alveoli provide a large surface area for gas exchange between the air and the bloodstream. If our lungs were smooth on the inside, like balloons, the surface area would be much less and materials would not be exchanged fast enough.

We can calculate surface area in different ways. For a rectangular shape, we multiply the length by the width. For example, an area of skin 4 cm long and 7 cm wide has a surface area of $(4 \times 7) = 28 \text{ cm}^2$.

Living things are not generally made up of regular shapes, such as rectangles, so we have to use other ways of finding the area. One way is to use squared paper and to count how many squares are covered (or are largely covered) by the specimen.

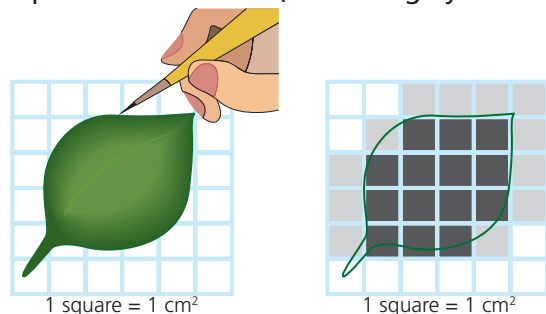


Figure 2.1.8 Counting squares that are largely covered is (approximately) balanced by not counting squares that are slightly covered.

- 1 Estimate the surface area of the leaf in Figure 2.1.9
- 2 Calculate the surface area of:
 - a a piece of tree bark that is 30 cm long and 3 cm wide
 - b a razor shell that is 50 mm long and 8 mm wide.



Figure 2.1.7 Elephants have wrinkled skin to increase their surface area.

KEY INFORMATION

Note that both the length and the width have to be measured in the same units and that the answer is in those units, squared.

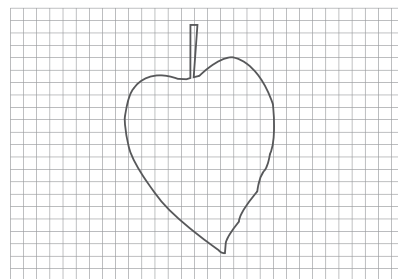


Figure 2.1.9 One square is 1 cm^2 .

Working out the volume

It is easier for warm-blooded animals to keep warm on cold days if their volume is large, but then it is harder for these same animals to lose heat on a hot day. We calculate the volume of a cube by multiplying length by width by height. A die with a side of 2 cm has a volume of $(2 \text{ cm} \times 2 \text{ cm} \times 2 \text{ cm}) = 8 \text{ cm}^3$. Again, all the distances need to be in the same units and the volume is also in those units, cubed.

- 3 What is the volume of:
 - a a science laboratory 10 m wide, 15 m long and 3 m high?
 - b a block of wood 2 cm wide, 3 cm long and 4 cm high?
- 4 Finding the volume of a tree branch is tricky, but one way is to immerse the branch in a tank full of water. Suggest how the volume is measured.

Surface area : volume ratio

In science it is useful to compare the surface area with the volume. We do this by finding the ratio of one compared with the other. To find the **ratio**, divide the surface area by the volume. For example, for a cube with sides 2 cm long:

surface area = $2 \times 2 \times 6 = 24 \text{ cm}^2$;

volume = $2 \times 2 \times 2 = 8 \text{ cm}^3$;

surface area : volume ratio = $24 : 8 = 3 : 1$

The shape of an organism also affects its surface area : volume ratio. Spheres have the smallest surface area compared with their volumes. Many small mammals have a shape that is almost spherical – for example, a mouse – and puppies and kittens curl up into a ball to sleep. As small animals, they want to minimise their surface area : volume ratio so as to minimise thermal energy loss.

- 5 Compare how surface area, volume, and surface area : volume ratio change as the size of a cube increases. Calculate values for cubes with sides of 1, 2, 3, 4, 6 and 8 cm.
- 6 Imagine the shapes below are animals. Look at A, B and C in Figure 2.1.10.

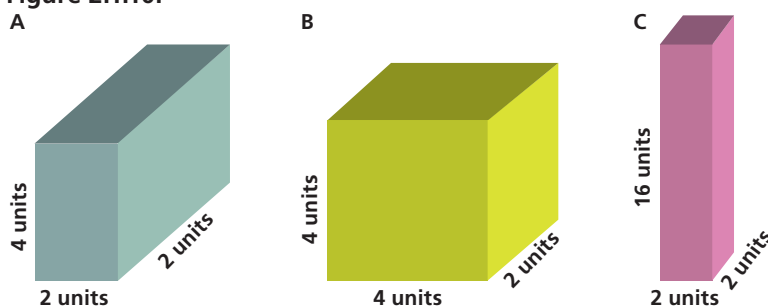


Figure 2.1.10 What do you notice about the surface area : volume ratios of these 'animals'?

Which animal will have problems keeping:

- a cool? Explain your answer.
- b warm? Explain your answer.
- 7 Devise a method to measure the volume of the air you breathe out in one breath.

DID YOU KNOW?

Arctic foxes have much smaller ears than desert-dwelling fennec foxes. Arctic foxes must reduce thermal energy loss but fennec foxes must increase thermal energy loss to their environment.

2.1e Exchange surfaces

Learning objectives:

- explain how efficient exchange surfaces are adapted to carry out their function
- calculate and compare surface area:volume ratios.

KEY WORDS

alveolus
(plural:
alveoli)
concentration
gradient

diffusion
exchange
surface
gas exchange
ventilation

A single-celled organism, with a relatively large surface area:volume ratio, can rely on diffusion alone to exchange substances with the environment. Multicellular organisms have much smaller surface area:volume ratios, and therefore need surfaces and organ systems that are specialised for exchanging materials efficiently with the surroundings.

Transport systems and exchange surfaces

When an organism is multicellular and has several layers of cells, oxygen and nutrients take longer to diffuse in and are all used up by the outer layers of cells. Exchange systems allow transport to and from all cells for the organism's needs. As well as exchanging substances, cells also have to lose thermal energy fast enough to prevent overheating.

An efficient **exchange surface** has a:

- large surface area to maximise rate of exchange
- thin membrane to provide a short diffusion path
- method of transporting substances to and from the exchange surface.

- 1 How are efficient exchange surfaces adapted to carry out their function?
- 2 Explain why large organisms need transport systems but small organisms do not.

Gas exchange

Gas exchange involves:

- taking in oxygen, which is used to release energy from food during cellular respiration
- releasing carbon dioxide, which is a waste product of cellular respiration.

Gas exchange happens at a respiratory surface – a membrane separating the inside of the body from the external environment. Single-celled organisms use their cell surface membrane for gas exchange. In large organisms, the exchange

Organism		Surface area : volume ratio
bacterium		6 000 000
amoeba		60 000
fly		600
dog		6
whale		0.06

COMMON MISCONCEPTIONS

Breathing is ventilation.
Respiration is the release
of energy from food inside
each cell.

surface is part of specialised organs, such as lungs and gills in animals and leaves in plants.

In humans, gas exchange happens in the **alveoli** of the lungs. Blood transports the gases to and from the surface of each alveolus through the capillaries that cover it.

Air entering the alveoli has a greater oxygen concentration than the deoxygenated blood flowing through the lungs. This causes a steep **concentration gradient**, from high to low concentration, and allows efficient diffusion of oxygen in the air to the blood.

Deoxygenated blood has a greater carbon dioxide concentration than air in the alveoli, so carbon dioxide diffuses from the blood into the alveoli before being breathed out.

All gas exchange surfaces have a large surface area, a thin permeable membrane and a moist exchange surface. Many also have a **ventilation** system and an efficient transport system to keep the diffusion gradients as high as possible, to maximise the rate of gas exchange.

- 3 Explain how gas exchange happens in the alveoli.
- 4 What is the difference between breathing and respiration?

Adaptations of your lungs

Your lungs are efficient exchange surfaces.

- Alveoli are spherical, and there are millions in each lung, which provides a vast total surface area.
- The exchange surface at the alveolus wall is very thin (one cell thick), so diffusion distance for gases is very short.
- Each alveolus is closely surrounded by a network of capillaries to ensure a good blood supply. Oxygen is constantly taken away in the blood, and carbon dioxide is constantly brought to the lungs to be removed. So gas exchange happens at a steep concentration gradient.
- Constant ventilation continually brings oxygen-rich air into the lungs and expels carbon dioxide, which also helps maintain steep concentration gradients of gases.
- The alveoli surfaces are moist. Gases dissolve to allow efficient diffusion across the exchange surface.

- 5 Why are lungs efficient exchange surfaces?
- 6 Explain how your breathing, together with the efficient blood supply to your lungs, maintains steep concentration gradients of oxygen and carbon dioxide across the gas exchange surface.
- 7 Explain why it is important to maintain concentration gradients across an exchange surface.

DID YOU KNOW?

The lungs have over 300 million alveoli and the left lung is slightly smaller than the right, so there is room for your heart.

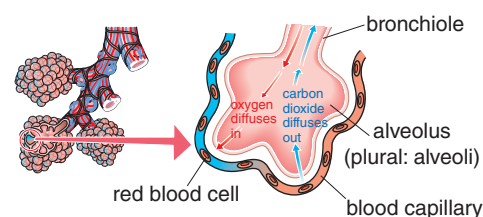


Figure 2.1.11 Gas exchange in an alveolus

KEY INFORMATION

All exchange surfaces have a large surface area, thin membranes and are moist. Many have an efficient transport system.

2.1f The human heart

Learning objectives:

- describe the structure and function of the heart
- explain how the structure of the heart is adapted to its function
- explain the movement of blood around the heart
- use simple compound measures such as heart rate
- carry out calculations of heart rate.

KEY WORDS

aorta
atrium (plural:
atria)
coronary artery
pacemaker
vena cava
ventricle

Larger animals like humans need specialised exchange surfaces and a transport system to carry important substances to every cell throughout the body, and to remove waste. To keep substances moving, the transport system needs a pump, called a heart.

The heart

The heart is made of muscle. Heart muscle continually contracts and relaxes. It uses a lot of energy. Heart muscle receives oxygen and glucose for respiration from the blood brought by the **coronary artery**.

The heart has two pumps (a dual circulation) that beat together about 70 times every minute of every day. This is a heart rate of 70 beats per minute (bpm).

Each pump has an upper chamber (atrium) that receives blood and a lower chamber (ventricle) that pumps blood out. Both **atria** fill and pump blood out at the same time, as do both ventricles.

Blood from the lungs contains oxygen and enters the heart at the left atrium. It passes into the left ventricle and is pumped out to the body.

Blood from the body contains very little oxygen and enters the heart at the right atrium, passes into the right ventricle and is pumped to the lungs, where gas exchange takes place.

The natural resting heart rate is controlled by a group of cells located in the right atrium that act as a **pacemaker**. If a person has an irregular heart rate – because of disease or injury to the heart, for example – an artificial pacemaker can be implanted. This electrical device sends small impulses to the heart muscle to correct irregularities in the heart rate.

- 1 What is the function of the heart?
- 2 A doctor took a patient's pulse, and counted 19 beats in 15 seconds. Calculate the patient's heart rate, in beats per minute (bpm).

The parts of the heart

The heart has four main blood vessels:

- The pulmonary vein transports oxygenated blood from the lungs to the left atrium.

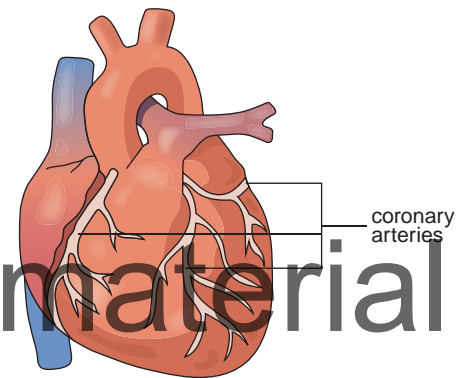


Figure 2.1.12 The coronary arteries supply the heart muscle, bringing oxygen and nutrients and carrying away waste substances

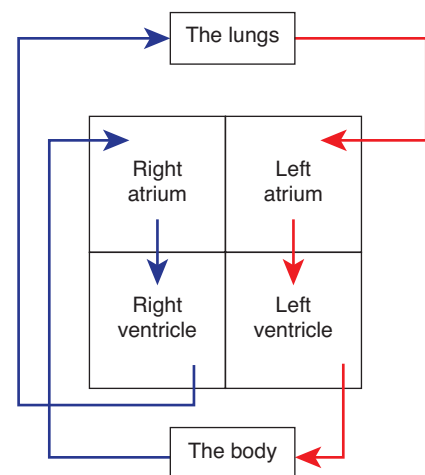


Figure 2.1.13 Blood flow through the heart

- The **aorta** (main artery) transports oxygenated blood from the left ventricle to the body.
- The **vena cava** (main vein) transports blood from the body to the right atrium.
- The pulmonary artery transports deoxygenated blood from the right ventricle to the lungs.

Ventricles have thicker walls than atria because they pump blood further. The left ventricle pumps blood around the body. It has a thicker wall than the right ventricle, which only pumps blood to the lungs. Valves between the atria and the ventricles prevent the backflow of blood. They open to let blood through and then shut.

- 3 Describe the functions of the different chambers of the heart.
- 4 Describe how the atria and ventricles move blood through the heart.

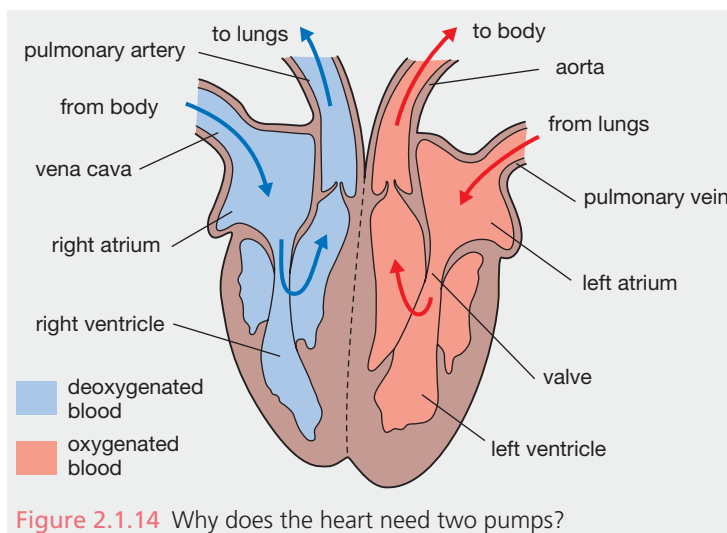


Figure 2.1.14 Why does the heart need two pumps?

Explaining blood flow

Figure 2.1.15 summarises the sequence of events in a heart beat, called the cardiac cycle.

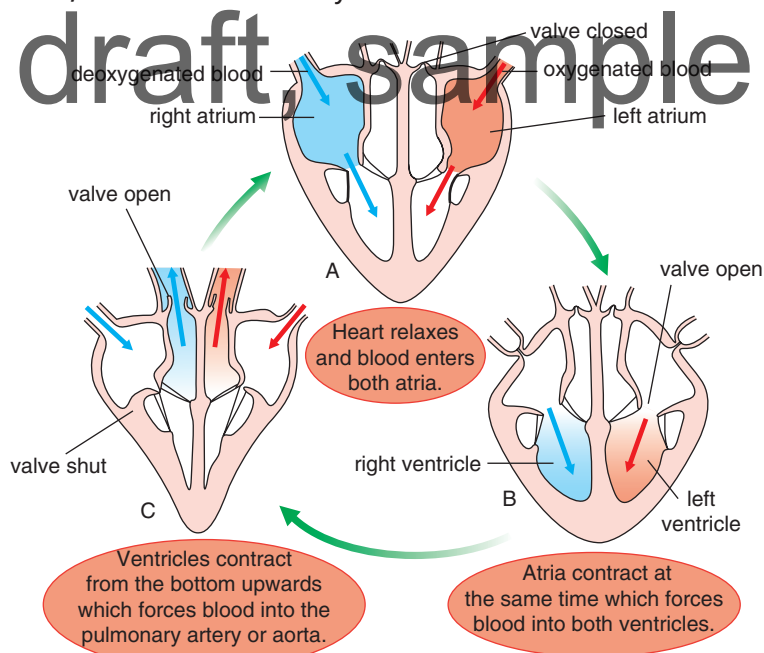


Figure 2.1.15 The cardiac cycle

- 5 Explain the sequence of contractions and valve openings as blood passes through the heart.
- 6 If a coronary artery supplying the left ventricle becomes blocked, what effect does this have on the functioning of the heart? Explain your answer.

KEY INFORMATION

Atria receive blood, ventricles pump it out.

DID YOU KNOW?

The complete cardiac cycle normally takes 0.08 seconds.

2.1g The human circulatory system

Learning objectives:

- describe the human circulatory system, including its relationship with the gaseous exchange system
- describe functions of parts of the circulatory system
- explain how the structures of the blood vessels are adapted for their functions
- describe some of the substances transported into and out of organisms.

KEY WORDS

artery
bronchus
capillary
dual circulatory
system
trachea
vein

The heart pumps blood through a vast system of blood vessels, which carry it close to every cell in the body, and then back to the heart. As the blood moves through this circulatory system, it delivers useful substances such as oxygen to respiring cells, and carries away waste products such as carbon dioxide.

Transport systems

Humans have a **dual circulatory system**. This means the blood flows in two circuits round the body:

- from the heart to the lungs, and back to the heart
- from the heart to the body, and back to the heart.

Blood is pumped out of the heart into vessels called **arteries**, under high pressure. As the blood flows from the arteries, through tiny capillaries in body tissues, and then back to the heart in **veins**, the pressure decreases.

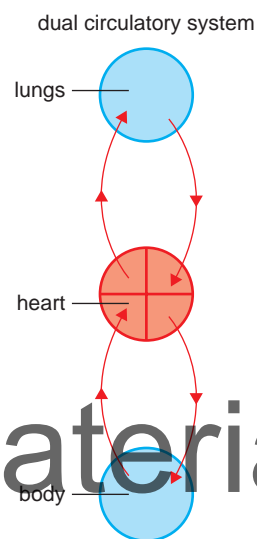


Figure 2.1.16 Why does blood travel to the lungs?

- 1 What is a dual circulatory system?
- 2 Which vessels carry blood away from the heart?

How does the system work?

As well as dissolved food, your body cells need oxygen for cellular respiration, and need to get rid of waste carbon dioxide. Your circulatory system, working with your respiratory system, delivers oxygen to and picks up carbon dioxide from every cell.

Deoxygenated blood from the body is pumped from the right ventricle of the heart, through the pulmonary artery, into the capillary networks around the alveoli of the lungs. Here, at the specialised surfaces of the alveoli, oxygen from the air diffuses into the blood, and carbon dioxide from the blood diffuses into the air.

As you breathe, you ventilate your lungs, bringing in fresh oxygen-rich air and exhaling air rich in carbon dioxide. This, with the efficient blood supply, maintains steep concentration gradients for diffusion of these gases across the exchange surface of the alveoli.

Oxygenated blood goes to the left side of your heart in the pulmonary vein. Then it is pumped from the left ventricle, through the main artery (aorta), to the body. It enters smaller arteries (arterioles) supplying your organs and tissues. Then it passes into networks of tiny capillaries, which lie very close to every body cell. Here, oxygen diffuses from the blood into the cells, and carbon dioxide diffuses from the cells into the blood, each down its concentration gradient. Next, deoxygenated blood moves into venules, and then into veins, which carry it back to the right side of the heart, and the circulation then begins again.

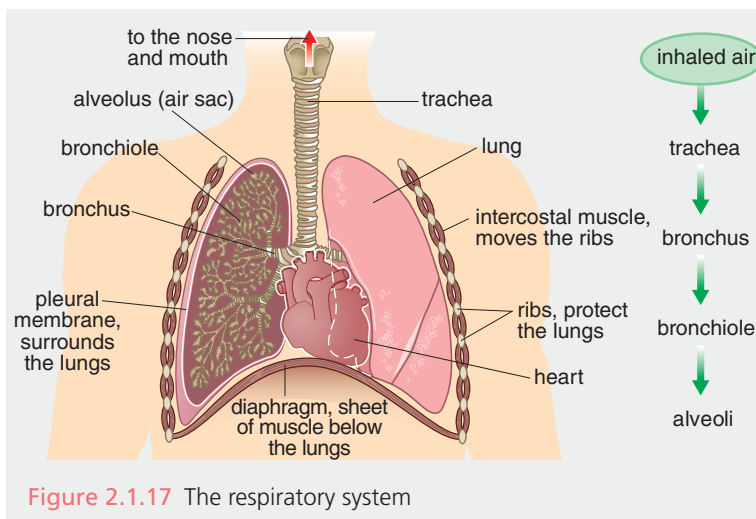


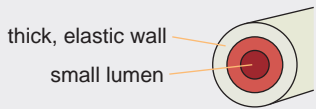
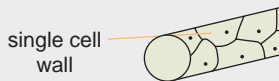
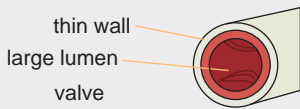
Figure 2.1.17 The respiratory system

- 3 Describe how air reaches the alveoli.
- 4 Describe how cells deep in your body can receive oxygen and dispose of carbon dioxide efficiently.

Adaptations of your circulatory system

Blood flows from the heart to arteries, arterioles (small arteries), capillaries, venules (small veins), veins and then back to the heart.

Each type of blood vessel is adapted to carry out different functions. The table summarises the adaptations.

Arteries	Capillaries	Veins
 <p>thick, elastic wall</p> <p>small lumen</p>	 <p>single cell wall</p>	 <p>thin wall</p> <p>large lumen</p> <p>valve</p>
carry blood from the heart, with a pulse from the heart beat	carry blood from arteries to veins, with no pulse	carry blood to the heart, with smooth flow and no pulse
carry oxygenated blood (except the pulmonary artery)	blood slowly loses its oxygen	carry deoxygenated blood (except the pulmonary vein)
have thick, impermeable, elastic walls with small lumen , to carry blood under high pressure	have one-cell-thick, permeable walls, with huge total surface area, for efficient exchange with body cells	have thinner, impermeable walls with a large lumen, providing less flow resistance, for carrying blood under low pressure
do not have valves	do not have valves	have valves to prevent backflow

- 5 Explain how each blood vessel is adapted for its function.
- 6 Why are the walls of arteries and veins impermeable?

2.1h Blood cells

Learning objectives:

- identify the parts of the blood and their functions
- explain how the different parts of the blood are adapted to their functions
- identify different types of blood cell in a photograph or diagram.

KEY WORDS

haemoglobin
oxyhaemoglobin
plasma
platelets
red blood cells
white blood cells

The blood is a liquid medium adapted to carry substances efficiently to and from every cell of the body, in the circulatory system. Blood is made up of different parts, each with its own function.

What is blood?

Blood is a tissue. It is a mixture of cells, solutes and a liquid. The straw-coloured liquid part of blood is **plasma**.

Red blood cells, **white blood cells** and **platelets** are suspended in the plasma. Each part of the blood has a specific function:

- Plasma transports substances around the body, for example, carbon dioxide.
- Red blood cells carry oxygen from the lungs to body cells.
- White blood cells help to protect the body against infection.
- Platelets are cell fragments which help the clotting process at wound sites.

There are millions of red blood cells in the plasma. This is why blood looks red.

- 1 Look at Figure 2.1.18. Identify the red blood cells, white blood cells and platelets.
- 2 What is the function of:
 - a red blood cells
 - b white blood cells?

Looking closer

The blood parts can be separated by spinning them very fast in a machine called a centrifuge. About 55% of blood is plasma; plasma consists of roughly 90% water and 10% solutes. It is very important because it transports many substances, for example:

- hormones
- antibodies
- nutrients, such as glucose, amino acids (proteins), minerals and vitamins
- waste substances, like carbon dioxide and urea.



Figure 2.1.18 Blood consists of several different parts

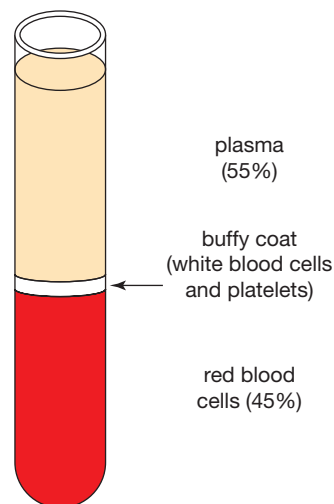


Figure 2.1.19 Blood looks like this if it is separated in a centrifuge

Red blood cells transport oxygen from the lungs to tissues all over the body. Blood is able to transport oxygen efficiently because in 1 mm³ of blood there are about 5 million red blood cells. Red blood cells:

- are tiny, allowing them to pass through the narrow capillaries
- have a biconcave disc shape, giving them a large surface area:volume ratio, which increases the efficiency of diffusion of oxygen into and out of the cell, and reduces the diffusion distance to the centre of the cell
- contain **haemoglobin**, which binds to oxygen to transport it from the lungs to the body tissues
- have no nucleus, increasing the space available for haemoglobin.

White blood cells are adapted to fight infections. There are several types. Some are able to produce proteins called antibodies, which help destroy invaders. Others can change shape to engulf bacteria, and can even squeeze out of blood vessels to get to an infection site.

Platelets are adapted to help seal wounds and prevent excessive bleeding. They are tiny cell fragments without a nucleus that become 'sticky' when activated at a wound site, and help form a clot.

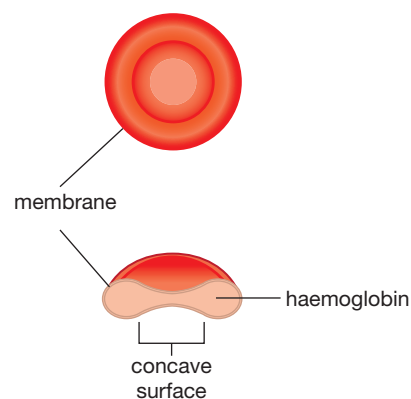


Figure 2.1.20 Red blood cells are adapted to carry oxygen

KEY INFORMATION

Red blood cells transport oxygen; plasma transports many substances including carbon dioxide.

3 Describe the role of plasma, and how it is adapted for this role.

4 How are red blood cells, white blood cells and platelets adapted to their different functions?

How the blood carries oxygen

Haemoglobin binds with oxygen at high concentration to form a bright red compound called **oxyhaemoglobin**. The bonds between the haemoglobin and oxygen are weak, and oxyhaemoglobin dissociates to haemoglobin and oxygen in low oxygen concentrations.



5 Describe how haemoglobin transports oxygen.

6 Use surface area:volume ratio to explain how red blood cells are adapted to their function.

7 Sickle cell anaemia is a serious inherited blood disorder in which the red blood cells develop abnormally and contain defective haemoglobin. Explain why somebody with sickle cell anaemia is likely to feel very tired and breathless while exercising.

DID YOU KNOW?

Crabs have blue blood, earthworms and leeches have green blood and starfish have clear or pale yellow blood!

2.1i The human digestive system

Learning objectives:

- explain how large insoluble food molecules are broken down by digestion into small soluble molecules
- explain how the products of digestion can be used in cells
- describe some of the substances transported into and out of organisms, including dissolved food molecules and urea.

KEY WORDS

absorption
carbohydrase
digestion
digestive system
enzyme
lipase
protease

Your body breaks down the food you eat. Large, insoluble food molecules are digested into much smaller, soluble molecules, which are absorbed into the blood from the small intestine, and carried to every body cell.

The digestive system

The **digestive system** is a long tube that runs from the mouth to the anus. It consists of several organs working together to break down and absorb food. Each organ is adapted to perform a different function.

The digestive system uses **enzymes** to break down, or digest, large insoluble food molecules into small soluble molecules.

Digestion is completed in the small intestine, where the products – the small, soluble food molecules – then pass through the gut wall into the blood. This is called **absorption**.

The blood carries the soluble molecules to the body cells, where they can be used for respiration or to make new large molecules that cells need as energy reserves or for growth and repair.

1 Why do we digest food?

2 What is absorption?

Digestion and synthesis

Digestion is the breakdown of large molecules into smaller ones, while synthesis is the process of building large molecules from smaller units. Enzymes catalyse both types of reaction in the body.

Most enzymes, including those that help synthesise large molecules, work inside cells. But digestive enzymes work outside cells. They are produced by cells in glands and in the lining of the gut, and pass into the gut to mix with the food. There are three groups of enzymes in digestion: carbohydrases, proteases and lipases.

- **Carbohydrases** break down carbohydrates into simple sugars. For example, amylase breaks down insoluble starch to water-soluble sugars, which are further broken down into glucose. Glucose is used in cells for respiration, and also to synthesise new carbohydrates.

- **Proteases** break down insoluble proteins to soluble amino acids. Cells use amino acids to synthesise new proteins. Any unwanted amino acids are converted by the liver to urea, which is carried by the blood to the kidneys and excreted in urine.
- **Lipases** break down lipids (fats and oils) to glycerol and fatty acids, which are used for energy, to build cell membranes and to make hormones. Cells can also use these building blocks to re-synthesise fats as a store of energy because cells can break them down and use them in respiration.

- 3 What reaction do proteases catalyse?
- 4 What are the products when a lipase breaks down fats?
- 5 Suggest why digestive enzymes do not work inside cells.

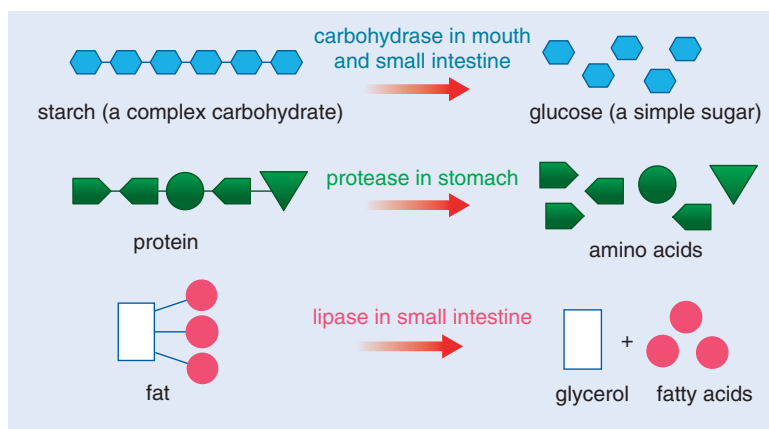


Figure 2.1.21 Why is digestion by enzymes important?

A special exchange surface

The soluble products of digestion pass through the wall of the small intestine, and are carried away in the blood capillaries. Fatty acids are also carried away in other vessels called lacteals.

The small intestine is an effective exchange surface because:

- it is about 7 m long, so there is time for absorption of soluble molecules as food travels along
- it has a very thin, permeable membrane for easy diffusion
- the cells lining the small intestine have many small projections called villi, each with even tinier projections called microvilli, increasing the surface area for absorption
- blood capillaries transport molecules away, maintaining the concentration gradient for diffusion
- lacteals carry fatty acids away through the lymphatic system, which eventually returns them to the blood.

Between meals, the concentration of dissolved food molecules in the blood can be higher than in the intestine. At this time, the molecules are moved into the blood using active transport.

- 5 Explain why the small intestine is an effective exchange surface.
- 6 Suggest why fatty acids are not absorbed directly into blood.

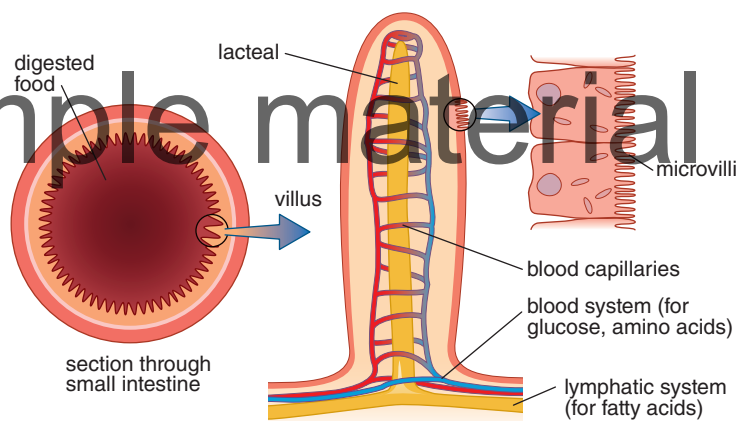


Figure 2.1.22 Villi help make the small intestine an effective exchange surface

DID YOU KNOW?

If flattened out, the surface of the small intestine would cover an area of about 250 m² (the size of a tennis court).

REQUIRED PRACTICAL

2.1j Food tests

Learning objectives:

- use a Bunsen burner and a boiling water bath safely
- carry out experiments appropriately having due regard for the correct manipulation of apparatus, and health and safety considerations
- interpret observations and draw conclusions.

KEY WORDS

Benedict's test
carbohydrates
qualitative
reagents

Food samples can be analysed using qualitative tests to see if they contain carbohydrates (starch and sugars), proteins and fats.

Describing how apparatus is used and working safely

Qualitative tests can be used to test for the presence of different food groups using ground up food. The food is added to distilled water, stirred and filtered.

The **Benedict's test** is used to test for sugars: the filtrate is transferred to a test tube, Benedict's reagent is added and the tube is placed in a water bath of boiling water for 5 minutes to see if a colour change occurs.

To test for lipids, the filtrate is added to a test tube and shaken gently with Sudan III stain.

The Biuret test is used to test for protein.

These pages are designed ! to help you think about aspects of the investigation rather than to guide you through it step by step.

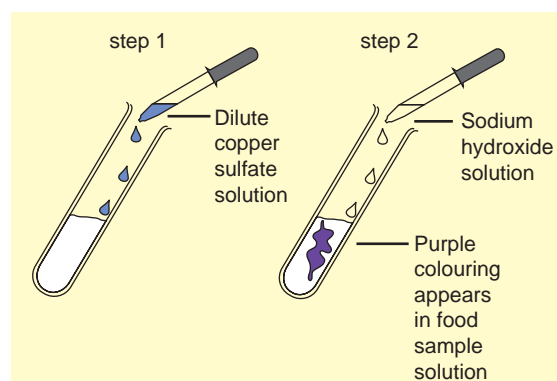


Figure 2.1.24 Test for protein (Biuret test)

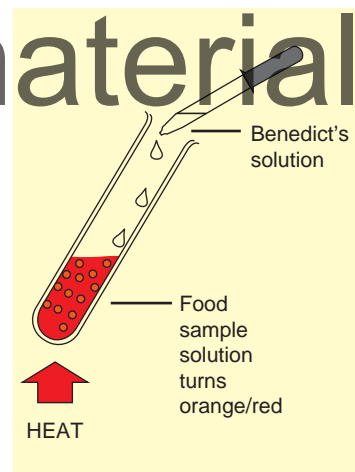


Figure 2.1.23 Test for glucose

1 Which piece of apparatus could be used to:

- grind the food up
- add drops of indicator solution
- measure small volumes of liquids?

- 2 Why is the ground up food stirred with the distilled water and then filtered?
- 3 Describe the test that could be carried out to show if protein was present in the food.
- 4 State two safety precautions that should be taken for each test.

Making and recording observations

Ravi is going to test three different foods to see which food groups, including starch, are present. She needs to design a table for the results that all the data will fit into. It needs to be fully labelled and include units. Ravi is going to test each food for each food group twice and is also going to use a control tube, using water.

- 5 Why is Ravi going to repeat the test for each food group?
- 6 Why is a control tube set up?
- 7 Construct a table that Ravi can use that will fit all the data she is going to collect.

Interpreting observations

Food samples A, B and C were tested for different food groups.

Complete this table to show the initial colour of the reagent and the colour change of a positive test.

Food group	Colour change of a positive test	
	Initial colour	Final colour
Glucose		
Protein		
Fat		

In the first test, the foods were boiled with Benedict's reagent, in the second test Biuret reagent was added and in the third test Sudan III reagent was added.

Food sample	Colour with Benedict's reagent	Colour with Biuret reagent	Colour with Sudan III reagent
A	brick red	blue	red layer at top of tube
B	blue	purple-pink	no red layer
C	brick red	purple-pink	no red layer

- 8 Which food/foods contained these different food groups?
Explain your answers.
 - a No protein
 - b Glucose
 - c Lipids

2.1k The human nervous system

Learning objectives:

- describe the structure of neurones and of the nervous system
- explain how the nervous system is adapted to its functions.

KEY WORDS

central nervous system
myelin sheath
neurone
receptor

Cells called **neurones in the nervous system** communicate with each other and with muscles, glands and other structures. This enables humans to react to their surroundings and to coordinate both their internal functions and their behaviour.

The structure of the nervous system

Your nervous system enables you to detect your surroundings, and coordinate your body and behaviour.

The structure of the nervous system is well adapted to these functions.

It is made up of:

- the central nervous system (CNS) – the brain and spinal cord
- the peripheral nervous system (PNS) – all the nerves extending to and from the body tissues and organs.

1 What is the function of the nervous system?

2 What are the two parts of the nervous system?

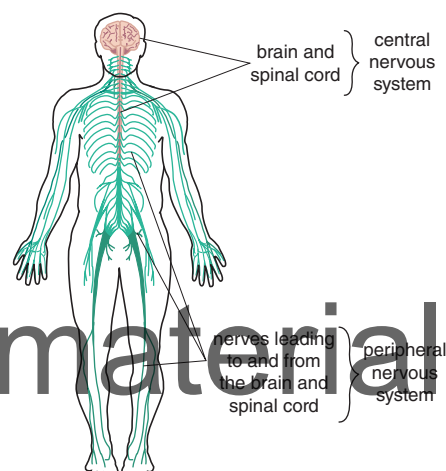


Figure 2.1.25 The human nervous system

Neurones

The nervous system consists of nerve cells or **neurones**. Neurones are specialised for transmitting messages in the form of an electrical impulse.

The part of the cell containing the nucleus is called the cell body. The cell body of all neurones is found in the CNS. Neurones, however, have an extended shape so that they can carry nerve impulses from one part of the body to another. They also have fine branches at their tips to communicate with other neurones.



Figure 2.1.26 The projections that extend from a nerve cell communicate with other nerve cells

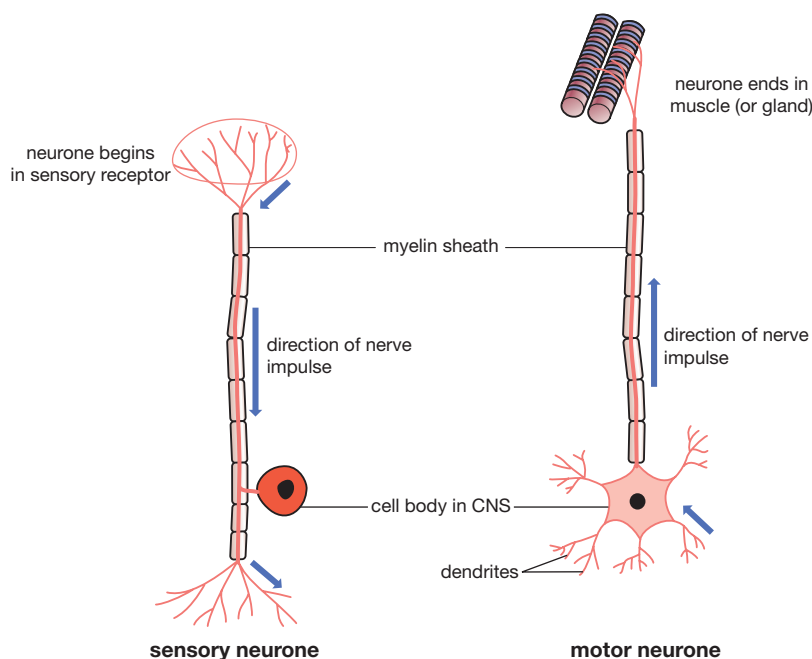


Figure 2.1.27 Two types of neurone

Receptors are cells that detect any changes in the environment. Receptors are sometimes grouped to form sense organs. Sensory neurones relay nerve impulses from these receptors to the CNS.

The CNS processes the information and coordinates how the body should respond.

Motor neurones relay impulses from the CNS to the effector – for instance, a muscle may respond by contracting or a gland by secreting a hormone.

The sequence of events is:

stimulus → receptor → coordinator → effector → response

- 3 What is the scientific name for a nerve cell?
- 4 Describe the pathway of a nerve impulse, beginning with the stimulus and ending with the response.

The transmission of a nerve impulse

The nerve impulse is electrical. It means that it can be transmitted quickly.

In vertebrates, neurones are covered with a fatty layer called the **myelin sheath**. The myelin sheath acts as an insulator and speeds up the transmission of the impulse. But the myelin sheath is not continuous. Periodically, there are small gaps in it – around 1 μm in size. These allow the nerve impulse to jump from one gap to the next, further increasing the speed of transmission.

- 5 What is the outer, fatty layer around a neurone called?
- 6 Explain how the nervous system is adapted to its function.

DID YOU KNOW?

If the myelin sheath does not develop properly, or becomes inflamed or damaged – in conditions such as multiple sclerosis, and diseases such as leprosy – the transmission of nerve impulses can be seriously affected.

MAKING LINKS

Link the information given here back to topic 1.6, and how nerve cells are adapted to their functions.

2.1 Reflex actions

Learning objectives:

- explain the importance of reflex actions
- describe the path of the pain withdrawal reflex arc
- explain how the structures in the reflex arc relate to their function.

KEY WORDS

reflex action
reflex arc
relay neurone
synapse

Many of the body's responses that are coordinated by the nervous system are not under conscious control. A reflex action is an example. An impulse from a receptor travels along a sensory neurone to the spinal cord, where it is passed to a relay neurone and then directly to a motor neurone, without passing through the brain. The impulse travels down the motor neurone and causes a response in an effector.

Reflexes are related to survival

Reflex actions are rapid, automatic responses to a stimulus. We do not have to think about them. Reflex actions form the basis of behaviour in simpler organisms. In humans, they prevent us from getting hurt. In other animals, our human ancestors and babies they are also related to survival.

Some reflex actions include:

- the pain withdrawal reflex, in which you remove your hand from a hot or sharp object
- the grasping reflex, in which a baby grips a finger
- blinking our eyes if an object approaches rapidly
- the pupil reflex, whereby the pupil gets wider in dim light and narrower in bright light.

1 What is a reflex action?

2 Why are reflex actions important?

The pain withdrawal reflex arc

Our spinal reflexes do not involve the brain. Or, at least, not to begin with. In a reflex action, the nerve impulse follows a pathway called the **reflex arc**.

Figure 2.1.29 shows the pathway taken by a nerve impulse when a person puts a hand on a hot object.

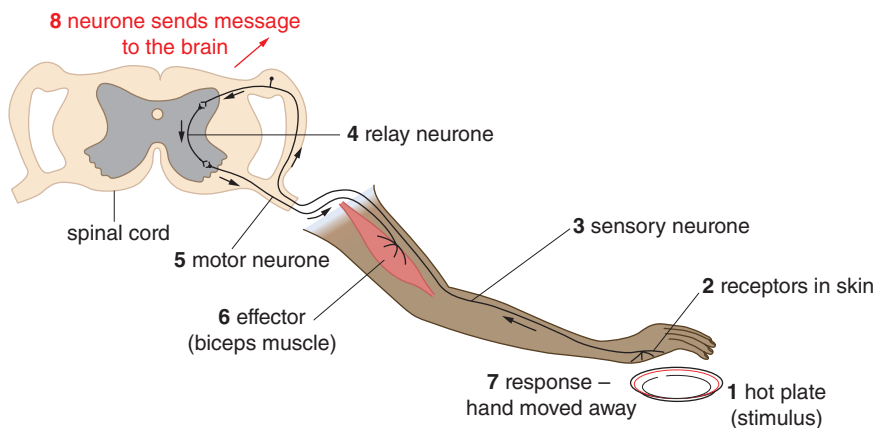


Figure 2.1.29 The pain withdrawal reflex arc. Follow the numbers 1–7. The pathway is through the spinal cord



Figure 2.1.28 Nasim's doctor taps the tendon just below the knee cap. Nasim's leg kicks up. This is the knee jerk reflex. A normal reaction time is around 50 ms

The pathway includes:

- a sensory neurone – transmits nerve impulses from the receptor to the CNS
- a **relay neurone**, in the spinal cord – transmits the impulses from the sensory to the motor neurone
- a motor neurone – sends impulses from the CNS to the effector.

In this case, the effector is the biceps muscle, which moves the arm. The hand is moved away from the hot object.

Because other neurones in the spinal cord link via a synapses with those of the reflex arc, a message is sent to the brain *after* the hand has been removed (number 8 in the figure). It tells us that the plate was hot.

- 3 Name the nervous pathway that a nerve impulse takes during a reflex action.
- 4 Explain how the parts of this pathway relate to their function.

DID YOU KNOW?

Over 100 different types of transmitter molecule, or neurotransmitter, have been identified. Many medical drugs, recreational drugs and poisons work by affecting transmitters.

Linking nerves

The three neurones in the reflex arc don't link together *physically*. There's a gap – called a **synapse** – between each pair. This means that *many* nerves can connect with each other. In the brain, neurones can link up with up to 10 000 others.

Nerve impulses pass across a synapse with the help of chemical transmitter molecules, which diffuse rapidly across the gap.

REMEMBER!

Be able to transfer your knowledge and describe the pathway taken by the reflex arc in another type of reflex action.

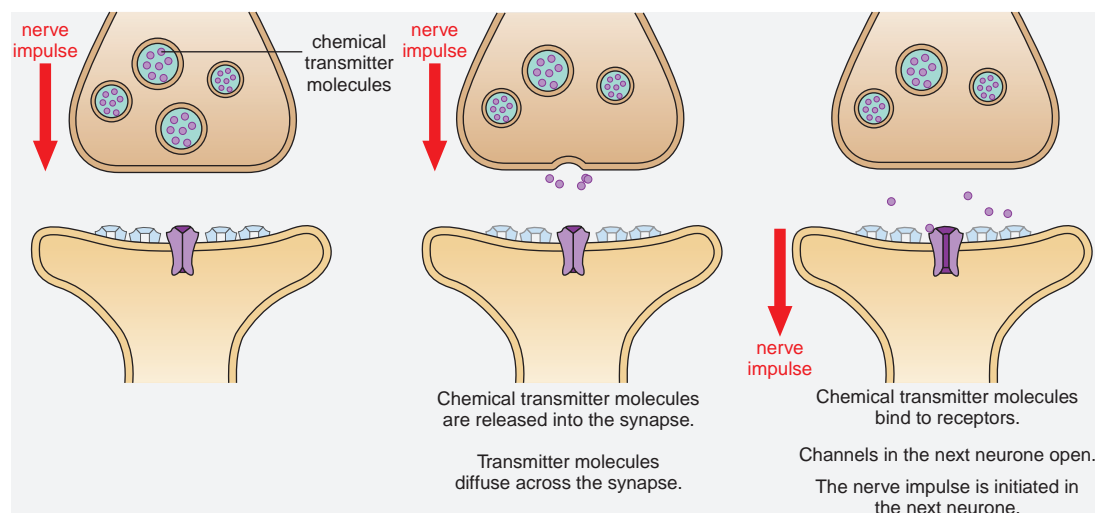


Figure 2.1.30 Chemical transmitter molecules cause an impulse to move from one neurone to the next

- 5 What is the gap between neurones called?
- 6 How does a nerve impulse travel from one neurone to the next?
- 7 Compose a flow diagram to describe and explain the sequence of events in a reflex arc.

REQUIRED PRACTICAL

2.1m Investigating reaction time

Learning objectives:

- select appropriate apparatus and techniques to measure the physiological function of reaction time
- carry out physiological experiments safely
- translate information between numerical and graphical form.

KEY WORDS

reaction time
valid

Our reflex actions protect us from harm. Quick reactions are also important in sport. Reaction times vary from person to person, but typical values range from 0.3 s to 0.9 s.

Measuring reaction time

A group of students worked in pairs to find their **reaction times** using the ruler drop test. One student dropped a 30 cm ruler while another student caught it between their outstretched thumb and index finger of their dominant hand.

In the test, the release of the ruler is detected by our eyes and a message is sent to the sensory region of our brain. A message is then sent to another part, the motor region, which instructs muscles in our hand to contract.

After the student has carried out the test 10 times, they rest their hand and then drink a cup of coffee. The student takes the test again to investigate the effect of coffee on their performance.

These pages are designed ! to help you think about aspects of the investigation rather than to guide you through it step by step.



Figure 2.1.31 In cricket, fielders need fast reaction times

Test number	Experiment 1: Normal	Experiment 2: After coffee
	Distance the ruler dropped (mm)	
1	119	98
2	116	98
3	117	92
4	113	91
5	150	92
6	113	93
7	108	92
8	109	92
9	108	91
10	107	91

The student's results for the ruler drop test

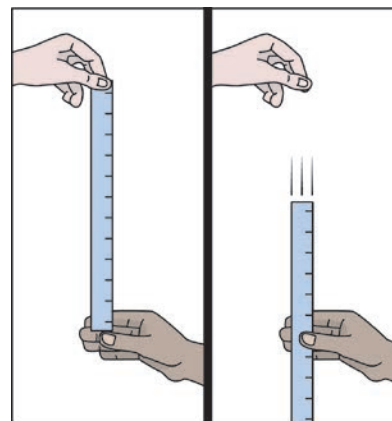


Figure 2.1.32 The ruler drop test

- 1 Write a risk assessment for this experiment.
- 2 Identify any anomalous results.
- 3 Calculate the average distance fallen by the ruler before and after drinking coffee.

Calculating reaction time

The distance travelled by the ruler before it is caught gives an indication of a student's reaction time, but not the reaction time itself.

Another group of students find a formula on the Internet that is used to calculate reaction time:

$$t = \sqrt{\frac{2d}{a}}$$

where t = time in seconds

d = distance in metres,

a = acceleration due to gravity = 9.81 m/s^2

They use this formula to calculate their reaction times.

- 4 Calculate the mean reaction time for the student before and after coffee.
- 5 The ingredient in coffee that affects our nervous system is caffeine. When testing its effect on other students, explain why the experiment must be carefully controlled to produce valid results.

DID YOU KNOW?

Caffeine works by affecting chemical transmitter molecules. It binds to one type that makes us sleepy. Fewer receptors are, therefore, available and nervous activity speeds up.

KEY SKILL

Selecting equipment, carrying out a risk assessment and processing data appropriately are important skills.

KEY INFORMATION

You will revisit reaction times in Unit 2 when you learn about drivers' stopping distances.

Pooling class results

All the students in the year group measured their minimum reaction time. They used an alternative test on the computer. They had to click on the mouse when the screen changed colour. The reaction time was measured by the computer timer.

The students produced a tally of those falling into different ranges of reaction time.

Mean reaction time (ms)	101–200	201–250	251–275	276–300	301–325	326–350	351–375	376–400	401–500
Number of students within range	1	3	16	24	33	14	6	2	1

The tally of student reaction times across the year group

- 6 What type of graph would be best suited to displaying the data shown above? Draw a graph of the results.
- 7 Calculate the median and modal reaction time categories.
- 8 Suggest why the computer method for measuring reaction time may be better than the ruler drop method.

2.1n The endocrine system

Learning objectives:

- recall that the endocrine system is made up of glands that secrete hormones into the blood
- understand why the pituitary gland is the 'master gland'
- describe the principles of hormonal coordination and control by the human endocrine system.

KEY WORDS

endocrine gland
endocrine system
hormone
target organ

The endocrine system is composed of glands that secrete hormones directly into the bloodstream. It works alongside the nervous system to coordinate and control the body's activities. Compared to the nervous system, the effects of the endocrine system are slower, but they act for longer.

The endocrine system

Hormones are produced by glands of the endocrine system. Endocrine glands secrete hormones directly into the blood. Some examples include the adrenal glands just above the kidneys, which secrete adrenaline, and the thyroid gland in the neck, which secretes thyroxine.

Hormones are often described as *chemical messengers*. They circulate in the blood and produce an effect on **target organs**. Many hormones are large molecules.

Like the nervous system, hormones work on effectors. But, unlike the nervous system, the effects they produce don't take milliseconds. With the exception of adrenaline, effects of hormones take minutes, hours or, in the case of hormones involved in our development, they act for years.

- 1 What is the function of the endocrine system?
- 2 On what does the endocrine system act?

The master gland

The pituitary gland is an outgrowth from the base of the brain.

Some of the hormones that it secretes, such as growth hormone, have a direct effect on their target organs. Other hormones have an indirect effect; they cause other glands to secrete hormones. It is, therefore, called the master gland as it regulates the secretion of other endocrine glands.

- 3 Explain why the pituitary gland is called the master gland.
- 4 Name one hormone that exerts its effects over the whole body.



Figure 2.1.33 The world's tallest man was Robert Pershing Wadlow (1918–1940). He was 2.72 m when he died at the age of 22. His height was caused by an excess of growth hormone, produced by the pituitary gland

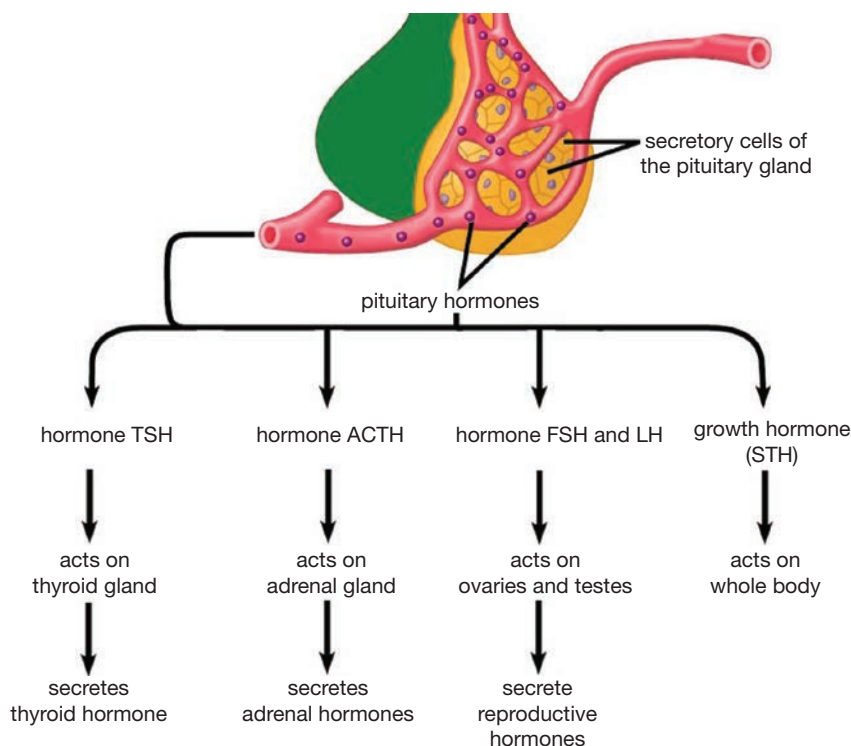


Figure 2.1.34 Some of the hormones secreted by the pituitary gland

Control systems

All control systems in the body, whether nervous or endocrine, have the same pattern.

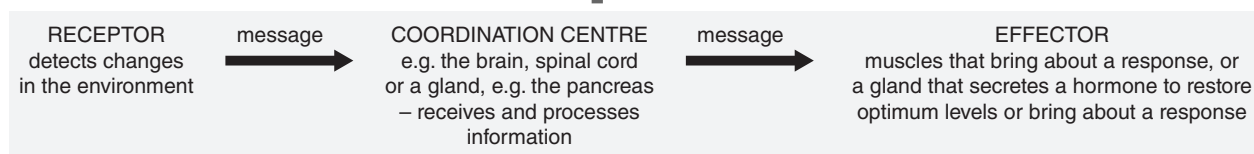


Figure 2.1.35 The components of the body systems that are responsible for coordination and control

The nervous system and endocrine system are different in nature but, in practice, the two systems interact with and regulate each other.

	Nervous system	Endocrine system
response	rapid and precise	slower but acts for longer
nature of message	nerve impulse – electrical	a hormone – chemical
action	carried in nerves to specific location, e.g. muscle	carried in blood to all organs, but affects the target organ only

- 5 How are changes detected by the body?
- 6 Compare and contrast the nervous system and the endocrine system.

DID YOU KNOW?

The squid has giant nerve cells, up to 1 mm in diameter. Study of these has been key to our understanding of how nerve impulses are transmitted.

REMEMBER!

Remember the sequence of receptor → coordination centre → effector.

2.1o Negative feedback

Learning objectives:

- describe the effects of adrenaline
- explain the role of thyroxine in the body
- understand the principles of negative feedback, as applied to thyroxine.

KEY WORDS

adrenal gland	negative
adrenaline	feedback
basal	pituitary
metabolic	gland
rate	thyroxine

Hormones maintain conditions in the body within narrow limits using negative feedback. This is important to ensure your body cells always have the optimum environment, even when external conditions change.

HIGHER TIER ONLY

Adrenaline

Harry is frightened of having a flu vaccination. His heart begins to race. His skin goes pale. He feels 'butterflies' in his stomach. These effects are the result of a hormone called **adrenaline**, secreted from the **adrenal glands**.

Adrenaline is called the 'flight-or-fight' hormone, because when you get a fright it prepares you very quickly to run, or maybe to fight. It causes blood flow to be diverted away from your skin and your digestive system toward your muscles and brain, carrying much needed oxygen and glucose for emergency action. At the same time, your heart rate rises, further boosting blood flow to your muscles and brain.

Once the danger is over (you've escaped!) and your brain and muscles no longer need increased oxygen and glucose, your adrenal glands stop secreting adrenaline, and your body returns to its normal state.

- 1 Which hormone is released when we become frightened?
- 2 There is only a set volume of blood in the body. Explain how more blood can be pumped to the brain and muscles.

Thyroxine

Priya feels tired and sluggish and is putting on weight. Her heart rate feels slow. She also feels the cold. Priya has an underactive thyroid gland. The thyroid gland affects your activity by producing the hormone thyroxine, which stimulates the body's **basal metabolic rate** – it increases the metabolism of all the body's cells. It also plays an important role in growth in children.

DID YOU KNOW?

Thyroxine is also involved in the growth and development of other animals. It is responsible for metamorphosis in amphibians – the process that transforms them from tadpoles to adults.

The **pituitary gland** controls secretions from the thyroid gland. When the pituitary gland secretes thyroid-stimulating hormone (TSH), the thyroid gland responds by secreting **thyroxine**. If levels of thyroxine become too high, TSH secretion is blocked, which stops secretion of more thyroxine. This is a negative-feedback system, which acts to stabilise a system – if a level becomes too high or too low, it stimulates a response that acts to bring the level back toward normal.

Here's another example of negative feedback control. If the body temperature falls, a thermoregulatory centre in the brain detects this and causes the pituitary gland to release TSH, which stimulates the thyroid to secrete more thyroxine. Because thyroxine increases the respiration rate of cells, it causes more thermal energy to be released, raising the body temperature back toward normal. If the body temperature becomes too high, the thermoregulatory centre detects the temperature rise, and the hormone's secretion is blocked.

- 3 Suggest a symptom of an overactive thyroid.
- 4 What is the function of thyroxine?
- 5 Which hormone regulates thyroxine production?

The principles of negative feedback

The endocrine system keeps the conditions in the body constant using feedback systems. A simple negative feedback system is the central-heating system in your home. If the temperature falls in your living room, the thermostat detects this and switches on the heating. The room warms up.

When the thermostat temperature is reached, it detects this, and turns off the heating. This is negative feedback because when the desired effect is reached, the system is switched off.

Negative feedback within the endocrine system tends to reverse a change. This prevents a system from becoming overactive. The system is stabilised by its own products.

- 6 Give a definition of a negative-feedback system.
- 7 Figure 2.1.37 illustrates a simple negative feedback system, but it's not a perfect comparison with thyroid secretion. Explain why.

2.1o

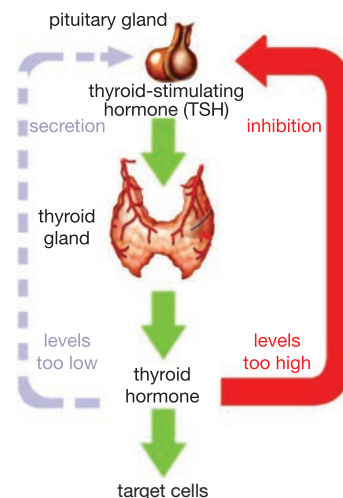


Figure 2.1.36 A simplified version of the negative-feedback system that controls thyroxine secretion

REMEMBER!

You need to be able to explain how negative feedback mechanisms involving thyroxine operate.

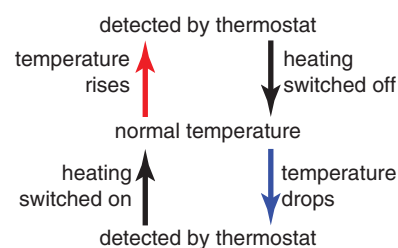


Figure 2.1.37 Negative feedback in a central-heating system

Check your progress

You should be able to:

■ recall that organisms can respire with oxygen (aerobic respiration) or without oxygen (anaerobic respiration)



■ use word equations to describe the processes of aerobic and anaerobic respiration



■ use a symbol equation for aerobic respiration and be able to compare the two processes

■ describe the functions of different parts of the circulatory system



■ describe how the circulatory system transports substances



■ explain how the circulatory system is adapted to its function

■ describe the effect of surface area: volume ratio on the diffusion of substances



■ describe the features of a range of exchange surfaces in plants and animals



■ explain the features of exchange surfaces

■ know that digested food is transported from the small intestine to body cells
■ recall how to test for carbohydrates, lipids and proteins



■ describe the adaptations of the intestine as an exchange surface



■ explain how the small intestine is adapted for efficient food absorption

■ describe the structure of the nervous system



■ describe how neurones are adapted to their role and the transmission of an impulse in a reflex arc



■ explain how nerve impulses are transmitted across synapses

■ recall typical results for factors affecting reaction time



■ plan methods of measuring human reaction times



■ explain and evaluate methods of measuring human reaction times

■ identify body temperature as a condition requiring control



■ describe how body temperature is controlled by the endocrine system

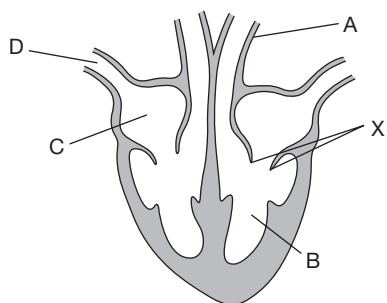


■ explain how negative feedback is involved in control

draft, sample material

Worked example

The diagram shows the human heart.



1 Label parts A–D on the diagram.

- A Artery
- B Left ventricle
- C Right atrium
- D Vena cava

2 a What is the name of part X?

valve

b Part X can become damaged or may leak. What effect will this have?

Person will have a lack of energy and breathlessness.

c How can a damaged or leaky part X be treated?

Transplant a valve from another person.

d Give an advantage and a disadvantage of the treatment.

It will not be rejected.

3 The heart pumps blood to the lungs so that gas exchange can happen.

Why are alveoli an efficient exchange surface?

They have a large surface area compared to volume to give a large area for gas exchange. Good blood supply to take oxygen to body cells where it is used for respiration for energy for growth.

B–D correctly identified. Giving 'artery' for A is insufficient.

'Aorta' is a better answer.

Valve is correctly identified.

Two symptoms correctly identified.

One treatment has been identified.

Artificial valves are another treatment.

The student has correctly identified an advantage of one treatment but they have only answered half the question for this. The failure to identify two treatments has lost marks.

Two correct answers are identified. Then the student forgets the question being asked and moves away from the topic of alveoli.

Overall, this student shows a good understanding of the topic but does not give complete answers. Careful reading of the questions, and consideration of exactly what is being asked for, in addition to more detailed responses, would help the student achieve a much higher mark.

End of chapter questions

Getting started [foundation tier]

- 1 Give two features of an efficient exchange surface. 2 Marks
- 2 Name the main blood vessels in the circulatory system. 2 Marks
- 3 What is the function of the heart? 1 Mark
- 4 What happens when the coronary artery becomes blocked? 1 Mark
- 5 How is glucose absorbed into the blood? 1 Mark

Going further [foundation and higher tier]

- 6 Use words from the box to complete the word equation for aerobic respiration.

alcohol	carbon dioxide	glucose	lactic acid
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..... + oxygen + water (+energy) 1 Mark

- 7 Give two ways in which the small intestine is adapted for efficient absorption. 2 Marks
- 8 Compare the nervous and endocrine systems according to their:
 - a type of message
 - b speed of response. 2 Marks

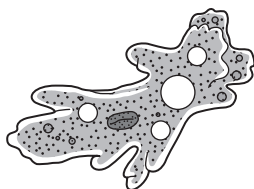
More challenging [higher tier]

- 9 What is the function of valves in the circulatory system? 1 Mark
- 10 A teenage girl had her heart beat measured at 74 beats per minute. Each beat pumped 70 cm³ of blood. Calculate how much blood will be pumped in 10 minutes. Give your answer in litres. 1 Mark
- 11 Why do the ventricles contract for longer than the atria? 1 Mark
- 12 Explain why the alveoli are an efficient exchange surface. 2 Marks
- 13 Why are molecules in the digestive system sometimes moved by active transport? 2 Marks

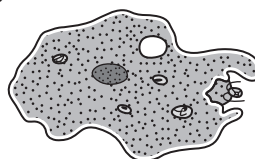
Most demanding [higher tier]

- 14 Explain how anaerobic respiration differs from aerobic respiration. 2 Marks
- 15 Which of these organisms can absorb nutrients quicker? Explain your answer. 2 Marks

a



b



- 16** What is the disadvantage of having a large volume compared with surface area? 2 Marks
- 17** Coeliac disease destroys the villi in the small intestine. Explain the effect of having many fewer villi in the small intestine. 4 Marks
- 18** A mother places her finger on her baby daughter's palm. The baby grasps it. It is a reflex action. Describe the process by which this reflex action occurs. You can use a diagram to help with your description. 4 Marks
- 19** Explain how thyroxine levels affect the temperature of the body. 2 Marks

draft, sample material