Digestion in humans

You will have already studied the digestive system in Key Stage 3 science. For the GCSE exam, you need to know the function of bile and how the digestive enzymes, carbohydrase, protease and lipase act.

2 Lock and key model

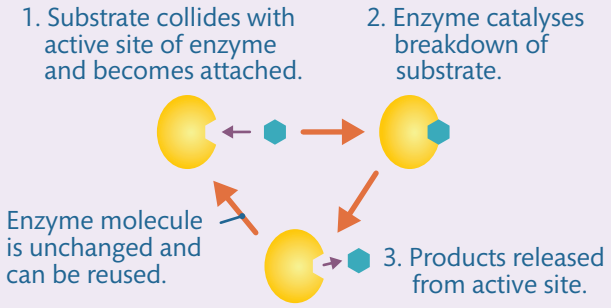


Figure 1 The lock and key model helps explain how enzymes work. Each type of enzyme has a differently shaped active site so can only work with a specific shape of molecule.

2 Worked example — Grade 5

Scientists use models to help to explain how things work. Which **two** of the following explain why **Figure 2** is called the lock and key model?
Tick **two** boxes. **[2 marks]**

A Keys can be made from metal or plastic. ☐

B Different keys can be kept on a key ring. ☐

C Keys can open and close a lock. ☑

D A key will only fit one specific lock. ☑

E Keys can be different colours. ☐

10 Enzymes and digestion

Digestion is the process of enzymes breaking down large food molecules into small simple molecules that can be absorbed into the bloodstream. Enzymes catalyse and speed up chemical reactions. They work best at specific temperatures and pH levels.

Protease enzymes

- Proteases, such as pepsin, break down proteins into amino acids in the stomach and small intestine.
- They are produced in the stomach, small intestine and pancreas.

Carbohydrase enzymes

- Carbohydrases, such as amylase and maltase, break down carbohydrates into simple sugars.
- Amylase is produced in the salivary glands, small intestine and pancreas. Amylase and maltase mixtures break down starch into glucose in the mouth and small intestine.

Lipase enzymes

- Lipases break down fats and oils into fatty acids and glycerol in the small intestine.
- They are produced in the pancreas and the small intestine.
- They need alkaline conditions.

The products of digestion are used to build up new proteins, carbohydrates and fats in our body. Some of the glucose produced is used for respiration and the release of energy.

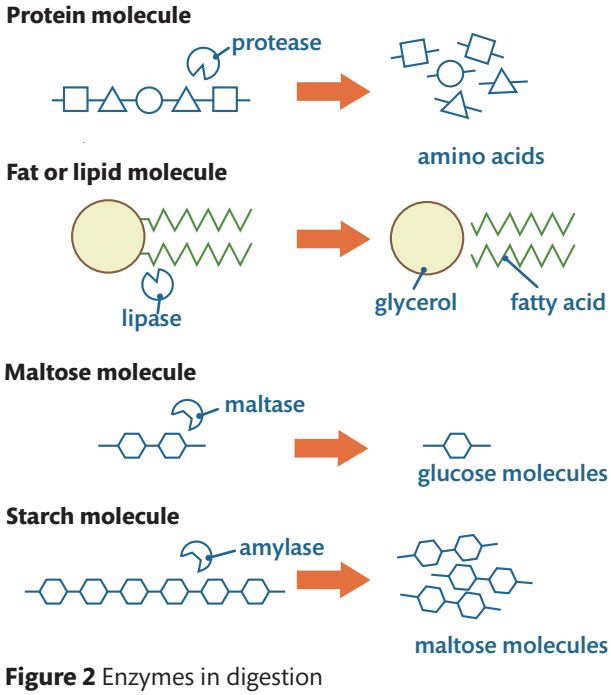


Figure 2 Enzymes in digestion

Bile

Bile is produced by the liver, stored in the gall bladder, and then released into the small intestine. It is alkaline, so it neutralises hydrochloric acid from the stomach. It also emulsifies fats by breaking them down into smaller droplets with a larger surface area, which can be broken down more quickly by lipase.

2 Exam-style practice — Grade 7

Suggest why acid from the stomach must be neutralised before it enters the small intestine. **[2 marks]**

Food tests

You need to know how food can be tested to see whether it contains carbohydrates, lipids or proteins.

Testing for lipids, proteins and carbohydrates

Type of food	Reagent used	Method	Positive result
starch	iodine solution	Drop iodine solution onto the sample.	turns black
simple sugars	Benedict's solution	1. Add Benedict's solution to the sample. 2. Boil in a water bath for two minutes.	turns red-orange or green depending on the amount of sugar present
lipids (fats)	ethanol	1. Add ethanol to the sample. 2. Shake the mixture. 3. Add a few drops of water to the mixture.	forms a milky white emulsion
proteins	Biuret reagent – sodium hydroxide and copper sulfate solution	1. Add dilute sodium hydroxide to the sample. 2. Add copper sulfate solution to the mixture.	turns purple/violet

Working scientifically

The results of a test involving Benedict's solution are **semi-quantitative**. They give you an approximation of how much sugar is present in each sample.

The results of tests involving iodine solution and the Biuret reagent are **qualitative**. They only indicate whether the type of food is present but they do not indicate how much is present.

Worked example — Grade 6

A student carries out food tests on an unknown sample of food.

Table 1

Test	Result
iodine solution	turns black
Benedict's solution	no change
Biuret reagent	no change

Table 2

Test	Result
iodine solution	no change
Benedict's solution	turns orange
Biuret reagent	turns purple/violet

(a) What is present in the food in **Table 1**? **[1 mark]**

Starch

The student adds an enzyme to the food and waits 30 minutes before testing the food again.

(b) Look at **Table 2**.

(i) What is now present in the food? **[2 marks]**

Sugar and protein

(ii) Suggest what enzyme was added to the food. **[1 mark]**

Amylase

(iii) Suggest why protein was detected in the second stage of food testing. **[2 marks]**

The enzyme amylase was added – enzymes are proteins.

Go to page 21 to revise enzymes.

Exam-style practice — Grade 6

A student carries out a test on a sample of food, thought to contain lipids. Explain the test the student should carry out and describe the appearance of a positive result obtained for a sample containing lipids. **[3 marks]**

Investigating enzymes

You need to know how to investigate the effect of pH on the rate of reaction of an enzyme. Most enzymes will only work efficiently within a narrow pH range.

2 Apparatus

- four beakers containing the same amount of water
- four test tubes containing starch solution
- four test tubes containing amylase solution
- water bath
- spotting tile with iodine solution
- thermometer
- pipette

Working scientifically

You must control temperature during this investigation, as it affects the behaviour of enzymes.

10 Worked example — Grade 7

1 Look at **Figure 1**. Which pH is the optimum condition for the enzyme amylase to break down starch? Justify your answer. **[3 marks]**

pH 7 – at pH 7 the drops go from black to brown the quickest, showing that the starch is easier to break down at pH 7

2 Explain why it is difficult to decide how long it takes for amylase to break down the starch at pH 8. **[2 marks]**

The drops change from black to brown gradually over a period of 2–3 minutes.

3 A student investigated the time taken for amylase to break down starch at different pH values. Calculate the rate of reaction for each pH value. Give your answers to two significant figures. **[3 marks]**

pH	Time taken for starch to disappear in s	Rate of reaction per second
4	474	0.0057
6	110	0.0091
8	272	0.0037

2 Maths skills

You need to know how to calculate the rate of a reaction. The rate of a reaction is inversely proportional to the time taken for it to complete.

$$\text{rate} \propto \frac{1}{\text{time}}$$

10 Method

1. Add one drop of iodine solution to each well in the spotting tile.
2. Make up four beakers of water, each containing a test tube of starch solution and a test tube of amylase solution in a buffer solution. Each buffer solution should be at a different pH, for example: pH 7, pH 8 and pH 9.
3. Using a water bath, heat the four beakers to 25 °C.
4. Pour the test tube of amylase solution into the test tube of starch solution.
5. Starting at 0 seconds, take a drop from each test tube every 30 seconds and add it to the iodine using a pipette.

Figure 1 Results

Working scientifically

Interpreting these results is tricky. Iodine solution turns from yellow to black in the presence of starch. When the spots on the tile no longer turn black, all the starch has been broken down into maltose by the amylase.

You need to make a sensible judgement of when all the starch has been broken down.

5 Exam-style practice — Grade 6

1 Explain why temperature must be controlled during this experiment. **[3 marks]**

2 Suggest **one** way the experiment could be improved. **[1 mark]**

The blood

You need to be able to recognise the different components of blood and describe their functions. You also need to know how blood is transported around the body by three different types of blood vessel.

15 Key components of the blood

Blood is a tissue. It consists of a fluid called plasma in which red blood cells, white blood cells and platelets are suspended. Platelets help blood to clot.

Plasma

Plasma transports carbon dioxide, water, dissolved food, urea, hormones and heat around the body.

Red blood cells

Red blood cells absorb oxygen from the lungs and carry it to muscles and tissue around the body. They are adapted for this function in several ways.

- They have no nucleus, which increases the space available for haemoglobin.
- They have a biconcave shape to increase the surface area for oxygen to diffuse in and out.
- They are small, which allows them to pass easily through the smallest capillaries.
- They have a large surface area to volume ratio.

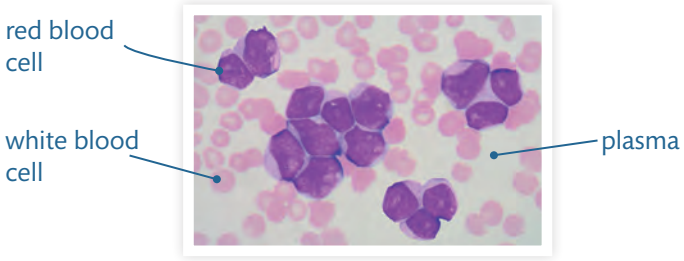


Figure 1 Blood viewed through a light microscope.

White blood cells

White blood cells fight disease by producing antibodies and destroying bacteria and viruses. White blood cells have three main roles.

- Many of them are **phagocytes**, which ingest and destroy pathogens (phagocytosis).
- They produce **antibodies**, specialised proteins produced in response to an **antigen**. An antigen is a substance that induces an immune response. Antibodies recognise when an antigen is foreign to the body and produce an immune response.
- They produce **antitoxins**. Bacteria produce harmful toxins, and white blood cells can produce antitoxins to neutralise specific toxins.

You can calculate the rate of blood flow using the following equation: $\text{rate of blood flow} = \frac{\text{volume of blood}}{\text{time}}$

10 Worked example — Grade 8

1 Complete the table with the rate of blood flow in each of the blood vessels over a period of one minute. **[3 marks]**

Vessel	Volume of blood in cm^3	Rate of blood flow in cm^3/s
Artery	24	0.4
Capillary	4.5	0.075
Vein	3.3	0.055

The lumen is the space inside the vein. Skeletal muscle contracts causing blood to be squeezed through veins back to the heart.

2 Explain how each blood vessel is adapted to its function. **[3 marks]**

Arteries have thick walls containing muscle and elastic tissue, enabling them to stretch and then return to their original shape, maintaining blood pressure.

Capillaries have very thin walls, usually one cell thick, to allow oxygen, carbon dioxide, glucose and urea to diffuse to and from tissues.

Veins have valves to prevent the blood flowing backwards, and keep it flowing in one direction towards the heart. They have a large lumen to maximis blood flow.

2 Working scientifically

Health care workers often come into contact with blood and products related to blood. It is important that they evaluate the risks of working with them. Risks include using sharp objects such as syringe needles and scalpels, and infection from contaminated blood.

5 Exam-style practice — Grade 7

1. Explain how the structure of a red blood cell is adapted to its function. **[4 marks]**
2. Describe the function of phagocytes. **[2 marks]**

The heart and lungs

You need to know how the structures of the heart and lungs are adapted to their functions within the circulatory system.

5 The heart

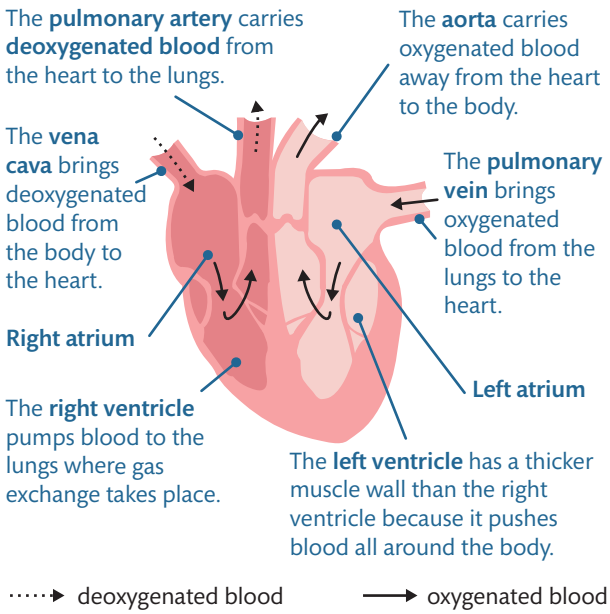
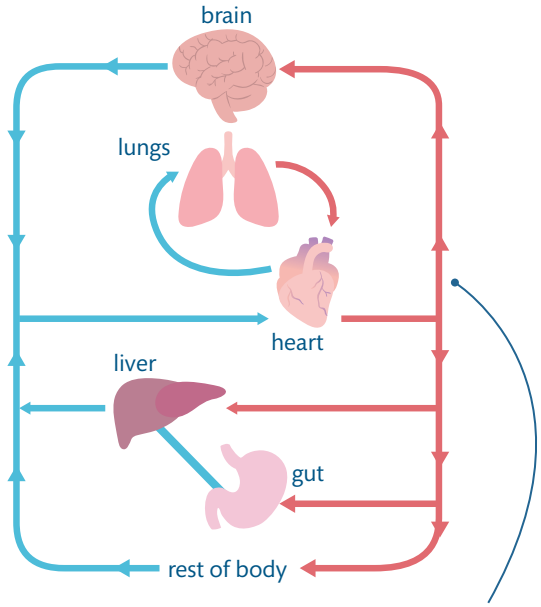


Figure 1 Structure of the heart

The coronary arteries supply **oxygenated blood** to the heart from the lungs. The blood enters the right and left atria, which contract, forcing blood into the ventricles. The left and right ventricles contract, forcing blood into the arteries.

5 The double circulatory system

Figure 2 The heart pumps blood around the body in a double circulatory system.



The resting beat rate of the heart is controlled by a group of cells in the wall of the right atrium. This group of cells is called the **pacemaker**. An artificial pacemaker may be installed when the body's natural pacemaker fails.

5 The lungs

The lungs consist of several different structures that are adapted for gas exchange. Air enters the lungs via the **trachea** (the windpipe). The trachea leads from the nose to the two **bronchi**, one **bronchus** for each lung. Bronchus branch into **bronchioles** and at the end of each bronchiole are **alveoli**.

Alveoli, the small air sacs in the lungs, have:

- a large surface area to absorb O_2 and remove CO_2
- thin, moist membranes to allow gases to diffuse
- a capillary network, which provides a good blood supply to transport the gases to and from the rest of the body.

The trachea contains rings of cartilage in its walls, which enables it to stay open, allowing air to pass through.

The cells lining the trachea and bronchus are covered in cilia. Cilia are tiny hair-like structures that help to remove dust and microorganisms before they enter the lungs.

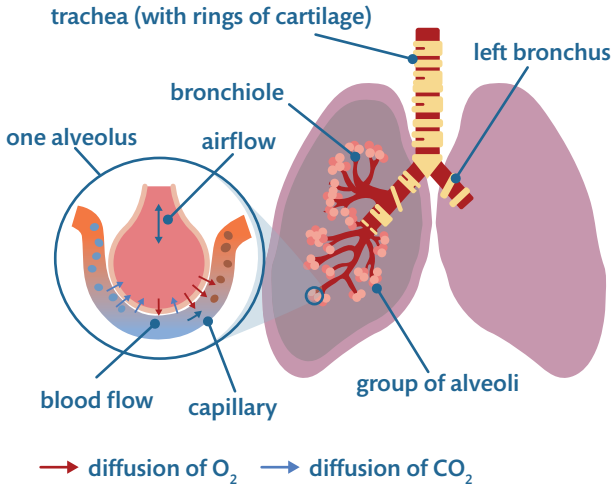


Figure 3 The lungs

2 Worked example — Grade 4

Give the names of the four chambers of the heart. **[2 marks]**

Left and right atria, left and right ventricles

10 Exam-style practice — Grade 7

1. Describe the path taken by a red blood cell from the left ventricle to the left atrium. **[4 marks]**
2. Explain how alveoli and capillaries are adapted to their function. **[4 marks]**

The human nervous system

The nervous system senses a stimulus (a change in the environment) and coordinates the body's response. You need to know the structure and function of the human nervous system.

Coordination

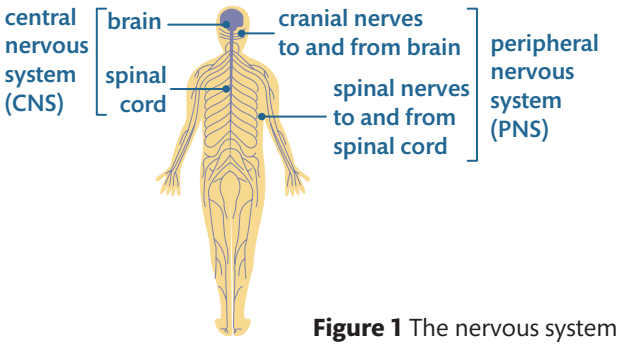


Figure 1 The nervous system

When receptors are stimulated, information in the form of electrical impulses is passed from the receptor along a sensory neurone to the central nervous system (CNS).

The CNS consists of the brain and spinal cord. The brain coordinates the information and passes instructions along motor neurones to an effector such as a muscle or gland.

stimulus→receptor→coordinator→effector→response

Examples include: touch, substances in food, temperature and light.

Types of neurone

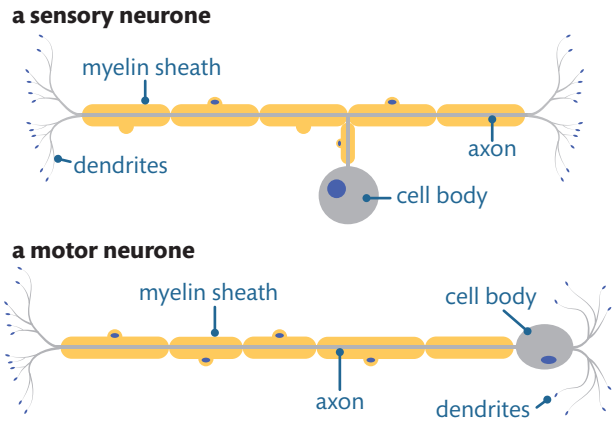
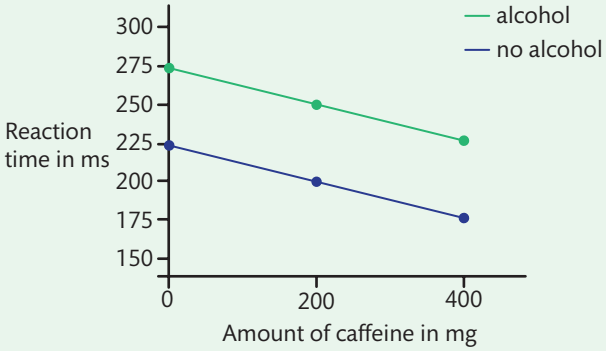


Figure 2 Neurones

Neurones are cells in the nervous system. **Sensory neurones** carry information from a receptor, such as light receptors in the retina and touch receptors in the skin, to the CNS. **Motor neurones** carry instructions from the CNS to an effector, such as a muscle or a gland. **Synapses** are gaps between each neurone where chemical messengers called **neurotransmitters** diffuse from one neurone to the next.

Worked example — Grade 6

Figure 3 A graph showing how reaction times are affected by alcohol and caffeine



Look at **Figure 3**.

(a) What conclusions can be made about the effects of alcohol and caffeine on reaction times?

Use data in your answer. **[3 marks]**

When no alcohol is drunk 400 mg of caffeine speeds up reaction time from 225 ms to 175 ms. Alcohol slows reaction times.

(b) To interpret the graph fully, what other information do you need? **[2 marks]**

To know whether the graph shows the effects on one person or the mean for a group of people, and what the amount of alcohol was.

Reflex arcs

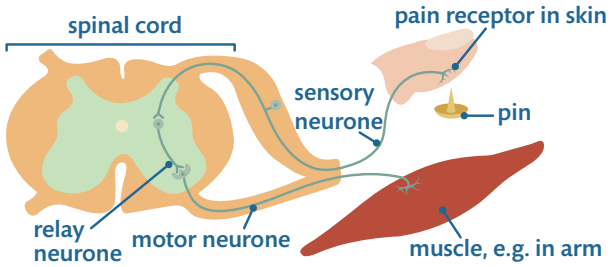


Figure 4 A reflex arc

Reflex arcs are automatic and do not involve the concious part of the brain. They are important because they speed up reaction times.

Instead of an impulse being sent via the CNS to the brain, the impulse just goes into the spinal cord and straight back out to an effector. The sensory neurone and motor neurone are connected by a relay neurone.

receptor→sensory neurone→relay neurone→motor neurone→effector

Exam-style practice — Grade 6

Give **two** examples of each of the following:

(a) a receptor **[2 marks]**

(b) an effector **[2 marks]**