

Animal tissues, organs and organ systems

Revision notes • The human digestive system, heart, lungs and blood, coronary heart disease, health and lifestyle, and cancer.

For AQA GCSE Biology 8461 and Combined Science: Trilogy 8464. **Triple only** is not in Combined Science. **Higher tier** is only on the Higher paper.

Animal tissues, organs and organ systems Spec 4.2.2

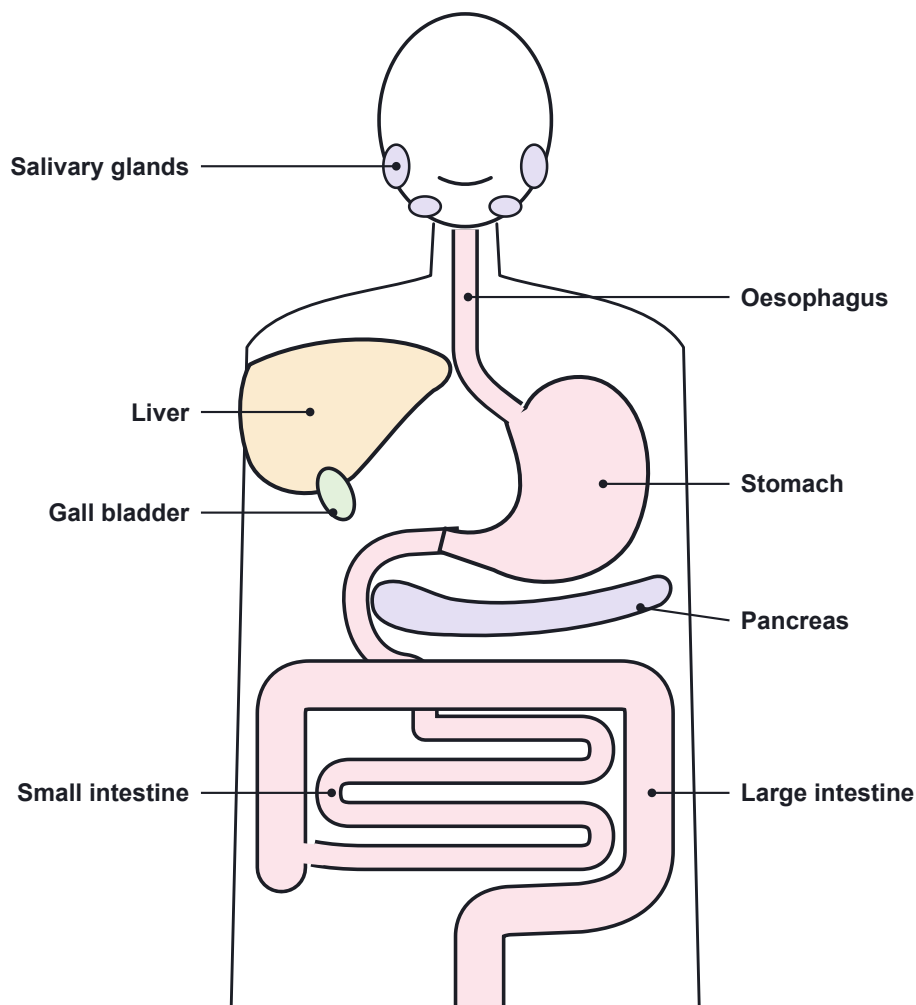
The digestive system Spec 4.2.2.1

The digestive system is an example of an **organ system** in which several organs work together to **digest and absorb food**.

Food contains large molecules of carbohydrate, protein and lipid. These are too big to pass into the blood. **Digestive enzymes** convert food into **small soluble molecules** that can be absorbed into the bloodstream.

Organs of the digestive system

Organ	Role
Salivary glands	Make amylase, which mixes with food in the mouth
Stomach	Churns food. Makes protease and hydrochloric acid
Liver	Makes bile
Gall bladder	Stores bile
Pancreas	Makes amylase, protease and lipase, and releases them into the small intestine
Small intestine	Makes amylase, protease and lipase. Digestion is finished here and the small soluble molecules are absorbed into the blood



The organs of the **digestive system** work together to digest and absorb food.

Exam tip: Digestion breaks big molecules into small ones. Absorption is the movement of the small molecules into the blood. Do not mix up the two words.

Enzymes Spec 4.2.2.1

Enzymes catalyse specific reactions in living organisms. A catalyst speeds up a reaction and is not used up. Enzymes are large protein molecules, and each one has a special shape.

Each enzyme has an **active site**. The shape of the active site is what makes the enzyme specific: it only works on one type of molecule, called the **substrate**.

The lock and key theory

The 'lock and key theory' is a simplified model of how enzymes work.

1. The substrate collides with the enzyme and fits into the active site, like a key into a lock. The shapes are complementary.
2. The enzyme catalyses the reaction while the substrate is in the active site.
3. The products leave the active site. The enzyme is unchanged and can be used again.

Scientists also use other models to explain enzyme action. If a question describes a different model, use the information given in the question.

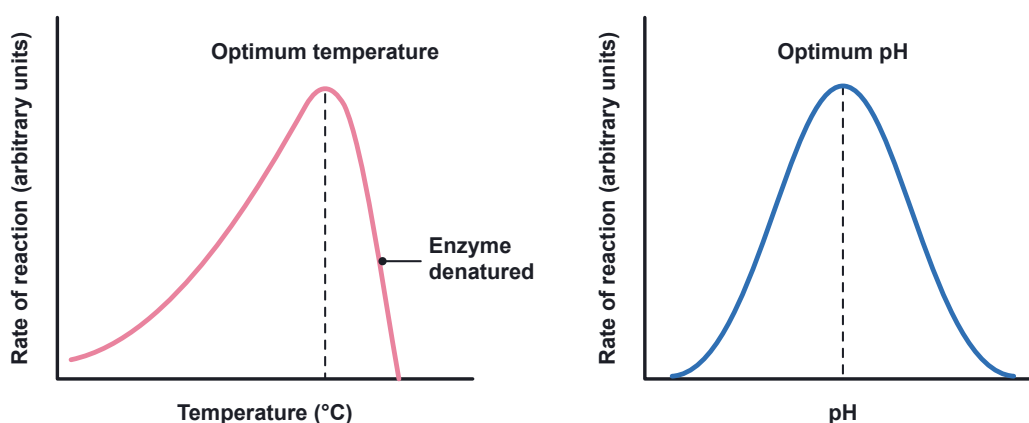
Temperature and pH

As temperature rises, the reaction gets faster because the particles move faster and collide more often. Each enzyme has an **optimum** temperature where its rate is highest.

If the temperature is too high, or the pH is too acidic or too alkaline, the shape of the active site changes. The substrate no longer fits. The enzyme is **denatured**, and it cannot be changed back.

Effect of conditions on enzyme activity

Condition	Effect on rate
Temperature below the optimum	Rate increases as temperature rises
Optimum temperature	Rate is highest
Temperature above the optimum	Rate falls quickly because the enzyme is denatured
Optimum pH	Rate is highest. Different enzymes have different optimum pH values
pH far from the optimum	Rate falls because the enzyme is denatured



Each enzyme works fastest at its **optimum** temperature and pH. Beyond the optimum the enzyme is **denatured**.

Rate calculations

$$\text{rate of reaction} = \text{amount of product formed} \div \text{time}$$

When the end point is a colour change, such as the loss of starch, you can use $\text{rate} = 1 \div \text{time taken}$. A shorter time means a faster rate.

Rate of an enzyme-catalysed reaction

An enzyme makes 12 cm^3 of product in 3 minutes. Calculate the rate of reaction in cm^3 per minute.

1. Use $\text{rate} = \text{amount of product} \div \text{time}$.
2. $\text{Rate} = 12 \div 3$.

Answer: $4 \text{ cm}^3/\text{min}$

Common mistake: Do not say the enzyme is 'killed' at high temperatures. Enzymes are not alive. Say the enzyme is denatured because the active site has changed shape.

Amylase, proteases and lipases Spec 4.2.2.1

Three types of digestive enzyme break the three main food molecules into small, soluble molecules. You need to recall where each is **made** and what it does.

Digestive enzymes			
Enzyme	Breaks down	Into	Made in
Amylase (a carbohydrase)	Starch	Simple sugars	Salivary glands, pancreas, small intestine
Protease	Proteins	Amino acids	Stomach, pancreas, small intestine
Lipase	Lipids (fats)	Glycerol and fatty acids	Pancreas, small intestine

Carbohydrases break down carbohydrates to simple sugars. Amylase is a carbohydrase which breaks down starch.

You only need simple word equations, not chemical symbol equations.

starch → simple sugars (catalysed by amylase)

protein → amino acids (catalysed by protease)

lipid (fat) → glycerol + fatty acids (catalysed by lipase)

The products of digestion are used to build new **carbohydrates, lipids and proteins**. Some glucose is used in **respiration**.

Exam tip: Learn the pairs: amylase with starch, protease with protein, lipase with lipid. The names of the products are what mark schemes ask for.

Bile Spec 4.2.2.1

Bile is made in the **liver** and stored in the **gall bladder**. It is released into the small intestine.

Bile does two jobs:

- It is **alkaline**, so it neutralises hydrochloric acid that comes from the stomach. This gives the enzymes in the small intestine the alkaline conditions they work best in.
- It **emulsifies** fat, breaking it into small droplets. This increases the surface area of the fat.

The alkaline conditions and the large surface area increase the rate of fat breakdown by lipase.

Common mistake: Bile is not an enzyme and it does not chemically break down fat. It emulsifies fat so that lipase can work faster.

Required practical: food tests Spec 4.2.2.1

You can use **qualitative reagents** to test for a range of carbohydrates, lipids and proteins. Qualitative means the test tells you whether a food molecule is present, not how much.

1. Prepare a food sample: grind a small amount of food with water and filter it or let it settle. Test the liquid.
2. Add the test reagent to a sample of the food solution.
3. Look for the colour change and compare with the table below.

Food tests		
Food molecule	Test	Positive result
Sugars	Benedict's test: add Benedict's solution (blue) and heat in a hot water bath	Blue changes to green, yellow, orange or brick-red
Starch	Iodine test: add iodine solution (orange-brown)	Orange-brown changes to blue-black
Protein	Biuret test: add Biuret reagent (blue)	Blue changes to purple (lilac)
Lipids	Sudan III test: add a few drops of Sudan III stain to the sample in water and shake	A red-stained oily layer forms on top of the water

Some schools use the ethanol emulsion test for lipids instead: shake the sample with ethanol, then pour it into water. A cloudy white emulsion shows that lipid is present.

The more the Benedict's colour moves towards brick-red, the more sugar there is. If the colour stays blue, no sugar is present.

Required practical: Take care with the hot water bath and wear eye protection. Sudan III and ethanol are flammable, so keep them away from flames. Always state the colour before and after the test.

Exam tip: Say 'blue-black', not just 'black', for the iodine test, and 'purple', not 'pink', for Biuret.

Required practical: the effect of pH on amylase Spec 4.2.2.1

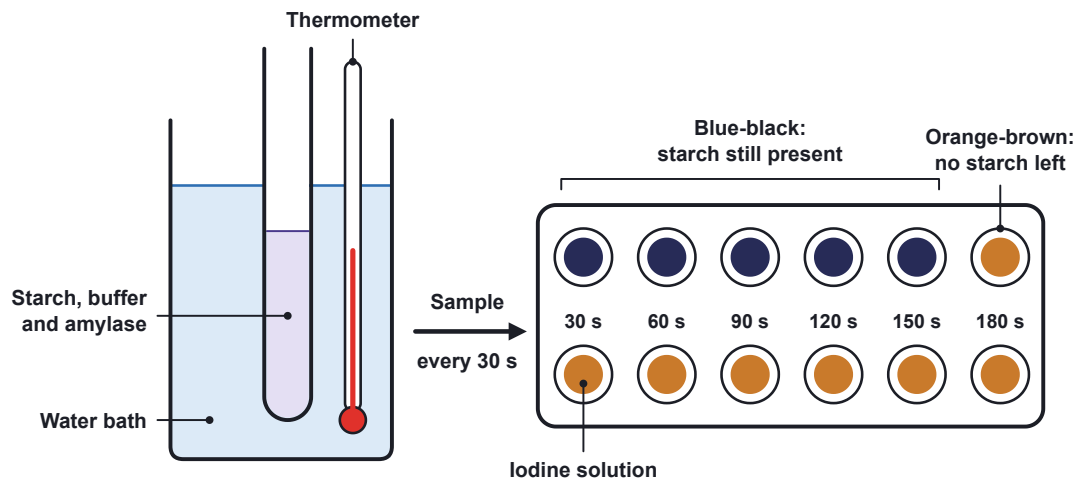
This practical investigates how **pH** affects the rate of reaction of the enzyme **amylase**. You use a **continuous sampling** technique to find the time taken to completely digest a starch solution at a range of pH values.

1. Put a drop of iodine solution into each well of a spotting tile.
2. Add starch solution and a buffer solution of a known pH to a test tube. Add amylase solution.
3. Place the tube in a water bath (or use an electric heater) so the temperature stays constant. Start a stopwatch.
4. Every 30 seconds, take a sample from the tube and add it to a fresh drop of iodine.
5. Stop when the iodine stays orange-brown. All the starch has been digested. Record the time taken.
6. Repeat at a range of pH values, using a different buffer each time.

Variables	
Type	Variable
Independent	pH of the buffer
Dependent	Time taken for the starch to be completely digested (rate = $1 \div \text{time}$)
Control	Temperature, volume and concentration of starch and amylase

The shorter the time, the faster the rate. The rate is highest at the optimum pH. Away from the optimum, amylase is denatured and the starch takes much longer to digest, or is not digested at all.

Required practical: Samples every 30 seconds means the time is only accurate to the nearest 30 seconds. Take samples more often for a more precise result. Wear eye protection, because iodine stains and irritates.



Sample every 30 seconds. When the iodine **stays orange-brown**, all the starch has been digested.

The heart and the double circulatory system Spec 4.2.2.2

The heart is an **organ** that pumps blood around the body in a **double circulatory system**. There are two separate loops, and blood passes through the heart twice on each complete circuit.

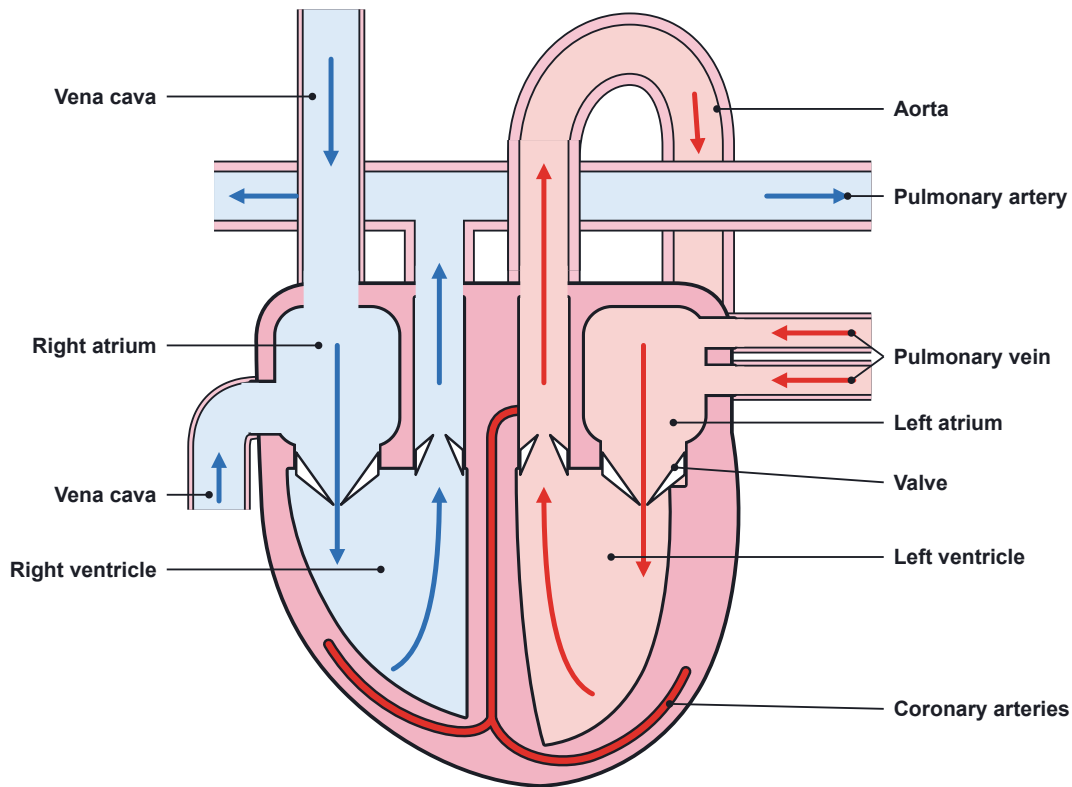
- The **right ventricle** pumps blood to the lungs, where gas exchange takes place.
- The **left ventricle** pumps blood around the rest of the body.

Blood returns from the body to the right atrium and from the lungs to the left atrium. The ventricles have thick muscular walls. The left ventricle has a thicker wall than the right, because it has to pump blood all the way around the body at a higher pressure. Valves in the heart stop blood flowing backwards. You do not need to know the names of the valves.

Blood vessels associated with the heart

Vessel	Carries blood	Oxygen content
Vena cava	From the body to the right atrium	Low (deoxygenated)
Pulmonary artery	From the right ventricle to the lungs	Low (deoxygenated)
Pulmonary vein	From the lungs to the left atrium	High (oxygenated)
Aorta	From the left ventricle to the body	High (oxygenated)
Coronary arteries	Over the surface of the heart, supplying the heart muscle	High (oxygenated)

1. Deoxygenated blood from the body enters the right atrium through the vena cava.
2. It passes into the right ventricle, which pumps it to the lungs through the pulmonary artery.
3. In the lungs the blood picks up oxygen and loses carbon dioxide.
4. Oxygenated blood returns through the pulmonary vein to the left atrium.
5. It passes into the left ventricle, which pumps it around the body through the aorta.



Blue arrows: **deoxygenated** blood to the lungs. Red arrows: **oxygenated** blood to the body. The left ventricle has the **thickest wall**.

Common mistake: The pulmonary artery carries deoxygenated blood and the pulmonary vein carries oxygenated blood. This is the opposite of most arteries and veins. Remember: arteries carry blood away from the heart.

Exam tip: On a heart diagram, left and right are the patient's left and right. The patient's left side appears on the right of the page.

Controlling the heart rate Spec 4.2.2.2

The natural resting heart rate is controlled by a group of cells located in the **right atrium** that act as a **pacemaker**.

Sometimes the heart rate is irregular. **Artificial pacemakers** are electrical devices used to correct irregularities in the heart rate.

Exam tip: Say 'a group of cells in the right atrium'. A common mistake is to say the pacemaker is the whole heart or the brain.

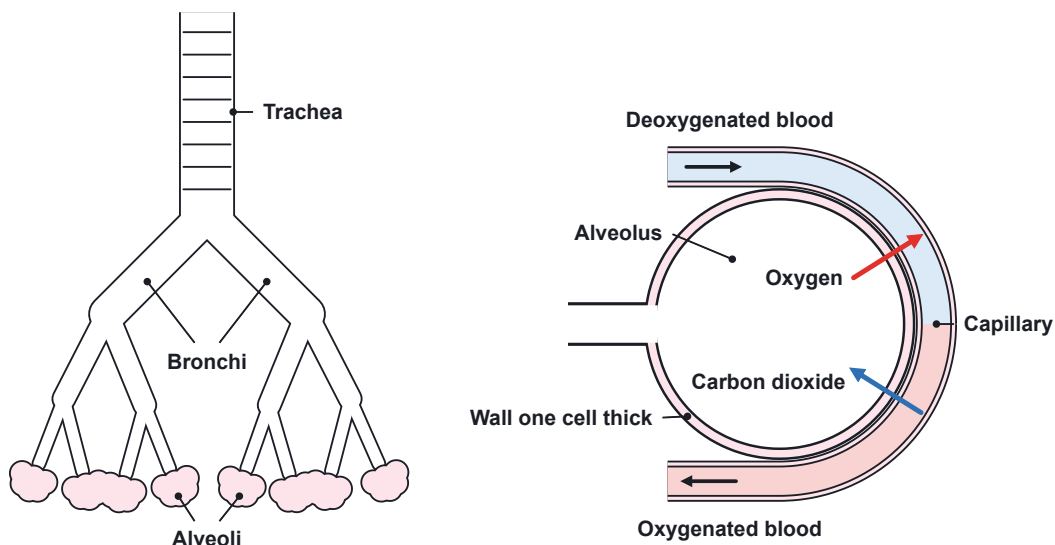
The lungs and gas exchange Spec 4.2.2.2

You need to know the structure of the lungs and how they are adapted for **gaseous exchange**. Knowledge of the lungs is restricted to the **trachea**, **bronchi**, **alveoli** and the **capillary network** surrounding the alveoli.

1. Air passes down the trachea.
2. The trachea divides into two bronchi, one to each lung.
3. The bronchi branch into smaller tubes that end in alveoli (air sacs).
4. At the alveoli, oxygen diffuses into the blood in the surrounding capillaries and carbon dioxide diffuses out of the blood into the air.

Blood arriving at the lungs has a low concentration of oxygen and a high concentration of carbon dioxide. Oxygen therefore diffuses from the air in the alveoli into the blood, and carbon dioxide diffuses the other way.

How the alveoli are adapted for gas exchange	
Adaptation	Why it helps
Millions of alveoli	Gives a very large surface area for diffusion
Walls one cell thick	Short diffusion distance, so gases cross quickly
Surrounded by a network of capillaries (a good blood supply)	Blood carries oxygen away and brings carbon dioxide, which keeps a steep concentration gradient
Constantly ventilated by breathing	Fresh air keeps the oxygen concentration high in the alveoli, which also keeps a steep concentration gradient



Oxygen diffuses into the blood and carbon dioxide diffuses out across a wall **one cell thick**.

Exam tip: In gas exchange answers, link each feature to its effect: 'thin wall, so short diffusion distance' earns the mark. Naming the feature alone does not.

Blood vessels Spec 4.2.2.2

The body contains three different types of blood vessel: **arteries**, **veins** and **capillaries**. Their structures are related to their functions.

Comparing blood vessels			
	Artery	Vein	Capillary
Function	Carries blood away from the heart at high pressure	Carries blood back to the heart at low pressure	Exchanges substances with body cells
Wall	Thick, with muscle and elastic fibres	Thinner walls	One cell thick, so substances pass through easily
Lumen (inside space)	Narrow compared with the thickness of the wall	Wide	Very narrow
Valves	No	Yes, to stop backflow	No

Arteries have thick, strong walls because the blood is at high pressure. The elastic fibres let the wall stretch and spring back. The muscle strengthens the wall.

Veins have a wide lumen and valves. The blood is at low pressure, so the valves stop it flowing backwards.

Capillaries are tiny and have very thin walls. This gives a short diffusion distance, so oxygen and nutrients can pass to the cells and carbon dioxide and waste can pass back into the blood. Capillary walls are permeable.

Blood flow rate

$$\text{rate of blood flow} = \text{volume of blood} \div \text{time}$$

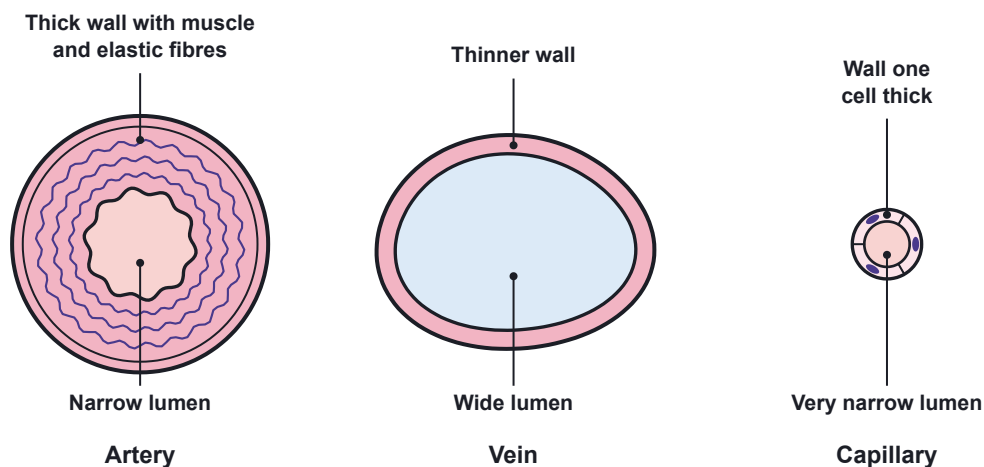
Calculating blood flow

300 cm³ of blood flows through an artery in 4 minutes. Calculate the rate of blood flow in cm³ per minute.

1. Rate = volume ÷ time.
2. Rate = 300 ÷ 4.

Answer: 75 cm³/min

Maths skill: A rate is always something per unit time. Make sure your answer has units such as cm³/min, and that the time is in the unit you are asked for.



Arteries have **thick walls**, veins have **wide lumens** and capillaries have walls **one cell thick**. Not drawn to scale.

Blood Spec 4.2.2.3

Blood is a tissue consisting of **plasma**, in which the **red blood cells**, **white blood cells** and **platelets** are suspended.

Components of blood		
Component	Function	Adaptation
Plasma	Transports carbon dioxide from the organs to the lungs, soluble products of digestion from the small intestine to other organs, and urea from the liver to the kidneys. Also transports hormones	A liquid, so substances dissolve in it
Red blood cells	Carry oxygen from the lungs to all the cells of the body	Biconcave disc shape gives a large surface area. No nucleus, so more room for haemoglobin. Contain haemoglobin, which binds to oxygen
White blood cells	Defend the body against pathogens. Some engulf pathogens (phagocytosis); others produce antibodies and antitoxins	Have a nucleus. Phagocytes can change shape to engulf pathogens
Platelets	Help the blood to clot at a wound	Small fragments of cells with no nucleus

In the lungs, haemoglobin combines with oxygen to form oxyhaemoglobin. In the body tissues the oxyhaemoglobin releases the oxygen.

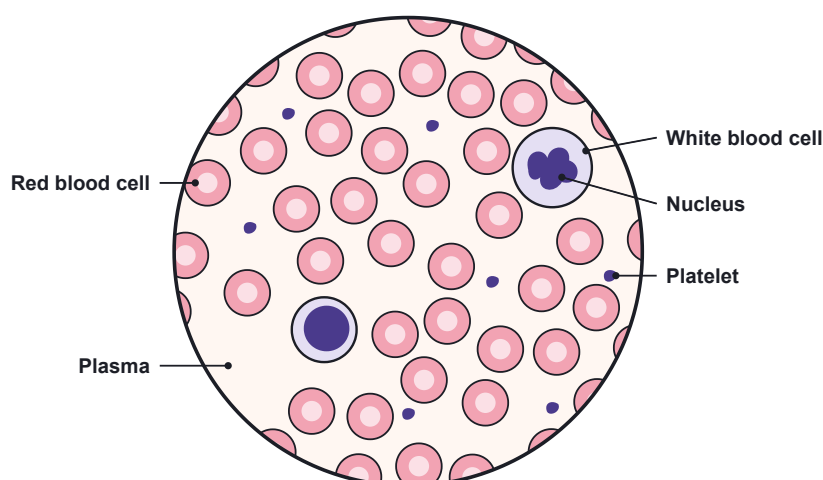
Recognising blood cells

You may need to identify cells in a photograph or diagram.

- Red blood cells are the most numerous. They are small, round and have no nucleus, and look paler in the middle.
- White blood cells are larger and have a clear nucleus, often stained dark purple.
- Platelets are tiny fragments, much smaller than the other cells.

Blood products, such as donated blood used in a transfusion, can save lives. There are risks, for example infection can be passed on from the donor, so donated blood has to be checked and matched to the patient.

Exam tip: When drawing cells from a microscope, use a sharp pencil, clear single lines, no shading, and label with straight lines that do not cross.



Red blood cells are the most numerous. White blood cells have a **nucleus**. Platelets are tiny fragments.

Coronary heart disease Spec 4.2.2.4

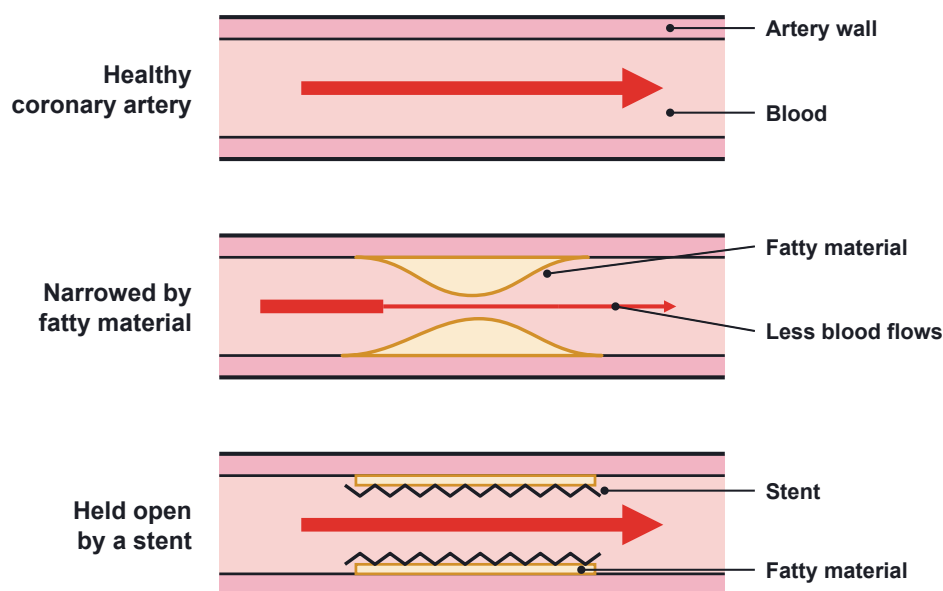
Coronary heart disease (CHD) is a **non-communicable disease**: it is not caused by a pathogen and cannot be passed from person to person.

In CHD, **layers of fatty material build up inside the coronary arteries**, narrowing them. This reduces the flow of blood through the coronary arteries, resulting in a **lack of oxygen for the heart muscle**.

- **Stents** are used to keep the coronary arteries open.
- **Statins** are widely used to reduce blood cholesterol levels, which slows down the rate of fatty material deposit.

1. Fatty material builds up inside a coronary artery.
2. The artery narrows, so less blood flows through it.
3. The heart muscle receives less oxygen.

Common mistake: CHD affects the coronary arteries, which supply the heart itself. It is not a problem with the blood vessels going to the lungs or the brain.



Fatty material **narrows the coronary artery**. A **stent** holds it open so blood can reach the heart muscle.

Treating cardiovascular disease Spec 4.2.2.4

Faulty heart valves

In some people heart valves may become faulty. A valve may be prevented from opening fully, or it might develop a leak.

- If a valve does not open fully, less blood can flow through, so the heart has to work harder and the body may receive less oxygen.
- If a valve leaks, blood flows backwards, so the heart pumps less blood forward with each beat.

Faulty heart valves can be replaced using **biological** or **mechanical** valves.

Heart failure

In the case of heart failure, a **donor heart**, or heart and lungs, can be transplanted. **Artificial hearts** are occasionally used to keep patients alive whilst waiting for a heart transplant, or to allow the heart to rest as an aid to recovery.

Evaluating treatments

You need to evaluate the advantages and disadvantages of treating cardiovascular diseases by drugs, mechanical devices or transplant.

Treatments compared		
Treatment	Advantages	Disadvantages
Drugs (such as statins)	Reduce cholesterol and slow down the rate of fatty deposit. Taken by mouth, with no operation	Must be taken regularly for a long time. May have side effects. Do not repair a damaged heart
Mechanical devices (stents, mechanical valves, artificial hearts)	Can quickly restore blood flow or heart function. Recovery is faster than for a transplant. Artificial hearts can keep a patient alive while waiting for a donor	Surgery has risks such as infection and bleeding. Blood clots can form on the device. Artificial hearts are only used for a limited time
Transplant (donor heart or heart and lungs)	Replaces a failed heart, so normal life may be possible	Few donors are available. Major surgery. The immune system may reject the organ, so drugs are needed to prevent this

Mechanical valves last a long time, but blood clots are more likely to form on them, so the patient must take drugs to stop clotting for the rest of their life. Biological valves are less likely to cause clots, but they wear out sooner and may need replacing.

Exam tip: For 'evaluate' questions, give advantages AND disadvantages, then finish with a judgement that refers to the patient, such as their age and how serious the disease is.

Health and disease Spec 4.2.2.5

Health is the state of physical and mental well-being.

Diseases, both **communicable** and **non-communicable**, are major causes of ill health. A communicable disease is caused by a pathogen and can spread from person to person. A non-communicable disease cannot. Other factors including diet, stress and life situations may have a profound effect on both physical and mental health.

How different types of disease interact

Interactions between diseases	
Interaction	Meaning
Immune system defects	Defects in the immune system mean that an individual is more likely to suffer from infectious diseases
Viruses and cancer	Viruses living in cells can be the trigger for cancers
Immune reactions and allergies	Immune reactions initially caused by a pathogen can trigger allergies such as skin rashes and asthma
Physical and mental health	Severe physical ill health can lead to depression and other mental illness

Exam tip: If asked how two diseases interact, name both diseases and say how one makes the other more likely, for example 'a weak immune system makes infection more likely'.

Handling data about disease Spec 4.2.2.5

You need to be able to translate disease incidence information between graphical and numerical forms. **Incidence** is how often a disease occurs in a population.

- Construct and interpret **frequency tables** and diagrams.
- Use bar charts for data in separate categories, and histograms for continuous data grouped into ranges.
- Use a **scatter diagram** to identify a **correlation** between two variables. A positive correlation means one variable increases as the other increases. A negative correlation means one decreases as the other increases. No pattern means no correlation.

Sampling

It is not possible to test everyone, so scientists collect data from a **sample**. In epidemiological studies, a larger sample that is representative of the population gives more reliable data.

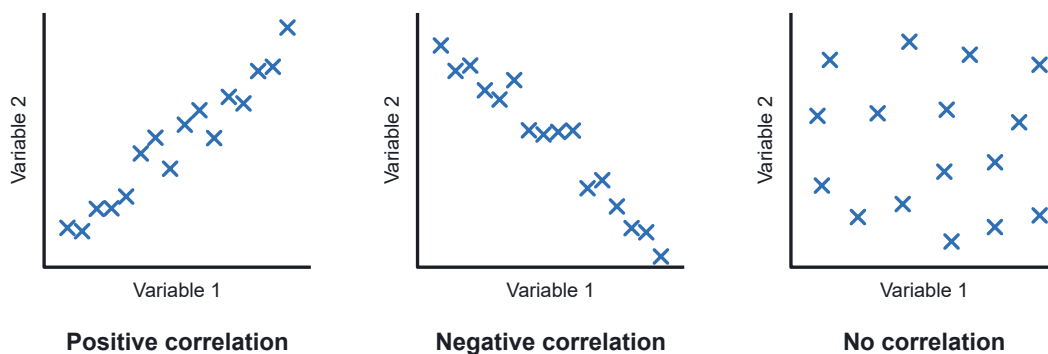
Disease incidence

In a town of 40 000 people, 60 new cases of a disease were recorded in one year. Calculate the number of new cases per 100 000 people.

1. Divide the number of cases by the population: $60 \div 40\,000 = 0.0015$.
2. Multiply by 100 000.

Answer: 150 cases per 100 000 people

Maths skill: Comparing places of different size is only fair if you use the number of cases per 100 000 (or another equal number of people), not the raw number of cases. The numbers in this example are for practice only.



The pattern of points shows the type of **correlation**.

Risk factors and causes Spec 4.2.2.6

Risk factors are linked to an increased rate of a disease. They can be:

- aspects of a person's **lifestyle**
- **substances** in the person's body or environment.

A **causal mechanism** has been proven for some risk factors, but not for others. A correlation between a risk factor and a disease does not prove that the risk factor causes the disease. A causal mechanism explains how the risk factor leads to the disease.

Many diseases are caused by the interaction of a number of factors. For example, CHD is affected by diet, smoking and how much exercise a person takes, as well as other factors.

Common mistake: 'Risk factor' does not mean the disease is certain. It means the disease is more likely. Someone with no risk factors can still get the disease.

The effect of lifestyle on disease Spec 4.2.2.6

You need to be able to explain the effect of lifestyle factors including **diet**, **alcohol** and **smoking** on the incidence of non-communicable diseases.

Lifestyle factors and disease	
Risk factor	Effect
Diet, smoking and exercise: cardiovascular disease	A diet high in saturated fat can raise blood cholesterol, which leads to fatty deposits in the arteries. Chemicals in tobacco smoke damage the artery lining and raise blood pressure, and carbon monoxide reduces the oxygen the blood can carry. Regular exercise reduces the risk
Obesity: Type 2 diabetes	Obesity is a risk factor for Type 2 diabetes
Alcohol: liver and brain	Drinking too much alcohol over a long time damages the liver. Alcohol also affects brain function, for example slowing reactions, and long-term heavy drinking can damage the brain
Smoking: lung disease and lung cancer	Smoking damages the lungs and airways, causing lung disease. Tar in tobacco smoke contains chemicals that cause lung cancer
Smoking and alcohol: unborn babies	Smoking in pregnancy can cause low birth weight and premature birth. Alcohol in pregnancy can damage the baby's development, including the brain
Carcinogens (including ionising radiation): cancer	A carcinogen is a substance or type of radiation that can cause cancer, such as chemicals in tobacco smoke. Ionising radiation, such as X-rays and gamma rays, can damage the DNA in cells

Because lifestyles differ, the incidence of these diseases is different in different places. Diseases linked to diet and obesity, for example, are more common in places where people eat more high-energy food and take less exercise. This is true at local, national and global levels.

Exam tip: To 'explain' an effect, give the link: risk factor, what it does in the body, then the disease it leads to.

The cost of non-communicable diseases Spec 4.2.2.6

You need to be able to discuss the **human** and **financial** cost of these diseases to an individual, a local community, a nation or globally.

Costs of non-communicable diseases		
Level	Human cost	Financial cost
Individual	Pain, loss of independence, a shorter life	Lost income if the person cannot work. Costs of care and travel
Local community	Family and friends become carers. Loss of community members	Local businesses lose workers and customers
Nation	Many people with a reduced quality of life	Health services pay for treatment, drugs and operations. Lost working days reduce the national income
Global	Large numbers of early deaths and illnesses worldwide	Health care and lost work cost large amounts of money across the world

Prevention through diet and lifestyle can reduce these costs, because many interventions would not be necessary if individuals reduced their risks.

Exam tip: A 'discuss' answer needs both human and financial costs and should state who pays: the person, their family, the health service or the country.

Using data about risk factors Spec 4.2.2.6

You need to interpret data about risk factors for specified diseases. The same skills apply as for incidence data.

- Translate information between graphical and numerical forms.
- Extract and interpret information from charts, graphs and tables.
- Use a scatter diagram to identify a correlation between a risk factor and a disease.
- Understand sampling: the sample should be large and representative for the conclusion to be reliable.

Describe what the data show first, then say whether there is a correlation. Then say whether the data prove a cause. A correlation alone does not. You also need a causal mechanism, or evidence that other factors were controlled.

Common mistake: Do not write 'this proves that smoking causes cancer' from a scatter diagram. Write that the data show a correlation.

Cancer Spec 4.2.2.7

You need to be able to describe **cancer** as the result of **changes in cells that lead to uncontrolled growth and division**. These cells can form a lump called a tumour.

Benign and malignant tumours		
	Benign tumour	Malignant tumour
Cells	Growths of abnormal cells	Cancer cells
Where they are	Contained in one area, usually within a membrane	Invade neighbouring tissues
Spread	Do not invade other parts of the body	Spread to different parts of the body in the blood, where they form secondary tumours
Cancer?	No	Yes

Scientists have identified **lifestyle risk factors** for various types of cancer, such as smoking, obesity and drinking alcohol. There are also **genetic risk factors** for some cancers. Viruses living in cells can also trigger some cancers.

Exam tip: Only malignant tumours are cancers. Say that malignant cells spread 'in the blood' to form secondary tumours.

Quick check

1. Which enzyme breaks down proteins, and what are the products?
2. Which ventricle pumps blood around the body?
3. Name the three types of blood vessel.
4. What does bile do?
5. How do malignant tumours spread?

Quick check answers

Animal tissues, organs and organ systems

1. Protease. It breaks proteins into amino acids.
2. The left ventricle.
3. Arteries, veins and capillaries.
4. It neutralises stomach acid and emulsifies fat, increasing its surface area.
5. Cells invade neighbouring tissues and spread in the blood to form secondary tumours.