

Circulatory systems and the heart

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Last checked 30 September 2026

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What you need to know

The heart turns up on almost every paper: a labelled section to name parts on, a question about the route blood takes, a list of risk factors for heart disease, or a graph of heart rate during exercise. Outcomes marked **Extended only** are tested on Papers 2 and 4 only. By the end of this topic you should be able to:

Circulatory systems

1. **Describe what a circulatory system is:** a set of blood vessels, a pump (the heart) and valves that keep the blood moving in one direction only.
2. **Extended only:** describe the **single circulation** of a fish.
3. **Extended only:** describe the **double circulation** of a mammal.
4. **Extended only:** explain why a double circulation is an **advantage**.

The heart

5. **Identify the parts of the heart** on diagrams and photographs: the muscular wall, the septum, the left and right atria, the left and right ventricles, the one-way valves and the coronary arteries.
6. **State that arteries carry blood away from the heart** and veins carry it back.
7. **State three ways of monitoring the heart:** an ECG, the pulse rate, and listening to the sounds of the valves closing.
8. **Investigate and describe how physical activity changes the heart rate.**
9. **Describe coronary heart disease** as a blockage of the coronary arteries, and state its risk factors: diet, lack of exercise, stress, smoking, genetic predisposition, age and sex.
10. **Discuss how diet and exercise can lower the risk** of coronary heart disease.
11. **Extended only:** identify the **atrioventricular** and **semilunar** valves.
12. **Extended only:** explain why the left ventricle has a thicker wall than the right ventricle, and why the atria have thinner walls than the ventricles.
13. **Extended only:** explain why the **septum** matters: it keeps oxygenated and deoxygenated blood apart.
14. **Extended only:** describe how the heart works: the atria and ventricles contracting in turn, and the valves opening and closing.
15. **Extended only:** explain **why** physical activity makes the heart rate go up.

The structure of arteries, veins and capillaries, the names of the vessels to the kidney and liver, and the parts of blood are in Blood vessels and blood. Lactic acid and the oxygen debt are explained fully in Respiration; this note gives just enough to explain the heart rate after exercise.

Understand it

A pump, pipes and valves

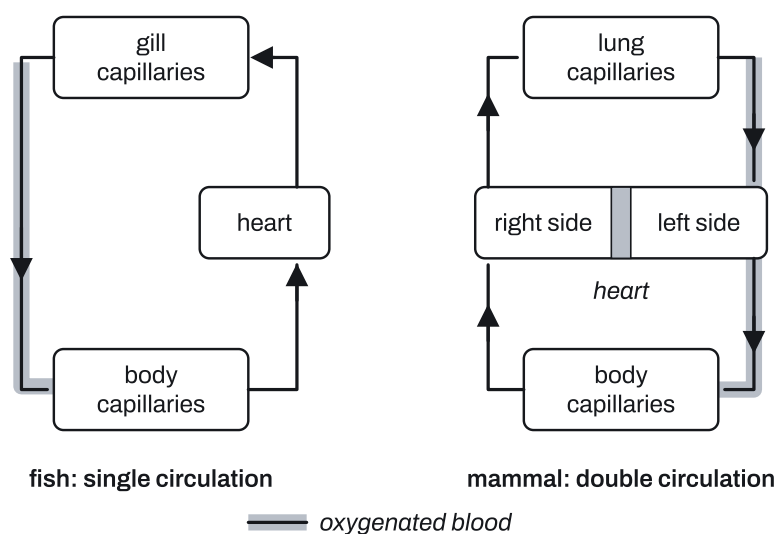
Every cell in your body needs a steady supply of oxygen and glucose and needs its carbon dioxide taken away. Diffusion alone is far too slow over more than a millimetre or so, so large animals move blood around in a **circulatory system**. It has three parts:

- a **pump**, the **heart**, which pushes the blood;
- **blood vessels**, the pipes the blood travels in;
- **valves**, which stop blood going backwards, so the flow is **one-way**.

Blood leaves the heart in **arteries** and comes back to it in **veins**. In between, it passes through **capillaries** in the organs, where substances are exchanged with the cells. So on any trip away from the heart and back, the order is heart → arteries → capillaries → veins → heart.

"Artery" means the blood is heading **away** from the heart; "vein" means it is heading **back**. It says nothing about how much oxygen the blood carries.

Extended: single and double circulations



A fish has a single circulation. Its heart has **one atrium and one ventricle** and no septum. The route of one complete circuit is

heart → gills → body → heart

The blood picks up oxygen in the gill capillaries and goes on to the body **without returning to the heart**. Squeezing through the gill capillaries makes it lose most of its pressure, so it reaches the body slowly.

A mammal has a double circulation: in one complete circuit of the body, the blood **passes through the heart twice**. There are two loops:

- the **pulmonary circulation**: right side of the heart → lungs → left side of the heart;
- the **systemic circulation**: left side of the heart → body → right side of the heart.

The **right side** of the heart always holds **deoxygenated** blood (coming back from the body, going to the lungs). The **left side** always holds **oxygenated** blood (coming back from the lungs, going to the body).

Why a double circulation is better:

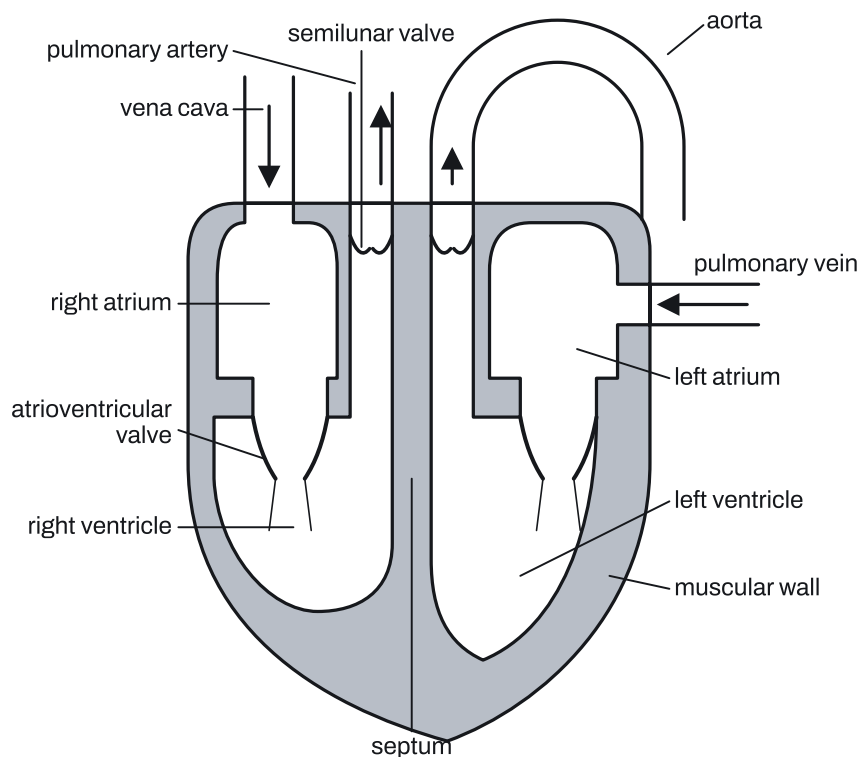
- After the lungs, blood goes **back to the heart** and is pumped again, so it reaches the body at **high pressure**. It flows fast, so oxygen and glucose are **delivered quickly** and carbon dioxide and urea are **removed quickly**. This supports a **high rate of respiration** (mammals need it to stay warm and active), and the high pressure also drives filtration in the kidneys.
- The lungs get blood at a **lower pressure**, so their delicate capillaries are not damaged, and the slower flow gives **more time for gas exchange**.
- Oxygenated and deoxygenated blood are **kept apart** (by the septum), so the blood going to the body carries as much oxygen as possible.

The heart

The heart is a bag of **cardiac muscle** that squeezes rhythmically all your life. It is divided into a right side and a left side by a wall called the **septum**, and each side has two chambers:

- an **atrium** (plural **atria**) at the top, which **receives** blood from veins;
- a **ventricle** below, which **pumps** blood out into an artery.

So blood always **enters** the heart through veins into the **atria**, and **leaves** through arteries from the **ventricles**.



Left and right are swapped on the page. A heart diagram shows the heart as if its owner were facing you, so the **heart's left side is on the right of the drawing**. The quickest check: the side with the **much thicker ventricle wall** is the **left** side.

The four big vessels attached to the heart:

Vessel	Joins	Blood
Vena cava	body → right atrium	deoxygenated
Pulmonary artery	right ventricle → lungs	deoxygenated
Pulmonary vein	lungs → left atrium	oxygenated
Aorta	left ventricle → body	oxygenated

Follow one red blood cell through the heart and lungs and you get the order to learn:

vena cava → right atrium → right ventricle → pulmonary artery → lungs → pulmonary vein → left atrium → left ventricle → aorta

Valves

Valves are flaps that open only one way. Blood pushing forwards opens them; blood trying to go backwards fills the flaps and shuts them. So they **prevent backflow** and keep the flow **one-way**. In the circulation, valves are found in the **heart** and in **veins**, not in arteries or capillaries.

Extended only: the heart has two kinds.

- **Atrioventricular valves**, one on each side, sit **between each atrium and its ventricle**. They stop blood being pushed back into the atria when the ventricles contract.
- **Semilunar valves** sit at the **base of the pulmonary artery and of the aorta**, where the vessels leave the ventricles. They are small pocket-shaped flaps that stop blood flowing back from the arteries into the ventricles when the ventricles relax.

The "lub-dub" sound of a heartbeat is the valves **closing**, not opening.

Extended: how the heart beats

One heartbeat has the same steps on both sides at the same time:

1. Blood flows from the veins into the **atria**. The **atria contract**, raising the pressure, and push the blood through the open **atrioventricular valves** into the relaxed ventricles, which fill.
2. The **ventricles contract**. The pressure in them rises above that in the atria, so the **atrioventricular valves close** (preventing backflow into the atria). When it rises above the pressure in the arteries, the **semilunar valves open** and blood is forced into the pulmonary artery and aorta.
3. The **ventricles relax**. The pressure in them falls below that in the arteries, so the **semilunar valves close** (preventing backflow from the arteries). The atria refill, and the cycle starts again.

Remember "contract" means the chamber squeezes and **pushes blood out**; "relax" means it lets **blood in**.

Extended: why the walls are different thicknesses

Muscle that is thicker **contracts with more force** and so makes a **higher pressure**.

- **Left ventricle vs right ventricle**. The left ventricle pumps blood into the aorta and **all round the body**, a long way through many vessels, so it needs a high pressure: it has the **thickest, most muscular wall**. The right ventricle pumps only to the **lungs**, which are close; a lower pressure is enough, and a high pressure would damage the lung capillaries. So its wall is thinner.
- **Atria vs ventricles**. The atria only push blood a short distance, **down into the ventricles** just below them, so they need little force and have **thin walls**. Ventricles pump blood out of the heart into arteries, so their walls are thicker.

Extended: the septum

The septum is a wall of muscle between the right and left sides. It **separates the deoxygenated blood** on the right from the **oxygenated blood** on the left. That keeps the blood reaching the body as rich in oxygen as it can be.

Some babies are born with a **hole in the septum**. Blood then passes between the two sides, and oxygenated and deoxygenated blood **mix**. The blood sent round the body carries **less oxygen**, so the cells get less oxygen for aerobic respiration and release less energy. The child may be breathless and tire easily, and may grow slowly.

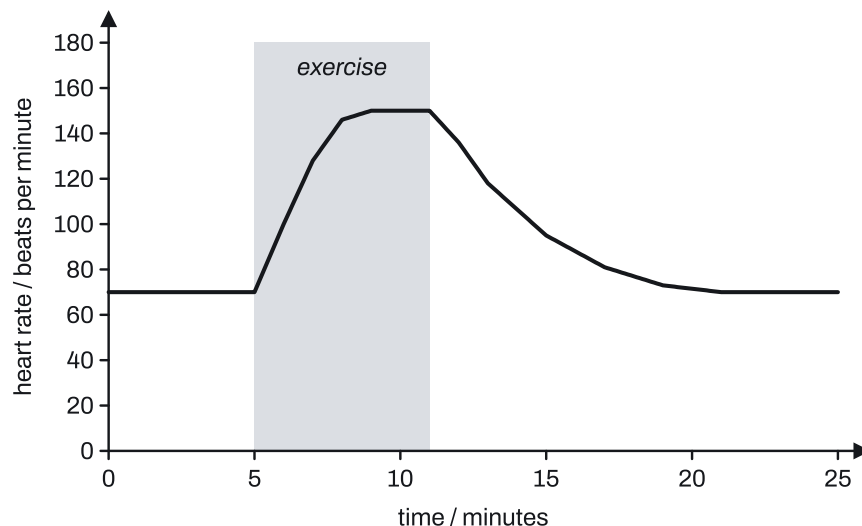
Monitoring the heart

There are three ways to check what the heart is doing:

- an **ECG** (electrocardiogram): electrodes on the skin record the electrical activity of the heart as a trace, with one repeating pattern for each beat;
- the **pulse rate**: count the pulses in an artery (at the wrist or neck) for a set time and scale up to beats per minute;
- **listening to the sounds of the valves closing**, with a stethoscope.

Counting beats. If you count 14 beats in 10 seconds, the rate is $14 \times 6 = 84$ beats per minute. On an ECG, measure the time for one beat and divide 60 by it: one beat every 0.8 s gives $60 \div 0.8 = 75$ beats per minute. A faster heart rate makes the beats on an ECG **closer together**.

Physical activity and the heart rate



The graph is typical. The resting heart rate here is 70 beats per minute. Exercise from minute 5 to minute 11 pushes it up to 150 beats per minute, a rise of $\frac{150 - 70}{70} \times 100 = 114\%$ (to the nearest whole number). When the exercise stops, the rate does **not** drop straight back: it takes several minutes to return to resting.

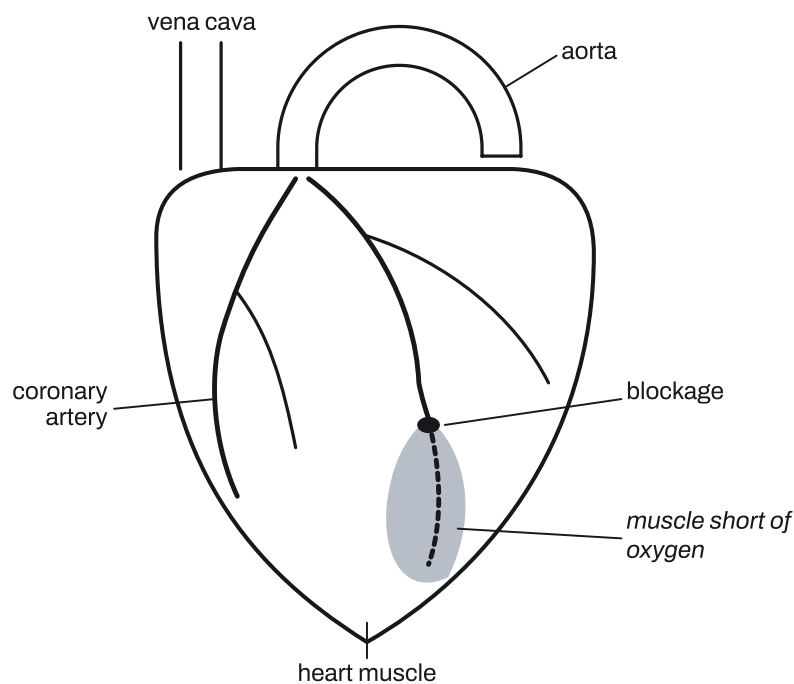
You can investigate this yourself: measure your pulse rate at rest, then after a fixed amount of exercise (for example, stepping on and off a step for 2 minutes), then every minute during recovery. Keep everything else the same (the same person, the same exercise, the same way of counting) and repeat to check the results.

Extended only: why it goes up. Working muscles contract more, and muscle contraction needs **energy**, which is released by **respiration**. So the muscle cells respire faster and need more **oxygen and glucose**, and make more **carbon dioxide**. The heart beats faster so that blood flows through the muscles faster, **delivering more oxygen and glucose** and **removing carbon dioxide** more quickly. (The rise in carbon dioxide in the blood and the hormone **adrenaline** both help to trigger the faster rate.)

Extended only: why it stays up afterwards. In hard exercise the muscles cannot get oxygen fast enough, so some respiration is **anaerobic** and **lactic acid** builds up in the muscles, creating an **oxygen debt**. After exercise the heart keeps beating fast to **carry the lactic acid to the liver**, where it is broken down using oxygen (aerobic respiration), and to keep supplying extra oxygen until the debt is repaid.

Coronary heart disease

The heart muscle works nonstop, so it needs its own blood supply. It gets it from the **coronary arteries**, which branch off the base of the aorta and spread over the **outside** of the heart. (The blood inside the chambers does not feed the heart wall.)



In **coronary heart disease (CHD)**, fatty material builds up inside a coronary artery and **narrows or blocks** it. Less blood gets through, so the heart muscle beyond the blockage gets **too little oxygen and glucose** for respiration. It cannot contract properly, and if the supply stops completely, that part of the muscle dies: a **heart attack**.

Risk factors are things that make CHD **more likely**:

- **diet**: a lot of saturated (animal) fat, cholesterol or salt;
- **lack of exercise**;
- **stress**;
- **smoking**;
- **genetic predisposition** (it runs in the family);
- **age**: the risk rises as you get older;
- **sex**: males are more at risk than females of the same age.

Being overweight, high blood pressure and drinking a lot of alcohol also count. The first four can be changed; genes, age and sex cannot.

Reducing the risk with diet and exercise:

- **Diet:** eat less saturated fat and cholesterol (less fatty meat, butter and fried food), so less fatty material builds up in the arteries; eat less salt, to keep blood pressure down; eat fewer high-energy foods to avoid becoming overweight; eat more fibre, fruit and vegetables.
- **Exercise:** regular exercise strengthens the heart muscle, helps keep body mass and blood pressure down and lowers blood cholesterol.
- To **discuss**, give both sides: diet and exercise lower the risk but **cannot remove it**, because genes, age and sex still count, and other factors such as smoking and stress matter too.

Key facts and formulas

There is no formula list in the IGCSE Biology exam. Everything below must be learnt.

Formula	Status
Circulatory system = blood vessels + a pump (heart) + valves for one-way flow	Learn it
Arteries carry blood away from the heart; veins bring it back; heart → arteries → capillaries → veins → heart	Learn it
Atria receive blood from veins; ventricles pump blood into arteries	Learn it
Vena cava → right atrium → right ventricle → pulmonary artery → lungs → pulmonary vein → left atrium → left ventricle → aorta	Learn it
Valves prevent backflow; the septum separates the two sides	Learn it
Monitoring: ECG, pulse rate, listening to the valves closing	Learn it
Heart rate rises during exercise and takes time to return to resting	Learn it
CHD: blockage of the coronary arteries; risk factors diet, lack of exercise, stress, smoking, genetic predisposition, age, sex	Learn it
Extended: fish heart → gills → body → heart (single); mammal: through the heart twice per circuit (double)	Learn it
Extended: atrioventricular valves between atria and ventricles; semilunar valves at the base of the aorta and pulmonary artery	Learn it
Extended: left ventricle wall thickest (pumps to the whole body); atria thinnest (pump only into the ventricles)	Learn it

Formula	Status
Heart rate (beats per minute) = $\frac{\text{beats counted}}{\text{seconds counted}} \times 60$; from an ECG = $60 \div \text{time for one beat in seconds}$	Learn it
Percentage change = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it

How to do it

We tagged 98 questions for this topic (2021–2025, Papers 1–4, some multiple-choice questions appearing on more than one paper). 23 of them are split between types, so the counts add up to 153.

Question type	Questions
Identify heart structures on a diagram	26
Coronary heart disease: risk factors, coronary arteries, lowering the risk	22
Functions of the valves and the septum (including a hole in the septum)	18
Single (fish) and double (mammal) circulation	16
The route of blood through the heart and body	15
Name organs and vessels on a whole-body circulation diagram	12
Ways of monitoring the heart	11
The circulatory system as a pump, vessels and valves	8
Heart-rate data: graphs, ECGs and percentage change	8
Advantages of a double circulation	7
Explain the effect of exercise on heart rate	6
Why chamber walls differ in thickness	4

1. Identify heart structures on a diagram (26 questions)

- Find the left side first:** the ventricle with the **thicker wall** is the left ventricle, and it is on the **right of the drawing**.
- Top chambers are atria, bottom chambers are ventricles.** The wall down the middle is the **septum**.
- Vessels:** the one arching over the top from the left ventricle is the **aorta**; the one leaving the right ventricle is the **pulmonary artery**; the one entering the right atrium is the **vena cava**; the one entering the left atrium is the **pulmonary vein**.
- Valves:** flaps between an atrium and a ventricle are **atrioventricular valves** (Extended); small cups at the bottom of the aorta or pulmonary artery are **semilunar valves** (Extended).

Variations you will meet:

- **"Draw an X on ..." or "label with a letter"**: put the mark clearly **inside** the part asked for. "The muscular wall of the left ventricle" means the thick muscle, not the space in the chamber.
- **"State two letters that identify arteries"**: the aorta and the pulmonary artery only. Don't add the septum or a vein; an extra letter can cost the mark.
- **"Which part pumps blood into the aorta?"** The left ventricle. **"Which part receives blood from the lungs?"** The left atrium (through the pulmonary vein).
- **"Name the main tissue of the heart wall"**: (cardiac) muscle.
- **External view** (multiple choice): the thin vessels branching over the surface are the **coronary arteries**.
- **Extended: "Which is the right atrioventricular valve?"** The flap between the atrium and ventricle on the **left of the drawing**.

2. Coronary heart disease: risk factors, coronary arteries, lowering the risk (22 questions)

1. **What is blocked**: the **coronary arteries** (not "an artery", not "a vein", not "the aorta").
2. **What happens**: less blood reaches the heart muscle, so it gets **less oxygen and glucose** for respiration.
3. **Risk factors**: choose from diet (high in saturated fat or salt), lack of exercise, stress, smoking, genetic predisposition, age, sex (also obesity, high blood pressure, a lot of alcohol).

Variations you will meet:

- **"State three risk factors other than ..."**: don't repeat the one in the question. If it says "a lack of exercise", pick three from the rest.
- **Be specific**: "high blood pressure", not "blood pressure"; "drinking too much alcohol", not "drinking"; "a diet high in saturated fat", not just "food". A symptom (chest pain) or a way to prevent CHD is not a risk factor.
- **"Discuss the role of diet (or exercise) in reducing the risk"**: say **what to change** and **why it helps** (less saturated fat, so less fatty material in the coronary arteries; less salt, so lower blood pressure; exercise, so a stronger heart and lower body mass), then the other side: it lowers the risk but does not remove it.
- **A bar chart of CHD by age and sex**: describe the **similarities** (both rise with age) and **differences** (males higher in most age groups), quoting figures with units (%), and the age groups.
- **Older papers only**: 2021 and 2022 questions asked how blocked coronary arteries are treated (aspirin, stents, bypass surgery). That is not in the current syllabus.

3. Functions of the valves and the septum (18 questions)

1. **Valves**: **prevent backflow** / make sure blood flows **one way**. Found in the heart and in veins.
2. **Septum**: **separates oxygenated and deoxygenated blood** (the left side from the right side).

Variations you will meet:

- **"What ensures one-way flow?"** Valves (not ventricles, not the septum, not capillaries).

- **Extended: "Explain how the structures of the heart make blood flow in one direction":** name both valve types and say when each closes: the atrioventricular valves close when the ventricles contract, so blood can't go back into the atria; the semilunar valves close when the ventricles relax, so blood can't flow back from the arteries.
- **Extended: a hole in the septum:** blood **mixes**, so **less oxygen** reaches the body's cells, **less aerobic respiration**, less energy released; effects are tiredness, breathlessness and slow growth.
- **"The role of structure X"** when X is a valve in the heart: prevents blood flowing back (for a semilunar valve: from the artery into the ventricle).

4. Single (fish) and double (mammal) circulation (16 questions, Extended)

1. **Fish:** heart → gills → body → heart; blood passes through the heart **once** per circuit.
2. **Mammal:** blood passes through the heart **twice** per circuit: heart → lungs → heart → body → heart.

Variations you will meet:

- **"Which statement describes a double circulation?"** The one saying blood goes through the **heart** twice in one circuit of the body (not the lungs, kidneys or brain twice).
- **Fish order after leaving the heart:** gills first, then the body (muscles), then back to the heart.
- **Name the organ on a fish diagram** between the heart and the body: gills.
- **Where is oxygen lowest (or highest)?** In a fish, highest just after the gills, lowest in the blood returning to the heart. In a mammal, highest in the pulmonary vein and left side, lowest in the vena cava, right side and pulmonary artery.
- **Differences between a fish heart and a human heart:** the fish heart has **two chambers** (one atrium, one ventricle), **no septum**, walls of similar thickness, fewer valves and fewer vessels.
- **Evidence of a double circulation on a diagram:** blood comes **back to the heart** after the lungs before going to the body; there are two separate loops.
- **Comparing a fish with another animal:** list similarities as well as differences if the question asks for both.

5. The route of blood through the heart and body (15 questions)

1. **Core:** blood **enters** the heart in **veins** into the **atria** and **leaves** in **arteries** from the **ventricles**. The order round the body is heart → arteries → capillaries → veins → heart.
2. **Learn the full route:** vena cava → right atrium → right ventricle → pulmonary artery → lungs → pulmonary vein → left atrium → left ventricle → aorta.

Variations you will meet:

- **"Describe the path from A to B"** on a heart diagram: give **only** the part asked for (for example vena cava into the right atrium, through the atrioventricular valve, into the right ventricle); don't describe the whole body.
- **Number the steps** (Extended): include the valves in their place: a semilunar valve **opens** between the ventricle filling and the blood entering the artery.

- **Extended: "Explain how a red blood cell moves from the vena cava to the aorta":** name each chamber and vessel in order, **plus** what moves it: atria contract, atrioventricular valves open, ventricles contract, atrioventricular valves close, semilunar valves open, and the trip through the lungs in between.
- **Extended: when blood flows from the atria to the ventricles:** the atria contract, the atrioventricular valves are open and the ventricles are relaxed.
- **"What is the role of the right side of the heart?"** To receive deoxygenated blood from the body and pump it to the lungs.
- **"Which vessel brings blood from the body to the right atrium?"** The vena cava ("vein" on its own is not enough).

6. Name organs and vessels on a whole-body circulation diagram (12 questions)

1. **Organs:** the organ at the top joined by pulmonary vessels is the **lungs**; the pump in the middle is the **heart**; the organ with renal vessels is the **kidney**; the one fed by the hepatic portal vein is the **liver**.
2. **Vessels:** out of the heart to the lungs is the **pulmonary artery**, back from the lungs is the **pulmonary vein**, out to the body is the **aorta**, back from the body is the **vena cava**.
3. **Oxygenated or not:** yes from the lungs to the body's capillaries (pulmonary vein, aorta, arteries to organs); no from the body back to the lungs (veins, vena cava, pulmonary artery).

Variations you will meet:

- **A table:** name each lettered vessel and say "yes" or "no" for oxygenated blood.
- **Draw arrows:** pulmonary artery from the heart to the lungs; pulmonary vein from the lungs to the heart.
- **"Shade the vessel with the highest oxygen concentration":** the pulmonary vein only, not the heart or the capillaries.
- **"Which organ is the pump?":** the heart, the organ that every loop passes through.

7. Ways of monitoring the heart (11 questions)

1. Name any of: **ECG, pulse rate, listening to the sounds of the valves closing** (with a stethoscope). A blood pressure monitor or a heart-rate watch is also accepted.

Variations you will meet:

- **"State two other ways"** after the question has used one (a watch, or an ECG): don't give that one again.
- Write **"pulse rate"**, not just "pulse", and don't describe how to find a pulse instead of naming the method.
- **Heart sounds come from the valves closing**, not opening.

8. The circulatory system as a pump, vessels and valves (8 questions)

1. The definition has **three parts**: a system of **blood vessels**, with a **pump** (the heart), and **valves** to make sure blood flows **one way**.

Variations you will meet:

- **Fill the gaps:** "The heart **pumps** blood round the body. Blood is carried away from the heart in **arteries** and back to it in **veins**."
- **Multiple choice rows** (blood vessels / one-way valves / pump): all three are "yes".
- **"Which part pumps blood?"** The heart only; blood vessels carry it but don't pump it.
- **Arteries don't "return" blood** to the heart; that is veins.

9. Heart-rate data: graphs, ECGs and percentage change (8 questions)

1. **Read the values carefully** from the graph or table, with units (beats per minute).
2. **Percentage change** = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$. The "original" is the **first** value in time. A fall gives a **negative** answer; keep the minus sign or write "decrease".
3. **Round** as the question says (nearest whole number, or 3 significant figures).

Variations you will meet:

- **From an ECG:** count the beats in a stated time and scale to a minute, or divide 60 by the time for one beat. The trace during exercise has beats **closer together**.
- **Match ECG traces** to rest, during exercise, just after and long after: the closest-together beats are during exercise, then just after, and the widest spacing is at rest or long after.
- **Read how long recovery takes:** from the moment exercise stops to the moment the line is back at the resting value.
- **Tick the correct conclusions:** check each against the numbers; "decreases" is wrong if the data rises again later.
- **Describe a trend:** say what happens (rises, levels off, falls) and quote figures with units and times.
- **A pressure graph** for heart chambers (multiple choice): the left ventricle reaches the **highest** pressure; the right atrium the lowest.

10. Advantages of a double circulation (7 questions, Extended)

Give three or four linked points:

1. Blood returns to the heart after the lungs and is pumped again, so it goes to the body at **high pressure** (and flows fast).
2. So oxygen and glucose are **delivered** to the cells quickly, and carbon dioxide and urea are **removed** quickly: this allows a **high rate of respiration** (and a high body temperature and activity level).
3. Blood goes to the lungs at **lower pressure**, so the lung capillaries are **not damaged** and there is **more time for gas exchange**.
4. Oxygenated and deoxygenated blood are **kept separate**.

Variations you will meet:

- **Multiple choice:** the right answer mentions oxygen being supplied to the body cells by blood at **high pressure**. Wrong options say it mixes the blood, keeps pressure high in the lungs, or removes less carbon dioxide.

11. Explain the effect of exercise on heart rate (6 questions)

1. **Describe:** the heart rate rises during exercise and falls slowly back to resting afterwards (quote the figures).
2. **Extended: explain the rise:** muscles contract more → need more energy → more **respiration** → need more **oxygen and glucose** and must lose more **carbon dioxide** → faster heart rate gives faster blood flow to the muscles.
3. **Extended: explain the slow fall:** lactic acid from **anaerobic respiration** built up an **oxygen debt**; the heart rate stays high to carry **lactic acid to the liver** (where it is broken down) and to deliver extra oxygen to repay the debt.

Variations you will meet:

- Respiration **releases** energy; don't say it "produces" or "makes" energy.
- **Adrenaline** released during exercise also raises the heart rate.
- **Fill-the-gaps versions** ask for the muscles (where lactic acid builds up), "debt", "liver" and "oxygen".

12. Why chamber walls differ in thickness (4 questions, Extended)

1. **Left ventricle vs right ventricle:** the left has **more muscle**, so it **contracts with more force** and makes a **higher pressure**, which is needed to push blood **round the whole body**; the right pumps only to the **lungs**, which are close, and a high pressure would damage them.
2. **Atria vs ventricles:** atria only pump blood **into the ventricles**, a short distance, so they need less muscle.

Variations you will meet:

- **"Which chamber has the thickest wall?"** The left ventricle.
- **A bar chart of wall thickness:** the tallest bar is the left ventricle, the second tallest the right ventricle, the two short ones the atria.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Core. A nurse is checking a 58-year-old man before an operation. He smokes, eats fried food most days and says his work is very stressful.

(a) State two ways, other than taking the pulse rate, that the nurse could monitor the activity of his heart. [2]

(b) The nurse counts 18 beats in 15 seconds. Calculate his heart rate in beats per minute. [1]

(c) The nurse is worried about coronary heart disease. State the name of the blood vessels that are blocked in this disease, and explain why a blockage harms the heart. [3]

(d) Identify **two** risk factors for coronary heart disease described in the passage, and state **two other** risk factors. [4]

(e) Discuss how changes to his diet and exercise could reduce his risk of coronary heart disease. [4]

(a) An ECG **B1**; listening to the sounds of the valves closing with a stethoscope **B1**.

(b) $18 \times 4 = 72$ beats per minute **B1** (there are four lots of 15 seconds in a minute).

(c) Coronary arteries **B1**. Less blood reaches the heart muscle, so it gets less oxygen **B1** and glucose for respiration, so the muscle cannot release enough energy to contract, and may die **B1**.

(d) From the passage: smoking **B1**; stress **B1** (also diet, age or sex; any two). Others: lack of exercise; genetic predisposition **B1 B1** (or any two not already used).

(e) Eating less saturated fat (less fried food and fatty meat) means less fatty material builds up in the coronary arteries **B1**. Eating less salt helps to keep blood pressure down **B1**. Regular exercise strengthens the heart and helps him lose body mass **B1**. But these changes lower the risk without removing it: his age, sex and genes still count, and his smoking and stress too **B1**.

Example 2

Extended. A student dissected a sheep's heart and measured the thickness of the wall of each chamber.

Chamber	right atrium	left atrium	right ventricle	left ventricle
Wall thickness / mm	2	3	5	15

(a) How many times thicker is the wall of the left ventricle than the wall of the right ventricle? [1]

(b) Explain why the wall of the left ventricle is thicker than the wall of the right ventricle. [3]

(c) Explain why the walls of the atria are the thinnest. [1]

(d) Describe how blood passes from the right atrium into the pulmonary artery, in terms of the contraction of the heart muscle and the action of the valves. [4]

(e) Explain the importance of the septum. [2]

(a) $15 \div 5 = 3$ times as thick **B1**.

(b) The left ventricle has more muscle, so it contracts with more force **B1** and produces a higher pressure **B1**, which is needed to pump blood round the whole body, whereas the right ventricle pumps blood only to the lungs, which are close by **B1**.

(c) The atria only pump blood a short distance, into the ventricles, so little force is needed **B1**.

(d) The right atrium contracts, pushing blood through the open atrioventricular valve into the relaxed right ventricle **B1**. The right ventricle then contracts **B1**; the atrioventricular valve closes, stopping blood going back into the atrium **B1**; the semilunar valve opens and blood is forced into the pulmonary artery **B1**.

(e) It separates the deoxygenated blood in the right side from the oxygenated blood in the left side **B1**, so the blood pumped to the body carries as much oxygen as possible **B1**.

Example 3

Extended. Three friends skipped with a rope at the same pace for 3 minutes. Each counted their own pulse for 15 seconds before skipping and again straight after, then kept checking until it was back to their resting value.

Student	Pulses in 15 s at rest	Pulses in 15 s straight after skipping	Minutes to get back to resting
Aroha	17	35	4
Ben	20	42	9
Chen	18	38	6

(a) Suggest one thing, other than the pace and the time spent skipping, that the friends should keep the same so their results can be compared. **[1]**

(b) Calculate Ben's heart rate straight after skipping, in beats per minute. **[1]**

(c) Calculate by how many beats per minute Chen's heart rate went up. **[2]**

(d) State whose heart rate recovered fastest, and how many minutes longer Ben's took. **[2]**

(e) Explain why all three heart rates stayed above resting for several minutes after the skipping ended. **[3]**

(f) Use ideas about respiration to explain why skipping made their hearts beat faster. **[3]**

(g) Later, Chen wore an ECG monitor while skipping. It showed one complete beat every 0.75 s. Calculate her heart rate. **[1]**

(a) Any one: the same way of counting (the same artery, the same person timing); count for the same time; rest for the same time before the first count **B1**.

(b) There are four lots of 15 seconds in a minute: $42 \times 4 = 168$ beats per minute **B1**.

(c) At rest $18 \times 4 = 72$; straight after $38 \times 4 = 152$ **M1**; an increase of $152 - 72 = 80$ beats per minute **A1**.

(d) Aroha's **B1**; Ben's took $9 - 4 = 5$ minutes longer **B1**.

(e) Some of their respiration while skipping was anaerobic, so lactic acid built up in the leg muscles and caused an oxygen debt **B1**. The heart keeps beating fast to carry the lactic acid to the liver, where it is broken down **B1**, and to go on supplying extra oxygen until the debt is repaid **B1**.

(f) Skipping makes the leg muscles contract more, and the energy for contraction is released by respiration, so the muscle cells respire faster **B1**. They need more oxygen and glucose and make more carbon dioxide **B1**. A faster heart rate makes blood flow through the muscles faster, bringing oxygen and glucose and taking carbon dioxide away more quickly **B1**.

(g) $60 \div 0.75 = 80$ beats per minute **B1**.

Example 4

Extended. A zoologist compares the circulation of a trout (a fish) with that of an otter (a mammal).

(a) Describe the route of the trout's blood from leaving its heart until it returns to its heart. **[2]**

(b) State how many times the blood passes through the heart in one complete circuit of each animal's body, and name the place in each animal where the blood carries the most oxygen. **[3]**

(c) Explain the advantages of the otter's double circulation. **[4]**

(d) An otter cub is born with a hole in the septum between its ventricles. Explain why the cub may be less active and grow more slowly than other cubs. **[3]**

(a) From the heart to the gills, where the blood picks up oxygen **B1**, then on to the body and back to the heart, so the route is heart → gills → body → heart **B1**.

(b) Trout once, otter twice **B1**. Trout: the vessel carrying blood from the gills to the body, just after the gills **B1**. Otter: the pulmonary vein (blood just back from the lungs) **B1**.

(c) Blood passes through the heart twice in each circuit, so after the lungs it is pumped again and reaches the body at high pressure **B1**. Oxygen and glucose are delivered to cells, and carbon dioxide removed, quickly, allowing a high rate of respiration **B1**. Blood goes to the lungs at a lower pressure, so the lung capillaries are not damaged and there is more time for gas exchange **B1**. Oxygenated and deoxygenated blood are kept apart **B1**.

(d) Blood passes through the hole, so oxygenated and deoxygenated blood mix **B1**. The blood pumped to the body carries less oxygen **B1**, so the cells carry out less aerobic respiration and release less energy for activity and growth **B1**.

Common mistakes

- **Mixing up left and right.** Diagrams show the heart facing you, so its left side is on the right of the page. Find the thick-walled left ventricle first.

- **Labelling the chamber when the wall is asked for** (or the other way round). Put the X or label line exactly on the part named.
- **Writing "vein" or "artery" when a named vessel is needed.** Vena cava, pulmonary artery, pulmonary vein, aorta, coronary artery.
- **Saying the heart is fed by the blood inside it**, or naming "an artery" for coronary heart disease. The coronary arteries are the vessels that are blocked.
- **Vague risk factors.** "Blood pressure", "drinking" or "food" earn nothing; "high blood pressure", "too much alcohol" and "a diet high in saturated fat" do. Symptoms and ways of preventing CHD are not risk factors.
- **Saying valves make a sound when they open.** The heart sounds are the valves closing.
- **Describing how to take a pulse instead of naming the method**, or writing "pulse" without "rate".
- **Explaining exercise only as "the body needs more energy (or oxygen)".** Link it to **muscle contraction** and **respiration**, and say respiration **releases** energy, never "produces" it.
- **Saying heart and breathing rates "increase" after exercise.** They **stay high** (then fall slowly) while the oxygen debt is repaid.
- **Getting the fish route wrong.** After the gills, fish blood goes straight to the body, not back to the heart.
- **Percentage change the wrong way.** Divide the change by the **original** value, not the new one, and show a fall with a minus sign or the word "decrease".
- **Explaining wall thickness without the chain.** Muscle → force → pressure → distance (whole body vs lungs). "The left ventricle is bigger" is not enough.

How to get the marks

- **"State" or "name":** a short, exact answer: "septum", "coronary arteries", "left ventricle". Don't give two answers; a wrong one can cancel a right one.
- **"Identify"** on a diagram: one letter, or a label line that ends exactly on the part. Extra letters lose the mark.
- **"Describe" the route:** name every chamber, valve and vessel in order, and stop where the question stops.
- **"Explain":** give the fact **and** the reason: "the left ventricle has a thicker wall **so that** it contracts with more force, making a higher pressure to reach the whole body". Mark schemes reward each linked step.
- **"Discuss"** diet and exercise: say what to change and how it helps, then the limits (genes, age and sex still count).
- **Risk factors:** exactly as many as asked, all different, none repeating the stem.
- **Calculations:** show the working, give the unit (beats per minute, %), round as asked, and show a decrease with a minus sign or in words. If you slip, the working can still earn a mark.
- **Graphs:** quote values with units and times, for example "rose from 70 to 150 beats per minute between minutes 5 and 9".
- **Use the exact terms:** atrium, ventricle, septum, atrioventricular valve, semilunar valve, vena cava, pulmonary artery, pulmonary vein, aorta, coronary artery, double circulation, backflow, oxygen debt, lactic acid.

Quick check

1. Name the two chambers of the heart that pump blood into arteries, and the artery each one pumps into.
2. A student counts 23 beats in 20 seconds at her wrist. Calculate her heart rate in beats per minute.
3. Using the heart rate graph in "Understand it", state by how many beats per minute the heart rate rose during exercise, and how long after the exercise stopped it took to return to resting.
4. **Extended:** A man's heart rate is 60 beats per minute sitting down and 81 beats per minute during a brisk walk. Calculate the percentage change.
5. **Extended:** A student wrote: "Fish have a double circulation because their blood passes through the gills and then the body. The valves between the atria and ventricles close when the atria contract." Correct both mistakes.

Answers

1. The **right ventricle**, into the pulmonary artery; the **left ventricle**, into the aorta.
2. There are three lots of 20 seconds in a minute: $23 \times 3 = 69$ beats per minute.
3. It rose from 70 to 150, so by 80 beats per minute. Exercise stopped at minute 11 and the rate was back to 70 at minute 21: 10 minutes.
4. $\frac{81 - 60}{60} \times 100 = 35\%$ (an increase).
5. Fish have a **single** circulation: their blood passes through the heart once per circuit (heart → gills → body → heart); a double circulation passes through the heart twice. The atrioventricular valves **open** when the atria contract (letting blood into the ventricles) and **close** when the ventricles contract.

Past questions to try

- **0610/43/M/J/23 Q3**: the septum, wall thickness, a red blood cell's route with valves, and a heart-rate percentage change (Extended).
- **0610/32/M/J/24 Q4**: the circulatory system, monitoring the heart, conclusions from a table, percentage change and diet (Core).
- **0610/41/M/J/22 Q2**: the thickest chamber, a semilunar valve, evidence for and advantages of a double circulation (Extended).
- **0610/32/O/N/23 Q3**: identify heart parts, then describe a bar chart of coronary heart disease by age and sex (Core).