Cambridge IGCSE · Biology 0610 · Notes

Blood vessels and blood

Read online at **pastopic.com/cambridge/biology-0610/notes/blood-vessels-and-blood**

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Read first: **Movement into and out of cells**

What you need to know

This topic turns up on nearly every paper. Most questions are one-mark multiple choice ("which component makes antibodies?", "which vessel takes blood away from the kidney?"), and the longer questions are built around a photomicrograph of blood, a block diagram of the circulation or a table comparing vessels. Outcomes marked **Extended only** are tested on Papers 2 and 4 only. By the end of this topic you should be able to:

Blood vessels

1. **Describe the structure of arteries, veins and capillaries**, limited to three things: how thick the wall is, how wide the lumen (the space inside) is, and the valves that veins have.
2. **State what capillaries do**: exchange substances between the blood and the body's cells.
3. **Identify the main blood vessels** in diagrams and pictures: to and from the **heart** (vena cava, aorta, pulmonary artery, pulmonary vein), to and from the **lungs** (pulmonary artery, pulmonary vein) and to and from the **kidney** (renal artery, renal vein).
4. **Extended only:** explain how the structure of arteries and veins suits the **pressure** of the blood inside them.
5. **Extended only:** explain how the structure of capillaries suits their **functions**.
6. **Extended only:** identify the vessels to and from the **liver**: the hepatic artery, the hepatic veins and the hepatic portal vein.

Blood

7. **List the four components of blood**: red blood cells, white blood cells, platelets and plasma.
8. **Identify red and white blood cells** in photomicrographs and diagrams.
9. **State the functions** of red blood cells (carrying oxygen, using haemoglobin), white blood cells (phagocytosis and making antibodies), platelets (clotting; no details needed) and plasma (carrying blood cells, ions, nutrients, urea, hormones and carbon dioxide).
10. **State the two roles of blood clotting**: it stops blood being lost and stops pathogens getting in.
11. **Extended only:** identify the two kinds of white blood cell, **lymphocytes** and **phagocytes**, in photomicrographs and diagrams.

12. **Extended only:** state that lymphocytes **make antibodies** and phagocytes **engulf pathogens** by phagocytosis.
13. **Extended only:** describe clotting as soluble **fibrinogen** being changed into insoluble **fibrin**, which forms a mesh.

The heart itself, the double circulation and coronary heart disease are in Circulatory systems and the heart. How antibodies and vaccines protect you is in Diseases and immunity; this topic only needs the jobs of the cells.

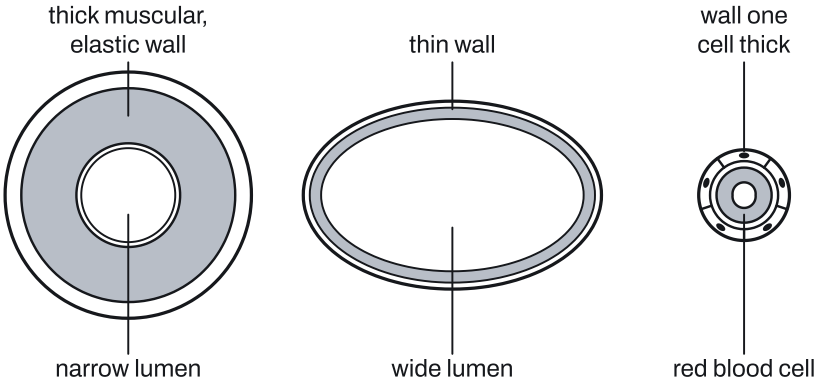
Understand it

Three kinds of blood vessel

Blood leaves the heart in **arteries**, which branch into smaller and smaller vessels until they become **capillaries**, tiny vessels that run between the cells of every tissue. Capillaries join up again into **veins**, which carry the blood back to the heart:

$$\text{heart} \rightarrow \text{artery} \rightarrow \text{capillaries} \rightarrow \text{vein} \rightarrow \text{heart}$$

"Artery" and "vein" describe the **direction** of flow, not the oxygen: **a**rteries carry blood **a**way from the heart, veins bring it back. The three vessels look different because they do different jobs.



not drawn to the same scale

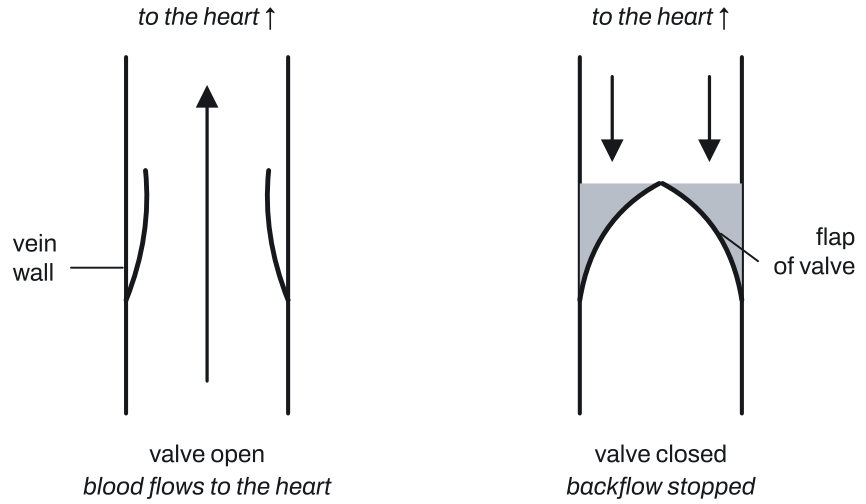
	Artery	Vein	Capillary
Carries blood	away from the heart	back to the heart	between arteries and veins, through the tissues
Wall	**thick**, with a lot of **muscle** and **elastic** tissue	**thin**, with little muscle and elastic tissue	**one cell thick**
Lumen	**narrow** (small compared with the wall)	**wide**	**very narrow**: red blood cells pass in single file

	Artery	Vein	Capillary
Valves	none	**yes**	none
Blood pressure	high, rising and falling with each heartbeat	low and steady	falling as blood passes through

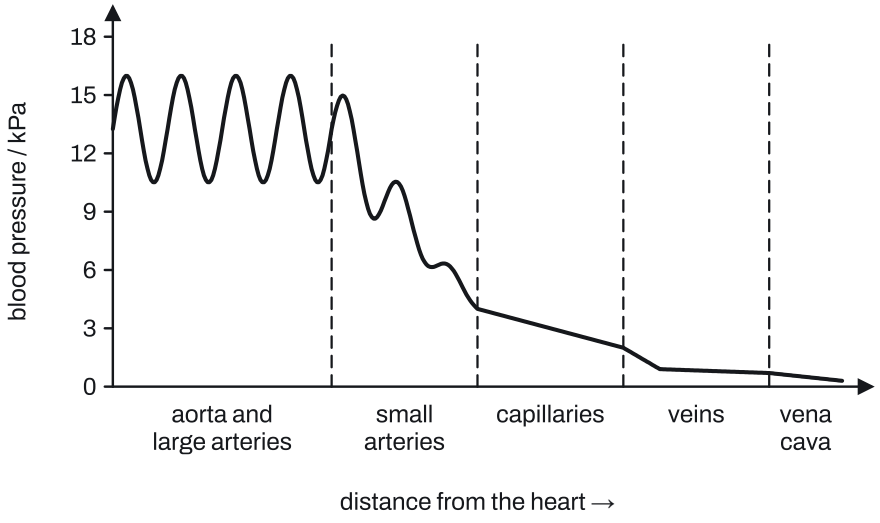
Only **veins** (and the heart) have valves. Arteries and capillaries do not.

Valves in veins

A valve is a pair of flaps, like pockets, attached to the inside of the vein wall and pointing towards the heart. When blood flows towards the heart it pushes the flaps flat against the wall and the valve **opens**. If blood starts to flow backwards, it fills the pockets, the flaps meet in the middle and the valve **closes**. So valves **prevent backflow** and make sure the blood only flows **one way, towards the heart**.



Extended: vessel structure and blood pressure



Each time the ventricles contract, blood is forced into the arteries at **high pressure**; when they relax, the pressure falls a little. So pressure in an artery rises and falls with every beat (that is the pulse you can feel). As the blood moves further from the heart, into narrower and narrower vessels and the huge network of capillaries, its pressure **falls**. By the time it reaches the veins it is **low and steady**.

Arteries (high pressure):

- The **thick wall** is strong enough to **withstand the high pressure** without bursting.
- The wall has a lot of **elastic tissue**. When a surge of blood arrives, the wall **stretches**; between beats it **recoils** (springs back), pushing the blood on. This evens out the flow and keeps the pressure up between beats. Elastic tissue stretches and recoils: it does not contract.
- The wall has a thick layer of **muscle**, which can contract to narrow the artery and change how much blood goes to an organ.
- The **narrow lumen** helps keep the pressure high.

Veins (low pressure):

- The pressure is low, so the wall does not need to be thick: a **thin wall** is enough.
- The **wide lumen** gives **less resistance** to flow, so blood at low pressure can still move, and a large volume of blood can be carried back.
- **Valves prevent backflow**, which would otherwise happen easily when the pressure is so low (for example, blood falling back down the legs).
- Many veins run between **skeletal muscles**. When the muscles contract they squeeze the thin-walled veins; the valves make sure the squeezed blood can only move towards the heart.

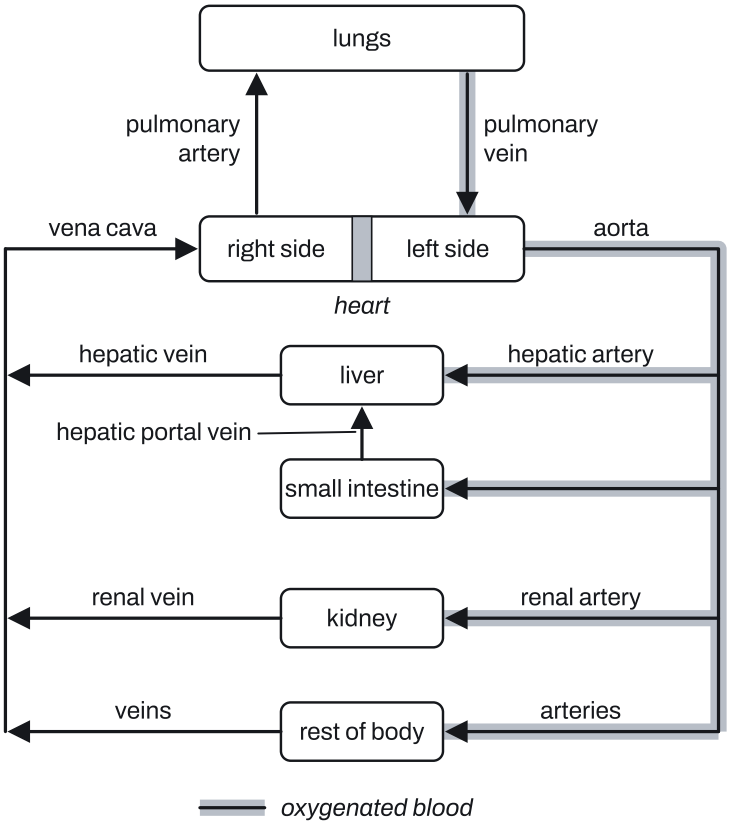
Capillaries and exchange

Capillaries are where the blood does its real work. Their function is to **exchange substances** between the blood and the cells: they **supply** the cells with **oxygen**, **glucose** and other nutrients, and **remove carbon dioxide**, **urea** and other wastes. Oxygen and glucose **diffuse** out of the capillaries into the cells, and carbon dioxide diffuses the other way, each **down its concentration gradient**. Diffusion is **passive**: it uses the kinetic energy of the moving particles, not energy from respiration.

Extended: how their structure suits this.

- The wall is **one cell thick**, so the **diffusion distance is short** and substances diffuse across quickly.
- The lumen is **very narrow**, so red blood cells squeeze through in single file, **close to the wall**, and the blood flows **slowly**, giving **more time** for diffusion.
- Capillaries **branch** into a huge network, so they have a **large surface area** and **every cell is close to a capillary**.
- There are small **gaps between the cells** of the wall, so some plasma and the small molecules in it can leak out to bathe the cells.

The main blood vessels



Name each vessel from **the organ** and **the direction**. "Pulmonary" means lungs, "renal" means kidney and "hepatic" means liver. Away from the heart or towards an organ it is an artery; back towards the heart or away from an organ it is a vein.

Vessel	Carries blood from	To	Oxygenated?
Vena cava	the body	the right atrium of the heart	no
Pulmonary artery	the right ventricle of the heart	the lungs	no
Pulmonary vein	the lungs	the left atrium of the heart	**yes** (the most oxygen of any vessel)
Aorta	the left ventricle of the heart	the body	yes
Renal artery	the aorta	the kidney	yes
Renal vein	the kidney	the vena cava	no
Extended: hepatic artery	the aorta	the liver	yes
Extended: hepatic portal vein	the small intestine (gut)	the liver	no, but rich in absorbed nutrients

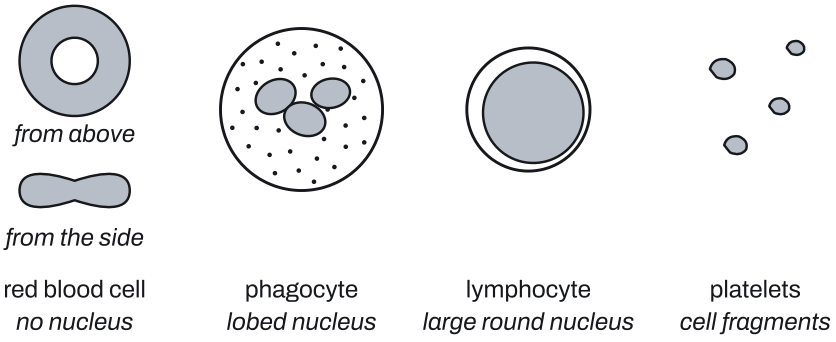
Vessel	Carries blood from	To	Oxygenated?
Extended: hepatic vein	the liver	the vena cava	no

Two things to watch:

- The **pulmonary artery** is the only artery with deoxygenated blood, and the **pulmonary vein** the only vein with oxygenated blood.
- **Extended:** the liver has **two** vessels bringing blood in: the hepatic artery (oxygen) and the hepatic portal vein (digested food from the gut). The hepatic portal vein runs from one organ to another, not to the heart; on a diagram it is the vessel between the intestine and the liver.

What blood is made of

If blood is left to stand in a tube with a chemical that stops it clotting, it separates. The pale yellow liquid on top is **plasma** (a bit over half the volume); under it is a thin pale layer of **white blood cells** and **platelets**; at the bottom are the **red blood cells**.



Component	What it looks like	What it does
Red blood cell	biconcave disc, **no nucleus**, by far the most common cell	**transports oxygen**, using **haemoglobin**
White blood cell	larger, **has a nucleus**, far fewer	defends against pathogens: **phagocytosis** and **antibody production**
Extended: phagocyte	larger; **lobed nucleus**; grainy cytoplasm	**engulfs** pathogens and digests them (**phagocytosis**)
Extended: lymphocyte	**large round nucleus** filling most of the cell; very little cytoplasm	**produces antibodies**
Platelets	tiny **fragments** of cells, no nucleus	**blood clotting**

Component	What it looks like	What it does
Plasma	the liquid part, mostly water	**transports** blood cells, ions, nutrients (such as glucose and amino acids), urea, hormones and carbon dioxide; also antibodies and heat

Red blood cells and haemoglobin. Red blood cells are packed with **haemoglobin**, a red protein that contains **iron**. In the lungs, where there is a lot of oxygen, haemoglobin **combines with oxygen**; in the tissues, where there is little, it **releases** the oxygen, which then diffuses into the cells for respiration. Having **no nucleus** leaves more room for haemoglobin, and the biconcave shape gives a large surface area for oxygen to diffuse in and out. The cells are flexible, so they can squeeze through capillaries.

White blood cells. There are two kinds, both defending the body against pathogens:

- **Phagocytes** move towards pathogens, **engulf** them (surround them and take them inside the cell) and digest them with enzymes. This is **phagocytosis**.
- **Lymphocytes produce antibodies**, proteins that stick to a particular pathogen and help destroy it.

Antibodies are made by **lymphocytes**, not phagocytes, not plasma and not platelets. **Antibiotics** are medicines, and white cells don't make them.

Plasma is mainly water with substances dissolved in it, so it carries everything that is not a cell, and it carries the cells themselves. Hormones such as adrenaline and oestrogen travel **dissolved in the plasma**, and so does most carbon dioxide and all the urea.

Blood clotting

When a blood vessel is cut, the blood **clots** to seal the wound. Clotting has two roles:

- it **prevents blood loss**;
- it **prevents pathogens entering** the body through the wound.

Platelets are what start clotting, so a person with very few platelets bleeds for much longer.

Extended: how a clot forms.

1. The damaged vessel wall exposes substances that **platelets** respond to; the platelets set off a chain of reactions.
2. **Fibrinogen**, a **soluble** protein always present in the plasma, is **converted** into **fibrin**, which is **insoluble** and forms long threads.
3. The fibrin threads form a **mesh** across the wound.
4. The mesh **traps red blood cells** (and platelets), making a clot; this dries into a scab, a **barrier** that pathogens cannot get through.

Remember the order: fibrin**ogen** comes first (the "-gen" means it is the starting material), fibrin is made from it.

Not in the current syllabus

A few older questions (2021–2023) asked about **arterioles**, **venules** and **shunt vessels** in the skin. Arterioles are narrow branches of arteries that widen or narrow to control blood flow; venules collect blood from capillaries into veins. These are not outcomes of this topic any more. Arterioles return in Homeostasis (temperature control), where you need them.

Key facts and formulas

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

Formula	Status
Arteries carry blood away from the heart; veins back to it; heart → artery → capillaries → vein → heart	Learn it
Artery: thick wall, narrow lumen, no valves. Vein: thin wall, wide lumen, valves. Capillary: wall one cell thick, very narrow lumen	Learn it
Valves in veins prevent backflow (one-way flow towards the heart)	Learn it
Capillaries exchange substances with cells: deliver oxygen and nutrients, remove carbon dioxide and wastes	Learn it
Vena cava, aorta, pulmonary artery, pulmonary vein, renal artery, renal vein: from, to, oxygenated or not	Learn it
Blood = red blood cells + white blood cells + platelets + plasma	Learn it
Red cells: oxygen, haemoglobin; white cells: phagocytosis and antibodies; platelets: clotting; plasma: transport	Learn it
Clotting prevents blood loss and the entry of pathogens	Learn it
Extended: thick elastic, muscular artery wall for high pressure; thin wall, wide lumen and valves in veins for low pressure	Learn it
Extended: capillary wall one cell thick (short diffusion distance), narrow lumen (slow flow), network (large surface area)	Learn it
Extended: hepatic artery (aorta → liver), hepatic portal vein (intestine → liver), hepatic vein (liver → vena cava)	Learn it
Extended: phagocytes engulf pathogens (lobed nucleus); lymphocytes make antibodies (large round nucleus)	Learn it
Extended: soluble fibrinogen → insoluble fibrin → mesh that traps red blood cells	Learn it

Formula	Status
Actual size $= \frac{\text{image size}}{\text{magnification}}$; $1\ \text{mm} = 1000\ \mu\text{m}$; percentage change $= \frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it

How to do it

We tagged 88 questions for this topic (2021–2025, Papers 1–4; 75 different, since some multiple-choice questions appear on more than one paper). 32 of them mix types, so the counts add up to 142.

Question type	Questions
State or match the function of a blood component	36
Name the main blood vessels (heart, lungs, kidneys, liver)	26
Compare the structure of arteries, veins and capillaries	18
Identify a blood cell from a photomicrograph or drawing	17
Blood clotting: what it does and how	11
Valves in veins: name and function	7
Haemoglobin: name it and state its role	6
State the function of capillaries	5
Name substances transported in plasma	4
Identify the vessel with oxygenated blood	4
Explain how vessel structure suits the blood pressure (Extended)	3
Put vessel types in the order blood flows through them	3
Arterioles, venules and shunt vessels (older syllabus)	2

Most are one-mark multiple choice on Papers 1 and 2. On Papers 3 and 4 they are parts of a longer question, often shared with the heart, immunity or diffusion.

1. State or match the function of a blood component (36 questions)

1. **Learn the four pairs**: red blood cells → **transport oxygen**; white blood cells → **phagocytosis** and **antibody production**; platelets → **clotting**; plasma → **transport** (of the cells and of dissolved substances).
2. **Extended**: split white cells: **lymphocytes** → **antibodies**, **phagocytes** → **phagocytosis** (engulfing pathogens).
3. **Use the precise words**. "Fights disease" or "protects the body" doesn't score; "engulfs pathogens" or "produces antibodies" does.

Variations you will meet:

- **"Which component transports hormones?"** Plasma (not red blood cells). Hormones, urea, glucose and most carbon dioxide are **dissolved in plasma**.
- **"Which component transports the blood cells?"** Plasma.
- **Distractors**: "produces antibiotics" (never), "transports glucose" for red cells (that is plasma), "platelets carry out phagocytosis" (no, they clot), "phagocytes produce antibodies" (no, lymphocytes do).
- **Draw lines to match** components to functions: draw exactly the number of lines asked; an extra line from one box loses the mark. White blood cells may need two lines (phagocytosis and antibodies).
- **"Describe the function of plasma"** (2 marks): **transport (1)** plus one named substance **(1)**, such as urea or a named hormone.
- **"List the components of blood"**: red blood cells, white blood cells, platelets, plasma.

2. Name the main blood vessels (26 questions)

1. **Find the organ**: lungs = **pulmonary**, kidney = **renal**, liver = **hepatic**; heart to body = **aorta**; body to heart = **vena cava**.
2. **Find the direction** from the arrows: towards the organ (away from the heart) = **artery**; away from the organ (back to the heart) = **vein**.
3. **Write the full name**. "Vein" alone is not accepted for the vena cava, and "artery" alone is not accepted for the aorta.

Variations you will meet:

- **Multiple choice with a diagram** of lungs, heart, kidney (and sometimes liver and gut) with numbered vessels: find the one labelled correctly. Check each label against the arrow direction.
- **"Which vessel carries blood away from the kidney?"** Renal vein. **"From the lungs to the heart?"** Pulmonary vein. **"From the heart to the body?"** Aorta.
- **A table of four jobs** (to the right atrium from the body; from the right ventricle to the lungs; from the lungs to the left atrium; from the left ventricle to the body): vena cava, pulmonary artery, pulmonary vein, aorta.
- **Organs on a block diagram**: the organ at the top linked by pulmonary vessels is the **lungs**; the pump in the middle is the **heart**; the organ with renal vessels is the **kidney**.
- **Draw arrows** on the pulmonary vessels: pulmonary artery from the heart to the lungs, pulmonary vein from the lungs to the heart.
- **"State the letters of all the arteries"**: give every vessel carrying blood away from the heart (aorta, pulmonary artery, renal and hepatic arteries), and nothing else.
- **Extended: the liver**: the vessel from the intestine to the liver is the **hepatic portal vein**; from the aorta to the liver the **hepatic artery**; from the liver to the vena cava the **hepatic vein**.
- **"Name the artery that brings blood to the lung / kidney / liver"**: pulmonary artery, renal artery, hepatic artery.

3. Compare the structure of arteries, veins and capillaries (18 questions)

1. Compare the **wall**, the **lumen** and **valves**, one mark each. Always write a **comparison** ("the vein has a **thinner** wall") or say which vessel you mean.
2. From a cross-section: thick wall and small round lumen = **artery**; thin wall and large, often squashed lumen = **vein**; wall one cell thick with red cells in single file = **capillary**.

Variations you will meet:

- **"Describe three ways a vein differs from an artery"**: thinner wall; wider lumen; has valves. (Less muscle and elastic tissue is also accepted.)
- **"State two structural features of arteries"**: thick wall; narrow lumen; muscle in the wall; elastic tissue in the wall.
- **Circle words in a table** (thick / thin, wide / narrow): artery thick and narrow; vein thin and wide.
- **Identify a vessel from a row of features**: "thin wall, large lumen, valves present" = vein; "very thin wall, very narrow lumen" = capillary; "thick wall, narrow lumen" = artery.
- **"Which vessel carries blood at low pressure?"**: the one with a thin wall, a large lumen and valves: a vein.
- **Evidence a vessel is a vein** on a diagram: it has a **valve**.
- **Lumen from measurements**: lumen diameter = total width – 2 × wall thickness (the wall is on both sides), as in Example 1.
- **Label the wall and the lumen** on a photomicrograph of an artery: the label line for the wall ends **in the tissue**; the label line for the lumen ends **in the empty space in the middle**.

4. Identify a blood cell from a photomicrograph or drawing (17 questions)

1. **No nucleus**, round with a pale centre, and by far the most numerous: **red blood cell**.
2. **Has a nucleus** (stains dark): **white blood cell**.
3. **Extended**: **lobed** nucleus (several lumps) and grainy cytoplasm: **phagocyte**. **One large round nucleus** filling nearly the whole cell: **lymphocyte**.
4. Tiny specks between the cells: **platelets**.

Variations you will meet:

- **Name and function together** (multiple choice rows "lymphocyte / produces antibodies"): identify the cell first from the nucleus, then pick its function. A phagocyte **engulfs pathogens**; a lymphocyte **produces antibodies**.
- **Complete a table** with letters from a photomicrograph: red cell (letter) transport of oxygen; lymphocyte (letter) antibodies; phagocyte (letter) phagocytosis; platelet (letter) clotting; and plasma is the liquid **between** the cells.
- **Structures inside a white cell** (cell membrane, nucleus, mitochondria, cytoplasm): these come from Organisation of the organism; a red cell has no nucleus, a white cell does.
- **A cell inside a vessel** on a photomicrograph of a small artery: it is a **red blood cell**.

- **Sizes from a photomicrograph** (magnification is given): actual size $= \frac{\text{image size}}{\text{magnification}}$. Measure the image in mm, convert to µm by multiplying by 1000, then divide by the magnification. A red blood cell is about 7–8 µm across, so an answer far from that means a slip. To convert a size in mm to µm on its own, multiply by 1000 (0.025 mm = 25 µm).

5. Blood clotting: what it does and how (11 questions)

1. **Core**: platelets are responsible for clotting; clotting **prevents blood loss** and **prevents the entry of pathogens**.
2. **Extended**: describe the process in order: **platelets** involved → soluble **fibrinogen** → insoluble **fibrin** → **mesh** → **traps red blood cells** → clot (scab), a barrier to pathogens.

Variations you will meet:

- **"Which process is slower in someone with very few platelets?"** Blood clotting.
- **A sequence with letters** (damage stimulates L; M is converted to N): L platelets, M fibrinogen, N fibrin.
- **"Outline how a clot forms and prevents infection"** (3 marks): up to two for the process (fibrinogen to fibrin; a mesh; platelets) and one for the clot being a **barrier** to pathogens.
- **"Describe the process"** (4 marks): platelets; fibrinogen converted to fibrin; soluble to insoluble; a mesh; traps blood cells. Give them in that order and name each substance.

6. Valves in veins: name and function (7 questions)

1. **Name**: valves.
2. **Function**: **prevent the backflow** of blood / make sure blood flows **one way** (towards the heart).

Variations you will meet:

- **"State the name and function of the structure present in X but absent in Y and Z"** when X is the vein: valve; prevents backflow.
- **A diagram of a vein with a valve labelled X** (multiple choice): its function is to make sure blood flows towards the heart.
- **"Which vessels have valves?"** Veins (and the heart), never arteries or capillaries.

7. Haemoglobin: name it and state its role (6 questions)

1. **Name**: haemoglobin, in red blood cells.
2. **Role**: it **combines with (binds to) oxygen** and so **transports** it; it releases the oxygen in the tissues.

Variations you will meet:

- **"State the name of the molecule oxygen binds to"**: haemoglobin, not "red blood cells" (those are cells) and not "iron" on its own.
- **"Which cell contains haemoglobin?"**: the red blood cell (no nucleus, biconcave).

- **Older papers only**: a 2022 question asked how sickle-shaped red cells affect blood flow. Sickle cell anaemia is not in the current syllabus, so a question would give you what you need.

8. State the function of capillaries (5 questions)

1. **Function**: **exchange** of substances between the blood and the cells: **supply** oxygen and nutrients to cells, **remove** carbon dioxide and other wastes.
2. **Extended: how oxygen gets from a capillary to a cell**: by **diffusion**, **down a concentration gradient**, across the **thin capillary wall**; it is **passive** (uses the particles' kinetic energy).

Variations you will meet:

- **"Which structures provide cells with oxygen and nutrients?"** Capillaries (not arteries, veins or lungs).
- **"State the name of the vessels that transfer substances to and from cells"**: capillaries.
- **Extended: "Explain how the structure of a capillary is related to its function"** (3 marks): wall one cell thick → short diffusion distance; narrow lumen → slow flow, more time; network → large surface area; plus the function itself (delivers oxygen, removes carbon dioxide).

9. Name substances transported in plasma (4 questions)

Name any of: **ions** (mineral ions such as sodium), **nutrients** (glucose, amino acids), **urea**, **hormones**, **carbon dioxide**, **water**; also antibodies and heat.

Variations you will meet:

- **"State two substances, other than blood cells, transported in plasma"**: any two from the list; name the substance, not "food".
- **"Circle two waste substances transferred from cells to the blood"**: carbon dioxide and urea (not glucose, amino acids, fatty acids or oxygen).

10. Identify the vessel with oxygenated blood (4 questions)

1. Blood becomes oxygenated in the **lungs**, so everything from the lungs to the body's capillaries is oxygenated: **pulmonary vein**, left side of the heart, **aorta**, and the arteries to the organs (renal artery, hepatic artery).
2. Everything from the body's capillaries back to the lungs is deoxygenated: veins of the body, **vena cava**, right side of the heart, **pulmonary artery**; also the **hepatic portal vein**.
3. **Highest concentration of oxygen**: the **pulmonary vein**, as the blood has just left the lungs.

Variations you will meet:

- **A table** "does this vessel carry oxygenated blood?": pulmonary artery no; aorta yes; hepatic portal vein no; renal vein no.
- **Shade the vessel** with the most oxygen: shade the pulmonary vein only.

11. Explain how vessel structure suits the blood pressure (3 questions, Extended)

1. **Arteries** (high pressure): **thick** wall to **withstand** the high pressure; **elastic** tissue that **stretches and recoils** to even out the flow and keep the pressure up; **muscle** to change the flow; **narrow lumen** keeps the pressure high.
2. **Veins** (low pressure): **thin** wall (no high pressure to withstand); **wide lumen**, less resistance, a large volume of blood; **valves** prevent backflow at low pressure; surrounding muscles squeeze the blood along.

Variations you will meet:

- **A graph of pressure along the vessels**: pressure in arteries rises and falls because the ventricles **contract** (pressure up) and **relax** (pressure down); it falls overall as blood gets further from the heart. Link each structure to a part of the graph.
- **"Explain the structural adaptations of arteries and veins"** (4 marks): give two or three linked points for each, each one "**feature** → **so that** ...".

12. Put vessel types in the order blood flows through them (3 questions)

1. **Identify** each cross-section (artery, vein, capillary) from the wall and the lumen.
2. On any journey between two points in the heart, blood goes **artery** → **capillaries** → **vein**. For example, from the right ventricle to the left atrium: pulmonary artery → capillaries in the lungs → pulmonary vein.

Variations you will meet:

- **"Which diagram shows the vessel red cells pass through in single file?"** The capillary.
- If the start is a vein (such as the vena cava) the order begins with the vein: vein → heart → artery → capillaries.

13. Arterioles, venules and shunt vessels (older syllabus, 2 questions)

These came from the 2020–2022 syllabus and are not outcomes of this topic now. If a question uses them, the question will say what they are. The one you still need is in Homeostasis: **arterioles** supplying the skin surface capillaries **widen (vasodilation)** or **narrow (vasoconstriction)** to control heat loss.

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. The table shows measurements from cross-sections of three blood vessels, P, Q and R, taken from the same person. The wall thickness is the thickness on one side.

Vessel	Total width / mm	Wall thickness / mm
P	4.0	1.0
Q	5.0	0.5
R	0.010	0.001

(a) Calculate the diameter of the lumen of each vessel, in mm. **[2]**

(b) Convert the diameter of the lumen of R into micrometres (μm). **[1]**

(c) Identify vessels P, Q and R. Give one reason for each. **[3]**

(d) Vessel Q came from the leg. Suggest what would happen to the blood in it if one of its valves stopped closing properly. **[2]**

(e) State the function of vessel R. **[1]**

(a) Lumen = total width – 2 × wall thickness **M1**. P: $4.0 - 2 \times 1.0 = 2.0$ mm; Q: $5.0 - 2 \times 0.5 = 4.0$ mm; R: $0.010 - 2 \times 0.001 = 0.008$ mm **A1**.

(b) $0.008 \times 1000 = 8\ \mu\text{m}$ **B1** (only just wide enough for a red blood cell).

(c) P is an artery: its wall is thick compared with its narrow lumen **B1**. Q is a vein: its wall is thin compared with its wide lumen **B1**. R is a capillary: its wall is one cell thick and it is far narrower than the others **B1**.

(d) The blood is at low pressure, so it would flow backwards, down the leg, through the faulty valve **B1**; blood would collect (pool) in the vein and less would return to the heart **B1**.

(e) Exchange of substances with the cells: it supplies oxygen and glucose to cells and removes carbon dioxide **B1**.

Example 2

Core, with an Extended part. A laboratory counted the cells in 1 mm^3 of a patient's blood.

Component	Number in 1 mm^3
red blood cells	5 000 000
platelets	250 000
white blood cells	8 000
of the white cells: lymphocytes	2 400

(a) Calculate how many red blood cells there are for every white blood cell. **[1]**

(b) Two more cells were seen through the microscope. Cell S had no nucleus and a pale centre. Cell T had a single large round nucleus that almost filled it. Name each cell and state its function. **[4]**

(c) State the name of the substance in cell S that combines with oxygen. **[1]**

(d) State the name of the component of blood that carries the hormone insulin, and name two other substances it carries. **[2]**

(e) **Extended:** calculate the percentage of the white blood cells that are lymphocytes. Name the other kind of white blood cell and describe what it does. **[3]**

(a) $\frac{5\,000\,000}{8\,000} = 625$ red blood cells for each white blood cell **B1**.

(b) S is a red blood cell **B1**; it transports oxygen **B1**. T is a lymphocyte (a white blood cell) **B1**; it produces antibodies **B1**.

(c) Haemoglobin **B1**.

(d) Plasma **B1**; any two of: urea, carbon dioxide, glucose, amino acids, mineral ions, water **B1**.

(e) $\frac{2\,400}{8\,000} \times 100 = 30\%$ **B1**. Phagocyte **B1**; it engulfs pathogens and digests them (phagocytosis) **B1**.

Example 3

Extended. A nurse injects a medicine into a vein in a patient's arm. The medicine is needed in the kidneys. Some of it is broken down in the liver.

(a) Name, in order, the blood vessels and chambers of the heart the medicine passes through between the vein in the arm and the capillaries of the kidney. **[4]**

(b) Name the blood vessel that carries the medicine into the liver from the aorta, and the vessel that carries blood from the liver back towards the heart. **[2]**

(c) After a meal, glucose absorbed from the small intestine reaches the liver before it reaches any other organ. Name the vessel it travels in, and state one way the blood in this vessel differs from the blood in the vessel you named first in (b). **[2]**

(d) Of the renal artery, renal vein, pulmonary artery and pulmonary vein, state which carries blood with the most oxygen. Explain your answer. **[2]**

(a) Vena cava → right atrium → right ventricle **B1** → pulmonary artery → lungs → pulmonary vein **B1** → left atrium → left ventricle **B1** → aorta → renal artery **B1**.

(b) Hepatic artery **B1**; hepatic vein **B1**.

(c) Hepatic portal vein **B1**; it carries deoxygenated blood (the hepatic artery's blood is oxygenated), but more glucose and other absorbed nutrients **B1**.

(d) Pulmonary vein **B1**; its blood has just come from the lungs, where it picked up oxygen, and has not yet passed through any respiring tissue **B1**.

Example 4

Extended. A student read the average blood pressure in different vessels of an adult at rest from a textbook graph.

Vessel	Large arteries	Capillaries	Veins
Average pressure / kPa	12.0	3.0	0.8

(a) Calculate the percentage decrease in pressure between the large arteries and the capillaries. **[2]**

(b) Explain how the wall of an artery is suited to the pressure of the blood in it. **[3]**

(c) At 0.8 kPa, blood returning from the feet has to travel upwards. Explain how the structure of the veins, and the muscles around them, help to return this blood to the heart. **[3]**

(d) Explain how the structure of capillaries helps oxygen to reach the muscle cells. **[3]**

(e) A cyclist grazes her knee. Describe how a clot forms and state why it matters. **[4]**

(a) $\frac{3.0 - 12.0}{12.0} \times 100$ **M1** $= -75\%$, a decrease of 75% **A1**.

(b) The wall is thick so it can withstand the high pressure **B1**. It contains elastic tissue that stretches as each surge of blood arrives and recoils between beats, keeping the pressure up and the flow even **B1**. The narrow lumen helps to maintain the high pressure **B1**.

(c) Veins have valves that close if blood starts to flow backwards, so it can only move towards the heart **B1**. The wide lumen gives little resistance, so blood at low pressure can still flow **B1**. The thin walls are squeezed when the leg muscles contract, pushing blood up through the valves **B1**.

(d) The capillary wall is only one cell thick, so the diffusion distance is short **B1**. The narrow lumen slows the blood and keeps red cells close to the wall, giving more time for oxygen to diffuse out **B1**. Capillaries form a large branching network, so there is a large surface area and every cell is near a capillary **B1**.

(e) Platelets respond to the damage **B1**; soluble fibrinogen is converted to insoluble fibrin **B1**, which forms a mesh that traps red blood cells to make a clot **B1**. The clot stops more blood being lost and stops pathogens entering through the wound **B1**.

Common mistakes

- **Leaving out valves** when asked how veins differ from arteries. Examiners report that few candidates mention them, and they are usually one of the three marks.
- **Putting valves in arteries or capillaries.** Only veins (and the heart) have them.

- **Answering "vein" or "artery" when a named vessel is asked for.** Write vena cava, aorta, renal vein and so on in full.
- **Mixing up the hepatic portal vein** with the other vessels near the gut. It is the one running from the small intestine **to the liver**.
- **Vague words for white blood cells.** "Fight bacteria", "defend the body" or "help immunity" earn nothing. Write "engulf pathogens (phagocytosis)" or "produce antibodies".
- **Saying phagocytes make antibodies.** Only lymphocytes do. Keep antibodies, antigens and antibiotics apart: antibodies are proteins made by lymphocytes; antibiotics are medicines.
- **Saying red blood cells carry hormones or glucose.** Hormones, glucose, urea and most carbon dioxide are carried dissolved in the **plasma**.
- **Swapping fibrinogen and fibrin.** Fibrinogen (soluble) is changed into fibrin (insoluble), never the other way round.
- **Saying elastic tissue in arteries "contracts and relaxes".** It **stretches and recoils**; it is muscle that contracts.
- **Explaining lumen sizes vaguely.** Say what the size does: a narrow lumen in an artery **maintains high pressure**; a wide lumen in a vein gives **less resistance** to blood at low pressure.
- **Stopping at "oxygen diffuses out of the capillary".** For extra marks, add "down a concentration gradient", "across a wall one cell thick" and "a passive process".
- **Writing "red blood cells" when asked for the molecule** that carries oxygen. The molecule is haemoglobin.

How to get the marks

- **"State"** or **"name"**: one word or a short phrase: "plasma", "renal vein", "valves", "haemoglobin". Don't give two answers; a wrong one cancels a right one.
- **"Describe" differences between vessels**: write comparisons, one feature per mark: wall, lumen, valves. "Thinner wall" is a comparison; "thin wall" is fine if you have said which vessel.
- **"Identify"** on a photomicrograph or diagram: a letter, or a label line that ends exactly on the structure (in the wall, or in the lumen space).
- **"Explain"** a structure: give the feature **and** what it does: "thick wall **to withstand** high pressure", "one cell thick **so** a short diffusion distance". A feature on its own is description, not explanation.
- **"Outline"** or **"describe"** clotting: name each substance and put them in order (platelets, fibrinogen, fibrin, mesh, trapped cells), then the role.
- **Draw lines**, **tick** or **circle**: exactly as many as asked. Each extra one loses a mark.
- **Calculations**: show the working, give units (mm, μm, kPa, %), and give a decrease as a negative number or say "decrease". To convert mm to μm multiply by 1000.
- **Use the exact terms**: lumen, valve, backflow, capillary, vena cava, aorta, pulmonary, renal, hepatic portal vein, haemoglobin, phagocytosis, lymphocyte, antibody, platelet, fibrinogen, fibrin, plasma.

Quick check

1. A student wrote: "Arteries have valves to stop blood flowing backwards, and veins have thick walls to cope with high pressure." Correct both mistakes.
2. For each vessel, say where its blood comes from and where it goes: (a) renal vein; (b) vena cava; (c) **Extended:** hepatic portal vein.
3. In a photograph taken at a magnification of ×2500, a red blood cell measures 19 mm across. Calculate its actual diameter in micrometres.
4. Before an operation, a surgeon checks that the patient's blood clots normally. State two risks to the patient, during or after the operation, if it did not.
5. **Extended:** Put these in the order they take part in clotting, and say which of the two proteins is soluble: fibrin, damage to a vessel, fibrinogen, platelets, trapped red blood cells.

Answers

1. **Veins** (not arteries) have valves, which stop blood flowing backwards. **Arteries** (not veins) have thick walls, to withstand the high pressure; veins have thin walls.
2. (a) From the kidney to the vena cava. (b) From the body (all its veins) to the right atrium of the heart. (c) From the small intestine to the liver.
3. $19\ \text{mm} = 19 \times 1000 = 19\,000\ \mu\text{m}$; actual diameter $= \dfrac{19\,000}{2500} = 7.6\ \mu\text{m}$.
4. They could lose a lot of blood, because cut vessels would not seal; pathogens could enter the body through the open wound.
5. Damage to a vessel → platelets → fibrinogen → fibrin → trapped red blood cells. Fibrinogen is soluble; fibrin is insoluble.

Past questions to try

- **0610/31/M/J/25 Q6**: identify vessels from a table of features, valves, and name organs and vessels on a circulation diagram (Core).
- **0610/42/M/J/25 Q2**: components of blood from a photomicrograph and their functions (Extended).
- **0610/42/F/M/23 Q1**: vessels on a circulation diagram, the hepatic portal vein and a blood pressure graph (Extended).
- **0610/41/M/J/24 Q1**: arteries and veins and the pressure they carry, and the arteries to named organs (Extended).