Grade 12 Biology Model Paper 1

ANSWER KEY

Full marks 75 · 3 hours

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

A practice paper by Science Playground, made to CDC's Specification Grid 2078, Grade 12 Biology (Bio. 202); not an official CDC or NEB paper.

Botany, Group A Multiple choice (Botany) 5 marks

Question 1 5 × 1 = 5

a. **(ii)** The vascular bundles of maize are closed: they have no cambium between the xylem and the phloem.

b. **(iii)** guttation

c. **(iv)** 36

d. **(ii)** Auxin coming down from the shoot tip keeps the lateral buds from growing.

e. **(ii)** 7 cells and 8 nuclei

Botany, Group B Short answers (Botany), each on one content area 16 marks

Question 2 4 marks

a. The **Casparian strip** is a band of **suberin** (with lignin) round the **radial and transverse walls** of the cells of the **endodermis**, through which water cannot pass, so water and minerals must go through the cells' living membranes to enter the stele. **[1]**

Marking scheme

- A band of suberin (and lignin) on the radial and transverse walls of the endodermal cells that water cannot pass through.

b. They are **passage cells**. The other endodermal cells have grown such thick walls that water can hardly pass them, so the thin-walled cells let **water and minerals pass from the cortex into the stele**; they lie opposite the **protoxylem** so that the water goes straight on into the xylem. **[1]**

Marking scheme

- Passage cells: they let water and minerals pass from the cortex through the endodermis into the xylem (protoxylem) just inside them.

c.

- **P is a dicot root.** It has radial bundles (so it is a root) with only four xylem strands (**tetrarch**, within the dicot range of two to six), angular vessels and almost no pith. **[2]**
- **Q is a monocot root.** It has radial bundles with many xylem strands (**polyarch**, more than six) round a **large pith**, and thick-walled endodermal cells with passage cells.

Marking scheme

- P, dicot root: two to six xylem strands (tetrarch) / small or no pith.
- Q, monocot root: many xylem strands (polyarch) / large pith.

Question 3 4 marks

a. **Double fertilization** is the fusion of the two male gametes from one pollen tube with two different cells of the embryo sac: **[2]**

1. **Syngamy:** one male gamete (n) fuses with the **egg** (n), forming the **zygote** (2n), which grows into the embryo.
2. **Triple fusion:** the other male gamete (n) fuses with the **two polar nuclei** (or the secondary nucleus, 2n) of the central cell, forming the **primary endosperm nucleus** (3n), which grows into the endosperm.

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Marking scheme

- Syngamy: one male gamete + egg → zygote (2n).
- Triple fusion: the other male gamete + the two polar nuclei (secondary nucleus) → primary endosperm nucleus (3n).

b. **She is not right.** The endosperm comes from **triple fusion** (one male gamete + two polar nuclei), so it is **triploid**: 3n = 30, and n = 10. **[2]**

The leaf is part of the sporophyte, which grows from the zygote (male gamete + egg): it is **diploid**, 2n = **20**. The egg is a cell of the female gametophyte: haploid, n = **10**.

Marking scheme

- Not right: the endosperm is triploid (3n = 30, so n = 10).
- Leaf cell 2n = 20; egg cell n = 10.

Question 4 — 4 marks

a. In peas the allele for tallness is **completely dominant**, so the heterozygote (Tt) looks like the tall parent. In the four o'clock plant **neither allele is dominant** (**incomplete dominance**): a plant with one R allele makes less red pigment than one with two, so the heterozygote Rr shows a color **in between**, pink. **[1]**

Marking scheme

- Tall is completely dominant in peas, but in the four o'clock plant neither allele is dominant (incomplete dominance), so the heterozygote Rr is in between, pink.

b. Parents: pink **Rr** × white **rr**. Gametes: R and r from the pink plant; r only from the white one. **[2]**

	R	**r**
r	Rr, pink	rr, white
r	Rr, pink	rr, white

Offspring: **Rr pink and rr white, in the ratio 1 : 1** (50% pink, 50% white). The genotypic and phenotypic ratios are the same.

Marking scheme

- Parents Rr × rr, gametes R, r and r, and the checkerboard.
- Offspring 1 pink (Rr) : 1 white (rr).

c. If the alleles had blended, pink plants would give only pink offspring. But **pink × pink gives red, pink and white offspring (1 : 2 : 1)**, and pink × white gives pure **white** plants again (Sujan's cross): the R and r alleles come out of the pink plant **unchanged**. Only the phenotype is in between; the alleles stay pure. **[1]**

Marking scheme

- Pure red or white plants reappear among the offspring of pink plants (pink × pink gives 1 red : 2 pink : 1 white; pink × white gives white), so the alleles have not blended.

OR

a. Its chromosomes come from two different species, so they are **not homologous**: in meiosis they have no partners to **pair** with, the gametes get uneven sets of chromosomes, and they do not work. So the hybrid sets no seed. **[1]**

Marking scheme

- The wheat and rye chromosomes are not homologous, so they cannot pair in meiosis and the gametes get uneven, useless sets.

b. **[2]**

- Gametes: durum wheat 28 ÷ 2 = **14**; rye 14 ÷ 2 = **7**.
- Hybrid (one gamete from each): 14 + 7 = **21**.
- Triticale (doubled): 21 × 2 = **42**.

Marking scheme

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- Gametes: wheat 14, rye 7.
- Hybrid 21; triticale 42.

c. It is an **allopolyploid**: its chromosome sets come from two different species. Its doubled chromosomes all have partners, so it is **fertile** and breeds true with other triticale, but it is cut off from both parents (a cross back to either gives sterile offspring), so it forms a **new species** in a single generation. **[1]**

Marking scheme

- Allopolyploid (sets from two species), and a new species because it breeds true with its own kind but not with either parent.

Question 5 — 4 marks

a. **Totipotency** is the ability of a living plant cell to grow into a complete new plant, given the right conditions. **[1]**

Marking scheme

- The ability of a single living plant cell to grow into a whole new plant.

b. Move the shoots to a medium with a **higher ratio of auxin to cytokinin**: more auxin gives roots (more cytokinin, the medium used so far, gives shoots). **[1]**

Marking scheme

- A medium with a higher auxin to cytokinin ratio (more auxin).

c. In the jars the plantlets lived in almost **100% humidity**, fed on sugar: their leaves have only a **thin waxy layer**, and their **stomata don't close well**. In the dry open air they lost water far faster than their small roots could replace it, and wilted. **[2]**

Kept in a humid greenhouse first, they were **hardened (acclimatized)**: moved gradually to drier, more natural conditions, so that their leaves built up wax, their stomata began to work and their roots grew, before they faced the field.

Marking scheme

- From the jars, the plantlets have a thin waxy layer and poorly closing stomata (grown at near 100% humidity), so they lose water fast in the open and wilt.
- The greenhouse hardens (acclimatizes) them gradually to drier conditions before planting out.

Botany, Group C Long answers (Botany), each on one content area — 16 marks

Question 6 — 8 marks

a. In the **cytoplasm** (cytosol) of the cell. **[1]**

Marking scheme

- In the cytoplasm.

b. The **Krebs cycle** (citric acid or TCA cycle) takes place in the **mitochondrial matrix**. **[3]**

1. **Acetyl CoA** (2 C), from the link reaction, joins **oxaloacetic acid** (4 C) to form **citric acid** (6 C), the first stable product.
2. Citric acid is changed step by step (isocitric acid, α-ketoglutaric acid, succinyl CoA, succinic, fumaric and malic acids): **two carbons leave as CO_2**, and hydrogen is passed to NAD and FAD. **Oxaloacetic acid** is formed again at the end, ready to take in the next acetyl group, so it is a cycle.
3. Each turn gives **2 CO_2, 3 $NADH_2$, 1 $FADH_2$ and 1 GTP (ATP)**; one glucose makes two turns.

Marking scheme

- Acetyl CoA + oxaloacetic acid → citric acid (the first stable product), in the mitochondrial matrix.
- Citric acid is oxidized step by step, giving off two CO_2, and oxaloacetic acid is regenerated.
- Per turn: 3 $NADH_2$, 1 $FADH_2$, 1 GTP (ATP) and 2 CO_2.

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c. One glucose gives two acetyl CoA, so **two turns** of the cycle: 6 $NADH_2$, 2 $FADH_2$ and 2 GTP (ATP). **[2]**

- 6 $NADH_2 \times 3 = 18$ ATP
- 2 $FADH_2 \times 2 = 4$ ATP
- directly: 2 ATP

Total: $18 + 4 + 2 =$ **24 ATP**.

Marking scheme

- Two turns per glucose: 6 $NADH_2$, 2 $FADH_2$ and 2 ATP.
- $18 + 4 + 2 = 24$ ATP.

d. Oxygen is the **final acceptor of electrons** at the end of the electron transport chain. Without it the chain backs up: $NADH_2$ and $FADH_2$ cannot pass on their hydrogen, so **NAD and FAD are not set free again**. **[2]**

The Krebs cycle needs NAD and FAD at each of its oxidation steps; with none free, it **stops**. Only glycolysis goes on, its NAD returned by **fermentation** (pyruvic acid to ethanol and CO_2), which gives just the 2 ATP of glycolysis.

Marking scheme

- Without oxygen, the final electron acceptor, the electron transport chain stops and NAD and FAD are not regenerated from $NADH_2$ and $FADH_2$.
- The Krebs cycle needs NAD and FAD, so it stops; only glycolysis with fermentation goes on, giving 2 ATP.

OR

a. **Photoperiodism** is the response of plants to the relative length of day and night (the photoperiod), shown above all in their **flowering**. **[1]**

Marking scheme

- The response of plants (in flowering) to the relative length of day and night.

b. **[3]**

1. **Short-day plants** (long-night plants) flower when the day is **shorter** than a critical length; what they need is a long, **continuous** dark period, and a flash of red light in the night stops them flowering. Example: **chrysanthemum** (also rice).
2. **Long-day plants** (short-night plants) flower when the day is **longer** than a critical length; the dark period is not critical, and a flash of light in the night helps them flower. Example: **radish** (also wheat).
3. **Day-neutral plants** flower whatever the photoperiod. Example: **tomato** (also sunflower).

Marking scheme

- Short-day plants flower when the day is shorter than the critical length (need a long unbroken night), e.g. chrysanthemum or rice.
- Long-day plants flower when the day is longer than the critical length, e.g. radish or wheat.
- Day-neutral plants flower under any photoperiod, e.g. tomato or sunflower.

c. **[2]**

- **December** (about 10-hour days): $10 < 15½$, so the **cocklebur** can flower; $10 < 11$, so henbane **cannot**.
- **June** (about 14-hour days): $14 < 15½$ and $14 > 11$, so **both** can flower.

The names compare the day with each plant's own critical length, not with 12 hours, so a short-day and a long-day plant can flower under the same day.

Marking scheme

- December: only the cocklebur (10 h is below 15½ h but also below henbane's 11 h).
- June: both (14 h is below 15½ h and above 11 h).

d. **[2]**

- The **leaves**, not the shoot tip, sense the photoperiod: the leafless shoot tip given short days doesn't flower, while one leaf given long nights is enough. (The leaves sense it with the pigment **phytochrome**.)

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- A **signal to flower** is made in the leaf that got the right photoperiod and is **carried to the shoot tips**, where the flowers form, even in parts of the plant that had long days.

Marking scheme

- The photoperiod is sensed by the leaves (by phytochrome), not by the shoot tip.
- A flowering signal travels from the induced leaf to the shoot tips, so the whole plant flowers.

Question 7 — 8 marks

a. A boy has only **one X chromosome** (XY), from his mother, and the Y carries no allele for color vision: a single X^c makes him color-blind. A girl has **two X chromosomes**, and is color-blind only if **both** carry the recessive allele (X^cX^c), from her father and from her mother; with one normal allele she is a carrier with normal vision. Two copies are much rarer than one, so color-blind girls are rare. **[2]**

Marking scheme

- A boy has one X (XY) and the Y has no allele for color vision, so one recessive allele makes him color-blind.
- A girl must get the recessive allele on both X chromosomes; with one she is a normal-sighted carrier, so color-blind girls are rare.

b. Sandhya's father (X^cY) gave her his only X, so she is a **carrier**: X^CX^c. Abhishek: X^CY. **[3]**

	X^C (egg)	X^c (egg)
X^C (sperm)	X^CX^C, normal daughter	X^CX^c, carrier daughter
Y (sperm)	X^CY, normal son	X^cY, color-blind son

Half of their sons may be color-blind; **none of their daughters** (half of them carriers).

Marking scheme

- Sandhya is a carrier, X^CX^c, because her color-blind father gave her his X; Abhishek X^CY.
- The checkerboard: X^CX^C, X^CX^c, X^CY, X^cY.
- Half the sons color-blind, no daughter color-blind (half the daughters carriers).

c. **Sheetal is right.** A color-blind girl is X^cX^c: she has one X from each parent, and both carry the recessive allele. **[3]**

- Her **father** gave her his only X, so his X is X^c: he is X^cY, **color-blind**.
- Her **mother** gave her an X^c, so she is X^CX^c (a carrier) or X^cX^c (color-blind).

When the girl grows up, every son of hers gets one of her X chromosomes, both X^c, so **all her sons will be color-blind**, whatever their father.

Marking scheme

- Right: the girl is X^cX^c, one recessive allele from each parent.
- The father, giving his only X, must be X^cY (color-blind); the mother is a carrier or color-blind.
- All of the girl's sons will be color-blind, since each gets an X^c from her.

Zoology, Group A Multiple choice (Zoology) — 6 marks

Question 8 — 6 × 1 = 6

a. **(ii)** BCG

b. **(iii)** transitional epithelium

c. **(i)** chief (peptic) cells

d. **(ii)** The left ventricle pumps blood through the whole body, against far more resistance than the lungs give.

e. **(iv)** 99.2%

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f. **(ii)** His lens has lost its elasticity, so it can no longer become rounder to focus on near objects.

Zoology, Group B Short answers (Zoology), each on one content area 16 marks

Question 9 4 marks

a. **Epithelial tissue** (epithelium) is a tissue of closely packed cells, with very little material between them, resting on a **basement membrane**, that covers the body's surface and lines its cavities, tubes and organs. **[1]**

Marking scheme

- Closely packed cells with little intercellular material, on a basement membrane, covering the body surface or lining its cavities and organs.

b.
- **Alveolus:** oxygen and carbon dioxide must **diffuse** between the air and the blood; a single layer of very thin, flat cells gives the shortest possible path for **exchange**. **[2]**
- **Palm:** the skin is rubbed and must keep water in and germs out; **many layers** replace the cells worn off, and the dead, **keratin**-filled top layers make the surface tough and **waterproof**.

Marking scheme

- Alveolus: a single thin layer for fast diffusion (exchange) of gases.
- Palm: many layers to replace worn cells, with dead keratinized cells making it tough and waterproof.

c. **Brush-bordered (simple) columnar epithelium**: it lines the **small intestine**, where its microvilli give a huge surface for absorbing digested food. **[1]**

Marking scheme

- Brush-bordered columnar epithelium, lining the small intestine.

Question 10 4 marks

a. Both meiotic divisions of the oocyte are **unequal**: each time one cell keeps almost all the cytoplasm and yolk, and the other is a tiny **polar body** that degenerates. So of the four haploid products, only one is an ovum. The divisions of a spermatocyte are **equal**, giving four spermatids of the same size, each of which becomes a sperm. **[1]**

Marking scheme

- The oocyte's divisions are unequal, giving one large ovum (with the yolk) and two or three polar bodies, while the spermatocyte's equal divisions give four spermatids.

b.
- Sperms: $50 \times 4 = \mathbf{200}$; ova: $50 \times 1 = \mathbf{50}$ (with 100 to 150 polar bodies). **[2]**
- Each sperm and each ovum is haploid: $n = \mathbf{13\ chromosomes}$.

Marking scheme

- 200 sperms and 50 ova.
- 13 chromosomes in each.

c. **No.** A frog lays its eggs as **secondary oocytes**: meiosis I is completed in the ovary just before ovulation, but meiosis II stops at metaphase II, and it is completed, with the second polar body pushed out, only **when a sperm enters** the egg. **[1]**

Marking scheme

- No: they are secondary oocytes arrested in meiosis II, which is completed only when a sperm enters.

Question 11 4 marks

a. A **synapse** is the junction where one neuron passes its signal to another (usually between the axon terminal of one and a dendrite or the cell body of the next), across a narrow gap, the synaptic cleft. **[1]**

Marking scheme

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- The junction between two neurons where the signal passes from one to the next (across the synaptic cleft).

b. Time = distance ÷ speed. **[2]**

- Myelinated fiber: 1 m ÷ 100 m/s = **0.01 s** (10 ms).
- Unmyelinated fiber: 1 m ÷ 1 m/s = **1 s**, a hundred times longer, which is why the burning pain arrives about a second later.

Marking scheme

- Myelinated: $1 \div 100 = 0.01$ s.
- Unmyelinated: $1 \div 1 = 1$ s.

c. Myelin insulates the axon, and the ion channels are packed into the **nodes of Ranvier**, so the action potential is produced only at the nodes: the impulse **leaps from node to node** (**saltatory conduction**), instead of each patch of the membrane firing in turn as in an unmyelinated fiber. **[1]**

Marking scheme

- The action potential arises only at the nodes of Ranvier, so the impulse jumps from node to node (saltatory conduction) instead of travelling patch by patch.

OR

a. **Triiodothyronine (T_3)** and **tetraiodothyronine (T_4, thyroxine)**. **[1]**

Marking scheme

- T_3 (triiodothyronine) and T_4 (thyroxine).

b. T_3 and T_4 are made by joining **iodine** to tyrosine, so without iodine the gland **cannot make enough hormone**. With little thyroid hormone in the blood, the pituitary **keeps sending TSH**, and TSH makes the thyroid grow as well as secrete: its cells multiply and the gland swells into a **simple goiter**. **[2]**

Marking scheme

- Without iodine the thyroid cannot make enough T_3 and T_4.
- The pituitary keeps releasing TSH, which makes the gland's cells multiply, so it swells (simple goiter).

c. The soil, water and so the food grown **far from the sea** contain very little iodine, and the people had no seafood or sea salt to make it up. Iodized salt, eaten every day by everyone, supplies the small amount of iodine the thyroid needs (about 150 micrograms a day). **[1]**

Marking scheme

- Food and water there have little iodine; iodized salt, eaten daily by everyone, supplies the iodine the thyroid needs.

Question 12 — 4 marks

a. So many young people are about to reach the **reproductive age** that, even with few children each, the total number of births stays high, while the number of deaths stays low because there are few old people. **[1]**

Marking scheme

- Many people are about to enter the reproductive age, so births stay high even with small families (and deaths are few).

b. Birth rate = 720 ÷ 40,000 × 1,000 = 18 per 1,000; death rate = 280 ÷ 40,000 × 1,000 = 7 per 1,000. **[1]**

Rate of natural increase = 18 − 7 = **11 per 1,000 a year** (1.1%).

Marking scheme

- Birth rate 18 and death rate 7 per 1,000, so natural increase 11 per 1,000 (1.1%) a year.

c. The births exceed the deaths, but the change in a population also depends on **migration**. Very many Nepalis have gone abroad (the 2021 census counted about 2.19 million people from Nepal's households living **[2]**

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abroad, four out of five of them men): this **net emigration is now about as large as the natural increase**, so the total hardly grows.

One effect: many young, working-age men are away, so villages are short of workers and farms are left untended (and the census counts fewer males than females, about 96 per 100), while the families at home live on **remittances**.

Marking scheme

- Net emigration (people going abroad) now about equals the natural increase, so the total population hardly grows.
- One effect: fewer working-age men at home (labor shortage, fewer males than females, families depending on remittances).

Zoology, Group C Long answers (Zoology), each on one content area 16 marks

Question 13 8 marks

a. *Vibrio cholerae*, a short, comma-shaped, Gram-negative bacterium with one flagellum. **[1]**

Marking scheme

- *Vibrio cholerae*.

b. **[3]**

1. *V. cholerae* sticks to the lining of the **small intestine** without invading it and releases **cholera toxin**.
2. The toxin enters the gut-lining cells and keeps them making **cyclic AMP**, which holds their **chloride channels open**: chloride ions pour into the gut, sodium follows, and **water follows the salts by osmosis**, giving the massive watery stools.
3. Losing up to a liter of water an hour, with sodium and potassium, causes severe **dehydration** and **electrolyte imbalance**: the blood volume and blood pressure fall, and the patient can go into **shock** (and kidney failure) and die within hours.

Marking scheme

- The bacteria stick to the small intestine and release cholera toxin (they don't invade).
- The toxin keeps the cells' chloride channels open (through cyclic AMP), so chloride, sodium and then water pour into the gut.
- The loss of water and salts causes dehydration and electrolyte imbalance, low blood pressure and shock.

c. **[2]**

- For 2 liters: $2 \times 6 =$ **12 level teaspoons of sugar** and $2 \times ½ =$ **1 level teaspoon of salt**, in boiled and cooled water.
- **Too much salt does harm**: a salty drink draws more water into the gut instead of letting the body take it up, and raises the sodium in the blood. It should taste no saltier than tears.

Marking scheme

- 12 level teaspoons of sugar and 1 level teaspoon of salt for 2 liters.
- Too much salt is harmful, so it must be measured (no saltier than tears).

d. **[2]**

- The gut-lining cells take up **glucose and sodium together**, and water follows them by osmosis; the cholera toxin doesn't stop this uptake.
- The toxin **does not destroy the gut wall**, so the cells can still absorb. So ORS, with its sugar and salt, brings water and salts back into the body faster than they are lost, and most patients need nothing else (IV fluids only when the patient can't drink enough).

Marking scheme

- Glucose and sodium are absorbed together by the gut cells, and water follows them, even while the toxin acts.
- The gut wall is not destroyed, so absorption still works and the lost water and salts are replaced.

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Question 14 — 8 marks

a. Inspiration is **active**: **[2]**

1. The **external intercostal muscles contract**, pulling the ribs and sternum upward and outward, and the **diaphragm contracts and flattens**, moving down: the chest grows in every direction, and the lungs expand with it.
2. With more room, the **pressure in the lungs falls** below the atmospheric pressure, and air **rushes in** until the pressures are equal.

Marking scheme

- The external intercostals contract (ribs up and out) and the diaphragm contracts and flattens, so the chest and lungs expand.
- The pressure in the lungs falls below the atmosphere's, so air flows in.

b. **[2]**

- Oxygen delivered: $5{,}000\ \text{mL} \times \frac{20}{100} = \mathbf{1{,}000\ mL\ a\ minute}$.
- Share used: $\frac{250}{1000} \times 100 = \mathbf{25\%}$; three-quarters of the oxygen comes back to the heart still in the blood, a reserve for exercise.

Marking scheme

- 1,000 mL of oxygen delivered a minute.
- 25% of it used.

c. **[4]**

- At 253 mmHg the air is a third as dense as at sea level, so the **partial pressure of oxygen** is only a third (about 53 mmHg against 160), and each breath brings in only a third as much oxygen.
- Gas exchange is **diffusion down the partial pressure gradient**: with less oxygen in the alveoli, the gradient into the blood is small, the hemoglobin is less loaded, and each 100 mL of blood carries much less oxygen to the tissues.
- To make up for it, the climber **breathes very fast and deep** (and the heart beats fast): this is the breathlessness, and most climbers carry bottled oxygen.
- A lowlander who stays high up makes **extra red cells**, which thicken the blood; many Sherpas (and Tibetans) carry a version of the gene **EPAS1** that lets them live high up without their blood thickening, so they cope better.

Marking scheme

- The partial pressure of oxygen on the summit is only a third of sea level's, so each breath brings a third as much oxygen.
- The smaller partial pressure gradient means less oxygen diffuses into the blood and the hemoglobin is less loaded.
- The climber breathes fast and deep to make up for it, hence the breathlessness.
- Many Sherpas carry a version of EPAS1 that lets them live high without the blood thickening with extra red cells, as a lowlander's does.

OR

a. The heart is **myogenic**: each beat starts in its own nodal tissue. **[2]**

1. The **SA node** (the pacemaker), in the wall of the right atrium near the superior vena cava, fires on its own, and the impulse spreads over both **atria**, which contract together.
2. The impulse reaches the **AV node**, which **delays** it by about 0.1 s so that the atria finish emptying; it then races down the **bundle of His**, its right and left branches and the **Purkinje fibers** to the ventricle muscle, and both ventricles contract from the apex upward.

Marking scheme

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- The SA node (pacemaker) in the right atrium starts the impulse, which spreads over both atria, making them contract.
- AV node (delay about 0.1 s) → bundle of His and its branches → Purkinje fibers → the ventricles contract.

b. Cardiac output = heart rate × stroke volume. **[2]**

- At rest: 72×70 mL = 5,040 mL ≈ **5.0 L/min**.
- During the match: 150×100 mL = 15,000 mL = **15 L/min**.

$15 \div 5.04 \approx$ **3 times** his resting output.

Marking scheme

- At rest $72 \times 70 = 5{,}040$ mL/min (about 5 L/min); during the match $150 \times 100 = 15{,}000$ mL/min (15 L/min).
- About 3 times the resting output.

c. **[4]**

- Length of one cycle: at rest $60 \div 72 \approx$ **0.8 s**; at 150 a minute $60 \div 150 =$ **0.4 s**.
- Time for the ventricles to relax and fill (cycle − ventricular systole): at rest $0.8 - 0.3 =$ **0.5 s**; during the match $0.4 - 0.25 =$ **0.15 s**.
- So a faster beat is bought almost entirely out of **diastole**: the cycle is halved, but the filling time falls to less than a third. The ventricles fill with blood during diastole.
- At still higher rates the ventricles would have too little time to fill: each beat would push out less blood, the **stroke volume would fall**, and the cardiac output would stop rising and then drop.

Marking scheme

- One cycle: 0.8 s at rest, 0.4 s at 150 a minute.
- Filling time: 0.5 s at rest, 0.15 s during the match.
- Almost all the shortening comes out of diastole, the time when the ventricles fill.
- With too little filling time, the stroke volume falls, so the output would drop at very high rates.

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