

END OF TERM III 2025

S.5 BIOLOGY

PROPOSED GUIDE

(a) Meaning of blood groups B⁻ and B⁺, and explanation for anaemia & jaundice

Meaning of blood group B⁻ and B⁺

Blood group B means that the person's red blood cells have B antigens on their surface.

The "+" or "-" refers to the Rhesus (Rh) factor.

B⁺ means the person has Rh factor (D antigen) on red blood cells.

B⁻ means the person lacks the Rh factor.

Why Patricia's second baby became anaemic and jaundiced

Patricia is B⁻ (Rh-negative) while her first child was B⁺ (Rh-positive).

During her first pregnancy or delivery:

The baby's Rh⁺ red blood cells entered Patricia's blood.

Her immune system recognized these Rh⁺ cells as foreign and produced anti-Rh antibodies.

These antibodies remained in her bloodstream (sensitization).

During the second pregnancy:

The second baby was also B⁺ (Rh-positive).

Patricia's anti-Rh antibodies crossed the placenta.

They attacked and destroyed the baby's red blood cells, causing haemolysis.

How this led to the baby's condition

1. Anaemia

Rapid destruction of red blood cells reduced the baby's RBC count from the normal $4.5-5.5 \times 10^6/\mu\text{L}$ to $2.0-3.0 \times 10^6/\mu\text{L}$, causing severe anaemia.

2. Jaundice

Breakdown of many RBCs released large amounts of haemoglobin, which was converted to bilirubin, raising levels from the normal $<1 \text{ mg/dL}$ to $8-15 \text{ mg/dL}$.

Excess bilirubin deposited in tissues produced the yellowish skin colour.

3. Conclusion

The baby's state is a classical case of Rhesus incompatibility (also called Haemolytic Disease of the Newborn – HDN), not HIV/AIDS, and it is treatable

(b) Advice to Patricia on living positively with her baby & how such cases can be prevented

How Patricia can live positively with her second born

1. Follow medical treatment

Ensure the baby receives the recommended treatments such as phototherapy or exchange transfusion if necessary.

Attend regular check-ups to monitor haemoglobin and bilirubin levels.

2. Exclusive breastfeeding

Breastfeed exclusively for 6 months to improve the child's immunity and growth.

3. Emotional support

Avoid unnecessary fear; the child's condition does not mean HIV/AIDS.

Seek counselling and support from family or health workers.

4. Nutrition

Provide a balanced diet (when baby grows older) rich in iron to rebuild blood levels

5. Immunization and health monitoring

Ensure the baby receives all immunizations and routine growth monitoring

How such cases can be prevented among couples before marriage

1. Blood group and Rhesus factor testing

Couples should determine their ABO and Rh blood groups before marriage or pregnancy.

2. Use of Anti-D immunoglobulin (RhoGam)

If a woman is Rh-negative and her partner is Rh-positive, she should receive Anti-D injection:

at 28 weeks of pregnancy

within 72 hours after delivery

after miscarriage, abortion, or ectopic pregnancy

This prevents formation of antibodies against Rh⁺ blood.

3. Health education and genetic counselling

Couples should undergo counselling to understand risks and preventive measures.

4. Regular antenatal care

Early and frequent antenatal visits allow early detection and management of blood incompatibility

(a) Using your knowledge of biochemistry of energy production in cells, justify the doctor's dietary recommendation. (12 marks)

1. Carbohydrates (posho) provide rapid ATP via aerobic respiration (4 marks)

- Ingested starch → digested to glucose → absorbed into blood; glucose enters cells and is metabolised by **glycolysis → pyruvate → acetyl-CoA → Krebs cycle → oxidative phosphorylation** in mitochondria. (2 marks — 1 for pathway named, 1 for mitochondria/oxidative phosphorylation).
- Aerobic breakdown of one glucose yields about **~36 ATP** (table), so carbohydrates are an efficient source of **rapid ATP** for muscle contraction and high intensity work. (1 mark)
- Carbohydrate stores as **muscle and liver glycogen** can be mobilised quickly during exercise to maintain blood glucose and ATP supply. (1 mark)

2. Proteins (soya beans) support muscle repair, provide amino acids and enable sustained energy (3 marks)

- Soya is a high-quality plant protein supplying **essential amino acids** necessary for **repair and synthesis** of muscle proteins damaged during training ; this helps performance and recovery. (1 mark)
- Amino acids can be deaminated and their carbon skeletons fed into Krebs cycle or used for **gluconeogenesis** when glycogen is low, providing **secondary energy**. (1 mark)
- Soya also contains micronutrients (e.g., B-vitamins) that are cofactors for respiration enzymes supporting ATP production. (1 mark)

3. Lipids yield more ATP per molecule but are slower to mobilise why a mixed diet helps (2 marks)

- Fatty acids (e.g., palmitic acid) yield **~129 ATP** on oxidation and higher energy per gram (≈ 38 kJ/g), but **β -oxidation and transport into mitochondria are slower** and less useful for immediate high-intensity bursts. (1 mark)
- Therefore, recommending **carbohydrate (fast ATP) + protein (repair and sustained supply)** is appropriate for an athlete needing both immediate energy and recovery. (1 mark)

4. Practical nutrient-timing & composition justification (3 marks)

- **Pre-exercise** carbohydrate (posho) helps top up glycogen and maintain blood glucose so muscles can rapidly produce ATP during events. (1 mark)

- **Post-exercise** protein (soya) supplies amino acids to repair muscle and stimulate protein synthesis (leucine effect), and also helps replenish glycogen when combined with carbohydrate. (1 mark)
- Combining both reduces muscle protein breakdown, improves performance and speeds recovery — exactly what an athlete needing more “energy productivity in form of ATP” requires. (1 mark)

Mark allocation summary (12 marks)

- Carbohydrate → pathway & ATP yield (4)
- Protein roles (repair / gluconeogenesis / cofactors) (3)
- Lipid vs carbohydrate tradeoffs (2)
- Nutrient timing and practical application (3)

What to lose marks for: vague statements without linking to ATP production, failing to mention glycogen or mitochondria, or claiming fats are best for immediate energy.

(b) Apart from dietary adjustment, suggest appropriate measures Nyakoojo should take to improve performance in upcoming finals. (8 marks)

1. **Structured training plan — periodisation** (2 marks)
 - Use periodised training (base → build → peak → taper) to progressively overload and then taper before finals to arrive rested and at peak performance. (1 mark for naming, 1 mark for reason)
2. **Incorporate interval and sport-specific conditioning** (1 mark)
 - High-intensity interval training (HIIT) and sport-specific drills improve aerobic and anaerobic energy systems and raise mitochondrial density and glycolytic capacity. (1 mark)
3. **Strength and resistance training** (1 mark)
 - Builds muscle power and improves efficiency of force production; reduces injury risk. (1 mark)
4. **Adequate rest & sleep** (1 mark)
 - Sleep (7–9 hrs) is essential for recovery, hormone regulation (e.g., growth hormone) and muscle repair poor sleep reduces performance. (1 mark)
5. **Hydration and electrolyte management** (1 mark)
 - Maintain hydration before/during/after events; dehydration reduces blood volume and cardiac output and impairs ATP delivery to muscles. (1 mark)
6. **Monitor and correct medical issues (e.g., anaemia, infections)** (1 mark)

- Check for iron deficiency or other medical causes of fatigue; treat appropriately (iron supplements, investigate endocrine issues). (1 mark)
7. **Psychological preparation and competition strategy** (bonus if included; folded into other points)
- Mental rehearsal, goal setting and stress management improve focus and performance (can be counted if candidate gives clear brief point). (up to 1 mark — included in the 8 if used)

SUMMARY

(a) The doctor's advice is justified because posho (starchy carbohydrate) supplies glucose which is rapidly metabolised by glycolysis, the Krebs cycle and oxidative phosphorylation in mitochondria to generate ≈ 36 ATP per glucose molecule; glycogen stores in muscle/liver provide immediately available fuel during competition. Soya beans provide high-quality protein (essential amino acids) needed for muscle repair and for gluconeogenesis when glycogen is low; they also provide B vitamins and cofactors important for enzymatic steps in respiration. Although fats yield more ATP per molecule (~ 129 ATP for palmitic acid) and have higher energy density (~ 38 kJ/g), they are slower to mobilise, so combining carbohydrate (fast ATP) and protein (repair and sustained supply) is optimal for boosting ATP availability and recovery. Proper timing carbohydrate before events to top up glycogen and protein after exercise to aid repair further supports performance. (Expand with a short sentence about glycogen, mitochondria and insulin if space/time allows.)

(b) Non-dietary measures: adopt a periodised training plan with specific interval and strength sessions to improve aerobic and anaerobic capacity; include resistance training to increase muscle power; ensure adequate sleep and recovery to allow muscle repair and hormonal recovery; maintain hydration and electrolyte balance; screen and treat medical causes of fatigue (e.g., iron-deficiency anaemia); use mental skills and competition tapering to peak at finals

Item 3

Human breast milk contains several **protective proteins** especially **IgA antibodies**, **lactoferrin**, and **lysozyme** which together form the infant's first line of immune defence.

1. IgA antibodies protect mucosal surfaces (4 marks)

- Human milk contains **high levels of IgA (0.6 mg/100 mL)** compared to cow's milk (0.02 mg) and plant milk (0 mg).
- These **secretory IgA antibodies** line the baby's **gut, throat, and respiratory tract**, forming a protective coating.

- They **bind to pathogens** (bacteria, viruses, and toxins) and **prevent them from attaching to the baby's epithelial cells**.
- IgA therefore **neutralizes pathogens without causing inflammation**, which is important because a baby's immune system is still immature.

Marks: 4

- Identification of IgA – 1 mark
 - Role in mucosal immunity – 1 mark
 - Prevents pathogen attachment – 1 mark
 - No-inflammation protection – 1 mark
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2. Lactoferrin prevents growth of microbes by starving them of iron (3 marks)

- Human breast milk contains **0.3 mg lactoferrin**, much higher than cow's milk.
- Lactoferrin **binds iron tightly**, making it unavailable to bacteria that require iron for growth.
- It therefore **inhibits multiplication of harmful bacteria** like *E. coli* and some fungi.
- Lactoferrin also **damages microbial membranes** and enhances growth of beneficial gut bacteria.

Marks: 3

- Iron-binding explanation – 1 mark
 - Prevention of bacterial growth – 1 mark
 - Additional antimicrobial function – 1 mark
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3. Lysozyme destroys bacterial cell walls (3 marks)

- Breast milk contains **high lysozyme levels (0.1 mg)** compared to cow's milk (0.001 mg).
- Lysozyme **breaks down peptidoglycan**, the main component of bacterial cell walls.
- This causes **lysis and death of bacteria**, especially Gram-positive organisms.
- Thus, lysozyme provides additional protection in the infant gut and respiratory tract

Humans have made significant use of the special protective proteins found in breast milk **IgA antibodies, lactoferrin, and lysozyme** to advance **medicine, food technology, and public health**.

1. Use of antibodies (especially IgA) in vaccine development (3 marks)

- IgA's ability to **neutralize pathogens at mucosal surfaces** has inspired the design of **oral and nasal vaccines**.
- Vaccines now stimulate **mucosal immunity** similar to IgA in breast milk, providing protection against diseases like polio, measles, and influenza.
- Monoclonal antibodies, designed based on natural IgA, are used to treat infections and immune disorders.

Marks:

- Application to vaccines – 1
 - Mucosal immunity concept – 1
 - Therapeutic antibodies – 1
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2. Use of lactoferrin as a natural antimicrobial additive (3 marks)

- Lactoferrin is now commercially extracted (mainly from cow's milk) and added to **infant formula** to mimic immunity provided by breast milk.
- It is also used in **food preservation** because its iron-binding ability inhibits microbial growth, increasing shelf-life of meat and dairy products.
- In medicine, lactoferrin is used in **wound dressings** and supplements to reduce infections.

Marks:

- Use in infant formula – 1
 - Use in food preservation – 1
 - Use in medical/health products – 1
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3. Use of lysozyme in food and pharmaceutical industries (3 marks)

- Lysozyme's ability to **break bacterial cell walls** makes it an important antimicrobial agent.
- It is added to **cheese, canned foods, and beverages** to prevent spoilage.
- Pharmaceutical companies use lysozyme in **eye drops, throat lozenges, and nasal sprays** to fight bacterial infections.

Marks:

- Use in food preservation – 1
- Use in medicine – 1
- Mechanism/basis for use – 1

4. Use in biotechnology and genetic engineering (1 mark)

- Human milk proteins like lactoferrin and lysozyme are produced through **recombinant DNA technology** in bacteria and plants, making large-scale production possible for medical and nutritional use

item 4

(a) Key feature of glandular epithelium + how modes of secretion explain the symptoms

Identification of glandular epithelium (2 marks)

A cell is identified as **glandular epithelium** when it shows:

- **Abundant secretory vesicles** in the cytoplasm (1 mark)
- **Well-developed Golgi bodies and rough ER** for synthesis and packaging of secretions (1 mark)

These features distinguish it from typical covering epithelium, whose main function is protection, not secretion.

How different modes of secretion explain the three patients' symptoms (6 marks)

1. Holocrine secretion; Excess oil production (2 marks)

- Holocrine glands (e.g., **sebaceous glands in skin**) release secretion when **the whole cell bursts** and disintegrates.
- This explains the patient with **excess oil**, because holocrine secretion continuously releases lipid-rich sebum when cells rupture.

→ **Excess holocrine activity = oily skin**

2. Merocrine secretion , Digestion problems (2 marks)

- Merocrine glands (e.g., **pancreatic acinar cells**) release enzymes by **exocytosis** without losing any cell material.
- If these cells malfunction, they may either over-release or under-release digestive enzymes, leading to **poor digestion or enzyme imbalance**.

→ **Impaired merocrine enzyme secretion = digestion problems**

3. Apocrine secretion; Fluctuating blood sugar (2 marks)

- Apocrine secretion involves **loss of part of the cell's apex**, which pinches off with the secretion.
- Some stomach and endocrine-related mucous cells use modified apocrine modes.
- If cells that secrete hormones (e.g., incretins from the stomach lining) release hormones irregularly, this can lead to **unstable blood sugar**.

→ **Irregular apocrine-associated hormone release = fluctuating glucose levels**

(Note: Pancreatic islet cells are merocrine, but the scenario involves stomach-derived hormones modulating glucose.)

(b) Identifying which slide belonged to an endocrine gland (4 marks)

To identify an endocrine gland under the microscope, look for:

1. Absence of ducts (1 mark)

Endocrine glands are **ductless**; they release hormones directly into the blood.

2. Dense network of capillaries (1 mark)

You would see numerous blood vessels to allow hormone uptake.

3. Cells arranged in clusters or cords (1 mark)

Endocrine tissues like the pancreatic islets appear as **clusters of lightly stained cells** distinct from surrounding exocrine cells.

4. Lack of large secretory vesicles with digestive or oil content (1 mark)

Endocrine cells have small hormone granules rather than enzyme- or lipid-filled vesicles typical of exocrine cells.

(c) Artificial gland implants: Ethical concern, benefit, and scientific reflection

(i) Ethical concern (2 marks)

- Artificial glands may require **genetic modification** of cells, raising concerns about unknown long-term effects, possible tumor formation, or modification of human genetic integrity.
- OR
- Access and cost may be unequal, creating **ethical inequality** in who can receive such therapy.

(Any one ethical concern earns 2 marks.)

(ii) One potential benefit (2 marks)

- Artificial gland implants can **restore normal secretion** (hormones, enzymes, mucus) for patients with damaged glands.
 - This may reduce dependency on lifelong medication, improving quality of life.
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(iii) How a biologist should respond when evidence contradicts their assumptions (2 marks)

A biologist should:

- **Re-evaluate their hypothesis** and accept that scientific conclusions must follow evidence.
- **Adjust interpretations** and redesign experiments rather than holding onto incorrect assumptions.
- Maintain **scientific objectivity**, openness, and integrity.

Item 5

(a) Justify the village health team’s observation as regards the health status of the citizens

The village health team (VHT) attributes the citizens’ respiratory and circulatory health problems to the use of charcoal for cooking in poorly ventilated kitchens. This observation is justified by the following:

1. High carbon monoxide (CO) levels in households

Table 4 shows that enclosed kitchens with no ventilation have CO levels of 350 ppm, which is extremely high.

CO binds strongly to haemoglobin to form carboxyhaemoglobin, reducing oxygen transport.

2. Reduced oxygen-carrying capacity of blood

Table 3 shows Katanga residents have:

Low blood oxygen saturation (75–85%) compared to 98% in normal individuals.

Low oxyhaemoglobin levels (65–70%) compared to 99% in normal individuals.

High carboxyhaemoglobin levels (20–30%), whereas normal is <1%.

This clearly indicates CO poisoning from charcoal smoke.

3. Compensatory increase in breathing and heart rate

Due to reduced oxygen available to tissues:

Respiratory rate increases to 28/min (normal is 16/min).

Pulse rate increases to 100–120 bpm (normal is 70 bpm)

These are physiological responses to hypoxia, confirming impaired respiratory and circulatory function caused by exposure to charcoal smoke.

4. Higher health complaints correlate with poor ventilation

Households with no ventilation report 70% health complaints, compared with only 10% in outdoor cooking.

This shows a direct relationship between poor ventilation, high CO levels, and increased illness.

Conclusion:

The medical data, increased CO levels, reduced oxygen saturation, and high reported illness all support the VHT's observation that charcoal use in poorly ventilated kitchens is causing respiratory and circulatory health complications.

(b) Practical measures to mitigate the reported health complications

1. Improve kitchen ventilation

Build windows, vents, or open eaves to allow smoke to escape.

Encourage construction of chimneys as shown by reduced CO (80 ppm) in such homes.

2. Promote outdoor cooking

Cooking outside reduces CO concentration drastically (to 25 ppm) and minimizes inhalation of smoke.

3. Transition to cleaner energy sources

Encourage the community to use:

Gas stoves (LPG)

Electric cookers

Improved biomass stoves that produce less smoke

4. Public health education

Sensitize residents about dangers of carbon monoxide poisoning.

Educate on early symptoms (headache, dizziness, shortness of breath).

5. Regular monitoring of indoor air quality

Routine checks for carbon monoxide levels.

Early detection can prevent severe poisoning.

6. Planting trees and improving general air quality

Trees increase oxygen availability and reduce air pollutants.

7. Medical interventions

Provide medical check-ups for vulnerable groups such as children and pregnant women.

Treat suspected CO poisoning early with oxygen therapy

Item 6

(a) Curve type, what it shows, which athlete's curve is shifted and why that helps (8 marks)

Answer (8 marks)

1. **Type of curve (2 marks)**
 - The relevant plot is the **oxygen–haemoglobin dissociation curve**, which is **sigmoid (S-shaped)**. (1)
 - The sigmoid shape reflects **cooperative binding**: binding of one O₂ to haemoglobin increases the affinity for the next O₂ molecules. (1)
2. **What the curve shows about oxygen binding (2 marks)**
 - At high partial pressures of O₂ (e.g., in the lungs) haemoglobin is highly saturated with O₂ (steep upper part → high loading). (1)
 - At lower PO₂ (e.g., in active muscle) the right-hand, steep portion means small drops in PO₂ cause large O₂ release (unloading). (1)
3. **Which athlete's curve is shifted and why that helps (4 marks)**
 - **Kato's curve is shifted to the right** compared with Angel's (1). This means Kato's haemoglobin has **lower affinity** for O₂ at any given PO₂ and therefore **releases O₂ to tissues more easily** (1).
 - A right shift can be produced by physiological factors common in highlanders: **higher 2,3-BPG (2,3-diphosphoglycerate) in RBCs, slight increases in temperature, and chronic exposure to elevated CO₂ or mild acidity** — all reduce Hb affinity and promote unloading. (1)
 - **Why this helps at high altitude**: ambient PO₂ is lower, so easier unloading at the muscle (despite a lower arterial PO₂) improves O₂ delivery to working muscle and helps sustain performance. (1)

(Marks: 2 for curve type/coop, 2 for explanation of binding/loading/unloading, 4 for identifying right shift + mechanism + functional benefit.)

(b) Prediction if Angel's blood became more acidic during intense exercise + ethics of artificial induction (7 marks)

Answer (7 marks)

1. **Physiological prediction (4 marks)**
 - **Acidosis (lower pH)** produces the **Bohr effect**, shifting the O₂–Hb curve **to the right**. (1)

- This **increases O₂ unloading** at active muscles which can **improve local O₂ delivery** and momentarily help performance. (1)
 - **However** excessive acidosis (high [H⁺]) also reduces Hb affinity for O₂ in the lungs, potentially **reducing arterial O₂ saturation**, especially at altitude where lung PO₂ is already low this may **limit VO₂max and endurance**. (1)
 - Additionally, systemic acidosis impairs muscle contractility and enzymatic metabolism (inhibits glycolytic enzymes, causes fatigue), so overall performance may **fall if acidosis is severe**. (1)
2. **Ethical/fairness discussion about artificial methods (e.g., blood doping) (3 marks)**
- **Fairness:** Artificially inducing a right shift (by blood manipulation or doping) is **unfair** because it gives an athlete an unnatural competitive advantage over others who follow rules. (1)
 - **Health risks:** Methods such as blood transfusions or drugs that alter blood chemistry carry **serious medical risks** (clotting, infections, cardiac strain). (1)
 - **Regulation and ethics:** Sports authorities ban blood doping; it violates the spirit of fair play and informed consent if athletes are pressured into it. Thus it is **unethical** and should not be used. (1)

(Marks: 4 for balanced physiological prediction (benefit vs harm), 3 for ethical/fairness/health/regulatory point.)

(c) Why scientists must remain objective and evidence-driven when comparing physiological adaptations (5 marks)

Answer (5 marks)

1. **Avoid bias and premature conclusions (2 marks)**
 - Scientists must not assume that one observed trait (e.g., performance) is caused solely by a single adaptation many confounding factors exist (training history, hydration, nutrition, genetics, illness, measurement error). (1)
 - Remaining objective prevents misattribution and faulty generalisation from a small sample. (1)
2. **Use rigorous methods and reproducible evidence (2 marks)**
 - Use controls, adequate sample sizes, statistical analysis, repeat experiments, and peer review to confirm findings before claiming adaptation differences. (1)
 - Consider alternative explanations and test them — e.g., measure 2,3-BPG, haemoglobin concentration, VO₂max, capillary density rather than infer from performance alone. (1)
3. **Scientific integrity and ethical reporting (1 mark)**
 - Report results honestly, acknowledge uncertainty, and update hypotheses when new data contradict initial assumptions. (1)

(Marks: 2 for bias/avoidance, 2 for methods/reproducibility, 1 for integrity.)

summary

- (a) **O₂–haemoglobin dissociation curve (sigmoid); Kato’s curve is shifted right allowing easier O₂ unloading at low PO₂, helping at altitude.**
- (b) **Acidosis shifts curve right (Bohr effect) may help unloading but excessive acidosis lowers arterial O₂ saturation and impairs muscle function; blood doping to induce such shifts is unethical, unsafe, and banned.**
- (c) **Scientists must be objective, control confounders, use reproducible measurements, and let data drive conclusions**

END