A-LEVEL BIOLOGY
BIOCLAS HUB

ITEM 1

A group of students from different regions of Uganda participated in a wildlife hiking camp around Mount Elgon. During the activity, the camp health team noticed that some students were unable to cope well with the environmental conditions.

One student from a lowland area became dizzy and breathed rapidly while climbing steep slopes. Another student repeatedly sneezed, developed swollen eyes, and experienced breathing difficulty after spending the night in a dusty grass shelter. A third student, who had taken very little water during the trek, later complained of intense thirst and muscle cramps.

The health team carried out simple examinations and obtained the following results.

Parameter	Student A	Student B	Student C
Blood oxygen saturation (%)	84	96	95
Heart rate (beats/min)	148	118	132
Plasma ADH level	Normal	Normal	Very high

TASK

(a) Analyse how transport of gases, body defence responses, and water balance mechanisms could have contributed to the conditions observed in the students.

(b) Evaluate possible measures that could reduce the physiological challenges experienced during future hiking activities.

Analysis

- *Low altitude exposure during hiking caused Student A to develop low blood oxygen saturation and rapid heartbeat because reduced atmospheric oxygen at high altitude lowered the diffusion gradient for oxygen into the blood. Less **oxyhaemoglobin** formed in red blood cells, shifting the oxygen dissociation process and reducing oxygen delivery to respiring tissues. The low oxygen concentration stimulated the **carotid body chemoreceptors** and the **medulla oblongata**, increasing breathing rate and sympathetic stimulation of the **sinoatrial node (SAN)**, which raised heart rate to transport more oxygen to muscles, leading to dizziness and fatigue.*
- *Exposure to dust containing pollen and animal fur caused Student B to develop sneezing, swollen eyes, and breathing difficulty because allergens triggered an exaggerated immune response. The allergens stimulated **B-lymphocytes** to produce **IgE antibodies**, which attached to **mast cells** and caused release of **histamine** during subsequent exposure. Histamine increased capillary permeability, mucus secretion, and bronchiole constriction, reducing efficient airflow and slightly increasing heart rate due to respiratory stress, leading to allergic symptoms and breathing difficulty.*
- *Water deprivation during prolonged trekking caused Student C to develop thirst, muscle cramps, and high plasma ADH levels because excessive sweating reduced blood water potential. **Osmoreceptors** in the **hypothalamus** detected the lowered water potential and stimulated the posterior pituitary gland to release **ADH**. ADH increased permeability of the distal convoluted tubule and collecting duct by inserting **aquaporins**, increasing water reabsorption into blood. Reduced water in tissues also disturbed ionic balance involving **sodium ions** and **potassium ions**, affecting muscle contraction and causing cramps.*

Evaluation

- ***Gradual acclimatisation before hiking /altitude training,*** *would improve Student A's oxygen transport because repeated exposure to low oxygen stimulates secretion of* ***erythropoietin*** *from the kidneys, increasing red blood cell and haemoglobin production. Increased haemoglobin raises oxygen-carrying capacity and improves formation of* ***oxyhaemoglobin****, while long-term adaptation also increases capillary density and efficiency of aerobic respiration, reducing rapid heartbeat, dizziness, and fatigue during high-altitude activities.*
- ***Avoidance of allergens/use of antihistamines*** *would reduce Student B's allergic reactions because antihistamines block* ***histamine receptors*** *on target tissues, preventing excessive vasodilation, mucus secretion, and bronchiole constriction. Reduced histamine activity maintains wider air passages for efficient gaseous exchange and lowers irritation of sensory receptors in the eyes and respiratory tract, reducing sneezing, swelling, and breathing difficulty during exposure to dust or pollen.*
- ***Regular water intake during physical activity /oral rehydration****, would maintain Student C's water balance because replacement of lost water restores blood water potential and reduces overstimulation of hypothalamic osmoreceptors. Lower* ***ADH*** *secretion decreases excessive water reabsorption, maintaining normal tissue hydration and ionic balance required for muscle contraction. Adequate water also supports blood volume and efficient transport of oxygen and nutrients to muscles, preventing cramps and dehydration.*

ITEM 2

During practical activities at a school farm in Mbarara District, learners observed unusual conditions among workers and animals kept in different sections of the farm.

A worker who spent several hours inside a poorly ventilated charcoal-heated rabbit house later developed headaches and rapid heartbeat. At the poultry section, vaccinated chicks remained healthy during a Newcastle disease outbreak affecting nearby farms, although some temporarily developed mild fever. Elsewhere on the farm, a student who continuously applied an ice-cold pack to an injured leg later experienced numbness and delayed movement of the affected limb.

The agriculture teacher recorded the following observations.

Parameter	Worker	Vaccinated chicks	Injured student
Blood oxygen saturation (%)	79	Normal	98
Heart rate (beats/min)	142	Normal	76
Antibody concentration	Normal	Very high	Normal
Sensory response	Normal	Normal	Delayed

TASK

(a) Analyse how gas transport, immune responses, and impulse transmission could have contributed to the observations recorded on the farm.

(b) Evaluate measures that could improve safety, immunity, and recovery during farm activities.

ANALYSIS

- *Exposure to carbon monoxide from the poorly ventilated charcoal-heated rabbit house caused the worker to develop headaches and rapid heartbeat because **carbon monoxide** combined strongly with **haemoglobin** to form **carboxyhaemoglobin**, reducing oxygen transport in blood. Reduced oxygen supply to tissues lowered aerobic respiration and ATP production, stimulating chemoreceptors and sympathetic nervous activity. The **medulla oblongata** increased heart rate through stimulation of the **SAN** to compensate for reduced oxygen delivery, leading to headaches, weakness, and rapid heartbeat.*
- *Vaccination of the chicks caused high antibody concentration and protection against Newcastle disease because weakened antigens stimulated **B-lymphocytes** to form **plasma cells** and **memory cells**. Plasma cells secreted specific antibodies complementary to viral antigens, while memory cells enabled rapid secondary immune response during later exposure to the pathogen. Mild fever resulted from temporary immune activation and release of pyrogens during antibody production, leading to disease resistance in vaccinated chicks.*
- *Continuous application of an ice-cold pack to the injured limb caused numbness and delayed movement because low temperature reduced permeability of neurone membranes to **sodium ions** and **potassium ions**, slowing depolarisation and impulse transmission along sensory and motor neurones. Cold conditions also reduced activity of enzymes involved in cellular respiration, lowering ATP supply required for operation of the **sodium-potassium pump** and synaptic transmission. Reduced impulse conduction delayed sensory perception and muscle response, leading to numbness and slow movement.*

EVALUATION

- ***Improving ventilation in enclosed houses /reducing charcoal smoke exposure**, would reduce carbon monoxide poisoning because increased airflow lowers accumulation of carbon monoxide in the environment, reducing formation of **carboxyhaemoglobin** in blood. More haemoglobin remains available for oxygen transport, restoring efficient aerobic respiration and ATP production in tissues. Adequate oxygen supply also normalises chemoreceptor stimulation and heart rate, preventing headaches and fatigue.*
- ***Proper vaccination schedules** /booster vaccination, would improve immunity because repeated controlled exposure to antigens maintains high levels of specific **memory cells** and antibodies in circulation. During later infection, memory cells rapidly divide into plasma cells that produce large quantities of antibodies, destroying pathogens before disease symptoms become severe. This strengthens adaptive immunity and increases survival during disease outbreaks.*
- ***Controlled use of ice-cold first aid /short-duration cold application,** would improve recovery after injury because moderate cooling reduces pain and inflammation without excessively slowing neurone depolarisation and synaptic transmission. Limiting duration of cold exposure allows normal movement of **sodium ions** and **potassium ions** across neurone membranes and maintains ATP-dependent nerve conduction, restoring normal sensory and motor coordination while still reducing tissue damage after injury.*

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