REVISION ITEMS AND RESPONSES

ITEM 1

At a boarding school in Mbale, several students developed red itchy eyes, sneezing, and skin rashes after sleeping in newly cleaned dormitories. One student, Daniel, experienced severe swelling and difficulty breathing. Another student, Sarah, did not show symptoms because she had previously been exposed to similar dust.

Further observations:

The dormitories had been cleaned using strong chemicals.

Daniel had a history of allergies since childhood.

Some students used cold water on their skin and felt relief.

A few students were recently vaccinated against influenza.

Students complained of poor sleep due to heat at night.

Laboratory findings:

Parameter	Daniel	Sarah	Normal
Histamine level (µg/mL)	9.5	2.0	1.5
Antibody level (IgE)	High	Moderate	Low
Body temperature (°C)	38.2	37.0	37.0
Heart rate (beats/min)	120	80	75
Breathing rate (breaths/min)	26	18	16

Task

(a) Explain how the immune system, histamine release, and nervous control of breathing and heart rate led to the observed symptoms in Daniel and differences between students.

(b) Recommend measures the school can take to reduce such health problems among students.

RESPONSES

(a) When Daniel was exposed to dust and chemicals in the dormitory, these substances acted as allergens (antigens). Because he has a history of allergies, his immune system had already been sensitised. His body produced a high level of IgE antibodies, as shown in the data.

The allergens combined with IgE antibodies attached to mast cells, causing them to release large amounts of histamine.

Histamine caused:

- Vasodilation and increased capillary permeability, leading to swelling (e.g. lips) and skin rashes
- Stimulation of mucus secretion and irritation of sensory receptors, causing sneezing and itchy eyes
- Constriction of airways (bronchoconstriction), leading to difficulty in breathing

The rise in body temperature (38.2 °C), activation of homeostatic responses, due to increased metabolic activity and inflammation.

The nervous system responded to stress caused by breathing difficulty and inflammation:

- The medulla oblongata increased the breathing rate (26 breaths/min) to supply more oxygen
- The heart rate increased (120 beats/min) to transport oxygen and remove carbon dioxide more quickly

In contrast, Sarah had moderate IgE levels and prior exposure to the allergen. Her immune system had developed some level of adaptive tolerance, so there was:

- Less histamine release (2.0 µg/mL)
- Normal body temperature, heart rate, and breathing rate
- No visible symptoms

The use of cold water reduced symptoms because it caused vasoconstriction, which reduces blood flow to the affected areas and limits swelling and irritation.
The influenza vaccination did not prevent the condition because it stimulates specific adaptive immunity against a virus, not against allergens like dust or chemicals.
Poor sleep due to heat may have weakened body regulation and increased sensitivity to the allergic reaction.

(b) Recommendations

- Improve ventilation in dormitories, this reduces the concentration of dust and chemical allergens in the air, lowering exposure.
- Use mild, non-irritating cleaning agents, this prevents triggering allergic reactions caused by strong chemicals.
- Regular dust removal and proper cleaning methods (e.g. damp dusting), This reduces airborne particles that act as allergens.
- Provide cooling measures (e.g. proper airflow, open windows), This supports temperature regulation and reduces irritation caused by heat.
- Encourage use of cold compresses or water for affected students, Cold reduces inflammation through vasoconstriction and relieves symptoms.
- Identify and monitor students with known allergies, this allows early management and prevention of severe reactions like Daniel's.
- Health education for students and staff, this helps them understand causes of allergies and how to avoid triggers.

ITEM 2

Brian used to be one of the fastest sprinters in his region, yet recently he has often lost many races. This has caused Brian to lose self-confidence and become depressed. His coach has observed that:

- He starts running at the correct time but fails to sustain strong muscle contractions.
- He sometimes staggers or loses balance near the finish line, especially in hot conditions.
- His body temperature is very high after races, yet he never sweats.
- He occasionally complains of blurred vision when focusing on the finish line.
- Even when not racing, Brian sometimes feels unsteady when he turns his head quickly.

Some of Brian's team members laugh at him because during training, he often leans toward the finish line and performs exaggerated movements, which the coach jokingly calls his "courtship display."
Due to Brian's high skill and fitness level, the coach suspected a biological cause and referred him to a sports doctor. The doctor tested Brian and compared his results with values of healthy trained sprinters.

Laboratory and Clinical Results

Parameter	Brian's Result	Normal Reference (trained athletes)
Synaptic vesicles at motor endplate	8.0×10^5	2.0×10^7
Acetylcholine per vesicle	5.0×10^1	1.0×10^4
Synaptic convergence (neurones per motor neurone)	Low	High
Arteriole wall thickness (skin)	12 µm	22 µm
Core temperature at onset of sweating (°C)	39.0	37.2
Sweat rate at 36 °C ($L \cdot h^{-1}$)	0.0	1.0
Visual acuity (distance focus)	Reduced	Normal
Vestibular function (balance test)	Reduced	Normal

TASK

(a) Using the results, explain how changes in neurotransmitter release, synaptic transmission, visual function, and temperature regulation led to Brian's weak muscle contractions, poor balance, and overheating.

(b) Suggest strategies that can improve Brian's performance and condition and briefly justify each.

RESPONSE

(a) At the neuromuscular junction, effective muscle contraction depends on the release of the neurotransmitter acetylcholine (ACh). Brian has Very few synaptic vesicles (8.0×10^5 vs 2.0×10^7), less acetylcholine is released into the synaptic cleft. As a result:

- Fewer receptors on the muscle fibre are stimulated
- A weaker end-plate potential is generated
- Fewer or no action potentials are triggered in the muscle

muscle fibres contract weakly; Brian fails to sustain strong muscle contractions during running.
low synaptic convergence (few neurones connecting to one motor neurone);

- Fewer impulses reach the motor neurone
- Reduced summation of impulses
- Less activation of muscle fibres

This further contributes to weak and poorly sustained muscle contractions.
Brian's poor balance and staggering are due to reduced vestibular function. The vestibular apparatus detects head movement and position. Reduced function leads to:

- Poor detection of movement and orientation
- Weak coordination of muscle responses
- Loss of balance, especially when turning or running

His blurred vision is due to reduced visual acuity:

- Light is not properly focused on the retina
- The image of the finish line is unclear
- Poor coordination between vision and movement

This affects his ability to run accurately toward the finish.
Brian's overheating is caused by failure of temperature regulation:

- Sweating starts at a very high temperature (39.0 °C instead of 37.2 °C)
- Sweat rate is zero, so no evaporative cooling occurs

In addition, his thin arteriole walls (12 μm) reduce effective vasodilation control in the skin. This limits heat loss by radiation.

As body temperature rises:

- Enzyme activity becomes less efficient
- Muscle fatigue increases
- Nervous coordination is impaired

Brian becomes weak, loses coordination, and performs poorly especially in hot conditions.

(b)

- Train in cooler conditions or at cooler times of the day, this reduces heat gain and prevents excessive rise in body temperature.
- Use external cooling methods (e.g. cold water, cold packs after exercise), This increases heat loss and helps maintain normal enzyme and muscle function.
- Ensure proper hydration before and during training, this supports thermoregulation and helps maintain body function.
- Provide visual correction (e.g. appropriate lenses if needed), This improves focusing of images on the retina, enhancing coordination and performance.
- Balance and coordination training exercises, this help improve vestibular function and muscle coordination.
- Allow adequate rest and recovery between training sessions, this supports efficient neurotransmitter production and proper nerve function.
- Gradual conditioning and controlled training intensity, this reduces stress on the neuromuscular system and improves performance over time.

END