3.1 Acute responses, fatigue and recovery

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

KEY WORDS anticipatory rise
- arteriovenous oxygen difference
- delayed-onset muscle soreness
- stroke volume
- peripheral fatigue
- vascular shunt

Objective

Build the skills to answer exam questions on the body's **acute responses** to exercise: heart rate, stroke volume, blood pressure, blood flow and oxygen extraction; HL adds **fatigue** and **recovery** .

You must be able to:

- describe and explain changes in heart rate, stroke volume, cardiac output and blood pressure during exercise
- explain the redistribution of blood flow and the rise in oxygen extraction
- distinguish central and peripheral fatigue and explain delayed-onset muscle soreness
- evaluate recovery strategies using evidence

1 Key knowledge and worked examples

■ Acute responses to exercise

Heart rate (HR): an **anticipatory rise** before exercise (adrenaline, sympathetic system); a rapid rise at the start; then a **steady state** in submaximal exercise. After exercise it falls fast, then slowly.

Stroke volume (SV) rises with intensity and levels off at about 40–60% of maximum. **Cardiac output** $Q = \text{HR} \times \text{SV}$ rises from about 5 L min^{-1} at rest to 20–25 L min^{-1} in untrained people (more in trained athletes).

Blood pressure: in dynamic exercise (running, cycling) **systolic** pressure rises; **diastolic** pressure stays about the same. Heavy lifting raises both.

Redistribution of blood (vascular shunt): arterioles to working muscles **dilate**; arterioles to the gut and kidneys **constrict**. Muscles get about 15–20% of cardiac output at rest and up to about 80% in maximal exercise.

Oxygen extraction: the **arteriovenous oxygen difference** (a–$\bar{v}O_2$ diff) is the oxygen removed from the blood by the tissues. It rises in exercise: working muscle has a low oxygen level, higher temperature, more CO_2 and acid, so haemoglobin releases more oxygen (the **Bohr shift**), and more capillaries open.

Ventilation rises (deeper, then faster breaths); **body temperature** rises.

AHL – fatigue: a fall in the ability to produce force or power. **Central** fatigue: less drive from the brain and spinal cord. **Peripheral** fatigue: in the muscle: phosphocreatine and glycogen run low; H^+ (acidity) and phosphate build up and interfere with enzymes and calcium. **DOMS** (delayed-onset muscle soreness) follows unfamiliar or **eccentric** exercise (e.g. downhill running): small tears in fibres and inflammation; it peaks after about 24–72 hours.

AHL – recovery: aims include refuelling, rehydration, repair and lower soreness. Options: sleep, carbohydrate and protein, active recovery, cold-water immersion, massage, compression. Evaluate each by its evidence, its aim and its timing (e.g. regular cold-water immersion may reduce strength gains from training).

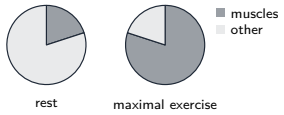
Answer shapes: describe the change with a direction and a size, then explain its cause.

2 Practice

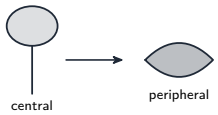
2.1 State what happens to systolic and diastolic blood pressure during a steady run. [2]



2.2 Explain how blood flow is redistributed during exercise. [3]

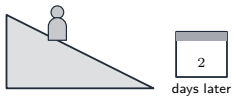


2.3 Distinguish between central and peripheral fatigue, giving **one** cause of each. [3]



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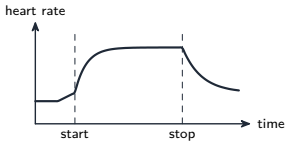
2.4 After a long downhill run, a runner's thighs are very sore two days later. Explain this. [3]



3 Exam-style questions

3.1 The graph shows a student's heart rate before, during and after a 10-minute run at a steady pace.

(a) Describe the changes in heart rate from before the run until the end of the run. [3]



(b) State what happens to heart rate when the run stops. [1]

3.2 Arterial blood holds about 20 ml O_2 per 100 ml. Venous blood leaving a muscle holds 15 ml O_2 per 100 ml at rest and 5 ml O_2 per 100 ml in hard exercise.

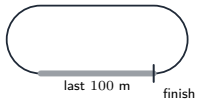
(a) Calculate the arteriovenous oxygen difference at rest and in exercise. [2]



(b) Explain why the difference increases in exercise. [3]

3.3 A 400 m runner slows down sharply in the last 100 m.

Explain **two** causes of peripheral fatigue in this race. [4]



3.4 A football team plays two matches in four days and wants to recover quickly.

Evaluate cold-water immersion and sleep as recovery strategies for the team. [6]



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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

systolic pressure rises; diastolic pressure stays about the same (or falls slightly)

2.2

arterioles supplying working muscles dilate (vasodilation); arterioles supplying the gut and kidneys constrict (vasoconstriction); so a much larger share of a larger cardiac output goes to the muscles, up to about 80%

2.3

central fatigue starts in the brain and spinal cord: less drive to the muscles, e.g. low motivation, changes in brain chemicals, high core temperature; peripheral fatigue happens in the muscle itself; e.g. phosphocreatine or glycogen depletion, build-up of H^+ or phosphate

2.4

downhill running uses many eccentric contractions of the quadriceps; these cause small tears in muscle fibres and connective tissue; inflammation follows and soreness (DOMS) peaks about 24–72 hours later

3.1

(a) heart rate rises slightly before the start (anticipatory rise); it rises quickly in the first minutes; then it levels off at a steady state

(b) it falls quickly at first and then more slowly back towards resting level

3.2

(a) rest: $20 - 15 = \mathbf{5}$ ml per 100 ml; exercise: $20 - 5 = \mathbf{15}$ ml per 100 ml

(b) working muscles use more oxygen, so the oxygen level in the muscle falls and the gradient rises; higher temperature, CO_2 and acidity make haemoglobin release more oxygen (Bohr shift); more capillaries open, giving more surface area and slower flow past the fibres

3.3

any two causes, each [2]: H^+ builds up from anaerobic glycolysis, lowering pH, which slows enzymes and interferes with calcium and the contraction process; phosphocreatine runs out, so ATP cannot be resynthesized fast enough; inorganic phosphate builds up, which reduces the force of cross-bridges

3.4

award up to [6]: cold-water immersion: reduces perceived soreness and swelling, and feels good, so useful between close matches; but evidence for faster recovery of performance is mixed, and regular use may reduce strength and muscle gains from training; sleep: needed for muscle repair, hormone release and mental recovery; poor sleep lowers performance and raises injury and illness risk; conclusion: prioritize sleep for everyone, use cold water selectively in congested match periods

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