2.3 Energy systems

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS ATP–PC system • anaerobic glycolysis • aerobic system • energy continuum • running economy • EPOC

Objective

Build the skills to answer exam questions on **energy systems** : how ATP is resynthesized by the **ATP–PC** , **anaerobic glycolysis** and **aerobic** systems, the energy continuum, $\dot{V}O_2$max and running economy.

You must be able to:

- explain why ATP must be resynthesized and describe the three energy systems
- relate energy systems to the duration and intensity of activities
- calculate percentage of maximum oxygen uptake and compare economy
- explain lactate production and removal, and oxygen recovery after exercise

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1 Key knowledge and worked examples

Energy systems

Muscles use **ATP** for contraction, but they store only enough for a few seconds. ATP is constantly **resynthesized** by three systems that work together; the one that **dominates** depends on intensity and duration.

system	fuel	where	speed of ATP supply	dominant in	by-products
ATP–PC	phosphocreatine (PC)	cytoplasm	fastest	up to about 10 s, maximal (100 m, jump)	none harmful
anaerobic glycolysis	glucose or glycogen	cytoplasm	fast	about 10 s to 2 min (400 m)	**lactate** and H^+ (acidity)
aerobic	glucose, fats (and some protein)	**mitochondria**	slow	over about 2 min (10 km, marathon)	CO_2 and water

Anaerobic glycolysis gives 2 ATP per glucose; full aerobic breakdown gives about 30–32. At low intensity more **fat** is used; as intensity rises, more **carbohydrate** is used.

Energy continuum: all systems work at the same time; their shares change with time. Aerobic and anaerobic supply are about equal at about 1–2 minutes of maximal exercise.

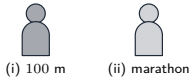
$\dot{V}O_2$max is the maximum rate of oxygen uptake (ml kg^{-1} min^{-1}). **Movement economy** is the oxygen cost of moving at a given speed: a more economical runner uses a smaller **percentage** of $\dot{V}O_2$max at the same speed.

AHL – lactate: lactate is always made and removed (used as fuel by the heart and slow fibres, or turned back into glucose in the liver). Above the **lactate threshold**, production is faster than removal, so blood lactate rises sharply. **EPOC** (excess post-exercise oxygen consumption): a **fast** component (first few minutes: restore PC and oxygen in myoglobin) and a **slow** component (removal of lactate, high temperature, heart rate and breathing).

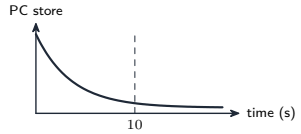
Answer shapes: name the system, its fuel, how fast it works and how long it lasts.

2 Practice

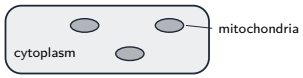
2.1 Identify the energy system that supplies most of the ATP in (i) a 100 m sprint and (ii) a marathon. [2]



2.2 Explain why the ATP–PC system can supply energy for only about 10 seconds of maximal work. [3]



2.3 Compare anaerobic glycolysis with the aerobic system. [3]

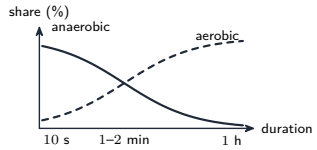


3 Exam-style questions

3.1 The graph shows the share of energy from aerobic and anaerobic systems in maximal exercise of different durations.

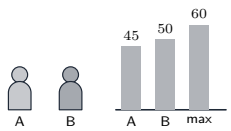
(a) Estimate the duration when the two shares are equal. [1]

(b) Explain why all three energy systems contribute in an 800 m race (about 2 minutes). [3]



3.2 Two runners both have a $\dot{V}O_2max$ of 60 ml kg^{-1} min^{-1}. At 16 km h^{-1}, runner A uses 45 ml kg^{-1} min^{-1} and runner B uses 50 ml kg^{-1} min^{-1}.

(a) Calculate the percentage of $\dot{V}O_2max$ each runner uses at this speed. [2]



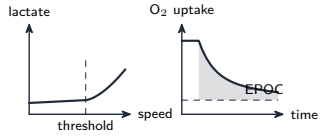
(b) Explain which runner is likely to run faster in a 10 km race. [2]

(c) Suggest **two** factors that improve running economy. [2]

3.3 Blood lactate is measured as running speed increases, and oxygen uptake is measured after the run.

(a) Explain why blood lactate rises sharply above a certain speed. [2]

(b) Describe the fast and slow components of excess post-exercise oxygen consumption (EPOC). [4]



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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

(i) ATP–PC system; (ii) aerobic system

2.2

muscles store only a small amount of phosphocreatine; in maximal work it is used very quickly to resynthesize ATP, so it runs out in about 10 s; rebuilding PC needs energy from the aerobic system during recovery, which takes minutes

2.3

anaerobic glycolysis does not need oxygen and happens in the cytoplasm; the aerobic system needs oxygen and happens mainly in mitochondria; anaerobic glycolysis supplies ATP faster but yields only 2 ATP per glucose; aerobic yields about 30 or more; anaerobic produces lactate (and acidity); aerobic produces CO_2 and water and can also use fat

3.1

(a) about 1–2 minutes (accept 60–120 s)

(b) the ATP–PC system supplies ATP in the first seconds, at the start and in the final sprint; anaerobic glycolysis supplies much ATP at high intensity in the middle of the race, producing lactate; the aerobic system rises as oxygen supply increases and gives about half the energy over two minutes

3.2

(a) A: $45 \div 60 \times 100 = \mathbf{75}\%$; B: $50 \div 60 \times 100 \approx \mathbf{83}\%$

(b) runner A, because A is more economical; A works at a lower percentage of maximum at the same speed, so A can sustain a higher speed before fatigue

(c) any two: good technique (less vertical bounce); strength and plyometric training (stiffer tendons); lighter shoes or body mass; experience and training volume

3.3

(a) above the lactate threshold, lactate is produced faster than it is removed; because more fast-twitch fibres are recruited and glycolysis is faster than the aerobic system can use pyruvate

(b) fast component: lasts a few minutes; restores phosphocreatine and re-oxygenates myoglobin; slow component: can last much longer; used for removing lactate, and for raised body temperature, heart rate, breathing and hormone levels

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