1.10 Biology: Energy Transfers in Organisms: Test Pack

AQA 7402 · Calculator allowed · about 35 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 When oxygen is not available, or is in short supply, cells can still generate a limited amount of ATP anaerobically by regenerating oxidised NAD without using the electron transport chain.

(a) Describe what happens to pyruvate during lactate fermentation in mammalian muscle cells, and explain why this reaction is essential for glycolysis to continue in the absence of oxygen. **(3)**

(b) Write balanced equations, using names or formulae and including state symbols, for the conversion of pyruvate to ethanol in yeast during anaerobic respiration, including the coenzyme involved. **(3)**

(c) Explain why anaerobic respiration releases far less ATP per glucose molecule than aerobic respiration. **(2)**

(Total for Question 1 is 8 marks)

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2 Chloroplasts and mitochondria are both double membrane-bound organelles central to energy transfer in eukaryotic cells. Both contain a fluid interior (the stroma in a chloroplast, the matrix in a mitochondrion) and an extensively folded internal membrane system, across which most ATP synthesis occurs.

(a) State two structural features that chloroplasts and mitochondria have in common, and for each feature explain how it contributes to the organelle's role in energy transfer. **(4)**

(b) The stroma of the chloroplast and the matrix of the mitochondrion each contain a small, circular DNA molecule and 70S ribosomes, both of which resemble structures found in free-living prokaryotes. Suggest why this evidence supports the endosymbiotic theory of the origin of these organelles. **(2)**

(c) Explain why the inner mitochondrial membrane is highly folded into cristae. **(2)**

(Total for Question 2 is 8 marks)

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3 Aerobic respiration of one mole of glucose theoretically releases 2880 kJ of energy. The hydrolysis of one mole of ATP to ADP and Pi releases approximately 30.5 kJ of energy under cellular conditions.

(a) Using the maximum theoretical yield of 32 ATP molecules per glucose molecule, calculate the total amount of energy transferred to ATP per mole of glucose respired. **(2)**

(b) Calculate the percentage efficiency of energy transfer from glucose to ATP, to 3 significant figures. **(2)**

(c) State what happens to the energy from glucose that is not transferred to ATP. **(1)**

(d) Mr Osei, a tutor, claims: 'Since only about a third of the energy in glucose is captured in ATP, aerobic respiration is an inefficient and wasteful process that evolution has failed to optimise.' Evaluate this claim. **(3)**

(Total for Question 3 is 8 marks)

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Mark scheme · 1.10 Biology: Energy Transfers in Organisms: Test Pack

Question 1

(a) pyruvate is reduced to lactate, using reduced NAD (which is oxidised back to NAD in the process); catalysed by lactate dehydrogenase: pyruvate(aq) + reduced NAD(aq) -> lactate(aq) + NAD(aq) **B1**

(a) this regenerates oxidised NAD, which is required as a coenzyme (hydrogen acceptor) in an earlier step of glycolysis **B1**

(a) without regenerating oxidised NAD, glycolysis (and therefore net ATP production by substrate-level phosphorylation) would stop, since no NAD would be available to accept hydrogen atoms in that step **B1**

(a) Answer: Pyruvate + reduced NAD -> lactate + NAD; regenerating NAD allows glycolysis, and its ATP production, to continue without oxygen.

(b) decarboxylation: pyruvate(aq) -> ethanal(aq) + CO_2(g), catalysed by pyruvate decarboxylase **B1**

(b) reduction: ethanal(aq) + reduced NAD(aq) -> ethanol(aq) + NAD(aq), catalysed by ethanol dehydrogenase **B1**

(b) correctly shows that reduced NAD is reoxidised to NAD, regenerating the coenzyme needed for glycolysis to continue **B1**

(b) Answer: Pyruvate(aq) -> ethanal(aq) + CO_2(g); ethanal(aq) + reduced NAD(aq) -> ethanol(aq) + NAD(aq).

(c) in anaerobic respiration only glycolysis proceeds, yielding a net 2 ATP per glucose by substrate-level phosphorylation, because the reduced NAD produced is reoxidised by reducing pyruvate (or ethanal) rather than by passing electrons through the electron transport chain **B1**

(c) the link reaction, Krebs cycle and oxidative phosphorylation, which together yield the great majority of ATP (around 30 further molecules), cannot occur without oxygen as the final electron acceptor, so most of the energy in glucose remains locked in lactate or ethanol rather than being transferred to ATP **B1**

(c) Answer: Only glycolysis (net 2 ATP) occurs anaerobically; the Krebs cycle and oxidative phosphorylation, which yield most of the ATP, require oxygen and cannot proceed.

Question 2

(a) feature 1: a highly folded internal membrane (cristae in the mitochondrion / thylakoid membranes stacked as grana in the chloroplast) **B1**

(a) explanation: this greatly increases the surface area available for electron transport chain proteins and ATP synthase, increasing the rate of chemiosmosis / ATP production **B1**

(a) feature 2: a fluid interior compartment (matrix / stroma) containing enzymes in solution **B1**

(a) explanation: this houses the enzymes for the link reaction and Krebs cycle (matrix) or the Calvin cycle (stroma), keeping the substrates and enzymes concentrated together, separate from the cytoplasm **B1**

(a) Answer: Folded inner membrane (cristae/thylakoids) increases surface area for electron carriers and ATP synthase; fluid matrix/stroma contains the enzymes for the Krebs cycle or Calvin cycle respectively.

(b) circular (naked) DNA and 70S ribosomes are characteristic of (free-living) prokaryotic cells, not of the (linear DNA, 80S ribosome) eukaryotic host cell **B1**

(b) this suggests mitochondria and chloroplasts originated as free-living prokaryotes that were engulfed by, and entered a mutualistic relationship with, an ancestral host cell (endosymbiosis), rather than evolving from within the host cell itself **B1**

(b) Answer: The prokaryote-like DNA and ribosomes suggest these organelles were once free-living prokaryotes engulfed by an ancestral host cell.

(c) cristae increase the surface area of the inner mitochondrial membrane **B1**

(c) allowing more electron transport chain carriers and ATP synthase molecules to be present, increasing the rate of oxidative phosphorylation / ATP synthesis **B1**

(c) Answer: Cristae increase inner membrane surface area, allowing more electron carriers and ATP synthase, increasing the rate of ATP production.

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Question 3

(a) correct method: multiplies 32 by 30.5 (ecf from Q9(b) if a different ATP yield was calculated there) **M1**

(a) 976 kJ mol^{-1} cao **A1**

(a) Answer: 976 kJ mol^{-1}.

(b) correct method: (energy transferred to ATP / total energy in glucose) * 100, ecf from part (a) **M1**

(b) 33.9% awrt, ecf from part (a) **A1**

(b) Answer: 33.9%.

(c) it is released as heat, since the chemical reactions of respiration are not 100% efficient at transferring energy; this heat can contribute to maintaining a constant body temperature in endotherms **B1**

(c) Answer: It is released as heat.

(d) the claim is only partly justified: although around a third of the energy is transferred directly to ATP, the remaining heat is not necessarily wasted, as it is essential for maintaining a constant, high body temperature in endotherms (mammals and birds), which supports enzyme activity **B1**

(d) an efficiency of around 34% is actually relatively high compared with many energy-conversion processes (e.g. combustion engines are typically only around 20-30% efficient), so aerobic respiration is comparatively efficient at capturing usable chemical energy **B1**

(d) natural selection optimises processes for reproductive fitness/survival, not necessarily for maximum thermodynamic efficiency; heat loss may itself be an adaptive trait (e.g. in thermoregulation) rather than a failure of evolution, so the claim's assumption that 'inefficiency' equates to an evolutionary failure is not fully justified **B1**

(d) Answer: The claim is only partly justified: the 'lost' energy is often useful as metabolic heat, and around 34% is high relative to many energy-conversion processes; evolution optimises for fitness, not maximum thermodynamic efficiency.

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