Past-paper walk-through

Origins of Life on Earth ▪ 7.12

eXercise

Questions in this set

- 2015 Q2

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

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[Figure 1. Glycolysis and pyruvate oxidation: Glucose (chain of 6 circles) reacts with 2 ADP + 2 Pi and 2 NAD^+ to yield 2 ATP, 2 NADH, and 2 Pyruvate (chain of 3 circles). The 2 Pyruvate are converted to 2 CO_2, 2 NADH, and 2 Acetyl-CoA (chain of 2 circles).]
[Figure 2. Krebs cycle: 2 Acetyl-CoA (2 circles) enters a cycle; 2 OAA (4 circles) combines with it going into the cycle, producing 2 TCA (6 circles) coming out. Around the cycle: inputs 2 NADH and 2 $FADH_2$ feed in; outputs are 2 CO_2, 2 NADH (first turn), 2 GTP (bottom), and 2 CO_2, 2 NADH (second turn).]
[Figure 3. Electron transport chain: A membrane diagram showing Complex I, Complex II, Complex III, and Complex IV embedded in a phospholipid bilayer. NADH and NAD^+ enter at Complex I; 2 electrons ($2e^-$) pass from Complex I and Complex II to Complex III, then to Complex IV. H^+ ions are pumped across the membrane at

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Complex I, Complex III, and Complex IV (shown by upward H^+ arrows). At Complex IV, $\frac{1}{2}O_2$ combines (with H^+) to form H_2O.]

Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

(a) Using the information above, **describe** ONE contribution of <u>each</u> of the following in ATP synthesis.

- Catabolism of glucose in glycolysis and pyruvate oxidation - Oxidation of intermediates in the Krebs cycle - Formation of a proton gradient by the electron transport chain

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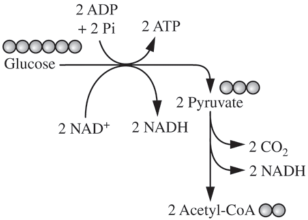


Figure 1. Glycolysis and pyruvate oxidation

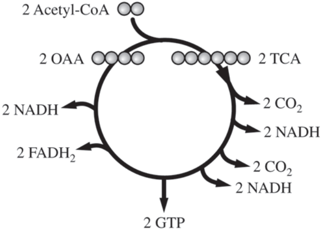
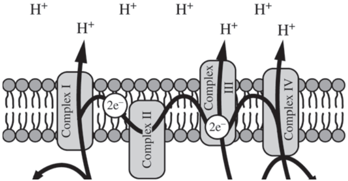


Figure 2. Krebs cycle



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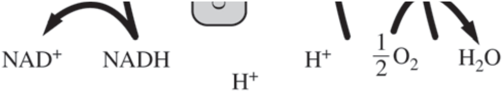

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(b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

- Nearly all existing organisms perform glycolysis.
- Glycolysis occurs under anaerobic conditions.
- Glycolysis occurs only in the cytosol.

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(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

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(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.

Solution 2

(a) Mark scheme

- 1 point per box, max 3 points. Catabolism of glucose in glycolysis and pyruvate oxidation: produces NADH for use in the electron transport chain (ETC), produces acetyl-CoA for entry into the Krebs cycle, and provides energy for substrate-level phosphorylation of ADP. Oxidation of intermediates in the Krebs cycle: produces NADH or FADH2 for use in the ETC, releases high-energy electrons for the ETC, provides energy to pump protons against their concentration gradient, and produces GTP via substrate-level phosphorylation of ADP. Formation of a proton gradient by the electron transport chain: the flow of protons through membrane-bound ATP synthase generates ATP, providing energy for oxidative phosphorylation of ADP.

Solution 2

(b) Mark scheme

- 1 point per box, max 3 points. Nearly all existing organisms perform glycolysis: the trait/gene/process originated early and was inherited/passed down/highly conserved because glycolysis provided a selective advantage passed on to descendants. Glycolysis occurs under anaerobic conditions: the origin of glycolysis pre-dates free atmospheric oxygen/photosynthesis. Glycolysis occurs only in the cytosol: the origin of glycolysis pre-dates cell types with membrane-bound organelles/eukaryotes/endosymbiosis. Each observation is used to justify that glycolysis is ancient enough to trace to a common ancestor of all life.

Solution 2

(c)

Mark scheme

- 1 point per box, max 3 points. Calculate available energy in ATP: 30 mol ATP $\times$ 7.3 kcal/mol $=$ 219 kcal. Calculate efficiency: 219 kcal / 686 kcal 0.31–0.32, i.e., 31–32%. Describe fate of excess energy: the remaining energy ($686 - 219$ 467 kcal) not captured in ATP is released as heat, which increases entropy.

Solution 2

(d)

Mark scheme

- 1 point for any valid, testable scientific question connecting the subcellular location of Krebs-cycle enzymes to the evolution of eukaryotes, e.g.: 'Since the Krebs cycle occurs in the "cytoplasm" of the mitochondria (the matrix), does this suggest that mitochondria were once free-living prokaryotes (i.e., arose via endosymbiosis)?' Any comparable question linking enzyme location to eukaryotic organelle origin earns the point.