InkBiology

ANSWER BOOK

# The Krebs cycle and oxidative phosphorylation

Respiration and cellular energy · Unit B12

AQA 3.5.2 · OCR A 5.2.2 · Edexcel A Topic 7.4–7.5 · CAIE 12.2

6 questions · 23 marks

NAVY EDITION


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## SECTION A · Short, 1 to 2 marks

**A1** **B1** one turn gives two molecules of carbon dioxide and one molecule of ATP. **B1** one turn also gives three reduced NAD and one reduced FAD, and the cycle turns twice per molecule of glucose. [2]

## SECTION B · Standard, 3 to 5 marks

**B1** **B1** reduced NAD is oxidised at the first carrier of the chain, handing over its electrons and releasing its protons into solution. **B1** the electrons pass from carrier to carrier along the inner membrane, releasing energy at each transfer because each carrier holds them a little less tightly than the one before. **B1** that energy is used to pump protons out of the matrix into the intermembrane space, and since the membrane is impermeable to protons an electrochemical gradient builds across it. **B1** protons return to the matrix down that gradient through the channel in ATP synthase, and the flow drives the enzyme to join ADP and inorganic phosphate into ATP, which is chemiosmosis. **B1** oxygen acts as the final electron acceptor at the end of the chain, taking up electrons and combining with protons to form water, so electrons do not pile up and the chain keeps running. [5]

**B2** **B1** the two-carbon acetyl group is transferred from coenzyme A onto the four-carbon acceptor oxaloacetate, giving the six-carbon compound citrate, and coenzyme A leaves at once to collect another acetyl group. **B1** citrate is decarboxylated and dehydrogenated to a five-carbon compound, and again to a four-carbon compound, so two molecules of carbon dioxide are released per turn. **B1** a series of further changes regenerates oxaloacetate, so the acceptor ends the turn exactly as it began it and the cycle can turn again. **B1** six carbons are present at the start of the turn, two leave as carbon dioxide, and the four handed back are the four the cycle borrowed, so the two carbons released are the two that arrived on the acetyl group. [4]

**B3** **M1** multiply each coenzyme by its ratio and add the ATP made directly by substrate-level phosphorylation. **M1** 10 × 3 = 30 from reduced NAD and 2 × 2 = 4 from reduced FAD, plus the 4 made directly. **A1** a theoretical total of 30 + 4 + 4 = 38 ATP per molecule of glucose. **A1** with the better ratios, 10 × 2.5 = 25 and 2 × 1.5 = 3, giving 25 + 3 + 4 = 32 ATP per molecule of glucose. [4]

**B4** **B1** the ratios of 3 ATP per reduced NAD and 2 per reduced FAD are round numbers chosen for convenience rather than measured values, and using the nearer figures of 2.5 and 1.5 brings the theoretical total down to 32. **B1** the reduced NAD made by glycolysis is in the cytoplasm and cannot cross the inner membrane, so its hydrogen is carried in by a shuttle that costs part of the gradient, and in some tissues delivers to FAD rather than to NAD. **B1** the inner membrane leaks, so some protons find their way back into the matrix without passing through ATP synthase, and their energy is not captured as ATP. **B1** the gradient is not reserved for ATP synthesis alone: it also drives the transport of pyruvate, phosphate and calcium ions into the matrix, and in brown adipose tissue it is deliberately short-circuited to make heat. [4]

**B5** **B1** protons can no longer return to the matrix through ATP synthase, so they accumulate in the intermembrane space and the gradient across the membrane becomes steeper. **B1** ATP production by oxidative phosphorylation stops, because there is no flow of protons through the enzyme to drive it. **B1** pumping further protons against an ever steeper gradient needs more energy than the transfers can supply, so electron transport slows and then stops. **B1** with few electrons reaching the end of the chain, little oxygen is needed as the final electron acceptor, so oxygen consumption falls even though the carriers themselves are untouched. [4]