GENERAL

ap bio cellular respiration study guide

Published: September 19, 2026 | Index ID: #-

Introduction

In the AP Biology curriculum, cellular respiration is one of the most frequently tested topics. The process by which cells convert glucose into usable energy—ATP—is foundational to understanding metabolism, evolutionary adaptation, and the intricacies of biochemical pathways. Whether you're a first year student tackling the AP exam for the first time or a seasoned reviewer polishing your knowledge, this comprehensive study guide will help you master the key concepts, mechanisms, and common exam questions surrounding cellular respiration. By the end of this article, you'll be equipped to explain the stages of respiration, calculate ATP yields, identify regulatory checkpoints, and confidently approach multiple choice, diagram, and short answer questions on the AP exam.

Understanding Cellular Respiration in AP Biology

Key Concepts and Terminology

Before diving into the pathways, it's essential to clarify the terminology that frequently appears on AP Biology exams:

- ATP (Adenosine Triphosphate) – the universal energy currency of the cell.
- Electron Transport Chain (ETC) – a series of protein complexes that transfer electrons and pump protons to create a gradient.
- Oxidative Phosphorylation – the process of producing ATP using the proton motive force generated by the ETC.
- Fermentation – an anaerobic process that regenerates NAD z, allowing glycolysis to continue.
- Substrate Level Phosphorylation – the direct transfer of a phosphate group to ADP, forming ATP during glycolysis and the Krebs cycle.

Why It Matters for AP Exams

AP Biology emphasizes the integration of structure, function, and regulation. Cellular respiration exemplifies this by linking molecular events to whole organism outcomes. The exam often asks students to:

- Explain the flow of electrons and the role of oxygen.
- Compare and contrast aerobic vs. anaerobic pathways.
- Calculate ATP yields from different metabolic states.
- Illustrate feedback inhibition and allosteric regulation.

Mastering these aspects not only boosts your score but also deepens your understanding of cellular energetics.

Cellular Respiration Overview

Photosynthesis vs Respiration

While photosynthesis captures light energy to produce glucose, cellular respiration breaks down glucose to release energy. Both processes are linked via the carbon cycle: glucose produced in photosynthesis is the substrate for respiration, and the oxygen produced in photosynthesis is the final electron acceptor in respiration.

Glucose Breakdown Pathways

Cellular respiration consists of four sequential stages:

1. Glycolysis – cytoplasmic cleavage of glucose into two pyruvate molecules.
2. Link Reaction – conversion of pyruvate into acetyl CoA.
3. Citric Acid Cycle (Krebs Cycle) – cyclic oxidation of acetyl CoA.
4. Oxidative Phosphorylation – electron transport and ATP synthesis.

ATP Yield Table

Below is a concise summary of ATP production per glucose molecule under aerobic conditions. (All figures are rounded to the nearest whole number.)

Stage	ATP (substrate level)	ATP (oxidative phosphorylation)	Net ATP
Glycolysis	2	2–4 (depending on shuttle)	4–6
Link Reaction	0	0	0
Krebs Cycle	2	18–20	20–22
Total (aerobic)	4	20–24	24–28

For anaerobic fermentation, the net ATP yield is only 2 per glucose.

Glycolysis

Location & Stages

Glycolysis takes place in the cytosol and is a ten step process that can be broken into two phases:

1. Energy Investment Phase – uses 2 ATP to phosphorylate glucose and its intermediates.
2. Energy Payoff Phase – generates 4 ATP and 2 NADH.

Energy Investment and Payoff

During the investment phase, glucose is first phosphorylated to glucose 6 phosphate (G6P) by hexokinase. The second ATP is used to form fructose 1,6 bisphosphate (F1,6BP) via phosphofructokinase 1 (PFK 1). The payoff phase splits the six carbon sugar into two three carbon molecules (glyceraldehyde 3 phosphate), each yielding 2 ATP (via substrate level phosphorylation) and 1 NADH (via glyceraldehyde 3 phosphate dehydrogenase). Summing these gives a net gain of 2 ATP and 2 NADH per glucose.

Regulation Points

Glycolysis is tightly regulated at three key points:

- Hexokinase – inhibited by its product, G6P.
- Phosphofructokinase 1 (PFK 1) – activated by AMP and fructose 2,6 bisphosphate; inhibited by ATP and citrate.
- Pyruvate kinase – activated by fructose 1,6 bisphosphate; inhibited by ATP and alanine.

These allosteric sites allow the cell to modulate flux based on energy status and metabolic demands.

Link Reaction

Pyruvate Oxidation

In aerobic respiration, pyruvate is transported into the mitochondrion where it is decarboxylated by the pyruvate dehydrogenase complex (PDC) to form acetyl CoA. This reaction also produces NADH and releases CO ,.

Acetyl CoA Formation

Acetyl CoA enters the Krebs cycle, linking glycolysis to oxidative phosphorylation. The NADH generated here feeds electrons into the ETC, contributing to ATP synthesis.

Citric Acid Cycle (Krebs Cycle)

Steps & Enzymes

The Krebs cycle is a cyclic series of eight enzymatic reactions that oxidize acetyl CoA to CO , and produce high energy carriers. Key enzymes include:

- Citrate synthase – condensation of acetyl CoA with oxaloacetate.
- Aconitase – isomerization of citrate to isocitrate.
- Isocitrate dehydrogenase – oxidative decarboxylation producing NADH.
- Alpha ketoglutarate dehydrogenase – another oxidative decarboxylation step.
- Succinyl CoA synthetase – generates GTP (or ATP).
- Succinate dehydrogenase – feeds electrons into the ETC.
- Malate dehydrogenase – regenerates oxaloacetate.

Energy Carriers

Each turn of the cycle yields:

- 3 NADH
- 1 FADH , (via succinate dehydrogenase)
- 1 GTP (converted to ATP)

Since two acetyl CoA molecules arise per glucose, the total per glucose is 6 NADH, 2 FADH ,, and 2 GTP.

Regulation & Feedback

The cycle is regulated primarily at the following checkpoints:

- Isocitrate dehydrogenase – inhibited by ATP, NADH, and citrate; activated by ADP and Ca^{2} z.
- Alpha ketoglutarate dehydrogenase – similar regulation.
- Malate dehydrogenase – sensitive to NADH/NAD z ratio.

These controls ensure that the Krebs cycle operates in harmony with the cell's energetic needs.

Oxidative Phosphorylation

Electron Transport Chain

The ETC consists of four multi protein complexes embedded in the inner mitochondrial membrane:

1. Complex I (NADH dehydrogenase) – accepts electrons from NADH.
2. Complex II (succinate dehydrogenase) – accepts electrons from FADH ,.
3. Complex III (cytochrome bc • complex) – transfers electrons to cytochrome c.
4. Complex IV (cytochrome c oxidase) – reduces O , to H ,O.

Protons are pumped from the matrix to the intermembrane space at complexes I, III, and IV, establishing a proton gradient.

Proton Motive Force & Chemiosmosis

The proton gradient generates two forces:

- Electrochemical (9CÈ) – electrical potential difference.
- Chemical (9G ,' b , F–f`erence between compartments.

Together, they constitute the proton motive force (9G 'à Protons flow back into the matrix via ATP synthase, driving the synthesis of ATP from ADP and inorganic phosphate.

ATP Synthase Mechanism

ATP synthase (Complex V) is a rotary motor. As protons pass through the F € subunit, the F • catalytic domain rotates,

facilitating the phosphorylation of ADP to ATP. The overall efficiency of oxidative phosphorylation is approximately 3 ATP per NADH and 2 ATP per FADH ,.

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