GENERAL

ap biology chapter 6 notes

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Ap Biology Chapter 6 Notes: Mastering Cellular Respiration and Energy Conversion

Welcome to your definitive guide to **AP Biology Chapter 6**, where we dive deep into the intricacies of cellular respiration, the processes that sustain life, and the molecular machinery that turns food into energy. Whether you're a high school student preparing for the AP exam, a biology teacher looking for concise yet thorough teaching materials, or a curious learner wanting to understand how cells generate ATP, this article will provide clear, organized, and comprehensive notes that align with the AP curriculum.

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1. Introduction to Cellular Respiration

Cellular respiration is the set of metabolic pathways that convert biochemical energy from nutrients into adenosine triphosphate (ATP), and then release waste products. It is a cornerstone concept in AP Biology, linking genetics, biochemistry, and physiology. Understanding how cells harness energy is essential for grasping topics such as photosynthesis, enzyme regulation, and the impact of genetic mutations on metabolic pathways.

The process is divided into three main stages:

1. Glycolysis – Cytoplasmic breakdown of glucose into pyruvate.
2. Citric Acid Cycle (Krebs Cycle) – Mitochondrial matrix reactions producing electron carriers.
3. Oxidative Phosphorylation – Electron Transport Chain (ETC) and chemiosmosis generating the bulk of ATP.

In addition to aerobic respiration, cells can also undergo anaerobic pathways such as fermentation, which are crucial under low oxygen conditions.

2. Glycolysis: The First Step

2.1 Overview

Glycolysis is a ten enzyme pathway that splits one glucose molecule (6 carbons) into two molecules of pyruvate (3 carbons each). It occurs in the cytoplasm and is independent of oxygen, making it the first step in both aerobic and anaerobic respiration.

2.2 Energy Investment vs. Energy Payoff

- Investment Phase – 2 ATP molecules are consumed in the phosphorylation of glucose and fructose 6 phosphate.
- Payoff Phase – 4 ATP molecules are produced via substrate level phosphorylation, and 2 NADH are generated.

Net yield: **2 ATP + 2 NADH + 2 pyruvate**.

2.3 Key Enzymes and Regulation

1. Hexokinase / Glucokinase – Phosphorylation of glucose; inhibited by ATP.
2. PFK 1 (Phosphofructokinase 1) – Rate limiting enzyme; activated by AMP, fructose 2,6 bisphosphate; inhibited by ATP and citrate.
3. Pyruvate kinase – Catalyzes final step; allosterically regulated by ATP and alanine.

These control points ensure that glycolysis matches the cell’s energy demands and substrate availability.

3. Link Reaction (Pyruvate Oxidation)

3.1 Transition from Cytoplasm to Mitochondria

Pyruvate produced in glycolysis is transported into the mitochondrial matrix, where it undergoes oxidative decarboxylation to form acetyl CoA.

3.2 Enzymatic Complex: Pyruvate Dehydrogenase

- Multi enzyme complex that removes a carbon as CO ,.
- Produces NADH and attaches the remaining two carbons to Coenzyme A.
- Regulated by phosphorylation (inactivated) and acetyl CoA/ NADH (negative feedback).

Net: **1 CO , + 1 NADH + 1 acetyl CoA per pyruvate**

4. The Citric Acid Cycle (Krebs Cycle)

4.1 Cycle Overview

The citric acid cycle is a series of enzymatic reactions in the mitochondrial matrix that oxidizes acetyl CoA to CO ,, generating high energy electron carriers.

4.2 Reaction Steps and Key Enzymes

1. Citrate synthase – Condenses acetyl CoA and oxaloacetate to citrate.
2. Aconitase – Isomerizes citrate to isocitrate.
3. Isocitrate dehydrogenase – Oxidative decarboxylation to ; °etoglutarate, producing NADH.
4. ; °etoglutarate dehydrogenase – Produces succinyl CoA and NADH.
5. Succinyl CoA synthetase – Substrate level phosphorylation of GDP to GTP.
6. Succinate dehydrogenase – Oxidizes succinate to fumarate, generating FADH ,.
7. Fumarase – Hydrates fumarate to malate.
8. Malate dehydrogenase – Oxidizes malate to oxaloacetate, producing NADH.

Net per acetyl CoA**3 NADH, 1 FADH ,, 1 GTP (ATP), 2 CO ,**

4.3 Regulation of the Cycle

- Allosteric activators: ADP, Ca^{2} z, ATP.
- Allosteric inhibitors: ATP, NADH, citrate.
- Transcriptional control via PPARs and SREBP 1c for fatty acid oxidation integration.

5. Oxidative Phosphorylation: Electron Transport Chain & Chemiosmosis

5.1 Electron Transport Chain (ETC) Complexes

1. Complex I (NADH Q oxidoreductase) – Transfers electrons from NADH to ubiquinone.
2. Complex II (Succinate Q oxidoreductase) – Transfers electrons from FADH , to ubiquinone.
3. Ubiquinone (Coenzyme Q) – Mobile electron carrier.
4. Complex III (Cytochrome bc • complex) – Transfers electrons to cytochrome c.
5. Cytochrome c – Shuttles electrons to Complex IV.
6. Complex IV (Cytochrome c oxidase) – Reduces O , to H ,O.

Protons are pumped from the matrix to the intermembrane space by Complexes I, III, and IV, generating a proton gradient.

5.2 Chemiosmosis & ATP Synthase

The proton motive force drives ATP synthesis via ATP synthase (Complex V). The flow of protons down the gradient returns them to the matrix, causing the rotation of the F € subunit and phosphorylation of ADP to ATP in the F • subunit.

5.3 Energy Yield

- Each NADH yields ~2.5 ATP.
- Each FADH , yields ~1.5 ATP.
- Net ATP per glucose: ~30–32 ATP (including substrate level phosphorylation).

6. Anaerobic Respiration and Fermentation

6.1 Glycolysis Re Use

When oxygen is limited, cells rely on fermentation to regenerate NAD z from NADH, allowing glycolysis to continue.

6.2 Types of Fermentation

- Lactic Acid Fermentation – Pyruvate + NADH !' lactate + NAD z; occurs in muscle cells and some bacteria.
- Alcoholic Fermentation – Pyruvate !' acetaldehyde !' ethanol + CO , + NAD z; occurs in yeast and some plants.

6.3 Energy Yield

Net yield: 2 ATP per glucose (substrate level phosphorylation). No NADH or FADH , produced.

7. Energy Yield and Efficiency

Understanding the stoichiometry of cellular respiration is essential for comparing metabolic efficiencies across organisms and conditions.

- ATP from Glycolysis – 2 ATP (net), 2 NADH.
- ATP from Citric Acid Cycle – 6 NADH, 2 FADH ,, 2 GTP.
- ATP from Oxidative Phosphorylation – 30–32 ATP (depending on shuttle systems).

Key factors influencing yield:

1. Shuttle systems (malate-aspartate vs glycerol-3-phosphate).

2. Proton leak and uncoupling proteins.
3. Cell type and metabolic state.

8. Regulation of Cellular Respiration

8.1 Hormonal Control

- Insulin – Stimulates glucose uptake and glycolysis.
- Glucagon & Epinephrine – Promote glycogenolysis and gluconeogenesis.

8.2 Feedback Inhibition

High ATP, NADH, and citrate levels inhibit key enzymes (hexokinase, PFK 1, pyruvate kinase) to prevent wasteful energy production.

8.3 Genetic Regulation

Transcription factors such as PGC 1; upregulate mitochondrial biogenesis during endurance training, increasing oxidative capacity.

9. Integration with Photosynthesis

While photosynthesis occurs in chloroplasts of plant cells, it is the counterpart of cellular respiration, producing glucose that is later oxidized for energy. The interplay between these processes is crucial for ecosystem energy flow.

- Photosynthesis produces O , !' electron acceptor for ETC.
- Glucose produced by photosynthesis is used in respiration by both plants (cyclic pathways) and animals.

In the context of AP Biology, understanding this balance is vital for answering questions on plant physiology and ecological cycles.

10. Study Tips & Practice Questions

10.1 Effective Note Taking Strategies

- Use flowcharts to map pathway sequences.
- Highlight regulatory points and their allosteric effectors.
- Include tables summarizing ATP yields per substrate.

10.2 Practice Questions

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