AP Biology Unit 3 – Cellular Energetics Study Guide & Key Concepts

(Prepared by Refresh Kid – Clear Notes, Key Concepts, and Practice Questions for AP Biology Exam Prep)

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1. Introduction to Unit 3

Unit 3 focuses on how cells capture, store, and use energy. This is where biology moves from "what cells look like" to "how cells actually work."

By the end of this unit, you should be able to:

- Explain how enzymes function and what affects their activity.
- Describe how cells harvest energy through respiration.
- Compare different types of photosynthesis.
- Show how ATP is used to power work in the cell.
- Apply data analysis to experiments involving energetics.

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2. What Is Cellular Energetics?

Cellular energetics = the study of **energy transformations inside cells.**

- **Respiration** → glucose is broken down into ATP.
- **Photosynthesis** → sunlight stored as sugars.
- **Enzymes** → speed up chemical reactions.
- **ATP** → the "energy currency" that powers cellular work.

Analogy: Think of a city:

- Food = fuel
- Respiration = power plants
- ATP = electricity grid
- Enzymes = workers making sure jobs get done

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3. Enzymes

3.1 Function & Mechanism

- Proteins that lower the activation energy.
- Highly specific for substrates.
- Do not get consumed in reactions.

Models:

- Lock-and-Key
- Induced Fit

3.2 Factors Affecting Enzymes

- **Temperature:** Too high → denaturation.
- **pH:** Extremes change the shape of the active site.
- **Substrate concentration:** Works until saturation.
- **Inhibitors:** Competitive vs. non-competitive.

Exam Tip: Graphs showing enzyme activity vs. temperature/pH are common.

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4. Cellular Respiration

4.1 Overview

Purpose: Break glucose into ATP.
Formula:
$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + ATP$

4.2 Stages

Stage	**Where**	**Inputs**	**Outputs**	**ATP**
Glycolysis	Cytoplasm	Glucose, NAD+	Pyruvate, NADH, ATP	2
Krebs Cycle	Mitochondrial Matrix	Acetyl-CoA, NAD+, FAD	CO_2, NADH, $FADH_2$, ATP	2
ETC & Oxidative Phosphorylation	Inner mitochondrial membrane	NADH, $FADH_2$, O_2	ATP, H_2O	~34

Total Yield: ~36–38 ATP per glucose

4.3 Anaerobic vs. Aerobic Respiration

- **Aerobic:** Uses O_2, yields ~36 ATP.
- **Anaerobic:** No O_2, only glycolysis → 2 ATP (fermentation).

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5. Photosynthesis

5.1 Overview

Formula:
$6CO_2 + 6H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2$

5.2 Stages

- **Light Reactions (Thylakoids):**
  - Split water → release O_2.
  - Make ATP & NADPH.
- **Calvin Cycle (Stroma):**
  - Use ATP & NADPH to fix CO_2 into glucose.

5.3 Plant Adaptations

Plant Type	**Adaptation**	**Best Environment**
C3	Standard Calvin Cycle	Moderate climates
C4	Spatial separation of steps	Hot, sunny
CAM	Temporal separation (stomata open at night)	Desert/arid

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6. ATP & Energy Transfer

ATP = adenosine triphosphate.

- Breaking phosphate bond → releases energy.
- Powers: muscle contraction, active transport, DNA/protein synthesis.
- Constantly recycled: ADP + Pi → ATP.

Energy Coupling:
Exergonic (energy-releasing) reactions drive endergonic (energy-requiring) ones.

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7. Regulation of Metabolic Pathways

Cells don't waste energy — they regulate it.

- **Feedback inhibition:** End product shuts down pathway (e.g., respiration slows when ATP is high).
- **Allosteric regulation:** Molecules bind enzymes to activate/inhibit them.

Exam Tip: Be able to explain *why* regulation matters (prevents waste, maintains balance).

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8. Connections to Other AP Biology Units

- **Unit 1 (Chemistry of Life):** Biomolecules provide fuel for respiration.
- **Unit 2 (Cell Structure):** Mitochondria & chloroplasts house energetics.
- **Unit 4 (Cell Communication):** Signals trigger energy use for growth/division.
- **Unit 5 & 6:** DNA replication and protein synthesis require ATP.

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9. Exam Tips & Strategies

- Expect 12–15% of exam questions from Unit 3.
- Focus on **graphs and data interpretation** — enzymes, photosynthesis rate curves, respiration experiments.
- Be ready for **FRQs**: design an experiment, analyze data, explain energy flow.
- Don't memorize every molecule — learn the **big picture**: inputs, outputs, locations.

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10. Practice Questions

Multiple Choice

1. Which of the following is the final electron acceptor in the ETC?
   A. ATP
   B. Oxygen
   C. NADH
   D. Carbon dioxide

2. Which condition would most likely denature an enzyme?
   A. Low substrate concentration
   B. High pH or high temperature
   C. Low temperature
   D. Addition of cofactors

3. In which part of the chloroplast do light reactions occur?
   A. Stroma
   B. Thylakoid membrane
   C. Inner membrane
   D. Cytoplasm

(... add 7 more MCQs in final guide)

Free Response Prompts

1. Design an experiment to test the effect of pH on enzyme activity. Include hypothesis, variables, and expected results.

2. Compare and contrast aerobic respiration and fermentation. Explain advantages of each.

3. A student measures photosynthesis rates in C3 vs. CAM plants. Predict results in a desert environment and justify your reasoning.

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11. Quick Cheat Sheets

Enzyme Activity Chart

Factor	Effect
Temp ↑ (to optimal)	Activity ↑
Temp too high	Denaturation ↓
pH extreme	Denaturation ↓
Substrate ↑	Activity ↑ until saturation

Respiration vs. Photosynthesis

	Respiration	**Photosynthesis**
Purpose	Break food → ATP	Build food from light
Location	Mitochondria	Chloroplasts
Reactants	Glucose + O_2	CO_2 + H_2O + light
Products	CO_2 + H_2O + ATP	Glucose + O_2

ATP Cycle Diagram (text version)

ATP → ADP + Pi → releases energy → powers work
ADP + Pi + energy (from respiration) → ATP

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12. Glossary of Key Terms

- **ATP:** Main energy currency of the cell.
- **Enzyme:** Protein that speeds up chemical reactions.
- **Glycolysis:** First step of respiration, breaks glucose into pyruvate.
- **NADH/$FADH_2$:** Electron carriers.
- **Calvin Cycle:** Photosynthesis step that fixes CO_2 into glucose.

Answer Key (Practice MCQs)

1. B
2. B
3. B