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CHAPTER NOTES

Respiration in Plants Class 11 Notes I CBSE Biology Chapter 12

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Respiration in Plants Class 11 Notes | CBSE Biology Chapter 12

Respiration in Plants is Chapter 12 of CBSE Class 11 Biology — the chapter that explains how a plant cell actually “earns” its energy. Photosynthesis builds glucose; respiration breaks it down to release the usable energy currency, ATP. Master how a single glucose molecule is dismantled step by step and you can answer almost any cellular-energetics question in NEET, AIIMS, and your board exam.

By the end of these notes you will be able to trace glucose through glycolysis, fermentation, the Krebs cycle, and the electron transport system, build the full respiratory balance sheet (the famous 36–38 ATP), and explain the amphibolic pathway and respiratory quotient with confidence. This is a high-weightage chapter — roughly 5–6 marks in boards and a near-guaranteed 1–2 questions in NEET — and the energetics backbone for the entire plant-physiology unit.

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Key Concepts

1. Cellular Respiration — The Basics

Cellular respiration is the enzyme-controlled, step-wise oxidation of food (mainly glucose) inside the cell to release energy stored in C–C bonds, trapping it as ATP. Unlike burning, it happens in many small steps so energy is released gradually and safely.

The substrate that is oxidised is called the **respiratory substrate** — usually carbohydrates, but fats and proteins can also be used. The molecule that supplies energy on demand is **ATP (adenosine triphosphate)**, often called the “energy currency” of the cell.

Overall Equation (aerobic)



2. Glycolysis (EMP Pathway)

Glycolysis ("splitting of sugar") is the breakdown of one glucose molecule into two molecules of **pyruvic acid**. It was given by Embden, Meyerhof and Parnas, so it is called the **EMP pathway**.

- **Site:** cytoplasm (cytosol) — does NOT need oxygen.
- It is common to both aerobic and anaerobic respiration.
- **Net products per glucose:** 2 pyruvate + 2 ATP (net) + 2 NADH + 2H⁺.

[DIAGRAM: Glucose → glucose-6-phosphate → fructose-1,6-bisphosphate → splits into 2 triose phosphate (PGAL) → 2 pyruvic acid; 2 ATP used in the investment phase, 4 ATP made in the payoff phase, net 2 ATP.]

Key idea: 2 ATP are spent early (priming) and 4 ATP are produced later, giving a **net gain of 2 ATP** per glucose.

3. Fate of Pyruvate

The fate of pyruvic acid depends on whether oxygen is available and on the type of cell.

- **Aerobic respiration:** pyruvate enters the mitochondrion and is completely oxidised to CO₂ and H₂O.
 - **Fermentation (anaerobic):** pyruvate is incompletely broken down in the cytoplasm without oxygen.
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4. Fermentation (Anaerobic Respiration)

Fermentation is the incomplete oxidation of glucose under anaerobic conditions. Only the 2 ATP of glycolysis are gained — most energy stays locked in the products.

Two Common Types

- **Alcoholic fermentation:** pyruvate → ethanol + CO₂ (by yeast). Enzymes: pyruvate decarboxylase and alcohol dehydrogenase.
- **Lactic acid fermentation:** pyruvate → lactic acid (in some bacteria and in our muscles during heavy exercise). Enzyme: lactate dehydrogenase.

Important: In both, NADH is reoxidised to NAD⁺ so glycolysis can continue. Fermentation yields less than 7% of the energy of glucose and can be dangerous (alcohol/acid accumulation).

5. Aerobic Respiration — Overview

Aerobic respiration is the complete oxidation of pyruvate to CO₂ and H₂O in the presence of oxygen, occurring in the **mitochondria**. It has two major steps after glycolysis: the Krebs cycle and the electron transport system.

First, pyruvate is converted in the mitochondrial matrix by **pyruvate dehydrogenase**:



6. Krebs Cycle (TCA / Citric Acid Cycle)

The **Krebs cycle**, also called the tricarboxylic acid (TCA) cycle or citric acid cycle, was discovered by Hans Krebs. It is the complete oxidation of acetyl CoA.

- **Site:** mitochondrial matrix.
- Acetyl CoA (2C) combines with oxaloacetic acid (4C) to form **citric acid (6C)**.
- The cycle regenerates oxaloacetic acid, so it turns continuously.

[DIAGRAM: Acetyl CoA + OAA → citrate → isocitrate → α-ketoglutarate → succinyl CoA → succinate → fumarate → malate → OAA; CO₂ released twice, NADH formed thrice, FADH₂ once, GTP/ATP once.]

Yield per turn (per acetyl CoA)

- 3 NADH + 1 FADH₂ + 1 GTP (≈ 1 ATP) + 2 CO₂.
- Since one glucose gives 2 acetyl CoA, the cycle turns **twice** per glucose.

7. Electron Transport System (ETS) and Oxidative Phosphorylation

The **electron transport system** is a chain of carriers on the **inner mitochondrial membrane** that passes electrons from NADH and FADH₂ to oxygen, the final electron acceptor.

- Electrons flow through Complex I → ubiquinone → Complex III → cytochrome c → Complex IV → O₂.
- Oxygen accepts electrons and protons to form **water (H₂O)** — this is why O₂ is vital.

Oxidative phosphorylation is the synthesis of ATP using the energy of this electron flow. As electrons move, protons are pumped into the intermembrane space, creating a gradient. Protons flow back through **ATP synthase (F₀-F₁ particle)**, driving ATP formation — the **chemiosmotic hypothesis** (Peter Mitchell).

- **1 NADH → 3 ATP**
- **1 FADH₂ → 2 ATP**

8. The Respiratory Balance Sheet (ATP Yield)

Adding up every step gives the total ATP from one glucose under ideal aerobic conditions.

Stage	ATP (direct)	NADH	FADH ₂	ATP via ETS
Glycolysis	2 (net)	2	—	6
Pyruvate → Acetyl CoA (×2)	—	2	—	6
Krebs cycle (×2 turns)	2 (GTP)	6	2	22
Total	4	10	2	34

Net = 4 + 34 = 38 ATP per glucose. In eukaryotic cells, glycolytic NADH must be shuttled into the mitochondrion, costing energy, so the practical yield is often quoted as **36 ATP**.

Note: These assumptions are theoretical (one substrate metabolised at a time, perfect functioning). Real values vary, so always state the assumptions in answers.

9. Amphibolic Pathway

The respiratory pathway is described as **amphibolic** because it works in *both* directions — it is catabolic (breaking molecules down) and anabolic (building molecules up).

- Intermediates like acetyl CoA and α -ketoglutarate are withdrawn to synthesise fatty acids and amino acids.
- Fats are broken into glycerol and fatty acids; proteins into amino acids — these feed into respiration at various points.

Key idea: Because the pathway both breaks down and builds up substrates, it is amphibolic, not purely catabolic.

10. Respiratory Quotient (RQ)

The **respiratory quotient (RQ)** is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed during respiration.

RQ = Volume of CO_2 released / Volume of O_2 consumed

Respiratory Substrate	RQ Value
Carbohydrates	1 (e.g. glucose)
Fats	Less than 1 (≈ 0.7)
Proteins	About 0.9
Organic acids	More than 1

Note: In anaerobic respiration of carbohydrates (no O_2 consumed), RQ is infinite (∞).

Weightage in Board & Entrance Exams

Exam	Typical Weightage	Most-Tested Areas
CBSE Board (Class 11)	5–6 marks	Glycolysis steps, Krebs cycle, ATP balance sheet, RQ
NEET / AIIMS	1–2 questions	ATP yield, ETS, fermentation, RQ of substrates
State CETs	1–2 questions	Site of each step, net products, amphibolic pathway

[TABLE: Question-type split — VSA (1 mark): definitions, sites, RQ values; SA (2–3 marks): glycolysis vs fermentation, ETS, amphibolic pathway; LA (5 marks): full aerobic respiration with the ATP balance sheet.]

Important Definitions

Term	Definition
Cellular respiration	Step-wise enzymatic oxidation of food to release energy as ATP
Respiratory substrate	The molecule oxidised in respiration (carbohydrate, fat or protein)
Glycolysis (EMP)	Breakdown of glucose to 2 pyruvate in the cytoplasm; net 2 ATP + 2 NADH
Fermentation	Incomplete anaerobic oxidation of glucose to ethanol or lactic acid
Krebs cycle (TCA)	Complete oxidation of acetyl CoA in the mitochondrial matrix
Electron transport system	Chain on inner mitochondrial membrane passing electrons to O ₂
Oxidative phosphorylation	ATP synthesis driven by the proton gradient (chemiosmosis)
Amphibolic pathway	A pathway involved in both breakdown (catabolism) and synthesis (anabolism)
Respiratory quotient (RQ)	Ratio of CO ₂ released to O ₂ consumed during respiration
ATP synthase	F ₀ -F ₁ enzyme that makes ATP as protons flow back across the membrane

Solved Examples

Example 1

How many ATP molecules are gained (net) during glycolysis of one glucose molecule, and where does it occur?

Answer: 2 ATP are used and 4 are produced, so the **net gain is 2 ATP**. It occurs in the **cytoplasm** and needs no oxygen.

Example 2

Calculate the total ATP produced via the ETS from the NADH and FADH₂ of one Krebs cycle turn.

Answer: One turn gives 3 NADH and 1 FADH₂. ATP = (3 × 3) + (1 × 2) = 9 + 2 = **11 ATP** via ETS (plus 1 GTP directly).

Example 3

Write the equation for alcoholic fermentation and name the enzymes involved.

Answer: Pyruvic acid $\rightarrow$ CO_2 + Ethanol. Enzymes: **pyruvate decarboxylase** (removes CO_2) and **alcohol dehydrogenase** (forms ethanol).

Example 4

A germinating seed rich in fats is used in an experiment. What will be its RQ, and why?

Answer: RQ will be **less than 1 (≈ 0.7)** because fats need more O_2 for complete oxidation than the CO_2 they release.

Example 5

Why is the total theoretical ATP yield often quoted as 36 instead of 38 in eukaryotes?

Answer: The 2 NADH made in glycolysis (cytoplasm) must be shuttled into the mitochondrion. This transport **costs energy**, reducing the net yield from 38 to about **36 ATP**.

Example 6

Name the final electron acceptor in the ETS and the product formed.

Answer: The final electron acceptor is **oxygen (O_2)**; it combines with electrons and protons to form **water (H_2O)**.

Important Questions for Board Exams

1-Mark Questions (VSA)

1. Where in the cell does glycolysis take place?
2. What is the RQ of a carbohydrate respiratory substrate?
3. Name the common metabolite at which glycolysis ends.
4. Which enzyme synthesises ATP during oxidative phosphorylation?
5. Name the final hydrogen/electron acceptor in aerobic respiration.

2–3-Mark Questions (SA)

1. Differentiate between aerobic respiration and fermentation with respect to site, oxygen and ATP yield.
2. Explain why the respiratory pathway is called an amphibolic pathway.
3. Describe the role of the electron transport system in ATP synthesis.
4. What is the respiratory quotient? Give RQ values for carbohydrates, fats and organic acids.

5-Mark Questions (LA)

1. Describe the Krebs cycle and state its net products per turn.

2. Prepare the respiratory balance sheet showing how 38 ATP are produced from one glucose molecule. State the assumptions made.
 3. Explain the chemiosmotic hypothesis of ATP synthesis in mitochondria.
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Quick Revision Points

- Glycolysis: glucose $\rightarrow$ 2 pyruvate in cytoplasm; net 2 ATP + 2 NADH; no O_2 needed
 - Fermentation: anaerobic; ethanol + CO_2 (yeast) or lactic acid (muscle); only 2 ATP
 - Link reaction: pyruvate $\rightarrow$ acetyl CoA + CO_2 + NADH (matrix)
 - Krebs cycle: complete oxidation of acetyl CoA in matrix; 3 NADH + 1 $FADH_2$ + 1 GTP + 2 CO_2 per turn
 - ETS: on inner mitochondrial membrane; O_2 is the final electron acceptor $\rightarrow$ forms water
 - 1 NADH = 3 ATP; 1 $FADH_2$ = 2 ATP (oxidative phosphorylation)
 - Balance sheet: 38 ATP total (36 ATP in eukaryotes due to NADH shuttle)
 - ATP synthase (F_0-F_1) makes ATP via the proton gradient — chemiosmotic hypothesis
 - Amphibolic pathway: respiration is both catabolic and anabolic
 - RQ = CO_2 released / O_2 consumed; carbohydrate = 1, fat < 1, protein $\approx$ 0.9, organic acid > 1
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Next Chapter: Chapter 13 — Plant Growth and Development



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