Chapter 12: Respiration in Plants

Comprehensive Study Notes

Class 11 Biology - NCERT Based

EXAM SPRINT - Complete Coverage for NEET and Board Examinations

Introduction

Respiration is the process of breakdown of food materials within cells to release energy and trap it for ATP synthesis. All living organisms, including plants, require energy for life processes like absorption, transport, movement, reproduction, and breathing itself.

Key Concepts:

- **Energy Source**: All energy for life processes comes from oxidation of macromolecules (food)
- **ATP**: Universal energy currency of the cell
- **Cellular Respiration**: Breaking of C-C bonds through oxidation, releasing energy in controlled steps
- **Respiratory Substrates**: Compounds that are oxidized (carbohydrates, proteins, fats, organic acids)

12.1 DO PLANTS BREATHE?

Plant Breathing Characteristics:

- **Gas Exchange**: Plants require O_2 for respiration and release CO_2
- **No Specialized Organs**: Unlike animals, plants lack respiratory organs
- **Gas Exchange Structures**: Stomata (leaves) and lenticels (stems)

Why Plants Don't Need Respiratory Organs:

1. **Local Gas Exchange**: Each plant part handles its own gas exchange needs
2. **Low Metabolic Rate**: Plant respiration rates are much lower than animals
3. **Short Diffusion Distance**: Living cells are close to plant surface
4. **Internal Structure**:
   - Woody stems: Living cells in thin layers with lenticels
   - Interior cells: Dead, provide mechanical support
   - Loose packing: Interconnected air spaces in parenchyma

Overall Respiration Equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy$$

12.2 GLYCOLYSIS

Definition and Origin:

- **Etymology**: Glycos (sugar) + lysis (splitting)
- **Alternative Name**: EMP pathway (Embden-Meyerhof-Parnas)
- **Location**: Cytoplasm of all living cells
- **Universality**: Present in all organisms

Process Overview:

- **Substrate**: Glucose (from sucrose or storage carbohydrates)
- **Product**: Two molecules of pyruvic acid
- **Steps**: Chain of 10 enzyme-controlled reactions

Key Steps and Energy Changes:

1. **ATP Investment Phase**:
   - Glucose → Glucose-6-phosphate (ATP used)
   - Fructose-6-phosphate → Fructose-1,6-bisphosphate (ATP used)
2. **Energy Payoff Phase**:
   - PGAL → BPGA (NADH + H^+ produced)
   - BPGA → PGA (ATP produced)
   - PEP → Pyruvic acid (ATP produced)

Net Gain Calculation:

- **ATP Used**: 2 molecules
- **ATP Produced**: 4 molecules
- **Net ATP Gain**: 2 molecules per glucose
- **NADH + H^+ Produced**: 2 molecules

12.3 FERMENTATION

Definition:

Incomplete oxidation of glucose under anaerobic conditions where pyruvic acid is converted to other products without involving oxygen.

Types of Fermentation:

1. Alcoholic Fermentation:

- **Organism**: Yeast (Saccharomyces)
- **Products**: CO_2 + Ethanol

- **Enzymes**: Pyruvic decarboxylase, Alcohol dehydrogenase
- **Limiting Factor**: Yeast dies at ~13% alcohol concentration

2. Lactic Acid Fermentation:

- **Organisms**: Bacteria, muscle cells during exercise
- **Product**: Lactic acid
- **Enzyme**: Lactate dehydrogenase

Characteristics of Fermentation:

- **Energy Release**: Less than 7% of glucose energy released
- **ATP Yield**: Net 2 ATP molecules per glucose
- **Hazardous Products**: Acid or alcohol accumulation
- **NADH Regeneration**: NADH + H^+ oxidized to NAD^+

12.4 AEROBIC RESPIRATION

Overview:

Complete oxidation of organic substances in presence of oxygen, releasing CO_2, water, and large amounts of energy.

Location: Mitochondria (eukaryotes)

Major Steps:

1. Pyruvate Oxidation:

- **Location**: Mitochondrial matrix
- **Process**: Pyruvate + CoA + NAD^+ → Acetyl CoA + CO_2 + NADH + H^+
- **Enzyme**: Pyruvate dehydrogenase complex

- **Product per glucose**: 2 Acetyl CoA, 2 NADH + H^+, 2 CO_2

2. Tricarboxylic Acid Cycle (Krebs' Cycle):

Key Features:

- **Location**: Mitochondrial matrix
- **Starting Material**: Acetyl CoA
- **Cycle Nature**: Regenerates starting compound (OAA)

Major Steps:

1. Acetyl CoA + OAA → Citric acid
2. Citric acid → Isocitric acid
3. Isocitric acid → α-ketoglutaric acid + CO_2 + NADH + H^+
4. α-ketoglutaric acid → Succinyl CoA + CO_2 + NADH + H^+
5. Succinyl CoA → Succinic acid + GTP (→ ATP)
6. Succinic acid → Fumaric acid + $FADH_2$
7. Fumaric acid → Malic acid
8. Malic acid → OAA + NADH + H^+

Products per Acetyl CoA:

- CO_2: 2 molecules
- NADH + H^+: 3 molecules
- $FADH_2$: 1 molecule
- ATP: 1 molecule

3. Electron Transport System (ETS) and Oxidative Phosphorylation:

Location: Inner mitochondrial membrane

Components:

- **Complex I**: NADH dehydrogenase
- **Complex II**: Succinate dehydrogenase ($FADH_2$ entry)
- **Complex III**: Cytochrome bc_1 complex
- **Complex IV**: Cytochrome c oxidase
- **Complex V**: ATP synthase

Process:

1. Electrons from NADH and $FADH_2$ pass through complexes
2. Energy released pumps H^+ across membrane
3. Proton gradient drives ATP synthesis
4. O_2 serves as final electron acceptor

ATP Yield:

- **NADH**: 3 ATP molecules
- **$FADH_2$**: 2 ATP molecules

ATP Synthase Structure:

- **F_1**: Peripheral protein (ATP synthesis site)
- **F_0**: Integral protein (proton channel)
- **Mechanism**: 4 H^+ per ATP synthesized

12.5 THE RESPIRATORY BALANCE SHEET

Theoretical Calculations (Assumptions):

1. Sequential, orderly pathway functioning
2. NADH from glycolysis enters mitochondria
3. No intermediates withdrawn for other processes
4. Only glucose is respired

ATP Accounting per Glucose:

Glycolysis:

- **Direct ATP**: 2 (net)
- **NADH**: 2 × 3 = 6 ATP
- **Subtotal**: 8 ATP

Pyruvate Oxidation:

- **NADH**: 2 × 3 = 6 ATP

Krebs Cycle (2 cycles):

- **Direct ATP**: 2
- **NADH**: 6 × 3 = 18 ATP
- **$FADH_2$**: 2 × 2 = 4 ATP
- **Subtotal**: 24 ATP

Total Theoretical Yield: 38 ATP molecules per glucose

Comparison: Fermentation vs Aerobic Respiration:

Aspect	Fermentation	Aerobic Respiration
Breakdown	Partial	Complete
ATP Yield	2 per glucose	38 per glucose

Aspect	Fermentation	Aerobic Respiration
NADH Oxidation	Slow	Vigorous
Final Products	Alcohol/Lactic acid	CO_2 + H_2O

12.6 AMPHIBOLIC PATHWAY

Definition:

Respiratory pathway involved in both anabolism (synthesis) and catabolism (breakdown).

Entry Points of Different Substrates:

- **Carbohydrates**: Enter as glucose at glycolysis start
- **Fats**:
  - Fatty acids → Acetyl CoA → Krebs cycle
  - Glycerol → PGAL → Glycolysis
- **Proteins**:
  - Amino acids (after deamination) → Various points in Krebs cycle

Withdrawal Points for Synthesis:

- **Fatty acid synthesis**: Acetyl CoA withdrawn
- **Protein synthesis**: Amino acids from Krebs intermediates
- **Other biomolecules**: Various respiratory intermediates

12.7 RESPIRATORY QUOTIENT (RQ)

Definition:

Ratio of volume of CO_2 evolved to volume of O_2 consumed in respiration.

Formula: RQ = Volume of CO_2 evolved / Volume of O_2 consumed

RQ Values for Different Substrates:

Carbohydrates:

- **RQ = 1.0**
- **Example**: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- **Calculation**: $6CO_2/6O_2 = 1.0$

Fats:

- **RQ < 1.0 (typically 0.7)**
- **Example**: Tripalmitin
- **Calculation**: $102CO_2/145O_2 = 0.7$

Proteins:

- **RQ ≈ 0.9**

Practical Considerations:

- Living organisms rarely use pure substrates
- Mixed substrates give intermediate RQ values
- RQ helps determine primary respiratory substrate

NEET-Specific Important Points

High-Yield Topics for NEET:

1. **Glycolysis**:
    - Location (cytoplasm)

- Net ATP gain (2)
- Products (pyruvate, NADH + H^+)
- Universal occurrence

2. **Krebs Cycle**:
   - Location (mitochondrial matrix)
   - Products per cycle
   - Enzymes involved
   - Connection with ETS

3. **ETS and Oxidative Phosphorylation**:
   - Location (inner mitochondrial membrane)
   - Complexes I-V
   - ATP yield from NADH and $FADH_2$
   - Role of oxygen

4. **Respiratory Balance Sheet**:
   - Total ATP calculation
   - Assumptions made
   - Efficiency comparison

Common NEET Question Patterns:

1. **Calculation Questions**:
   - ATP yield calculations
   - RQ determinations
   - Net gain computations

2. **Process Questions**:

- Location of reactions
- Enzyme identification
- Product formation

3. **Comparison Questions**:
   - Aerobic vs anaerobic
   - Fermentation vs respiration
   - Different substrates

Memory Aids and Mnemonics

Glycolysis Steps:

"Good Friends Play Games Together"

- **G**lucose
- **F**ructose-6-phosphate
- **P**GAL
- **G**lycerate
- **T**riose phosphate

Krebs Cycle Intermediates:

"Can I Keep Selling Seashells For Money, Officer?"

- **C**itrate
- **I**socitrate
- **K**etoglutarate
- **S**uccinyl CoA

- **S**uccinate
- **F**umarate
- **M**alate
- **O**xaloacetate

ETS Complexes:

"Never Saw Cats Climb Anything"

- **N**ADH dehydrogenase (Complex I)
- **S**uccinate dehydrogenase (Complex II)
- **C**ytochrome bc_1 (Complex III)
- **C**ytochrome oxidase (Complex IV)
- **A**TP synthase (Complex V)

Practice Questions for NEET

Multiple Choice Questions:

1. The net gain of ATP during glycolysis is: a) 4 molecules b) 2 molecules c) 6 molecules d) 8 molecules
2. Krebs cycle occurs in: a) Cytoplasm b) Mitochondrial matrix c) Inner membrane d) Outer membrane
3. RQ value for fats is: a) 1.0 b) 0.9 c) 0.7 d) 1.2

Short Answer Questions:

1. Why is respiratory pathway called amphibolic?
2. What is the significance of step-wise energy release in respiration?
3. Define respiratory quotient and give its value for carbohydrates.

Long Answer Questions:

1. Describe the electron transport system and oxidative phosphorylation.
2. Give a detailed account of Krebs cycle with its significance.
3. Compare aerobic and anaerobic respiration with examples.

Summary Table: Respiratory Processes Overview

Process	Location	Substrate	Products	ATP Yield	O_2 Required
Glycolysis	Cytoplasm	Glucose	Pyruvate, $NADH+H^+$	2 (net)	No
Fermentation	Cytoplasm	Pyruvate	Alcohol/Lactate	0	No
Krebs Cycle	Matrix	Acetyl CoA	CO_2, $NADH+H^+$, $FADH_2$	2	No
ETS	Inner membrane	NADH, $FADH_2$	H_2O	32	Yes

Key Equations to Remember

1. **Complete Respiration**: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38$ ATP
2. **Alcoholic Fermentation**: Pyruvate $\rightarrow CO_2$ + Ethanol + 2 ATP
3. **Lactic Acid Fermentation**: Pyruvate $\rightarrow$ Lactic acid + 2 ATP
4. **Respiratory Quotient**: RQ = CO_2 evolved / O_2 consumed

EXAM SPRINT - Master Respiration with focused study on energy calculations, pathway locations, and comparative aspects. Regular practice of numerical problems is essential for NEET success.

Source: NCERT Biology Class 11, Chapter 12 - Comprehensive coverage for NEET preparation