NCERT Exemplar Solutions of Class 11 Biology – Chapter 14: Respiration in Plants

VERY SHORT ANSWER TYPE QUESTIONS

1. Energy is released during the oxidation of compounds in respiration. How is this energy stored and released as and when it is needed?

Solution: The energy released during oxidation of compounds in respiration is stored as **Adenosine Triphosphate (ATP)** in the form of high-energy phosphate bonds.

Storage Process: ADP + P_i + Energy → ATP

Release Process: ATP → ADP + P_i + Energy (7.3 kcal/mol)

Enhanced Explanation: ATP contains two high-energy phosphoanhydride bonds. When these bonds are hydrolyzed, approximately 7.3 kcal/mol of energy is released per mole of ATP. This energy is immediately available for cellular processes like muscle contraction, active transport, and biosynthesis.

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2. Explain the term "Energy Currency". Which substance acts as energy currency in plants and animals?

Solution: Energy Currency: The term refers to a molecule that can store and transfer energy efficiently within living organisms, acting as a universal energy exchange medium in cellular metabolism.

Substance: Adenosine Triphosphate (ATP) acts as the energy currency in both plants and animals.

Enhanced Explanation: ATP is called the "energy currency" because:

- It's universally accepted in all cellular energy transactions
- It can be easily synthesized and broken down
- It releases energy in manageable quantities (7.3 kcal/mol)
- It's rapidly recycled (an ATP molecule is recycled about 1000 times per day)

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3. Different substrates get oxidized during respiration. How does Respiratory Quotient (RQ) indicate which type of substrate (carbohydrate, fat, or protein) is getting oxidized?

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

Where:

- **A = Volume of CO_2 released**
- **B = Volume of O_2 consumed**

RQ Values:

- **RQ = 1:** Carbohydrates (e.g., glucose)
  - $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy
- **RQ < 1:** Fats/lipids (typically 0.7)
  - Fat requires more oxygen relative to CO_2 produced
- **RQ > 1:** Organic acids (like malic acid)
  - More CO_2 is produced relative to O_2 consumed

Enhanced Explanation: RQ provides insight into metabolic substrate utilization by comparing gas exchange ratios during different types of substrate oxidation.

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4. F_1 particles participate in the synthesis of _______________.
Solution: F_1 particles participate in the synthesis of **ATP**.
Enhanced Explanation: F_1 particles are the catalytic component of ATP synthase complex. They contain the active site where ATP synthesis occurs from ADP and inorganic phosphate, driven by the proton gradient established across the inner mitochondrial membrane.

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5. When does anaerobic respiration occur in man and yeast?
Solution:
In Humans:

- During intensive exercise or physical stress
- When oxygen supply to muscles becomes inadequate
- Results in lactic acid fermentation in muscle cells

In Yeast:

- When there is incomplete oxidation of glucose
- In oxygen-limited environments
- Results in alcoholic fermentation (ethanol + CO_2)

Enhanced Explanation: Anaerobic respiration serves as an emergency energy production mechanism when aerobic respiration cannot meet energy demands due to oxygen limitation.

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6. Which of the following will release more energy on oxidation? Arrange them in ascending order:
a) 1 gm of fat
b) 1 gm of protein
c) 1 gm of glucose
d) 0.5 g of protein + 0.5g glucose
Solution: Ascending Order of Energy Release: 1 gm of glucose < 0.5 g of protein + 0.5g glucose < 1 gm of protein < 1 gm of fat
Energy Values:

- **Carbohydrates:** ~4 kcal/g
- **Proteins:** ~4 kcal/g
- **Fats:** ~9 kcal/g

Enhanced Explanation: Fats contain more C-H bonds per gram, which release more energy upon oxidation. The mixed substrate releases intermediate energy levels.

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7. The product of glycolysis (under hypoxia) in skeletal muscle and anaerobic fermentation in yeast are respectively ____________ and _______________.

Solution:

- **Skeletal muscle (under hypoxia): Lactic acid**
- **Yeast (anaerobic fermentation): Ethanol and CO_2**

Enhanced Explanation:

- **Muscle:** Pyruvate + NADH → Lactic acid + NAD^+ (lactic acid fermentation)
- **Yeast:** Pyruvate → Acetaldehyde + CO_2 → Ethanol + CO_2 (alcoholic fermentation)

SHORT ANSWER TYPE QUESTIONS

1. If a person is feeling dizzy, glucose or fruit juice is given immediately, but not a cheese sandwich. Explain.

Solution: Glucose or fruit juice is preferred because:

Immediate Availability:

- Simple sugars are readily absorbed in the small intestine
- Glucose enters bloodstream within minutes
- Directly available for cellular respiration

Quick Energy Release:

- Glucose immediately enters glycolysis
- Rapid ATP production
- Fast restoration of blood glucose levels

Cheese Sandwich Limitations:

- Contains complex proteins and fats
- Requires extensive digestion
- Takes hours to break down and absorb
- Delayed energy availability

Enhanced Explanation: Dizziness often indicates hypoglycemia (low blood sugar). The brain requires immediate glucose supply, making simple carbohydrates the fastest solution.

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2. What is meant by the statement "aerobic respiration is more efficient"?

Solution: Efficiency Comparison:

Aerobic Respiration:

- Complete glucose oxidation
- Produces ~38 ATP molecules per glucose
- High energy yield per substrate molecule
- Complete breakdown to CO_2 and H_2O

Anaerobic Respiration:

- Incomplete glucose oxidation
- Produces only 2 ATP molecules per glucose

- Low energy yield
- Organic end products (lactic acid, ethanol)

Enhanced Explanation: Aerobic respiration is ~19 times more efficient than anaerobic respiration in ATP production, extracting maximum energy from glucose through complete oxidation.

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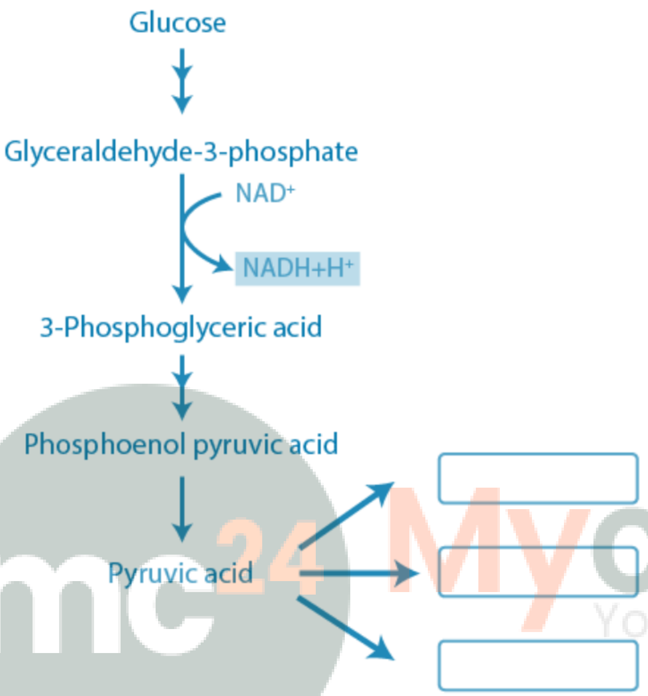
3. Pyruvic acid is the end product of glycolysis. What are the three metabolic products of pyruvic acid produced under aerobic and anaerobic conditions?



Solution: Three Metabolic Fates of Pyruvic Acid:

1. **CO_2 + H_2O** (Complete aerobic oxidation)
2. **Lactic acid** (Anaerobic - muscle fermentation)
3. **C_2H_5OH + CO_2** (Anaerobic - alcoholic fermentation)

Pathways:

1. **Aerobic:** Pyruvate → Acetyl CoA → TCA cycle → CO_2 + H_2O
2. **Anaerobic (muscle):** Pyruvate + NADH → Lactic acid + NAD^+
3. **Anaerobic (yeast):** Pyruvate → Acetaldehyde + CO_2 → Ethanol + CO_2

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4. The energy yield in terms of ATP is higher in aerobic respiration than anaerobic respiration. Why does anaerobic respiration occur even in organisms that live in aerobic conditions like human beings and angiosperms?

Solution: Reasons for Anaerobic Respiration in Aerobic Organisms:

In Humans:

- **Emergency situations:** Intense exercise exceeding oxygen supply

- **Tissue oxygen limitation:** Poor circulation or high metabolic demand
- **Rapid energy requirement:** When aerobic respiration cannot meet immediate needs

In Angiosperms:

- **Seed germination:** Limited oxygen penetration to deep seed tissues
- **Root growth:** Soil oxygen may be insufficient
- **Waterlogged conditions:** Reduced oxygen availability
- **Rapid growth phases:** High energy demand exceeding oxygen supply

Enhanced Explanation: Anaerobic respiration serves as a crucial backup energy system, ensuring survival during oxygen-limited conditions or high energy demands.

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5. Oxygen is an essential requirement for aerobic respiration but it enters the respiratory process at the end? Discuss.

Solution: Role of Oxygen in Aerobic Respiration:

Entry Point: Oxygen enters at the **end of the electron transport chain** as the **final electron acceptor**.

Critical Functions:

1. **Electron Acceptor:** $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
2. **Maintains Electron Flow:** Enables continuous electron transport
3. **Proton Gradient Formation:** Drives ATP synthesis via chemiosmosis

Why It's Essential Despite Late Entry:

- **Chain Reaction:** Without oxygen, the entire electron transport chain stops
- **NADH Oxidation:** Cannot regenerate NAD^+ for continued glycolysis and TCA cycle
- **ATP Synthesis:** No proton gradient = no oxidative phosphorylation

Enhanced Explanation: Though oxygen enters last, its presence is essential for the entire process to function. It's like the drain in a sink - positioned at the end but crucial for the entire system's operation.

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6. Respiration is an energy-releasing and enzymatically controlled catabolic process which involves a step-wise oxidative breakdown of organic substances inside living cells. Explain the meaning of:

1) Step-wise oxidative breakdown:

Solution: Energy is released in **controlled, sequential stages** rather than all at once.

Advantages:

- **Temperature control:** Prevents harmful heat buildup
- **Energy management:** Allows efficient ATP capture
- **Metabolic regulation:** Enables pathway control at multiple points

Example: Glucose → Pyruvate → Acetyl CoA → TCA intermediates → CO_2

2) Organic substances (used as substrates):

Solution: Primary Substrates:

- **Carbohydrates:** Glucose, fructose, sucrose
- **Lipids:** Fatty acids, glycerol
- **Proteins:** Amino acids (during starvation)

Enhanced Explanation: The step-wise nature allows cells to harvest maximum energy while maintaining cellular integrity through controlled energy release.

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7. Comment on the statement – "Respiration is an energy-producing process but ATP is being used in some steps of the process."

Solution: ATP Investment vs. Returns:

ATP Usage (Energy Investment):

- **Glycolysis:** 2 ATP molecules used in initial steps
  - Glucose → Glucose-6-phosphate (1 ATP)
  - Fructose-6-phosphate → Fructose-1,6-bisphosphate (1 ATP)

ATP Production (Energy Returns):

- **Glycolysis:** 4 ATP molecules produced (net gain: 2 ATP)
- **TCA Cycle:** 2 ATP molecules
- **Electron Transport:** ~34 ATP molecules
- **Total:** ~38 ATP molecules

Net Result: Despite initial ATP investment, the overall process yields substantial net ATP gain.

Enhanced Explanation: This is similar to "spending money to make money" - the initial ATP investment enables the breakdown process that ultimately yields much more ATP.

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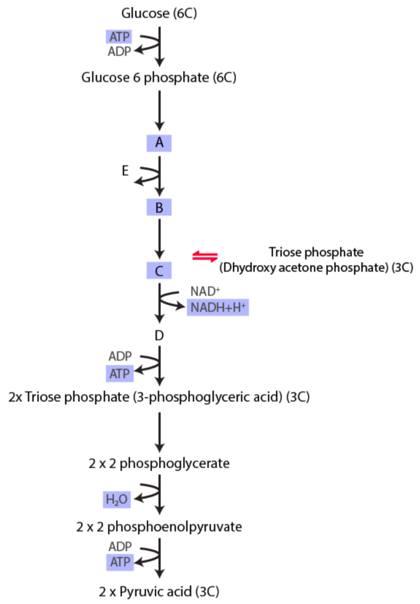
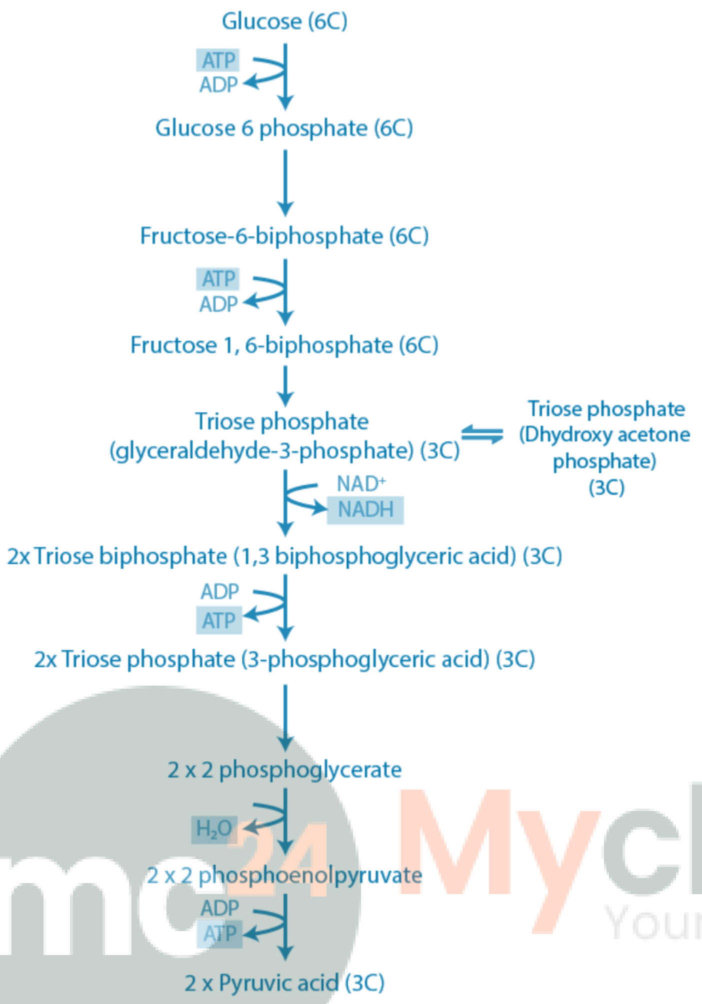
8. Fill in the missing steps A, B, C, D in glycolysis and indicate whether ATP is being used up or released at step E?



Solution: Based on the glycolysis pathway diagram:



Missing Steps:

- **A:** Fructose-6-phosphate
- **B:** Fructose-1,6-bisphosphate
- **C:** Triose phosphate (Dihydroxy acetone phosphate)
- **D:** 2x Triose biphosphate (1,3-biphosphoglyceric acid)

Step E: ATP is consumed (used up)

- This represents the second ATP-requiring step in glycolysis
- Fructose-6-phosphate + ATP → Fructose-1,6-bisphosphate + ADP

Enhanced Explanation: The glycolysis pathway has two phases:

1. **Energy Investment Phase:** Steps 1-5 (consumes 2 ATP)
2. **Energy Payoff Phase:** Steps 6-10 (produces 4 ATP)

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9. Why is respiratory pathway referred to as an amphibolic pathway? Explain.

Solution: Amphibolic Pathway Definition: A metabolic pathway that involves both **anabolic (biosynthetic)** and **catabolic (breakdown)** processes.

Respiratory Pathway as Amphibolic:

Catabolic Aspects:

- **Glucose breakdown:** Glucose → Pyruvate → CO_2 + H_2O
- **Fat oxidation:** Fatty acids → Acetyl CoA → CO_2 + H_2O
- **Protein degradation:** Amino acids → TCA cycle intermediates

Anabolic Aspects:

- **Fatty acid synthesis:** Acetyl CoA → Fatty acids
- **Amino acid synthesis:** TCA intermediates → Amino acids
- **Glucose synthesis:** TCA intermediates → Gluconeogenesis

Enhanced Explanation: The respiratory pathway serves as a metabolic hub, simultaneously breaking down substrates for energy while providing building blocks for biosynthesis, making it both catabolic and anabolic.

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10. We commonly call ATP as the energy currency of the cell. Can you think of some other energy carriers present in a cell? Name any two.

Solution: Other Energy Carriers:

1. **GTP (Guanosine Triphosphate)**
   - Used in protein synthesis
   - Formed in TCA cycle (succinyl CoA → succinate)
2. **ADP (Adenosine Diphosphate)**
   - Intermediate energy carrier
   - Can be phosphorylated to ATP

Additional Examples:

- **NADH:** Electron carrier with high energy potential
- **$FADH_2$:** Electron carrier in respiratory chain
- **Creatine phosphate:** Energy storage in muscles

Enhanced Explanation: While ATP is the primary energy currency, cells use multiple energy carriers for specialized functions and to maintain metabolic flexibility.

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11. ATP produced during glycolysis is a result of substrate-level phosphorylation. Explain.

Solution: Substrate-Level Phosphorylation: Direct transfer of phosphate group from a high-energy substrate to ADP, forming ATP **without involving electron transport chain**.

In Glycolysis:

1. **1,3-bisphosphoglycerate → 3-phosphoglycerate + ATP**
2. **Phosphoenolpyruvate → Pyruvate + ATP**

Characteristics:

- **Direct phosphorylation:** No electron transport involved
- **Enzyme-catalyzed:** Specific kinases catalyze the reactions
- **Energy source:** High-energy phosphate bonds in substrates

Enhanced Explanation: This differs from oxidative phosphorylation, which requires electron transport and chemiosmosis. Substrate-level phosphorylation provides immediate ATP without oxygen requirement.

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12. Do you know any step in the TCA cycle where there is substrate-level phosphorylation? Which one?
Solution: TCA Cycle Substrate-Level Phosphorylation:
Step: Succinyl CoA → Succinate + GTP
Enzyme: Succinyl CoA synthetase
Reaction: Succinyl CoA + GDP + P_i → Succinate + GTP + CoA-SH
Note: GTP is energetically equivalent to ATP and can be converted to ATP by nucleoside diphosphate kinase: GTP + ADP → GDP + ATP
Enhanced Explanation: This is the only step in the TCA cycle that directly produces high-energy phosphate bonds through substrate-level phosphorylation, contributing 1 ATP equivalent per turn of the cycle.

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13. A process is occurring throughout the day, in 'X' organism. Cells are participating in this process. During this process ATP, CO_2 and water are evolved. It is not a light-dependent process.
a) Name the process: Cellular Respiration
b) Is it a catabolic or an anabolic process? Catabolic process - involves breakdown of glucose molecules
c) What could be the raw material of this process? Raw materials: Glucose (organic substrate) and Oxygen
Enhanced Explanation: The description clearly indicates cellular respiration, which occurs continuously in all living cells to produce energy, regardless of light availability.

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14. When a substrate is being metabolized, why does not all the energy get released in one step? What is the advantage of step-wise release?
Solution: Advantages of Step-wise Energy Release:

1. **Temperature Control:**
    - Prevents excessive heat production
    - Maintains cellular integrity
    - Avoids protein denaturation
2. **Energy Management:**
    - Allows efficient ATP capture
    - Prevents energy wastage as heat
    - Enables controlled energy storage
3. **Metabolic Regulation:**
    - Multiple control points for pathway regulation

- Responds to cellular energy needs
- Allows metabolic flexibility

4. **Safety:**
   - Prevents explosive energy release
   - Maintains cellular homeostasis

Enhanced Explanation: Step-wise energy release is like walking down stairs instead of jumping off a building - it's controlled, safe, and allows energy to be captured efficiently at each step.

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15. Respiration requires O_2. How did the first cells on the earth manage to survive in an atmosphere that lacked O_2?

Solution: Survival Mechanisms of Early Cells:

Anaerobic Metabolism:

- **Fermentation processes:** Converting organic compounds without oxygen
- **Alternative electron acceptors:** Using nitrate, sulfate, or other compounds instead of oxygen
- **Chemosynthesis:** Obtaining energy from inorganic chemical reactions

Examples:

- **H_2S utilization:** Breaking down hydrogen sulfide for energy
- **Methane production:** Methanogenic pathways
- **Sulfur metabolism:** Using sulfur compounds as electron acceptors

Enhanced Explanation: Early Earth's atmosphere was reducing (lacking oxygen). The first cells evolved various anaerobic metabolic pathways that didn't require oxygen, some of which are still used by certain organisms today in oxygen-free environments.

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16. Red muscle fibres in animals can work for longer periods continuously. How is this possible?

Solution: Adaptations of Red Muscle Fibres:

High Myoglobin Content:

- **Myoglobin:** Oxygen-binding protein (similar to hemoglobin)
- **Oxygen storage:** Stores oxygen as oxymyoglobin
- **Red color:** Due to heme groups in myoglobin

Efficient Oxygen Utilization:

- **Sustained oxygen supply:** During prolonged activity
- **Aerobic respiration:** Continues even during extended exercise
- **ATP production:** Maintains high energy output

Enhanced Explanation: Red muscle fibers are designed for endurance activities. The stored oxygen in myoglobin allows continued aerobic respiration even when blood oxygen delivery might be temporarily insufficient.

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17. The energy yield in terms of ATP is higher in aerobic respiration than during anaerobic respiration. Explain.

Solution: ATP Yield Comparison:

Aerobic Respiration:

- **Complete oxidation:** Glucose → CO_2 + H_2O
- **ATP yield:** ~38 molecules per glucose
- **Pathways involved:** Glycolysis + TCA cycle + Electron transport

Anaerobic Respiration:

- **Incomplete oxidation:** Glucose → Organic compounds
- **ATP yield:** Only 2 molecules per glucose
- **Pathway:** Only glycolysis

Efficiency Ratio: Aerobic is ~19 times more efficient

Enhanced Explanation: Aerobic respiration extracts maximum energy by completely oxidizing glucose, while anaerobic respiration only partially breaks down glucose, leaving much of the energy locked in the end products.

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18. Select enzymes involved in:

a) Photosynthesis:

- RuBP carboxylase
- PEP carboxylase
- ATPase

b) Respiration:

- Hexokinase
- Pyruvate dehydrogenase
- Cytochrome oxidase
- Lactate dehydrogenase
- ATPase

c) Both photosynthesis and respiration:

- ATPase

Enhanced Explanation: ATPase is involved in both processes - synthesizing ATP during photosynthesis (photophosphorylation) and during respiration (oxidative phosphorylation), as well as hydrolyzing ATP for energy in both processes.

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19. How does a tree trunk exchange gas with the environment although it lacks stomata?

Solution: Gas Exchange through Lenticels:

Lenticels:

- **Structure:** Small openings in bark
- **Function:** Allow gas exchange
- **Location:** Scattered across trunk surface

Gas Exchange Process:

- **Oxygen intake:** For cellular respiration
- **CO_2 release:** From respiratory processes
- **Water vapor:** May also be exchanged

Enhanced Explanation: Lenticels serve as the "breathing pores" of woody stems, compensating for the absence of stomata in bark tissue. They're particularly visible as small, raised patches on smooth bark.

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20. Write any two energy-yielding reactions of glycolysis:

Solution: Energy-Yielding Reactions:

1. 1,3-bisphosphoglycerate → 3-phosphoglycerate + ATP

- Enzyme: Phosphoglycerate kinase
- Energy: Substrate-level phosphorylation

2. Phosphoenolpyruvate → Pyruvate + ATP

- Enzyme: Pyruvate kinase
- Energy: Substrate-level phosphorylation

Net Energy: These reactions produce 4 ATP molecules (2 from each reaction occurring twice per glucose), resulting in net gain of 2 ATP after subtracting the 2 ATP consumed in earlier steps.

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21. Name the site(s) of pyruvate synthesis. Also, write the chemical reaction wherein pyruvic acid dehydrogenase acts as a catalyst.

Solution: Site of Pyruvate Synthesis: Cytoplasm (during glycolysis)

Pyruvate Dehydrogenase Reaction: Pyruvate + CoA-SH + NAD^+ → Acetyl CoA + CO_2 + NADH + H^+

Location: Mitochondrial matrix **Enzyme Complex:** Pyruvate dehydrogenase complex (multienzyme complex)

Enhanced Explanation: This reaction links glycolysis to the TCA cycle, converting the 3-carbon pyruvate into the 2-carbon acetyl group while releasing CO_2 and generating NADH for the electron transport chain.

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22. Mention the important series of events of aerobic respiration that occur in the matrix and inner membrane of the mitochondrion.

Solution:

Mitochondrial Matrix: 1. Citric Acid Cycle (TCA Cycle/Krebs Cycle)

- Complete oxidation of Acetyl CoA
- Production of NADH, $FADH_2$, and GTP
- Release of CO_2

Inner Mitochondrial Membrane: 2. Electron Transport System and Oxidative Phosphorylation

- Electron transport through complexes I-IV
- Proton pumping creating electrochemical gradient
- ATP synthesis via ATP synthase (chemiosmosis)

Enhanced Explanation: The compartmentalization allows efficient coupling of substrate oxidation (matrix) with ATP synthesis (membrane), maximizing energy extraction from organic substrates.

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23. The respiratory pathway is believed to be a catabolic pathway. However, the nature of the TCA cycle is amphibolic. Explain.

Solution: TCA Cycle as Amphibolic:

Catabolic Functions:

- **Substrate breakdown:** Complete oxidation of Acetyl CoA
- **Energy production:** NADH, $FADH_2$, and GTP formation
- **Waste removal:** CO_2 elimination

Anabolic Functions:

- **Biosynthetic precursors:** TCA intermediates serve as building blocks
- **Fatty acid synthesis:** Acetyl CoA → fatty acids
- **Amino acid synthesis:** α-ketoglutarate → glutamate → other amino acids
- **Heme synthesis:** Succinyl CoA → porphyrins

Enhanced Explanation: While respiration is overall catabolic (energy-releasing), the TCA cycle serves dual roles - both breaking down substrates for energy and providing raw materials for biosynthesis, making it amphibolic.