

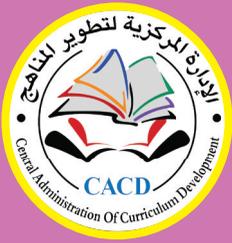
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INTEGRATED SCIENCE
FIRST SECONDARY GRADE

Second Semester

2025-2026



INTEGRATED SCIENCE

FIRST SECONDARY GRADE

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Introduction

Planet Earth faces numerous risks that threaten the sustainability of life, and the pace of these risks is escalating due to intensive human activities and rapid environmental changes. The most prominent of these are climate change, violent weather events, the loss of biodiversity, environmental pollution, the depletion of natural resources, desertification, urban expansion, plastic pollution, food insecurity, and other risks. Addressing these threats requires a joint global effort that includes implementing sustainable environmental policies, limiting harmful emissions, protecting biodiversity, and encouraging technological innovations that preserve the planet's safety and the future of life on it.

From this perspective, education has a crucial and impactful role in achieving this goal, especially by employing an integrated approach to the study of various branches of science. This approach aims to crystallize this issue in the consciousness of young people and encourages them to use different scientific disciplines to think creatively and develop solutions that contribute to achieving this objective.

This curriculum comes as a response to the growing need to teach students how the world around them works in a comprehensive and integrated way. It focuses on connecting the various branches of science (physics, chemistry, life sciences, and earth and space sciences) so that students can see the full picture of the world and gain a deep understanding of its workings. They will realize that natural and technological phenomena are not separate but are interconnected and intertwined in complex ways.

This curriculum is based on an educational philosophy that aims to build a deep and comprehensive understanding of science, with a focus on using scientific knowledge to solve real-world problems and challenges facing society and the world. The curriculum aims to present science as a unified body of knowledge where concepts support one another. In each module, concepts from physics, chemistry, life sciences, and earth and space sciences are integrated. This integration enhances students' ability to apply scientific knowledge in multiple contexts and prepares them to face challenges that require comprehensive and multi-faceted thinking.

Practical activities are the core of this curriculum, as they give students an opportunity to apply what they have learned in real and experimental contexts. Through these activities, students can explore scientific concepts directly, which enhances their understanding and improves their problem-solving skills. These activities also encourage critical thinking and teamwork, which boosts students' skills in research, experimentation, exploration, and innovation.

The curriculum is based on the principle that students should be at the center of the educational process. Students are encouraged to be active participants in their learning through capstone projects and scientific challenges. These projects give them the opportunity to apply what they have learned in real-world situations, which enhances their critical and creative thinking skills. Students are also motivated to collaborate with their peers, which enhances their social skills and prepares them for future teamwork.

In conclusion, we hope that this curriculum will achieve its goals of building a generation of students capable of thinking critically and comprehensively, and equipped with the necessary knowledge and skills to face future global challenges in the fields of energy, the environment, and technology.

The Authors

General Objectives of the Integrated Science Curriculum

1. Deepening the Understanding of Scientific Phenomena:

The curriculum aims to enhance students' understanding of scientific phenomena in an integrated way, allowing them to grasp the connections between different branches of science and apply this knowledge to solve real-life problems.

2. Developing Critical and Analytical Thinking Skills:

The curriculum seeks to develop students' critical thinking and analysis skills through interdisciplinary lessons that connect physics, chemistry, and life sciences, which helps them analyze scientific phenomena and problems from multiple angles.

3. Fostering Experiential Learning:

The curriculum aims to encourage students to participate in practical activities and scientific experiments to deepen their understanding and apply what they have learned in real situations, which enhances their practical skills.

4. Encouraging Innovation and Exploration:

The curriculum seeks to foster students' curiosity and encourage them to explore scientific concepts in new and innovative ways, with a focus on the practical application of technology in solving various environmental problems.

5. Promoting Collaboration and Teamwork:

The curriculum aims to develop students' skills in collaboration and teamwork through group activities and capstone projects, which enhances their ability to work effectively within multi-disciplinary teams.

6. Applying Science to Solve Global Problems:

The curriculum seeks to prepare students to be able to use their scientific knowledge to address global challenges such as climate change, biodiversity conservation, and the development of sustainable energy sources.

7. Building Environmental Awareness and Social Responsibility:

The curriculum aims to build students' awareness of environmental issues and the challenges facing global communities, while encouraging them to take responsibility for their role in preserving the environment and contributing to the development of sustainable solutions.

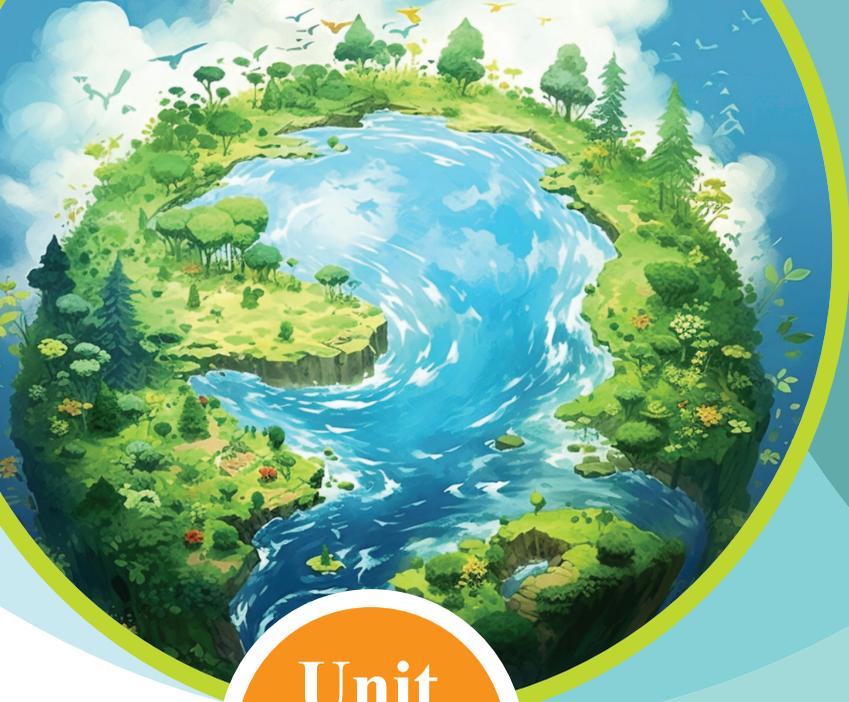
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Unit 3

Biosphere

Learning Outcomes

By the end of this unit, the student will be able to:

1. Define the biosphere and explain its relationship with other spheres (Atmosphere – Hydrosphere – Lithosphere) as an integrated system that supports life.
2. Identify the components of the biosphere and explain the role of biotic and abiotic factors in shaping different environments.
3. Explain the effect of abiotic factors such as light, temperature, water, and soil on the distribution and behavior of living organisms.
4. Classify levels of biological organization, starting from a cell to an ecosystem, providing examples from the surrounding environment.
5. Distinguish between types of systems (open – closed – isolated) and explain why a living organism is considered an open system that depends on the exchange of matter and energy with the surrounding environment.
6. Describe the mechanism of photosynthesis as the main entry point for energy into the biosphere.
7. Compare autotrophic and heterotrophic organisms and identify the benefits of each in the food chain.
8. Classify consumers (herbivores – carnivores – omnivores) according to their pattern of obtaining food.
9. Determine the chemical compounds essential for life (carbohydrates – proteins – lipids – nucleic acids) and explain their relationship to cell functions.
10. Justify that the building of macromolecules is an endothermic reaction, while their breakdown is an exothermic reaction, and relate this to chemical energy.
11. Explain the mechanisms of transport in living organisms (active and passive transport) and compare transport vessels in plants with the circulatory system in humans.
12. Connect transport in living organisms to homeostasis and its role in maintaining the stability of the internal environment of the organism.
13. Explain cellular respiration and illustrate its importance in producing the ATP molecule as an energy source.
14. Compare aerobic and anaerobic respiration in terms of the conditions of occurrence, and the amount of energy produced.
15. Illustrate the importance of excretion in eliminating metabolic waste products and regulating the internal environment of the organism.
16. Explain the transmission of nerve signals and the nerve impulse and interpret the role of the synapse in regulating responses.
17. Define the properties of nanomaterials and explain their role in improving energy efficiency and drug delivery in modern applications.
18. Discuss the environmental dimensions of nanotechnology and its impact on biological sustainability.
19. Connect concepts of the biosphere to energy and technology through modern applied examples.

Unit Summary

This unit starts with the **biological processes inside the living organism** as the entry point for understanding the mutual relationship between life and the environment within the biosphere. The student begins exploring the biosphere, its components, and levels of organization, to recognize how living systems integrate with the surrounding environment.

The student then learns about **trophic patterns** and **relationships** that regulate the transfer of energy between organisms, before delving into the **chemical compounds** necessary for life and their role in body structure and functions.

The concepts then proceed through a series of **fundamental biological processes** such as **digestion**, which breaks down nutrients into less complex materials, followed by **transport**, which distributes materials inside the body. The student also learns about **respiration** for energy production, then excretion to maintain homeostasis in the body, and **sensation and response** to understand the organism's interaction with its environment.

The unit concludes with a look into the future by studying the **applications of nanotechnology** in bioenergy and medicine, illustrating how modern science and our understanding of vital processes are utilized to serve humanity and the environment.



3.1

Biosphere and its Stability

Biosphere is the part of Earth where life exists, extending from the depths of the oceans to the highest mountain peaks, and encompassing land and air.

The biosphere is considered a vast, integrated system that includes all living organisms (plants, animals, and microorganisms) as well as the environments in which they live. Living organisms in the biosphere constantly interact with their surroundings, in a continuous exchange of matter and energy.

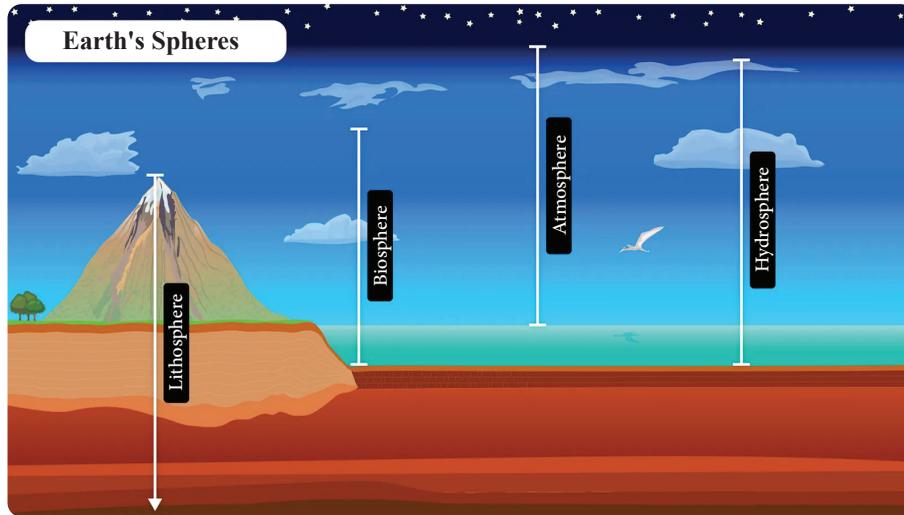


Figure (1) Earth's Spheres

Biosphere's Relationship with Earth's Other Spheres

Biosphere is closely connected to the other spheres that make up planet Earth. It does not function in isolation but depends on these spheres for continuation and balance of life.

Living organisms that form the biosphere constantly interact with the **hydrosphere**, which provides the water necessary for all vital processes, and with the **atmosphere**, which supplies essential gases such as Oxygen for respiration and Carbon dioxide for photosynthesis.

Lithosphere, which will be studied in detail in the next unit, provides mineral elements through the soil, upon which plants depend for growth and stability.

The life cycle of a plant provides a clear example of this interaction. When a plant absorbs water from the soil (Hydrosphere and lithosphere) and Carbon dioxide from the air (Atmosphere), it uses the energy of the sun to produce food that enables its growth within biosphere. The plant releases Oxygen into the air (Atmosphere) and returns part of the water to the atmosphere as water vapor (Hydrosphere). When the plant dies, it decomposes in the soil into simple substances (Lithosphere).

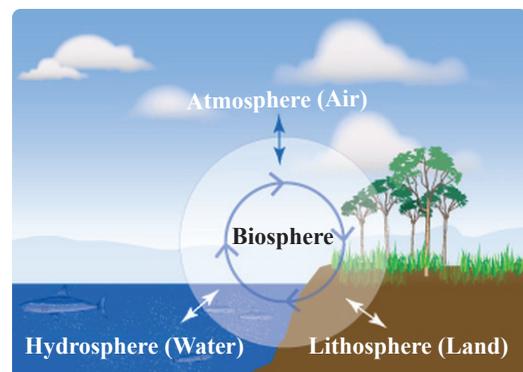


Figure (2) Biosphere's Relationship with Earth's Other Spheres

Biotic and Abiotic Factors

Biosphere consists of living (biotic) and non-living (abiotic) components that work together in a balanced system, making life possible on the Earth's surface

Biotic Factors

Biotic factors include all living organisms that affect the environment and are affected by it, such as plants, animals, and microorganisms. These organisms play different roles within the ecosystems. Plants produce food through the process of photosynthesis which is considered the primary source of energy for the rest of the organisms.

As for animals, they are classified as consumer organisms that depend on plants or other animals (preys) for their food.

Meanwhile, decomposer organisms, such as bacteria and fungi, break down the remains of dead organisms and return the essential substances and elements to the environment for a new ecosystem to

benefit.

Abiotic Factors

Abiotic Factors are the non-living components in the environment, and they include light, water, temperature, soil, minerals, and air. These factors are responsible for determining the type of living organisms that can inhabit a specific area, as every living organism requires defined environmental conditions to grow and survive.

The interaction of biotic and abiotic factors together forms a balanced ecosystem that maintains the continuity of life within the biosphere.

For example, in a lake ecosystem, fish, algae, and bacteria interact with the physical and chemical elements of water in a continuous cycle of matter and energy exchange.

When several ecosystems share similar climatic characteristics and dominant living organisms, they form what is known as a biome. For example, the tropical rainforests in the Amazon, Africa, and Asia represent biomes that share a warm, humid climate and abundant biodiversity. while, major deserts share harsh climatic characteristics and plants adapted to drought.

The highest and most comprehensive level is the biosphere, which is the vast system that encompasses all biomes on the Earth's surface, including the land, water, and air, and contains all forms of life and their interactions with the other spheres of the planet. The biosphere extends from the depths of the oceans to the peaks of mountains.

Therefore, the organization of life progresses in an integrated hierarchical sequence, where a higher level is composed of a group of the levels below it. These levels are interconnected by complex and mutual interactions that ensure the survival of living organisms and the balance of ecosystems on our planet.

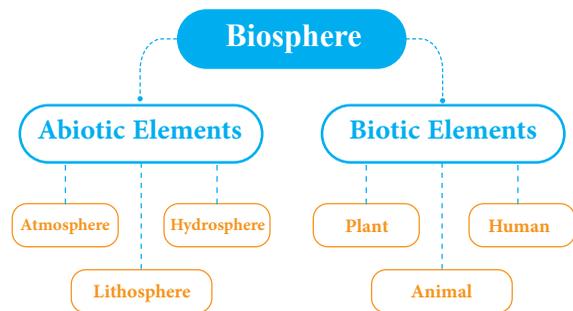


Figure (3) Illustration of the Biosphere

Levels of Organization in the biosphere

Living organisms exist within an integrated system, and no species can exist in isolation from other species or the surrounding environment. Life on Earth is organized into hierarchical levels of complexity, beginning with the smallest unit which is the individual organism and ending with the largest, which is the biosphere. Biosphere encompasses all life on planet Earth.

The Organism represents the first level of this sequence; it is a single individual of a specific species, such as one fish in a pond or one tree in a forest. A collection of individuals of the same species forms a population, such as a herd of antelope in the African savanna or a gathering of fish in the Red Sea. Individuals in the population share the same place and time period and interact with each other in terms of food, reproduction, and protection.

When different populations of multiple species gather and live in one area, they form a biological community, such as a forest that includes trees, herbaceous plants, insects, birds, and mammals, all interacting in a complex web of trophic relationships.

One of the essential mechanisms linking these levels is the Food webs, which is the way living organisms obtain matter and energy. Identifying how each organism obtains its food reveals its role within the community and its position in the food web, illustrating how energy and nutrients transfer across the different levels of life organization.

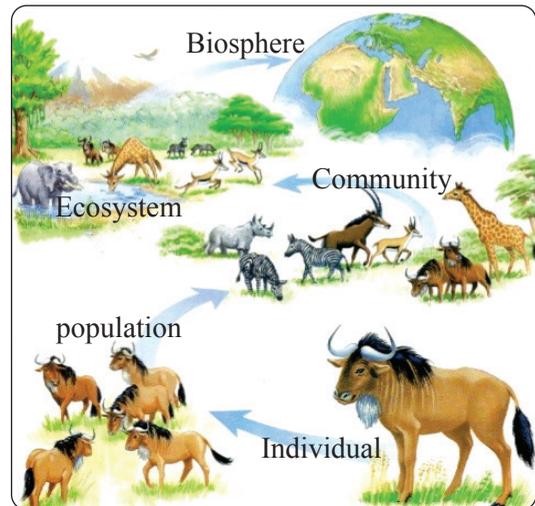


Figure (4) Levels of Organization in the Biosphere

Trophic Patterns and Energy Transfer in the Ecosystem

The production of food in the ecosystem begins with organisms known as Autotrophic Organisms, or Producer Organisms. These are organisms capable of converting inorganic substances into organic compounds that store energy. The most common of these organisms are green plants and algae, as well as some specialized bacteria.

Plants use light energy, Carbon dioxide, and water to produce sugars and organic nutrients in the process of photosynthesis. This process can be simply expressed by the following chemical equation:

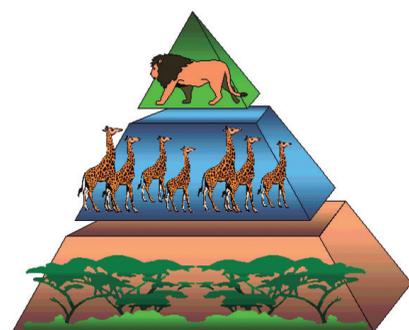
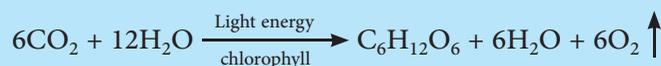


Figure (5) Trophic Levels in the Ecosystem



Unit 3... Biosphere

Producer organisms form the base of the **pyramid**, because all the energy available to the other trophic levels primarily comes from their transform of light energy into chemical energy that is available for consumption.

Next come the **Heterotrophic Organisms**, or Consumer Organisms, which cannot produce their own food. Instead, they obtain it by consuming the producers or other consumer organisms.

Consumer organisms can be divided into trophic levels according to their food source:

- **Primary Consumer Organisms (Herbivores):**

These feed directly on plants.

- **Secondary Consumer Organisms:**

These feed on herbivores and proceed to the highest levels where the top predators are found.

Examples of Trophic Levels:

In a **River Ecosystem**: Microscopic Algae (Producer Organisms) feed small fish (Primary Consumers), which in turn feed larger predatory fish (Secondary or Tertiary Consumers).

In a **Terrestrial Ecosystem**: Trees and plants form the base upon which rabbits and deer feed, which are then consumed by wolves or eagles as higher-level consumers.

Decomposers come in among levels of the food pyramid where they play a vital role in recycling matter within the ecosystem. Bacteria and fungi break down the remains of dead plants and animals and convert them into simple mineral elements that return to the soil and water. In the absence of decomposer organisms, organic materials and dead organisms accumulate, and the cycle of nutrients stops, negatively affecting all levels of ecological organization.

For example, in the Nile Delta and its connected lakes, algae and aquatic plants act as primary producer organisms. Fish consume small phytoplankton and zooplankton, while aquatic birds and large fish perform as top consumer organisms.

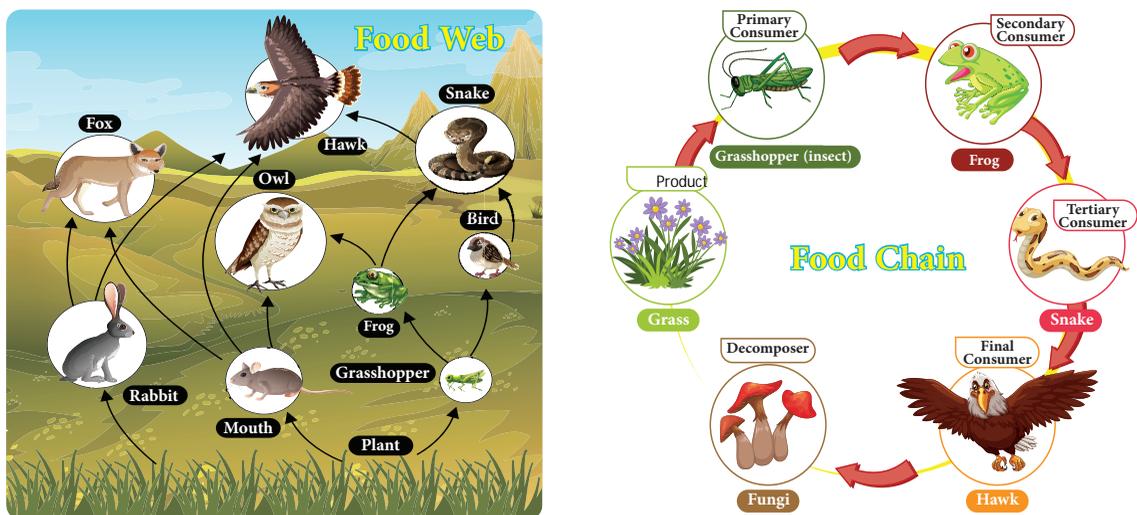


Figure (6) Food Web and Food Chain

Energy Flow in the Ecosystem

Trophic levels can also be studied through **energy flow** among them. When a herbivore eats a plant, it doesn't obtain all the energy stored in that plant, but only a small portion. Part of the energy (10%) transferred to the animal is stored in its cells and tissues. The rest of the energy is (90%) not transferred to the next trophic level, as it is distributed across several pathways, such as:

1. Energy used by the animal in vital processes:

The animal uses part of the energy transferred to it from the plant to carry out vital processes and activities such as digestion, respiration, movement, and other functions. These activities consume a large amount of energy.

2. Energy lost as heat:

During the animal's activity and execution of vital processes, an amount of produced thermal energy is transferred to the environment, and that energy is not transferred to the organism that feeds on this animal.

3. Energy stored in undigested materials:

Some parts of the plant, such as tough fibers, consumed by the animal, are not fully digested, and consequently, the animal expels a portion of the energy stored in its waste.

Based on the data mentioned above, we conclude that a **minor fraction** of the energy stored in the plant's tissues is transferred to the herbivore. Similarly, a minor fraction of the energy transfers from the herbivore to the animal that preys on it.

Thus, the amount of energy transferred from one trophic level to the next decreases as we move up the **energy pyramid** from producers to consumers.

For this reason, ecological pyramid models are used to represent the amount of energy, the number of living organisms, or their biomass across different trophic levels.

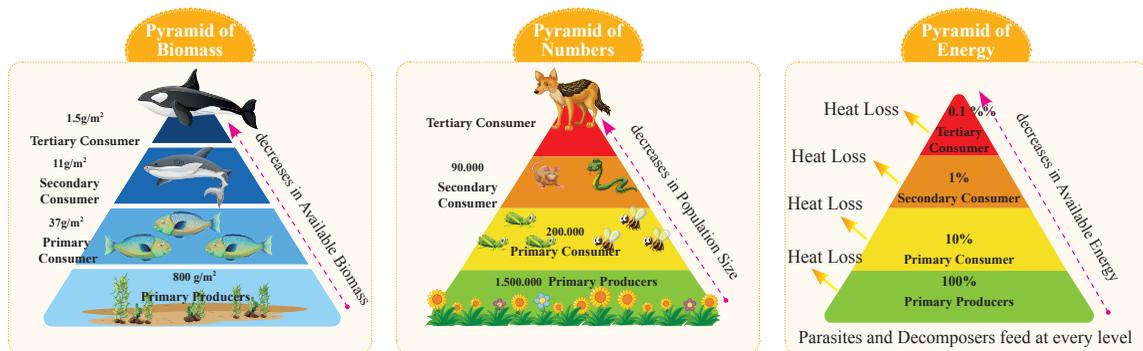


Figure (7) Ecological Pyramids

Producer organisms form the base of the pyramid and its largest level, as they are the most numerous and possess the largest amount of energy. The amount of energy, the number of organisms, or the biomass gradually decreases as we move from one level to the next, where the available energy diminishes little by little toward the top of the pyramid.

The number of organisms decreases in the upper level of the pyramid, as the available energy only supports a **small number of individuals**. This explains the low numbers of

large predators compared to the abundance of plants and herbivores.

Example

If you have 10,000 units of energy stored in a certain number of plants (producer organisms), only 1,000 units of that energy may reach the herbivores that feed on them (primary consumers). Then, only 100 units may reach the carnivores that feed on the herbivores (secondary consumers), and perhaps only 10 units may reach the top predator that feed on the carnivores (tertiary consumers).

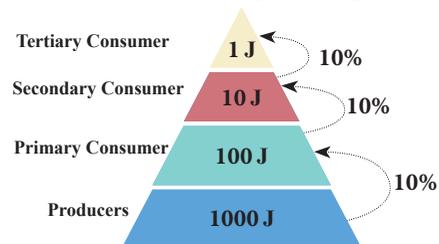


Figure (8) Pyramid of Energy

In contrast, in desert regions, producer organisms are limited due to the scarcity of water and extreme heat. Animals adapt to being energy-efficient, and the food webs are simpler and rely more on intermittent food sources. There are also complex food webs that consist of multiple interconnected chains where the consumer does not rely on a single type of food, but on multiple sources. This interconnection makes the biological community more resilient to the loss of a single species, but it also makes negative, wide-ranging impacts, such as the removal of vegetation cover or water pollution, whose influence extends throughout the entire web.

Technological Applications

Scientists have developed **smart collars** with **precise sensors** placed around the necks of wild animals located in the "Nature Reserves in Kenya". These sensors measure the **amount of energy** the animal consumes each day during its activity and search for food, by measuring the rate of movement, pulse, and body temperature. By using Artificial Intelligence (AI), the data is analyzed to determine the amount of **energy the animals lose**. This innovation helped save herds of **endangered lynx** after researchers discovered that the decline in prey numbers significantly **reduced the amount of energy available** to them, enabling experts in these reserves to intervene and provide a better trophic environment.



Figure (9) Iberian lynx

Thus, studying trophic types is not merely a classification of organisms, but a tool for understanding the dynamics of ecosystems, and how they maintain their balance or how ecological functions collapse when exposed to disruptive human or natural factors.

After learning how living organisms obtain their food, it is important to understand what this food is made of, and what substances provide cells with energy and build the bodies of organisms.

Chemical Compounds in the Biosphere

All modes of nutrition, regardless of their differences, ultimately aim to supply the bodies of living organisms with the essential chemical compounds upon which life is based. These organic compounds consist of four main groups: Carbohydrates, Proteins, Lipids, and Nucleic Acids. These compounds represent the sources where energy is stored, and the elements that regulate vital processes.

In the following section, we will identify the most important compounds, their structure, and their vital functions.

First: Carbohydrates: The main source of energy

Carbohydrates are the most common organic compounds in living organisms. Their molecules are composed of Carbon, Hydrogen, and Oxygen in an approximate ratio of (1:2:1), respectively. They are considered the main source of energy in most living organisms, as these compounds are broken down in cells to produce the energy required for vital activities. Carbohydrates are divided into three main types:

- **Monosaccharides:** These are the simplest forms of carbohydrates and are used directly in cellular respiration to produce energy, such as glucose (grape sugar) and fructose (fruit sugar).

- **Disaccharides:** These result from the combination of two monosaccharide molecules, such as sucrose (cane sugar) and lactose (milk sugar).

- **Polysaccharides:** These are complex compounds composed of many monosaccharides. They are involved in building cells, storing energy, or forming supportive structures, such as cellulose, which is a component of plant cell walls; chitin, which is a component of the exoskeletons of arthropods; starch, which is stored in plants (in leaves and tubers); and glycogen, which is stored in animals (inside the liver and muscles).

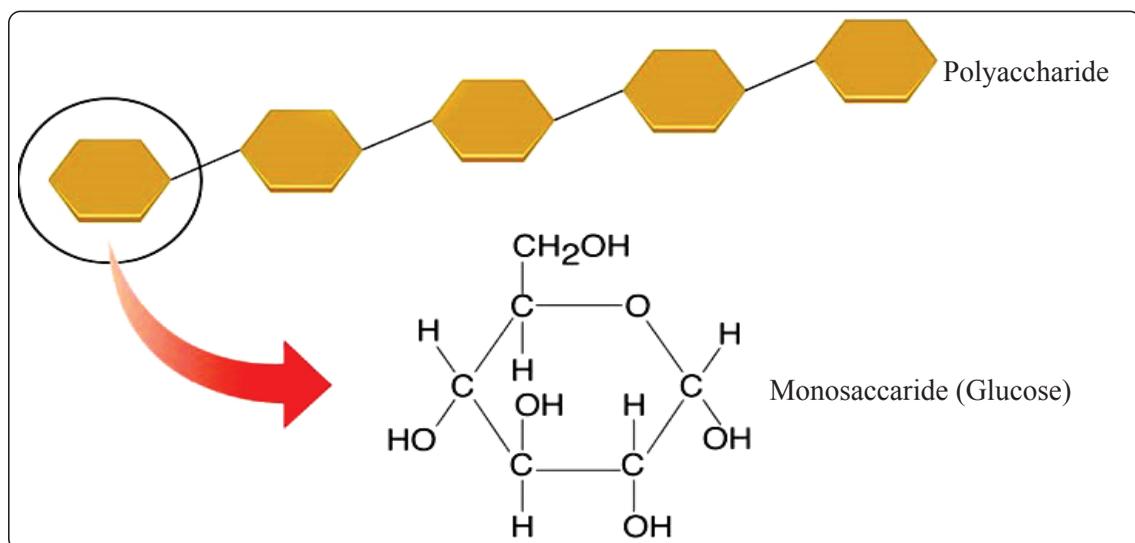


Figure (10) Polysaccharides are composed of many monosaccharides

Energy in living cells

Adenosine Triphosphate (ATP) molecules are the direct source of energy in living cells, as they represent the form of chemical energy that can be used directly in various vital processes.

An **ATP molecule (Adenosine Triphosphate)** consists of three phosphate groups attached to a molecule called **Adenosine**. **The bond between the second and third phosphate groups** is a high-energy bond, because it requires significant energy to form. When this bond is broken, a quantity of energy is released that the cell can use directly to perform its vital functions, such as muscle contraction or transport of substances across membranes.

When **glucose**, resulting from photosynthesis or obtained from food in heterotrophic organisms, enters the cell, it is broken down in a series of complex reactions known as **cellular respiration**. During this process, its chemical bonds are gradually broken, leading to the release of energy. This energy is not used directly but is stored in an organized manner within ATP molecules.

When the cell needs energy, this bond is broken, converting the **ATP molecules into Adenosine Diphosphate (ADP)**, and releasing the energy required for the cell to perform its functions, such as muscle contraction, transporting substances across membranes, or building biological molecules.

By adding a new phosphate group, the cell can reform the active ATP molecule from ADP, using part of the energy released from the oxidation of glucose. Thus, this precise vital cycle continues, ensuring that cells are supplied with continuous and renewable energy that sustains life.

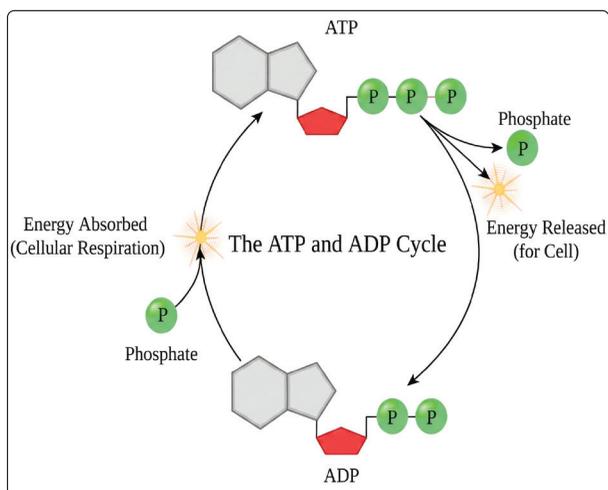


Figure (11) The cycle of adenosine diphosphate (ADP) and adenosine triphosphate (ATP) (For Knowledge Only)

Medical Applications

Continuous Glucose Monitoring (CGM) devices are among the most important modern health innovations. They measure blood sugar level inside the body every few minutes without pricking, which helps track the availability of carbohydrates as an energy source before their conversion into **ATP molecules**.

These devices assist patients and athletes in understanding how carbohydrate meals affect energy production, and in accurately adjusting their diet pattern and physical effort levels to maintain stable energy and better health.



Figure (12) CGM Device

Second: Proteins: The functional building units of living organisms within biosphere.

Proteins are large, complex molecules composed of small units known as **amino acids**. These molecules contain the elements Carbon, Hydrogen, Oxygen, and Nitrogen, and sometimes Sulfur. They constitute the main structural material in the bodies of living organisms, and are involved in the composition of muscles, enzymes, hormones, and immune bodies.

Proteins differ according to the arrangement of amino acids within their chains, and this arrangement determines their shape and function. For example, structural proteins like keratin provide strength to hair and nails, while enzymatic proteins like amylase accelerate biochemical reactions inside the body without being consumed in the process.

When proteins break down during digestion, they are broken down into amino acids that are reused to build new proteins according to the needs of the cells.

Third: Lipids: Energy Stores

Lipids are organic compounds whose molecules consist mainly of Carbon, Hydrogen, and Oxygen. They are considered a compact storage of energy in the body, as their oxidation produces double the energy generated by carbohydrates. Lipids also function as thermal insulation that maintains body temperature, such as the thick layer of fat in the Polar Bear. Phospholipids are lipid molecules that contain a phosphate group and constitute an essential component of cell membrane. They contribute to the formation of a bilayer that surrounds the cell.



Figure (13) Polar Bear

Lipids exist in several forms, including vegetable oils and animal fats, and are stored in adipose tissues to be used by cells when energy is needed. Certain types of lipids, such as cholesterol, also participate in the formation of some hormones and Vitamin D.

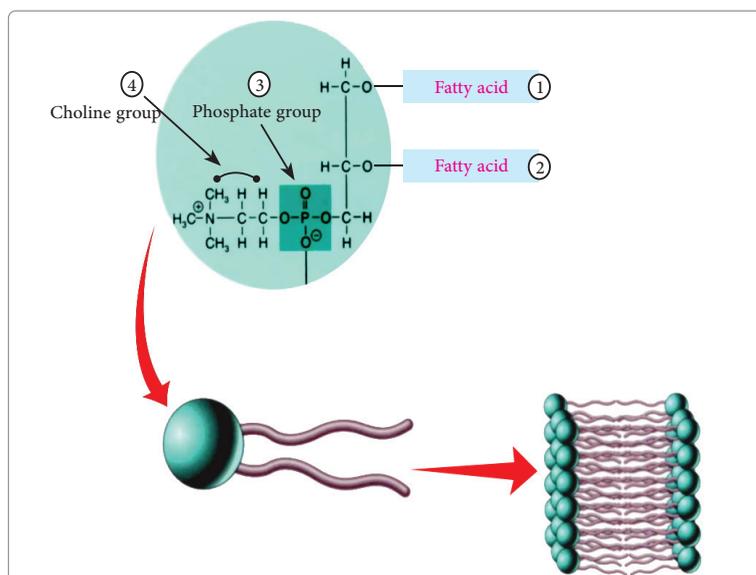


Figure (14) The molecular structure of phospholipids

(For Reference Only)

Comparing the caloric content of fats and carbohydrates

The **caloric content** is defined as the amount of heat produced by the combustion of 1 gram of food, and it is measured in kilojoules per gram (kJ/g). In practical applications, the unit kilocalorie per gram (kCal/g) is commonly used. It should be noted that:

(1 Calorie = 4.18 J)



Practical Experiment

Tools:

Test tube - Combustion spoon - Bunsen burner - Sensitive balance - Thermometer - Water - Sample of white sugar (Carbohydrate) - Sample of pure vegetable oil (Lipid)

Procedures:

- 1-Place a suitable volume of water in the test tube.
- 2-Record the initial temperature (t_1) of the water using the thermometer.
- 3-Put a specific mass of sugar (10 g) in the combustion spoon.
- 4-Begin burning the food sample using the Bunsen burner at a distance of 1 cm from the test tube until it is completely combusted.
- 5-Record the final temperature (t_2) of the water. The magnitude of change in the temperature of the water sample ($t_2 - t_1$) represents the amount of energy absorbed by the water and the tube, which in turn reflects the quantity of energy released by the food sample during combustion.
- 6- Repeat the previous steps with an equivalent mass of vegetable oil.

Record your observation:.....

Conclusion:

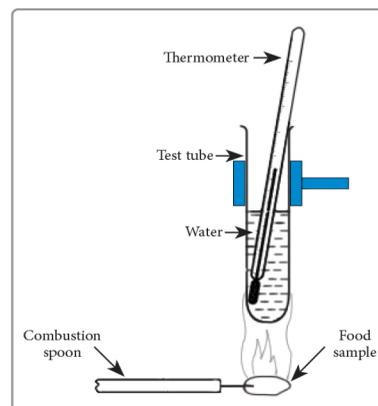


Figure (15) Determining caloric content of a food sample

Modern technology and the interpretation of the structure of biomolecules from a physical perspective

Modern technology has led to the development of precise devices that have enabled scientists to study the essential compounds of life at the molecular level. One of the most important of these devices is the electron microscope, which relies on the use of a beam of electrons instead of light to form an image. The wavelength associated with the electron can be controlled to become much shorter than the wavelength of light, which allows viewing very small structures such as membrane proteins and lipids that cannot be seen with traditional light microscopes.

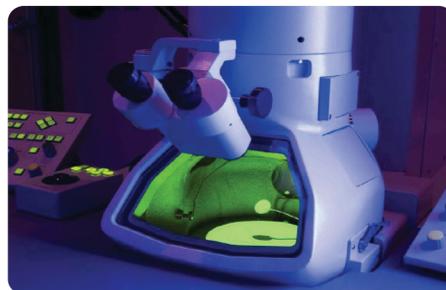


Figure (16) Electron Microscope

This advancement has helped to understand how molecules are arranged inside cells, especially biological membranes which are built from double layers of lipids. This, in turn, has contributed to the design of modern drugs that target specific proteins inside the cell with greater precision. This demonstrates the extent of the integration among different branches of science in producing modern materials and tools that improve the quality of life and maintain balance on planet Earth.

Fourth: Nucleic Acids and Ensuring Life Sustainability in the Biosphere

Nucleic acids are the basis of heredity in all living organisms, as they carry the genetic code responsible for determining the organism's traits and regulating its cell functions.

Nucleic acids are composed of small units called **nucleotides**, each consisting of a pentose sugar, a phosphate group, and a nitrogenous base. The nitrogenous bases are **Adenine(A)**, **Thymine (T)**, **Cytosine(C)**, and **Guanine (G)**. The arrangement of these bases gives rise to what is known as the "**Genetic Code**", which determines all the characteristics of the living organism.

There are two main types of nucleic acids:

- **Deoxyribonucleic Acid (DNA):** This is the nucleic acid that carries the genetic information inside the cell's nucleus and is transmitted from one generation to the next.

- **Ribonucleic Acid (RNA):** This participates in translating this genetic information into proteins that execute the cell's functions.

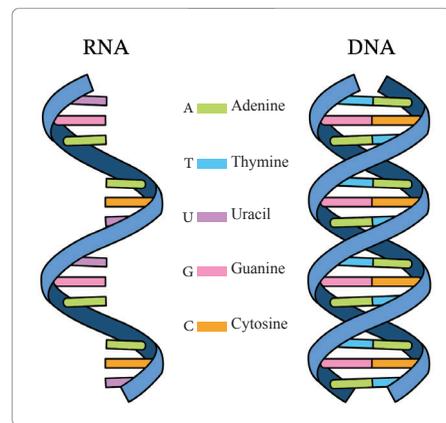


Figure (17): Nucleic Acid

Modern Technological Applications

In modern laboratories, the CRISPR-Cas9 technique is one of the latest tools in genetic engineering used for modifying Deoxyribonucleic Acid (DNA). Scientists use this system as a highly precise "**molecular scissor**" to target a specific sequence of **nitrogenous bases (Adenine A, Thymine T, Cytosine C, and Guanine G)** within the cell's genome. This high degree of precision allows for specific genetic modifications, with the purpose of:

- **Correcting defective or disease-causing genes**, such as those that cause sickle cell anemia.
- **Adding new genes or removing undesirable genes** to produce crops with improved characteristics and resistance to diseases.



Figure (18) Genetic Engineering

Lesson One Assessment

First: Multiple Choice Questions

Choose the correct answer:

1. Which of the following most accurately describes the Biosphere?

- A. The layer of gases surrounding the Earth
- B. Living organisms and their habitats on Earth
- C. The water found on the Earth's surface
- D. The rocks that form the Earth's crust

2. The biosphere interacts with the hydrosphere when:

- A. Living organisms breathe oxygen
- B. Plants absorb water from the soil
- C. Mountains are formed from rocks
- D. Wind moves in the atmosphere

3. Which of the following levels represents a collection of multiple species living and interacting in one area?

- A. Organism
- B. Population
- C. Community
- D. Ecosystem

4. In the ecosystem, sunlight represents a/an:

- A. Biotic factor
- B. Reproductive factor
- C. Abiotic factor
- D. Genetic factor

5. Which of the following examples illustrates an interaction between Biotic and Abiotic Factors?

- A. A lion preying on a deer
- B. A plant absorbing sunlight to produce its food
- C. A fruit decaying due to fungi
- D. The formation of a community of birds in a forest

6. Plants are considered Autotrophic Organisms because they:

- A. Consume other organisms to obtain energy
- B. Obtain their food only from salts and minerals
- C. Produce their own food from inorganic substances
- D. Rely on fungi for food decomposition

7. Which of the following processes represents the conversion of light energy into chemical energy?

- A. Cellular respiration
- B. Photosynthesis
- C. Organic decomposition
- D. Digestion

8. Which of the following compounds is considered the main source of energy in the cell?

- A. Proteins B. Lipids C. Carbohydrates D. Nucleic Acids

9. Which of the following statements accurately explains the role of proteins?

- A. They store long-term energy
B. They form cell walls
C. They accelerate biological reactions and build tissues
D. They carry genetic information

10. Nucleic acids carry genetic information because their structure contains:

- A. Chains of amino acids
B. High-energy phosphate bonds
C. Nitrogenous bases arranged in a specific system
D. Chains of fatty acids

11. The glucose molecule releases its energy in the cell to form:

- A. DNA B. ADP C. ATP D. RNA

12. The third bond in the (ATP) molecule is characterized by being:

- A. Weak and does not store energy
B. Strong and stores energy available for release
C. An ionic bond between two metallic atoms
D. A hydrogen bond between two water molecules

13. Which of the following shows the relationship between trophic patterns and chemical compounds?

- A. Autotrophic organisms make organic compounds that store energy
B. Heterotrophic organisms consume salts only
C. Decomposer organisms use light to make proteins
D. All organisms use light energy directly

14. If the light intensity decreases in an environment, what is the probable effect on energy levels in the ecosystem?

- A. Food productivity increases
B. The amount of glucose produced decreases
C. Plant biomass increases
D. No change occurs

15. Which of the following relationships demonstrates the integration of Earth's spheres?

- A. The decomposition of dead leaves in the soil by bacteria
- B. The movement of wind above the sea surface only
- C. The evaporation of water from the surface of rocks
- D. The formation of mountains from volcanic lava

Second: Essay Questions

Explain why:

- 1. Biosphere is considered an integrated system that includes all living organisms and their habitats on Earth?**
- 2. The types of living organisms differ in different environments?**
- 3. Plants are considered biotic factors in the ecosystem?**
- 4. The ecosystem is considered an integrated unit in nature?**
- 5. Predators are necessary for the stability of the ecosystem?**
- 6. Carbohydrates are considered the main source of energy in living organisms?**
- 7. Proteins are necessary for building the body of living organisms?**

3.2 Biological Processes in Living Organisms and the Stability of the Biosphere

Living organisms require a precise system that ensures the transfer of essential substances within them, such as water, salts, oxygen, and nutrients. Transportation, respiration, and excretion are among the most important biological processes that maintain this balance. The transportation process provides every cell with the materials it needs, while respiration converts these materials into energy used to perform various vital activities. In excretion, the organism gets rid of waste products resulting from biological processes. Through this integration, living organisms contribute to the stability and balance of the biosphere, as they recycle materials and energy in a way that preserves the continuation of life on planet Earth.

First: Transportation in Living Organisms and its Role in Distributing Materials and Energy

1. Vascular Tissues in Plants

Higher plants have transportation systems that enable them to transfer water, salts, and nutrients within their parts, despite the absence of a specialized organ for pumping, like the heart in humans. These systems are the **xylem tissues** and the **phloem tissues**.

Xylem Tissues: Transporting Raw Materials for Photosynthesis.

The **Xylem tissue** is responsible for transporting water and mineral salts absorbed from the soil to the leaves, where the process of photosynthesis takes place.

The xylem tissue is primarily composed of long, hollow tubes that extend from the root to the leaves, formed from specialized cells known as **Tracheids** and **Vessels**. These cells are dead in the mature plant to facilitate the passage of water through them.

The walls of the xylem vessels are supported by a rigid substance called **Lignin**, a substance that gives the vessels strength and stiffness and prevents their collapse. The lignin layer also helps to resist compression, allowing the vessels to maintain their shape even in the tallest plants. Water and mineral salts move through the xylem vessels in one direction from the roots to the leaves, relying on unique physical properties of water molecules.

In the **xylem** vessels, water moves in a continuous column from the root to the summit due to what is known as the **Cohesion–Adhesion Theory**, which explains how water ascends against gravity without the presence of any pump inside the plant.

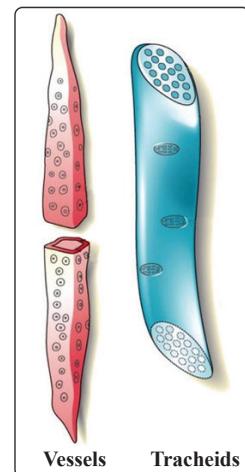


Figure (19) Xylem

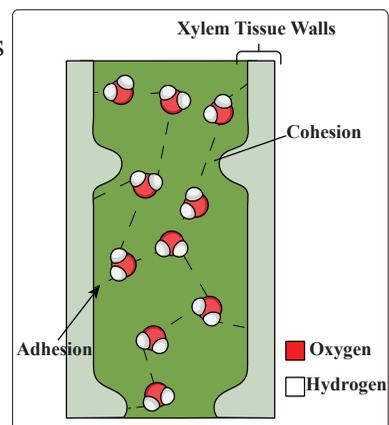


Figure (20) Cohesion and Adhesion Forces of Water inside Xylem Vessels

Cohesion-Adhesion Theory

This theory is based on three basic types of forces:

1. Cohesion Forces: These are the forces that link water molecules to each other because of the hydrogen bonds between them, which makes the water column in the xylem vessels cohesive during its movement.

2. Adhesion Forces: These are the forces that attract the walls of the xylem vessels to water molecules, which helps stabilize the water column inside the vessels as they ascend.

3. Transpiration Pull:

The loss of water vapor from the leaves through the stomata during the process of transpiration reduces the number of water molecules in the leaf cells. Consequently, the water pressure in the leaf becomes less than that in the stem or root, meaning it becomes negative, creating a **pulling force** known as the "transpiration pull," which pulls the continuous water column in the xylem vessels upwards.

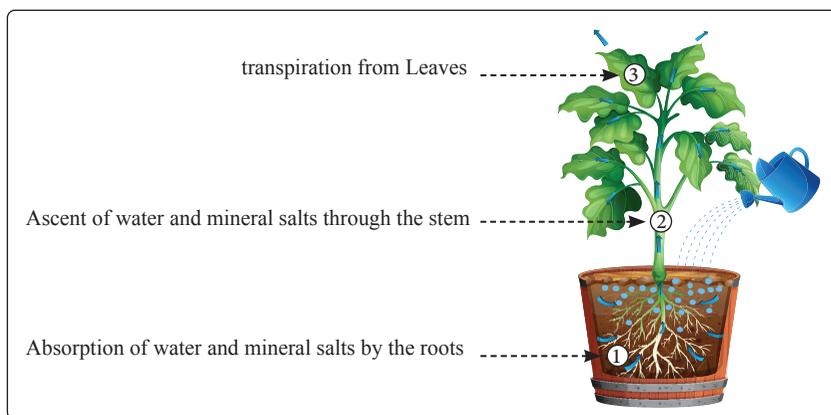


Figure (21) Ascent of Water and Salts through the Plant Stem

Thus, water and mineral salts move continuously from the root to the stem and the leaves. Therefore, a tall plant—like a pine tree—can raise water tens of meters without a pump.

Thus, the process of transpiration is not limited to being a means of getting rid of excess water or regulating the plant's temperature; it also contributes to **adding water vapor to the atmosphere**, contributing to cloud formation and rainfall as part of the water cycle in nature.

• **Phloem Tissues: Transporting Photosynthesis Products as an Energy Source in the Biosphere**

Phloem tissue transports the products of photosynthesis, such as glucose and amino acids, from the leaves to all parts of the plant, including the roots, fruits, and seeds.

The **phloem tissue** is primarily composed of interconnected living cells known as Sieve Tubes that line side by side to form continuous transport channels.

Sieve tube cells do not contain a nucleus but are linked to specialized cells called **Companion Cells** that supply them

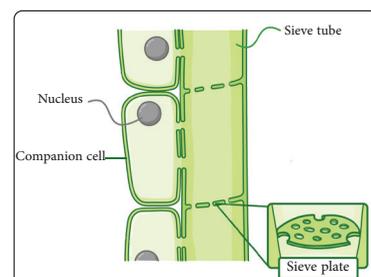


Figure (22) Structure of Phloem Tissue

with energy and help regulate the movement of nutrients through the phloem.

This transport occurs in two directions—upward and downward—depending on the plant's needs at each growth stage. For example, sugars are stored in the roots during winter, and then they are transported back to the leaves in spring to nourish new growth. Thus, it appears that plants, despite being fixed in place, possess an efficient and balanced system for distributing water and energy that ensures their continued life and growth.

Modern Technology Applications

Studying Fluid Movement in Plants

Modern techniques, such as **Micro-CT Scanning (Micro-X-ray Computed Tomography)**, are used to study the complex mechanisms of water and nutrient transport within the plant with high precision, specifically in the **Xylem** and **Phloem** tissues. This technique works by creating three-dimensional (3D) images of the structures of the vascular vessels and the xylem and phloem tissues without destroying the plant sample. These images allow scientists to monitor the movement of water through the xylem vessels and check for phenomena inside the vessels, such as the formation of air bubbles that impede the continuity of the water column's upward movement against gravity.

These experiments and applications help in understanding the role of the properties of **Cohesion** and **Adhesion** in the ascent of water to the tops of tall trees, providing information to develop drought resistance strategies and improve water-use efficiency in agriculture.



Figure (23) Micro-CT Scanning (Micro-X-ray Computed Tomography)

The Circulatory System in Humans and its Role in the Transportation Process

Like plants, humans also require an internal transport system that ensures the delivery of Oxygen and nutrients to all body cells. The **Circulatory System** performs this vital role through an integrated network consisting of the **heart, blood vessels, and blood**.

1. **The Heart:** The heart acts as a powerful muscular pump that drives blood through two main, integrated circuits:

A) The Major (Systemic) Circulation:

Oxygen-rich (**Oxygenated**) blood is pumped from the left ventricle through the aorta to all body tissues. Conversely, oxygen-poor (deoxygenated) blood returns via the veins to the right atrium, and rich in Carbon dioxide and then to the right ventricle.

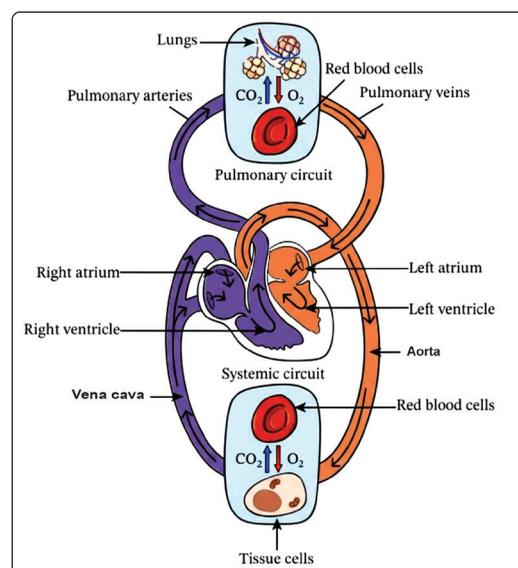


Figure (24) Blood Flow Through the Human Circulatory System

B) The Minor (Pulmonary) Circulation:

Deoxygenated blood is pumped from the right ventricle to the lungs to supply the red blood cells with Oxygen from the inhaled air and to release Carbon dioxide, which is expelled from the body with exhaled air. The blood then returns, loaded with Oxygen, to the left atrium, and then to the left ventricle.

2. Blood Vessels: Networks for Transporting Energy and Vital Materials within the Organism. Blood vessels are divided into:

- **Arteries:** They transport oxygenated blood at high speed and high pressure from the heart to different parts of the body.
- **Veins:** They return deoxygenated blood to the heart at low pressure with the help of valves that prevent its backflow inside the vein.
- **Capillaries:** This is where the actual exchange of substances takes place, such as Oxygen, Carbon dioxide, Glucose, and Waste products, between the blood and the body's cells.

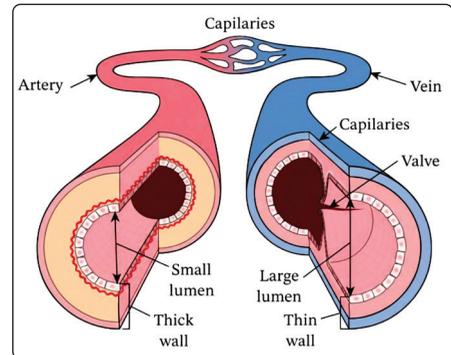


Figure (25) Blood Vessels

This system integrates with the Respiratory System, which works to supply the blood with Oxygen, and with the Excretory System, which disposes of waste. For example, during physical exertion, both the rate of breathing and the heart rate increase simultaneously to supply the muscles with more Oxygen and energy, and the rate of sweating also increases. This is considered a simple example of Homeostasis in the body's function.

Blood Pressure in Humans

The pumping of blood by the heart serves as the vital driving force that ensures the delivery of Oxygen and nutrients to all cells and tissues. The blood exerts pressure on the walls of the blood vessels (arteries and veins) as it circulates throughout the body. This pressure is essential to ensure continuous blood flow. The pressure is usually measured by two values:

Systolic Pressure: It is the higher value of blood pressure, representing the maximum pressure exerted by the blood on the artery walls during the contraction of the heart (the left ventricle) to pump blood into the body, and its normal value is 120 mmHg

Diastolic Pressure: It is the lower value of blood pressure, representing the minimum force exerted by the blood on the artery walls during the relaxation of the heart, and its normal value is 80 mmHg.



Figure (26) Blood Pressure Measuring Device

Measuring Blood Pressure

The **mercury sphygmomanometer** is the most common device for measuring blood pressure, and digital alternatives are now widely available.

Physical Properties of Blood and Maintaining Normal Blood Pressure:

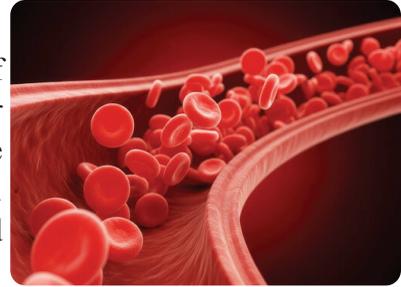
The physical properties of blood as a fluid play an essential role in maintaining blood pressure at its normal level. The most important of these properties is:

Viscosity: Blood is a **viscous fluid** (higher viscosity than water) due to its content of red blood cells, white blood cells, platelets, and dissolved proteins.

Viscosity controls the **resistance to blood flow**. If blood viscosity increases (as in cases of dehydration or an increase in the number of blood cells), its resistance to flow increases, causing a **rise in blood pressure**. Conversely, if viscosity decreases, blood flows better, and its pressure drops.

Density: The density of blood, which changes with the variation in the ratio of its components (especially hemoglobin), affects the effort required to pump the blood.

In addition to the **properties of blood** that affect its pressure, the elasticity of the blood vessel walls during contraction and relaxation, and the **strength of the heart's pump** also affect this vital pressure.



Figure(27) Blood Flow Inside Blood Vessels

Modern Physical Applications for Treating High Blood Pressure

The technique of **Renal Denervation (RDN)** is one of the latest technologies that helps to stabilize blood pressure in patients who do not respond to medicines.

This technique is a **simple, non-surgical** medical intervention that relies on using **Radiofrequency Energy** or **ultrasound waves** to inhibit or deactivate the overactive nerves surrounding the kidney that send nerve signals leading to an excessive rise in blood pressure.

Thus, advanced physical applications can contribute to protecting human health and supporting its stability within the biosphere.



Figure (28) Use of ultrasound imaging on the kidneys

Second: Respiration and Obtaining Energy

Cellular Respiration

Every cell in a living organism's body requires continuous energy to perform its vital activities, from transporting materials across membranes to division and growth. Cells obtain this energy from the process of **Cellular Respiration**, which is a series of chemical reactions that convert the chemical energy in glucose into usable energy in the form of **ATP**.

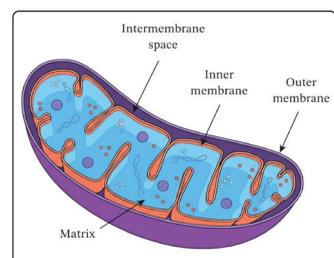


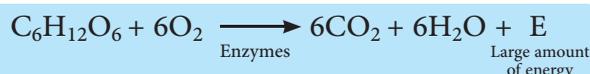
Figure (29) Structure of the Mitochondrion

Unit 3... Biosphere

The process begins in the cytoplasm with a stage known as **Glycolysis**, where a single glucose molecule is broken down and a small amount of energy is produced in **ATP** molecules.

The products of the breakdown then move to the Mitochondria, which is the "power station" of the cell, where **aerobic respiration** occurs in the presence of oxygen, resulting in the production of Carbon dioxide, water, and large amount of **ATP** molecules.

The reaction that occurs in aerobic cellular respiration can be expressed by the following chemical equation:



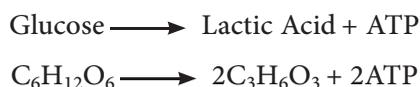
The Law of Conservation of Energy is fulfilled in chemical reactions, where energy is converted from one form to another without being created or destroyed. The chemical energy latent in glucose (food) and Oxygen molecules is converted into energy stored in Carbon dioxide and water molecules, in addition to energy released in **ATP** molecules.

Based on the availability of Oxygen, cellular respiration is divided into two types:

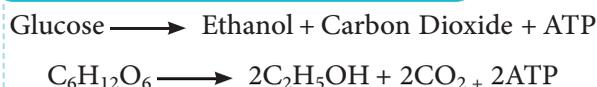
- **Aerobic Respiration:** Occurs in conditions where Oxygen is available. Aerobic respiration is the most efficient in energy production, as it produces about **36 ATP molecules** from a single glucose molecule.
- **Anaerobic Respiration:** The cell switches to this type in the absence of Oxygen. It is less efficient in energy production, as it yields limited energy (only about **2 ATP molecules**) with the formation of products such as lactic acid in muscle cells, or **alcohol** in yeast.

For example, when engaging in strenuous exercise, the available Oxygen in the muscles for energy production decreases. The cells temporarily resort to anaerobic respiration, which leads to the accumulation of **lactic acid** in muscle and a feeling of muscle fatigue.

Reaction: Lactic Acid Fermentation



Reaction: Alcoholic Fermentation



From the previous data, it is clear that, in cellular respiration processes, chemical reactions occur that result in the release of energy. This type of chemical reaction is known as an Exothermic Reaction.

Energy and Chemical Reactions

In a chemical reaction, bonds are broken in the molecules of the reactants, and new bonds are formed in the molecules of the products. This process is accompanied by:

- **Consumption of a quantity** of energy to break the chemical bonds between the reactant molecules.
 - **Production of a quantity of energy** to form new bonds between the product molecules.
- The relationship between these two quantities results in two types of chemical reactions:

1. Exothermic Reactions

In Exothermic Reactions, the product molecules contain less stored energy (E_p) than the stored energy in the reactant molecules (E_R), meaning that a quantity of energy is released during these reactions. This thermal energy is released into the surrounding medium, causing the temperature of the surrounding medium to rise. The blood exerts pressure on the walls of the blood vessels

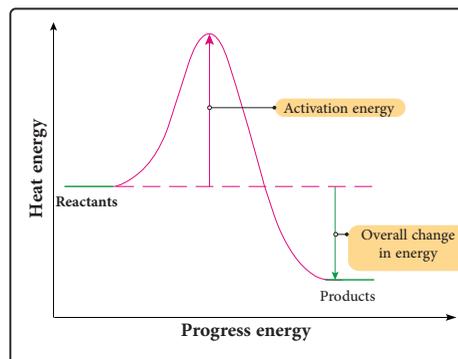


Figure (30) Graphical Representation of an Exothermic Reaction

Example of an Exothermic Reaction

When you add a solution of Hydrochloric acid (HCl) to a solution of Sodium hydroxide (NaOH) (a base) in a glass flask, you feel warmth or heat when touching the container. The reaction between Sodium hydroxide solution and Hydrochloric acid to form Sodium chloride and water is an exothermic reaction, where thermal energy is released from the reaction into the surrounding medium.



2. Endothermic Reactions

In Endothermic Reactions, the product molecules contain more stored energy (E_p) than the stored energy in the reactant molecules (E_R), meaning that there is a need to absorb a quantity of energy during these reactions.

These reactions require a large **activation energy** to occur. This energy is absorbed by the reactants through heating or from the surrounding medium, which causes the temperature of the surrounding medium to drop.

Photosynthesis in plants is considered an example of an endothermic reaction, as the plant absorbs light energy from the sun to convert carbon dioxide and water into glucose and Oxygen.

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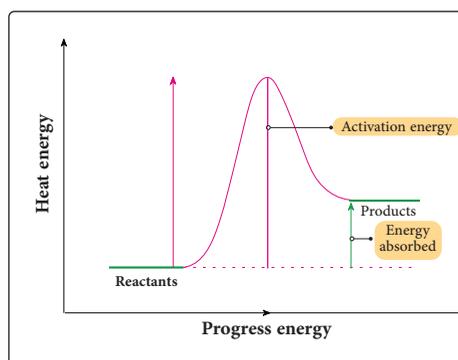


Figure (31) Graphical Representation of an Endothermic Reaction

Example of an Endothermic Reaction

The decomposition of solid potassium chlorate by heat into potassium chloride and Oxygen gas.



Calculating the Amount of Heat Released or Absorbed During the Reaction (Enthalpy Change)

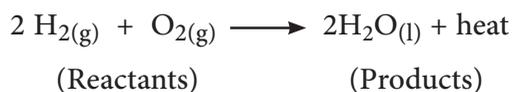
Is it sufficient to describe the reaction as only exothermic or endothermic? Wouldn't it be useful to know the quantity of heat released or absorbed during the reaction, which we call the enthalpy change (ΔH) accompanied by the reaction?

To calculate the enthalpy change (ΔH) accompanied by a reaction, we follow the following steps:

1. Achieving the Law of Conservation of Mass in Reaction

A chemical reaction can be expressed by a symbolic chemical equation that shows the reactants and products. The chemical equation must be balanced to achieve the Law of Conservation of Mass (Matter), which states that the sum of the masses of the reactants equals the sum of the masses of the products and that the mass neither be destroyed nor created during the chemical reaction, but it transforms from one form to another.

Example: The Reaction for the Formation of Water



As we see in the equation, one molecule of Oxygen reacts with two molecules of Hydrogen to form two molecules of water.

Practically, chemists express the quantities of reactants and products using the unit, (Mole).

A mole is the quantity of a substance that has a mass in grams numerically equal to its molecular mass.

For example:

- The mass of one mole of Hydrogen (H_2) = 2g (where its atomic mass is 1). The mass of one mole of Oxygen (O_2 = 32g) (where its atomic mass is 16). The mass of one mole of Water (H_2O) = $1 \times 2 + 16 = 18\text{g}$

In the previous equation, when the quantities of reactants and products are expressed by mole and gram, respectively:

In Moles: We find that 2 moles of water are produced from the reaction of 1 mole of Oxygen with 2 moles of hydrogen.

In Grams: 36 g = 32g + 4g

As we can see, the Law of Conservation of Mass is achieved in this reaction.

2. Calculating the Enthalpy Content of Products and Reactants

The Enthalpy (H) of a substance is the amount of chemical energy stored in one mole of that substance, and its unit of measurement is kilojoules per mole (kJ/mole).

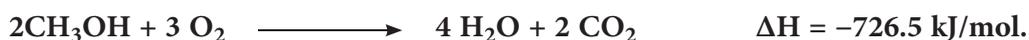
Enthalpy Change(ΔH) is the difference between the sum of the enthalpy content of the reaction Products (H_P) and the sum of the enthalpy content of the Reactants (H_R).

$$(\Delta H) = (H_P) - (H_R)$$

2. If $(H_P) < (H_R)$, then (ΔH) , then is negative, and the reaction is Exothermic (heat-releasing).

Example

The equation illustrates the **complete combustion reaction** of a type of alcohol



1. Is this reaction Endothermic or Exothermic? And why?
2. Calculate the amount of heat released (in kJ) from the combustion of 80g of methanol.

Given that: (C = 12, H = 1, O = 16)

Solution:

- 1- Since ΔH is negative, this means that the enthalpy content of the products is less than the enthalpy content of the reactants. The difference between them is released into the surrounding medium; therefore, the reaction is exothermic (heat-releasing).
- 2- Calculating the amount of heat released from the combustion of 80g of methanol.

- Calculating the Molar Mass of Methanol CH_3OH

$$M(\text{CH}_3\text{OH}) = 12 + (3 \times 1) + 16 + 1 = 32 \text{ g.}$$

- Calculating the Number of Moles (n) Equivalent to the Given Mass:

$$n(\text{CH}_3\text{OH}) = 80 \div 32 = 2.5 \text{ mol}$$

- Calculating the Amount of heat released from the Combustion of CH_3OH

From the chemical equation:

\therefore Combustion of 1 mole of methanol gives -726.5 kJ

\therefore Combustion of 2.5 moles of methanol gives ΔH

$$\Delta H = -726.5 \times 2.5 = -1816.25 \text{ kJ}$$



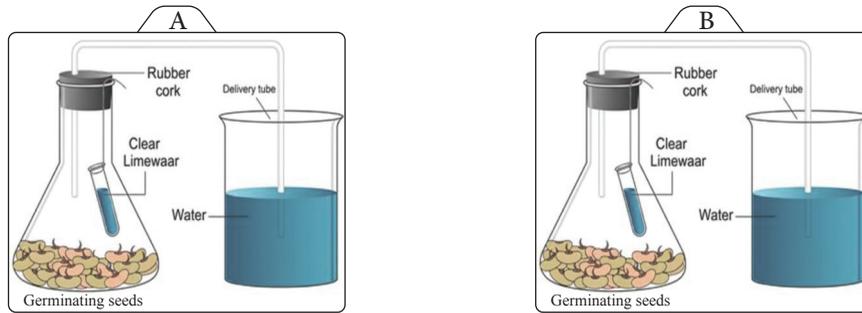
Inquiry Activity

Is the Rate of Respiration Affected by Temperature?

Tools: Two identical flasks - Two identical test tubes, each containing an equal amount of clear limewater - Two equal groups of germinating seeds - Two identical pieces of cotton wool moistened with water - Connecting tubes.

Steps:

- Place a group of germinating seeds on a moistened piece of cotton in each flask.
- Place a test tube containing clear limewater, and a connecting tube, in each flask and seal it as shown in the figure (as per the implied diagram for the setup).



- Submerge the end of each connecting tube below the water surface in a beaker.
- Maintain one of the two flasks, labeled (A), at room temperature (from 20°C to 25°C), and the other (B) in a cold medium (such as a refrigerator).
- Observe what happens to the clear limewater in each flask every hour.
- Record your observations.

Think and Discuss:

1. What is the role of limewater in the experiment?
2. What is your expectation regarding the purpose of placing the end of each delivery tube below the water surface in the beaker?
3. What is the independent variable and the dependent variable in this inquiry?
4. What are the variables that were kept constant in this inquiry?
5. In which flask was the rate of respiration higher?
6. What is the relationship between temperature and the speed of biochemical reactions in the seeds?

Lesson tWO Assessment

**First: Multiple Choice Questions**

Choose the correct answer:

1. Movement of water in xylem vessels relies primarily on physical forces, the most important of which are:

- A) Cohesion and adhesion only
- B) Cohesion and adhesion and the tensile force resulting from transpiration
- C) Active transport of energy
- D) The tensile force resulting from transpiration only

2. The presence of lignin in the walls of xylem vessels helps to:

- A) Store organic materials
- B) Give the cells flexibility and softness
- C) Resist the tension pressure during the ascent of water
- D) Regulate stomata opening

3. Which of the following is an example of active transport in a cell?

- A) Oxygen passing across the membrane
- B) Water moving by osmosis
- C) Transport of ions against their concentration gradient in root cells
- D) Diffusion of gases from the lungs into the blood

4. Which of the following statements explains the relationship between transport in plants and transport in humans?

- A) Both occur in only one direction
- B) Both aim to distribute materials and energy within the body
- C) Both rely on lignin
- D) Both rely on the process of transpiration

5. In the human circulatory system, digested nutrients are transported to the cells via the:

- A) Capillaries
- B) Arteries
- C) Veins
- D) Heart

6. Aerobic cellular respiration in cells produces:

- A) Carbon dioxide, water, and energy
- A) Alcohol and energy
- C) Lactic acid only
- D) Energy without other products

7. Mitochondria is the primary site in the cell for:

- A) Photosynthesis
- B) Aerobic respiration
- C) Protein synthesis
- D) Fat storage

8. In the absence of oxygen, some cells use anaerobic respiration to obtain energy, and its products include:

- A) Water only
- B) Ethanol alcohol or lactic acid
- C) Carbon dioxide only
- D) Extra glucose

9. Which of the following is considered an exothermic reaction?

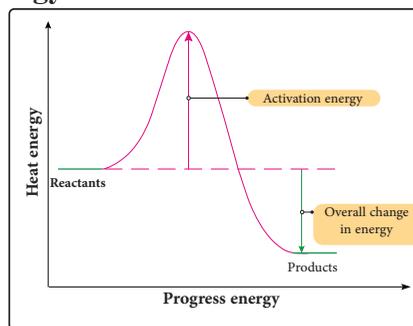
- A) Glucose synthesis in photosynthesis
- B) Glucose breakdown in aerobic respiration
- C) Formation of ATP from ADP
- D) All of the above

10. The relationship between the processes of respiration and photosynthesis is that:

- a) The products of respiration are reactants for photosynthesis
- b) Both occur in the mitochondria
- c) Both require sunlight
- d) Both occur in all organisms

11. The opposite graph represents the change in energy in a chemical reaction. What can be concluded about this reaction?

- A) Endothermic reaction
- B) Exothermic reaction
- C) The change in energy is positive
- D) The temperature of the surrounding medium decreases



Second: Essay Questions

Explain why ?

1. Water ascends in plants despite the lack of an internal pump?
2. There are two types of vascular tissues (xylem and phloem) in plants?
3. Aerobic cellular respiration is more efficient at energy production than an aerobic respiration?
4. Cellular respiration is considered an exothermic reaction?

3.3 Excretion and Homeostasis, and their Role in the Stability of the Biosphere

Metabolic Wastes, Excretory Systems, and their Role in Restoring Energy and Material Balance

The cells of the human body perform a vast number of precise biochemical reactions non-stop. These reactions enable the body to perform its various functions, such as: obtaining energy from food, building essential biological molecules, resisting infection, and replacing damaged cells. Collectively, these reactions are known as **Metabolism**. Metabolism includes two opposite processes: Anabolism, in which new substances needed by the body are produced, and Catabolism, in which complex molecules are broken down to obtain energy.

Although metabolic reactions are essential for life, they do not always produce beneficial substances. Many of them leave behind by-products that the body does not need, and which may be harmful if they accumulate. These products are known as **metabolic wastes**, and they include Carbon dioxide resulting from cellular respiration, ammonia resulting from the breakdown of Amino acids in the liver, and Urea, which is produced by converting toxic Ammonia into a less harmful form, along with excess water and mineral salts that are excreted in various methods.

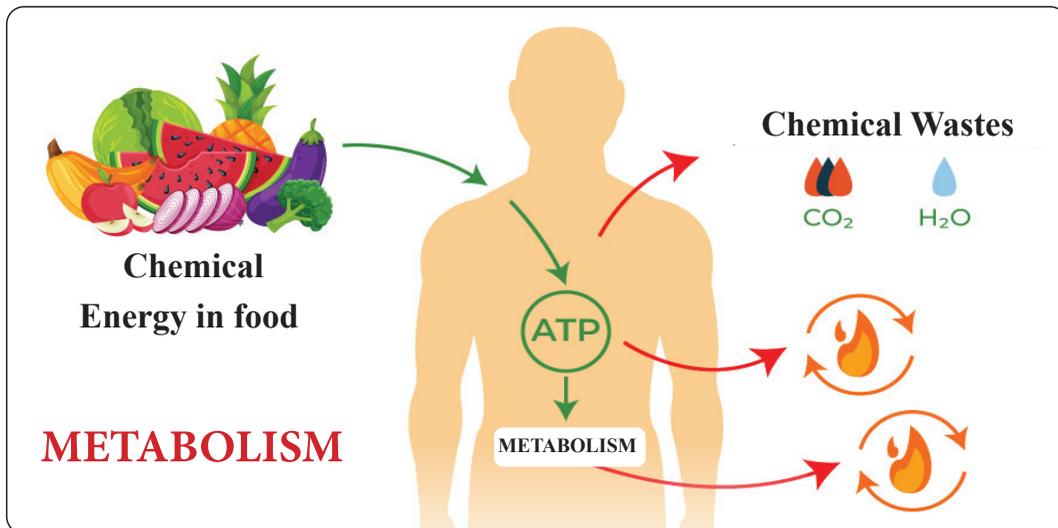


Figure (32) Metabolic Wastes (Metabolism)

Since the accumulation of these wastes leads to a disruption in the **chemical balance** of the body fluids and affects the efficiency of cell function, the organism requires a precise mechanism to eliminate them. This is where the importance of the process of **excretion** emerges. It is a vital process through which **metabolic wastes** are removed from the body and maintaining the **balance of the internal environment (Homeostasis)**

The **kidneys** regulate the concentration of water and ions in the blood, the **skin** excretes water and salts through the sweat glands to help regulate body temperature, and the **lungs** expel Carbon dioxide and Water vapor into the atmosphere. while the liver is considered a major center for waste processing, as it converts toxic substances into compounds that can be safely excreted.

Water and Salt Balance within the Body

The **kidneys** are among the most critical organs of the excretory system. They work to **filter the blood** from the liquid wastes resulting from the bio chemical reactions within the body. Each kidney is approximately the size of a fist, shaped like a kidney bean, and located on either side of the spine in the lower back. The kidneys are responsible for producing **urine**, the fluid created to eliminate **excess water, excess salts, urea**, and other dissolved wastes.

Urine is produced by filtering the blood inside microscopic units known as **nephrons**. Where wastes are removed from the blood, while useful substances such as **glucose, ions, and water** are returned to the body in the amount needed by the body in a process called **reabsorption**, to maintain **homeostasis**. After urine is produced, it moves through the **ureters** to the **urinary bladder**, where it is stored until it is expelled from the body through the **urethra** (urinary canal).

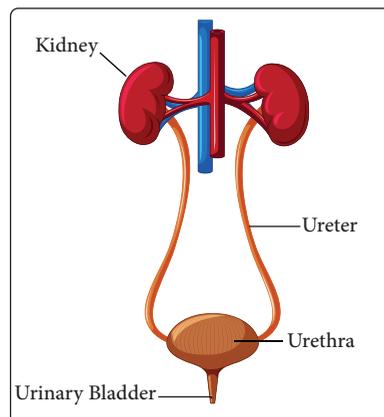


Figure (33) Diagram of the Urinary System

Maintaining Ionic Balance in the Body

Ions such as **Sodium, Potassium, and Chloride** are essential for the function of nerves and muscles, and for regulating the **osmotic pressure** both inside and outside the cells. When an imbalance occurs in the concentration of these ions, precise biological processes are affected. Therefore, the excretory system—especially the **kidneys**—regulates this balance with great precision.

For example, when the concentration of Sodium in the blood **rises**, the kidneys **retain water** to dilute its concentration. When it **falls**, a larger amount of water is released to maintain the ionic balance in the body.

Excretion contributes to maintaining the balance between ions and water in body fluids, ensuring the stability of the **internal environment** (Homeostasis).

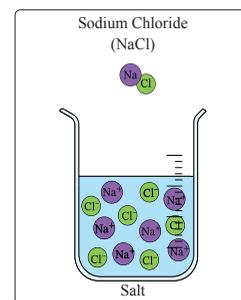


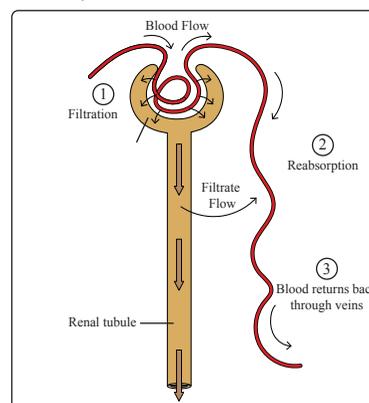
Figure (34) The excretory system controls the concentration of sodium and chloride ions.

Reabsorption

Reabsorption is the process of retrieving useful from the substances fluid filtered in the nephron back into the bloodstream. This occurs in the fine tubular parts of each nephron, where beneficial materials move across the surrounding cell walls into the minute blood vessels (capillaries).

During this process:

- **Most glucose is reabsorbed** back into the blood to



Figure(35) Simple Diagram of a Nephron Illustrating the Steps of Urine Formation (for illustration)

provide energy for the cells.

- **A large part of the water is reabsorbed** to maintain blood volume and fluid balance in the body.

- **Important ions** such as Sodium, Potassium, and Chloride **are also reabsorbed** to regulate muscle and nerve functions and maintain blood pressure.

As for the materials the body does not need, such as Urea, excess water, and some ions, they are left behind to be excreted later with urine.

The Importance of Reabsorption

Reabsorption is considered a vital step in maintaining **Homeostasis** (biological balance) in the body, as it enables the body to control what it retains and what it discards. Without reabsorption, the body would lose large amounts of water and nutrients, leading to **severe dehydration, electrolyte imbalance, low blood pressure**, and possibly the failure of vital organs.

The Skin and its Role in Excretion and Temperature Regulation

The skin is the outer covering of the body and has a dual role in **protection and excretion**.

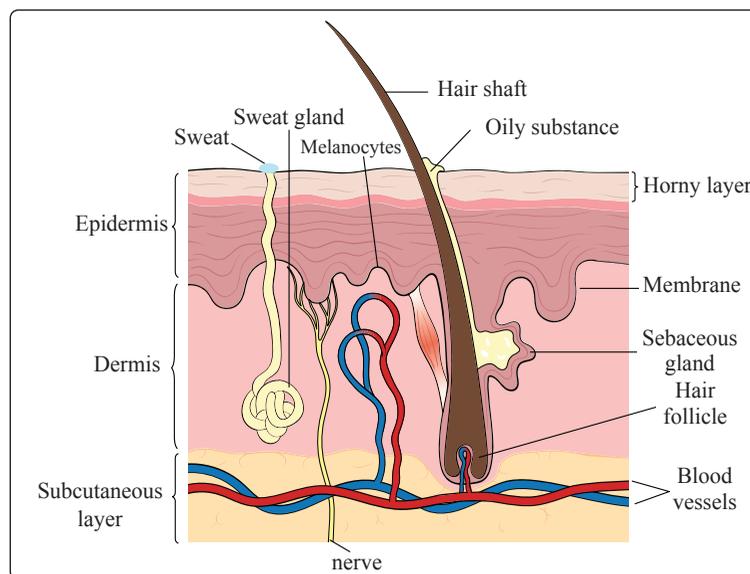


Figure (36) Diagram of Human Skin

The skin contains **Sweat glands** that secrete **Sweat**, which is a liquid composed of **water, mineral salts (such as Sodium chloride), and small quantities of Urea**.

The secretion of Sweat helps **regulate body temperature**; when sweat evaporates from the surface of the skin, it removes some of the excess heat, which keeps the body at a relatively constant temperature. Furthermore, the expulsion of water, salts, and a very small percentage of Urea with Sweat is considered a form of excretion that helps maintain the **balance of fluids and ions** within the body.

The skin is composed of three main layers:

- **Epidermis:** This is the outer layer that protects the body from microbes and water loss.
- **Dermis:** It contains the Sweat glands, Hair follicles, and Blood vessels that help regulate temperature.

- **Subcutaneous Layer (Hypodermis):** It is rich in lipids (fats) that act as thermal insulation.

The integration of the skin with the kidneys in the excretion of excess water and ions is an excellent example of the integration of the excretory systems in maintaining Homeostasis.

The Liver and its Role in waste processing operation

The liver is considered one of the most important organs body's in the waste processing operation, as it works to **purify the blood from harmful substances and wastes resulting from biochemical reactions**. The liver contributes to maintaining Homeostasis by converting toxic substances into safe compounds that are easy for the body to dispose of. It serves as a **detoxification center or a "treatment plant"** that protects the body from the accumulation of toxins.

The liver helps protect the body from the accumulation of harmful substances in multiple ways:

When proteins are broken down, toxic ammonia is formed; the liver converts it into less harmful Urea to be transported to the kidneys and excreted with urine.

The liver also breaks down hemoglobin from old red blood cells, producing **Bilirubin**, which is secreted in bile and excreted with feces. While the accumulation of Bilirubin leads to the occurrence of Jaundice. The liver removes toxins and foreign substances, such as medications and food additives, by converting them into less harmful substances before disposal.

In addition, bile helps in disposing of some water-insoluble wastes, such as excess cholesterol and certain pigments, which contributes to maintaining the body's internal balance.

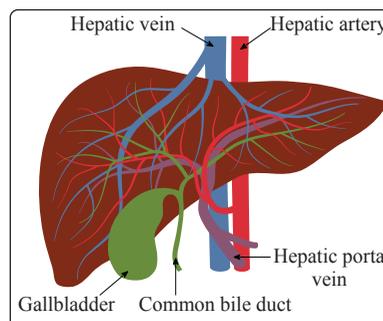


Figure (37) Diagram Illustrating the Liver and Gallbladder

The Role of the Lungs in the Excretion of Gaseous Waste

In the process of **cellular respiration**, the body's cells use **Oxygen and Glucose to produce energy**, which results in **water and Carbon dioxide**. Carbon dioxide moves from the cells into the blood, which carries it to the lungs to be expelled outside the body with **exhaled air**. Thus, the process of exhalation is considered a part of excretion, as it rids the body of **gaseous waste**.

The accumulation of **Carbon dioxide gas** in the blood increases the blood's acidity, which disrupts the function of enzymes and threatens biological processes. For this reason, **regular respiration** is essential for maintaining the balance of gas levels in the blood, and consequently, the body's **Homeostasis**.

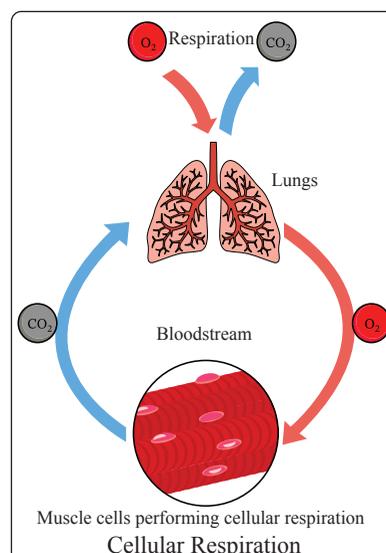


Figure (38) The Role of the Lungs in Excretion

Technological Applications

1. The Artificial Bio-Kidney: A Future Solution for Kidney Failure

The **Bio-artificial Kidney** (renal assist devices) is considered one of the promising modern technological applications for treating kidney failure. This kidney works inside the patient's body or is implanted in it, and aims to perform the functions of a normal kidney.

The basic physical principle in its operation is **filtration**, where blood fluid passes through fine, semi-permeable membranes that allow the passage of small molecules and waste into a purifying liquid or to the other side of the membrane, while preventing the passage of proteins and large blood cells. The biological aspect relies on **cell engineering**; the Bio-artificial Kidney contains specialized cells (either harvested or engineered in the laboratory) that mimic some of the biochemical functions of the kidney, such as regulating the levels of certain salts and secreting important compounds.

With the presence of these cells alongside the filtration units, a more precise monitoring of substance balance in the blood is achieved.

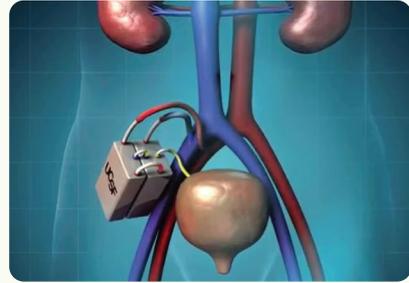


Figure (39) The Artificial Kidney

2. Physics of Ultrasound Waves in the Kidneys and Bladder diagnosis.

Ultrasound (high-frequency) devices are used to image excretory organs and diagnose stones or inflammations. The operation of these devices relies on the properties of sound waves, such as reflection and refraction, to create a precise image of the condition of internal organs without the need for surgical intervention.



Figure (40) Detection with Ultrasound Waves

- **Wave Reflection:** Ultrasound waves strike the boundaries between different tissues (such as the bladder wall or the surface of a stone), and a portion of them bounces back. The strength of this reflection depends on the acoustic impedance of the tissue.

- **Wave Scattering:** This occurs when waves collide with irregular surfaces or small particles within the tissues, which helps reveal the details of the organ's texture.

- **Digital Processing:** The device calculates the time taken for the echo to return; based on the speed of sound in tissues, it accurately determines the depth and location of the organ and converts it into a digital image.

3. Thermal Physics and the Function of Sweat Glands

The process of sweating relies on absorbing a quantity of body heat to evaporate sweat, which is an application of the concept of thermal equilibrium and evaporation. Infrared Thermography devices are used to analyze the rate of heat loss through the skin, which helps in monitoring the body's internal thermal equilibrium (Homeostasis).

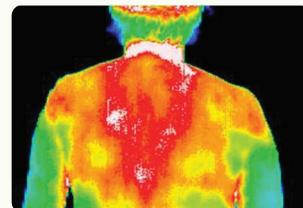


Figure (41) Temperature Measurement with Infrared Rays

Nutrient cycles in the Biosphere

After learning about **excretion processes** and how they contribute to maintaining **Homeostasis** within living organisms, it's time to consider how this balance extends to encompass the **entire ecological system**.

Just as the body's systems work together to maintain its internal equilibrium, the **elements of the biosphere**—such as water, carbon, and nitrogen—operate in **continuous natural cycles** that ensure the persistence of life on Earth.

The most important of these elements are: Carbon, Nitrogen, and Phosphorus, which enter into successive cycles during which they move between the air, water, soil, and living organisms.

The Carbon Cycle

Green plants absorb Carbon dioxide gas from the air during the process of photosynthesis to produce food. The compounds that contain Carbon then pass to animals when they feed on the plants. When living organisms respire or decompose, Carbon dioxide gas returns to the air again. In addition, Carbon oxides are emitted from factories and fuel combustion.

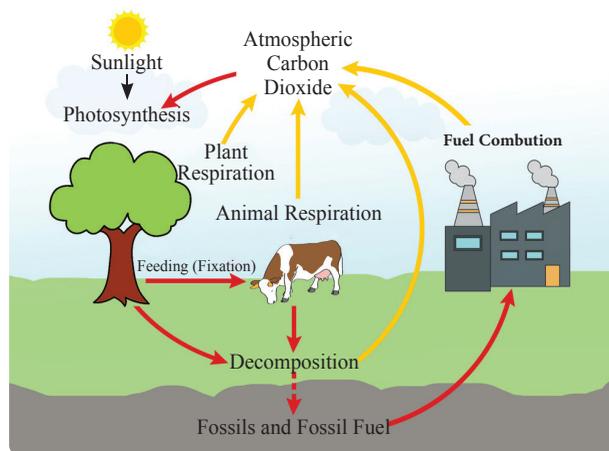


Figure (42) The Carbon Cycle

The Nitrogen Cycle

Nitrogen represents an essential component of proteins within the bodies of living organisms.

The nitrogen cycle begins with the fixation of atmospheric nitrogen in the soil by a type of bacteria, which converts it into compounds that plants can absorb.

These compounds are transferred to animals through food and then return to the soil again through waste or dead organisms, where types of bacteria convert them back into Nitrogen gas, which returns to the atmosphere.

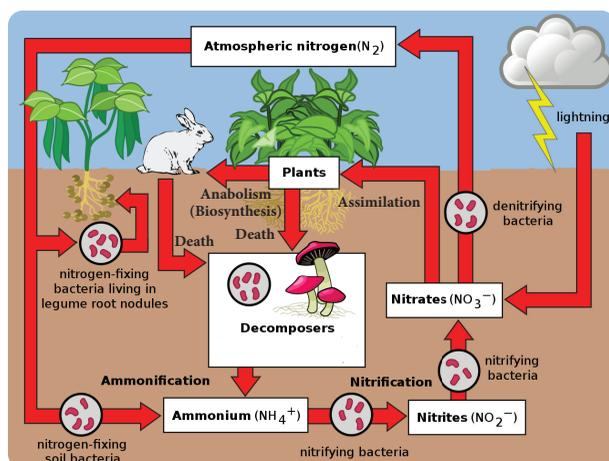


Figure (43) The Nitrogen Cycle

The Phosphorus Cycle:

Phosphorus compounds are found in rocks and soil. Plants absorb Phosphorus compounds after they are released from rocks as a result of weathering processes. Phosphorus is then transferred to animals through the food chain, where it is used in the formation of bones, and teeth, nucleic acids (DNA and RNA), and energy molecules (ATP). When living organisms die or through their waste products, decomposers return Phosphorus to the soil once again. In contrast to the Carbon and Nitrogen cycles, the atmosphere is not part of the Phosphorus cycle; instead, the Phosphorus cycle remains confined between the biosphere, lithosphere, and hydrosphere.

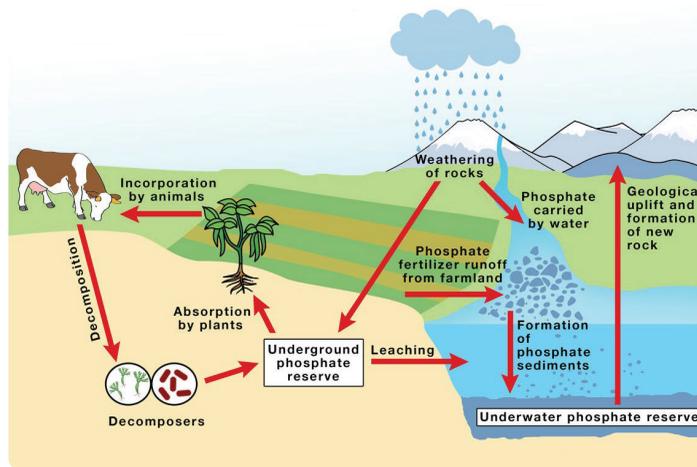


Figure (44) The Phosphorus Cycle

Element cycles are essential for the continuity of life on Earth, as they ensure the recycling of vital elements between living organisms and the environment in a balanced manner.

From the preceding discussion, we conclude that the process of excretion is not limited to getting rid of waste from within living organisms but represents an important link in the continuity of the element cycles in nature. The substances resulting from excretion, such as Carbon dioxide and Urea, return to participate in the Carbon and Nitrogen cycles and others, where Urea is decomposed in the soil by bacteria into ammonia, the nitrates to be absorbed by the plant which ensure the reuse of elements and the continuity of life in the biosphere.

Thus, excretion processes and natural cycles contribute together to maintaining the equilibrium and stability of the biosphere, so that it remains capable of supporting different forms of life.



Inquiry Activity

Reflect on how the bodies of living organisms work to eliminate waste resulting from biological processes to maintain a stable internal environment. Now, consider the broader sphere in which we live—the Biosphere—which encompasses all living organisms and their habitats on Earth.

Research Task: Search the internet for examples illustrating how the excretion processes of different living organisms affect the balance of ecosystems within the biosphere. You may use scientific sources or reliable educational websites.

Lesson tree Assessment



First: Multiple Choice Questions

Choose the correct answer:

1. Which of the following organs is considered the primary organ responsible for removing nitrogenous waste from the blood?

- A) The Liver B) The Skin C) The Kidneys D) The Lungs

2. When the salts in the blood increase, the kidneys respond by:

- A) Secreting more Sweat B) Increasing the reabsorption of water
C) Increasing the excretion of water D) Storing salts

3. Toxic ammonia in the body is converted into Urea in the:

- A) Kidneys B) Liver C) Lungs D) Skin

4. What explains the relationship between excretion and Homeostasis in the body?

- A) Expelling water only
B) Maintaining the stability of the body's internal environment
C) Energy production
D) Oxygen transport

5. If the kidneys fail to perform their function, the first thing to be affected is:

- A) Oxygen level B) The percentage of waste in the blood
C) The number of blood cells D) Hormone production

6. The amount of Sweat secreted by the body increases when:

- A) The temperature decreases B). Humidity increases
C) The temperature rises D) Blood flow to the skin decreases

7. What component is reabsorbed in the kidneys to maintain water balance?

- A) Glucose B) Carbon dioxide C) Water D) Ammonia

8. Expelling Carbon dioxide from the lungs is an example of:

- A) Temperature regulation B) Gaseous excretion
C) Solid excretion D) Nerve transmission

9. What is the common role between the skin and the kidneys in Homeostasis?

- A) Hormone production B) Waste storage
C) Excretion of water and salts D) Energy production

10. Body toxicity increases when:

- A) The respiration rate decreases B) Metabolic waste accumulates
C) Sweat secretion increases D) Blood pressure decreases

Second: Essay Questions**Explain why?**

- 1. Ammonia is converted into Urea in the body before it is excreted.**
- 2. Excreting a large amount of Sweat in hot weather helps the body remain in Homeostasis.**
- 3. A disturbance in body functions occurs when metabolic waste accumulates**
- 4. The volume of Urine increases when large amounts of water are drinkin.**
- 5. Excretion is essential for maintaining the biological balance (or Homeostasis) of the living organism.**

3.4

Sensation and Response and Their Role in the Interaction of Living Organisms with the Biosphere

Sensing stimuli and responding to them are fundamental characteristics that distinguish living organisms. They enable them to interact with their environment and maintain their survival. **The nervous system** is the main system responsible for receiving information from the surrounding environment, processing it, and then issuing appropriate responses through a precise system that enables the organism to adapt to environmental changes. This contributes to **the stability and balance of the biosphere**, as every organism maintains its internal balance and appropriate response to external factors.

The Nervous System

- The nervous system mainly consists of the **Central Nervous System (CNS)**, which is composed of the brain and the spinal cord, and the **Peripheral Nervous System (PNS)**, which includes all the nerves spread throughout the body, connecting the central nervous system to the rest of the organs.

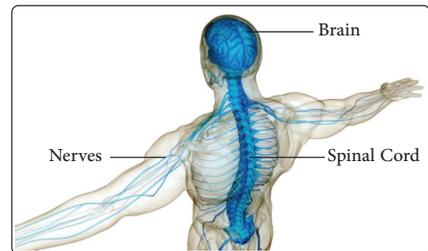


Figure (45) The Nervous System

- The nervous system receives signals from the senses, processes them, and then sends commands to the rest of the body parts for a suitable response, whether this response is voluntary or involuntary.

Nerve Cells (Neurons): The Unit of Interaction Between the Living Organism and the Environment

Nerve cells (neurons) are the **basic building blocks of the nervous system**. Each nerve cell typically consists of a **cell body** which contains the nucleus and organelles, extensions called **dendrites** that receive signals, and an **axon** that transmits the signal away from the cell body toward other cells, muscles, or glands. At the ends of the axon, there are branches called **nerve endings** which communicate with other cells via **synapses**.

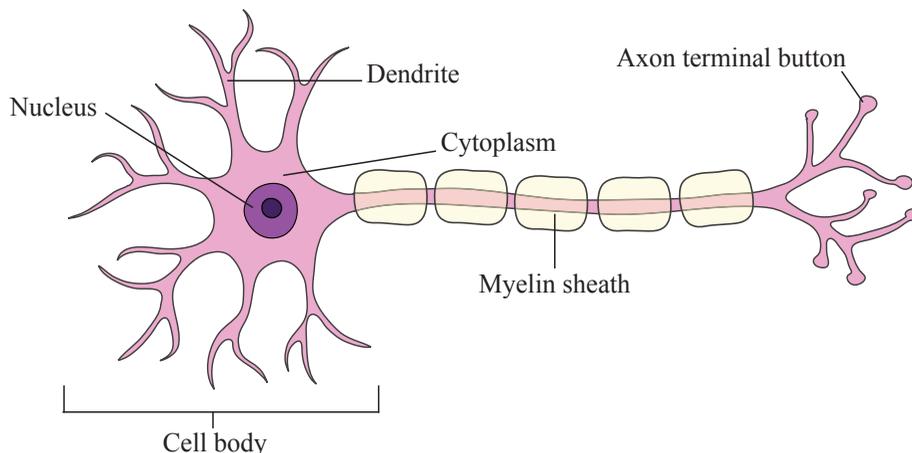


Figure (46) The Nerve Cell (Neuron)

Types of Nerve Cells (Neurons)

Nerve cells are classified according to their function into:

- **Sensory Neurons:** These transmit information from the sensory receptors to the Central Nervous System (CNS) (the brain and spinal cord).
- **Motor Neurons:** These transmit commands to the response organs, which are, muscles and glands.
- **Interneurons (Association/Relay Neurons):** These act as a link between the sensory and motor neurons.

Mission of the Nerve Impulse and Membrane Potential

In nerve cells, the distribution of ions inside the cell differs from that outside. The concentration of the sodium ion (Na^+) outside the cell is much higher than its concentration inside, while the potassium ion (K^+) is concentrated more inside the cell than outside. This difference leads to the generation of a potential difference across the cell membrane, called the **Membrane Potential**.

When the cell is not stimulated, meaning it is at rest, the outer surface of the cell membrane is **positive**, and the inner surface is **negative**. This state is known as **Polarization**, with a potential difference of approximately (**-70 mV**), resulting from three primary mechanisms:

- **Selective Permeability of the Cell Membrane:** Which allows the exit of K^+ ions at a higher rate than the entry of Na^+ ions into the cell.
- **Unequal Distribution of Ions:** Where the concentration of negative ions and proteins is higher inside the cell than outside. There are negative Chloride ions and some proteins
- **Sodium-Potassium Pumps:** Which utilize ATP energy. The energy from each ATP molecule leads to the export of three Na^+ ions in exchange for the import of two K^+ ions.

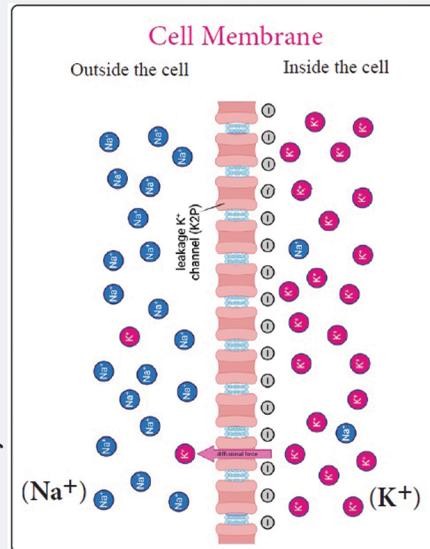


Figure (47) Ion Concentration Across the Cell Membrane

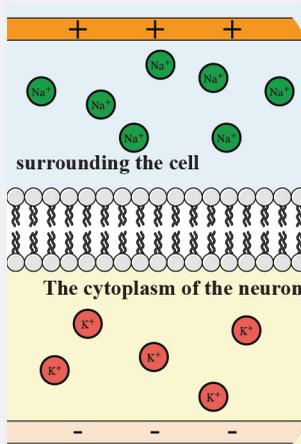


Figure (48) Resting Potential

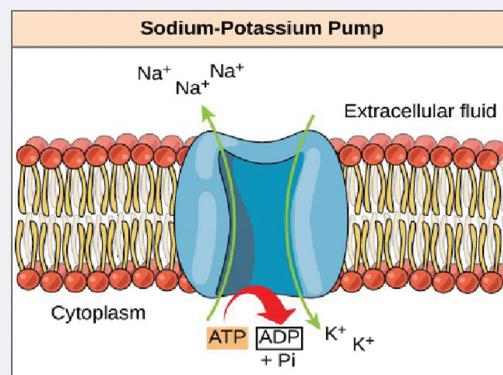


Figure (49) The Sodium-Potassium Pump

When the nerve cell receives **sufficient stimulus to excite it**, special channels in the neuronal membrane open, allowing **Sodium ions (Na^+)** to move in at a rapid rate. The potential inside the cell becomes **positive**. The potential difference across the cell membrane reaches approximately **(+40 mV)**, and this phase is known as Depolarization.

Depolarization acts as a stimulus to the adjacent region of the nerve, causing exactly the same changes that occurred when the nerve cell was first stimulated, and so on. Thus, a **Nerve Impulse** (on the form of pulses) travels along the nerve cell through cycles of depolarization, followed by repolarization, then depolarization again, and so on.

The first region of the membrane undergoes **Repolarization** when the Sodium channels closed and the Potassium channels opened, allowing Potassium ions to exit. The potential difference then returns to its previous negative value.

Subsequently, for a short period (approximately 0.001 – 0.003 seconds) called the **Refractory Period**, the cell does not respond to a new stimulus. After this period, it regains its readiness to respond to a new stimulus.

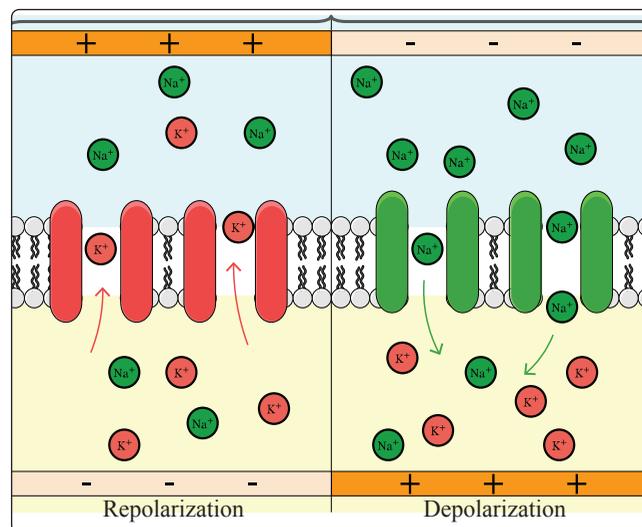


Figure (50) Changes in the state of the nerve cell (neuron)

The Synapse: The Chemistry of Neural Communication

After learning how a **nerve impulse** is generated inside a nerve cell and travels along its axon, a crucial question remains:

How does this impulse transmit from one nerve cell to another?

At the end of a nerve cell's axon, the nerve signal does not pass directly to the next nerve cell. Instead, it passes through a specialized connection area called the **Synapse**. Every nerve cell connects with a tremendous number of other cells through these synapses.



Figure (51) Synapse

To imagine the complexity of this system, a single **Purkinje cell** (a type of nerve cell

found in the brain) can receive signals from about **200,000 synapses** at the same time, from different nerve cells that converge upon it to determine one coordinated response.

The **synapse** consists of three parts:

1. The Synaptic Knob (Terminal Button): An enlargement at the end of the axon of the signal-transmitting cell (presynaptic cell). Inside the synaptic knobs are small sacs called **synaptic vesicles**, which contain important chemical substances for transmitting the nerve impulse, such as: **Acetylcholine** and **Noradrenaline**.

2. The Synaptic Cleft: A tiny gap between the two adjacent cells.

3. The Postsynaptic Membrane: Part of the membrane of the signal-receiving cell (postsynaptic cell).

Inside the synaptic knob are small vesicles containing **Neurotransmitters** such as Acetylcholine and Noradrenaline, which are chemical substances that transmit the signal between cells.

Mechanism of Impulse Transmission Across the Synapse

1. **When the nerve impulse arrives** at the end of the axon, a number of special **calcium ion (Ca^{+2})** channels open, allowing (Ca^{+2}) ions to pass into the synaptic knob.

2. The entry of (Ca^{+2}) ions leads to the **release of neurotransmitters** into the synaptic cleft.

3. The neurotransmitters diffuse across the cleft and **bind to specific receptors** on the next cell. This opens the **sodium and potassium ion channels** in its membrane, generating a new nerve impulse.

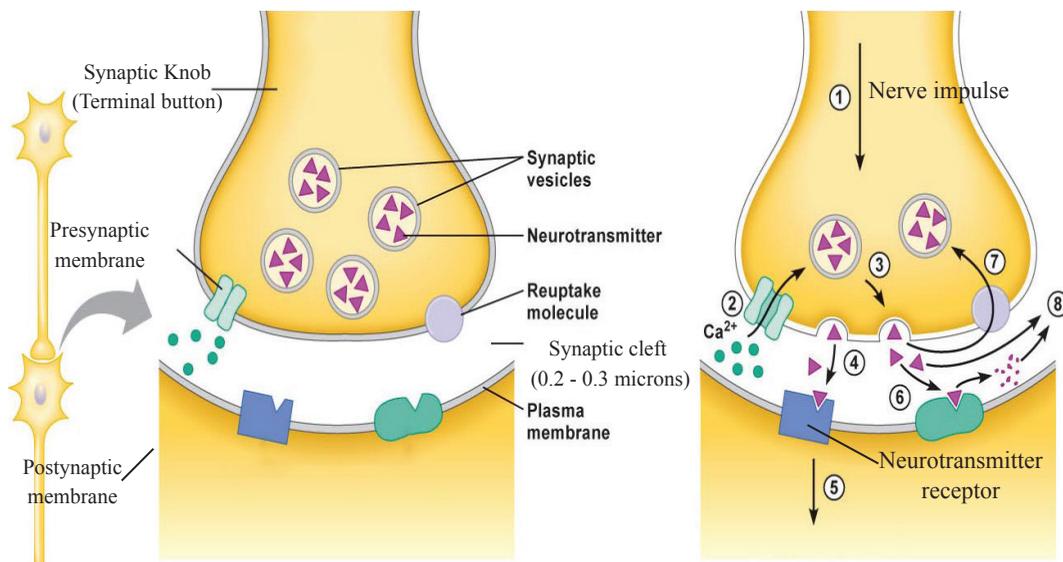


Figure (52) Nerve Impulse Transmission Across the Synapse

4. After the neurotransmitters, such as Acetylcholine, have performed their role, they are **broken down by specific enzymes**, and the cell membrane returns to the resting state. In this way, the nerve impulse is transmitted in the nervous system with high precision and speed, enabling the body to respond to stimuli.

Technological Applications

Nerve Conduction Velocity (NCV) Test:

It is a diagnostic procedure used to evaluate nerve function and integrity. It helps in to assess nerve damage, detecting related disorders, and determining the extent and location of nerve injuries or abnormalities. It is often used to diagnose and assess conditions affecting the nerves and spinal cord.

During the test, small electrical currents are passed on to specific nerves using surface electrodes placed on the skin. These electrical pulses stimulate the nerves, and the resulting responses are recorded and analyzed. The test is generally considered safe and non-invasive.



Figure (53) Nerve Conduction Velocity (NCV) Test

In conclusion, it is clear that the nervous system plays a fundamental role in achieving Homeostasis within organisms, as its signals regulate various vital activities to ensure the body's rapid and precise response to environmental changes. Through this capacity for self-regulation, sensation and response contribute to maintaining internal balance in living organisms, and consequently to the stability of the biosphere, as balanced interaction between organisms and their environments remains the foundation for the continuity of life on Earth.

Lesson four Assessment



First: Multiple Choice Questions

Choose the correct answer:

1. The nerve cell is considered the fundamental unit in the formation of the nervous system, and its basic function is:

- A) Hormone production
- B) Nerve impulse transmission
- C) Energy storage
- D) Body defense

2. The period during which a new nerve impulse cannot be generated is called:

- A) Depolarization
- B) Repolarization
- C) Refractory period
- D) Resting potential

3. Which of the following statements explains why the Sodium-Potassium pump requires energy?

- A) Because it moves ions down the concentration gradient
- B) Because it moves ions against the concentration gradient
- C) Because it does not depend on ATP
- D) Because it only works during sleep

4. During depolarization, the membrane potential:

- A) Stays constant at -70 mV
- B) Becomes more negative
- C) Changes from negative to positive
- D) Does not change

5. During repolarization, what happens?

- A) Sodium ions enter the cell
- B) Potassium ions exit the cell
- C) The sodium-potassium pump stops
- D) The positive potential inside the cell increases

6. What is the main function of neurotransmitters in the synapse?

- A) Storing energy
- B) Transmitting the signal between two cells
- C) Breaking down ions
- D) Increasing axon speed

7. Which of the following occurs immediately after the nerve impulse reaches the terminal knobs (buttons)?

- A) Calcium exits the cell
- B) Calcium enters and vesicles fuse with the membrane
- C) Sodium channels close
- D) Neurotransmitter breakdown

8. The enzyme Cholinesterase acts to:

- A) Stimulate depolarization
- B) Rebuild vesicles
- C) Break down Acetylcholine after it performs its role
- D) Increase membrane permeability

9. What explains the importance of the resting potential in a nerve cell?

- A) It prevents the cell from responding
- B) It keeps the membrane ready to transmit the impulse when a stimulus occurs
- C) It increases the number of synapses
- D) It decreases the membrane permeability to water

10. The Purkinje cell, which can receive hundreds of thousands of synapses, demonstrates that:

- A) The nervous system is slow to respond
- B) Nerve cells function independently
- C) The nervous system is an interconnected network that transmits information quickly and accurately
- D) Synapses are few in the brain

Second: Essay Questions

Explain why?

- 1. The Sodium-Potassium pump is essential for maintaining the resting potential in nerve cells.**
- 2. Hyperpolarization occurs immediately after repolarization.**
- 3. The presence of a synaptic cleft between two nerve cells is essential despite its extremely small size.**
- 4. The nervous system operates at a speed that exceeds the hormonal system.**
- 5. Inhibiting the Sodium-Potassium pump by the toxin Ouabain leads to the cessation of nervous system function.**

3.5 Nanotechnology Applications and Biosphere Sustainability

Thanks to science, humanity has been able to observe what is smaller than cells and control the composition of matter at the level of molecules and atoms.

This led to the emergence of **nanotechnology** which has revolutionized how humans interact with the biosphere.

One of the real challenges facing doctors and scientists is how to treat the cancerous tumor in the patient's body without destroying the healthy cells and tissues?

For many years, traditional cancer treatments—whether chemically or by radiation—were a double-edged sword; they kill the cancerous cells but cause severe side effects to the entire body. The field of nanotechnology has developed and offered an exciting solution, where the cancer drug is enclosed by programmed nanoparticles that direct themselves only to the cancerous cells. They release the drug directly there and reduce the chances of the rest of the tissues being exposed to the toxic drug substance. This has led to increased treatment effectiveness and reduced side effects. This advancement opens the door to many other applications in the fields of medicine, energy, and the environment, and forms a suitable introduction for studying what we mean by nanomaterials and why they possess this power.

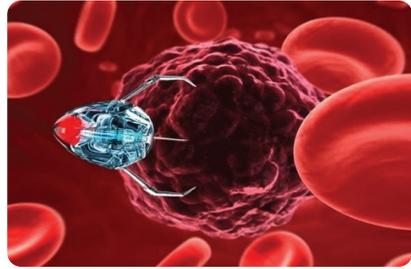


Figure (54) Using Nanotechnology to Eliminate Cancerous Cells

What is meant by nanotechnology?

The word nanotechnology is composed of two parts:

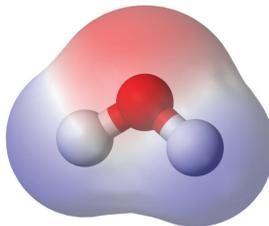
- **Nano** is a Greek word meaning "dwarf", which signifies something extremely small.
- **Technology** means the practical application of knowledge in a specific field.

Therefore, nanotechnology is the technology of interacting with materials in extremely small dimensions measured in the nanometer unit. This is done to produce new materials and devices that possess unique properties not found in their normal states.

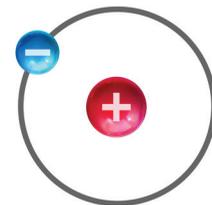
What is the nanoscale?



The diameter of a grain of sand $\approx 1,000,000$ nm



The diameter of a water molecule ≈ 0.3 nm



The diameter of a single atom $\approx 0.1 - 0.3$ nm

Figure (55)

The nanometer ("nm") is a very small unit of measurement, equal to one billionth of a meter ($1 \text{ nm} = 10^{-9} \text{ m}$). This means that one nanometer is about one hundred thousand times smaller than the diameter of a human hair!

Nanomaterials are materials in which at least one of their dimensions ranges between 1- 100 nm . This nanoscale size gives them different properties compared to their larger counterparts.

Why do the properties of materials change at the nanoscale?

When matter shrinks to this tiny size, its chemical and physical properties change, such as color, hardness, solubility, electrical conductivity, and even melting point.

This is due to two main factors:

1. Increase in the Ratio of Surface Area to Volume:

Imagine you have a large sugar cube and another that is broken down into small granules. Which one dissolves faster in water?

Naturally, the fragmented sugar, because its **surface area is larger**, which increases the chances of contact and collision between water and sugar molecules

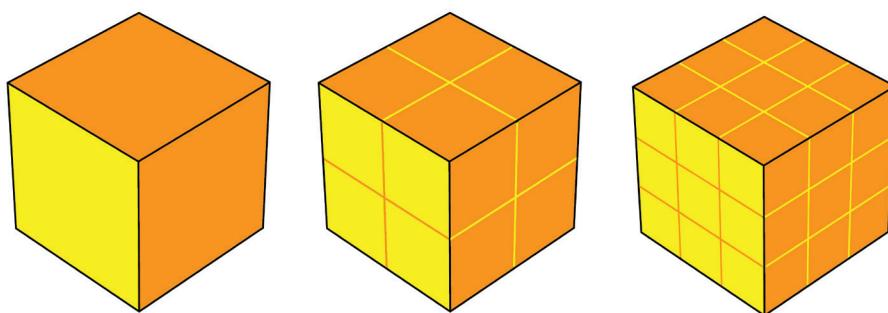


Figure (56) Ratio of Surface Area to Volume

This applies to nanomaterials: the smaller the particles, the greater their active surface area relative to their volume, and the greater their capacity for interaction.

2. Quantum Effects: What is called “Quantum Effects” appears when the dimensions of the particle become comparable to the wavelengths accompanying the motion of electrons, causing matter to behave in entirely new ways.

Examples of Nanomaterials

• **Nano Gold:** Gold in its normal state is shiny yellow. However, when it is reshaped at the nanoscale, its color changes according to the size of the particles; it may become red, orange, or blue!

• **Nano Copper:** When copper particles are reduced to the nanoscale, their hardness and strength increase compared to ordinary copper.



Figure (57) Different Colors of Nano Gold

Nano Chemistry

It is the branch that studies **how to manufacture, describe, and apply nanomaterials**. It is concerned with understanding the changes in properties at this small scale. Nanomaterials come in different forms according to their dimensions:

1. Zero-Dimensional Nanomaterials (0D Nanomaterials)

In this type, all dimensions of the material (length, width, and height) are within the nanoscale. These materials appear as points or ultrafine grains.

- Examples: Quantum Dots and Nanoparticles, such as gold or silver nanoparticles.

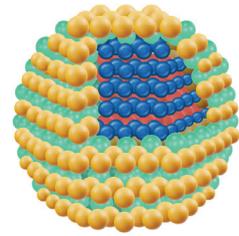
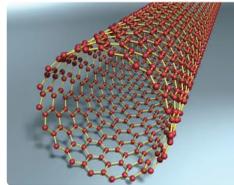


Figure (58) Quantum Dots

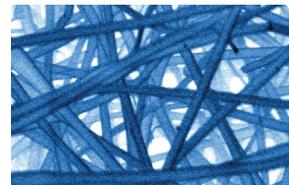
2. One-Dimensional Nanomaterials (1D Nanomaterials)

These materials have only one dimension outside the nanoscale (meaning their length can be relatively large), while the other two dimensions remain within the nanoscale.

- Examples: Nanotubes (such as carbon nanotubes), nanofibers, and nanowires.



Carbon Nanotubes



Nanofibers

Figure (59)

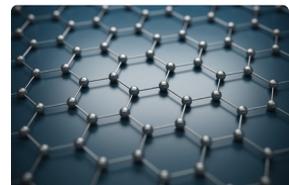
3. Two-Dimensional Nanomaterials (2D Nanomaterials)

These materials possess two dimensions outside the nanoscale (resulting in a large flat surface area), while only their thickness remains within the nanoscale. They typically appear in the form of nanosheets or ultrathin layers.

- Examples: Graphene, thin films, and nanolayers.



Thin Films



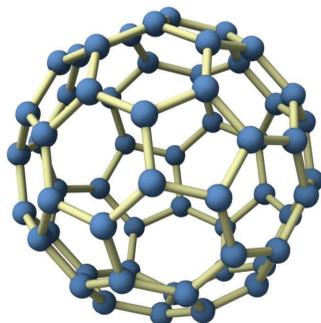
Graphene

Figure (60)

4. Three-Dimensional Nanomaterials (3D Nanomaterials)

These are materials where none of the external dimensions are within the nanoscale (meaning they are large in all three dimensions). However, they are composed of nanoscale building blocks or possess an internal nanostructure, such as pores or embedded grains.

- Examples: Porous nanomaterials, polycrystalline nanomaterials, and nanocomposites.



Porous nanomaterials



polycrystalline

Figure (61)

Nerve Conduction Using Nanomaterials

In the previous lesson, we learned that the **nerve impulse** travels through neurons in the form of electrical pulses, moving from one cell to another across the **synapse**, allowing the body to respond rapidly to various stimuli. But what happens if part of this neural pathway is damaged? Can the nerve impulse cross the damaged area

Nanotechnology has enabled scientists to innovate new methods for reconnecting damaged nerves, helping the nerve impulse pass through again as if the nerve were never injured.

Conductive nanomaterials, such as **Carbon nanotubes** and **nanowires**, are used in this field. These materials function by transmitting neural signals between damaged neurons, exactly like impulses traveling through a healthy nerve.

When Carbon nanotubes or nanowires are placed between the two ends of a severed nerve, they form a **nanobridge** that allows electrical nerve pulses to pass from one end to the other, helping to gradually

Furthermore, **Neural Nanotech Interfaces** (Neural Nano-electrodes) are used to record neural signals and transmit them to external devices, such as **smart prosthetic limbs**.

In this way, our previous study of the **nerve impulse** integrates with advanced developments in **nanotechnology** to enhance the flow of neural impulses, even in cases of nerve damage."



Figure (62) Nano-neural Interfaces

Applied Example

Scientists have been able to help paralyzed patients move their limbs or communicate via devices merely by thinking, using nano-chips implanted in the brain. The chip captures the nerve impulses and sends them to the computer or the prosthetic arm that moves according to the nerve command, as shown in Figure (63).

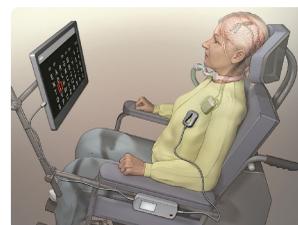


Figure (63)

Biofuel Cells and Nanotechnology Applications

In previous lessons, you learned how living cells generate energy from food through **cellular respiration**. In this process, Glucose is broken down inside the **Mitochondria** in the presence of Oxygen to produce energy molecules known as **ATP**, which cells use for their various activities.

But can science benefit from this biological concept to generate power for man-made devices? From this question, the idea of **Biofuel Cells** was born. They operate in a manner like what happens in cellular respiration:

In both cases, **Glucose is oxidized** (meaning it loses electrons) to obtain energy. The difference is that biofuel cells do not produce **ATP**; instead, they convert chemical energy directly into **electrical energy** that can be used to power devices.

Biofuel cells function as **sustainable batteries**, where enzymes at the negative electrode (**anode**) oxidize Glucose, leading to the release of **electrons and protons**. Thanks to **Carbon nanotubes**, which increase the efficiency of electron transfer, these electrons flow through an external electrical circuit (generating a current) toward the positive electrode (**cathode**) — exactly how electrons move through wires to light a bulb

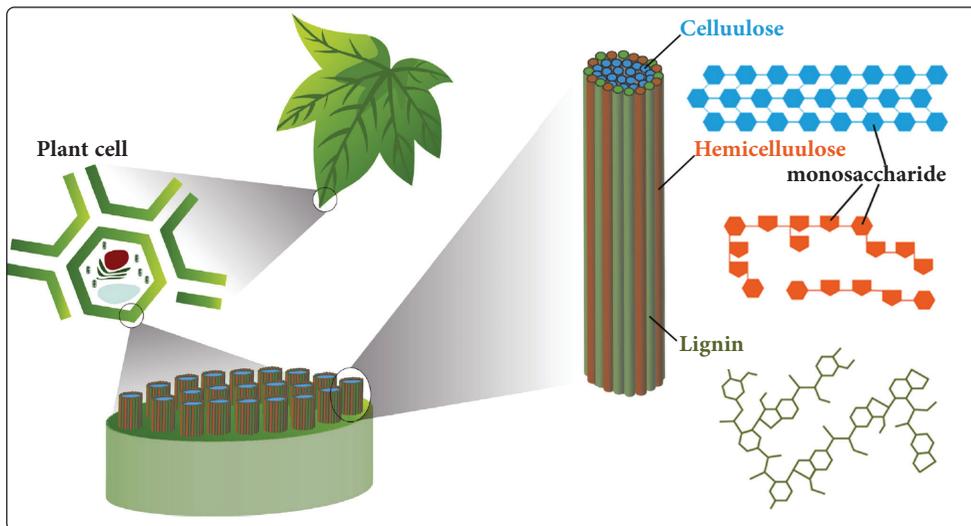


Figure (64) Biofuel

This is where **nanotechnology** plays a role in raising the efficiency of this process. Nanoparticles such as **nano gold** or **Carbon Nanotubes** are used to coat the electrodes inside the cell, where they act as electrical catalysts that accelerate the reactions and facilitate the transfer of electrons, exactly as enzymes inside the Mitochondria accelerate the cellular respiration reactions.

Thus, biofuel cells are a wonderful example of **mimicking biological processes in technology**, where scientists were inspired by the idea of energy production inside living cells to design devices that generate clean and safe energy. This energy can operate **implantable medical devices inside the body** by using the glucose found in the blood as an energy source.

Inquiry Activity

Inquire how nanomaterials can be used to improve human life without harming the biosphere.

1. Search for a medical or environmental product that relies on nanotechnology.
2. Identify the specific nanomaterial used and its function.
3. Discuss in your group: Does this technology have side effects on living organisms or the environment?
4. Suggest modifications or more sustainable uses.
5. Present your results in a scientific poster that clarifies the relationship between nano and equilibrium in the biosphere.

Lesson five Assessment



First: Multiple Choice Questions

1. The properties of matter change at the nanoscale compared to its properties in the normal state due to:

- A) Decrease in mass.
- B) Increase in the ratio of surface area to volume.
- C) Change in the composition of atoms.
- D) Decrease in the temperature of matter.

2. When the size of gold is reduced to the nanoscale, its color changes because:

- A) The number of electrons in its atoms decreases.
- B) Its interaction with light changes.
- C) Its density increases.
- D) It loses its metallic properties.

3. The hardness of copper increases at the nanoscale as a result of:

- A) Increase in the number of electrons in its atoms.
- B) Convergence of molecules.
- C) Increase in the ratio of surface area to volume.
- D) Increase in the energy of the nucleus in its atoms.

4. Carbon Nanotubes are used in electronics because they are:

- A) Insulators of electricity.
- B) Conductors of electricity more than copper.
- C) Decomposed quickly.
- D) Soluble in water.

5. Buckyballs are useful in medicine because they:

- A) Are resistant to heat.
- B) Contain rare minerals.
- C) Can carry drugs inside them.
- D) Absorb light.

6. The function of biofuel cells is similar to the process of cellular respiration in that both:

- A) Produce energy from the oxidation of glucose.
- B) Consume ATP molecules.
- C) Store energy.
- D) Depend in their function on solar energy.

7. Nanoparticles are used in biofuel cells because they:

- A. Reduce the rate of reactions.
- B) Increase the rate of transfer of electrons.
- C) Prevent the oxidation of reactants.
- D) Invalidate the function of enzymes.

8. In drug delivery using nanotechnology, nanoparticles help to:

- A) Spread the drug throughout the whole body.
- B) Increase the drug dosage.
- C) Deliver the drug directly to the infected cells.
- D) Prevent its absorption.

9. When matter is fragmented, the relationship between surface area and volume shows that:

- A) The volume is unchanged and the surface area increases.
- B) Both the volume and surface area decrease.
- C) The volume decreases and the surface area does not change.
- D) Neither the volume nor the surface area is affected.

10. Nanotechnology contributes to biosphere sustainability because it:

- A) Relies on polluting materials.
- B) Reduces the consumption of energy and resources.
- C) Produces toxic waste.
- D) Uses fossil fuel.

Second: Essay Questions

Explain why?

- 1. Materials exhibit new properties when they reach nanoscale dimensions less than 100" nm".**
- 2. Biofuel cells are considered a biological application of clean energy.**
- 3. The rate of chemical reactions increase in nanoparticles compared to the normal size of matter.**
- 4. Carbon Nanotubes are used in the design of future space elevators.**
- 5. Nanotechnology is considered a bridge between biology, physics, and chemistry in the service of environmental sustainability.**



Unit 4

Lithosphere

Learning Outcomes

By the end of this unit, the student will be able to:

1. Describe the internal structure of the Earth, including the crust, the mantle, and the core.
2. Clarify the concept of the lithosphere.
3. Identify and explain the physical properties of rocks, such as hardness, porosity, permeability, and resistance to erosion, and relate each property to the behavior of rocks in the Earth.
4. Explain the movement of tectonic plates and its impact on the formation of earthquakes, volcanoes, and mountain ranges in a practical manner.
5. Recognize the importance of the lithosphere as a source of rocks, minerals, and soil, and explain how these resources are used in daily life and industry.
6. Explain the exploitation of the lithosphere for energy generation, including petroleum, natural gas, nuclear energy, and geothermal energy.
7. Relate the characteristics and sustainability of the lithosphere to the rock cycle and the conservation of natural resources on the planet.

Unit Storyline

The unit begins by exploring the internal structure of the Earth, where the student learns about the Earth's crust, lithosphere, mantle, and core, with a focus on the layers close to the surface that control the formation of landforms and rock movement. Next, we move on to the physical properties of rocks and minerals, such as hardness, porosity, permeability, and resistance to erosion. These properties determine how rocks behave when exposed to weathering and landslides, and how they interact with water and air.

Then the student learns about rocks as natural resources, and their role in manufacturing tools and construction, along with supplying soil with nutrients for plants, and how minerals are used in modern devices, such as silicon in technology and quartz in watches and navigation devices. We then proceed to tectonic rock movement, where the student explains how rock masses move on the Earth's surface, and the effect of these movements on the occurrence of earthquakes, volcanoes and the formation of mountains. In the meantime, the student understands the relationship between rock density and their physical properties and their role in determining the location of landforms and surface features. This leads to the concept of the rock cycle, where the student explains how rocks transform from one type to another through erosion, pressure, and heat. The student also explains how this cycle contributes to renewing minerals and soil and links this cycle to the sustainability of resources. Finally, the student discovers the role of lithosphere as an energy source. This includes learning about the extraction of petroleum and natural gas, the use of nuclear energy, and harnessing the heat stored in the Earth's interior to generate clean energy. The unit concludes with an understanding of lithosphere sustainability and conserving its resources for future generations.

4.1 Lithosphere and the Stability and Balance of Earth

Lithosphere is one of Earth's main spheres, along with the hydrosphere, atmosphere, and biosphere. Although this sphere may appear stable to us, it is, in reality, **dynamic and changes over time** due to the Earth's internal forces and external processes on its surface. This unit focuses on understanding the nature of lithosphere: What is it composed of? How are its layers arranged? How do the properties of rocks and minerals affect the behavior and sustainability of this sphere?

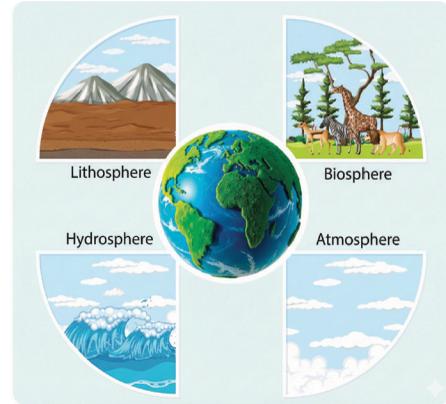


Figure (1) Earth's Spheres

Layers of the Earth

Earth is consisted of three main layers that differ in their chemical composition and physical properties: the crust, the mantle and the core.

1. The Crust

The crust is the Earth's thin, outermost layer, making up only about 1% of the planet's total volume. It is divided into two types: the continental crust, which lies beneath the atmosphere, and the oceanic crust, which lies beneath the oceans and open seas.

A. Continental Crust: This crust is the part of Earth that forms the landmasses on Earth's surface. It is characterized by a composition rich in Silica and Aluminum, a combination scientifically referred to as "Sial." Due to the nature of its rocks and chemical composition, the continental crust has a lower density compared to the oceanic crust. This explains why the continents rise and stand out above sea level.

B. Oceanic Crust: The oceanic crust lies beneath the floors of the oceans and is much thinner than the continental crust. Its composition is rich in Silica and Magnesium, known as "Sima," along with iron. The high proportion of Magnesium and Iron in its composition gives the oceanic crust a greater density compared to the continental crust.

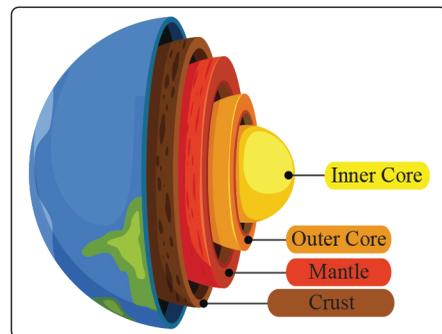


Figure (2) Earth's Layers

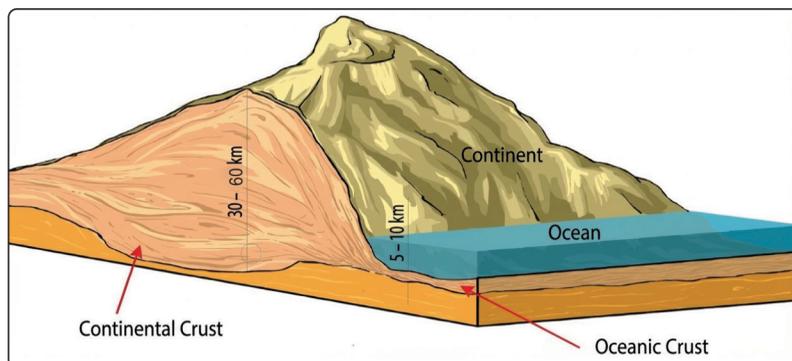


Figure (3) Continental and Oceanic Crusts

2. The Mantle

The Mantle lies directly beneath the Earth's crust and is the largest layer by mass, making up approximately 67% of the planet's total mass. The mantle consists of rocks rich in iron and Magnesium. Due to variations in pressure and temperature, the mantle is divided into two layers that differ in density and physical properties:

A. The Upper Mantle: The upper Mantle consists of two parts: the upper part is made up of solid rocks and along with the Earth's crust, they form lithosphere. The lower part of the upper mantle is called the Asthenosphere, which is a zone of ductile, semi-molten rocks known as Magma. These rocks behave like highly viscous fluids. In this region, convection currents occur, and they are the driving force behind the movement of the tectonic plates above.

B. The Lower Mantle (Mesosphere): The Lower Mantle extends to greater depths, reaching near the outer core. Its rocks are characterized by extreme rigidity due to exposure to immense pressure that increases with depth. Despite the high temperatures in this region, the high pressure keeps the rocks in a solid state and prevents them from melting, giving Mesosphere physical properties different from those of asthenosphere.

3. The Core

The Core is the deepest part of the Earth, representing approximately 33% of its total mass. It is divided into a liquid outer core and a solid inner core.

A. Outer Core: The outer core is a liquid layer composed of molten Iron and Nickel, where the temperature reaches approximately 5000°C. The mineral materials in this layer undergo continuous dynamic movement, leading to generating Earth's magnetic field, which acts as the shield that protects the planet from cosmic rays and harmful solar particles.

B. Inner Core: The inner core represents the center of the Earth. It is a solid, extremely dense sphere composed of Iron and Nickel. The inner core remains in a solid state despite the extremely high temperatures due to the immense pressure exerted upon it by the surrounding layers.

What is Lithosphere?

The Earth's crust and the upper part of Mantle combine to form a geological unit called Lithosphere. It is considered the rigid, outer part of the Earth. It is bordered above by the atmosphere and below by asthenosphere (the other part of the upper Mantle), with an average thickness of approximately 100 km. Lithosphere represents the "geological surface" where most geological phenomena occur, including the formation of landforms, earthquakes, and volcanic activity.

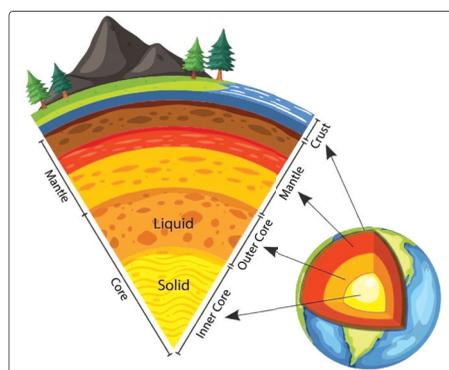


Figure (4) Lithosphere

Components of Lithosphere

Lithosphere is made up of several components, the most important of which are:

- **Rocks:** Rocks are considered the primary building blocks of lithosphere. They are classified into igneous, sedimentary, and metamorphic rocks, which together form Earth's solid crust.
- **Minerals:** Minerals are natural, inorganic substances with a chemical composition and a specific crystalline structure. They are the building units of rocks and are vital for usage in industry and construction.
- **Soil:** An essential layer of lithosphere that nourishes plants and retains nutrients. It is crucial for agriculture and the natural ecosystem.

The Importance of Lithosphere for Earth's Other Spheres

Lithosphere serves as the fundamental foundation upon which Earth's other spheres depend. It represents the solid base that supports the crust and everything above it and provides physical and chemical processes that regulate the planet's stability and balance.

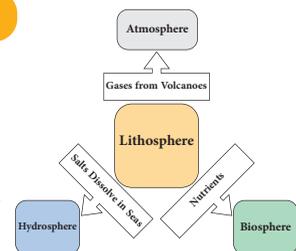


Figure (5) Lithosphere & Earth's Spheres

First: The Impact of Lithosphere on Atmosphere

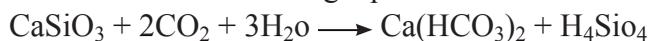
For example, rocks existing in lithosphere contribute to controlling the concentration of Carbon dioxide through chemical reactions known as weathering processes.

- When Silicate rocks rich in Calcium pyroxene (CaSiO_3), such as basalt and gabbro are exposed to water and Carbon dioxide, a chemical reaction occurs leading to the formation of Calcium BiCarbonate. This process contributes to reducing the percentage of Carbon dioxide in the air.



Figure (6) Rocks Exposed to Water & CO_2

as shown in the following equation:



- When Carbon dioxide (CO_2) dissolved in rainwater reacts with the rocks of lithosphere, part of it is converted into biCarbonate ions (HCO_3^-). These ions dissolve in water and carry Carbon away from the atmosphere.
- These ions are transported via rivers to the seas, where they may later be deposited as solid Calcium Carbonate (CaCO_3).

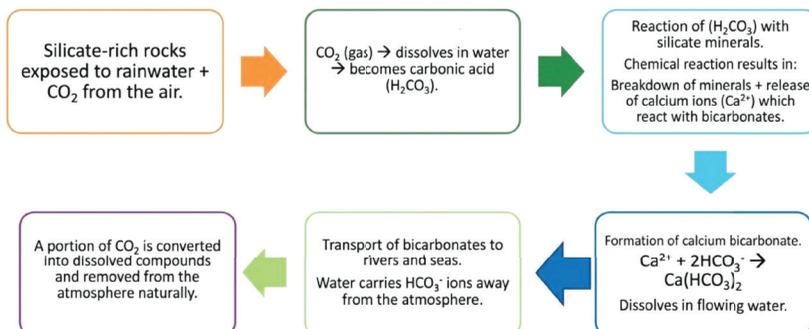


Figure (7) The role of rocks in regulating the concentration of Carbon dioxide in the

This reaction is an example of the role of lithosphere in achieving a kind of “**natural regulation**” of the air’s composition. The processes of weathering and the formation of bicarbonate salts act as natural mechanisms that help reduce the concentration of CO₂ in the atmosphere and limit the greenhouse effect over the long term.

Second: The Impact of Lithosphere on Hydrosphere

Rocks affect the properties of water through the dissolution of some minerals. When water passes through different layers of rock, the concentration of salts and dissolved elements, such as Calcium, Magnesium, and Iron salts changes, according to processes explained by the laws of solubility in chemistry.

The laws of Solubility explain why water properties differ from one region to another, and why certain areas produce "hard" water rich in Calcium and Magnesium due to its passage over specific rock types. They also explain lithosphere's role in supplying Hydrosphere with salts and elements essential for life and industry. The amount of substance that dissolves in water depends on several factors, the most important of which are:

Water Hardness

Hardness is a property of water resulting from high concentrations of positively charged ions, specifically dissolved Calcium (Ca²⁺) and Magnesium (Mg²⁺) ions. Hard water causes numerous problems, such as reducing the effectiveness of soap and forming limescale deposits (scales) in boilers and water pipes.

1. Nature of Chemical Bonds in Minerals

Minerals with ionic bonds, such as Calcium carbonate (CaCO₃) found in limestone, break down easily in water, especially if the water contains Carbon dioxide, which converts it into an acidic solution. In contrast, minerals with covalent bonds, such as Silica (SiO₂) in quartz, dissolve very slowly. For this reason, Silicate rocks remain more resistant to weathering.

2. Temperature

The solubility of most salts and minerals increases with rising temperature. Thus, hot spring water, for example, can dissolve more minerals than cold water. This explains the appearance of mineral deposits when this water cools down.

3. Pressure

As pressure increases, the solubility of gases in water such as Carbon dioxide increases. For example, deep groundwater contains a high concentration of dissolved CO₂ due to the increased pressure acting on it. This enhances the ability of the water to dissolve many types of rock and leads to a higher concentration of bicarbonate salts within it.

4. Presence of Acids in Nature

Rainwater can dissolve a certain amount of CO₂ from atmosphere, forming weak Carbonic acid (H₂CO₃). Acid rain increases the rate at which ionic bonds in minerals such as Calcite break down, leading to the formation of caves and cavities in Limestone.



Figure (8) Hot Springs

These factors affect the solubility of minerals and salts in water, which directly impacts the quality of drinking water, agriculture, and industry. In some industrial systems, these factors can be applied to purify water using porous rocks that act as natural filters.

Technological Applications

Some water treatment plants employ a nature-inspired technology that relies on **porous volcanic rocks**, such as Zeolite. These rocks act as natural filters capable of trapping impurities and heavy metals within their fine pores.

These rocks have demonstrated their effectiveness in modern purification facilities across Europe and Asia, where they have helped improve drinking water quality without the need for excessive chemicals.

This application serves as a prime example of harnessing lithosphere's properties to protect hydrosphere and support sustainability.

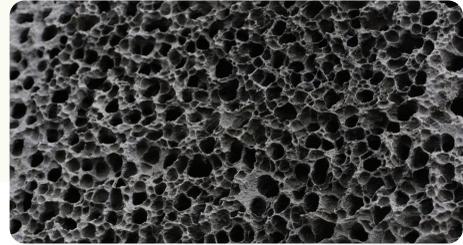


Figure (9) Porous Volcanic Rocks

Third: Impact of Lithosphere on Biosphere

When rocks in lithosphere are exposed to weathering factors, such as rainwater, temperature fluctuations, or weak acids produced by solubility Carbon dioxide in their minerals begin to decompose gradually. This process transforms into a "natural production line" for the nutrients that plants need.

For example, Phosphate rock contains minerals rich in Phosphorus. When these minerals chemically decompose, they release **Phosphate ions (PO_4^{3-})** into the soil, which is the form that plant roots can absorb. Similarly, feldspar mineral found in granite decomposes, releasing **Potassium ions (K^+)**, which are used for regulating the opening and closing of stomata and for energy production within plant cells. The soil retains these ions between its particles, making them available to plants through the absorption of soil water. Thus, the lithosphere acts as a natural reservoir that continuously nourishes the biosphere through a series of simple chemical reactions that convert minerals into an absorbable form.



Figure (10) Phosphate Rocks

Tectonic Plates and their Role in Shaping Earth's Surface

Lithosphere consists of a large group of massive rock pieces resembling floating "plates" called **Tectonic plates**. These plates move very slowly, several centimeters per year, due to the heat rising from the Earth's interior. This heat causes the softer rocks beneath the lithosphere to move, driven by convection currents within the molten rock or Magma in the **Asthenosphere below**. As a result, the plates move above it just as slow boats drift on water. Although the speed of movement is very slow, its effects are significant and visible.

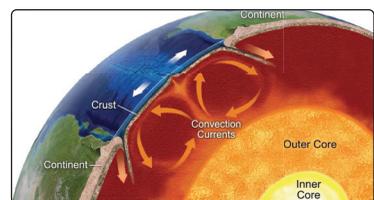


Figure (11) Convection currents in the Mantle

- When two plates move apart, known as **divergent movement**, cracks and fissures form allowing Magma to erupt from the Earth's interior. This results in the formation of volcanic mountains or a new Ocean floor, as well as rifts and valleys, such as the African Rift.

- However, when two plates slide alongside each other, known as **transform movement**, the movement of one plate may get stuck. Energy then accumulates and is released suddenly in the form of ground tremors and frequent, destructive earthquakes, such as the San Andreas Fault in the U.S.

- In other cases, plates collide in what is called **convergent movement**, causing the rock to compress and its layers to rise, forming towering **mountain ranges**, such as the Himalayas.



Figure (12) Convergent, Transform & Divergent Movements

The effects of these movements are evident in our daily lives in multiple ways: The mountainous regions we see today were once semi-flat areas before being uplifted by plate movement, and coastal valleys have widened due to the divergence of Oceanic plates, just as volcanic islands are regenerated as a result of Magma erupting through fissures in the plates. Thus, Tectonic plate movement acts as a natural tool that continuously reshapes the Earth's surface and maintains its geological balance.



Research Activity

Using the internet to search for Tectonic Plates, conduct a research activity on one of the following topics:

- What is the impact of Tectonic plate movement on human life?
- What is the role of Tectonic plate movement in the water cycle in nature?
- What is the impact of Tectonic plate movement on the climate and the phenomenon of global warming?

7. The role of the lithosphere in the biosphere includes:

- A) Providing oxygen directly to plants
- B) Producing minerals necessary for plant growth
- C) Increasing the proportion of Carbon dioxide in the atmosphere
- D) Preventing water from leaking into the soil

8. Which of the following industrial applications demonstrates harnessing lithosphere's properties?

- A) Using limestone in the cement industry
- B) Formation of organic Carbon in plants
- C) Increasing wind speed on mountains
- D) Absorbing Ozone in the atmosphere

Second: Essay Questions

Explain why?

- 1. Rocks that are composed of Carbonate salts, such as limestone, develop more caves and cavities than rocks composed of Silica.**
- 2. Chemical weathering of rocks plays a role in supplying plants with the minerals necessary for their growth.**
- 3. Mountain ranges appear in areas of Tectonic plate collision, whereas they do not appear in areas of plate divergence.**
- 4. Using porous rocks, such as zeolite, in water purification instead of industrial chemicals.**

4.2

Materials Composing Lithosphere and Their Role in Earth's Stability and Continuity

Minerals that compose rocks interact with water, air, and living organisms in subtle ways, leading to the formation of soil, release of nutrients, and facilitation of the movement of water and gases. By studying the materials that compose Lithosphere, we can understand how Lithosphere remains balanced and continues to perform its vital and structural role on Earth.

Lithosphere consists of **minerals** that are chemically bonded together to form **rocks**. In geology, the term mineral refers to a naturally existing solid substance that has a fixed or semi-fixed chemical composition and a regular crystalline structure. Minerals and rocks differ from each other according to **the following properties**:

1. Hardness

Hardness is a physical property that expresses the degree of resistance of a mineral or rock to scratching, which determines some of the mineral's uses. Hardness is often measured by the Mohs scale, which arranges minerals from (1 to 10); (1) represents the least hard, meaning it is the easiest to scratch, and (10) represents the hardest, meaning it is the most difficult to scratch.

For example, quartz is considered a mineral with high hardness (about 7 on the Mohs scale), so it resists scratching and is used in making glass tools and wear-resistant parts. In contrast, gypsum is a very soft mineral (hardness ≈ 2), as it easily breaks apart and is not suitable for bearing loads or for applications that require scratch resistance.

Hardness affects the mechanical behavior of rocks. Rocks containing minerals with high hardness (such as some types of sandstone and granite) are more resistant to erosion than rocks containing soft minerals (such as limestone rich in calcite). Thus, in the field of construction and building, materials with high hardness such as granite are used in high-traffic areas, such as major stores, hospitals, and train stations.

The following images show some ancient Egyptian statues and the hardness degree of the rocks they are made of, on the Mohs scale:



Statue of Amenhotep III
Rock: Alabaster
Hardness: 2.5-3



Great Sphinx of Giza
Rock: Limestone
Hardness: 3-4



Statue of Ramesses II
Rock: Red granite
Hardness: 6-7



Statue of Khafre
Rock: Diorite
Hardness: 7



Figure (13) Identifying Hardness Degree



Figure (14) Materials with High Hardness



Testing the Hardness Degree of Some Rocks

Tools:

- Samples of different rocks: Granite, limestone, sandstone, gypsum, or other samples.
- Iron nail – Metal coin – Fingernail

Steps:

1. Try to scratch each rock sample with your fingernail (Hardness ≈ 2.5).
2. Try to scratch each rock sample with the metal coin (Hardness ≈ 3).
3. Try to scratch each rock sample with the iron nail (Hardness ≈ 4.5).
4. Record your observations by placing (Yes) or (No) in a table as follows:



Was the sample scratched by ...	Granite	Limestone	Sandstone	Gypsum
- The fingernail?				
- The metal coin?				
- The iron nail?				

By observed of the results, what is the ranking of the samples according to the degree of hardness from highest to lowest?

2. Color and Luster

Color may help to identify some minerals; for example, the mineral **Malachite** clearly appears in green. However, one cannot rely on the color of the mineral alone, as different minerals may share the same color.

Luster refers to the extent of light reflection from the mineral surface. A mineral may have a metallic luster (**like gold**), a glassy appearance (**like quartz**), or a dull surface (**like charred basalt**).



Figure (15) Malachite, Green in Color



Figure (16) Quartz, Glassy Appearance



Figure(17) Pyrite (Fool's Gold)

The mineral **pyrite** is known as "fool's gold" because it displays a golden metallic luster, but it differs from real gold in composition and density. Similarly, the mineral **calcite** has a glassy appearance even if its colors vary, and it may be transparent or opaque. Thus,

color and luster are used along with other properties (such as hardness, cleavage, and reaction with dilute acids) to identify the mineral accurately.

3. Specific Gravity

Specific gravity (or relative density) is the ratio of the mass of a specific volume of a material to the mass of the same volume of water at a temperature of 4 °C. The specific gravity of a mineral is an indicator of its content of heavy or high-density elements. Minerals rich in heavy elements such as lead or silver have high specific gravities, such as the mineral **Galena** (lead sulfide), while lighter minerals like **Feldspar** have low specific gravities.



Figure (18) Galena has a relatively high specific gravity

In engineering and geological applications, the weight of rock samples is observed during examination. Iron and the minerals found in volcanic rocks give them a higher relative density than sedimentary rocks such as light sandstone. Determining the specific gravity of rocks at construction sites helps in determining the composition of the rock strata during drilling or geophysical surveying.

4. Cleavage and Fracture

Cleavage is the ability of a mineral to split along specific crystalline planes that reflect the structure of the bonds within the crystal. Cleavage appears as smooth, similar surfaces when the mineral is broken. **Fracture**, on the other hand, is the pattern of breakage. When breakage does not follow specific crystalline planes, irregular broken surfaces are produced, such as conchoidal fracture.

Examples: **Mica** demonstrates very perfect cleavage in one direction, which is the reason beyond its flakes easily separating into thin sheets.

Feldspar shows cleavage in two or three directions at specific ratios and angles. In contrast, **Quartz** breaks with a conchoidal fracture and does not display clear cleavage.



Figure (19) Mica

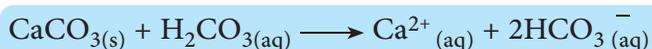
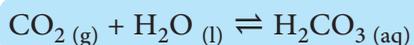


Figure (20) Feldspar

From an engineering perspective, knowing the cleavage or fracture pattern is very useful for identifying the type of mineral. Using rocks that contain minerals with clear cleavage in the construction of quarry walls or building sites may lead to them splitting into layers or breaking apart when exposed to mechanical stress, increasing the probability of collapse or slides.

5. Chemical Composition

The chemical composition of a mineral or rock is meant to determine the types of elements and their proportions within it. Minerals are classified into major groups based on their chemical composition, such as the **silicates** group (silicates), the **carbonates** group, the **sulfides** group, the **oxides** group, etc. Each group has its specific properties; for example, the **silicates**, which form most of the Earth's crust, usually have good hardness, while **calcite**, which is found in **limestone** and is composed of calcium carbonate (CaCO_3), partially dissolves in weak acids, such as dilute carbonic acid (which is CO_2 dissolved in water), producing effervescence due to the release of carbon dioxide gas according to the following chemical equations:



And calcium ions (Ca^{+2}) and bicarbonate ions (HCO_3^{-}) transfer into the aqueous solution.

Thus, the test of reaction with diluted acids is used to identify rocks that contain carbonate groups. As for minerals that contain the silicate group, such as feldspar and quartz, they have a resistance to dissolving in weak acids, which is why soil and rock sediments retain the minerals feldspar and quartz for long periods of time.

Mineral Resources in Lithosphere

The Earth's lithosphere is primarily composed of minerals, which are the fundamental building blocks from which most rocks are formed. A mineral is defined as a naturally occurring, solid substance, inorganic, with a definite chemical composition and a regular crystalline structure that imparts distinctive physical properties to it.

Minerals are formed within the Earth's crust through various geological processes; among these are the crystallization of magma upon cooling, the precipitation of salts when water evaporates, or as a result of rocks being exposed to great pressure and heat leading to the rearrangement of their atoms. This diversity in formation conditions leads to the existence of more than 4,000 known minerals on Earth, though a limited number of these minerals form the bulk of the rocks that constitute lithosphere.

Minerals play an important role in the **Earth's stability and continuity**; they impart hardness and cohesion to rocks, contribute to the formation of continents and mountains, and determine the properties of soil. Furthermore, their **chemical and physical** diversity allows for a different distribution of elements within the Earth's crust, which supports natural processes like the **rock cycle and Tectonic plates**.

The influence of minerals extends directly to daily Human life, as they are incorporated into a wide range of modern industries. For example,

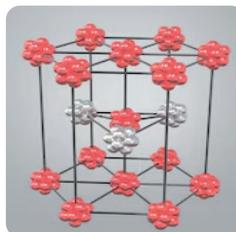


Figure (21) The Crystal Lattice of Magnesium

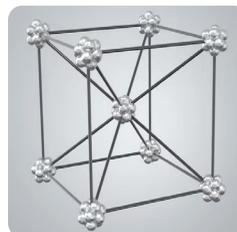


Figure (22) The Crystal Lattice of Iron

- **Quartz** plays an essential role in modern technology thanks to its unique property of electrical **oscillation when exposed to an electric potential difference**. This property is used in the manufacture of accurate watches.

Quartz is also used in **mobile phones and GPS navigation devices** to adjust electronic signals and provide accurate timing for data transmission, ensuring that calls, messages, and map locations arrive synchronously and accurately.



Figure (23) Satellite Global Positioning System (GPS) Devices

- **Iron** is extracted from minerals such as **Hematite and Magnetite** and is used in the manufacture of **metal structures and heavy machinery**. The role of Iron is not limited to traditional structures only, but it has become an essential element in **modern technology and renewable energy** as it used for manufacturing **electric cars and high-speed trains**, which contributes to reducing Carbon emissions and achieving a more sustainable future. It is also used for manufacturing **giant wind turbines**, where their metal structures form the backbone of clean electricity production.



Figure (24) High-Speed Train



Figure (25) Wind Turbines

Egypt Heading to Future

Egypt is moving quickly toward modern technology, recently inaugurating the High-Speed Electric Train, a project to create a high-speed electric rail network with a length of approximately 2000 km, to transport individuals and goods. The project aims to connect the Red Sea and Mediterranean cities, enhance connectivity between production areas and export ports, and support economic and urban development across the country.

In the medical field, minerals play a pivotal role in the manufacture of drugs and medical equipment, such as.

- **Calcium and Iron** compounds are major components in the production of nutritional supplements used to compensate for mineral deficiencies in the body,

- **Titanium** maintains its position as the most important metal in bone and artificial joint implants due to its amazing ability to integrate with the body's tissues without being rejected by



Figure (26) Prosthetic Limb

the immune system, in addition to its great strength despite its light weight.

- **Cobalt** also plays a pivotal role in the production of Lithium-ion batteries used in smart medical pumps and in wearable devices that monitor patients' health in real time.

- Rare earth minerals such as, **Neodymium (Nd), Iron (Fe), and Boron (B) alloys** are used in manufacturing the strongest permanent magnets in the world, upon which **Magnetic Resonance Imaging (MRI)** machines depend. These magnets generate enormous magnetic fields that help image internal body organs with extreme clarity and high precision without surgical intervention.

- Gold and silver nanoparticles are used to deliver drugs directly to infected cells for cancer treatment with methods that are more precise and less harmful.

- **Lithium** is called the “oil of the twenty-first century” at present. It is the lightest metal on Earth's surface and is distinguished by its great ability to store energy for long periods and release it with high efficiency. **Lithium** is used in manufacturing batteries for portable medical devices, such as cardiac pacemakers and precision glucose monitors, and is also found inside batteries of smartphones, digital watches, laptops, electric vehicles, drones, and even satellites.

- **Silicon is an element extracted from sand**, but it is considered one of the most important materials that has transformed modern life. It is the main component in the manufacture of **electronic chips (microchips)** inside computers and smartphones. Silicon is distinguished by its ability to **control the flow of electric current in electronic circuits**, which makes it the basis for the operation of processors and electronic circuits. It is also used in the production of **solar panels** that convert sunlight into clean electrical energy.

Thus, lithosphere represents a natural reservoir rich in mineral resources whose importance is not limited to shaping the Earth's surface but extends beyond that to become an essential part of the industrial, technological, and medical development in the world.

How do the materials of Lithosphere move and constantly reshape themselves?

Rocks are primarily composed of minerals whose properties you previously studied. Although rocks appear at first glance to be stable and unchanging entities, they are in fact part of a continuous dynamic system known as the **rock cycle**.

In every moment, **heat, pressure, water, wind, and the Earth's internal forces** reshape minerals and rocks, transforming them from one type to another in a long journey that may take thousands or millions of years.



Figure (27) X-rays Showing a Pacemaker Inside the Body



Figure (28) Lithium Batteries

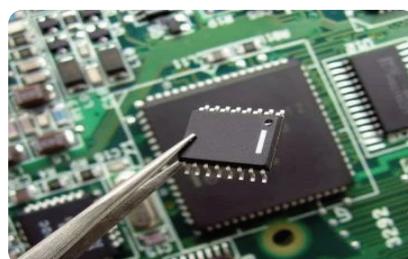


Figure (29) Electronic Chips

The Rock Cycle

- Rock cycle often begins with igneous rocks that form as a result of the cooling of magma from the Earth's interior or lava on the surface.
- As these rocks are exposed to factors like wind, rain, and temperature change, they disintegrate into small sediments that are transported by water or wind to settle in seas and rivers.
- With the accumulation and pressure of these sediments over time, they transform into sedimentary rocks.
- With the continued movement of

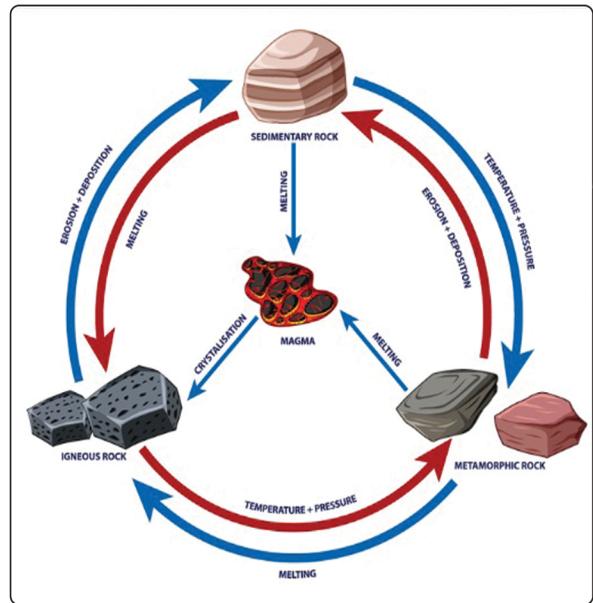


Figure (30) The Rock Cycle

Tectonic plates, the sedimentary rocks may be

pushed to great depths where heat and pressure rise. The minerals making them up begin to change without melting, transforming into **Metamorphic rocks** with completely new properties, such as the rearrangement of the mineral grains.

- With the increase in depth and a sufficient rise in temperature, the metamorphic rocks or sedimentary rocks may reach the stage of complete melting to return to Magma again, and thus the cycle begins once more.

You can observe parts of this cycle in nature around you:

When you see successive rock strata in mountains or mountain roads, this represents the accumulation of sediments over millions of years.

Industrial products such as marble used in buildings are an example of metamorphic rocks that originated from limestone under the influence of heat and pressure.

Even the glass we use daily depends on the sand composed of silica minerals resulting from the fracturing of rocks. Thus, the rock cycle shows how lithosphere functions as an integrated unit that continually reshapes its materials, ensuring stability of the Earth and continuity of its resources through the ages.



Figure (31) Sedimentary Rocks



Figure (32) raw marble piece



Inquiry Activity

The Journey of Rocks and Minerals

1. Select a rock from your surroundings or a picture of natural rocks.
2. Identify the minerals that the rock might contain using a mineral properties guide.
3. Observe the shape, color, and hardness of the grains.
4. Discuss with your classmates: How can the composition of the minerals affect the rock's hardness or its susceptibility to fragmentation?
5. Think: What type of rock does this example belong to? Igneous, sedimentary, or metamorphic?
6. Note any signs of weathering or transport for this rock.
7. Attempt to draw a potential rock cycle path starting from this rock and leading to another rock.
8. Consider a practical application: Which minerals in this rock could be used in industry or technology?
9. Record your observations and conclusions on the activity sheet.
10. Share your conclusions with the classmates and discuss how minerals and rocks maintain the Earth's stability.



Lesson to Assessment

First: Multiple Choice Questions

Choose the correct answer:

1. Which of the following factors can change the type of rock without changing its chemical composition?

- A) Complete melting
- B) Rapid cooling
- C) High pressure and heat
- D) Chemical weathering

2. A mineral characterized by an ability to cut glass and used in precision industries. This description indicates which property?

- A) Color
- B) Hardness
- C) Cleavage
- D) Luster

3. If sedimentary rocks are transformed into metamorphic rocks, this indicates that the rocks:

- A) were exposed to weathering factors only
- B) melted and then cooled
- C) were exposed to pressure and heat without melting
- D) were directly transformed into igneous rocks

4. Which of the following explains the use of mineral Titanium in artificial joints?

- A) Its high density
- B) Its shiny silver color
- C) Its high resistance to corrosion and high strength
- D) The easy with which it melts

5. The presence of large crystals inside an igneous rock usually indicates that the rock:

- A) cooled slowly deep within the Earth
- B) was exposed to mechanical weathering
- C) was formed by a rapidly erupting volcano
- D) had its layers deposited at the bottom of the sea

6. Which of the following processes is considered the beginning of the formation of sedimentary rocks?

- A) Melting
- B) Weathering and erosion
- C) Crystallization from magma
- D) Rearrangement of minerals

7. A mineral that is used in the manufacturing of smartphones and electric cars, and is characterized by its light weight and ability to efficiently store energy, is:

- A) Copper
- B) Lithium
- C) Iron
- D) Bauxite

8. When studying a rock that contains clear layers and grains of varying sizes, it can be concluded that this rock was formed as a result of:

- A) cooling of magma
- B) pressure on sediments over a long time
- C) change in minerals under severe heat
- D) melting of an older rock

Second: Essay Questions

Explain why?

1. Rocks differ in their properties even though they are composed of common minerals.

2. Minerals are considered the basis for modern industries such as medicine and technology.

3. The rock cycle is a continuous process despite the difference in geological ages.

4. Metamorphic rocks do not usually contain fossils.

4.3

The Lithosphere and the Sustainability of Energy Resources

The lithosphere is considered as a source for a wide range of energy resources, both renewable and non-renewable, which cover a significant portion of the global energy demand.

The lithosphere is the primary source for conventional fossil fuels such as coal, petroleum (oil), and natural gas. In addition to fossil fuels, the lithosphere also contains radioactive minerals, such as Uranium, which are the source of nuclear energy, as well as the geothermal energy produced from the Earth's internal heat.

Therefore, studying the lithosphere allows us to identify the locations of these resources and determine how to efficiently and sustainably extract and manage them.

First: The Lithosphere and Fossil Fuels

The lithosphere contains vast deposits of fossil fuels, which are currently the main source of energy globally and the most abundant within the lithosphere.

The **Organic Origin Theory**, which attempts to explain the formation of petroleum (oil) and natural gas, suggests that they were formed from the remains of certain living organisms, especially marine micro-organisms, that were buried in the sedimentary rocks after their death on the sea beds and oceans millions of year ago and the thickness of these rock layers increased overtime

Under immense pressure and high temperatures resulting from the Earth's internal heat, layers of sedimentary rocks known as "source rocks" were formed. Within these layers, the Carbon- and Hydrogen-rich organic remains were converted into hydroCarbons, forming petroleum and natural gas.

Petroleum and natural gas typically accumulate underground within impermeable rock layers in sedimentary basins, which are shaped like a dome and known as "oil traps." In these traps, petroleum exists under high pressure, floating on top of water, with natural gas situated above it. Below, we shed more justified on the extraction of petroleum.

Petroleum Extraction

After identifying the location of petroleum within the reservoir rocks, the process of **deep drilling** begins. This is done using specialized drilling rigs that can reach significant depths, either underground or beneath the sea floor. Companies insert strong

steel casings (pipes) into the well to ensure its stability and prevent unwanted leakages. When the drills reach the rock layer containing the oil, the natural pressure within the reservoir is often allowed to push the oil upwards. Modern techniques such as **water or gas injection** could be used to lift the petroleum to the surface when the pressure is low.

The crude oil continues to flow until the **pressure** causing its surge diminishes.

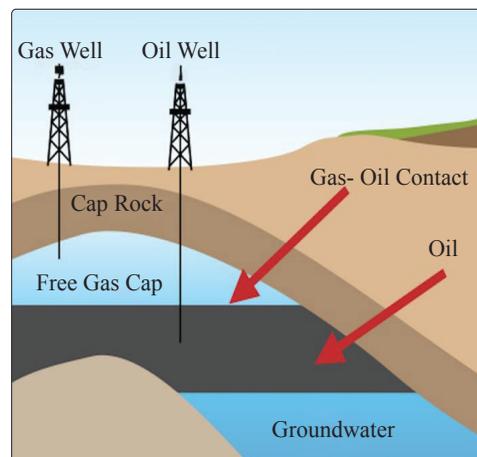


Figure (33) Oil and Natural Gas Underground

Unit 4... Lithosphere

The crude oil continues to flow until the **pressure** causing its surge diminishes.

At that point, the amount extracted is estimated to be about 20% of the crude oil present in the field. The quantity of petroleum that can be extracted depends on the **viscosity of the crude** oil. Viscosity affects the fluid's resistance to flow; highly viscous fluids are thick and flow slowly due to increased attractive forces between their molecules (cohesive forces). Consequently, the rate of crude oil extraction decreases as its viscosity increases.

In recent years, companies have begun to rely on **3D seismic sensing** (or surveying), which enables geologists to map the rock structures accurately and pinpoint the locations of oil accumulation with greater precision. This significantly increases the success of the extraction process and reduces the environmental impact

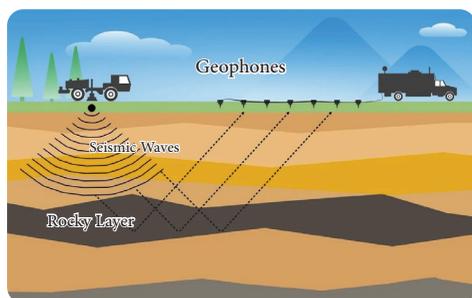


Figure (34) Seismic Sensing (or Surveying)

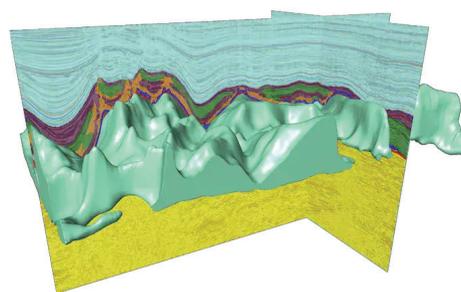


Figure (35) 3D Seismic Sensing Data Analysis

Technological Applications

Microorganisms Enhance Crude Oil Extraction Rate (Enhanced Bio-Oil Recovery)

Some modern companies are resorting to the use of **microorganisms**, such as certain types of **bacteria**, to help increase the amount of petroleum extracted from rocks. These organisms are injected into old or low-producing oil wells, where they begin to multiply within the rock pores. The bacteria secrete natural chemical substances, such as **organic gases, acids, and biopolymers**.

These substances work to change the properties of the petroleum and the surrounding rock layer. For example, **bio acids** help dissolve certain minerals that impede oil movement. And **Biopolymers** which reduce the **viscosity** of the oil, allowing the oil to move and flow more easily into the well.

This process increases the efficiency of extraction without the need for strong pumping operations or high energy consumption. This makes it a modern and **environmentally friendly technique** that is used today in several fields worldwide to support production and reduce the loss of stored petroleum.

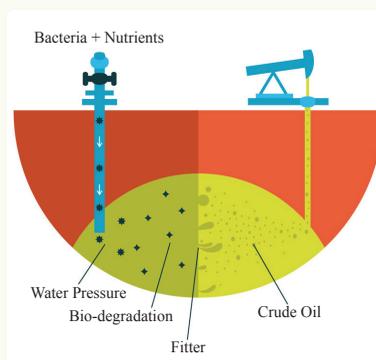


Figure (36) Enhanced Bio-Oil Recovery

Fractional Distillation of Crude Oil

Crude oil is primarily composed of chemical compounds called **hydrocarbons**, which are organic compounds containing only Carbon (**C**) and **Hydrogen (H)** elements. In

addition to hydrocarbons, crude oil also contains a small amount of non-hydrocarbon compounds that include elements like Sulfur, Nitrogen, Oxygen, and some metals.

The various hydrocarbon compounds that make up crude oil, which, after separation, are known as **petroleum products**, are what give oil its practical and economic importance, as each petroleum product has numerous uses and different applications.

Crude oil arrives at the refineries as a **complex mixture** of hydrocarbon compounds with varying properties. To convert it into usable products, such as gasoline (benzine), diesel, and cooking gas, the process of **fractional distillation** is performed.

How is Fractional Distillation Performed?

1. Heating the Crude Oil:

Crude oil is heated to high temperatures, reaching up to 400 C°, inside specialized furnaces until it turns into a mixture of vapors.

2. Vapors Enter the Distillation Tower:

The hot vapor is pumped into a tall tower called the fractional distillation column (or tower). This tower is characterized by having high temperatures at the base and temperatures that gradually decrease towards the top.

3. Collection of Components Based on Boiling Point:

Hydrocarbons differ in their boiling points, and thus they condense at different levels:

- **Diesel and Kerosene** condense at middle levels.
- **Gasoline** (benzine) condenses at higher levels where the temperature is lower.
- Light gases such as **Butane** and **Propane** exit from the top of the tower.

Modern Examples of Industrial Applications

- In modern **refineries** across the **Arabian Gulf and Egypt**, digital control systems are used to precisely adjust temperatures and cooling rates. This makes the distillation process more efficient and reduces energy consumption.
- Some refineries also rely on **thermal and hydro-cracking units** to convert heavy hydrocarbons into high-quality, lighter gasoline (benzine). This high-quality gasoline is then used in modern vehicles with low emissions.
- In advanced industries, the light gases produced from the top of the tower are utilized in the production of **petrochemicals**, such as plastics, resins, and synthetic fibers. These materials are essential components in electronic devices, electric vehicles, and lightweight building materials.

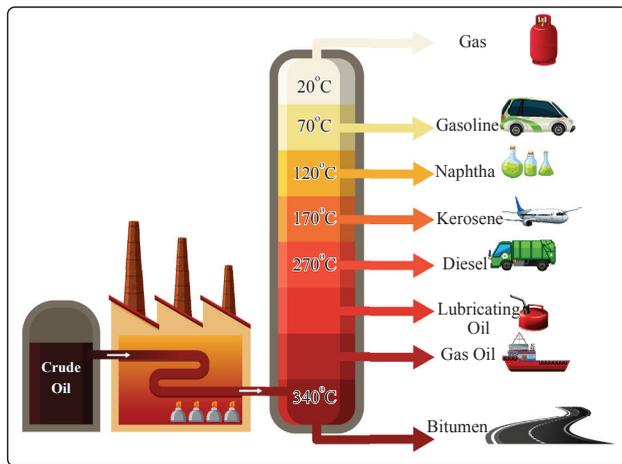


Figure (37) Fractional Distillation Process of Oil

In addition to petroleum and natural gas, the lithosphere provides another critically important resource: **radioactive elements** used in the production of **nuclear energy**, foremost among them being **Uranium**.

Uranium occurs naturally within certain **igneous and sedimentary rocks**. It is extracted in the form of minerals such as **Uraninite** and **Carnotite**.



Figure (38) Radioactive Uranium Element

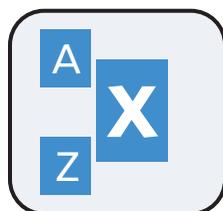
What makes this element special is its ability to release enormous amounts of energy when its atomic nucleus splits in a process called **nuclear fission**.

How is Nuclear Energy Extracted from Uranium?

Uranium atoms are characterized by having **large, unstable atomic nuclei**.

The nucleus is composed of positively charged **protons** and neutral **neutrons**. When these numbers are large, the cohesion (stability) of the nucleus becomes weak, which makes some elements, such as uranium, **naturally radioactive elements**.

The number of protons (the number of positive electrical charges) inside the nucleus is known as the **Atomic Number (Z)**, and the sum of the numbers of protons and neutrons is the **Mass Number (A)**.



The atomic number (Z) is typically written at the lower left of the element symbol (X), and the mass number (A) is written at the upper left of the symbol, as shown in the figure. Atoms of the same element may have different forms that agree in the number of protons (Z) in their nuclei but differ in the mass number (A), and consequently in the number of neutrons (N). These forms are known as isotopes.

There are three natural isotopes of uranium:

Uranium- 234(U-234), Uranium- 235(U-235), and Uranium- 238(U-238). Uranium-238 is the most common, accounting for nearly 99% of the natural uranium found on Earth.

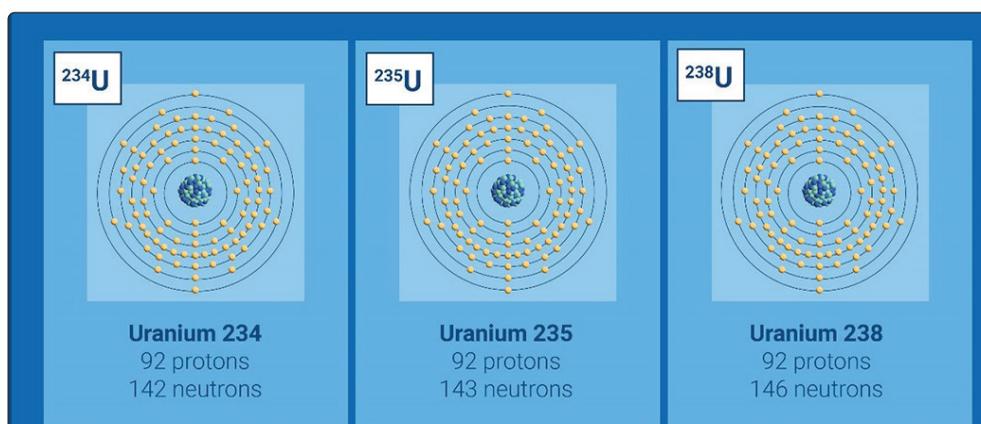


Figure (39) Uranium Isotopes (For reference only)

Uranium is the basis for nuclear energy production. Its ores are **extracted from rocks**,

Uranium is the basis for nuclear energy production. Its ores are **extracted from rocks**, then refined and prepared in the form of **nuclear fuel rods** inside nuclear reactors.

When a neutron strikes the nucleus of a uranium atom, the nucleus splits into smaller parts in a process called **nuclear fission**, releasing a massive amount of thermal energy. This thermal energy is used to heat water and convert it into steam, which drives turbines that, in turn, operate electrical generators to generate electricity.

Nuclear reactions

These are processes that occur within the nucleus of an atom, causing a change in its structure. The most important types of nuclear reactions are:

1. Nuclear Fission: In which the nucleus of an atom splits into several parts, as occurs in nuclear reactors.

2. Nuclear Fusion: where small nuclei combine to form a larger, heavier nucleus, as occurs naturally in the **Sun and other stars**.

Technological Applications

Today, nuclear energy is an essential part of the global energy system because it produces large, consistent quantities of electrical energy with almost zero Carbon emissions. Many countries rely on nuclear energy to secure a significant portion of their electricity needs, such as France, Japan, South Korea, and the United Arab Emirates. El-Dabaa Nuclear Power Plant in Egypt is a modern example of exploiting lithospheric resources for nuclear energy production. The plant is located in Matrouh Governorate on the Mediterranean coast and comprises four advanced reactors that use radioactive elements extracted from rocks, such as Uranium, to generate substantial electrical power.



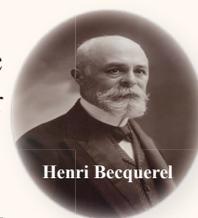
Figure (40) El Dabaa Nuclear Power Plant

El-Dabaa project is a significant step in Egypt's transition toward safe and clean energy sources, as it contributes to providing a stable electricity supply that reduces reliance on fossil fuels and supports development plans. Furthermore, the project enhances Egypt's scientific and engineering capabilities and paves the way for developing modern technologies based on the responsible use of lithospheric resources.

Modern research is trending toward the development of Generation IV reactors and Small Modular Reactors (SMRs), which use smaller amounts of nuclear fuel and are easier to install, making nuclear energy a promising option to support the global transition toward sustainable and environmentally friendly energy sources.

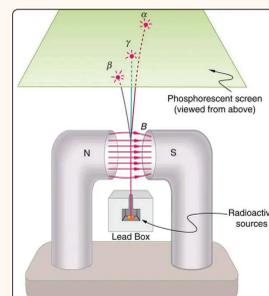
The Discovery of Radioactivity

In 1896, Henri Becquerel was studying the properties of X-rays. He exposed Uranium salt to sunlight and placed it on photographic plates wrapped in black paper, believing that Uranium absorbed solar energy and then released it as X-rays. When he conducted his experiment during cloudy weather, the images remained strong and clear, proving that Uranium emits radiation without the need for an external energy source like the sun.



Henri Becquerel

Becquerel used a device, as shown in the figure, to demonstrate that the radiation he discovered could not be X-rays; X-rays are electrically neutral and their path is not altered by a magnetic field. Unexpectedly, the magnetic field affected the emitted radiation, revealing three paths that indicated the presence of three types of radiation: negative, positive, and electrically neutral.



Marie Curie and her husband, Pierre, began studying various radioactive materials, and she coined the term "radioactivity" for the phenomenon Becquerel had recently discovered. Curies extracted uranium from its ore and, to their surprise, found that the remaining ore exhibited greater radioactivity than pure uranium. They concluded that the ore contained other radioactive elements, which led to the discovery of the elements polonium and radium.

Precautions for Nuclear Radiation Protection

Certain precautions must be taken to minimize the risks associated with radioactive materials, including:

- Keeping radioactive sources protected (preferably by placing them in a lead-lined container).
- Transporting them only when necessary and while following strict regulations.
- Wearing protective clothing to shield the body from radiation emitted by radioisotopes.
- Wearing face masks to avoid inhaling the vapors of radioactive materials.
- Continuously monitoring the radiation levels in the environment surrounding the radioactive materials using a Geiger counter or similar device.



Promising Sources of Renewable Energy

Modern science offers us new horizons for understanding the relationship between the lithosphere and renewable energy sources, and how the properties of rocks and minerals contribute to generating clean energy that supports the sustainability of planet Earth.

In the following part of the lesson, we will learn about methods through which humans obtain energy from the lithosphere, such as geothermal heat originating from thermal activity deep within the rocks, and energy produced by piezoelectricity which is generated by certain minerals when subjected to pressure or vibration. We will also study compressed air energy storage within rocks and natural Hydrogen energy.

Through this diversity of sources, we understand how the lithosphere opens multiple pathways for science to generate clean energy, offering us practical solutions to support ecological balance and resource sustainability.

1. Geothermal Energy

The lithosphere is an important source for multiple types of energy, including **geothermal energy**. This energy originates from the heat stored deep within the Earth, resulting from several natural processes such as **the decay of radioactive elements** inside rocks and the presence of **hot magma** beneath the Earth's crust. temperature increases as we move inward, in a phenomenon known as the geothermal gradient of Earth.

When fissures or openings are present in the lithosphere, groundwater can penetrate to deep layers, where it is intensely heated. It then rises to the surface in the form of hot springs or pressured steam.

Some countries exploit this natural heat by establishing **geothermal power plants**, where the rising steam is used directly to drive turbines for electricity production, or utilized for heating buildings and in various industrial applications. Geothermal energy is characterized as a renewable and clean energy source, as it produces negligible pollution.

Furthermore, its source within the lithosphere is continuously available in regions where suitable geological conditions exist.

Therefore, it is considered one of the important solutions for achieving sustainable development and reducing reliance on fossil fuels.



Figure (41) Geothermal Power Plant



Figure (42) Heating Buildings using Geothermal Energy

Modern Technological Application

Generating Electricity from Deep Rock Heat using EGS Technology

In recent years, scientists have developed an advanced technology called **Enhanced Geothermal Systems (EGS)**. This system relies on drilling deep wells into extremely hot rocks at depths that may reach 4–6 kilometers. Engineers pump quantities of water into fine fractures within the rocks to absorb high heat, which then returns to the surface to drive turbines and generate electricity.

Countries such as the United States have successfully operated pilot plants based on this technology, proving that geothermal heat can become a source of **clean energy that operates 24 hours a day, year-round**. This development is considered a major scientific achievement, as it enables the utilization of the lithosphere's heat and looks toward a future of sustainable energy resources that rely on "Deep Earth Heat" as a global source of electricity.

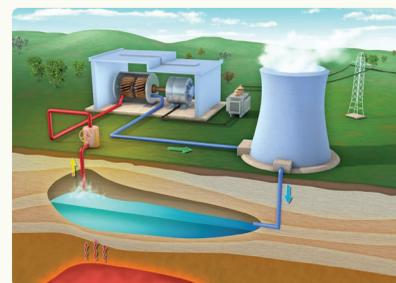


Figure (43) Design of a Geothermal Power Generation Plant

2. Energy from Piezoelectricity

Piezoelectricity is one of the modern innovations that relies on the properties of certain minerals found in the lithosphere, such as Quartz. When these minerals are subjected to pressure, vibration, or bending, they generate an electric charge without the need for any external energy source. This property is currently used to produce clean energy from ambient vibrations and movement around us.

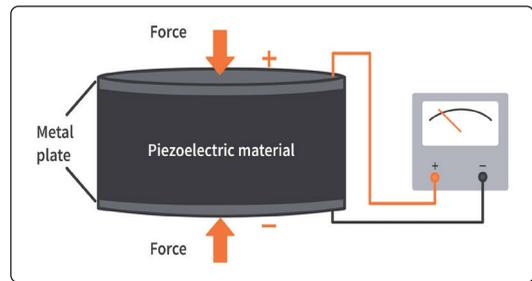


Figure (44) Generating Electric Charge Without an External Energy Source

The mechanical pressure applied to the material deforms its **crystal structure**, causing an imbalance in the distribution of charges, which generates an electrical potential difference (voltage). The **piezoelectric effect** is used in the type of lighters that generate an electric spark to ignite gas by pressing a button, which in turn applies pressure to crystal.

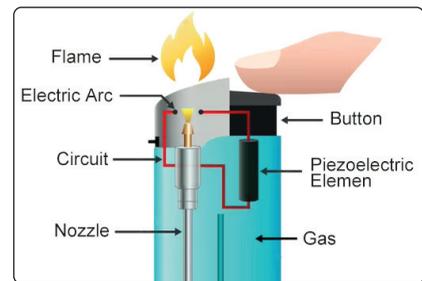


Figure (45) Pressure Lighter for Gas Ignition

Piezoelectricity has become a promising field in modern applications. Some cities rely on it to generate electricity from **pedestrian footsteps** in stations and shopping centers, where **smart flooring** converts the pressure of feet into energy used to power lighting or charge small devices.

This technology is also used in automotive sensors and security systems, and in devices that track vibrations in bridges and buildings. Additionally, it is used to charge **implanted sensors** inside the human body without a battery, representing a breakthrough in **medical applications**.

Thus, science continues to explore the properties of minerals in the lithosphere to invest in the production of innovative and smart energy that contributes to building a future based on clean and renewable sources.



Figure (46) Energy Generation from Foot Movement



Figure (47) Energy Generation from Foot Movement

3. Compressed Air Energy Storage (CAES) in Rocks

Storing compressed air within underground rock cavities is one of the modern technologies that rely on the lithosphere as an essential component for producing clean, renewable energy. The concept is based on using electricity generated from renewable

sources, such as solar or wind power, to compress air and force it into deep rock cavities. The air remains trapped under high pressure within the rocks. When the power plant requires an additional amount of energy, the air is released from the cavities into the plant, where it drives turbines that operate generators to produce electricity again.

The efficiency of this technology depends on the gas laws, which study the relationship between gas pressure, volume, and temperature. The level of pressure the air reaches inside the rocks depends on several factors, including:

- When the power plant forces a large amount of air into a small space within the rocks, the pressure increases significantly within that space.

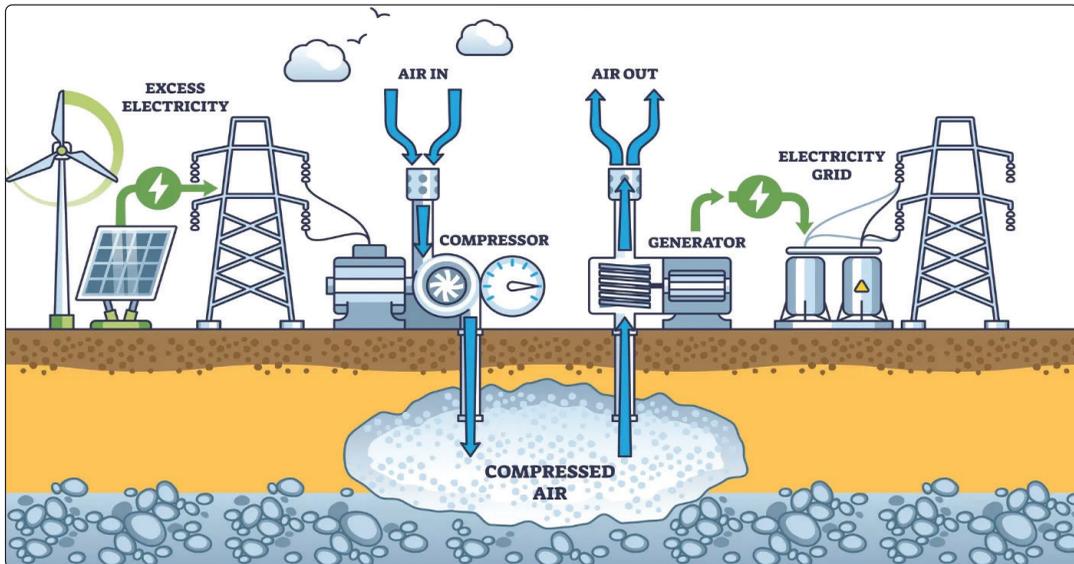


Figure (48) Compressed Air Storage Plant

- When air is compressed, its pressure does not only increase, but its temperature rises as well, due to the air molecules drawing closer together and moving at higher speeds. Some power plants store the thermal energy generated by air compression and then reuse it when the air is released into the turbines, which minimizes energy loss and increases the plant's efficiency.

• The efficiency of this technology also depends on the properties of the lithosphere, such as the strength of the rocks and their ability to withstand pressure, which makes storing compressed air within them possible and safe. Solid rocks can withstand high air pressure without collapsing, allowing for the containment of large volumes of air within their cavities. This high pressure is what provides the air, upon its later release, with the capacity to operate generators and produce electricity.



**Enrichment
Information**

The Huntorf power plant in Germany—the world's first compressed air energy storage (CAES) facility—has been operational for over 40 years. The plant stores air in two underground salt caverns and utilizes it today to support the electrical grid during peak consumption. This helps stabilize the grid, particularly on days when wind speeds fluctuate or sunlight decreases.

4. Natural Hydrogen Energy (White Hydrogen)

Natural Hydrogen is one of the latest renewable energy sources discovered by science today, and is sometimes known as **White Hydrogen** because it forms naturally within the lithosphere without human intervention. It is cheaper than industrially produced Hydrogen and produces no Carbon dioxide emissions when used as fuel.



Figure (49) Hydrogen Gas Storage for Energy Production

- Gas forms within deep rocks when water seeps into fractures in the lithosphere.
- Water encounters iron-rich minerals such as **olivine iron and Magnesium silicates**, triggering a chemical reaction where water molecules (H_2O) bond with Iron atoms (Fe) inside the rock.
- Part of the mineral transforms into a new mineral called **Serpentine**, which consists of hydrous Magnesium silicates, and **Hydrogen gas** (H_2) is released as a byproduct of the reaction.
- Pure Hydrogen rushes into the voids and fractures within the rocks, accumulating in locations from which it can potentially be extracted.
- **White Hydrogen** is characterized by being cheaper than industrially produced Hydrogen, and it produces no Carbon emissions when used as a fuel.



Enrichment Information

In 2023, in the town of Bourg in France, scientists discovered a small fissure in the ground continuously releasing **natural Hydrogen**. This gas flows from rock fractures. Testing is currently underway to use this Hydrogen to power local electricity generators, potentially making the town the first community to benefit from **natural Hydrogen from the Lithosphere**.



Practical Activity

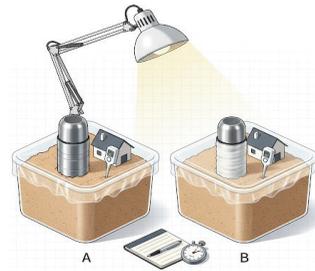
Required Materials:

- Two small, transparent boxes (clear, sealable plastic containers).
- Soil or sand (to fill both boxes) halfway up.
- Two thermos bottles or insulated flasks containing hot (but not boiling) water.
- Two temperature measuring devices (simple digital thermometers).
- Cardboard to make a "roof" and a transparent cover representing a plastic house (optional: a transparent cover to simulate a greenhouse).
- A timer and a measurement log (paper and pen).
- A light source (table lamp) to simulate solar heat (optional).

Procedures:

1. Place soil in both boxes at the same height. Label Box A as "Thermal Reservoir" and Box B as "Reference/No Storage."

2. Bury the hot water flask in the center of the soil in Box A, ensuring the flask is protected and its lid is sealed tightly.
3. In Box B, leave only soil, or place a flask of the same volume but inside a well-insulated casing so that heat does not escape.
4. Place a thermometer inside each box near the soil surface (similar to where the "inside of the house" would be). Record the initial temperature.
5. If available, place a transparent cover over each box (to simulate the same conditions of a plastic house). Turn on the light source above the boxes for 1–2 hours to simulate solar heating, then turn it off (or wait for the time to pass).
6. Measure the temperatures in each box every 15–30 minutes for at least two hours. Record the measurements. Observe how the temperature drop/rise differs between the two boxes.



Discussion and Evaluation Questions:

1. Why did Box A maintain a higher temperature? Describe the physical process responsible.
2. How can the design of the "Thermal Reservoir" be improved so that it retains heat for a longer period?
3. In what real-world applications can this idea be implemented? Provide one civil and one agricultural example.
4. What are the environmental and economic advantages of using geothermal energy instead of burning fuel?

Lesson tree Assessment



First: Multiple Choice Questions

Choose the correct answer:

1. Which of the following methods is used to extract petroleum from rocks?

- A) Conventional drilling and crude oil extraction
- B) Direct distillation of water
- C) Distillation under atmospheric pressure only
- D) Iron extraction

2. What is the purpose of the fractional distillation process for petroleum?

- A) Separating compounds based on color
- B) Separating compounds based on their density and different boiling points
- C) Mixing chemical compounds together
- D) Producing water

3. Which of the following products results from the fractional distillation of petroleum?

- A) Gasoline, diesel, wax, and asphalt
- B) Water, salt, limestone, and iron
- C) Uranium, silicon, and quartz
- D) Gypsum, limestone, and clay

4. Why are some microorganisms (microbes) used in petroleum extraction?

- A) To color the petroleum
- B) To break down rocks and mobilize oil trapped in rock pores
- C) To freeze petroleum
- D) To generate electricity directly

5. What is the main factor affecting the quantity of petroleum extracted from rocks?

- A) The amount of salts in surface water
- B) The permeability and pore size of the rocks
- C) Air temperature only
- D) The type of surrounding vegetation

6. Which of the following illustrates the source of nuclear energy used at the El Dabaa plant?

- A) Solar heat
- B) Coal
- C) Uranium
- D) Natural gas

7. Why is geothermal energy considered a sustainable energy source?

- A) Because it relies on fossil fuels
- B) Because it is continuous and renewable due to the heat of the Earth's interior
- C) Because it produces high pollution
- D) Because it is limited and depletes quickly

8. When nuclear fission occurs in a uranium nucleus, the energy is released in the form of:

- A) Heat only
- B) Light only
- C) Heat, kinetic energy, and nuclear particles
- D) Sound waves

9. Which of the following uses demonstrates the exploitation of geothermal energy in daily life?

- A) Operating mobile phones
- B) Heating homes and farms
- C) Glass manufacturing
- D) Iron production

10. Which of the following characteristics makes rocks a good source for nuclear energy?

- A) Low density and containing mica
- B) Containing radioactive minerals with unstable nuclei
- C) Its dark color
- D) High permeability to water

11. What role do groundwater reservoirs play in geothermal power plants?

- A) Storing solar radiation
- B) Transferring heat from hot rocks to the turbines
- C) Generating electricity directly without heat
- D) Increasing air pressure

12. Which of the following statements correctly describes the EGS project?

- A) It relies on concentrated solar power
- B) It uses deep drilling to pump water into hot rocks to generate electricity
- C) It burns coal to produce steam
- D) It relies on wind to heat the rocks

13. What is the main environmental benefit of using nuclear and geothermal energy instead of fossil fuels?

- A) Increased coal consumption
- B) Reducing greenhouse gas emissions
- C) Increased production of toxic gases
- D) Greater consumption of river water

14. Which of the following situations best illustrates a practical application based on the principle of storing energy using compressed air inside lithospheric caverns?

- A) Storing electricity in lithium batteries inside industrial buildings
- B) Using natural salt caverns to compress and release air to power generators during peak consumption
- C) Increasing wind speed around turbines to boost generation efficiency
- D) Storing natural gas in underground pipelines

15. Natural hydrogen relies on a reaction inside the rocks. What is the most logical result if the rocks have a low content of the Olivine mineral?

- A) Natural hydrogen production increases due to high rock permeability
- B) Hydrogen production stops completely because rocks become unable to absorb water
- C) The rate of natural hydrogen formation decreases due to the absence of the essential element in the **reaction**
- D) Pressure increases inside the rocks, leading to their explosion

16. Which explanation clarifies why some countries prefer storing compressed air energy inside rock caverns instead of industrial concrete structures?

- A) Rocks provide a stable temperature that reduces energy loss during storage
- B) Concrete structures are more expensive but store more energy
- C) Compressed air moves faster inside concrete compared to rocks
- D) Rocks completely prevent air loss during operation

17. If a country wanted to reduce carbon dioxide emissions in the heavy industry sector, which option based on natural hydrogen would be the most effective?

- A) Using hydrogen as fuel to burn coal at higher temperatures
- B) Replacing traditional iron and steel furnaces with hydrogen-powered furnaces to produce zero-emission iron
- C) Mixing natural hydrogen with natural gas without modifying the technology
- D) Using hydrogen only to power small vehicles

18. Which conclusion is the most accurate when comparing compressed air energy and natural hydrogen energy as resources from the lithosphere?

- A) Both require high heat from Earth's interior for their production
- B) Natural hydrogen is produced via a chemical reaction inside the rocks, while compressed air relies on the physical properties of the rocks for energy storage
- C) Compressed air is more environmentally hazardous because it releases greenhouse gases upon use
- D) Neither can be stored in the lithosphere due to poor rock permeability

Second: Essay Questions**Explain why?**

- 1. Crude oil requires fractional distillation before being used in cars and factories.**
- 2. Microorganisms help improve the quantity of petroleum extracted from rocks.**
- 3. There is a relationship between rock permeability and the quantity of petroleum that can be extracted from them.**
- 4. The difference in the usage of petroleum products is based on their boiling points after fractional distillation.**
- 5. The box containing the thermal reservoir in the previous activity remains warmer than the reference box.**
- 6. Radioactive elements like Uranium in nuclear power generation are used instead of other stable metals.**
- 7. The heat stored deep within the Earth can help warm homes and farms throughout the year.**
- 8. There is a relationship between rock density and the amount of heat that can be stored in it in geothermal energy.**

Review and modify

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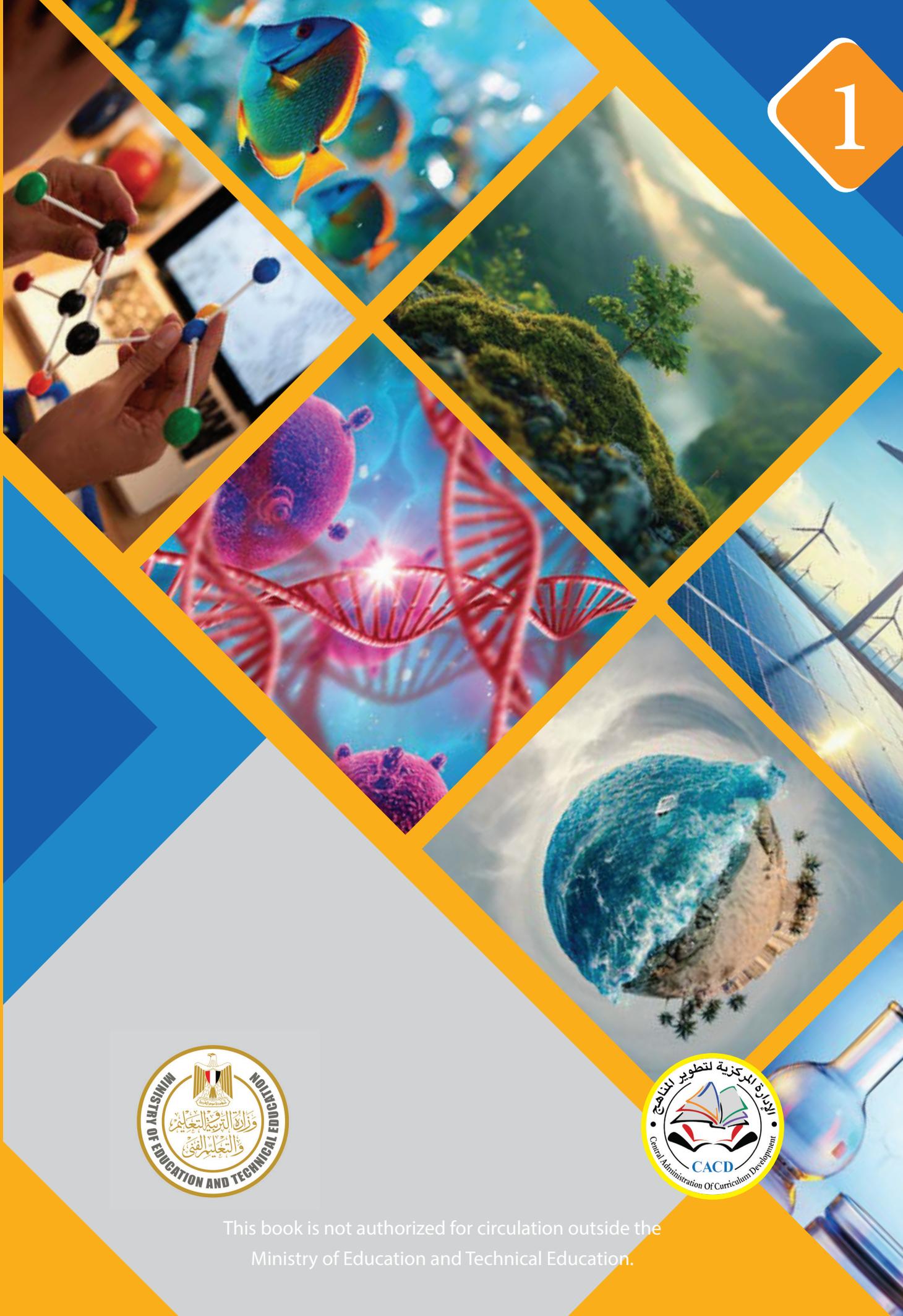
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