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INTEGRATED SCIENCE

FIRST SECONDARY GRADE

First Semester

2025-2026

INTEGRATED SCIENCE

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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.

Content

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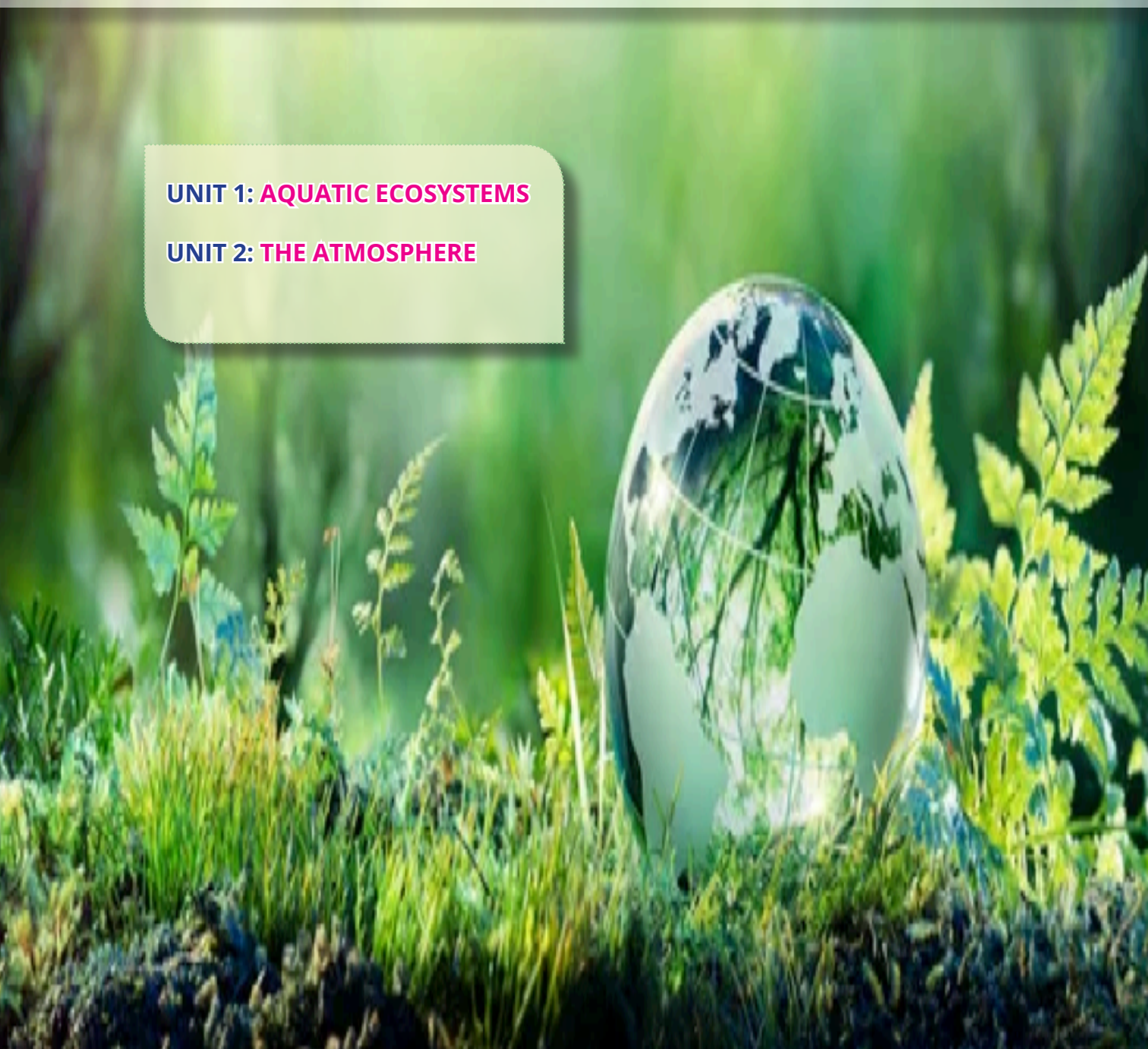
Unit One: The Aquatic Ecosystem

Unit Two: The Atmosphere

Semester One

Ecosystems and the Sustainability of Life



UNIT 1: AQUATIC ECOSYSTEMS

UNIT 2: THE ATMOSPHERE

UNIT 1: AQUATIC ECOSYSTEMS

Learning Outcomes:

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

1- Identify the hydrosphere and explain its relationships with the other systems on Earth.

2- Explain the water cycle in nature and how it contributes to environmental changes.

3- Describe the chemical reactions in the aquatic ecosystem and evaluate their effect on water quality and sustainability of marine life.

4-Interpret the role of transpiration in the water cycle and its importance to ecosystem sustainability.

5- Explain the effect of the physical properties of water - such as specific heat - and the environmental factors, including temperature and pressure, on the distribution of living organisms and sustainability of aquatic ecosystems.

6- Recognize the biological importance of water and its role in maintaining cellular structure and function.

7-Assess the biological adaptations of aquatic organisms and their contribution to ecosystem sustainability.

Included Issues:

1 . Water Pollution

2 .Climate Change

3 .Sustainability of Water Resources

4 . Conservation of Biodiversity

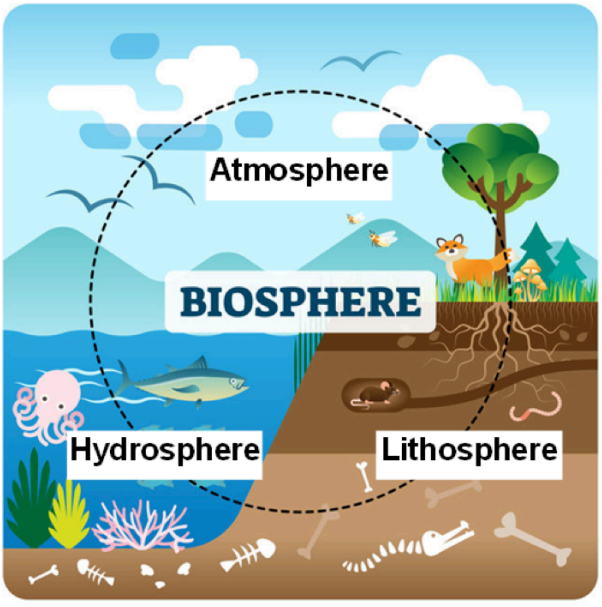
5 . Water Resources Management

6 . Sustainability Challenges in the Context of Population Growth

Unit Introduction

Get Ready!

The term environment is derived from the French word « **Environ** », that means "what surrounds us." The environment includes both biotic factors, such as humans, plants, animals, and microorganisms, and abiotic factors, light, air, water, and soil. It also involves the complex interrelationships among water, air, land, humans, and other living organisms.



The environment is a whole system whose components cannot be separated from one another. This system is made up of physical, chemical, and biological elements, and it is influenced by a variety of variables surrounding humans and other living organisms.

An ecosystem is a community of living organisms that interact with each other and with non-living components for adapting to the changing conditions. There are different types of ecosystems around us, such as aquatic ecosystems, deserts and the various kinds of forests.

The natural environment consists of four interconnected spheres:
Hydrosphere , Atmosphere , Lithosphere , and Biosphere
These four spheres are in continuous change, and they affect on and influenced by the human activities.

Think!

Why are scientists interested in looking for water on other planets? Why is water so important?

First: The Hydrosphere

1-1 Hydrosphere on Earth

The hydrosphere distinguishes Planet Earth from the other planets in the solar system. Hydrosphere refers to the water found on Earth. Water covers about 70% of Earth's surface (Figure 1 - 1). About 97% of this water exists as salty water in oceans, seas, and salt lakes. Such salty water is not suitable for human consumption or for other uses such as irrigation due to of the high content of salt. Only about 1% of Earth's water is available as fresh water in rivers, lakes, streams, reservoirs, and groundwater that can be used for human consumption. Approximately 2% of water exists in a frozen form in polar ice caps and glaciers.

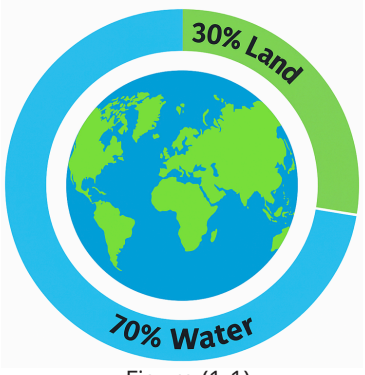


Figure (1-1)
The Ratio of the Hydrosphere to Landmass on Planet Earth

Water Cycle in Nature

Water exists on or near Earth's surface in a constant state of change between the three states of matter—solid, liquid, and gas—within the range of temperatures found on Earth. Water moves continuously from one place to another through many different pathways, forming an almost closed system known as the water cycle in nature or the hydrological cycle. This cycle describes the continuous movement of water around the planet. Water cycle is a system that can alter Earth's surface physically, chemically, and biologically.

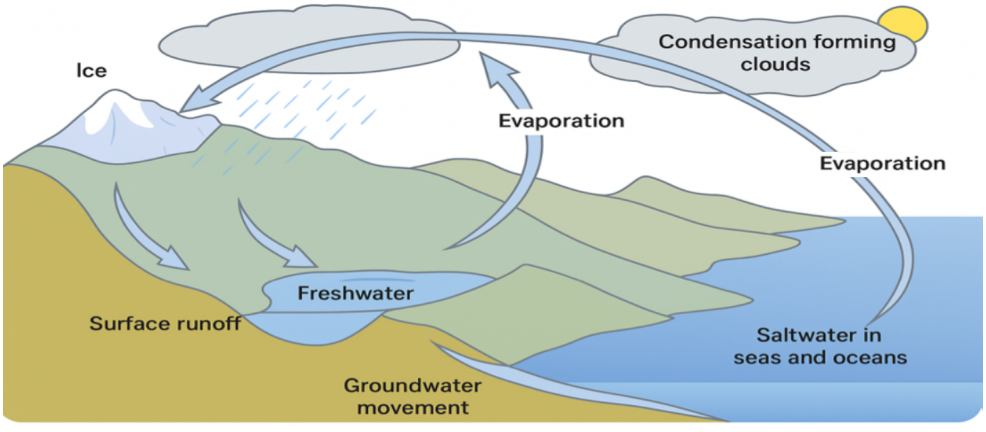


Figure (1-2) Water Cycle in Nature

Water Cycle in Nature includes many processes such as evaporation from water bodies, and some biological activities like respiration and excretion in plants and animals. It also involves transpiration in plants. The process of condensation leads to formation of cloud. The process of precipitation includes rainfall and snowfall. Another important process is the infiltration of water through the pores of soil and sedimentary rocks, leading to the formation of groundwater (Figure 1 - 2).

Transpiration is the process by which plants release excess water in the form of water vapor from the plant surfaces exposed to air. Most transpiration occurs through microscopic openings found on the surfaces of leaves and green stems, called stomata. Transpiration helps in decreasing the temperature of the plant and create a pulling force that draws water and minerals upward from roots to the upper parts of the plant through xylem tissue.

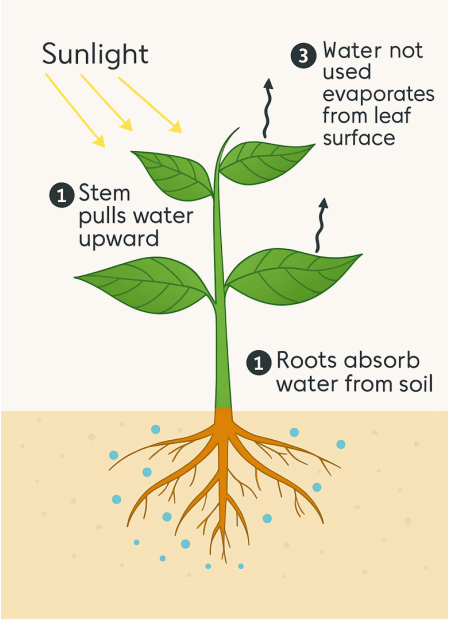


Figure (1-3) : The Plant as Part of Water Cycle in Nature

In excretion, living organisms eliminate the wasts resulting from metabolic activities, such as carbon dioxide, water vapor, and nitrogenous wastes (including ammonia, urea, and uric acid).

Activity **Using different knowledge sources , search for:**

1- The tools and measurements used by meteorologists to measure the annual rainfall over a specific area of Earth's surface.

2- How do scientists predict future change in the water cycle on Earth?

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) The continuous change between the states of matter on Earth's surface through an almost closed system is known as .... cycle.

a) Nitrogen b) Carbon

c) Oxygen d) Water

(2) The percentage of Earth's surface covered with water is .....

a) 1% b) 3%

c) 70% d) 30%

(3) Which process of the following if stopped, could directly disturb the balance of water cycle on Earth's surface and in the atmosphere?

a) Surface runoff b) Evaporation

c) Infiltration into soil d) Transpiration

(4) An increase in the rate of plant transpiration can indirectly affect the water cycle in nature through ....

a) Decreasing rainfall

b) Increasing water vapor in the atmosphere

c) Reducing evaporation from water bodies

d) Fixing carbon dioxide in leaves

Second: Essay Questions

(5) What biological processes contribute to the water cycle in nature?

(6) Why is the water cycle in nature considered an almost closed system?

1-2 Chemical Properties of Water

Water has unique properties that support life. It can dissolve many chemicals. All cells in living organisms are surrounded by a membrane called the plasma membrane (cell membrane), through which water passes into the living cell, carrying the substances needed by the cell. Water also passes from inside to outside through the same membrane, carrying wastes away.

Chemical Composition of Water:

Properties of water can be best understood by studying the structure of water molecule. A water molecule is formed binding one oxygen atom with two hydrogen atoms. Oxygen represents 88.89% of the molecular mass of water, while hydrogen represents just 11.11%. The two hydrogen atoms are bonded to the oxygen atom by two single covalent bonds, having an angle of approximately 104.5° between them. The covalent bond is a type of chemical bonds between two atoms in which each atom shares one or more electrons.

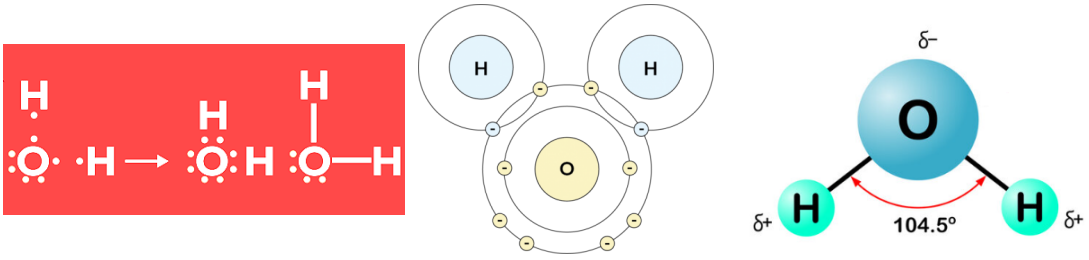


Figure (1-4) structure of water molecule

Water does not exist in its pure form on Earth, as it contains many ions and dissolved chemicals that react with it in different ways. Below, we will go through some main properties of water.

➲ Polarity of Water:

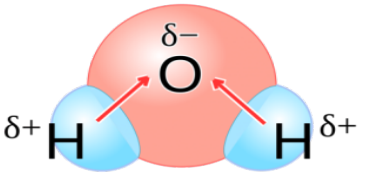


Figure (1-5) Polarity of water molecu

Oxygen atom has a higher electronegativity than hydrogen atom. Electronegativity is defined as a measure of an atom's ability to pull the electrons of a chemical bond toward it for a longer period of time. Therefore, the bond electrons are attracted to the oxygen atom that has a higher electronegativity, forming a partial negative charge on the oxygen atom and

a partial positive charge on the hydrogen atom that has a lower. electronegativity. This is known as polarity of water molecule.

Polarity of water molecules causes them to bond with each other, or with polar covalent molecules of other substances. Such type of bonding is called hydrogen bonds.

The hydrogen bond between water molecules is defined as an electrostatic attraction between the partially negative (δ-) oxygen atom of a water molecule and the partially positive (δ+) hydrogen atom in a neighboring water molecule.

Hydrogen bonds enable water to dissolve many salts and break them down into hydrated ions.

Each molecule of liquid water can be surrounded by up to four hydrogen bonds with neighboring water molecules, resulting in a network of hydrogen bonds. This network gives water many of its unique properties. For example, the ability of water molecules to form hydrogen bonds among them is a main reason for the high boiling point of pure water compared to compounds of a similar structure, such as hydrogen sulfide.

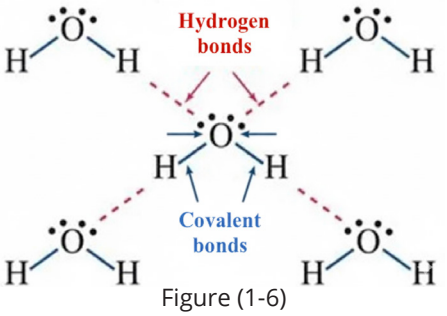


Figure (1-6)
Hydrogen bonds between water molecules

It is expected that the higher the molecular mass of the compound, the higher the boiling point. Although the molecular mass of water is less than that of hydrogen sulfide, the boiling point of pure water under normal atmospheric pressure reaches 100°C, while the boiling point of hydrogen sulfide is equivalent to (- 61°C).

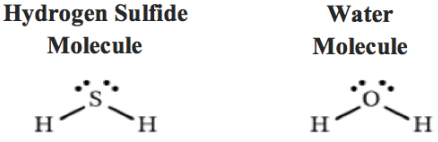


Figure (1-7) Water molecule and Hydrohen sulfide molecule

➲ Water as a Universal Solvent

Water is referred to as a universal solvent for most substances; it is capable to dissolve ionic compounds and other compounds with polar molecules. This is because water is a polar compound that can easily dissolve many ionic compounds and polar covalent compounds. When an ionic compound is added to water, its crystal lattice breaks down into free ions surrounded by water molecules, which prevent them from recombining. Positive ions are attracted to the negative pole of water molecules (oxygen atoms), while the negative ions are attracted to the positive pole of the water molecules (hydrogen atoms).

Practical Example:

Dissociation of Table Salt (NaCl) in Water:

When sodium chloride crystals (an ionic compound) are added to water, molecules of sodium chloride dissociate into (Na^+)ions and (Cl^-) ions. Water molecules surround the ions, as shown in Figure (1-8). Sodium ion, which is positively charged, is surrounded by the partially-negative charged oxygen atoms in the neighbor water molecules. Meanwhile, chloride ion, which is negatively charged, is surrounded by the partially-positive charged hydrogen atoms in the neighbor water molecules. The salt ions remain in the solution without bonding to water ions. So, dissolution of sodium chloride in water is not considered as a hydrolysis process because the ions resulting from the salt dissociation do not react with water to form acids or bases.

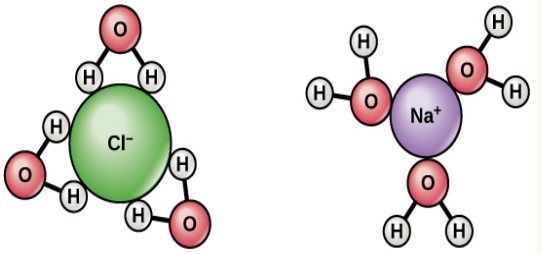


Figure (1-8) sodium and chloride ions in water

$$NaCl_{(s)} \xrightarrow{H_2O} Cl^-_{(aq)} + Na^+_{(aq)}$$

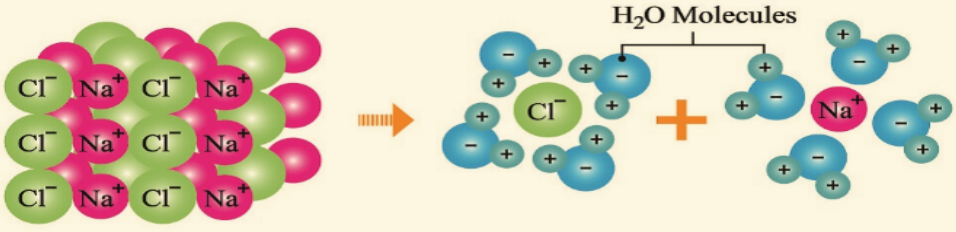


Figure (1-9) Dissociation of sodium chloride salt in water

➲ Ionic Equilibrium of Water:

Pure water is slightly ionized, where some of its molecules dissociate to form hydrogen ions (H^+) that cause acidity and hydroxide ions (OH^-) that cause basicity, in equal concentrations, making pure water neutral.

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

➲ Hydrolysis of Salts :

Hydrolysis is the reaction occurring when a solid salt dissolves in water, forming an acid and a base, one or both of which are weak.

Base + Acid ⇌ Water (liquid) + Salt (solid)

Salts are classified into three categories according to their hydrolysis:

(a) Acidic salts :

When an acidic salt dissolves in water, hydrolysis of the salt occurs, leading to a decrease in concentration of hydroxide ion (OH^-) and an increase in concentration of hydrogen ion (H^+) , making the salt solution acidic.

Example: Dissolving ammonium chloride salt (NH_4Cl) in water:

$$NH_4Cl_{(s)} + H_2O_{(l)} \longrightarrow NH_4OH_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)}$$

(b) Basic salts :

When a basic salt dissolves in water, hydrolysis of the salt occurs, leading to a decrease in concentration of hydrogen ion (H^+) and an increase in concentration of hydroxide ion (OH^-), making the salt solution basic.

Example: Dissolving sodium bicarbonate salt ($NaHCO_3$) in water:

$$NaHCO_{3(s)} + H_2O_{(l)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)} + H_2CO_{3(aq)}$$

(c) Neutral Salts :

When a neutral salt is dissolved in water, hydrolysis of the salt occurs that does not affect the equity of the concentration of hydrogen ions (H+) and hydroxide ions (OH^-), which maintain the salt solution neutral.

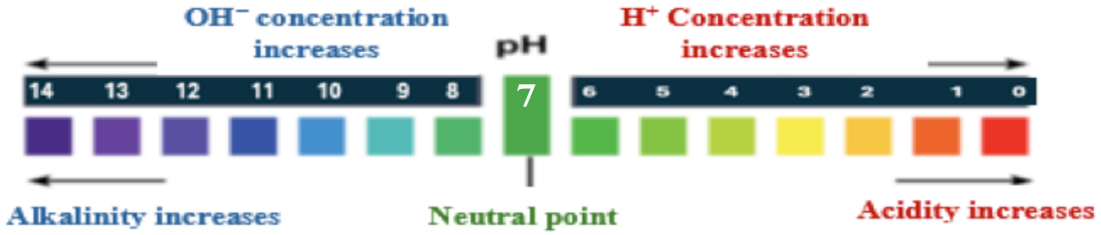
Example: Dissolving Ammonium bicarbonate salt (NH_4HCO_3) in water:

$$NH_4HCO_{3(s)} + H_2O_{(l)} \longrightarrow H_2CO_{3\,(aq)} + NH_4OH_{(aq)}$$

pH Value :

pH Scale is a quantitative scale that expresses the degree of acidity or alkalinity of liquids or solutions. It ranges from 0 to 14.

pH value expresses the relationship between the concentrations of hydrogen ions (H^+) and hydroxide ions (OH^-). This term is widely used in the fields of chemistry, biology, and agriculture.



The acid-base balance in water depends on the of the concentrations of hydrogen ions (H^+) relative to hydroxide ions (OH^-). Pure water is neutral because the concentrations of hydrogen ions and hydroxide ions are equal, and its pH value equals 7. If the concentration of H^+ increases, the aqueous solution becomes acidic, and its pH value becomes less than 7. If the concentration of OH^- increases, the aqueous solution becomes alkaline, and its pH value gets greater than 7.

Activity: Measuring pH Values of Various Water Samples:

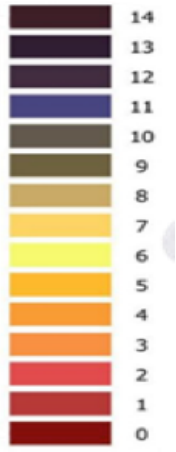
To measure pH values of different water samples (sea water, river water, well water), you can perform the following experiment:

Tools Required:

1. pH meter or pH test strips.
2. Water samples (sea water, river water, well water).
3. Sample cups.
4. Distilled water (for calibration).
5. Stirring rod.
6. Paper towels.

Figure (1-10) Measuring pH value

Experiment Procedure:



1. Calibration: Calibrate the pH meter according to the manufacturer's instructions using distilled water. Then, dry the electrode with paper towels.
2. Sample Preparation: Number the cups according to the water sample and place a small amount of each type of water in the assigned cup.
3. Testing: Immerse the calibrated pH meter electrode in the sample and record the reading once it stabilizes.
4. Repeat steps 1 to 3 with each sample.

Measuring pH Value Using Test Strips:

In case of using test strips, dip the strip into each sample for a few seconds, then compare its color with the standard chart.

pH Values of Water from Different Sources (Table for Reference Only)

Material		pH Value
Distilled water (pure water)		7
Sea water		7.5 to 8.4
Fresh water	River water	6.8 to 7.8
	Lakes water	7.3 to 8.5
Ground water		6 to 8.5
Cloud water		4.5 to 5
Mine water		3 to 4

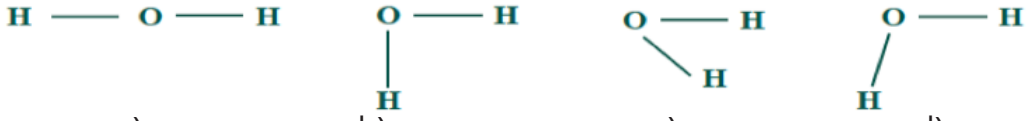
The values in the table are approximate and can vary depending on different environmental factors and human activities in that area, which affect the pH value of the water.

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) Which of the following shapes correctly represents the structure of water molecule and the angle between the two covalent bonds?

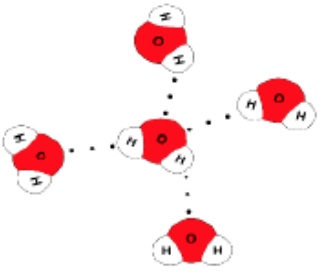


a) ○ b) ○ c) ○ d) ○

(2) Which choice correctly identifies the type of bonds shown in the adjacent figure?

Types of Interactions Involving Water Molecules

Test	Between Atoms Within a Water Molecule	Between Water Molecules
A	Covalent	Hydrogen
B	Covalent	Covalent
C	Hydrogen	Covalent
D	Hydrogen	Hydrogen



(3) The polarity of water molecule is due to the fact that .....

a) Oxygen atom in water molecule becomes a positive ion, and hydrogen atom becomes a negative ion.

b) Electronegativity of hydrogen is greater than electronegativity of oxygen.

c) Oxygen atom in water molecule carries a partial positive charge, and hydrogen atom carries a partial negative charge.

d) Oxygen atom in water molecule carries a partial negative charge, and hydrogen atom carries a partial positive charge.

(4) The solution resulting from the hydrolysis of ammonium chloride salt is considered acidic because .....

a) The concentration of OH^- ions in the solution is less than the concentration of H^+ ions.

b) The concentration of OH^- ions in the solution is greater than the concentration of H^+ ions.

c) The concentration of OH^- ions in the solution equals the concentration of H^+ ions.

D) The concentration of OH^- ions in the solution is less than or equal to the concentration of H^+ ions.

(5) The solution resulting from the hydrolysis of sodium bicarbonate salt is considered alkaline because.....

a) The concentration of OH^- ions in the solution is less than the concentration of H^+ ions.

b) The concentration of OH^- ions in the solution is greater than the concentration of H^+ ions.

c) The concentration of OH^- ions in the solution equals the concentration of H^+ ions.

d) The concentration of OH^- ions in the solution is less than or equal to the concentration of H^+ ions.

(6) What are the two elements that make up water molecule?

a) Carbon and hydrogen

b) Nitrogen and oxygen

c) Oxygen and hydrogen

d) Chlorine and sodium

(7) What is the mass ratio of hydrogen to oxygen, respectively, in a water molecule?

a) $\frac{1}{8}$

b) $\frac{1}{9}$

c) $\frac{2}{1}$

d) $\frac{8}{9}$

(8) Which of the following correctly describes the composition of the water molecule?

a) The percentage of hydrogen mass in the molecule is 66.67%

b) The percentage of oxygen mass in the molecule is 33.33%

c) The percentage of hydrogen mass in the molecule is 11.11%

d) The percentage of oxygen mass in the molecule is 50%

Second: Essay Questions

(9) Explain the following:

a) Water is considered a polar solvent

b) The dissolution of table salt in water

(10) What happens to the concentration of both (H^+) and (OH^-) ions during the hydrolysis of ammonium chloride?

1-3 Physical Properties of Water

Water possesses unique physical properties that distinguish it from other fluids (liquids and gases). Of these properties, a decrease in density upon freezing and a high specific heat. These properties affect many natural phenomena and the distribution of living organisms in different environments.

Have you ever wondered: Why does solid ice float on the surface of liquid water? Why does sand on the beach always feel much hotter than the ocean water? Why does water in seas and oceans remain warm even after sunset? How does temperature affect living organisms, especially marine life?

Density:

Density is the mass per unit volume of a substance at a specific temperature. Since a substance is composed of molecules, its density depends on the mass of molecules, and the intermolecular spaces between them. For pure water, the mass of 1 cm3 at 4 °C is 1 g. This means that density of water at 4 °C is $1 g/cm^3$, which is equivalent in international units to 1000 kg/m^3

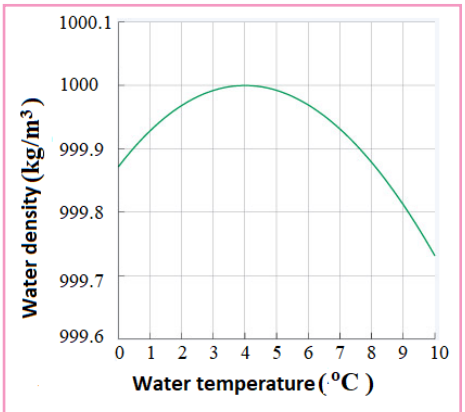


Figure (1-11) Change of Water Density with Temperature

As the temperature of water decreases below 4 °C to its freezing point, its density decreases. The ratio between the density of a specific substance and the density of pure water at 4 °C is known as the relative density of substance.

Hydrometer (Liquid Density Meter):

Density or relative density of liquids is measured with a hydrometer. Its operating principle is based on the law of buoyancy, where a body floating in different liquids shows a smaller submerged part in the more dense liquid. The hydrometer is a sealed, hollow glass vessel with a wider lower part for flotation, containing lead or mercury balls (ballast) to make it vertically stable. Its reservoir is


Figure (1-12) Hydromet

connected to a long glass rod with a small diameter, graduated with density values. The lower part of the scale indicates the highest density measures, while the upper part of the scale indicates the lowest density measures (Figure 1-12).

Activity: Measuring Density of Different Water Samples:

To measure pH values of different water samples (sea water, river water, well water), you can perform the following experiment:

Materials :

1. Hydrometer (liquid density meter).
2. A sample of the liquid you want to measure its density.
3. Test tube.

Procedure:

1. Pour a sample of the liquid into the hydrometer's test tube.
2. Carefully insert the hydrometer into the liquid, ensuring that it does not touch the tube sides .
3. Gently spin the hydrometer to remove any trapped air bubbles.
4. Allow the hydrometer to settle for a moment.

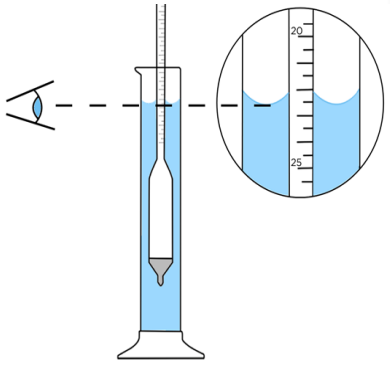


Figure (1-13) Using a Hydromet

5. Take a reading from the part of the scale that corresponds to the meniscus (the curved surface) of the liquid (Figure 1-13). This reading represents the relative density of the liquid.

Density of Ocean Water:

Density of water in oceans is affected by:

➲ Water Pressure :

In shallow water, density of water does not change significantly with increasing depth because water is almost incompressible. However, at great depths in the ocean, density of water may increase slightly. At these depths, pressure increases, and water molecules are pushed closer together. That in turn increases water density.

➲ Amount of Dissolved Salts:

The higher the salinity of water (the higher the concentration of dissolved salts), the higher the water density.

➲ Water Temperature:

As water temperature decreases, (till it reaches 4°C), its molecules get closer together, taking up less volume and increasing the water density. If the temperature drops below 4°C, the density of water decreases again. Differences in water density are one of the factors that cause ocean currents. Vertical ocean currents are usually produced due to density variations resulting from changes of temperature and salinity. These currents transport heat and salt from tropical regions to Earth's poles, nutrients from the deep ocean to the surface, and fresh water from rivers or melting glaciers to different regions around the world.

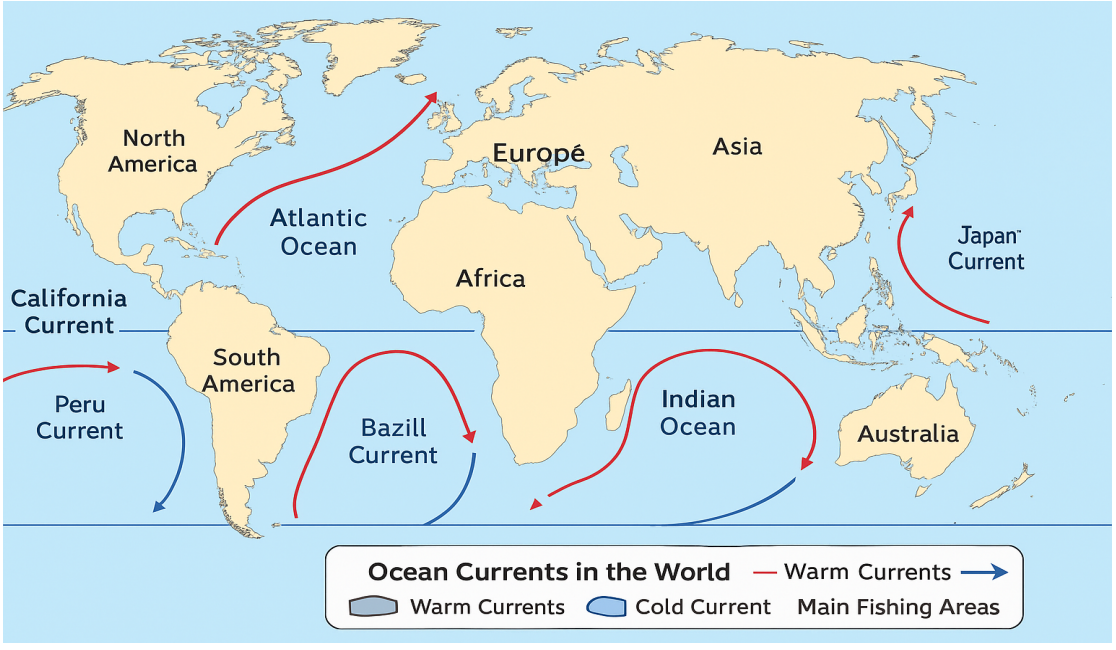


Figure (1-14) Ocean Currents

Water Density and Temperature in Polar Regions:

Generally, the liquid volume increases as its temperature rises and decreases as its temperature falls. However, water is an exception to this rule.

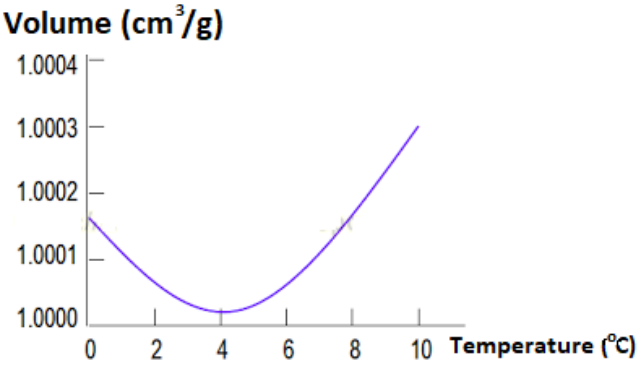


Figure (1-15) Change in Water Volume with Temperature

As the temperature of pure water increases from 0 °C to 4 °C, water contracts (its volume decreases), and its density increases. The density of water reaches its maximum value (of 1000 kg/m^3) at 4 °C. Above 4 °C, as temperature increases, water expands (its volume increases), and its density decreases.

These scientific facts help explain why water in a lake in a polar region begins to freeze at its surface instead of the bottom. As the air temperature drops from 4 °C to 0 °C, the water surface in the lake expands and becomes less dense than the water below. This means that when water freezes and turns into ice, it becomes even less dense. This is because ice molecules are spaced farther apart than in liquid water. Consequently, ice floats, creating an insulating layer that prevents the rest of water below from freezing. This allows aquatic organisms to survive in that environment, which is another reason why water is considered as an ideal habitat. (Figure 1-16)

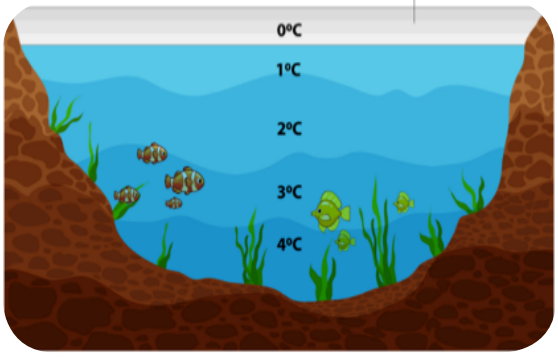


Figure (1-16) Aquatic Organisms in a Frozen Lake

Heat and Temperature:

In daily experience, some people confuse the concepts of "temperature" and "heat" . Although these concepts are related, there is a distinct difference between their meanings in physics.

A body or a system is composed of a huge number of constantly moving molecules with intermolecular spaces among them. The sum of the potential energy (due to the relative positions of these molecules) and the kinetic energy (due to their motion) is called the internal energy of the body or system.

The concept of heat refers to the energy transferred from or to a body or system when there is a difference in temperature. Heat is measured in Joules (J).

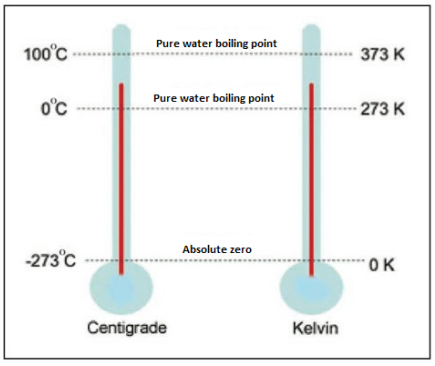


Figure (1-17)
Kelvin and Celsius Scales of Temperature

Temperature is a quantitative description of how hot or cold a body or system is. It represents the average kinetic energy of the molecules within that body or system, and its international unit is the Kelvin (K).

To find the value of temperature in Kelvin that corresponds to a value in degree Celsius, the following relation is used: $(T\ K = t°C + 273)$

Keep in mind that an increase in temperature by one degree Celsius (°C) is equivalent to an increase of one Kelvin (K).

When a body or system gains a quantity of thermal energy, the amplitude of its molecules' vibration and their kinetic energy increase. Thus, its temperature rises.

The question here is, does a unit mass (1 kg) of different substances require the same amount of heat to raise the temperature of each by one Kelvin?

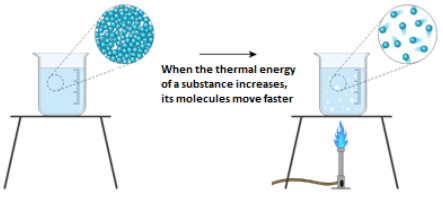


Figure (1-18)
Thermal Energy and Temperature

Specific Heat (c):

The amount of heat gained by 1 kg of the substance to raise its temperature by 1 K is called specific heat of substance, symbolized by (c). Its measuring unit is J/kg. K

The higher the specific heat of substance, the more thermal energy a given mass of that substance needs to have its temperature raised by 1 K, compared to the same mass of another substance with a lower specific heat. The following table shows the specific heat of some substances, most of which are at room temperature.

Material	Temperature	Physical state	Specific heat (c) J/kg.K
Ice	0°C	Solid	2100
Aluminum	25°C	Solid	900
Copper	25°C	Solid	390
Lead	25°C	Solid	128
Mercury	25°C	Liquid	140
Salt water	25°C	Liquid	3900
Pure water	25°C	Liquid	4200
Water vapor	100°C	Gas	2020
Air	25°C	Gas	1005

Note that specific heat depends on the type of substance, its physical state, and the presence of impurities or dissolved substances. Also, note that water has a relatively high specific heat capacity compared to the other substances.

The amount of thermal energy (Q_{th}) gained or lost by a body can be calculated using the relation:

$$Q_{th} = m\ c\ \Delta t$$

m: mass of the body in kilograms (kg)

Δt: change in the body's temperature in (°C) or (K)

c: specific heat of the substance in ($J/kg.\ °C$) or ($J/kg.\ K$)

Example: Calculate the amount of heat required to raise the temperature of 0.3 kg of copper from 20 °C to 70 °C Knowing that the specific heat of copper is =390 J/kg.K.

Solution:

$$Q_{th} = mc\ \Delta t = 0.3 \times 390 \times (70 - 20) = 5850\ J$$

Example:

A 200 g piece of aluminum at 80 °C was placed in a quantity of water at room temperature. If the final temperature of the system became 40 °C, calculate the amount of heat gained by the water. Assume the specific heat of aluminum is 900 J/kg.K and that no thermal energy was lost from the system.

Solution:

(Important note: Use international units)

According to the law of conservation of energy, the amount of thermal energy gained by the water is equal to the amount of thermal energy lost by the piece of aluminum.

Thermal energy gained by the water = Thermal energy lost by the aluminum piece

$$Q_{th} = mc\,\Delta t = 0.2 \times 900 \times (40 - 80) = -7200\ J$$

The negative sign here indicates that the piece of aluminum has lost heat, which has been gained by the water sample.

Therefore, the amount of heat transferred to the water is 7200 J.

Sea Breeze:

Water is characterized by its high specific heat due to the presence of hydrogen bonds between its molecules. This property partially contributes to the moderation of the climate near large bodies of water. The temperature of a large body of water during the summer is low compared to the temperature of the beach sand and rocks. The air above the land heats up, its density decreases, and it rises. The cooler air from over the surface of water moves toward the land to replace the rising hot air, creating a sea breeze .

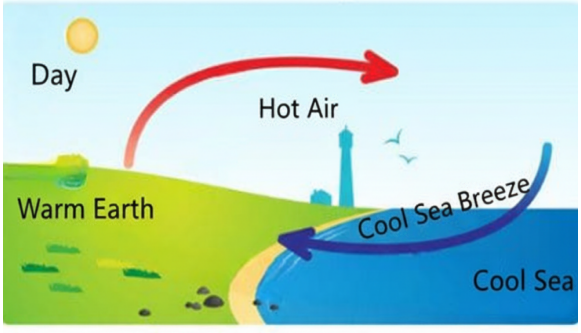


Figure (1-19) Sea Breeze

Latent Heat of Vaporization:

Latent heat of vaporization is the thermal energy absorbed by a unit mass (1 kg) of a substance to change from a liquid to a gaseous (vapor) state without a change in temperature. (Or, released when the substance changes from a gaseous (vapor) state to a liquid state without a change in temperature).

Water has a high latent heat of vaporization due to the presence of hydrogen bonds between its molecules. To vaporize water, the hydrogen bonds between its molecules must be broken down. That requires a significant amount of energy.

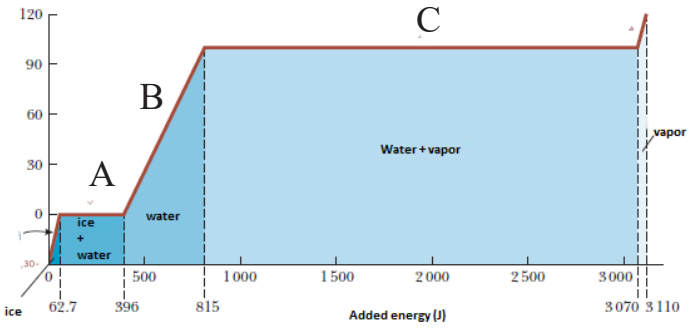


Figure (1-20) Amount of heat gained by water when heated

This property is useful for many living organisms, as they can use water evaporation as a mechanism for regulating their body temperature. When animals sweat or plants perform transpiration, the evaporating water molecules carry heat away from the body.

(Figure 1-20) shows the amount of energy needed to vaporize a mass of water (area C) compared to the amount of heat needed to raise the temperature of the same mass of water from 0 °C to 100 °C (area B).

Effect of Heat and Temperature on Marine Organisms

1. Most living organisms require a specific temperature range to survive. Abrupt changes in temperature can often be fatal, especially for very small organisms.
2. Changes in ocean temperature affect the distribution of marine organisms. Organisms living in warm surface waters may be unable to live in colder deep waters. For example, coral reefs require specific temperatures to survive. Temperature changes due to climate change may lead to their death.

3.The high specific heat of water makes oceans and lakes act as massive thermal reservoirs. During the day, when water absorbs large amounts of solar energy, its temperature is not significantly rising. This is why water maintains a relatively constant temperature. This energy is then slowly released at night, that helps maintain stable temperatures in the surrounding marine habitats. This thermal balance is very important for the sustainability of marine life.

This property helps protect marine organisms from rapid changes in temperature, especially poikilotherms (cold-blooded organisms) whose body temperature depends on the surrounding temperature. For this reason, we often find many of these organisms in the deep of seas and oceans, where the temperature is stable.

Figure (1-21) (a) Cold -blooded organisms

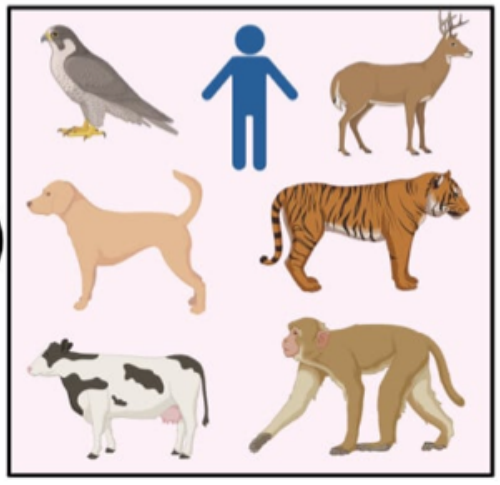


Figure (1-21) (b) Warm-blooded organisms

(Figure 1-21a) Cold-blooded organisms, (which include: most vertebrates like fish, amphibians, and reptiles, as well as all invertebrates like arthropods and mollusks,) rely on external sources like sunlight or warm environment to regulate their body temperature. Their body temperature changes with the surrounding temperature.

(Figure 1-21b) Warm-blooded organisms, such as birds and mammals, can maintain a constant internal body temperature through metabolic processes, regardless of the surrounding temperature in their environment.

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) Given that the density of water at 4°C equals 1g/cm^3, then when is raised to 8°C .....

Choice	Water volume	Water density
a	increases	increases
b	decreases	decreases
c	decreases	increases
d	increases	decreases

(2) Given that the density of water at 4°C equals 1g/cm^3, then mass of 4m^3.

a) 0.004 kg b) 1 kg

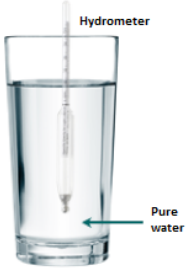
c) 4 kg d) 4000 kg

(3) Four samples of water, each is of mass 1 kg. Which sample has the greatest volume?

a) Salt water at 4°C b) Salt water at 8°C

c) Fresh water at 4°C d) Fresh water at 4°C

(4) In the opposite figure, when a large amount of salt is dissolved in pure water, the volume of the submerged part of a hydrometer placed in this water...



a) increases b) decreases

c) does not change d) cannot be determined

(5) Given that the density of water at 4°C equals 1g/cm^3, this means .....

a) The mass of 1 cm^3 of water equals 4 kg.

b) The mass of 1 cm^3 of water equals 1 g.

c) The mass of 1 m^3 of water equals 1 g.

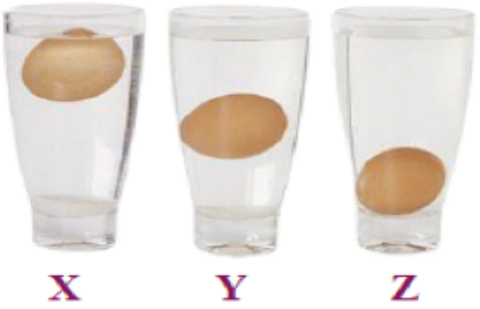
d) The mass of 1 cm^3 of water equals 1 L.

(6) The temperature at which the density of water is at its maximum value is...

a) $0^{o}C$ b) $4^{o}C$

c) $2^{o}C$ d) $6^{o}C$

(7) The figure shows three cups of water with different salinities, with densities (X, Y, and Z), all at the same temperature. An identical egg was placed in each cup.



What is the correct order of water samples according to their densities?

a) $X = Y = Z$

b) $X > Y > Z$

c) $Z > Y > X$

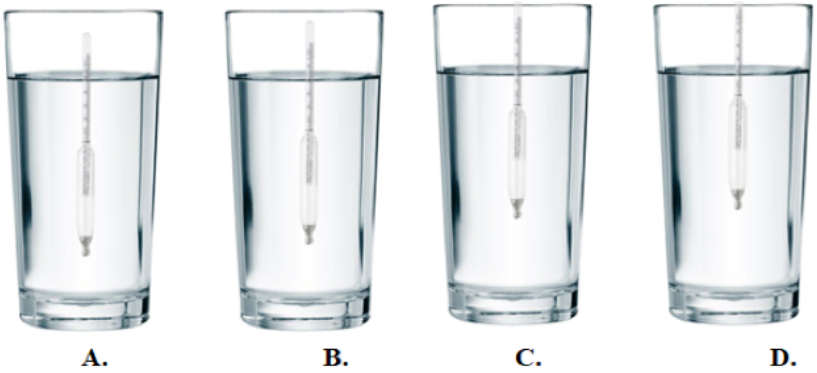
d) $Z > Y = X$

(8) Which of the following devices is used to measure the density of liquids?

a) Hydrometer b) Barometer

c) Manometer d) Thermometer

(9) Which of the cups shown in the following figures contains water with the highest density?



(10) The international unit of temperature is...

a) Celsius b) Kelvin

c) Fahrenheit d) Rankine

(11) The freezing point of pure water is equal to...

a) -273 °C b) 0 K

a) 273 °C b) 273 K

Second: Essay Questions

(12) A quantity of pure water with a mass of 1 kg and a temperature of 0 °C.

What happens to its density in each of the following cases:

First: Adding 1 kg of pure water at a temperature of 0 °C to it?

Second: Dissolving 34 g of table salt in it?

(13) Calculate the amount of heat required to raise the temperature of 0.9 kg of copper by 70 °C, given that the specific heat of copper is 390 J/kg.K.

(14) When the same amount of heat was given to four samples of equal mass but of different materials (W, X, Y and Z), the following were observed:

- Temperature of the sample of material W increased by 20 °C.
- Temperature of the sample of material X increased by 40 °C.
- Temperature of the sample of material Y increased by 60 K.
- Temperature of the sample of material Z increased by 80 K.

Which of the materials has the highest specific heat? Explain your answer.

1-4 Properties of Aqueous Solutions

You've learned that water has unique properties, such as the polarity of its molecules, the hydrogen bonds between them, its ability to dissolve other polar molecules and ionic compounds, and its high boiling point. However, the water found in natural bodies like lakes and oceans is not pure. It is mixed with various dissolved or suspended substances. These dissolved materials directly affect the properties of water, leading to changes in water currents and biodiversity.

A solution is a homogeneous mixture of a solvent and a solute. In aquatic environments, water is usually the solvent, while the solute can be a chemical substance such as salts or other materials.

Colligative Properties of Solutions:

Colligative properties are properties of solution that depend on the number of molecules or ions of a non-volatile solute in the solution, and not on the type of solute.

Colligative properties of solutions include:

Decrease in Vapor Pressure, Elevation of Boiling Point, Depression of Freezing Point , and Osmotic Pressure.

1.Decrease in the vapor pressure of a liquid:

Assume a liquid in a closed flask (a closed system). At a certain temperature, some molecules of the liquid escape from its surface and become vapor molecules, meanwhile some vapor molecules return from air to the liquid. When the rate of evaporation equals the rate of condensation, resulting in a stable amount of both the liquid and the vapor. are said to be in a state of dynamic equilibrium.

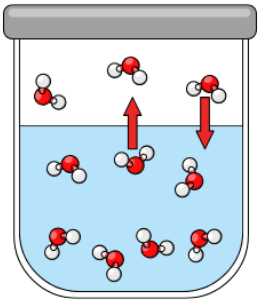


Figure (1-22) Dynamic equilibrium between a liquid and its vapor

The vapor formed above the liquid surface due to evaporation exerts pressure on the liquid surface. This is called the vapor pressure of the liquid.

In pure water, the surface molecules are able to escape and convert into vapor. Between water molecules, there are attractive forces resulting from hydrogen bonding.

When dissolving a non-volatile substance in water, some molecules or ions of the dissolved substance occupy part in the liquid surface, reducing the number of water molecules exposed to evaporation at the surface. There are also strong attractive forces between water molecules and the solute molecules or ions, besides the attractive forces among water molecules. This requires more energy to overcome such attractions and liberate water molecules. Consequently, the number of water molecules able to evaporate is reduced, and the vapor pressure of the liquid decreases. The decrease in vapor pressure is directly proportional to the number of solute molecules or ions in the solution.

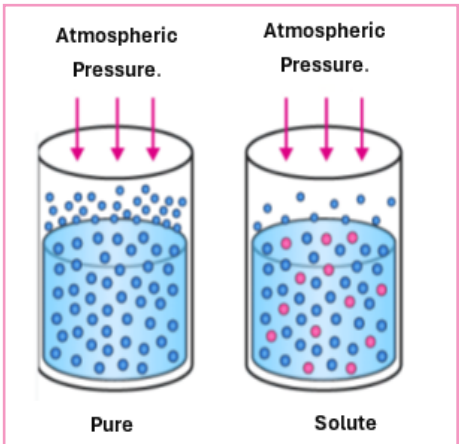
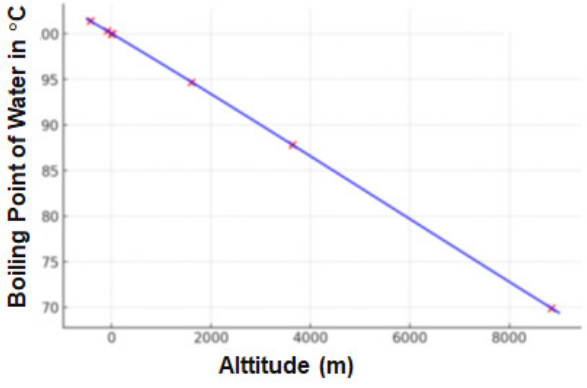


Figure 1-23) Vapor pressure of liquid decreases when a substance is dissolved in it.

2. Rising in Boiling Point,

The boiling point of a liquid is the temperature at which its vapor pressure becomes equal to the atmospheric pressure at the liquid surface. Therefore, the boiling point of a pure liquid under normal atmospheric pressure is constant, and can be used as an indicator of the purity of liquids.

The boiling point of pure water under standard atmospheric pressure is 100°C. However, the boiling point of water varies depending on the pressure exerted on its surface. An increase in external pressure raises the boiling point of water, as in a pressure cooker. On the other hand, the boiling point decreases when the air pressure acting on its surface decreases. That takes place at high-altitude locations where atmospheric pressure is lower, resulting in a decreasing the boiling point for water.



(Figure 1-24)
Decrease of water boiling point as altitude increases.

When a non-volatile substance is dissolved in water to form a solution, the vapor pressure of the solution becomes lower than that of pure water.

Consequently, the boiling point of the solution under normal atmospheric pressure gets higher than that of pure water. This is due to the attractive forces between the solute molecules or ions and the solvent (water), which require more energy to vaporize the liquid. The rising in boiling point is directly proportional to the number of dissolved molecules or ions in the solution.

3. Decrease in the freezing point of water (melting point of ice):

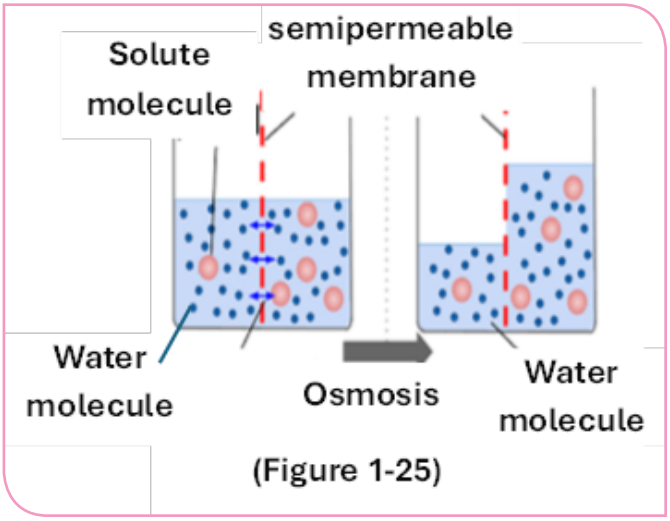
The freezing point of an aqueous solution is always lower than that of pure water under normal atmospheric pressure. This is due to the attractive forces between water molecules and the molecules or ions of the solute, which hinder the ability of water molecules to bond together and form ice crystals.

In cold countries, where temperature drops around 0°C, salt is spread on roads to prevent rainwater from freezing on the roads. That reduces car skidding and minimizing accidents.

4. Osmosis and Osmotic Pressure:

Osmosis is a phenomenon observed as water moves from a dilute solution to a concentrated solution through a semi-permeable membrane separating the two solutions.

Osmotic pressure is the pressure that arises in the solution due to the difference in solute concentrations between its parts. It causes water to move from the solution of lower concentration (lower osmotic pressure) toward the solution of higher concentration. (with higher osmotic pressure). (Figure 1 - 25).



(Figure 1-25)

1-5 Biological Importance of Water

Water is essential for life due to its unique properties, and the vital activities in all living cells depend on these properties. Cells of living organisms consist of organic molecules such as carbohydrates, proteins, lipids, and inorganic molecules, the most important of which are water and mineral salts. Water is the most abundant chemical substance in living organisms. Water is present in almost all chemical reactions occurring in vital activities. Water is found both inside and outside the cells. In mammals, water constitutes about 70% of the body mass. About 47% of this percentage is found inside cells, and about 23% is found outside cells, whether in blood plasma or other body fluids.

Water in Living Cells:

The cell is the basic unit of life. If we break down a living organism to its cellular level, the smallest independent constituent we find is the cell. The cell is the structural and functional unit of all living organisms.

Most living cells have a nucleus containing genetic material. Accordingly, living organisms are classified into: Prokaryotes, in which the genetic material is not surrounded by a nuclear membrane, and Eukaryotes, in which the genetic material is enclosed by a nuclear membrane.

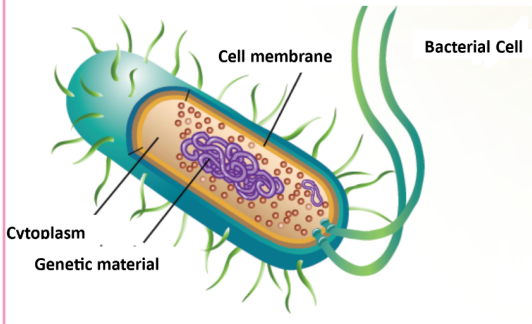
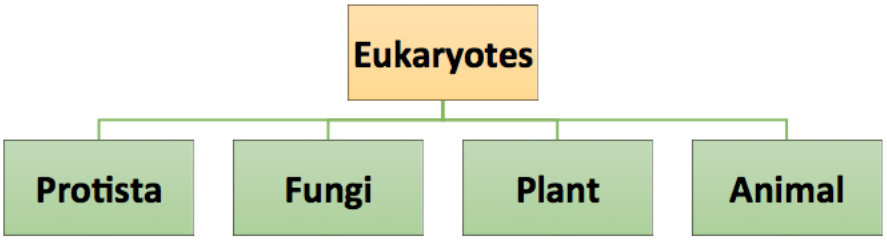


Figure (1-26) Bacterial Cell

Examples of prokaryotes include bacteria, which are unicellular organisms that have a cell wall containing a substance called peptidoglycan that gives them shape and rigidity.

The cell in eukaryotes contains a nucleus surrounded by a membrane, and specialized organelles such as mitochondria and plastids. Eukaryotes are classified into four kingdoms: Protista, fungi, plants, and animals.



- Protists are mostly unicellular or simple multicellular organisms, often aquatic, and can be autotrophic (such as golden algae) or heterotrophic (such as protozoa).
- Fungi are mostly multicellular (except yeast), have cell walls made of chitin, and are heterotrophic organisms.
- Plants are multicellular, autotrophic organisms, having cell walls made of cellulose, and can perform photosynthesis to produce food.
- Animals, are multicellular, heterotrophic organisms, having no cell walls, and they are usually capable to move. They have complex body systems to survive.

Animals are classified into invertebrates and vertebrates. Invertebrates have no backbone, such as: sponges, coelenterates (like jellyfish), worms, arthropods (like insects), mollusks (like clams), echinoderms (like starfish). Vertebrates have a backbone, such as: fish, amphibians, reptiles, birds, and mammals, including humans at the top.

Water in Living Cells:

1. Cell wall:

A thick wall made of cellulose surrounds the cell, defines its shape, encloses its components, and protects it. It is found in plant and fungal cells. Cellulose walls are characterized by being permeable to water and salts.

2. Cell membrane (Plasma Membrane):

A thin semi-permeable membrane surrounds the cell in all living organisms. It separates the cell components from the surrounding environment, consequentially, protecting them. Also, it regulates the passage of materials into and out of the cell.

3. Cytoplasm :

A gel-like substance mostly composed of water, containing some important chemicals necessary for the cell's survival.

4. Nucleus :

The nucleus is located inside the cell, and controls the cell's activities. It contains the genetic material that determines the organism's traits. It is found in both plant and animal cells. But, it is usually located at the center of the animal cell.

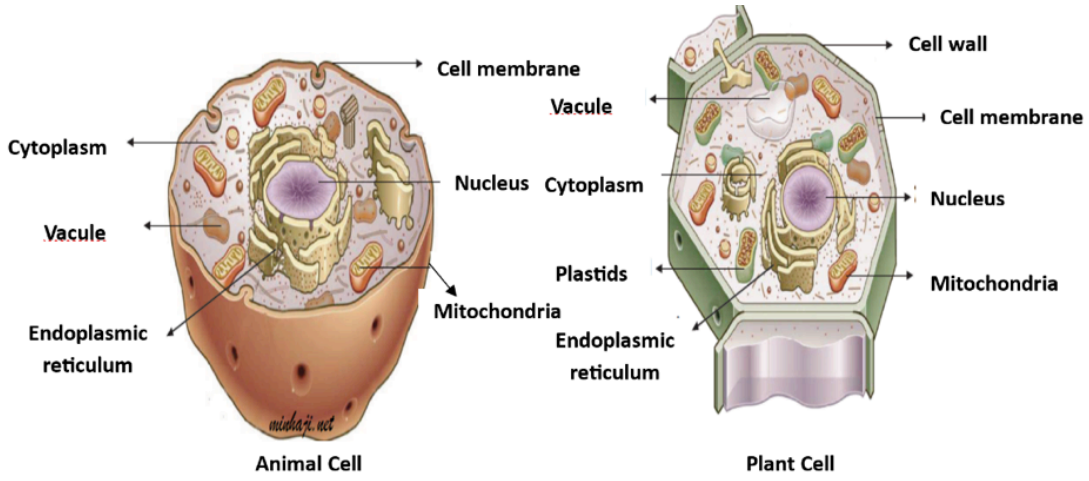


Figure (1-27) Bacterial Cell

5. Chloroplasts :

Chloroplasts are found only in plant cells. They contain chlorophyll substance and carry out photosynthesis process.

6. Vacuoles :

They store food, water, and excess salts. They are few, large and located at the center of the plant cell. Meanwhile, they are numerous and small-sized in animal cells.

7. Mitochondria :

Organelles that serve as energy-production centers in the cell.

8. Endoplasmic reticulum :

A group of membranes used to transport various materials from one place to another inside the cell.

Importance of Water to Living Organisms:

➲ Water has significant importance for living organisms that include:

1 - Water is described as a universal solvent, allowing biochemical reactions to occur by dissolving mineral salts and nutrients and carrying gases such as oxygen and carbon dioxide to facilitate their transport inside the organism and getting rid of wastes out of it.

2- The main component of cytoplasm is water. Cytoplasm enables the cell to maintain its shape and form and create an internal pressure that resists the pressure surrounding the cell. It contributes to the success of biochemical processes within the cell and allows the organelles to function properly.

3- Due to high specific heat of water, it helps living organisms maintain stable internal temperatures despite its fluctuations outside.

4- Water is considered a basic factor in maintaining internal balance and supporting the complex chemical activities of life, as it directly participates in metabolic processes, on which the organism life depends.

➲ Water and Metabolism:

Living organisms' life depends on a set of continuous biochemical reactions that take place in the presence of water inside their cells. Among these reactions are "metabolic processes."

Metabolic processes are divided into catabolic and anabolic processes. In catabolic processes, chemical bonds between the atoms of complex molecules are broken to release the energy stored in them. An example of catabolic processes is the breakdown of glucose sugar during cellular respiration into carbon dioxide and water. This process releases energy. In anabolic processes, large and complex molecules are made up of simple molecules. Such processes consume energy. Examples of anabolic processes include photosynthesis and the synthesis of proteins from amino acids.

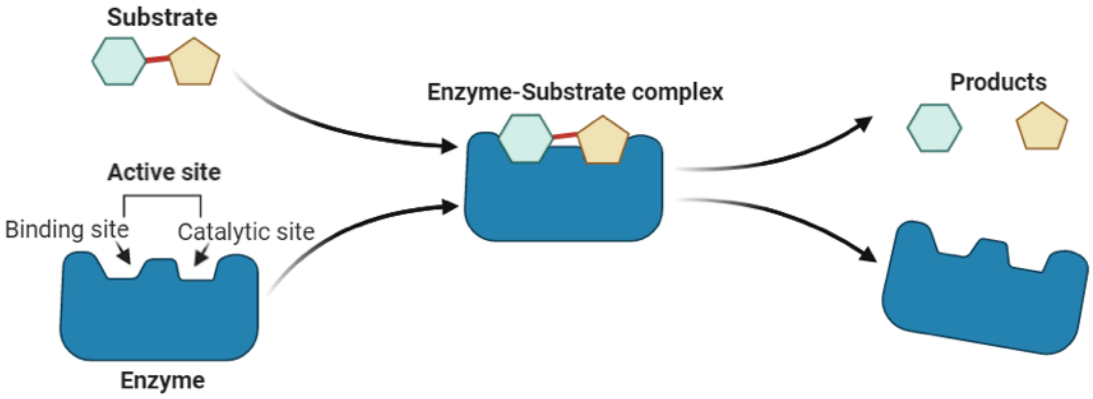


Figure (1-28) Enzyme as a catalyst

For metabolic processes to occur in the cell, they require a high activation energy to initiate the reaction. Activation energy is the minimum amount of energy needed to start a chemical reaction. Some substances, such as enzymes, work to lower the activation energy of reactions. These substances are called catalysts or activators.

Enzymes are composed of specialized protein substances that increase the speed of chemical reactions in living cells. Enzymes work through a mechanism called "lock and key," where the active site of the enzyme binds specifically to the substance it affects (the substrate), which helps reactants convert into products more efficiently. At the end of the reaction, the enzyme remains unchanged, ready to catalyze another reaction of the same type.

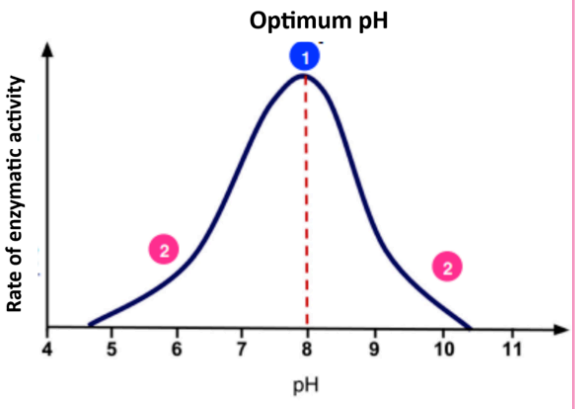


Figure (1-29) Enzyme activity curve

Each enzyme has an ideal temperature and **pH** value at which it works most effectively. If the temperature or pH value deviates higher or lower than its optimal range, the enzyme's activity gradually decreases until it stops completely.

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) If a living organism has its genetic material free in the cytoplasm and lacks mitochondria, then this organism is a/an ...

a. Prokaryote
b. Eukaryote
c. Plant
d. Animal

(2) Which of the following correctly links water and metabolic reactions?

a. Water stores energy directly
b. Water is a medium for biochemical reactions
c. Water stops enzyme activity
d. Water forms the plasma membrane

(3) Which of the following factors directly slows down enzyme activity?

a. Increasing the number of mitochondria
b. Raising the temperature above the optimal limit
c. Availability of "substrate" molecules in abundance
d. Increasing the size of the sap vacuole

(4) If the nuclear membrane is removed from a eukaryotic cell, the cell with this feature will resemble e that of ...

a. Bacteria
b. Protists
c. Fungi
d. Multicellular algae

(5) Dysfunction of mitochondria in the cell directly leads to ...

a. Cessation of protein synthesis
b. Reduction of ATP production
c. Failure of cell division
d. Cessation of transpiration maintain

Second: Essay Questions

(6) Explain: Water helps living organisms maintain a stable internal temperature despite its external outside.

1-6 Biological Adaptations of Living Organisms in Aquatic Environments

In aquatic environments, whether in deep oceans or shallow lakes, every living organism possesses a set of adaptations that help it reproduce and survive according to different conditions such as changes in temperature, increased salinity, and others. In this lesson, we will study the types of adaptations.

Adaptation refers to the behavioral or physical traits of a living organism that help it survive better in its ecosystem. Types of adaptations in living organisms are classified into:

1- Structural (Anatomical) Adaptations
2- Behavioral Adaptations
3- Physiological (Functional) Adaptations

First: Structural Adaptations:

Structural adaptations include changes in the structure and shape of parts of a living organism that help it survive in its environment.

General structural adaptations of fish include the streamlined body that reduces water resistance to the fish movement, fins that serve as organs of locomotion, scales that cover the body, and mucus to be water-resistant and reduce water resistance to the fish movement, and gills that enable them to extract dissolved oxygen from water.

Figure (1-30) Structural adaptations of fish

Bony fish have a swim bladder or air sac that helps them float in water. Fish that live deep in ocean possess very large eyes to enable them to see in the dark, and their bodies are compressed to withstand the extremely high pressure in deep waters. Examples of compressed deep-sea fish include the Icefish that lives in the cold southern oceans at

Figure (1-31) Icefish

depths reaching up to 2000 meters.

It is known that dolphins are mammals, but they differ structurally from mammals that live on land. They have a streamlined shape and fins instead of legs to help them swim, and breathing openings at the top of their heads instead of noses that allow them to breathe atmospheric air.

Figure (1-32) Structural Adaptation of Dolphin

Second: Behavioral Adaptations:

Behavioral adaptations include certain behaviors or actions, whether inherited or learned behaviors, that help living organisms face harsh conditions or better utilize available resources.

Figure (1-33) Behavioral Adaptations of Whales

For example: whales produce sounds that allow them to communicate and hunt their preys, and some fish migrate between fresh water and salt water for reproduction and survival, such as salmon.

Figure (1-34) Migration of Salmon

When salmon eggs hatch, their young spend the first period of their lives in fresh water, and the young adapt to the freshwater environment. Then juvenile salmon migrate to the sea where they spend most of their adult lives. When salmon reach sexual maturity, they begin returning again to the rivers where they were born for reproduction.

Third: Physiological (Functional) Adaptations:

Living organisms in aquatic environments develop special physiological adaptations - that is, adaptations or modifications in how they perform their vital functions that enable them to survive in their environments.

For example, some fish that live in ocean depths possess special abilities to regulate respiration under oxygen-deficient conditions, where they can slow down their metabolic rate (Metabolism) to reduce their oxygen requirements. They also have the ability to effectively regulate blood pressure, to be proportional to the high pressure exerted on them, in

addition to having strong and durable arteries and veins to withstand the pressure.

Among the famous examples of structural and physiological adaptations of deep-sea fish is the Viper Fish, which is found in the tropical regions of the major oceans and is characterized by the flexibility of its skeletal structures to withstand high pressure in the depths. It also has high concentrations of hemoglobin in its blood to adapt to the decreased oxygen levels in the depths.

Figure (1-35) Viper fish

You have learned that a solution of higher concentration has a higher osmotic pressure than a solution of lower concentration, That causes water to move to it from the solution of lower concentration. The osmotic pressure of aquatic organisms' bodies differs from that of the surrounding environment, whether it is fresh water or salt water, so these organisms adapt to the difference in osmotic pressure.

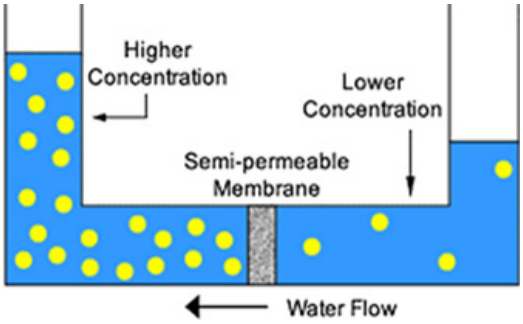


Figure (1-36) Osmotic pressure

Physiological adaptation of freshwater organisms to low osmotic pressure:

In this case, large amounts of fresh water pass into the bodies of these organisms, so the bodies of these organisms get rid of excess water to prevent their bodies from bursting.

Unicellular organisms, such as amoeba, paramecium, and euglena, possess a cellular structure called the contractile vacuole, where the cell collects excess water, then pushes it toward the cell membrane to discharge the water inside it to the outside of the cell as shown in Figure (1-37).

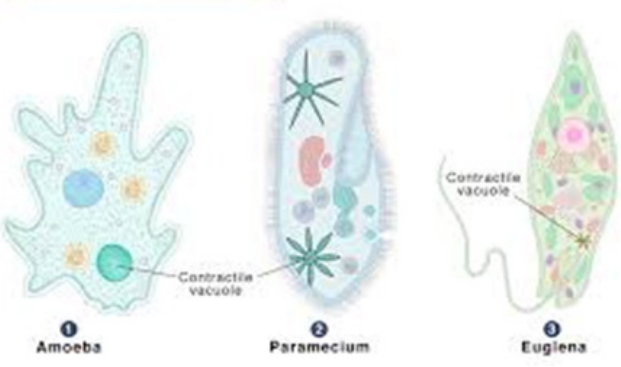


Figure (1-37) Unicellular organisms

As for multicellular organisms like fish, they get rid of excess water through the kidneys in the form of diluted urine.

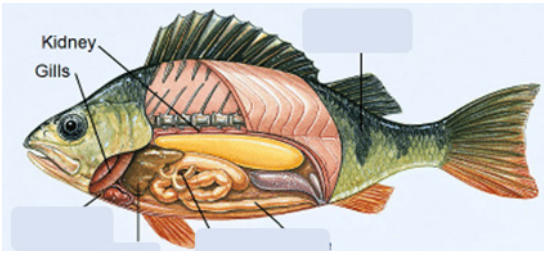


Figure (1-38) Kidney in fish

➲ Physiological adaptation of saltwater organisms to high osmotic pressure:

Most fish that live in salt water need to swallow large amounts of seawater to compensate for the water they lose through osmosis from their bodies, due to osmosis. Then, they excrete excess salts through the kidneys and specialized cells in the gills.

Sharks maintain water and salt balance inside their bodies in a different way, They retain a high concentration of urea (a nitrogenous compound excreted in the urine of many animals) in their blood, which increases their osmotic pressure to become close to the osmotic pressure of the surrounding water. This helps reduce water loss from their bodies.

Activity!

Analysis of the relationship between biological adaptations and the aquatic environment:

Research on the internet to find the biological adaptations present in the lionfish and the colorful octopus.


Colored octopus


Lionfish

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) Which of the following is considered a physiological adaptation for ocean fish?

a) Compressed body
b) Strong arteries
c) Increased blood pressure
d) Large-sized gills

(2) Which of the following adaptations enables deep-sea fish to cope with oxygen deficiency?

a) Slowing metabolic rate
b) Compressed body
c) Increased salt concentration in cells
d) Strong blood vessels

(3) What type of osmotic adaptation is found in salmon fish?

a) Behavioral adaptation
b) Physiological adaptation
c) Structural adaptation
d) Physiological and structural adaptation

(4) Among the adaptations of deep-sea fish:

Adaptation (I): Strong arteries and veins.

Adaptation (II): Special abilities to regulate respiration under oxygen-deficient conditions.

In the following table, what type of adaptation are (I) and (II) respectively?

Choice	Adaptation (I)	Adaptation (II)
a	Physiological adaptation	Structural adaptation
b	Structural adaptation	Physiological adaptation
c	Physiological adaptation	Physiological adaptation
d	Structural adaptation	Structural adaptation

(5) The figure shows the migration of salmon fish, which is considered:

a) Only a behavioral adaptation
b) Only a functional adaptation
c) Both behavioral and functional adaptation together
d) Not considered an adaptation

6- Icefish live in the cold Southern Oceans at depths of up to approximately.....

a) 2 km
b) 20 km
c) 200 km
d) 2000 km

7- The streamlined body, mucus, and scales in fish help reduce water resistance to their movement. This is considered a _____ adaptation.

a) Behavioral
b) Functional
c) Structural
d) Osmotic

8- What is the importance of the swim bladder for bony fish?

a) It helps with buoyancy.
b) It improves the fish's ability to extract oxygen.
c) It reduces water resistance to their movement.
d) It makes fish withstand high pressure in the depths.

Second: Essay Questions

9- How do deep-sea fish adapt to each of the following, and what type of adaptation is it in each case?

a) Oxygen deficiency
b) Increased pressure
c) Light deficiency

10- Physiological adaptations require structural adaptations to occur. Give one example.

11- What challenges do deep-water fish face? And how do they adapt to them structurally?

12- What is the effect of fresh water on the osmotic pressure of freshwater organisms' cells? And how do these organisms deal with this effect?

1-7 Effect of Atmospheric Air Gases on Aquatic Environments

In previous chapters, we studied the properties of pure water and the colligative properties of solutions, and we understood their importance for biological processes within the living cell. We also discussed how aquatic organisms developed specific adaptations which enable them to adapt to these properties and ensure their survival.

In this lesson, we move on to studying the external factors that affect aquatic environments and, consequently, the living organisms that inhabit them. These factors include the effect of the dissolution of atmospheric gases in water, the penetration of light and solar radiation through water, in addition to the effect of pressure in water.

Oxygen and Carbon Dioxide in the Aquatic Environment

Rivers and seas naturally contain sufficient levels of oxygen and carbon dioxide gases necessary for the continuation of aquatic life.

➲ Sources of Oxygen in the Aquatic Environment

Atmospheric air is considered the main source of oxygen in water, where oxygen is slightly soluble. In seas and oceans, more oxygen dissolves in water as a result of waves and water currents in the ocean, which increase the rate of gas exchange between the atmosphere and water.

Figure (1-39) Waves increase the solubility of gases

In addition, phytoplankton, algae, and aquatic plants contribute to the production of oxygen in water through photosynthesis.

Dissolved oxygen in water plays a crucial role in producing the energy necessary for marine organisms to carry out various biological processes. This occurs through oxidizing glucose molecules (the main source of energy) during the process of cellular respiration, which is known as catabolism is one of the two processes of metabolism.

➲ Sources of Carbon Dioxide in the Aquatic Environment

The atmosphere is considered the main source of carbon dioxide (CO_2) in water, as carbon dioxide is exchanged between the atmosphere and water.

Marine organisms produce carbon dioxide gas that dissolves in the

surrounding water as a waste product of their metabolism (catabolism). Additionally, a quantity of the gas dissolves in the water due to human activities, such as industrial pollution and the decomposition of organic matter carried by agricultural wastewater.

Aquatic plants and most algae obtain carbon dioxide gas through a physical property called diffusion, where CO_2 gas moves from a medium with a higher concentration of the gas into living cells where the concentration is lower.

CO_2 gas is considered a key element in the formation of organic materials like carbohydrates, such as glucose, as shown by the following chemical equation:

$$6\,CO_2 + 12\,H_2O \xrightarrow[\text{Sunlight}]{\text{chlorophyll}} C_6H_{12}O_6 + 6\,H_2O + 6\,O_2\uparrow$$

Solubility of the Two Gases in Water

Solubility is the ability of a solute to dissolve in a solvent to form a homogeneous solution at a specific temperature and pressure. It can also be defined as the maximum amount of solute required in a certain volume of a solvent to form a saturated and stable solution at a specific temperature and pressure. Solubility is affected by several factors, such as temperature, pressure, and the nature of materials.

$$\text{Solubility} = \frac{\text{Mass of the dissolved gas}}{\text{Volume of the solution}}$$

The concentration of oxygen gas in the air is about 500 times higher than the concentration of carbon dioxide gas, but the solubility of oxygen gas in water is about 50 times less than the solubility of carbon dioxide gas. The solubility of both gases in salty ocean water is about 20-30% lower than their solubility in fresh water.

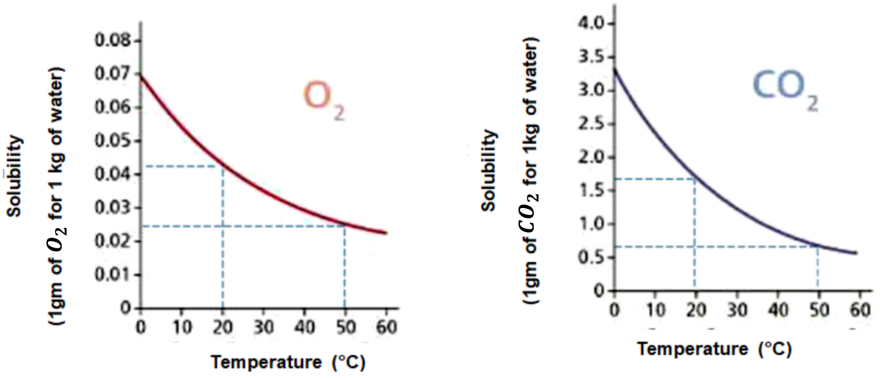


Figure (1-40) The relationship between solubility of the two gases O_2 and CO_2 in water and temperature

In general, the solubility of both gases decreases at higher temperatures. As the temperature increases, the percentage of carbon dioxide dissolved in water decreases, but at a greater rate than the percentage of dissolved oxygen in water.

The two graphs in figure (1 - 40) illustrate the relationship between the solubility of oxygen and carbon dioxide in fresh water at different temperatures under the natural composition of atmospheric air. Notice that with an increase in temperature from 20 °C to 50 °C, the solubility of CO_2 in water decreases by a greater amount than the solubility of O_2 in water.

Effect of an Increase in the Percentage of Dissolved Oxygen in Water:

1. Supporting Respiration: Aquatic organisms depend on dissolved oxygen in water for respiration. Increasing the amount of oxygen in water improves their ability to breathe.
2. Improving Metabolism: High levels of dissolved oxygen can support the metabolism of aquatic organisms and promote their growth.

Figure (1-41) Aquatic organisms depend on dissolved oxygen in water

3. Increasing Activity: Adequate levels of dissolved oxygen stimulate aquatic organisms to be more active in swimming, hunting, and reproduction.
4. Maintaining Ecosystem Balance: A healthy balance of dissolved oxygen in water is critical for maintaining a stable aquatic ecosystem by supporting diverse populations of fish, invertebrates, and plants.

Research Activity

Research various sources for the factors that lead to a lack of oxygen gas in water and the effects of a decrease in its concentration..

Effect of the Increase in CO_2 ratio in Water on Aquatic Organisms

An increase in the percentage of carbon dioxide (CO_2) in water can have several negative effects on aquatic organisms, including:

1. Acidification: When carbon dioxide gas level is high in the atmosphere, it dissolves in greater amounts in the water, leading to an increase in the formation of carbonic acid (H_2CO_3) and a decrease in the water's pH value. This acidification can be harmful to many species of aquatic organisms, especially in sensitive life stages such as the egg and larva stages.
2. Impairing Respiration: High levels of carbon dioxide in water can reduce the amount of dissolved oxygen necessary for aquatic organisms to breathe.
3. Weakening Support Structure: Support structure in living organisms is divided into two types:

Figure (1- 42) Oyster with an external skeleton

a. External Support : is the external skeleton of living organisms such as corals (from Cnidarians), oysters (from mollusks). This support provides protection and support for the animal's body. These organisms rely on the process of calcification by depositing calcium carbonate to form their shells or skeletal structures, while the external skeleton in some crustaceans, like shrimp, is made of chitin.

An increase in the percentage of carbon dioxide in the water leads to the conversion of slightly soluble calcium carbonate into calcium bicarbonate, which is soluble in water. This reduces the process of calcification, hindering these organisms' ability to build or maintain their skeletons.

b. Internal Support: is the internal skeleton of aquatic organisms such as fish and marine mammals (like dolphins and whales). The internal

skeleton may be bony, consisting primarily of calcium phosphate in addition to the protein collagen,

as in bony fish (like tilapia).

An increase in carbon dioxide affects calcium balance in the bodies of fish, which weakens their growth.

Effect of the Decrease in CO_2 ratio in Water on Aquatic Organisms:

1. Reducing Efficiency Rate of Photosynthesis and Energy Production: Aquatic plants and algae need carbon dioxide to perform photosynthesis.

   A decrease in the availability of carbon dioxide in water leads to a decrease in their sugar formation and weakening their energy production.

2. Impacting Food Chains: A decrease in carbon dioxide levels in water leads to a lower rate of sugar formation, such as glucose, which limits the energy reserves in producer organisms like phytoplankton and algae. Consequently, the amount of energy available to living organisms at higher levels of the food chain decreases.

3. Disrupting Water pH Balance: Low concentrations of carbon dioxide may lead to an increase in the pH value of water, which negatively affects sensitive species that are adapted to a specific pH range.

Exercise

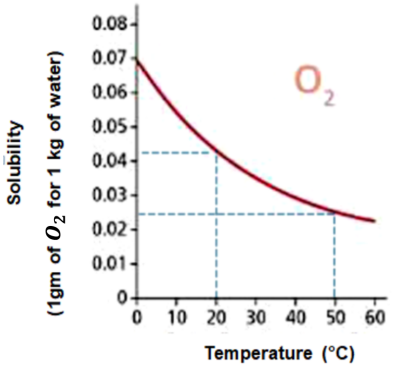
First: Objective Questions

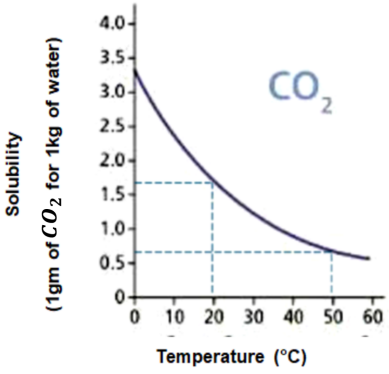
➲ Choose the correct answer:

1. All of the following are sources of dissolved carbon dioxide in water, except:

   a) The atmosphere
   b) Marine organisms
   c) Decomposition of organic materials
   d) Photosynthesis

2. Analyze the following two graphs.





From the two graphs, it is clear that by raising the temperature:

   a) The solubility of O_2 decreases at a greater rate than the decrease in the solubility of CO_2.
   b) The solubility of CO_2 decreases at a greater rate than the decrease in the solubility of O_2.
   c) The solubility of both O_2 and CO_2 decreases at the same rate.
   d) The solubility of both O_2 and CO_2 increases at the same rate.

3. An increase in the percentage of CO_2 gas in water leads to.....

   a) Increased water acidification, and increased coral calcification.
   b) Increased water acidification, and reduced coral calcification.
   c) Reduced water acidification, and increased coral calcification.
   d) Reduced water acidification, and reduced coral calcification.

4. Which of the following causes a decrease in pH value of water ?

   a) Increase in dissolved O_2 in water

   b) Increase in dissolved CO_2 in water

   c) Decrease in dissolved O_2 in water

   d) Decrease in dissolved CO_2 in water

5. When carbon dioxide gas combines with water, it produces ..... acid.

   a) H_2CO_2 b) H_2CO_3

   c) H_2CO_4 d) H_2CO_5

6. An increase in the percentage of dissolved carbon dioxide gas in water leads to converting:

   a) Calcium carbonate, which does not dissolve in water, into calcium bicarbonate, which dissolves in water.

   b) Calcium carbonate, which dissolves in water, into calcium bicarbonate, which does not dissolve in water.

   c) Calcium bicarbonate, which does not dissolve in water, into calcium carbonate, which dissolves in water.

   d) Calcium bicarbonate, which dissolves in water, into calcium carbonate, which does not dissolve in water.

Second: Essay Questions

7. Compare the causes of acidification and calcification in terms of the percentage of dissolved CO_2 gas in water.

1-8 Effect of Light and Solar Radiation on Aquatic Environments

Figure (1-43) Solar radiation through water

Imagine you are diving in the sea, and you notice how the intensity of light changes the deeper you go into the water. You might have wondered: How does this affect the living organisms that live in the depths? How does light in different water layers affect photosynthesis? And what is the role of solar radiation in maintaining the ecological balance in the oceans?

Light (visible spectrum) represents a small part of electromagnetic spectrum. Electromagnetic spectrum propagates in the form of electromagnetic waves that differ from each other in wavelength (λ) and frequency (ν). (Figure 1-44)

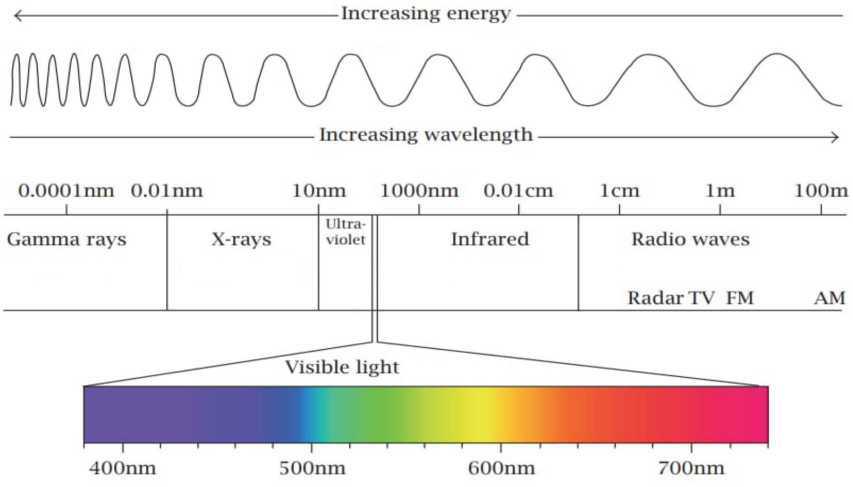


Figure (1- 44) Electromagnetic Spectrum

Visible light consists of different wavelengths known as the spectrum colors (which are in order: Red, Orange,Yellow, Green, Blue, Indigo, and Violet).

Solar Radiation Through Water:

Solar radiation is the primary source of energy on Earth, and it directly affects the different layers of water. When sunlight penetrates the surface of the water, a part of it is absorbed by the water, suspended materials, and aquatic plants, while the other part is scattered as the light penetrates to the deep.

Figure (1- 45) Penetration of Solar Radiation in Water

➲ The Photic Zones in Oceans Waters

When the sun rays fall on the ocean waters, the surface of the water reflects a part of them back into the atmosphere. The amount of energy that penetrates the water surface depends on the angle at which the sun rays strike it. The amount of light that penetrates the water surface is high when the sun rays strike it perpendicularly, whereas the amount of light that penetrates the surface decreases when the sun rays strike it at an angle.

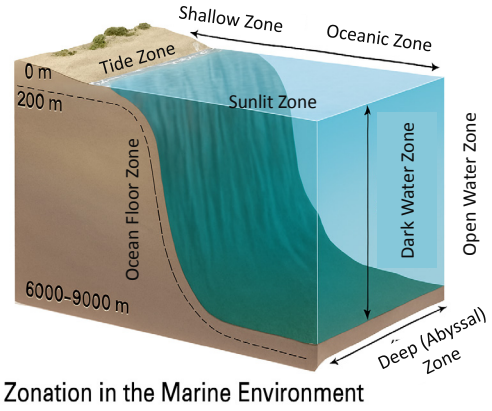


Figure (1- 46) Classification of Zones in the Marine Environment

As water depth increases, the light intensity gradually decreases. This light gradient defines different zones in the oceans, such as the sunlit (surface) zone, the twilight (mid-depth) zone, and the dark (deep) zone. Marine organisms live in each of these zones according to their ability to adapt to the amount of available light.

➲ Absorption of Solar Radiation in Water

Water absorbs almost all of the infrared energy from sunlight at a depth of 10 centimeters from the surface. At a depth of 10 meters, water absorbs more than 50% of the visible light energy. Even in clear tropical waters, only about 1% of visible light - most of it in the blue range - reaches a depth of 100 meters.

So, while the different colors of the spectrum penetrate the ocean's waters, the water absorbs the warm colors, such as red and orange (which have long wavelengths), and scatters the cooler colors (which have short wavelengths).

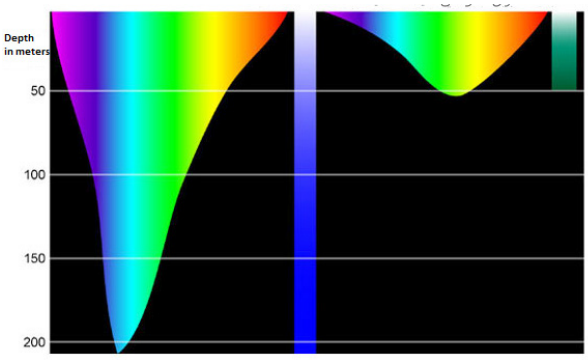


Figure (1- 47)

Figure (1 - 47) shows the difference in light penetration between shallow coastal waters and deep open ocean waters.

Effect of Solar Radiation on Aquatic Environments

Solar radiation is a vital factor in maintaining the ecological balance in aquatic environment. It not only affects photosynthesis, which is the basis of marine life, but it also directly impacts water temperature and the distribution of marine organisms.

➲ The Role of Solar Radiation in the Distribution of Marine Organisms:

Marine organisms are distributed unevenly in the water according to their needs for light and energy.

Autotrophic organisms that rely on photosynthesis - such as aquatic plants, algae, and phytoplankton - are abundant in the surface layers of the water where sufficient solar radiation is available.

In clear waters, algae and aquatic plants grow well down to a depth of 100 meters. However, they are found closer to the surface in turbid waters (which contain sediments or phytoplankton).

Coral reefs thrive in warm, shallow waters near the equator, where solar radiation is available year-round. This radiation stimulates the growth of symbiotic algae that live inside the coral tissues and provide them with food.

Effect of Solar Radiation on Water Temperatures:

Solar radiation directly affects water temperatures, which in turn influences the distribution of marine organisms. The warm water resulting from solar radiation in tropical regions attracts certain types of fish and marine animals that require specific temperatures to survive and reproduce. For example, tropical fish such as tuna and barracuda live in warm waters, while other species, such as Cod, prefer the cooler waters found in regions farther from the equator.

Effect of Changes in the Intensity of Solar Radiation:

Changes in the intensity of solar radiation due to seasonal or climate change can lead to disruptions in the ecological balance. For example, in polar regions, where solar radiation is low or nonexistent during winter, photosynthesis rates decrease significantly, which affects the availability of food for marine organisms.

Effect of Solar Radiation on Ocean Currents:

Solar radiation also contributes to the formation of ocean currents. These currents affect the distribution of marine life and make some areas rich in food resources. For example, the Gulf Stream carries warm water from the equator toward the North Atlantic Ocean, which leads to a moderate climate in regions like Western Europe and enhances marine life diversity there.

Exercise

First: Objective Questions

➲ Choose the correct answer:

1) As water depth increases, the intensity of light under the water surface...

a) gradually increases
b) gradually decreases
c) decreases then increases
d) increases then decreases

2) Which of the following statements represents the correct order of the light zones in water according to their depth from top to bottom?

a) Twilight zone – Dark zone – Sunlit zone
b) Dark zone – Sunlit zone – Twilight zone
c) Sunlit zone – Twilight zone – Dark zone
d) Twilight zone – Sunlit zone – Dark zone

3) The amount of light that penetrates the water surface is greatest when the angle between the incident sun's rays and the water surface equals...

a) 0^{o}
b) 45^{o}
c) 90^{o}
d) 120^{o}

4) Which of the following light colors is absorbed first after penetrating the surface of a body of water?

a) Red and blue
b) Orange and blue
c) Orange and red
d) Red and yellow

5) Which of the following statements is correct?

a) Water depth affects only the absorption of light.
b) Water depth affects only the intensity of light.
c) Water depth affects both the absorption and intensity of light.
d) Water depth affects neither the absorption nor the intensity of light.

6) Photosynthesis mainly occurs in the ..... layers of bodies of water.

a) Surface
b) Mid-depth
c) Deep
d) Abyssal floor

Second: Essay Questions

7) Give reasons:

a) Photosynthesis mainly occurs in the surface layers of bodies of water.

b) Solar radiation is a vital factor in maintaining the ecological balance in aquatic environments.

c) Algae and phytoplankton are abundant in the surface layers of bodies of water.

d) Coral reefs thrive in warm, shallow waters near the equator.

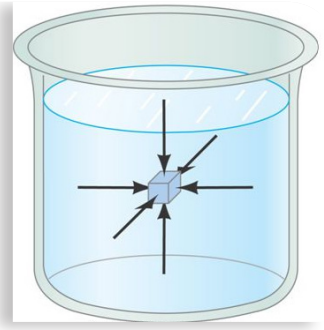
1-9: Effect of Water Pressure on Organisms

Organisms at great depths in oceans face harsh environmental conditions such as immense water pressure that require unique adaptations for survival. How does water pressure affect organisms at deep water? And how do the physiological adaptations of these organisms help them live under this immense pressure?

Fluids are substances characterized by their ability to flow, and include liquids and gases. While gases are easily compressible and occupy any space they are in, liquids resist compression and therefore maintain an approximately constant volume.

Pressure at a Point Inside a Static Liquid

A liquid has pressure at any point inside it that equals the weight of the liquid column above that point, acting on the unit of area around that point. If an object exists at that point, it is affected by a force resulting from this pressure, and the force is perpendicular to its surface.

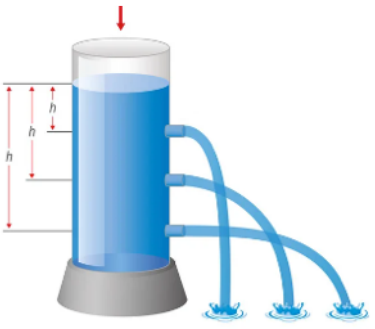


(Figure 1-48) The pressing forces acting on an object submerged in a liquid

The force acting on an object submerged in a liquid - measured in Newtons - is calculated using the formula: $F = P \times A$, where P is the pressure at that point in N/m^2 and A is the surface area exposed to that pressure in m^2.

Water Pressure

Water pressure is the pressure exerted by water at any point below the water surface. This pressure increases as the depth (h) from its surface increases, due to the increase in the weight of water acting on the unit areas at that point.



(Figure 1-49) Pressure increases with depth

The pressure inside water also increases with the increase in water density (ρ). Therefore, water pressure at a certain depth in seawater will be greater than its pressure at the same depth in a fresh water lake having lower proportion of salts and plankton.

At sea level, the pressure equals the atmospheric pressure (Pa). The standard atmospheric pressure at 0°C equals one atmosphere (1 atm.), which is equivalent to 1.013×10^5 N/m².

Water pressure increases by approximately one atmospheric pressure for every 10 meters below the surface. For example, at a depth of 100 meters, the pressure caused by water will be about 10 times the atmospheric pressure. Therefore, the total pressure at this depth equals 11 times the atmospheric pressure, where the total pressure acting at the point is:

$$P = P_a + P_{water}$$

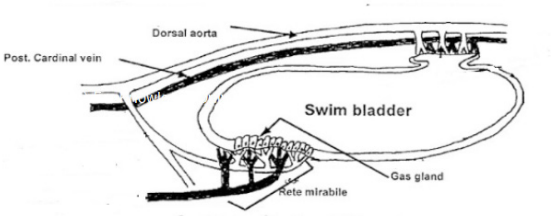
In the depths of seas, pressure is unimaginable, yet many marine organisms can adapt to the high water pressure.

Effects of Pressure on Biological Adaptations of Marine Organisms

➲ First: The Air Bladder (Swim Bladder)

Surface organisms: Organisms that live near water surface face a relatively low water pressure, and therefore their physical structure is less strong compared to organisms that live in the depths.

Organisms at intermediate depths: At depths from 200 meters to 1000 meters, living organisms are more specialized to deal with increasing pressure. For example, some fish have swim bladders filled with gas that help them control their buoyancy and balance in water, or to move between different depths during their migration between seas and rivers, such as salmon fish.



(Figure 1-50) Air Bladder

Organisms at great depths: Greater than 2000 meters, water pressure is very intense. Organisms that live in these environments are often characterized by compact body structures, protein components and internal fluids that withstand high pressure. Also, some of these organisms, such as rays do not have gas bladders to ensure they don't collapse under such high pressure.

Or they have a bladder that contains liquids instead of gases and rely on a large, oil-rich liver to increase their buoyancy and control depth.

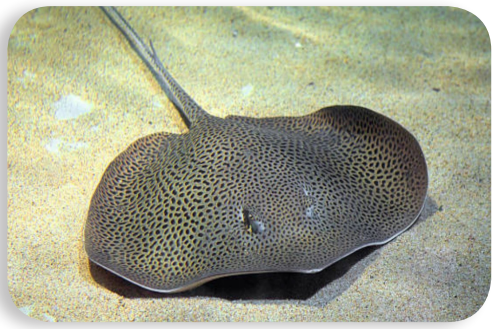
➲ Second: Bony and Cartilaginous Skeletons

Bony fish or Osteichthyes, such as tilapia and mullet are characterized by having a skeleton made of bones. It provides strong support for the fish's body and stabilizes the body under various pressures such as water movement or water pressure.

Cartilaginous fish or Chondrichthyes such as sharks and rays are a group of fish characterized by having a cartilaginous skeleton instead of a bony one. Cartilage is a more flexible and lighter tissue compared to bone, which gives cartilaginous fish a flexibility that distinguishes them from bony fish.

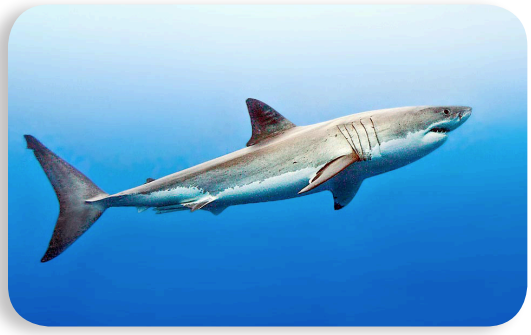
➲ Third: Cellular Membranes

Deep-sea fish have developed unique adaptations in their cell membranes to withstand the immense pressure at great depths. This is achieved by increasing the levels of unsaturated fatty acids in the composition of their cell membranes. These fatty acids help maintain the fluidity and stability of membranes under pressure, preventing cell damage.

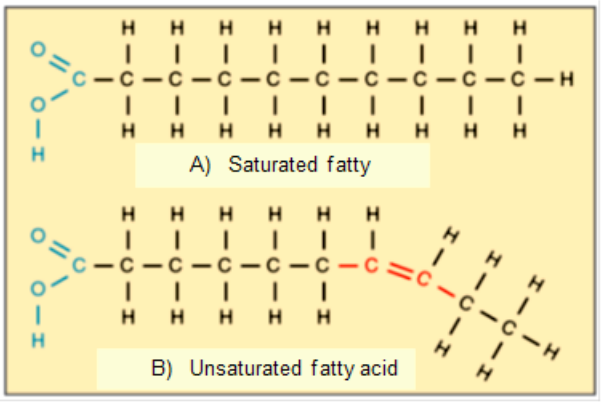


(Figure 1-51) Ray

(Figure 1-52) Bony Fish



(Figure 1-53) Shark



(Figure (1-54) Just for Knowledge Only

Exercise

First: Objective Questions

➲ Choose the correct answer:

1. A liquid has pressure at any point inside it that is equal to the weight of the liquid column above that point, and act on the unit of area around that point.
   a) density b) volume c) weight d) mass
2. Water pressure increases by approximately ..... for every 10 meters below the surface.
   a) one Pascal b) 10 Pascal
   c) one atmosphere d) 10 atmosphere
3. What is the main function of the swim bladder in fish that live at intermediate depths?
   a) Producing heat to maintain body temperature.
   b) Assisting in digestion
   c) Controlling Buoyancy
   d) Storing oxygen for respiration
4. How do fish that live at great depths adapt to high pressure?
   a) By increasing the size of their swim bladder.
   b) By decreasing their body density.
   c) By increasing their heart rate.
   d) By increasing the size of their gills.
5. What is the importance of lipoproteins in the cell membranes of marine organisms that live in the depths?
   a) They increase membrane rigidity.
   b) They increase membrane flexibility.
   c) They increase membrane permeability.
   d) They reduce membrane surface area.

Second: Essay Questions

6. Give Reasons:
   a) Ray fish has a bladder containing liquids instead of gases.
   b) Organisms that live at great depths are characterized by compact body structures, protein components and internal fluids.
7. What is the role played by the swim bladder in some bony fish?

1-10 Ecological Balance and the Human Role in Sustaining Aquatic Life

How Can Human Activities Affect Aquatic Ecosystems?

Importance of Ecological Balance in Aquatic Ecosystems

Ecological balance is a state of dynamic stability that occurs when living organisms within an ecosystem interact with the nonliving components in a way that sustains the continuity of life. This balance involves maintaining the balance of nutrients, the diversity of living organisms, and the flow of energy through food webs

1. **Nutrient Balance:** In aquatic systems such as lakes and rivers, there must be a balance in the levels of nutrients like nitrogen and phosphorus. These elements are essential for the growth of plants and algae, which form the foundation of the food chain. However, if nutrient levels increase excessively, that can lead to an abnormal increase in algal growth.
2. **Balance Among Living Organisms:** In aquatic ecosystems, each species interacts with others in multiple ways. The presence of predatory fish in the aquatic environment helps maintain the balance of prey populations, including fish and other organisms

For example, in a marine environment with various species of fish, if the number of predatory fish decreases (due to overfishing, for instance), the population of smaller fish may increase excessively. This leads to overconsumption of food resources, causing an imbalance and disturbance in the ecosystem.

3. **Energy Flow Through the Food Web:** In an aquatic ecosystem, energy flows from producers (such as algae and plants that perform photosynthesis) to consumers (such as herbivorous and predatory fish). This natural flow of energy helps regulate the populations of organisms at each level of the food chain

For example, if small fish (which feed on zooplankton) are consumed in large numbers by predatory fish, this can lead to an increase in zooplankton populations. Such a rise affects the growth of algae, and consequently, disrupts the balance of the ecosystem

Example of Ecological Balance in Aquatic Ecosystems

- **Coral Reefs and the Marine Ecosystem:**

Coral reefs provide a habitat for many marine organisms. Predatory fish help maintain the balance of coral reefs by controlling the populations of small organisms, such as sea urchins, which can destroy the reefs if their numbers increase abnormally

Impact of Human Activities on Aquatic Life:

- **Pollution:** Chemical substances such as pesticides and heavy metals that discharged into water bodies can affect water quality and harm the health of aquatic organisms.

- **Overfishing:** This can lead to a decline in the populations of certain species and disrupt ecological balance.
- **Habitat Destruction:** The destruction of natural habitats, such as coral reefs and wetlands, causes a loss of biodiversity.

Human Role in Maintaining Ecological Balance:

Humans are a significant factor in environmental changes, whether positive or negative.

Below are some roles humans can play in maintaining ecological balance:

1. Conserving Natural Resources: Humans should handle natural resources with care, using them in a sustainable manner and avoiding pollution and depletion.
2. Environmental Awareness and Education: People should learn and understand the impact of their actions on the environment and share this knowledge with others. This can be achieved through awareness campaigns, workshops, and educational curricula.
3. Sustainable Development: Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. They should strive to develop and implement clean and sustainable technologies in agriculture, industry, and urban sectors.
4. Adopting Environmentally Friendly Practices: Humans can take small steps in their daily lives to help preserve ecological balance, such as reducing water and energy consumption, sorting waste, and using public transportation or bicycles.

Research and Inquiry

Developing a Plan to Protect Aquatic Ecosystems

You can study the following example:

The Nile River is the backbone of life in Egypt, as millions rely on its water for agriculture, drinking, and fishing. However, the river faces significant challenges that threaten its sustainability, including pollution, overexploitation of water resources, and the impacts of climate change.

Decisive actions must be taken to protect this vital ecosystem and ensure its sustainability for future generations.

Design a Comprehensive Plan to Protect the Nile River as an Aquatic Ecosystem. Your plan should include specific actions and strategies that can be implemented to protect it from degradation.

Research-Guiding Questions :

1. Pollution:

- What are the primary sources of industrial pollution in the Nile River?
- How does industrial pollution impact water quality and aquatic life in the Nile River?
- What actions can be taken to reduce industrial pollution in the Nile River?
- Are there successful examples from other countries in controlling industrial pollution in rivers? How could these approaches be applied in Egypt?

2. Overexploitation of Water Resources:

- How does excessive water use affect the water levels of the Nile River?
- What modern agricultural techniques can be applied to minimize water consumption in farming?
- How do dams and water diversion projects affect the flow and ecological health of the Nile River?
- How can water use be effectively managed across agriculture, industry, and domestic sectors to ensure sustainable water resources?

3. Climate Change:

- How does climate change affect the Nile River in terms of water flow, drought, and flooding?
- What climate changes are expected in Egypt over the coming decades, and how will they affect the Nile River?
- What strategies can be adopted to adapt to the impacts of climate change on the Nile River?
- How can technology be utilized to develop early warning systems for floods and droughts in the Nile River?

4. Ecosystem Protection:

- Which plant and animal species in the Nile River are currently threatened with extinction due to environmental challenges?
- How can environmental awareness be promoted among local communities to engage in efforts to protect the Nile River?
- What are the current government policies for protecting the Nile River, and are they sufficient?
- How can local communities and non-governmental organizations be effectively involved in efforts to protect the Nile River ecosystem?

Exercise

First: Objective Questions

➲ Choose the correct answer:

1-The role of predatory fish in maintaining ecological balance in aquatic ecosystems is:

a. Reducing the number of small fish

b. Controlling the number of predatory fish

c. Reducing nutrient levels d. Reducing algae growth

2-When nutrient levels in an aquatic ecosystem are excessive, it leads to:

a. Decreased plant growth rate b. Increased biodiversity

c. Abnormal algae bloom d. Ecosystem stability

3-Which of the following is an example of the impact of overfishing on ecological balance?

a. Improved water quality

b. Decline in numbers of predatory fish

c. Increased biodiversity d. Stable prey populations

4-What is the main cause of biodiversity loss in aquatic ecosystems?

a. Sustainable fishing b. Habitat destruction

c. Natural predation d. Balanced nutrient levels

5-The role of humans in maintaining ecological balance is:

a. Ignoring resource management b. Preserving natural resources

c. Increasing pollution levels d. Overusing water resources

6-What is the primary strategy for protecting aquatic ecosystems?

a. Ignoring climate change

b. Developing comprehensive protection plans

c. Promoting industrial pollution d. Overexploiting natural resources

7-Which of the following is NOT a role that humans can play to help maintain ecological balance?

a. Preserving natural resources

b. Limiting environmental awareness programs

c. Promoting sustainable development

d. Avoiding pollution and overuse of resource

8-Sustainable development contributes to maintaining ecological balance by:

a. Increasing pollution

b. Responsibly meeting current needs

c. Ignoring the needs of future generations

d. Promoting unsustainable agricultural practices

9-Which of the following human activities positively contributes to maintaining ecological balance?

a. Overfishing marine species

b. Using clean and sustainable technologies

c. Increasing fertilizer use in aquatic environments

d. Overfishing to control fish populations

10-What is the most effective way to rise awareness about ecological balance?

a. Reducing educational programs

b. Conducting environmental awareness campaigns in schools and through media

c. Reducing the study of ecosystems in school curricula

d. Encouraging overuse of natural resources

11-Which of the following is NOT a negative impact of human activities on aquatic ecosystems?

a. Pollution from pesticides and heavy metals

b. Sustainable development programs

c. Overfishing

d. Destruction of natural habitats, such as coral reefs

12-How can humans contribute effectively to preserving natural resources?

a. By promoting pollution

b. By using resources sustainably and avoiding overexploitation

c. By destroying coral reefs for economic purposes

d. By reducing environmental awareness initiatives

13-How does energy flow in an aquatic food web?

a. From producers, such as algae, to consumers, such as herbivorous and predatory fish
b. Directly from predators to plants
c. From nitrogen to phosphorus
d. From deep-sea organisms to surface-dwelling organisms

14-One of the major consequences of not protecting aquatic ecosystems is:

a. Improved ecological balance
b. Loss of biodiversity
c. Improved water quality
d. Increased species diversity

15-What is the main purpose of maintaining ecological balance in aquatic ecosystems?

a. To increase the population of all organisms
b. To ensure the continuous flow of energy through the food web
c. To increase the production of fish and other seafood
d. To maintain the dynamic stability of the ecosystem

16-Which of the following human activities can lead to ecological imbalance in aquatic ecosystems?

a. Pollution
b. Overfishing
c. Habitat destruction
d. All of the above

17-Which of the following is not a strategy humans can use to maintain ecological balance in aquatic ecosystems?

a. Preserving natural resources
b. Promoting unsustainable development
c. Increasing environmental awareness and education
d. Participating in environmental policy initiatives

Second: Essay Questions:

➲ Explain the following:

1- The importance of nutrient balance in aquatic environments.
2- The negative impact of overfishing on the ecological balance of aquatic environments.

Unit Two: The Atmosphere

Learning Outcomes:

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

1. Explain the structure of the atmosphere, identify its main components and its effect on the Earth's surface.
2. Distinguish between different atmospheric layers and describe the characteristics of each layer.
3. Analyze the effect of physical factors in the atmosphere, such as: heat, pressure, humidity, solar radiation, and wind speed, on living organisms.
4. Analyze the impact of changes in the ozone layer on human health and vital organ functions.
5. Explain the effect of atmospheric pressure variations on living organisms.
6. Explain strategies of living organisms to adapt to environments with harsh climates.
7. Compare between types of simple plant tissues in terms of their structure and role in supporting the plant.
8. Compare between the effects of different 9. physical factors in the atmosphere on climate.
9. Explain how chemical reactions in the atmosphere affect air quality and climate change.
10. Explain chemically the formation of acid rain from nitrogen and sulfur oxides and analyze its impact on humans and plants.
11. Evaluate the role of gaseous pollutants in threatening atmospheric sustainability.
12. Illustrate how science and technology have helped reduce pollution and protect the atmosphere.
13. Suggest practical solutions to air pollution and climate change problems based on what has been learned.

Included Issues:

1. Air pollution.
2. Climate change.
3. Resource sustainability.
4. Biodiversity conservation.

2.1 Components and Layers of the Atmosphere

Get ready

Which planets in the solar system have an atmosphere? What is its thickness? What are its components?

What is expected to happen if planet Earth did not have an atmosphere surrounding it?

Figure (1–2) The Atmosphere

In the previous chapter, you learned that the natural environment on planet Earth consists of four spheres, one of which is the hydrosphere. We now move on to shed light on another of these spheres—the atmosphere. So, what is the atmosphere?

The atmosphere is a layer of gases that surrounds planet Earth. It is primarily composed of several gases, the most important of which are nitrogen, oxygen, and carbon dioxide, along with argon and trace amounts of other gases.

Atmospheric Dynamics:

The proportions of atmospheric components are not constant, but change continuously through various natural processes. Living organisms play a pivotal role in this change. In the process of respiration, living organisms consume oxygen from the atmosphere and release carbon dioxide into it. In the process of photosynthesis, plants absorb carbon dioxide from the atmospheric air and release oxygen. Geological phenomena such as volcanic eruptions can also add large amounts of gases to the atmosphere.

Importance of the Atmosphere:

The atmosphere acts as an insulating cover that protects Earth from harmful solar radiation and objects coming from space, which can cause significant damage to living organisms. The atmosphere also retains part of the solar radiation, helping to maintain the planet's surface temperature at moderate levels suitable for life. The atmosphere plays a major role in the water cycle in nature through processes of evaporation, condensation, and precipitation, allowing the distribution of fresh water across the planet's surface.

Main Chemical Components of the Atmosphere.

The atmosphere is composed of a mixture of several gases, the most important of which are:

- **Nitrogen** (N_2) Nitrogen gas makes up approximately 78% of the Earth's atmosphere .

It enters the atmosphere through the decomposition of dead plants and animals, or as part of the gases released from volcanic eruptions. Nitrogen is largely inert and does not easily react with other gases or elements. Its reactions require special conditions such as lightning or extremely high temperatures. As a result, the proportion of nitrogen oxides in the atmosphere is very low.

- **Oxygen** (O_2) Oxygen is one of the most abundant gases in Earth's atmosphere, making up about 21% of its volume. It is primarily produced by food-producing organisms during the process of photosynthesis. Oxygen,(O_2), is chemically active and essential for the respiration of living organisms. It also plays a key role in combustion processes and in many natural and industrial chemical reactions.

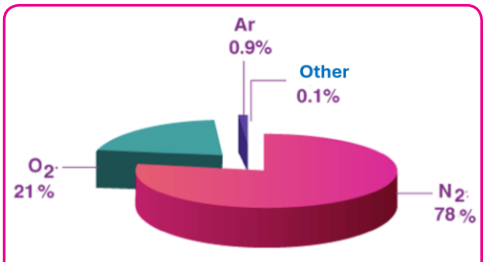


Figure (2-2) Percentage of gases in air

- **Argon** (Ar): Argon makes up about 0.93% of the Earth's atmosphere. It is one of the noble (inert) gases, which also include helium and neon.
- **Carbon Dioxide** (CO_2): Carbon dioxide makes up about 0.04% of the Earth's atmosphere. Its concentration varies significantly from one region to another across the planet. CO_2 is one of the greenhouse gases that trap heat within the Earth's atmosphere, preventing it from escaping into space—a phenomenon known as the greenhouse effect.

➲ **The atmosphere also contains other gases such as** water vapor (H_2O), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), and nitrogen dioxide (NO_2).

Layers of the Atmosphere:

The atmosphere is divided into several layers, each with its own distinct characteristics. These layers are arranged starting from the Earth's surface as follows:

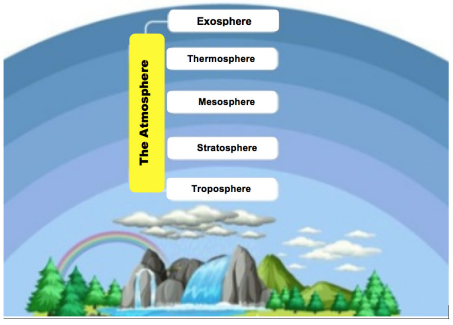


Figure (2-3) Layers of the Atmosphere

1. Troposphere

The troposphere is the closest layer of the atmosphere to Earth's surface. On average, it extends up to an altitude of about 10 km above the ground. This layer is the densest of all atmospheric layers.

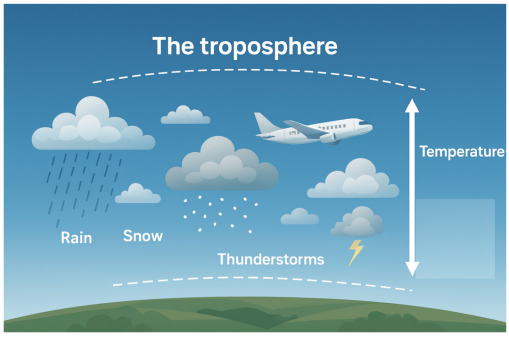


Figure (2-4) Troposphere

Most weather phenomena occur in the troposphere, including cloud formation, rainfall, wind movement, and other climate-related events.

The average temperature at Earth's surface beneath this layer is about 15°C, and it decreases with altitude at a rate of approximately 6.5°C per kilometer (or per 1000 meters).

This temperature drop is due to the decrease in atmospheric pressure with increasing altitude, which causes the air to expand. This expansion requires energy, which is drawn from the kinetic energy of air molecules, leading to cooling.

This temperature decline continues until the tropopause, which marks the upper boundary of the troposphere, located at an altitude of approximately 11 km.

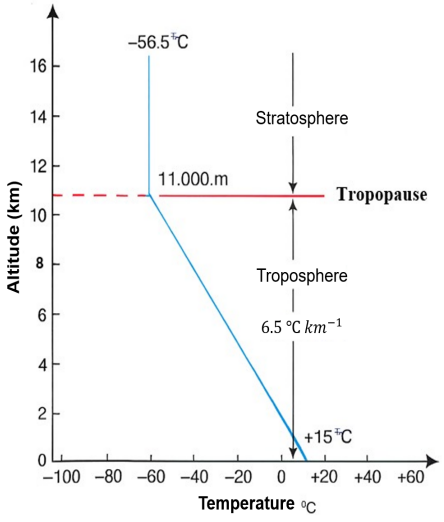


Figure (2-5) Troposphere

Tropopause

A thin layer of air located at the top of the troposphere acts as a barrier or transitional zone between the troposphere and the stratosphere.
This layer prevents the cold air in the troposphere from mixing with the warm air in the stratosphere.

Biodiversity in the Troposphere

The troposphere is home to the richest and most diverse forms of life on planet Earth. By biodiversity, we mean all living organisms present in a specific place, from the smallest microbes in soil to the largest animals and plants on land or in water.

The existence of life in the troposphere is directly related to the characteristics of this layer, where oxygen and carbon dioxide gases exist, in addition to water vapor and other gases, providing the essential components for life. Also, the appropriate temperature for biological processes to occur, in addition to suitable atmospheric pressure for most living organisms.

The interaction between these environmental conditions and the enormous diversity of living organisms makes the troposphere the most biologically active layer and the most important for sustaining life on Earth.

2. Stratosphere:

The stratosphere is the layer that lies above the troposphere, extending from an altitude of 10 km up to about 50 km above Earth's surface.

The temperature remains relatively constant in the lower stratosphere until around 20 km, where the ozone layer begins.

Within the ozone layer—which extends up to approximately 40 km—the temperature increases with altitude due to the absorption of ultraviolet (UV) radiation from sunlight by ozone gas.

Air movement in the stratosphere is mostly horizontal, which makes it a preferred layer for aircraft flight due to its stability and low turbulence

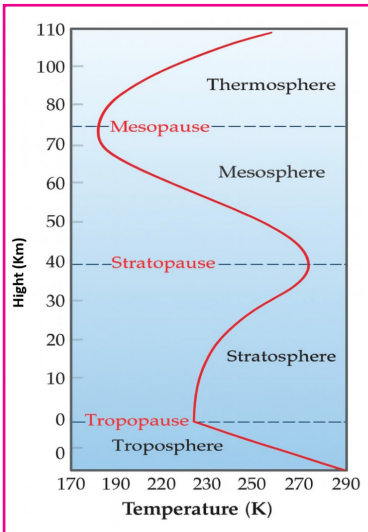


Figure (2- 6) Stratosphere

Ozone Layer

The ozone layer acts as an indispensable shield for protecting life and sustaining the biosphere on Earth. Ozone molecules (O_3) absorb most of the harmful ultraviolet (UV) radiation coming from the sun.

If large amounts of this radiation were to reach Earth's surface, it could cause severe damage to the DNA in living cells and lead to serious diseases such as skin cancer. In addition, it could disrupt and destroy both terrestrial and aquatic ecosystems.

3. Mesosphere:

The mesosphere extends from an altitude of 50 km to about 80 km above Earth's surface. It is the coldest layer of the atmosphere, with temperatures dropping to around –93°C, due to the scarcity of gas molecules capable of absorbing solar radiation.

The mesosphere plays a vital role in protecting life on Earth, as most meteors that enter the atmosphere from outer space burn up and disintegrate within this layer.

4. Thermosphere:

The thermosphere extends from 80 km above Earth's surface to an altitude of about 700 km.

In this layer, nitrogen and oxygen gases absorb solar radiation, causing temperatures to rise dramatically—reaching over 2000°C.

Ionosphere:

In the lower part of the thermosphere-from 80 km to about 550 km above Earth's surface - oxygen and nitrogen atoms absorb high-frequency solar radiation, such as X-rays and gamma rays.

This radiation causes the gas atoms to become ionized, meaning they lose or gain electrons and become electrically charged.

These lower regions of the thermosphere are referred to as the ionosphere due to the presence of a high concentration of charged gas ions.

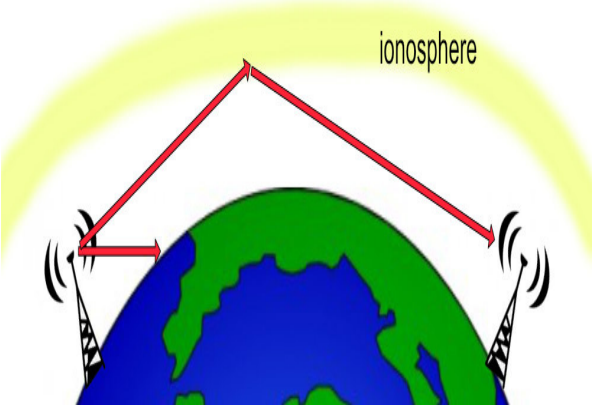


Figure (2-7) Ionosphere

The ionosphere can reflect electromagnetic waves, that is why it is used in long-distance wireless communication. Its ability to reflect radio waves allows signals to travel over vast distances without the need for satellites or cables.

Aurora :

The importance of the ionosphere is not limited to wireless communication; it is also responsible for the phenomenon known as the aurora.

Figure (2-8) Aurora

This phenomenon is observed near the Earth's north and south poles. When high-energy charged particles from the sun (part of the solar wind) reach Earth, they are influenced by the planet's magnetic field and are directed toward the poles.

There, these particles collide with ions and atoms in the ionosphere, exciting them. As these atoms return to their ground state (lower energy level), they release light photons of various wavelengths, resulting in the bright, colorful lights we see in the sky.

5. Exosphere:

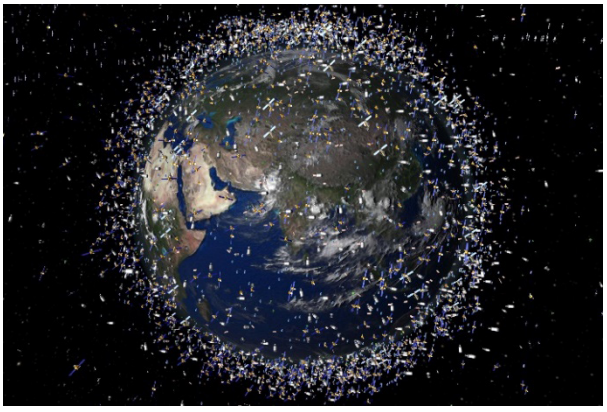


Figure (2-9) Ionosphere

The exosphere is the highest layer of Earth's atmosphere. Some scientists consider it the uppermost part of the thermosphere. It extends from an altitude of about 700 km to 1000 km above Earth's surface.

In the exosphere, atoms and molecules move over vast distances without colliding with one another. This allows them to reach extremely high speeds, enabling some particles to escape Earth's gravity and drift into outer space.

Due to its extremely low density and near-vacuum conditions, the exosphere is an ideal region for placing satellites and spacecraft, as they face virtually no resistance, allowing them to remain in orbit for long periods.

Satellites in this layer have a direct impact on our daily lives-they facilitate international communication, wireless internet, and are a core part of Global Positioning Systems (GPS).

They also provide accurate data on weather and climate, helping to predict natural disasters, monitor Earth and outer space, and enhance our understanding of the planet and the universe.

Escape Velocity :

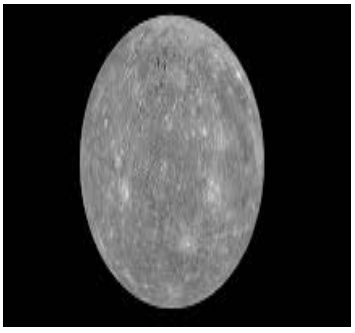


Figure (2-10) Mercury

It's fascinating to know that Mercury is the smallest planet in the solar system and has no gaseous atmosphere. As a result, an enormous amount of solar radiation reaches the planet's surface, causing its temperature to rise significantly due to the absorption of that radiation.

When the sun is no longer shining on Mercury-as the planet rotates-this radiation is emitted back into space, and the planet cools rapidly because there is no atmosphere to retain the heat.

You might be wondering why Earth retains its atmosphere, while Mercury does not have one?

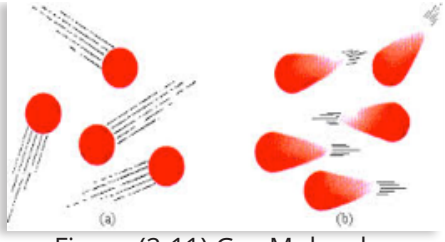


Figure (2-11) Gas Molecule Movement

Gas molecules move at extremely high speeds, depending on the mass of the gas molecule and the temperature. Naturally, the effective speed of gas molecules, known as Vrms becomes greater when the molecular mass is lower and the temperature is higher.

To escape a planet's gravity, an object-regardless of its mass-must reach a specific speed called the escape velocity (Ve), which is a fixed value for any given planet.

Figure (2-12) Escape from Gravity

For Earth, the escape velocity is approximately 11.2 km/s.

The presence of a gas around a planet is linked to the relationship between the Vrms of gas molecules and the planet's escape velocity (Ve).

If the effective speed of gas molecules (Vrms) is less than Ve, (Vrms< Ve), the gas molecules cannot escape into space, and the planet retains its atmosphere.

If the effective speed of gas molecules (Vrms) is equal to or greater than the escape velocity (Ve) of a planet, (Vrms $\geq$ Ve), then the gas molecules can escape the planet's gravity and drift into space.

As a result, that gas becomes rare or entirely absent on the surface of the planet.

Activity: Model of the Atmospheric Layers :

Objective:

Understand the structure of the atmosphere through a visual model.

Materials:

Use foam sheets to create a model of the atmospheric layers, taking into account the relative thickness of each layer.

Steps:

1. Identify the main characteristics of each layer.
2. Provide a description of how each layer affects life on Earth.

Exercise

First: Objective Questions

➲ Choose the correct answer:

1. Although nitrogen gas is highly abundant in the atmosphere, its oxides are found in very small quantities because...

   a) Nitrogen gas is produced from the decomposition of animals and plants.

   b) There is a strong triple bond between the two nitrogen atoms in its molecule, making it largely inert.

   c) It reacts with oxygen at low temperatures.

   d) It reacts with oxygen during natural phenomena such as rainfall.

1. The most abundant gas in Earth's atmosphere is .....

   a) Oxygen b) Argon

   c) Nitrogen d) Carbon dioxide

3. Oxygen gas makes up approximately ..... of the volume of atmospheric air.

   a) 0.04% b) 0.93% c) 21% d) 78%

4. The layer that absorbs short-wavelength ultraviolet (UV) radiation is .....

   a) Argon b) Ozone c) Nitrogen d) Oxygen

5. The ozone layer in the atmosphere extends approximately from an altitude of ..... above Earth's surface.

   a) 10 km – 20 km b) 10 km – 50 km

   c) 20 km – 40 km d) 20 km – 50 km

6. The thickness of the thermosphere is approximately .....

   a) 30 km b) 40 km c) 620 km d) 700 km

7. What is the temperature at the top of a mountain 2 km high, if the air temperature at ground level is 5°C?

   a) 0°C b) 1.5°C c) –1.5°C d) –8 °C

8. The layer of the atmosphere with the lowest temperature, reaching approximately –93°C, is:

a) Mesosphere
b) Exosphere
c) Stratosphere
d) Troposphere

Second: Essay Questions :

➲ Q2: Give reason:

1-The percentage of nitrogen oxides in the air is very low.

2-Carbon dioxide is important for plants

3-Air temperature decreases with altitude in the troposphere.

2-2 : Chemical Reactions in the Atmosphere

The atmosphere is a medium for multiple chemical reactions, such as Ozone formation by the effect of ultraviolet rays, the oxidation of certain gases in the air, and others. These reactions may affect air quality, climate change, and the health of humans and other living organisms.

Ultraviolet Rays:

In Chapter One, we learned about the electromagnetic spectrum emitted by the Sun, and it can propagate through space as electromagnetic waves. Each spectral region has a specific range of wavelengths (λ) and frequencies (ν). One type of electromagnetic radiation within this spectrum is ultraviolet rays.

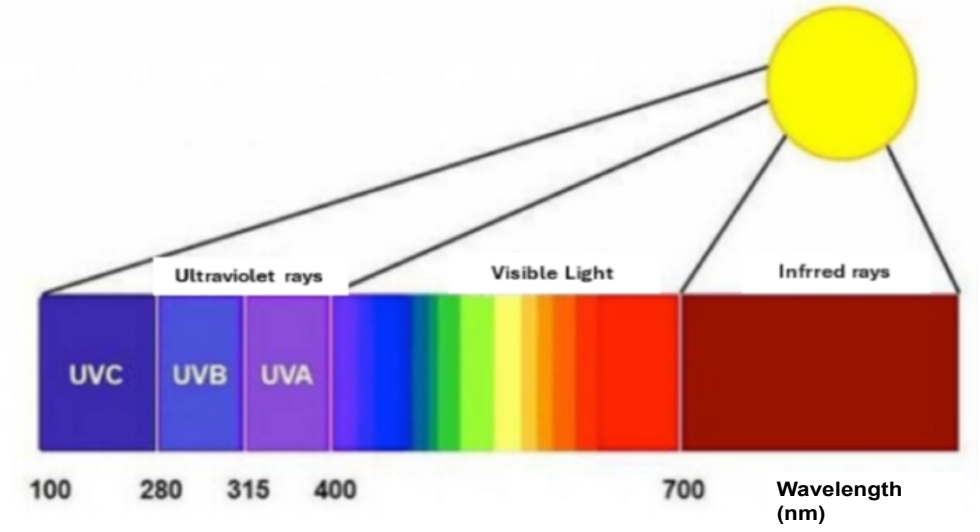


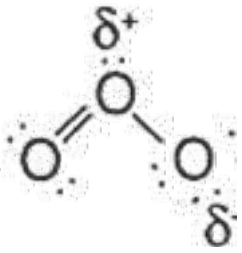
Figure (2-13) Types of Ultraviolet Radiation

Ultraviolet Rays has short wavelengths and high energy compared to visible spectrum. Ultraviolet rays can be produced by special lamps used in sterilizing surgical instruments and laboratory equipments to avoid microbial contamination. and to detect counterfeit banknotes in stores.

Figure (2-14) Verifying the Authenticity of Banknotes.

In the atmosphere, nitrogen (N_2) , oxygen (O_2) molecules and atomic oxygen absorb photons of electromagnetic spectrum with wavelengths shorter than 240 nm.

Meanwhile, the formation of ozone (O_3), causes the absorption of photons in the ultraviolet region with wavelengths ranging from 240 nm to 310 nm.

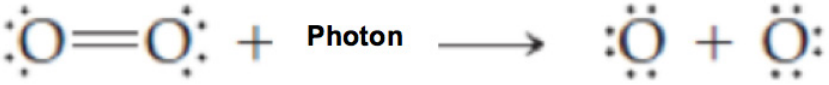


In this way, the ozone present in the stratosphere protects us from these high-energy photons.

Ozone Formation:

Ozone is a molecule made up of three oxygen atoms (O_3) bonded together. It is formed by the effect of ultraviolet (UV) rays coming from the Sun, on oxygen molecules (O_2), as follows:

1- Photodissociation occurs, in which the chemical bonds of the oxygen molecule are broken as a result of light absorption.



Ultraviolet (UV) rays with a wavelength shorter than 240 nm breaks the covalent bond in the oxygen molecule (O_2), resulting in two individual oxygen atoms (O).

$$O_2\,(gas) + \text{UV energy} \longrightarrow O\,(gas) + O\,(gas)$$

2- The individual oxygen atom (in its atomic state) combines with an oxygen molecule (O_2) to form an ozone molecule (O_3).

$$O_{2(gas)} + O_{(gas)} \rightleftharpoons O_{3(gas)}$$

Ozone Layer Depletion:

It is the gradual deterioration of the protective ozone layer in the atmosphere. This deterioration occurs mainly due to the release of chemical compounds containing chlorine and bromine, such as chlorofluorocarbons (**CFCs**), which result from industrial activities.

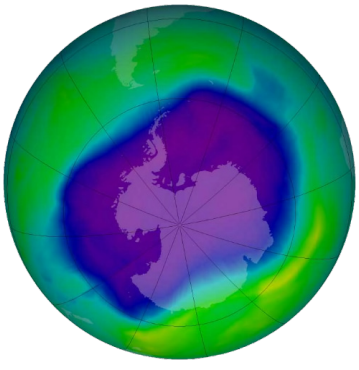


Figure (2-15) Ozone Hole

Effects of Ozone Layer Depletion on Human Health:

As a result of ozone layer depletion, a greater amount of harmful ultraviolet (UV) rays may reach the Earth's surface.

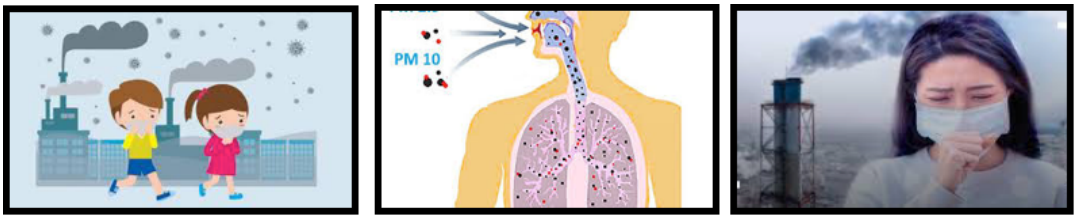


Figure (2-16) Effects of Ozone Layer Depletion on Human Health

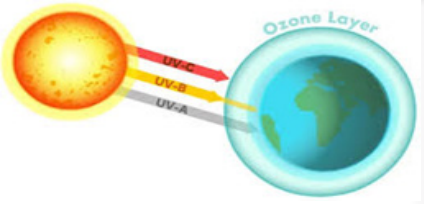
Among the effects of ultraviolet (UV) rays on human health:

- **On the Skin:** Increased exposure to ultraviolet (UV) rays leads to DNA damage in skin cells. This damage can cause genetic mutations that may result in skin cancers, such as melanoma.

The body attempts to repair this damage by activating special DNA repair enzymes; however repeated exposure to UV rays may exceed the cells' ability to repair.

- **On the Immune System:** Ultraviolet (UV) rays affects certain immune cells, such as helper T-cells, which leads to a weakened immune response and makes the body more vulnerable to diseases and infections.
- **On the Eye:** The absorption of ultraviolet (UV) rays by the eye's lens accelerates the development of cataract, reducing the transmission of light to the retina.

Enrichment Fact



Despite the challenge of ozone layer depletion, international efforts have shown remarkable success in addressing it.

The Montreal Protocol is considered a prominent example of these efforts, as it banned the production and use of many ozone-depleting chemicals.

Thanks to this global cooperation, the ozone layer has begun to recover gradually, affirming humanity's ability to tackle major environmental issues through collective action

Reducing Ozone Layer Depletion

Ozone layer depletion is a major environmental issue, and following simple actions can help address it.

These actions aim to reduce the emission of harmful chemical substances.

1. Choose Ozone-Friendly Products

Many traditional cleaning products contain chlorine and bromine compounds, whose emissions can damage the ozone layer.

It is better to look for cleaning products labeled "eco-friendly", or use natural cleaning alternatives such as vinegar and baking soda.

2. Avoid Ozone-Depleting Substances

Reducing the use of devices and materials that contain harmful compounds is essential. For example:

- **Refrigerants:** Avoid cooling devices like refrigerators and air conditioners that use CFCs (chlorofluorocarbons) in their cooling systems. Instead, choose modern appliances that use safer alternatives, such as refrigerant gas 410A.
- **Fire Extinguishers:** Avoid fire extinguishers that contain halon gas, which contains bromine - one of the most powerful ozone-depleting substances. These should be replaced with modern extinguishers that are free of this substance.

Figure (2-17)
Ozone-Friendly Refrigerant

Ozone in the Troposphere

Ozone may form in the troposphere as a result of the reaction between nitrogen oxides and hydrocarbons in the presence of sunlight.

Among the effects of its formation near Earth's surface:

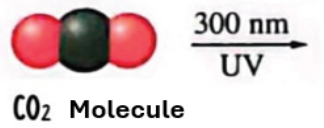
- Smog Formation: It forms when ozone combined with other pollutants in the air such as sulfur dioxide, nitrogen dioxide, and fine particles.
- Burning of Plant Leaves: This reduces their ability to carry out photosynthesis.
- Damage to Plants and Crops: and affecting their growth and quality.
- Corrosion of Materials: such as plastic and rubber.

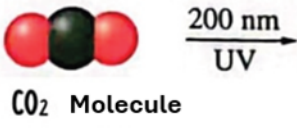
Exercise

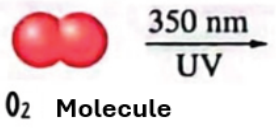
First: Objective Questions

➲ Choose the correct answer:

(1) Which of the following could represent the first step in the formation of ozone gas?

a) 

b) 

c) 

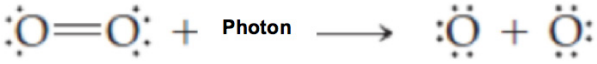
d) 

(2) Ozone can absorb photons with a wavelength equal to...

a) 200 nm b) 250 nm

c) 350 nm d) 400 nm

(3) What type of reaction is represented by the following equation?



a) Photodissociation b) Nuclear dissociation

c) Thermal dissociation d) Ionic dissociation

(4) When the bond between the two oxygen atoms in an oxygen molecule breaks due to photodissociation...

a) two oxygen ions (O^{-2}) b) two single oxygen atoms (O)

c) one oxygen atom (O) and one oxygen ion (O^{-2})

d) two single oxygen atoms (O) and two oxygen ion (O^{-2})

(5) Which of the following ultraviolet wavelengths causes photodissociation of the covalent bond in an oxygen molecule?

a) 230 nm b) 240 nm

c) 290 nm d) 305 nm

6) An ozone molecule is formed by the combination of...
   a) two oxygen molecules (O_2)
   b) two individual oxygen atoms (O)
   c) three individual oxygen atoms (O)
   d) one individual oxygen atom (O) and one oxygen molecule (O_2)
7) Smog is formed as a result of the accumulation of products from all the following reactions except...
   a) the reaction of nitrogen and atmospheric oxygen during lightning
   b) the reaction of oxygen with sulfur under suitable conditions
   c) the reaction of hydrogen with oxygen under suitable conditions
   d) the reaction of nitrogen oxides with hydrocarbons in the presence of sunlight
8) Which of the following options represents some of the health effects of ozone gas on humans?
   a) Cataracts, skin cancer, and decline in bee populations
   b) Skin cancer, weakened immunity, and destruction of plankton
   c) Reduced photosynthesis, impaired brain development, and delayed child growth
   d) Allergies, bronchitis, and cardiovascular diseases.

Second: Essay Questions

1- What is meant by ozone depletion?

2- Explain three strategies used to reduce pollution.

3- How does ozone in the troposphere negatively affect plants?

2-3 Physical factors and their effect on the atmosphere

First: Heat:

Heat is considered one of the most important climatic factors because it affects other factors such as atmospheric pressure, wind, humidity, condensation, and consequently rainfall. When the Sun's rays reach Earth's surface, both land and water, heats up more, then the heat transfers to the gaseous atmosphere surrounding Earth, causing its temperature to begin rising. The layers of the atmosphere close to the earth's surface are higher in temperature than those farther away.

? Critical Thinking

Why is the temperature in the lower part of the troposphere higher than that in the upper part?

Measuring Air Temperature:

The meteorological authorities periodically measure the air temperature and compare it with the temperature in other regions, as well as with the temperatures recorded in previous years during the same climate season. These authorities use one of the following scales:

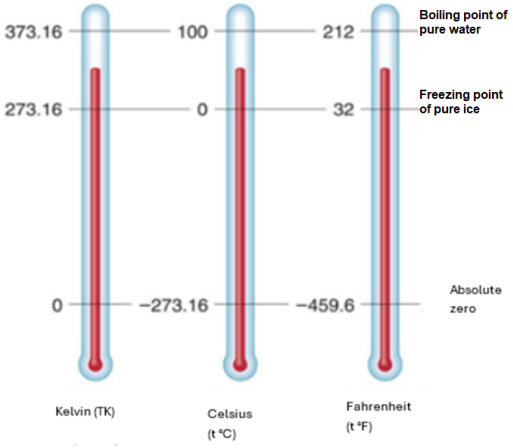


Figure (2-18) Temperature Scales

1- Celsius scale (t °C): For example, it is the scale used in Egypt.

2- Fahrenheit scale (t °F): For example, it is The scale used in the United States of America.

3- Kelvin scale (T_K): The absolute temperature scale used in scientific fields.

The Relationship Between Temperature Scales:

The relationship between the Celsius scale (t_c) and the absolute temperature scale (T_K) is:

$$T_K = t_c + 273$$

The relationship between the Celsius scale (t_c) and the Fahrenheit scale (t_F) is:

$$t_F = (1.8 \times t_c) + 32$$

Exercise

Find the value of the freezing point of pure water and its boiling point on the Kelvin and Fahrenheit scales, and record them in the following table.

Temperature	t_c	t_F	T_K
Freezing point of pure water (Melting point of ice)	$0^\circ C$		
Boiling point of pure water	$100^\circ C$		

Mechanisms of Heat Transfer:

Heat generally transfers through three methods, which are:

1. Conduction: Heat transfers through a solid body or between two touching bodies, moving from the region with a higher temperature to regions with lower temperatures, without the particles of the body themselves moving. Some materials are characterized by good thermal conductivity, such as metals, while others have low thermal conductivity, such as cork.

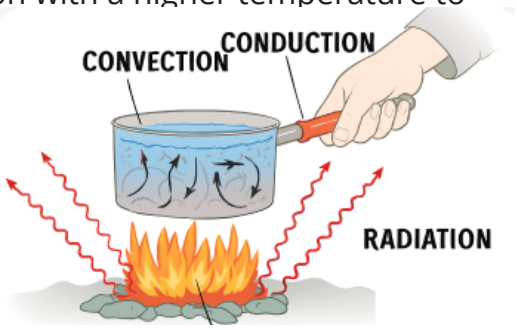


Figure (2-19) Mechanisms of Heat Transfer

2. Convection: Heat transfers through fluids (liquids and gases) by convection currents, where the density of the fluid parts with higher temperature is less than those with lower temperature. The less dense parts begin to rise, replacing the denser parts.

Have you ever seen a bird soaring high without flapping its wings?

This is not just a wonderful sight; it is the result of birds exploiting what is known as thermal flight. Thermal flight is a phenomenon that birds use to stay in the air for long periods without the need to constantly flap their wings, saving energy as the bird floats over rising warm air currents by convection and maintains its altitude.

Figure (2-20) Convection Currents in The Air

3. Radiation: is the transfer of heat in the form of electromagnetic radiation, where thermal radiation spreads in all directions without the need for a physical medium. It can spread in vacuum and also through gases.

Inquiry!

1. **In collaboration with your colleague, draw a diagram showing the methods of heat transfer starting from the Sun to Earth's surface, then to the atmosphere.**
2. **Which materials are considered the best in terms of thermal conductivity for use in making cooking pots to save the energy used in heating? Are there other factors that affect your choice to reach the best cooking pots?**

Adaptation of Living Organisms to Natural Changes in Temperature:

- Adaptation to Freezing:

The wood frog lives in cold areas in the north such as Alaska and Canada, where temperatures drop below zero in winter. The frog's body partially freezes in winter as its breathing stops and its heart stops beating. It remains in a state of deep hibernation.

The frog stores large amounts of glucose in its vital organs (heart, liver, brain) before freezing. Glucose acts as an antifreeze substance by preventing the formation of ice crystals in the cells and protecting them from damage.

Figure (2-21) Wood Frog

When the temperature rises in spring, the ice melts, the heart starts beating, and vital functions begin to work again.

Ice Fish:

This type of fish lives in the freezing waters of Antarctica where water temperatures drop below zero, which is lethal for most marine creatures.

Figure (2-22) Ice Fish

However, the ice fish adapts to this frozen environment in amazing ways; it secretes special proteins in its blood called antifreeze proteins. These proteins prevent the formation of ice crystals in the fish's blood and tissues.

Ice fish is one of the rare species whose blood does not contain hemoglobin (the pigment responsible for oxygen transport in the blood), and instead, it absorbs oxygen directly from the water.

Adaptation to High Temperatures

Desert Lizards

Desert lizards live in extremely hot environments such as deserts, where temperatures can reach very high levels that may be uninhabitable for other creatures. However, desert lizards have developed unique adaptations that help them survive in such harsh environments.

Figure (2-23) The Thorny Devil Lizard

The thorny devil lizard has tiny channels on the surface of its skin that help collect moisture from the air or even from the sand and direct it to its mouth, helping it stay hydrated in a dry desert environment.

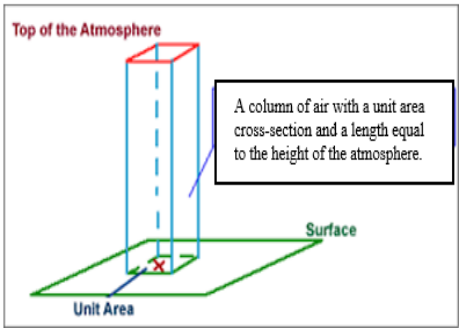
Second: Atmospheric Pressure (Air pressure)

The atmosphere remains attracted to Earth's surface due to the force of Earth's gravity. Gravity pulls air molecules downward, resulting in the atmosphere being denser near Earth's surface, with most of the atmospheric mass concentrated in the layer from the surface up to 30 kilometers in altitude. The amount and density of air decrease in the upper layers. Therefore, breathing at high altitudes becomes more difficult.

Figure (2-24)

The Fighter Needs to Be Supplied With Oxygen at High Altitudes

In high-altitude areas, the amount of oxygen the body can obtain decreases. This oxygen deficiency puts pressure on the body, prompting it to adapt in various ways. The body responds to the lack of oxygen by increasing the production of red blood cells responsible for carrying oxygen in the blood, which helps transport a larger amount of the available oxygen to the tissues.



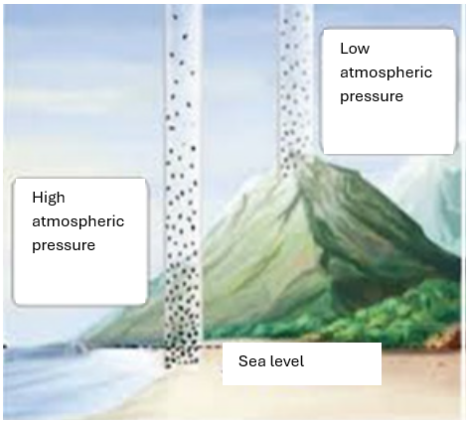


Figure (2-25)

The Atmospheric Pressure and Altitude

Atmospheric Pressure results from the weight of the column of air extending from a specific point to the end of the atmosphere and affecting the unit areas around it. Atmospheric pressure varies from one point to another in the atmosphere, decreasing as we ascend above sea level.

Standard Atmospheric Pressure:

Standard atmospheric pressure is defined as the atmospheric pressure value at sea level at 0°C, equal to 1.013 × 105 N/m². Atmospheric pressure decreases with altitude above sea level. The unit Millibar is used to express atmospheric pressure on weather maps.

The lines drawn on maps to connect areas with equal atmospheric pressure are called isobars.

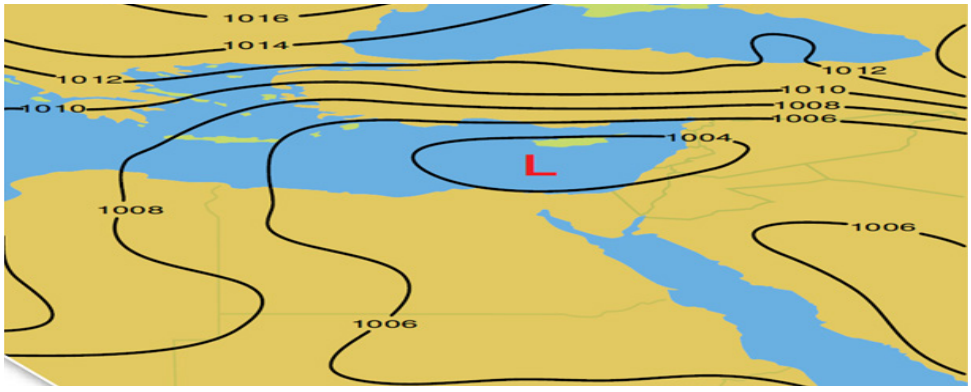


Figure (2-26) Isobaric Lines

Activiy

A mercury barometer is used to measure atmospheric pressure. In the figure in front of you is a mercury barometer with a vertical height difference of 760 mm between the mercury levels.

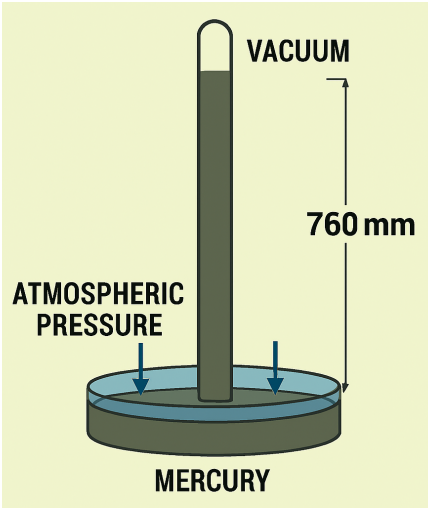


Figure (2-27) Mercury Barometer

Discuss with your colleague:

- Why is this height considered indicative of atmospheric pressure?
- How can the barometer be used to determine the height of a mountain, for example?

Atmospheric Pressure and Living Organisms:

In high places such as mountain peaks, atmospheric pressure is low. The large difference between the pressure inside the body and the low atmospheric pressure outside can lead to undesirable effects, such as the rupture of tiny capillaries in the nose of some mountain climbers.

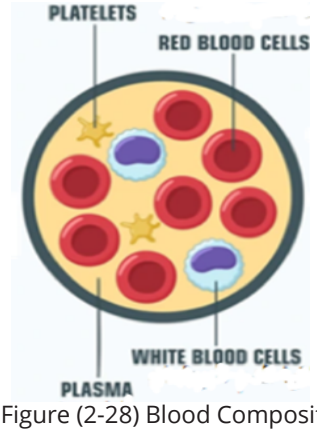


Figure (2-28) Blood Composition

Blood Components

Blood is a specialized connective tissue consisting of an inter-cellular substance called plasma in which blood cells swim. Plasma is the liquid component of blood that contains proteins, nutrients, hormones, and wastes. As for blood cells, they include red blood cells whose cytoplasm contains the red pigment hemoglobin responsible for transporting oxygen and a small part of carbon dioxide gas.

White blood cells protect the body from bacteria, viruses, fungi, and other foreign substances. Platelets participate in blood clotting during bleeding.

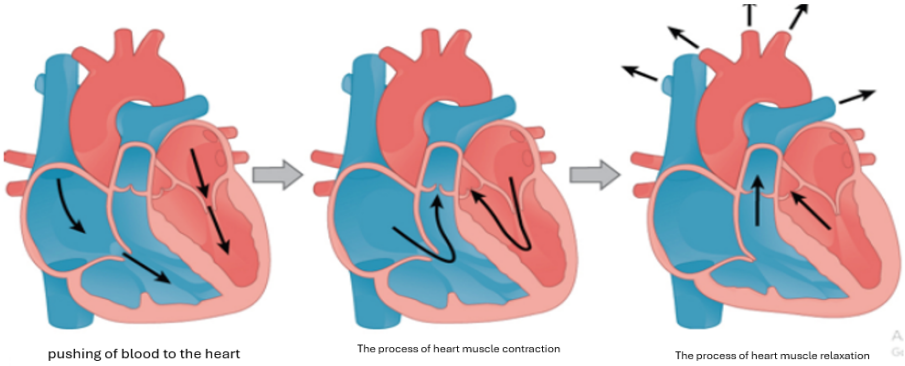


Figure (2-29) Heart Contraction and Relaxation

Blood pressure is the force exerted by the blood as it circulates on a unit area of the walls of blood vessels. Blood pressure is expressed by two values: systolic pressure (when the heart contracts) and diastolic pressure (when the heart relaxes).

Normal blood pressure for healthy adults is about 120 / 80 mmHg. Maintaining this rate is essential for delivering oxygen and nutrients to tissues and for the overall health of the heart and blood vessels.

Third: Wind

Atmospheric pressure affects weather and climate because the difference in atmospheric pressure between two regions at the same horizontal level leads to air movement, with air moving from the high-pressure area to the low-pressure area, resulting in wind blowing.

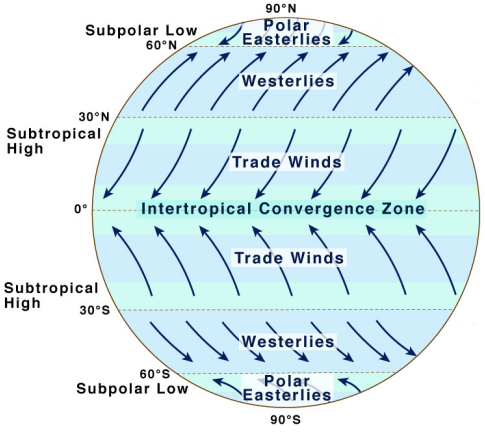


Figure (2-30) Wind Systems

There are several wind systems at the Earth's surface, including polar winds, which are dry and cold winds that blow from high-pressure areas around the North and South Poles to low-pressure areas in the subpolar regions.

Wind Speed:

Wind speed affects the distribution of heat and moisture in the atmosphere; strong winds may lead to significant changes in the weather.

The Role of Plant Tissues in Wind Resistance:

Strong winds affect plants; they may cause stems to break or leaves to tear if they are not supported by strong tissues. Therefore, plants have special tissues that differ in their structure and functions, contributing to varying degrees in supporting plant organs and resisting the effects of wind.

Parenchyma Tissue:

Parenchyma tissues consist of living cells that form most of the soft, flexible tissues inside various parts of the plant, such as leaves, stems, and roots. This tissue contains a large number of chloroplasts and thin cell walls mainly composed of cellulose. The cells of the parenchyma tissue also contain large vacuoles filled with water, starch, and minerals. Parenchyma cells perform several functions such as photosynthesis, storing nutrients and water, secreting sap, and aiding in ventilation.

Parenchyma Tissue | Collenchyma Tissue | Sclerenchyma Tissue

Figure (2-31) Some Simple Plant Tissues

Collenchyma Tissue:

Collenchyma tissues consist of cells longer than those of parenchyma tissue, with an irregularly thickened cell wall made of cellulose and pectin. Collenchyma tissues provide some strength, as well as flexibility and elasticity to the growing parts of the plant. These cells are usually found beneath the epidermis of leaf veins and stems, especially in small stems.

Sclerenchyma Tissue:

Sclerenchyma tissues consist of hard cells because their function is to provide significant mechanical strength to the plant thanks to their very thick cell walls made of cellulose and lignin, which make the cells impermeable to water. Usually, the older sclerenchyma cells are dead.

Fourth: Humidity

Humidity is the amount of water vapor present in the air.

High humidity levels in tropical areas affect cloud formation and rainfall, where the rain is heavy and supports the growth of dense forests.

The humidity level in the air depends on temperature and atmospheric pressure; the higher the air temperature, the greater the amount of water vapor it can hold. When the air contains the maximum amount of water vapor it can hold at a certain temperature and pressure, the air is said to be saturated with water vapor.

Humidity in the air is measured by a hygrometer.

Figure (2-32) Hygrometer

Effect of Humidity on Humans:

A person feels most comfortable when the relative humidity of the air ranges between 40% and 60%. Within this range, physiological body mechanisms, such as sweating and regulating blood temperature, work efficiently. Humidity directly affects human comfort and health, as it controls the body's efficiency in eliminating excess heat through sweating, where water absorbs the heat required to evaporate from the body.


Figure (2-33) Human Sweating

When humidity is high, the rate of sweat evaporation from the skin surface slows down, causing the body to lose its ability to cool itself. This leads to feeling hotter and more fatigued quickly, and prolonged exposure to high humidity may cause heat stress or even heatstroke.

In dry atmospheres, sweat evaporates very quickly, leading to

dry skin and chapped lips.

Dryness can also occur in the mucous membranes of the nose and respiratory system, increasing susceptibility to respiratory infections. Rapid loss of water from the body raises the risk of dehydration.

Osmoregulation

The human body maintains certain proportions of water and salts within it in a process known as water balance. This maintains blood pressure at a normal level, ensures the continuation of vital reactions within cells, and prevents dehydration, which may cause dizziness or kidney failure in severe cases.

Severe changes in the body's water levels may harm the integrity of cells and their ability to perform vital functions.

For example: when the humidity in the air is low, the body loses water more quickly through sweating via the skin and exhaling through the lungs. The body senses this water deficiency through special receptors in the brain, prompting the kidneys to reabsorb water from the urine, so the body maintains a stable fluid level despite dry conditions. The urine becomes concentrated as it contains less water.

Figure (2-35) Humid Tropical Environment

Figure (2-34) Dry Desert Environment

Effect of Humidity on Living Organisms:

Some vital processes in living organisms are affected by the humidity level in the atmospheric air. With increased relative humidity around plants, the rate of transpiration decreases, reducing the rate of water and salt uptake from the roots to the leaves. In animals, the rate of sweat evaporation decreases, reducing the efficiency of lowering body temperature.

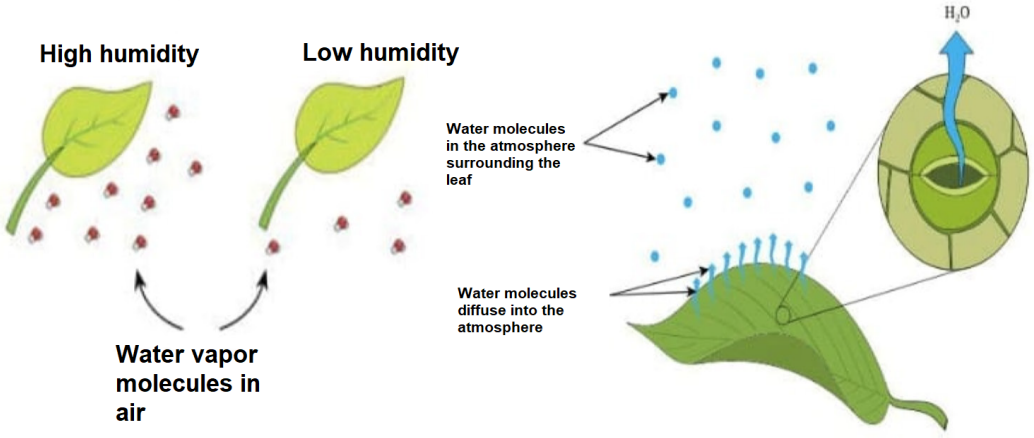


Figure (2-36) Effect of Humidity on Plants

Activiy (1)

Measuring the Effect of Physical Factors:

- Objective: Understand the effect of physical factors on the atmosphere.
- Tools: Thermometer, pressure gauge, humidity meter, wind speed measuring device.

Procedure:

1. Measure temperature, pressure, humidity, and wind speed in your area over a full day.
2. Record the data and analyze how changes in these factors affect the local weather.

Activiy (2)

Weather Data Analysis:

Objective: Analyze weather data to understand the impact of physical factors.

Tools: Local or global weather data.

Procedure:

1. Choose two different geographical regions (such as tropical and polar regions).
2. Compare temperature, pressure, humidity, and wind speed data between the two regions.
3. Analyze how these factors affect the climate in each region.

Inquiry!

Use various sources, and with a group of your colleagues, prepare a presentation about climate change and its impact on local and global ecosystems. Can environmental changes be predicted and adapted to its effects, in order to ensure the sustainability of life on Earth?

Exercise

First: Objective Questions

➲ Choose the correct answer:

1) ..... is used to measure atmospheric pressure.

a) Thermometer b) Hydrometer

c) Barometer d) Hygrometer

2) If the atmospheric pressure at the top of a mountain is 750mm.Hg, it equals ..... (Given that the usual atmospheric pressure equals 1.013x105 N/m2 = 76 cm.Hg)

a) 99967.11 N/m^2 b) 89967.11 N/m^2

c) 101300 N/m^2 d) 1013 N/m^2

3) Which of the following correctly expresses the effect of atmospheric pressure on the amount of oxygen available for breathing?

a) Less in areas of low pressure

b) More in areas of low pressure

c) Equal in all areas of different pressures

d) The amount in low-pressure areas is less than or equal to that in high-pressure areas

4) A body with a temperature of 283 K equals ..... on the Fahrenheit scale.

a) 10 °F b) 30 °F

c) 50 °F d) 70 °F

5) The boiling point of pure water equals .....

a) 100 K b) 212 °F

c) 373 °F d) 373 K

6) Mount Sinai is approximately 2285 meters above sea level. If the temperature at the base of the mountain is 32 °C, the temperature at an altitude of 528 meters above the base equals:

a) 16 °C b) 35 °C

c) 19 °C d) 29 °C

7) 8 millibar = ...

a) 1000 N/m^2 b) 100 N/m^2

c) 0.01 N/m^2 d) 0.1 N/m^2

8) Which of the following expresses a form of adaptation to freezing?

a) Producing a large amount of proteins before entering hibernation, as in the wood frog

b) Producing a large amount of fats before entering hibernation, as in the wood frog

c) Producing a large amount of antifreeze proteins, as in the ice fish

d) Producing a large amount of antifreeze glucose, as in the ice fish

Second: Essay Questions

➲ Q1: Explain the following:

1) The effect of atmospheric pressure on weather and climate.

2) Why mountain climbers may suffer from the rupture of tiny capillaries in the nose.

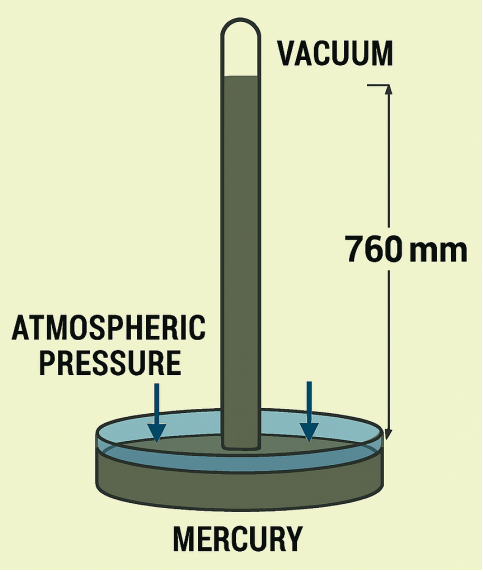
3) The necessity of maintaining normal blood pressure in a healthy person.

Q2: The figure shows a scientific instrument:

First: What is the name of the instrument?

Second: What is it used for?

Third: What does the height shown in the diagram (760 mm) represent? Explain your answer.



Q3: If the temperature of a body is 20°C, what is the equivalent temperature on:

First: The absolute scale

Second: The Fahrenheit scale

2-4:The Atmosphere and the Role of Science in Its Sustainability

Get ready

Changes in the atmosphere lead to climatic changes that have long-term effects on our lives and our planet. In recent years, a continuous rise in global temperatures has been observed, known as global warming, for which air pollution is considered the main cause.

Scientists indicate that if air quality continues to deteriorate at the same rate, living organisms in the future may need to live in closed environments or bubbles to protect them from pollution and radiation.

Understanding and Protecting the Atmosphere:

Understanding the components of the atmosphere and its vital functions helps us realize the importance of protecting it. Changes in the proportions of its constituent gases reduce its ability to regulate temperature, making the atmosphere less effective in maintaining a suitable temperature for living organisms and protecting from radiation, as its ability to protect Earth from harmful solar radiation decreases.

Understanding these changes and developing practical solutions is essential to ensure the sustainability of life on our planet for future generations.

Global Warming and Climate Change:

Global warming is defined as the continuous rising in the temperature of the air adjacent to Earth's surface. It results from burning fossil fuels such as coal, oil, and gas, which emit greenhouse gases that act like a blanket around Earth, leads to trapping heat in the atmosphere and raising temperatures. The greenhouse gases that cause global warming include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons compounds (CFCs), and water vapor.

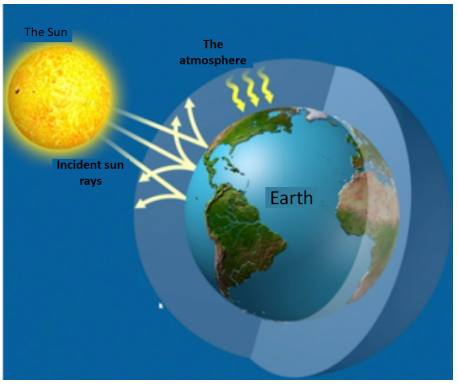


Figure (2-37) Global Warming

The increase in the proportion of greenhouse gases in the atmosphere works similarly to the principle as a glass greenhouse, where the atmosphere allows short-wavelength solar radiation to pass towards Earth, which in turn absorbs this radiation and then re-emits it as long-wavelength thermal radiation. Greenhouse gases significantly prevent this radiation from escaping into outer space, leading to a gradual rise in Earth's surface temperature year after year.

Figure (2-38) Greenhouse

Negative Effects of Global Warming:

1. Melting of Ice:

Since a large amount of fresh water is frozen in glaciers and ice masses at the poles. As Earth's temperature rises, ice blocks frequently break off threatening the risk of coastal flooding and posing an environmental disaster, including:

Figure (2-39)
Melting of Ice at the Poles

A. Extinction of polar species due to the destruction of their natural habitat, leading to reduced biodiversity and disruption of ecological balance.

B. Severe climate changes, such as hurricanes, floods, droughts, and more.

Some strategies to reduce global warming:

1. Using public transportation to reduce vehicle exhaust emissions, as vehicles emit large amounts of greenhouse gases that lead to global warming and ozone layer depletion. Therefore, the use of vehicles should be minimized as much as possible.

Figure (2-40) Shuttle Bus Reduces Environmental Pollution

2-Improving energy efficiency by using energy-effective technologies in homes and factories, such as using high-efficiency electrical appliances and LED lamps, and switching to clean renewable energy sources like solar energy, wind energy, and hydropower can reduce greenhouse gas emissions.

Figure(2-41)
Energy-saving Lamps

3- Increasing green spaces (afforestation) in general to help improve air quality. This is due to the large amount of vegetation that helps increase the process of photosynthesis carried out by plants, that plays a fundamental role in absorbing carbon dioxide gas, which is considered the main cause of global warming. Therefore, afforestation is one of the most important methods to reduce global warming

Figure(2-42)Afforestation Reduces Global Warming

Air pollution and its impact on atmospheric sustainability

Air pollution is one of the greatest dangers threatening the atmosphere and the health of living organisms. Among the most prominent pollutants are: sulfur oxides (SO_2, SO_3), carbon monoxide (CO), and nitrogen oxides (NO, NO_2).

Carbon monoxide

Carbon monoxide is a colorless and odorless gas, commonly produced by the incomplete combustion of fossil fuels (such as gasoline, coal, and natural gas). It is characterized by a molecule that can quickly penetrate from the lungs into the bloodstream, where CO competes with oxygen (O_2) to bind with hemoglobin inside red blood cells. Carbon monoxide binds to hemoglobin with a strength approximately 200 to 250 times greater than oxygen bonding, and when it binds it form a compound called carboxyhemoglobin (HbCO). This compound is relatively stable and prevents oxygen from binding to hemoglobin.

The reduced binding of oxygen to hemoglobin leads to a decrease in oxygen supply to tissues, causing hypoxia—a condition where cells do not receive enough oxygen for cellular respiration. As a result, cells begin to rely on anaerobic respiration, leading to the accumulation of lactic acid and symptoms such as fatigue and headache.

If HbCO concentration in the blood increases, serious symptoms may occur, including dizziness, loss of consciousness, and brain damage.

Sulfur oxides and nitrogen oxides

Sulfur oxides (SOx), especially sulfur dioxide (SO_2), are mainly emitted from the combustion of coal and oil in power plants and factories, as well as from certain industrial processes sich as oil refining and metals melting.

Nitrogen oxides (NO_x), including nitric oxide (NO) and nitrogen dioxide (NO_2), are produced in large quantities during high-temperature combustion (e.g., in car engines, power stations, and industrial furnaces).

Formation of acid rain:

In the atmosphere, a series of reactions lead to the acidity of rain:

First: Formation of sulfuric acid

sulfur dioxide (SO_2), emitted from the burning of sulfur-containing fossil fuels, reacts with oxygen (O_2), to form sulfur trioxide (SO_3). This reaction occurs in the presence of catalysts such as sunlight.

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$$

Then, sulfur trioxide reacts with water droplets in clouds to form sulfuric acid, which is a very strong acid. (H_2SO_4)

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$

Second: Formation of nitric acid

Nitrogen oxides (NO_x), which form naturally from lightning or from fuel combustion emissions at high temperatures, react with water to form nitric acid (HNO_3).

$$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{2(aq)} + HNO_{3(aq)}$$

In this equation, nitric acid and nitrous acid are formed; generally, the reaction can be summarized as follows:

$$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 4HNO_{3(aq)}$$

Harmful Effects Resulting:

A. On Human Health

- Direct inhalation of NO_2 and SO_3 causes irritation in the respiratory tract and increases the likelihood of asthma attacks, bronchitis, and pneumonia.
- Formation of ground-level ozone (O_3) is formed secondarily from the reaction of nitrogen oxides (NO_x) and volatile organic compounds in the presence of sunlight.

Ground-level ozone harms the lungs and reduces respiratory capacity

B-On plants

- Direct Damage to Leaves: Gases like SO2 and NO2 enter through the stomata, causing oxidation reactions, which directly damage leaf tissue and deform the stomata.
- Reducing Photosynthesis: Damaged chlorophyll and clogged stomata decrease the absorption of CO2 and, consequently, the production of glucose.
- Nutrient depletion: Acid rain leaches essential salts (such as calcium and magnesium) from the soil reducing its fertility, and plants lack essential elements for growth.

C- On buildings and infrastructure

- The reaction of acids with limestone ($CaCO_3$) causes corrosion, which leads to the damage of monuments and historical buildings.

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + CO_2 + H_2O$$

Why does this threaten the sustainability of ecosystems and humans?

Biological productivity (forests, water bodies, wild plants) declines, affecting food and resources. There is also a loss of biodiversity due to the death of sensitive species or disruption of their functional roles. This also reduces the quality of air and water, imposing a health and economic burden on communities (healthcare, building repairs, resource loss).

The role of science and technology in protection and recovery

Scientists have developed technologies such as gas scrubbers installed in factory and power plant chimneys, which remove sulfur and nitrogen oxides before they are released into the atmosphere. Science also prompotes the use of cleaner energy sources such as solar, wind, and hydropower, which do not produce these harmful oxides.

Monitoring and forecasting

The role of science goes beyond understanding the components of the atmosphere or the challenges it faces. It also includes accurate monitoring of weather and climate changes using advanced tools and technologies. This helps in developing preventive solutions to preserve its sustainability.

(1) Satellites and Remote Sensing

Figure (2-43) Satellites for Remote Sensing

Satellites perform multiple tasks to monitor the components of the atmosphere and their interactions. Remote sensors devices aboard satellites measure concentrations of gases such as carbon dioxide and methane, which are gases responsible for the global warming phenomena. Satellites also continuously monitor the state of the ozone layer, detecting any depletion and track its recovery over time. Additionally, satellites provide data on cloud movement and wind patterns, helping climate scientists understand how weather and climate patterns are changing.

(2) Meteorological Monitoring Stations

Weather stations distributed around the world measure temperature, air pressure, humidity, wind speed, and pollutant concentrations. These measurements help in the early detection of air pollution or dangerous weather phenomena (such as dust storms or heat waves).

Figure (2-43) Weather Monitoring Station

- In 1985, a weather monitoring station in Antarctica, operated by the British Meteorological Office, discovered a large hole in the ozone layer. This discovery was not just a scientific finding—it led to the launch of the Montreal Protocol in 1987, an international agreement that limited the use of ozone-depleting substances such as chlorofluorocarbons (CFCs). As a result, the ozone layer began to gradually recover, helping to protect humans and living organisms.

(3) Climate Models

These are computer programs based on physical, chemical, and biological equations that describe the movement and interactions of the atmosphere. These models allow predicting the long-term effects of human activities, such as the impact of burning fossil fuels on the accumulation of carbon dioxide and the effect of deforestation on the carbon cycle and gases balance.

Data collected by satellites and weather monitoring stations are used to create complex climate models. These models are powerful computer programs that simulate Earth's climate system by inputting current and future data (such as gas emission levels). Scientists can predict some potential changes such as:

- Rising temperatures.

Scientists have used climate models to predict that the continued increase in atmospheric carbon dioxide concentration will lead to rising in Earth›s average temperature by approximately 1.5 to 2 °C over the coming decades

- Changes in rainfall patterns.
- Increased frequency of extreme weather conditions.

Enrichment Information

The 2015 Paris Climate Agreement aims to limit the global temperature rise to less than 2°C and urges countries to develop renewable energy sources (such as solar and wind energy) and reduce reliance on fossil fuels.

(4) The Biological Importance of Forecasting

- In public health, predicting pollution levels or increases in ultraviolet radiation helps protect humans from respiratory diseases or skin cancer.
- In agriculture, forecasting temperatures and rainfall enables farmers to choose appropriate planting and harvesting times.
- In ecosystems, predicting changes helps protect sensitive organisms and plan environmental conservation programs.

Example 1

In 2016, climate monitoring centers predicted a marine heatwave (a significant rise in ocean water temperatures) along the Great Barrier Reef in Australia. The increase in water temperature leads to coral bleaching, where symbiotic algae are expelled from the coral tissues, causing the coral to lose its primary source of food and energy. Thanks to early forecasting, the government and researchers took steps such as reducing pollution from coastal activities and temporarily restricting fishing and tourism. These actions did not completely prevent damage but reduced the extent of losses and helped some coral areas to recover.

Figure(2-44) Coral Bleaching

Example 2

During migration seasons, some birds rely on long routes across continents.

In one case, weather stations predicted a strong storm along the expected migration path of bird flocks. Wildlife protection centers issued environmental warnings, which helped reroute some migration paths or reduce hunting during that period. This intervention helped protect large numbers of birds from death due to exhaustion or collision during the storm.

Figure(2-45) Bird Migration

Various scientific activities

Activiy (1)

Developing projects or models for environmental solutions

Objective: Applying scientific knowledge to develop practical solutions for environmental problems.

Tools: Environmental materials, miniature models, design software.

Steps:

1.Choose an environmental issue related to the atmosphere (such as air pollution).

2.Design a model or project that contributes to solving this issue.

3.Present your model with a scientific explanation of how it works and its potential impact.

Activiy (2)

Discussing Real Case Studies

Objective: Understand real applications of air pollution and climate change mitigation techniques.

Tools: Scientific articles, environmental reports.

Steps:

1. Select a case study related to a specific environmental problem.
2. Read the study and extract the key points.
3. Discuss in a group how solutions were applied in this case and how they could be improved.

Activiy (3)

Field Visit

Visit an meteorological station or environmental research center to understand how atmospheric changes are measured.

Integration of Sciences (Technology and Environmental Science)

- Technology: How do modern technologies contribute to reduce air pollution and improving life quality?
- Environmental Science: How can we assess the environmental impact of human activities on the atmosphere and propose sustainable solutions?

Exercise

First: Objective Questions

➲ Choose the correct answer:

(1) All of the following are greenhouse gases that cause global warming except:

a) CH_4 b) CFCs c) O_3 d) N_2O

(2) All of the following are negative effects of global warming **except**:

a) melting ice and flooding of coasts

b) decreased biodiversity due to extinction of polar organisms

c) drought waves and hurricanes

d) decreased biodiversity due to extinction of desert organisms

(3) The increase in greenhouse gases in the atmosphere prevents the penetration of _____, causing global warming.

a) ultraviolet rays b) infrared rays

c) radio waves d) microwave waves

(4) The main role of emissions from burning fossil fuels in causing global warming is...

a) increasing Earth's surface absorption of sunlight.

b) forming a layer in the atmosphere that traps heat and prevents it from escaping.

c) directly reacting with polar ice, causing its melting.

d) increasing the amount of oxygen in the air, which raises its temperature.

(5) Earth's surface absorbs short-wavelength solar radiation and then re-emits it in the form of...

a) thermal radiation b) visible rays

c) ionizing radiation d) ultraviolet rays

Second: Essay questions:

Explain:

1) The increase in greenhouse gases in the atmosphere causes the global warming phenomena.

2) Global warming has some negative effects as it causes some natural disasters. Explain this.

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