

Student's Book

Discover and Learn

SCIENCE

Third Preparatory - First Term

The Ministry of Education and Technical Education dedicates this book with love to students, teachers, and families throughout the Arab Republic of Egypt



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Discover and Learn

SCIENCE

Third Preparatory - First Term

Name : .....

Class : .....

School : .....

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Introduction

Dear student,

We are pleased to present this Science textbook to our third preparatory students, and to emphasise the role of science in the development and progress of society. Science is not just a subject to be studied, it is a way of thinking that helps them to understand the world more deeply and make well-informed decisions based on precise knowledge. Learning science is an active process based on discovery, research, experimentation, thinking, and practicing different scientific processes such as observation, interpretation, communication, prediction, experimentation, and drawing conclusions. Reflecting this philosophy, the curriculum has been entitled: 'Discover and Learn!'

This book aims to foster students' love of exploration and experimentation, encouraging critical thinking, collaboration, and questioning—guiding them to discover answers through observation, hands-on experiments, and diverse activities that make scientific concepts engaging and fun. This book also aims to help students develop a deep understanding of scientific concepts, apply scientific knowledge in new situations, solve problems, develop scientific research and inquiry skills. The content encourages students to ask questions, design experiments, analyse information, develop innovative solutions, and enhance understanding of the relationships between science, technology, engineering and mathematics.

It also prepares students to be lifelong learners and capable of meeting future challenges.

To achieve these goals, this book covers different fields of science such as chemistry, physics, biology, and space science in cohesive, interconnected units that also align with other subjects. This promotes a comprehensive and integrated understanding of how these fields intersect in the real world. The topics covered in this curriculum address key concepts in the fields of matter, energy, living things, and space, which helps to encourage scientific inquiry.

The curriculum relies on active learning strategies in the implementation of its lessons, addresses many scientific and social issues and reinforcing values. The lessons are supported by knowledge resources, communication and information technology, encouraging research and self-learning skills, developing critical thinking skills, and helping students reflect on and assess their understanding of what they are studying and learning.

We hope that you will find inspiration in this book to encourage you to pursue your scientific curiosity. Always remember that scientists were once just curious children like you. They search for answers to their questions and discovered new wonders. Maybe you will be one of the scientists who discover what no one has discovered before!

In presenting this book, we hope that it will be of benefit to you.

And God is the source of all success.

The Authors

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UNIT 1

Chemical Reactions and Their Environmental Impacts

Unit lessons

Lesson One : Types of Chemical Reactions

Lesson Two : Combustion Reactions and Environmental Pollution

Lesson Three : Smoking and Its Hazards



Learning Outcomes:

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

1. Compare metals in their reactions with water, acids, oxygen and salt solutions.
2. Differentiate among the main types of chemical reactions (including single replacement reactions, double replacement reactions such as neutralization reactions, combustion reactions, and oxidation - reduction reactions (redox reactions).
3. Deduce the arrangement of metals according to their chemical reactivity by analysing and interpreting experimental results.
4. Construct a scientific explanation of the flammability of substances (combustion reaction), explaining the properties of combustion products and their impact on the environment.
5. Design solutions to reduce pollution and protect the environment from the effects of combustion products, focusing on environmental pollution caused by burning materials and its hazards to the environment (such as burning agricultural waste, vehicle exhaust, and fuel combustion, etc.).
6. Collect information about the chemical substances of tobacco.
7. Identify the chemicals in smoke produced by tobacco combustion (nicotine, tar, carbon monoxide, ammonia, radioactive elements, etc.).
8. Evaluate the harmful effects of all forms of smoking on the environment, smokers, and people around them (passive smoking).

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Lesson **One**

Types of Chemical Reactions



Lesson Terminology:

- Chemical Reaction
- Chemical Reactivity Series
- Direct Combination Reactions
- Decomposition Reactions
- Single Replacement Reactions
- Double Replacement Reactions
- Neutralization Reactions
- Combustion Reactions
- Universal Indicator
- Redox Reactions
- Oxidizing Agent
- Reducing Agent

Included Skills, Values and Issues:

- **Skills:** Practical - modeling - measurement.
- **Values :** Curiosity – Responsible Consumption.
- **Issues :** The Impact of Metal Corrosion on the Economy.

Cross-Cutting Concepts:

- Cause and Effect - Patterns.

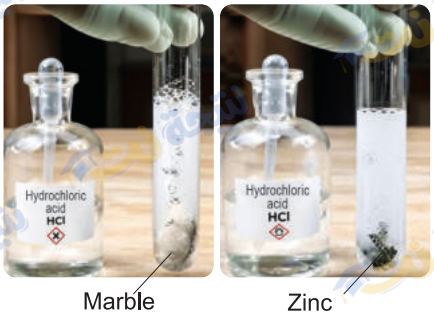
Lesson Objectives:

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

1. List the main types of chemical reactions.
2. Compare metals in their reactions with water, acids, and oxygen.
3. Deduce the arrangement of metals according to their chemical reactivity.
4. Use the chemical reactivity series to predict chemical reactions.
5. Differentiate between a single replacement reaction and a double replacement, giving examples.
6. Identify the concepts of oxidation, reduction, the oxidizing agent, and the reducing agent in terms of electron transfer.

Lesson Introduction:

The figure shows two experiments in which clear effervescence occurs: the first occurs when dilute hydrochloric acid is added to a piece of marble, and the second when it is added to zinc.



Marble Zinc

This lesson explores the ideas that help answer the questions below.

- Does what we observed mean that the reaction is the same?
- Is the gas evolved in both experiments the same?
- Do both reactions occur in the same way? And are they classified as the same type of reaction?
- Does every reaction involving dilute hydrochloric acid produce a gas?

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You previously learned that a **Chemical reaction** is a process in which bonds are broken in molecules of reactants, and new bonds are formed in molecules of products, leading to the formation of new substances with different properties.

We identify that a chemical reaction has occurred through one or more observations taking place during the reaction, **such as** a change in colour or odour, gas evolution, formation of a precipitate, or emission of light and heat, as shown in Figure (1).

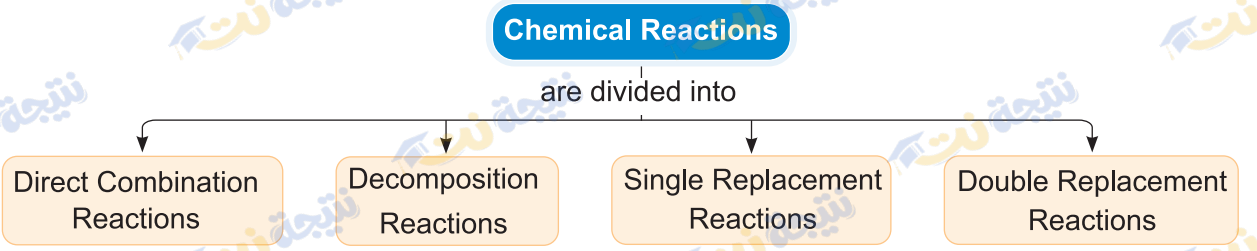


Figure (1)
Chemical reaction

Main Types of Chemical Reactions

Chemical reactions are classified into several main types based on how atoms or ions rearrange and bond with one another during the reaction. Classification of chemical reactions helps understand how a reaction occurs and predict the products of other chemical reactions.

Chemical reactions can be classified as follows:



First Direct Combination Reactions

Reactions in which two or more substances combine to form a new compound, as shown in Figure (2).



Figure (2)
Direct combination reaction

Activity 1 Experiment and Conclude

Reaction of a metal with oxygen.

Materials and Tools:

• Bunsen burner. • Metal tongs. • Magnesium ribbon (Mg) (Sanded).
• A piece of steel wool (Fe) (pot-cleaning wire). • Copper wire (Cu).

Steps:

1. Using the tongs, expose the magnesium ribbon to a Bunsen flame for two minutes (Figure 3).
2. Expose both the steel wool and the copper wire to the same flame for the same period.

What do you observe? .....

What do you conclude? .....



Figure (3)
Heating a magnesium ribbon

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• Magnesium (Mg) ignites rapidly and burns with a bright white flame, producing a white substance of magnesium oxide (MgO) (Figure 4).

$$2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$$



Figure (4)
Combustion of magnesium

Safety Precautions

- Avoid staring at the glare

Burning magnesium produces intense light accompanied by ultraviolet radiation that may damage the retina, so safety goggles must be worn.

• Steel wool (Fe) burns when placed in a Bunsen flame with bright sparks and mainly produces magnetic iron oxide (Fe_3O_4) (Figure 5).

$$3Fe_{(s)} + 2O_{2(g)} \xrightarrow{\Delta} Fe_3O_{4(s)}$$

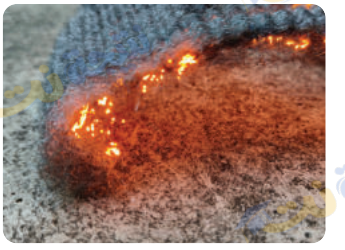


Figure (5)
Combustion of steel wool

• Copper (Cu) does not burn with a visible flame; instead, a black layer of copper oxide (CuO) is formed on its surface (Figure 6).

$$2Cu_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2CuO_{(s)}$$



Figure (6)
Heating of copper wire

Based on the above, we conclude that: Most metals combine with oxygen when heated in air, but they differ in chemical reactivity. Magnesium is more reactive than iron, and iron is more reactive than copper.

Second Decomposition Reactions

Reactions in which some compounds decompose into simpler components using a form of energy such as heat or light, as shown in Figure (7).

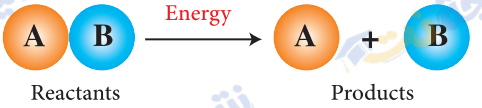


Figure (7)
Decomposition reaction

Example:

(1) Red mercury oxide (HgO) decomposes upon heating into silver-coloured mercury (Hg) and oxygen gas (O_2), as shown in Figure (8).

$$2HgO_{(s)} \xrightarrow{\Delta} 2Hg_{(\ell)} + O_{2(g)}\uparrow$$



Figure (8)
Decomposition of mercury oxide

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(2) Calcium carbonate ($CaCO_3$) decomposes upon heating into calcium oxide (CaO) and carbon dioxide gas (CO_2).

$$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}\uparrow$$

Check Your Understanding

A chemical reaction occurs when each of the following is heated: a magnesium ribbon in air and red mercury oxide.

(1) What is the type of each reaction?

.....

(2) What are the products of each reaction? State the physical state and colour of each.

.....

Third Single Replacement Reactions

Reactions in which one element replaces another element in one of its compounds, as shown in Figure (9).

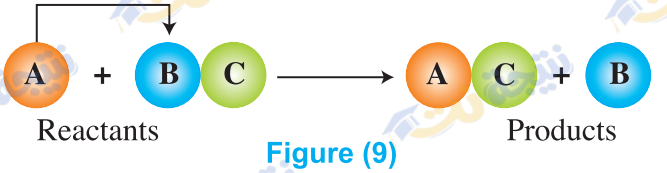


Figure (9)
Single replacement reaction

There are several types of single replacement reactions, such as:

1 Replacement of Hydrogen in an Acid by a Metal

Activity 2 Experiment and Conclude

Materials and Tools:

- Test tube.
- Dilute hydrochloric acid (HCl).
- Magnesium ribbon (Mg)(sanded).

Steps:

1. Place the magnesium ribbon in the test tube.
2. Add an amount (5 mL, for example) of dilute hydrochloric acid to the test tube.
3. Temporarily close the mouth of the test tube for a few seconds.
4. Carefully bring a lighted splint close to the mouth of the test tube.

What do you observe? .....

What do you conclude? .....



Figure (10)
Reaction of magnesium with dilute hydrochloric acid

- When dilute hydrochloric acid (HCl) is added to magnesium (Mg), an instant and rapid reaction occurs and gas bubbles evolve. When a lighted splint is brought close to the mouth of the test tube, the evolved gas burns with a pop sound.
- Reactive metals react with dilute hydrochloric acid, forming **metal chloride**,and **hydrogen gas** (H_2) evolves,and burns with a **pop sound**.

$$Mg_{(s)} + 2HCl_{(aq)} \xrightarrow{dil.} MgCl_{2(aq)} + H_{2(g)}\uparrow$$

But do other metals react with dilute hydrochloric acid at the same reactivity?

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Activity 3 Observe and Conclude

Materials and Tools:

- Three test tubes.
- Dilute hydrochloric acid (HCl).
- Equal masses (1 g, for example) of zinc (Zn), iron (Fe), and copper (Cu).

Steps:

1. Place in each test tube a suitable equal volume of dilute hydrochloric acid.
2. Add the equal masses of zinc, iron, and copper to the acid in the test tubes.
3. Observe the rate of bubble evolution in each test tube (Figure 11).
4. Record your observations in the following table:

Metal	The rate of bubble evolution	The reaction rate
Zinc	.....	.....
Iron	.....	.....
Copper	.....	.....

5. Arrange the three elements in comparison with magnesium according to the rate of each metal reaction with the dilute acid.



Figure (11)
The reaction of different metals with dilute hydrochloric acid

What do you conclude? .....

Metals differ in their chemical reactivity; this is indicated by how rapidly each metal reacts with oxygen, acids, and water. Metals have been arranged in what is known as the **Chemical Reactivity Series**.

Chemical Reactivity Series: The arrangement of metal elements in a descending order according to their chemical reactivity.

Figure (12) shows that:

- Metals that **precede** hydrogen in the series **replace** it in dilute acids.
- Metals that **follow** hydrogen in the series **do not react** with dilute acids or water because they cannot replace hydrogen of the acid or water.

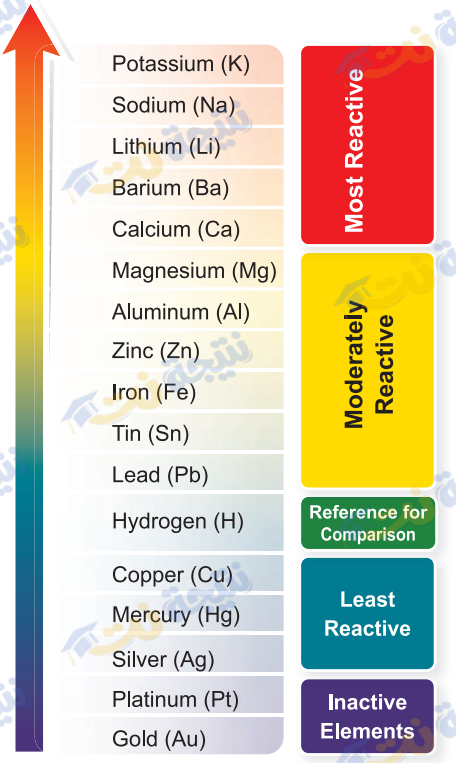


Figure (12)
Chemical reactivity series

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Enrichment Information

Aluminum (Al) does not react instantly with dilute hydrochloric acid (HCl) because a layer of aluminum oxide (Al_2O_3) coats its surface and acts as an isolating layer prevents the acid from reaching the metal. This layer needs some time to corrode, after which **effervescence** and hydrogen gas bubbles appear as aluminum reacts with the acid (Figure 13).



Figure (13)
Reaction of aluminum with dilute hydrochloric acid

Check Your Understanding

If small pieces of copper, zinc, silver, and iron are placed separately in dilute hydrochloric acid, in which case hydrogen gas evolves? **Why?**

.....

2 Replacement of Hydrogen in Water by a Metal

Highly reactive metals, which are at the top of the chemical reactivity series, and therefore precede hydrogen, react with water (H_2O), replacing hydrogen, which evolves as a gas that can burn with a pop sound.

Activity 4 Observe and Conclude

Materials and Tools:

- Glass trough.
- Water.
- Sodium metal (Na) (usually kept in kerosene)
- Forceps.
- Filter paper.

Steps:

1. The trough is filled approximately halfway with water.
2. Use the forceps to pick up carefully a very small piece of sodium (the size of a rice grain).
3. Use the filter paper to dry the piece of sodium thoroughly and remove the kerosene.
4. Place the piece of sodium carefully on the water surface.

What do you observe? .....

What do you conclude? .....



Figure (14)
Reaction of Sodium with Water

Safety Precautions

A large amount of heat is released when sodium reacts with water, which may lead to ignition of the evolved hydrogen gas or cause an explosion. Since water should not be used to extinguish sodium fires, dry sand must be prepared for use in case of emergency.

- Sodium floats on the surface of water since its density is lower than the density of water.
- The piece of sodium moves rapidly on water surface because it reacts instantly and violently with water.
- Sodium (Na) replaces hydrogen of water, producing an alkaline sodium hydroxide solution (NaOH), and hydrogen gas (H_2), and usually a yellowish-orange flame is formed (Figure 14).

$$2Na_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}\uparrow + \text{heat}$$

Do all metals react with water with the same reactivity?

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Activity 5 Observe and Conclude

1. Place a magnesium ribbon in cold water.
   Does a reaction occur?
2. Transfer the magnesium ribbon to hot water.
   What do you observe? .....
   What do you conclude? .....

While sodium (Na) reacts instantly and violently with cold water, magnesium (Mg) requires some thermal energy to begin reacting with water (Figure 15). This indicates that magnesium is less reactive than sodium.

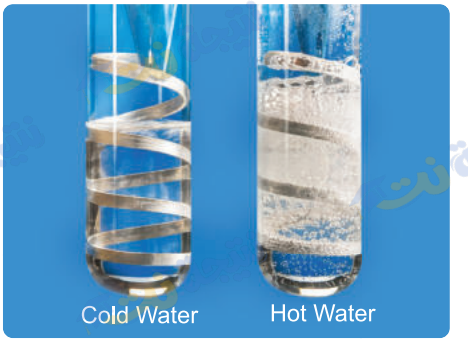


Figure (15)
Reaction of magnesium with cold and hot water

3 Replacement of a Metal by Another (More Reactive) in Its Salt Solution

Some metals can replace the metals that follow them in the chemical reactivity series in their salt solutions.

Activity 6 Experiment and Conclude

Materials and Tools:

- Beaker.
- Blue copper sulphate solution ($CuSO_4$).
- Zinc rod (Zn).
- A piece of sandpaper.

Steps:

1. Place a suitable amount of blue copper sulphate solution in the beaker.
2. Use the sandpaper to clean the surface of the zinc rod thoroughly.
3. Immerse the zinc rod in copper sulphate solution for 10 minutes.
   What do you observe? .....
   What do you conclude? .....



Figure (16)
Reaction of zinc with copper sulphate solution

- When the zinc rod (Zn) is immersed in copper sulphate solution ($CuSO_4$), the colour of the blue solution gradually fades, and red copper (Cu) deposits (Figure 16).
- Zinc (the more reactive) replaces copper (the less reactive) in copper sulphate solution.

$$Zn_{(s)} + \underset{\text{Blue}}{CuSO_{4(aq)}} \longrightarrow \underset{\text{Colourless}}{ZnSO_{4(aq)}} + \underset{\text{Red}}{Cu_{(s)}}\downarrow$$

Based on the above, we conclude that: According to the chemical reactivity series, the metal that comes earlier in the series can replace the metal that follows it in its salt solutions.

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Life Application

Silverware may lose its luster over time as a black layer of silver sulphide is formed. The silverware can be cleaned by placing it in a container of boiling water with sodium bicarbonate salt and a piece of aluminum foil. Because aluminum is more chemically reactive than silver, it replaces silver during the reaction, restoring its luster (Figure 17).



Figure (17)
Restoring the luster of silver

Cross-Cutting Concepts: Patterns

Chemists look for patterns in how chemical reactions occur. Chemical reactions are not random; they follow predictable patterns, such as combination, decomposition, or replacement.

Fourth Double Replacement Reactions

A reaction between two ionic compounds, usually in an aqueous solution, in which the anions and cations exchange their positions to form two new compounds, as shown in Figure (18).

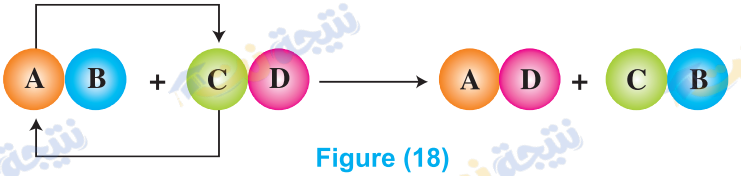


Figure (18)
Double replacement reaction

Examples of double replacement reactions include:

Cumulative Knowledge

- An ionic compound, such as sodium chloride salt (NaCl), consists of two parts:

1- A positive ion (or a positive atomic group), called a cation, such as sodium ion (Na^+).
2- A negative ion (or a negative atomic group), called an anion, such as chloride ion (Cl^-).

1 Reaction of an acid with an alkali (Neutralization Reaction)

Activity 7 Experiment and Conclude

Materials and Tools:

- Test tube.
- Dilute hydrochloric acid (HCl).
- Dilute sodium hydroxide solution ($NaOH$).
- Universal indicator.

Steps:

1. Place a suitable volume of dilute sodium hydroxide solution in the test tube.
2. Add drops of the universal indicator to it (Figure 19).
   What colour does the solution become? .....
3. Gradually add Dilute hydrochloric acid to the solution.
   What do you observe? .....
   What do you conclude? .....

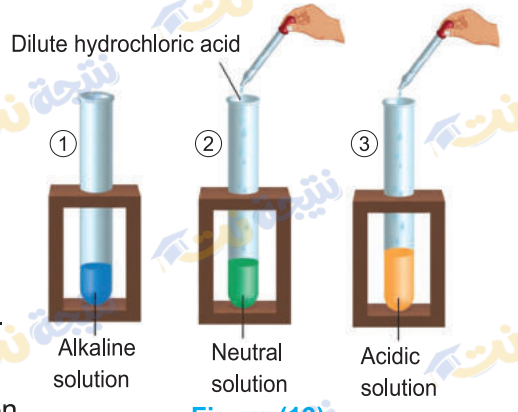


Figure (19)
Reaction of an acid with an alkali in the presence of a universal indicator

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• When the universal indicator is added to a solution, the solution develops a colour that depends on the degree of alkalinity or acidity of the solution (Figure 20).

• Sodium hydroxide solution (NaOH) is a clear, strong alkali that is colourless and it usually turns violet when the universal indicator is added to it.

• By adding dilute hydrochloric acid (HCl) gradually to the solution, its colour changes to green, and this state is called the neutralization point.



Figure (20)
Colours of the universal indicator in different solutions

• As more dilute hydrochloric acid is added, the colour of the solution changes gradually to yellow, then orange, and may reach red.

A reaction between dilute hydrochloric acid (an acid) and sodium hydroxide solution (an alkali) is a double replacement reaction, producing sodium chloride salt (neutral) and water. A reaction of an acid with an alkali producing a salt and water is called a "neutralization reaction".

$$HCl_{(aq)} + NaOH_{(aq)} \xrightarrow{\text{dil.}} NaCl_{(aq)} + H_2O_{(\ell)}$$

2 Reaction of an Acid with a Salt

Activity 8 Experiment and Conclude

Materials and Tools:

• Conical flask. • Dilute hydrochloric acid (HCl). • Sodium carbonate powder (Na_2CO_3).
• Stopper. • Delivery tube. • Funnel fitted with a stopcock. • Beaker.
• Clear limewater.

Steps:

1. Set up the apparatus as shown in Figure (21).
2. Put sodium carbonate powder in the flask.
3. Slowly open the stopcock to add the acid gradually to the powder.
4. Allow the evolved gas to pass into a beaker of clear limewater for a short time.

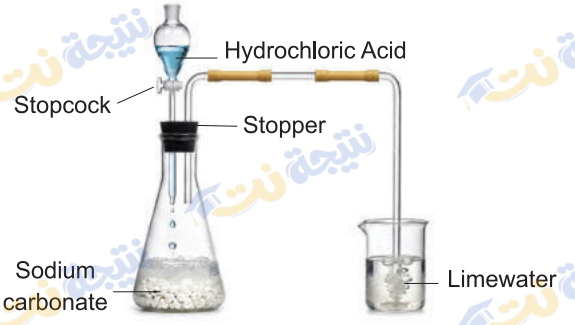


Figure (21)
Reaction of an acid with a salt

What do you observe? .....

What do you conclude? .....

When hydrochloric acid (HCl) reacts with sodium carbonate (Na_2CO_3), the ions exchange their positions, producing sodium chloride (NaCl), and carbonic acid (H_2CO_3) that decomposes into water (H_2O) and carbon dioxide (CO_2).

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \xrightarrow{\text{dil.}} 2NaCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}\uparrow$$

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3 Precipitation Reactions (between Two Salt Solutions)

Activity 9 Experiment and Conclude

Materials and Tools:

- Test tube.
- Sodium chloride solution ($NaCl$).
- Silver nitrate solution ($AgNO_3$).

Steps:

1. Put an amount of sodium chloride solution in the test tube.
2. Add drops of silver nitrate solution to sodium chloride solution (Figure 22).



Figure (22)
Precipitation reaction

What do you observe? .....

What do you conclude? .....

When silver nitrate solution ($AgNO_3$) is added to sodium chloride solution ($NaCl$), a double replacement reaction occurs, forming sodium nitrate solution ($NaNO_3$), and silver chloride salt ($AgCl$), which is a white precipitate because it is insoluble in water. This precipitate turns violet when exposed to light for a while.

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow NaNO_{3(aq)} + AgCl_{(s)} \downarrow$$

white precipitate

Check Your Understanding

You have two test tubes, each containing an equal amount of silver nitrate solution. Sodium chloride solution is added to the first tube, and a piece of aluminum is placed in the second.

(1) How can you conclude that a chemical reaction has occurred in each test tube?

.....

(2) What is the type of reaction occurring in each test tube?

.....

Life Application

Hard Water Treatment:

Some groundwater contains a high percentage of calcium and magnesium salts. This water is known as "hard water". It causes hard deposits inside water pipes (Figure 23), water heaters and washing machines, ultimately damaging them.

At water treatment plants, sodium carbonate is added to the water to remove these salts. Precipitation reactions occur as calcium and magnesium ions combine with carbonate ions to form insoluble solid precipitates, which then can be removed easily.



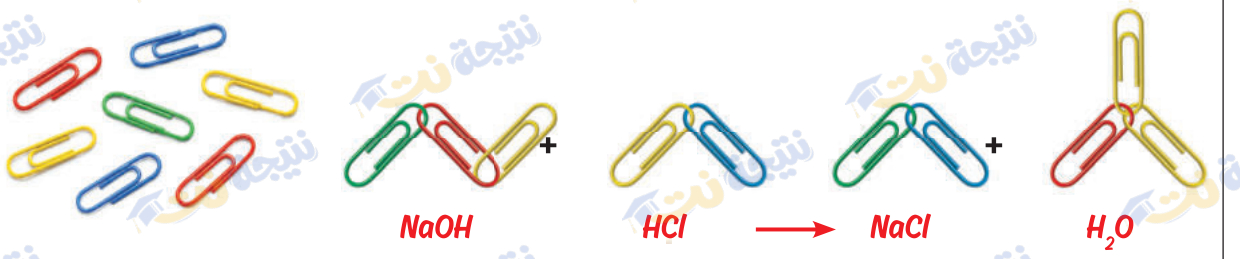
Figure (23)
Hard deposits inside water pipes

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Designing Models for Some Reactions

Collaborate with your classmates to design models illustrating the rearrangement of atoms in different types of reactions using coloured paper clips.

Example:



.....

.....

Oxidation-Reduction Reactions (Redox Reactions)

You learned that Oxidation is a chemical process that results in an increase in the percentage of oxygen, or a decrease in the percentage of hydrogen, in a substance whereas Reduction is a chemical process that results in an increase in the percentage of hydrogen , or a decrease in the percentage of oxygen, in a substance.

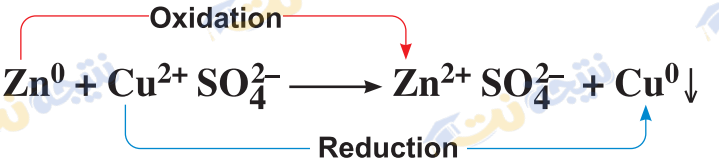
Are there chemical reactions in which oxidation and reduction occur without depending on a decrease or an increase in the percentage of oxygen or hydrogen in the reactants?



Figure (24)
Reaction of zinc with copper sulphate solution

Refer to Activity (6), which shows the reaction of zinc with blue copper sulphate solution to form zinc sulphate and copper (Figure 24). What happened to zinc and copper during the reaction?

- Before starting the reaction, zinc consisted of electrically neutral atoms, while copper was present as positive ions (cations) in the solution.
- **The chemical reaction occurs according to the equation:**



(1) During the reaction, a zinc atom loses two electrons and changes into a positive zinc ion (Zn^{2+}).

Half-reaction: "Oxidation" $Zn \longrightarrow Zn^{2+} + 2e^-$

Zinc atom — Zinc ion

The process of losing electrons by zinc atoms is known as oxidation, and zinc is the reducing agent.

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② Meanwhile, the positive copper ion gains these two electrons and changes into a neutral copper atom.

Half-reaction: "Reduction" $Cu^{2+} + 2e^- \longrightarrow Cu$

Copper ion — Copper atom

The process of gaining electrons by copper ions is known as reduction, and copper sulphate is the oxidizing agent.

Based on the above, we conclude that:

- Oxidation: A chemical process in which an atom or ion loses one electron or more.
- Reduction: A chemical process in which an atom or ion gains one electron or more.
- Oxidizing Agent: The substance that gains one electron or more during a chemica reaction.
- Reducing Agent: The substance that loses one electron or more during a chemical reaction.

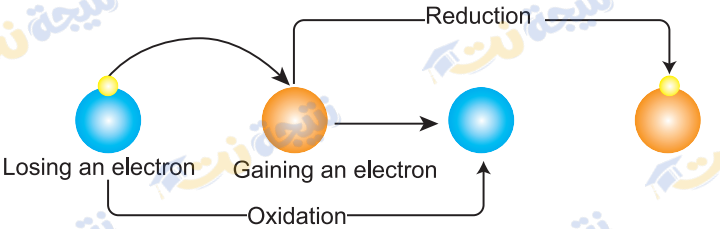


Figure (25)

Representation of an oxidation-reduction reaction

Note: Oxidation and reduction are two concurrent processes; that is, they occur at the same time, (Figure 25).

Check Your Understanding

Magnesium (Mg) reacts with bromine (Br_2) directly to form magnesium bromide, according to the equation:

$$Mg_{(s)} + Br_{2(\ell)} \longrightarrow MgBr_{2(s)}$$

Which substance...?

(1) is oxidized .....

(2) is reduced .....

(3) acts as an oxidizing agent .....

(4) acts as a reducing agent .....

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Assessment of Lesson One

1 Choose the correct answer for questions (1) – (5).

(1) Burning steel wool in air is an example of a ..... reaction.

(a) direct combination
(b) thermal decomposition
(c) single replacement
(d) double replacement

(2) You have two chemical reactions, (X) and (Y).

Reaction (X):

$2Na_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}\uparrow$

Reaction (Y):

$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$

Which of the following is correct about these two reactions?

(a) Both are single replacement reactions
(b) Both are double replacement reactions
(c) Reaction (X) is single replacement, while reaction (Y) is double replacement
(d) Reaction (X) is double replacement, while reaction (Y) is single replacement.

(3) Which gas evolves when red mercury oxide is heated?

(a) Oxygen (b) Hydrogen
(c) Nitrogen (d) Carbon dioxide

(4) When a zinc rod is immersed in copper sulphate solution, zinc .....

(a) is oxidized
(b) is reduced
(c) turns blue
(d) precipitates in the solution

(5) You have three test tubes numbered (1), (2), and (3), containing equal masses of zinc (Zn), lead (Pb), and magnesium (Mg), respectively. An equal volume of dilute hydrochloric acid is added to each metal, and the gas evolving from each tube is collected. What is the correct order of the test tubes according to the amount of gas collected one minute after the reaction begins?

(a) (3) < (2) < (1) (b) (1) < (2) < (3)
(c) (1) < (3) < (2) (d) (2) < (1) < (3)

2 Give reasons for :

(1) Silver does not react with dilute hydrochloric acid.
(2) A small piece of sodium moves rapidly when placed in a trough of water.
(3) Sodium reacts instantly and violently with cold water, whereas magnesium reacts only with hot water.
(4) Zinc is considered a reducing agent when reacting with blue copper sulphate solution.

3 Dilute hydrochloric acid reacts with each of the following :

(1) Sodium carbonate salt.
(2) Magnesium metal.
(3) Sodium hydroxide solution.

Write balanced symbolic chemical equations for these reactions, then classify them.

4 Explain how precipitation reactions are used to remove salts from hard water.

5 In terms of electron loss and gain, explain oxidation and reduction in the following chemical reaction:

$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}\uparrow$

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Lesson **Two**

Combustion Reactions and Environmental Pollution



Lesson Terminology

- Combustion
- Complete Combustion
- Incomplete Combustion
- Flammability
- Ignition Point
- Soot

Included Skills, Values and Issues:

- **Skills:** Practicality – Communication – Evaluation of Sources and Credibility.
- **Values:** Environmental Conservation.
- **Issues:** Future of Energy.

Cross-Cutting Concepts:

- Stability and Change
- Cause and Effect.

Lesson Objectives:

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

1. Explain scientifically the flammability of materials.
2. Compare the products of complete and incomplete combustion of some materials.
3. Conclude the properties of combustion products and their impact on the environment.
4. Design solutions to reduce pollution resulting from combustion reactions.

Lesson Introduction:

The opposite figure shows attempts to extinguish a forest fire. This lesson explores ideas that help answer the questions below:



- Why do tree leaves ignite easily, while a tree branch takes a longer time?
- What effect do forest fires have on the atmosphere?
- How can we protect the environment from pollution resulting from combustion?

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For combustion to occur, all three elements that form what is known as combustion triangle (fire triangle), Figure (1), must all be present. They are:

- Flammable material (fuel).
- Oxygen.
- Heat energy (ignition source).

But what happens if one of these elements is absent?



Figure (1)
Combustion triangle

Ignition Point and Flammability

Activity 1 Experiment and Conclude

Materials and Tools:

- Two identical strips of printing paper, one dry and the other wet with water.
- A candle.
- Metal tongs.
- A stopwatch.
- A heat-resistant board.

Steps:

1. Fix the candle onto the board, then light it.
2. Use the metal tongs to hold the dry paper strip.
3. Carefully bring the strip to about 2 cm above the tip of the candle flame.
4. Use the stopwatch to measure the time taken by the dry paper strip to start catching fire.
5. Use the tongs to hold the paper strip wet with water.
6. Carefully bring the strip to about 2 cm above the tip of the candle flame.
7. Use the stopwatch to measure the time taken by the wet paper strip to start catching fire.

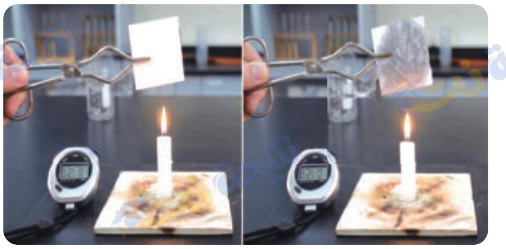


Figure (2)
Exploring the ignition point

Safety Precautions

- Wear goggles and heat-resistant gloves.
- Work on a stable, heat-resistant surface away from all flammable materials.
- Make sure a fire-extinguisher is available for emergency.

What do you observe?

.....

What do you conclude?

.....

Combustion begins only when a material reaches its ignition point. Dry paper reaches its ignition point quickly, while wet paper does not burn easily because water absorbs heat, which delays the paper from reaching its ignition point.

- Ignition point is the lowest temperature a material must reach to start catching fire and continue burning spontaneously.
- Flammability: expresses how easily and quickly a material ignites at the surrounding temperature.

Flammable substances (such as gasoline and alcohol) are classified as "highly flammable materials". Warning signs are placed on their containers to indicate their hazard (Figure 3).



Figure (3)
Warning sign for flammable materials

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Life Application

Ignition of matchsticks:

- The matchstick head contains several chemical compounds, most importantly an oxidizing agent such as potassium chlorate ($KClO_3$) and rapidly flammable substances, in addition to adhesives and glass powder or sand.
- The side of the matchbox contains red phosphorus, as well as adhesives and glass powder or sand.



Figure (4)
Ignition of a matchstick

- When a matchstick is ignited (Figure 4), the heat generated by friction converts a tiny amount of red phosphorus into white phosphorus, which ignites spontaneously in air and causes potassium chlorate ($KClO_3$) to decompose, producing potassium chloride (KCl) and oxygen (O_2), which helps the matchstick head and wood burn more intensely and rapidly.

Combustion Reactions

Combustion: is a chemical reaction between a substance and oxygen that releases heat, light, or both. It also produces new substances that vary according to the type of substance burned.

Activity 2 Experiment and Conclude

Materials and Tools:

- Magnesium ribbon (Mg) (sanded).
- Heat-resistant tongs.
- A piece of coal (C).
- Bunsen flame.

Steps:

1. Carefully hold the magnesium ribbon using the heat-resistant tongs.
2. Heat the ribbon in the flame until it ignites.
3. Repeat the previous two steps with the piece of coal.

What do you observe? .....

What do you conclude? .....

Combustion of Metals

- Magnesium (Mg) burns with bright white light, forming a white powder of magnesium oxide (MgO) (Figure 5).

$$2Mg_{(s)} + O_{2\,(g)} \xrightarrow{\Delta} 2MgO_{(s)}$$

Most metals burn and produce metal oxides that are basic.

- Some of these oxides dissolve in water, forming alkaline solutions, which turn litmus blue.



Figure (5)
Combustion of magnesium

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Combustion of Nonmetals

- Coal (carbon) (C) glows, and carbon dioxide gas evolves (CO_2) (Figure 6).

$$C_{(s)} + O_{2\,(g)} \xrightarrow{\Delta} CO_{2\,(g)}$$

- Most nonmetals burn and produce nonmetal oxides that are acidic.
- Most of these oxides dissolve in water, forming acids, which turn litmus red.



Figure (6)
Combustion of coal

Complete and Incomplete Combustion

Activity 3 Experiment and Conclude

Materials and Tools:

- Bunsen burner.
- Test tube.
- An amount of water.
- Test-tube tongs.

Steps:

1. Place an amount of water in the test tube.
2. Light the Bunsen burner with the air valve fully open until the flame turns blue.
3. Use the tongs to expose the test tube to the flame for one minute.
4. Partially close the burner's air valve until the flame turns yellow.
5. Expose the test tube to the yellow flame for one minute.

What do you observe? .....

What do you conclude? .....

- With the blue flame, the bottom of the test tube remains completely clean.
- With the yellow flame, a black powder of unburned carbon forms on the bottom of the test tube (Figure 7).

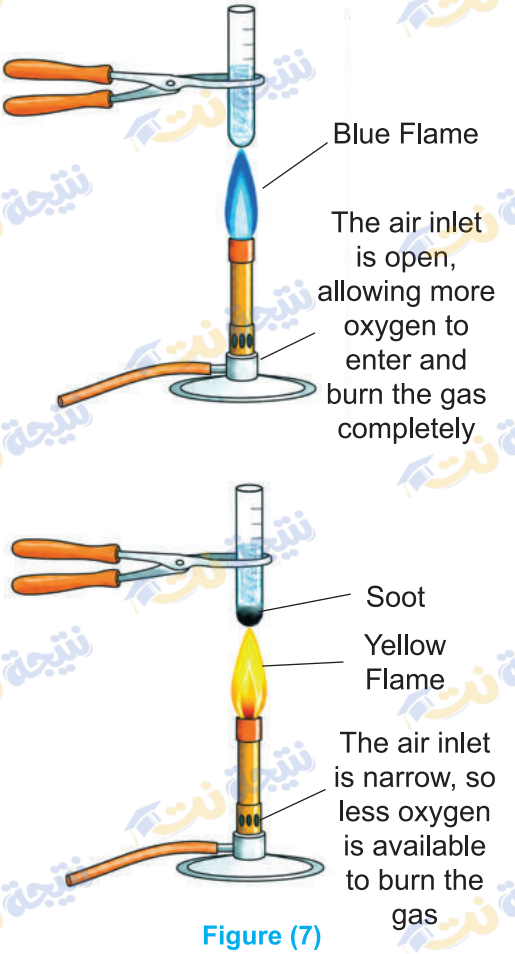


Figure (7)
Complete and incomplete Combustion of gas in a bunsen flame

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Cumulative Knowledge

► The gases used in Bunsen burners and domestic gas stoves belong to a group of chemical compounds known as **hydrocarbons**. These compounds are composed mainly of hydrogen and carbon. Natural gas consists mainly of methane, while butagas consists mostly of propane and butane.

Complete Combustion of Hydrocarbon Gases

Complete combustion of hydrocarbon gases, such as methane gas (CH_4) occurs in an abundant supply of oxygen gas (O_2), producing carbon dioxide gas (CO_2) and water vapor (H_2O) in addition to large amount of heat energy (Figure 8).

$$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + 2H_2O_{(v)} + \text{heat} \longrightarrow ①$$

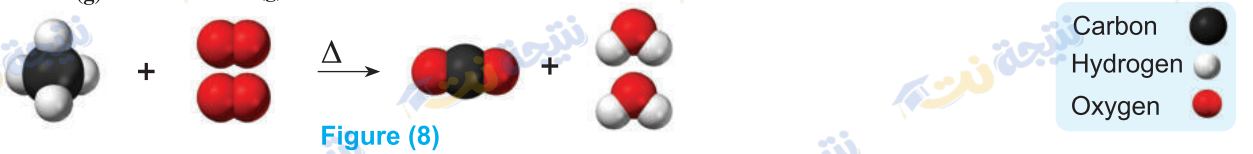


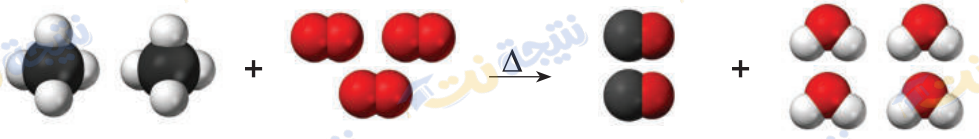
Figure (8)

Complete combustion of methane

Incomplete Combustion of Hydrocarbon Gases

It occurs when there is not enough oxygen. The products of incomplete combustion depend on the amount of oxygen available for the reaction. In the case of methane (CH_4), carbon monoxide (CO) gas may be produced along with water vapor (H_2O), or soot (a form of carbon) (C) and water vapor (H_2O) (Figure 9).

$$2CH_{4(g)} + 3O_{2(g)} \xrightarrow{\Delta} 2CO_{(g)} + 4H_2O_{(v)} + \text{heat} \longrightarrow ②$$



or

$$CH_{4(g)} + O_{2(g)} \xrightarrow{\Delta} C_{(s)} + 2H_2O_{(v)} + \text{heat} \longrightarrow ③$$



Figure (9)

Incomplete combustion of methane

Note:

Incomplete combustion of a given mass of a hydrocarbon fuel releases less thermal energy than complete combustion of the same mass of that fuel.

Check Your Understanding

Deduce the number of oxygen molecules needed to burn two methane molecules in each reaction represented by equations 1, 2 and 3

	Reaction ①	Reaction ②	Reaction ③
Number of oxygen molecules needed to burn two methane molecules	.....	.....	.....

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Life Application

Flame colour and Heating Efficiency:

The flame colour in a domestic gas stove indicates the type of combustion. The flame appears **blue** when enough oxygen is available for complete combustion of the gas. This combustion produces carbon dioxide and water vapor, in addition to a large amount of heat that enables faster cooking and lower gas consumption.

The flame colour may be **yellow or orange**, as shown in Figure (10), indicating incomplete combustion due to a lack of oxygen. This combustion produces toxic carbon monoxide gas and black soot that deposits on cookware, in addition to reducing heating efficiency.

In this case, the flame openings should be cleaned or the air intake adjusted to ensure safety and efficient use.



Figure (10)

Complete and incomplete combustion of butagas

Products of Combustion

We have learned how a combustion reaction occurs and its conditions: so, what are the products of this reaction?

Activity 4 Experiment and Conclude

Materials and Tools:

- A test tube containing an amount of clear limewater.
- A U-shaped tube containing light-blue anhydrous cobalt chloride paper ($CoCl_2$).
- A basin containing ice.
- A funnel
- Delivery tubes.
- Bunsen burner
- A stand.

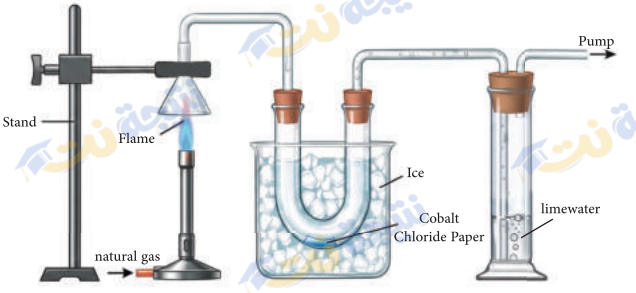


Figure (11)

Detection of combustion products

Steps:

1. Use the tools and materials to set up the apparatus shown in the opposite figure.
2. Light the Bunsen burner for a short time (for example, two minutes), as shown in Figure (11).

What do you observe? .....

What do you conclude? .....

- When hydrocarbon gases, such as natural gas, undergo complete combustion, they produce carbon dioxide gas (CO_2) and water vapor (H_2O).
- The ice around the U-shaped tube helps condense the water vapor produced by combustion. The resulting water changes anhydrous cobalt chloride paper from pale blue to pink.
- Clear limewater turns turbid due to its reaction with carbon dioxide gas.

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Properties of Combustion Products

Combustion products vary according to several factors, including the chemical composition of the burned substance and the amount of oxygen available for combustion. These products include:

- **Carbon dioxide gas (CO_2):** It is produced by the complete combustion of carbon-containing materials, such as organic substances. It is a colourless, odourless gas that **does not burn** or support combustion. It is also heavier than air and dissolves in water, forming carbonic acid (H_2CO_3).
- **Carbon monoxide gas (CO):** It is formed during incomplete combustion due to a lack of oxygen. It is a toxic colourless odourless gas.
- **Water vapor (H_2O) :** It is produced by the combustion of hydrogen and hydrogen-containing materials, such as hydrocarbons, and condenses into water droplets when cooled.
- **Carbon (soot, C) :** It is produced during the incomplete combustion of hydrocarbons as fine black solid particles that deposit on surfaces.
- **Sulphur dioxide gas (SO_2) :** It is produced when a fuel containing sulphur burns. It is a colourless gas with a choking odour and it dissolves in water, forming sulphurous acid **(H_2SO_3)**.
- **Nitrogen oxides (NO_x):** Nitrogen oxides are produced mainly by the combustion of nitrogen-containing compounds in fossil fuel. These oxides include nitric oxide **(NO)**, a colourless gas that reacts rapidly with oxygen in the atmosphere to form Nitrogen dioxide gas **(NO_2)**, which is a reddish-brown gas (Figure 12) with a pungent, choking odour. It dissolves in water, forming nitrous acid (HNO_2) and nitric acid (HNO_3).



Figure (12)
Nitrogen Dioxide Gas

Check Your Understanding

Choose:

(1) What are the products of complete combustion of methane?

(A) Carbon monoxide – hydrogen
(B) Sulphur dioxide – water vapor
(C) Carbon dioxide – water vapor
(D) Nitrogen dioxide – hydrogen

(2) Burning fuel containing sulphur impurities produces a gas with a choking odour that dissolves in water to form an acid. What is the gas, and what is the name of the acid it forms?

(A) Carbon dioxide – carbonic acid
(B) Sulphur dioxide – sulphurous acid
(C) Nitrogen dioxide – nitric acid
(D) Carbon monoxide – sulphurous acid

Cross-Cutting Concepts: Stability and Change

In combustion reactions, the composition of the reactants changes, but the total mass of the products equals the total mass of the reactants (the law of conservation of matter). Combustion reactions can also change environmental factors and even human health over time.

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Combustion reactions and environmental pollution

Combustion reactions, especially incomplete combustion, produce gases and substances that pollute the environment. Polluting combustion processes include:

Burning of Agricultural Wastes

- Some farmers burn "rice straw" in fields at the end of the harvest season (usually in October and November every year) in order to get rid of it and prepare the land quickly for planting the next crop.
- Rice straw often undergoes incomplete combustion because it is piled up, preventing the adequate amount of oxygen to pass through the piles.
- Large amounts of carbon monoxide, carbon dioxide, and suspended carbon particles (soot) are released forming dense smoke known as "the black cloud", (Figure 13).
- The **black cloud** reduces visibility, causes breathing difficulty, and increases the cases of asthma and chest allergies.



Figure (13)
Burning of agricultural wastes

Research Activity

Search online for other alternatives that make use of rice straw instead of burning it.

Combustion in Car Engines

- Burning fuel inside a car engine produces thermal energy that generates the mechanical energy needed to move the car.
- This combustion produces a mixture of emissions known as exhaust (Figure 14).
- Car exhaust consists of harmful gases and substances, such as carbon monoxide, carbon dioxide, carbon (soot), and nitrogen oxides.
- Car exhaust is one of the main causes of air pollution in cities.
- In some cases, fuel combustion in an engine is incomplete, either because too little air is pumped into it or because engine efficiency is low. This increases harmful emissions and environmental pollution.
- **Pollution caused by car exhaust can be reduced through several measures, including:**
  1. Regular maintenance of car engines to improve their efficiency.
  2. Using cleaner fuels for vehicles, such as natural gas, or switching to electric cars.
  3. Relying on eco-friendly public transportation.



Figure (14)
Car exhaust

Technological Application

Catalytic Converter in Cars (Exhaust Emission Control Device):

The catalytic converter (Figure 15) is used to reduce environmental pollution caused by fuel combustion in a car engine. Its operating principle depends on the presence of catalysts (substances that increase the rate of a chemical reaction without being changed). These catalysts speed up redox reactions in the exhaust system, converting toxic gases such as carbon monoxide and nitrogen oxides into safer substances such as carbon dioxide and nitrogen.



Figure (15)
Catalytic converter

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Combustion Reactions in Industry



Figure (16)
Pollution caused by combustion in industry

- Combustion reactions **are a main source of energy** in many heavy industries, such as metal smelting, ceramic production, cement and glass manufacturing, and petroleum distillation.
- Many power plants rely on burning fossil fuels (such as coal and natural gas) to produce steam that drives turbines and then electric generators.
- **Pollution caused by combustion processes in industry (Figure 16) can be reduced through several measures, including:**

1. Using natural gas as a fuel because it causes less environmental pollution.
2. Installing filters to purify gases before they leave factory chimneys.
3. Using renewable energy sources to generate electricity, such as solar and wind energy.

Why is natural gas preferred to coal as a source of heat energy?

- **Combustion of natural gas** is less harmful to the environment. Compared with the combustion of other fossil fuels, it produces low carbon dioxide emissions, while emissions of sulphur oxides and carbon particles are very low.

Cross-Cutting Concepts: Cause and Effect

Increased Combustion processes (Cause) leads to emissions that disrupt ecological balance (Effect).

- By contrast, **combustion of coal** produces a very high proportion of carbon dioxide and greater amounts of sulphur oxides and carbon particles.

Technological Application

Acid Gas Scrubbers:

These devices reduce industrial pollution caused by combustion. Their principle of work is based on passing toxic acidic gases, such as sulphur dioxide, through a spray of alkaline solutions as the gases travel through factory chimneys. Neutralization reactions occur, producing safe precipitated salts, reducing the possibility of forming acid rain and smog (Figure 17).

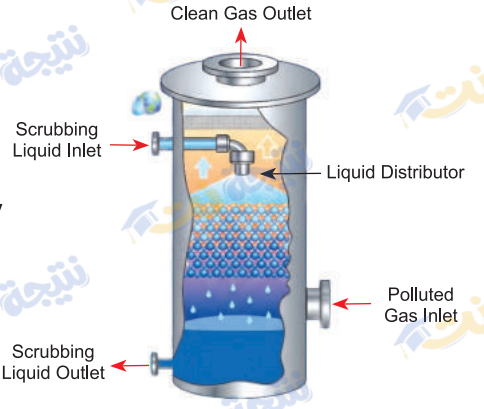


Figure (17)
Acid gas scrubbing

Be an Environmental Engineer

Design a Cleaner Future

Imagine that you are a member of an environmental protection team. Choose one environmental problem (the black cloud, car exhaust, or waste burning).

Suggest **practical solutions** to reduce it, such as:

- Technologies to reduce harmful emissions from combustion products.
- Designing a filter to convert harmful gases from incomplete combustion into less harmful gases.

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Assessment of Lesson Two

1 Choose the correct answer for questions (1) - (5).

(1) Why does the percentage of harmful gases in car exhaust increase when the engine is not properly maintained?

(a) Because the fuel does not burn completely.
(b) Because the fuel combustion rate increases.
(c) Because the engine temperature decreases.
(d) Because water vapor condenses inside the engine.

(2) How many oxygen molecules are needed for the complete combustion of 4 methane molecules?

(a) 2 (b) 4
(c) 6 (d) 8

(3) Which of the following gases is brown, has a pungent odour and is produced by the combustion of an impurity in fossil fuel?

(a) Nitric oxide.
(b) Carbon monoxide.
(c) Sulphur dioxide.
(d) Nitrogen dioxide.

(4) The matchstick head contains .....

(a) mercury oxide and glass powder.
(b) red phosphorus and glass powder.
(c) Sulphur and red phosphorus.
(d) potassium chlorate and antimony Sulphide.

(5) The colour of anhydrous cobalt chloride changes from blue to pink in the presence of .....

(a) H_2O (b) CO_2
(c) NO_2 (d) SO_2

2 Define each of the following:

(1) The black cloud. **(2)** Combustion.
(3) Flammability. **(4)** Acid rain.

3 Give reasons for the following :

(1) Carbon monoxide is considered dangerous to humans.

(2) Black soot is produced when a candle burns in a small amount of oxygen.

(3) The black cloud forms as a result of some farmers burning "rice straw" in fields.

(4) Natural gas is preferred as a fuel compared to coal.

4 Write a balanced chemical equation for each of the following:

(1) Complete combustion of methane gas.

(2) Incomplete combustion of methane gas, producing carbon monoxide.

(3) Combustion of carbon in air.

5 Explain how fuel combustion contributes to air pollution.

6 You have two burners that both use butagas. The first burns with a blue flame, while the second burns with a smoky yellow flame:

(1) Explain the difference in flame colour in both cases.

(2) Which one produces gases that cause more direct harm to humans?

7 Compare:

The catalytic converter in cars **and** The acid gas scrubber in factories.

(In terms of purpose, operating method, and the main gases treated.)

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Lesson Three

Smoking and Its Hazards



Lesson Terminology :

- Tobacco
- Nicotine
- Tar
- Mineral Elements
- Radioactive Elements
- Emphysema
- Traditional Smoking
- Active Smoking
- Passive Smoking
- Vaping
- World Health Organization (WHO)

Included Skills, Values and Issues:

- **Skills** : Practical – Communication – Evaluation of Sources and Reliability.
- **Value** : Self-Preservation.
- **Issues** : Hazards of Vaping and Regular Cigarettes.

Cross-Cutting Concepts:

- Structure and Function.

Lesson Objectives :

By the end of the lesson, students will be able to :

1. List some of the chemical substances that are contained in tobacco.
2. Identify the chemicals produced by tobacco combustion.
3. Distinguish among types of smoking (active smoking, passive smoking, traditional smoking, and vaping).
4. Evaluate the harmful effects of smoking forms on smokers and those around them.
5. Evaluate the harmful effects of smoking on the environment.
6. Contribute to preparing awareness materials (printed or digital) against smoking.

Lesson Introduction :

The opposite figure shows a behavior that threatens public health.

This lesson explores ideas that help answer the questions below:

- What are the components of cigarette smoke?
- What effect does this behavior have on human health?
- Why should people quit smoking?



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Tobacco plant grows mainly in warm regions, particularly tropical regions. It is characterized by a thick, upright stem, large green leaves and tubular-shaped flowers that may be white (Figure 1), pink, or red. What substances does tobacco contain, and what are the combustion products of these substances?



Figure (1)
Tobacco plant

A simple, well-known experiment is often used to collect and identify the combustion products of tobacco. Researchers use a transparent plastic bottle with a hole near the bottom. This hole is tightly sealed with a stopper, and the bottle is filled with water to about two-thirds of its capacity. (Figure 2-a), as follows:

1. A hole in the bottle cap is made to fix the cigarette tightly.
2. A piece of white cotton is packed into the mouth of the bottle then the bottle is closed (Figure 2-b).
3. The cigarette is lit and the stopper is removed. As water flows out of the bottle, a stream of air passes through the cigarette into the bottle, carrying its combustion products (Figure 2-c).



(Figure 2-a) (Figure 2-b) (Figure 2-c)

Figure (2)
Exploring tobacco combustion products

It is observed that: As the cigarette smoke passes through the piece of cotton , its colour changes from white to dark or brown as some combustion products deposit among the cotton fibers (Figure 3).



Figure (3)
Tobacco combustion products

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Tobacco plant leaves (Figure 4) contain many chemical substances. The most important are :



Figure (4)
Dried tobacco leaves

1 Nicotine

- A natural organic compound that contains carbon, hydrogen, and nitrogen in its chemical structure and has an alkaline effect.
- The high temperature generated when a cigarette is lit causes nicotine to vaporize and change into a gas, which then mixes with the smoke and is inhaled by the smoker. The combustion of tobacco leaves and their components releases a mixture of harmful gases, **including:**

1. **Toxic Gases** such as carbon monoxide (CO) and hydrogen cyanide (HCN).
2. **Gases that irritate to the respiratory system**, such as nitrogen oxides (NO and NO_2) and ammonia gas (NH_3).



Figure (5)
Cigarette components

2 Carbohydrates and Proteins

Substances found in tobacco leaves (Figure 5), **when burned, produce** carbon monoxide and tar, which is a viscous liquid made up of a mixture of the combustion products of sugars, plant proteins, and fibers.

3 Mineral Elements

Tobacco contains mineral elements such as potassium, magnesium, and calcium, as well as toxic heavy elements, most importantly cadmium, lead, and arsenic.



Figure (6)
Incomplete combustion of a lit cigarette

4 Radioactive Elements

- Small amounts of radioactive Elements such as polonium-210 can cause radiation damage to a smoker's lungs.
- **During smoking, mineral and radioactive elements pass through the following stages:**

1. **Volatilization:** Some heavy metals and radioactive elements vaporize when tobacco ignites, becoming gases or adhering to fine tar particles.
2. **Inhalation:** Radioactive atoms enter the lungs and deposit in the "bronchi branches."
3. **Radioactive Accumulation:** The accumulation of radioactive elements causes DNA damage in lung cells. This damage increases the risk of developing cancerous tumors.
4. **Ash:** The residual ash contains nonvolatile minerals (such as calcium and potassium), which give the ash its white or gray colour (Figure 6).

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A cigarette is not merely a paper roll containing dried plant leaves. Once the cigarette is lit and the tobacco leaves burn, complex chemical reactions occur and produce several thousand chemicals, most of which are toxic gases and carcinogenic substances. Therefore, tobacco smoking is considered one of the greatest threats to public health. It is estimated to cause more than 8 million deaths worldwide every year, according to reports from the World Health Organization (WHO) and the Egyptian Ministry of Health (Figure 7).



Figure (7)
Egyptian ministry of health poster

Research activity

Search online for "World No Tobacco Day" and international efforts toward a smoke-free world.

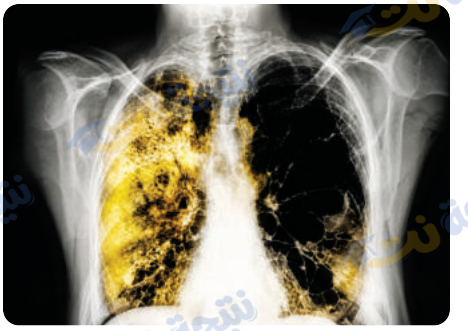


Figure (8)
X-ray image of a smoker's lungs

Harmful Effects of Smoking

First Health Hazards

The chemicals produced by combustion combine to attack the body's vital systems as follows:

1 Respiratory System

Activity 1 Observe and Explain

Figure (9) shows smoker's lungs compared with normal lungs. Observe and answer the following questions:

1. **Why** does the colour of lungs differ in the two cases?
.....
2. **Which** lungs have a greater ability to supply the blood with oxygen?
.....
3. **How** does a smoker's lung capacity change over time?
.....



Normal lungs Smoker's lungs

Figure (9)
Smoker's lungs compared with normal lungs

Smoking changes the lungs from their normal **pink** colour to a **dark or black colour** (Figure 9) due to the deposition of **tar** and fine chemical particles within the lung tissues. Over time, the lungs lose their elasticity and their capacity gradually decreases. So, smokers suffer from chronic shortness of breath, continuous coughing, and a noticeable decline in the ability to perform physical activity. The risk of **lung cancer also increases**.

Cross-Cutting Concepts: Structure and Function

Alveoli in the lungs are small, thin-walled, and numerous structures (structure), providing a large surface area that allows gas exchange (oxygen and carbon dioxide) between the lungs and blood (function).

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Integration with the Medical Field

Emphysema:

- **Smoking may cause a smoker to develop emphysema.**
- **When smoke is inhaled, sticky tar condenses and gradually deposits on the inner walls of the alveoli, causing lung tissue to lose its elasticity.**
- **As tar continues to accumulate, the walls of the alveoli rupture and change from numerous small sacs into large, sagging cavities (Figure 10).**
- **As a result, the surface area available for gas exchange decreases greatly, reducing the amount of oxygen that reaches the blood. The patient suffers from severe, chronic difficulty breathing.**

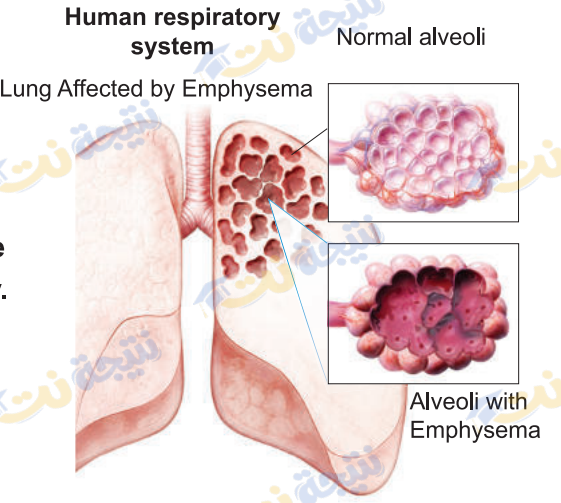


Figure (10)
Comparison of normal and damaged alveoli

2 Circulatory System (Heart)

Carbon monoxide produced by smoking binds to blood hemoglobin much faster than oxygen does, reducing the amount of oxygen carried in the blood. Nicotine also increases heart rate, raises blood pressure, and constricts blood vessels, which increases the risk of heart disease and atherosclerosis (Figure 11).

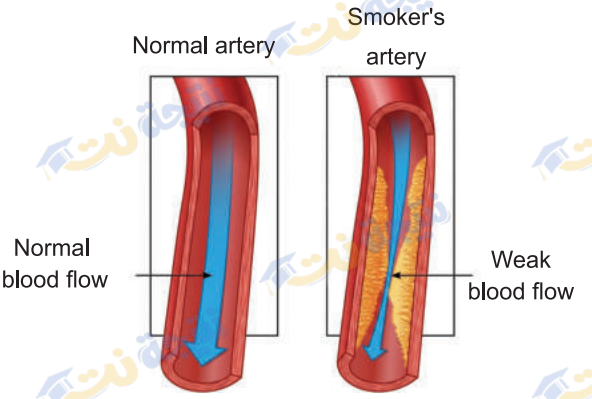


Figure (11)
Smoking-induced vasoconstriction

3 Nervous System and Senses

Toxins from smoking cause disorders in the nervous system. Nicotine may increase anxiety and cause sleep and vision disorders. In the long term, it may negatively affect brain function and concentration, especially in adolescents.

4 Fertility and Reproductive Health

Smoking negatively affects fertility (the ability to reproduce) in both genders and increases the risk of fetal abnormalities.

5 Immune System and General Appearance

Smoking weakens the immune system. Its effects are also evident in pale skin and hair loss.

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Check Your Understanding

(1) Choose the correct answer:

Tobacco smoking produces a toxic, colourless, odourless gas (X) and a dark, sticky substance (Y). What do (X) and (Y) represent, respectively?

(A) Carbon dioxide / nicotine
(B) Carbon monoxide / tar
(C) Carbon monoxide / lead
(D) Carbon dioxide / lead

(2) Explain: Smoking can reduce the amount of oxygen carried by the blood and cause chronic shortness of breath.

Health and Community Awareness

- When a person smokes, nicotine quickly reaches the brain.
- It stimulates the secretion of substances that cause a temporary feeling of well-being.
- This effect fades quickly, craving another trial.
- Repeated smoking leads to addiction, causing smoking to be harmful habit that is difficult to quit (Figure 12).



Figure (12)

Second Environmental Damage

The harm caused by smoking is not limited to people; its negative effects extend to ecosystems:

1. **Air Pollution:** Large amounts of carbon dioxide produced by smoking are released into the atmosphere, further contributing to **global warming**.
2. **Water and Soil Pollution:** Cigarette butts are among the most widespread forms of litter. They contain harmful chemicals that leach into the soil and water and affect living organisms (Figure 13).

Enrichment Information

Global Warming: An increase in Earth's temperature due to a rise in the proportion of certain gases in the atmosphere.



World Health Organization:
Several trillion cigarette filters end up in oceans, rivers, on sidewalks, floors, and on beaches every year.



World Health Organization:
Smoking releases tens of millions of tons of carbon dioxide into Earth's atmosphere.

Figure (13)
Environmental damage caused by smoking

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Activity 2 Analyse and Conclude

Several people in different situations:

Situation (A): Person (X) smokes a cigarette and exhales smoke into the air.

Situation (B): Person (Y), a non-smoker, sits next to another person who smokes a cigarette and exhales smoke into the air.

Situation (C): Person (Z) uses a vape (e-cigarette) and exhales aerosol (vapor) into the air.

Answer the following questions:

1. **What are** the similarities and differences among the three situations?

.....

2. **In which of** the three situations does smoke or aerosol enter a person's body directly?

.....

3. **In which** situation does smoking cause harm to a person involuntarily?

.....

Based on the above, we conclude that:

There are different forms of smoking. In each one, a person or those nearby inhale harmful substances (smoke or vapor) that negatively affect their health.

Types of Smoking

Types of smoking include:

1 Traditional Smoking

Traditional smoking relies on burning the tobacco leaves in cigarettes.

2 Vaping (E-Smoking)

Vaping relies on heating a nicotine-containing liquid with an electronic device.
There is a common misconception that vaping is less harmful than traditional smoking. However, it has been proven that both cause severe, direct damage to the lungs and heart. In addition, the high nicotine concentration in vaping also causes rapid addiction and may lead to acute disorders of the heart and nervous system functions.

Exposure to Smoking Products

The danger of smoking is not limited to its types and methods; it also includes the different ways people are exposed to its toxins. Forms of exposure to smoking can be classified into:

1 Active Smoking

Active smoking occurs when a smoker deliberately inhales smoke from burning tobacco or aerosol released by vaping devices into the lungs.

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2 Passive smoking

It occurs when non-smokers inhale Smoke exhaled by a smoker, or smoke released from the burning tip of a cigarette. This smoke contains higher concentrations of toxic and carcinogenic gases because it has not passed through the cigarette filter. Therefore, non-smokers are at risk of the same heart and respiratory diseases that may affect active smokers.



Health Awareness

Prevention of smoking begins with a conscious personal decision supported by the surrounding environment and healthy behaviors.

Ways to Prevent Smoking:

- **Decide to refuse:** Learn to say "**No**" to anyone who offers you to smoke.
- **Choose positive friends:** Stay away from peers who encourage smoking, and befriend those who take care of their health.
- **Keep yourself engaged in positive and beneficial activities:** Such as exercise or reading or hobbies.
- **Avoid smoking areas:** Stay away from places where smoke is prevalent to protect yourself from passive smoking.
- **Ask for help when needed:** If you feel pressured by someone to try smoking, talk to a parent or a teacher.
- **Learn about the harmful effects of smoking:** The more you know about its harmful hazards, the better you can avoid it.



Issue for Discussion

Does vaping pose less risk than active smoking?

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Assessment of Lesson Three

1 Choose the correct answer for questions (1)–(6).

(1) Which of the following substances causes addiction to cigarette smoking?

(a) Tar. (b) Nicotine.
(c) Water vapor. (d) Oxygen.

(2) Which of the following gases, if inhaled, reduces the blood's ability to carry oxygen?

(a) Carbon dioxide. (b) Nitrogen.
(c) Carbon monoxide. (d) Oxygen.

(3) The walls of the alveoli become damaged and the surface area available for gas exchange decreases due to the accumulation of .....

(a) nicotine. (b) tar.
(c) lead. (d) ash.

(4) Which body organs are directly damaged by smoking, negatively affecting human health and activity?

(a) Lungs. (b) Teeth.
(c) Bones. (d) Nails.

(5) Hazard of tobacco smoking lies in the fact that it .....

(a) produces toxic and carcinogenic substances.
(b) increases the amount of oxygen in the blood.
(c) improves lung function.
(d) reduces air pollution.

(6) Which of the following elements is radioactive and leaks into Lungs during cigarette smoking?

(a) Cadmium. (b) Lead.
(c) Polonium. (d) Arsenic.

2 Define each of the following:

(1) Active smoking. (2) Emphysema.
(3) Tar. (4) Vaping.

3 Give reasons for the following :

(1) Smoking is a harmful habit that is difficult to quit.
(2) A smoker suffers chronic shortage of breath over time.
(3) Vaping is not less harmful than traditional smoking.

4 State one effect of smoking on each of the following:

(1) The nervous system.
(2) The circulatory system.
(3) The surrounding environment.

5 Two people are in front of you: one is smoking and the other is standing nearby:

(1) What harmful gases or substances might the person standing next to the smoker inhale?
(2) Suggest two ways to reduce passive smoking.



6 Write a short paragraph explaining the importance of raising awareness about the risks of smoking to human health and the environment.

7 A friend tells you that some classmates are offering him a cigarette. He finds it difficult to refuse their request. In light of what you have learned, **write** three specific, practical tips that will help him decide to refuse and protect his health.

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UNIT 2

Electricity and Magnetism

Unit Lessons

Lesson One : Electric Current

Lesson Two : Electric Circuits

Lesson Three : Electric and Magnetic Forces



Learning Outcomes:

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

1. Collect data from reliable scientific sources about the components of an electric circuit and various electrical measuring instruments.
2. Compare series and parallel electric circuits..
3. Verify Ohm's Law experimentally.
4. Calculate the cost and rate of electrical energy consumption at home.
5. Collect information about devices that use electric and magnetic forces, such as an electromagnet, electric motor, and electric generator.
6. Explain how the number of wire turns and electric current intensity affect the strength of an electromagnet.
7. Explain how the number or strength of magnets, number of turns, and electric current intensity affect the rotational speed of an electric motor.
8. Explain how increasing the rotational speed of an electric generator coil relative to the magnet affects the generated electromotive force.

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Lesson One

Electric Current



Lesson Terminology:

- Free Electrons
- Electric Current
- Electric Current Intensity
- Conductor
- Potential Difference
- Electromotive Force
- Electric Cell
- Battery
- Direct Current (DC)
- Alternating Current (AC)
- Electric Resistance

Included Skills, Values, and Issues

- **Skills:** Practical – Cognitive – Communication – Data Analysis – Mathematical.
- **Values:** Collaboration – Self-Perservation
- **Issues:** Resource conservation.

Cross-Cutting Concepts:

- Cause and Effect.

Lesson Objectives:

By the end of the lesson, students will be able to:

1. Define the concepts of electric current and electric current intensity.
2. Conclude the concepts of electric potential difference and electromotive force.
3. Compare the two ways of connecting electric cells: in series and in parallel.
4. Identify the types of electric resistance.
5. Conclude the factors affecting the electric resistance of a conductor.
6. Appreciate the role of scientists in inventing and developing electric devices that serve humanity.
7. Design a simple electric circuit using standard symbols.

Lesson Introduction:

The opposite figure shows how one of the light bulbs in a household electric circuit is turned on.

This lesson explores the ideas that will help you answer the questions below:



- Why do the light bulbs light up as soon as the light switch is pressed?
- Why do some light bulbs shine brighter than others?
- Can the intensity of the light emitted by the bulbs be controlled?

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You have learned that metals such as copper and aluminum are good conductors of electricity because their atoms tend to lose some electrons, which become free. **Free electrons** are electric charges that move within the metal.

Activity 1 Observe and Conclude

Figure (1) shows a bicycle transmission system, and Figure (2) shows a simple electric circuit.

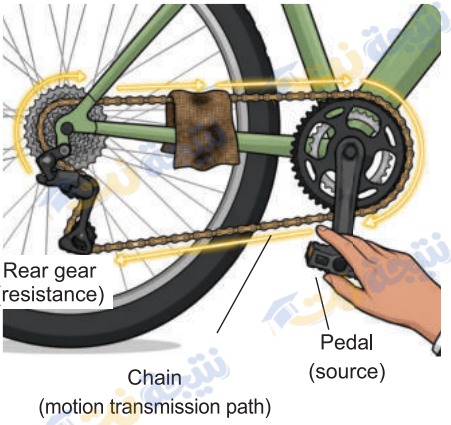


Figure (1)
Bicycle transmission system

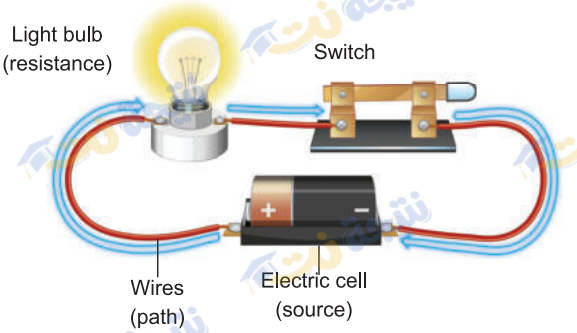


Figure (2)
Simple electric circuit

When the bicycle pedal is moved or the electric circuit is closed, a type of motion begins in both systems.

1. While the pedals cause the links of the bicycle chain to move, what moves through the components of the electric circuit?

.....

2. All the links in the chain move together at the same rate; does the same apply to what flows through the electric circuit?

.....

3. When something obstructs the moving bicycle chain, it slows down. Is there something similar in an electric circuit?

.....

What do you conclude?

Metals contain an abundance of free electrons that move randomly (Figure 3). When metal wires form a closed electric circuit, the electric cell pushes these free electrons in one direction along a continuous path (Figure 2). The flow of the electric charges through a conducting material is called electric current (Figure 4).

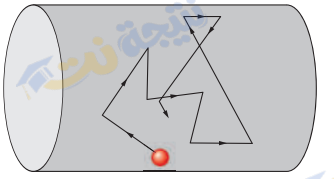


Figure (3)
Random motion of a free electron

For electric current to flow through an electric circuit, the following are required:

1. An electric source to drive the electric charges.
2. A closed electric circuit so that the electric charges can flow through a closed path.

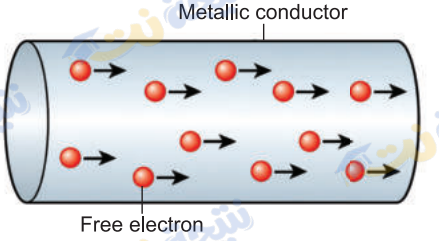


Figure (4)
Flow of free electrons

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Electric Current Intensity

Imagine you were observing the movement of cars crossing a specific line on a racetrack (Figure 5). During the first lap of the race, 10 cars crossed the line in one minute, while during the second lap, 5 cars crossed the line in one minute.

In which of the two laps was the rate of cars passing the line higher?

.....



Figure (5)
Cars on a racetrack

The motion of cars on a racetrack is somewhat similar to the flow of electric charges through an electric circuit. The number of cars crossing the line per unit time is analogous to what is known as the electric current intensity in an electric circuit.

Electric current intensity: expresses 'the quantity of electric charge that passes through a cross-section of a conductor per second' (Figure 6).

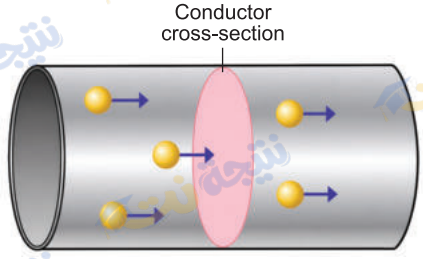


Figure (6)
Electric charges passing through a cross-section of the conductor

Suppose a quantity of electric charge (Q) coulombs passes through a cross-section of a conductor in time (t) seconds. The electric current intensity (I) through the conductor is given by the equation: $I = \frac{Q}{t}$

The unit of measuring the electric current intensity is the ampere (A). The ampere is equivalent to coulomb per second (C/s).

To measure the electric current intensity in an electric circuit, we use an ammeter (Figure 7). The ammeter is connected in series with the component through which the current intensity is to be measured (Figure 8).

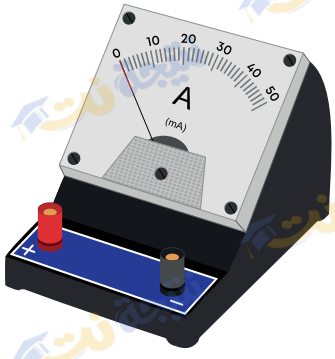


Figure (7)
Ammeter

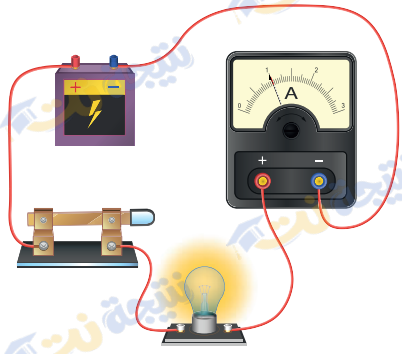


Figure (8)
Connecting an ammeter in an electric circuit

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Electric Potential Difference Between Two Points

Activity 2 Predict and Conclude

Materials and Tools:

Two transparent containers, (X) and (Y), connected by a tube fitted with a valve.

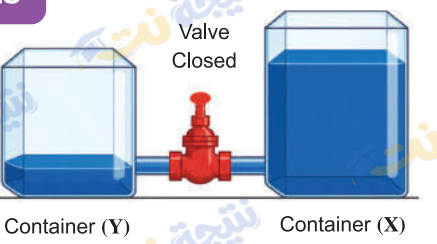


Figure (9)

Steps :

1. With the valve closed, pour water in the two containers so that the water level in container (X) is higher than that in container (Y) (Figure 9).
2. Predict what will happen when the valve between the two containers is opened?

.....

3. Open the valve between the two containers (Figure 10).

What do you observe? .....

What do you conclude? .....

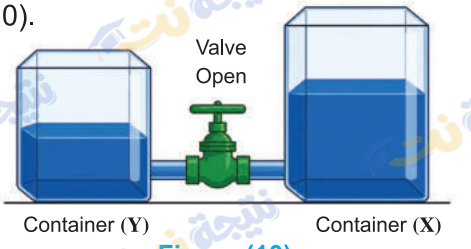


Figure (10)

The difference in the water levels in the two containers causes a difference in water pressure on the two sides of the valve.

When the valve is opened, water flows from container (X), where water pressure on this side of the valve is higher, to container (Y), where water pressure is lower.

As the water levels in the two containers become equal, the pressure on both sides of the valve also becomes equal and the flow of water stops (Figure 11).

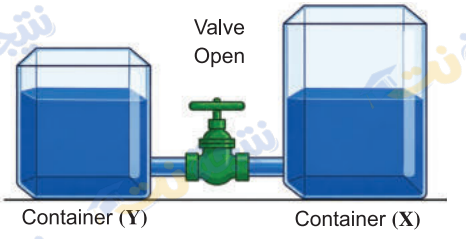


Figure (11)

In a similar way, electric charges flow through a conductor from a point of higher electric potential to a point of lower electric potential.

By convention, the electric current flows through a circuit from the positive pole of the electrical source, which is of higher electric potential, to its negative pole which is of lower electric potential.

No electric current flows between two points in an electric circuit if there is no electric potential difference between them.

Cross-Cutting Concepts:

Cause and Effect

An electric potential difference between the terminals of a conductor (Cause).

causes an electric current to pass through that conductor (Effect).

Enrichment Information

- Free electrons flow through the electric circuit from the negative pole of the source toward its positive pole (Figure 12).
- Before electrons were discovered, scientists defined electric current as flowing from the positive pole to the negative pole. This convention is used throughout this unit.

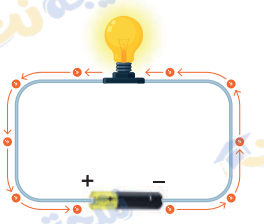


Figure (12)
Direction of free electrons

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The electric potential difference between two points (Voltage) is the work done to move one coulomb of electric charge between these two points.

If (W) joules of work are done to move (Q) coulombs of electric charge between two points, the electric potential difference (V) between those two points is given by the equation:

$$V = \frac{W}{Q}$$

The unit of measuring potential difference is the volt (V). The volt is equivalent to joule per coulomb (J/C).

To measure the potential difference between two points in an electric circuit, we use a voltmeter (Figure 13). The voltmeter is connected in parallel across those two points (Figure 14).

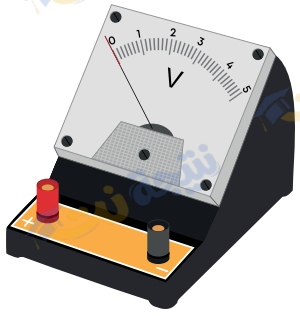


Figure (13)
Voltmeter

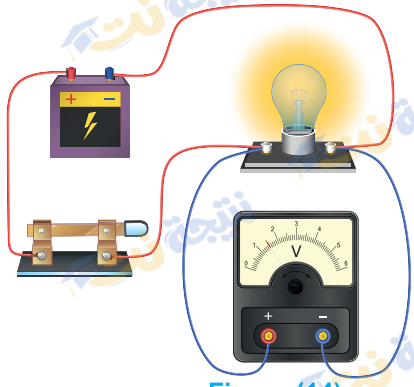


Figure (14)
Measuring the potential difference across a light bulb

Electromotive Force

The electric source: is the source of electrical energy in a circuit, responsible for driving electric charges through it.

There are two types of electric sources:

1. **Direct-voltage source: such as** an electric cell (Figure 15) and a battery (Figure 16). They supply a direct current that has constant intensity and flows in one direction in the circuit.
2. **Alternating-voltage source: such as** an alternating-current generator (Figure 17). It supplies an alternating current whose value and direction change with time.



Figure (15)
Electric cell

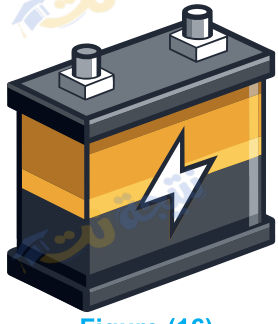


Figure (16)
Battery

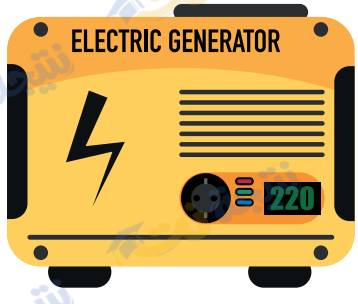


Figure (17)
Electric generator

The total work done by an electrical source to move one coulomb of electric charge through the whole electric circuit is called the electromotive force (*emf*) of the source. It is denoted by the Greek letter epsilon (ε) and is measured in volts.

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For electric charges to move continuously, the circuit must form a complete conducting path. Therefore, electric current flows through the source as well as through the external circuit components. Therefore, the electromotive force (ε) is divided into an external potential difference (V) across the battery terminals and an internal potential difference within the source to overcome the internal resistance.
Thus, ($\varepsilon > V$).



Figure (18)
Measuring the potential difference between the terminals of an electric cell.

In this unit, for simplicity, we assume that the internal resistance of the electrical sources is negligible because it is very small. Therefore, we consider the potential difference between the battery terminals (V) is equal to its electromotive force (ε).

Connecting Electric Cells

A single electric cell provides a limited electromotive force that may not be sufficient to power some devices. Therefore, a number of cells are connected together to provide the required electromotive force. A group of connected electric cells is called a 'battery'. One example is the battery used in an electric vehicle (Figure 19)

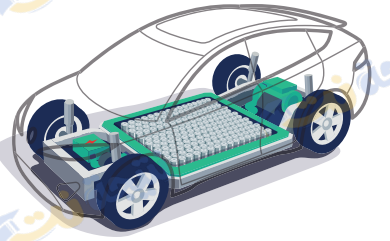


Figure (19)
Electric vehicle battery

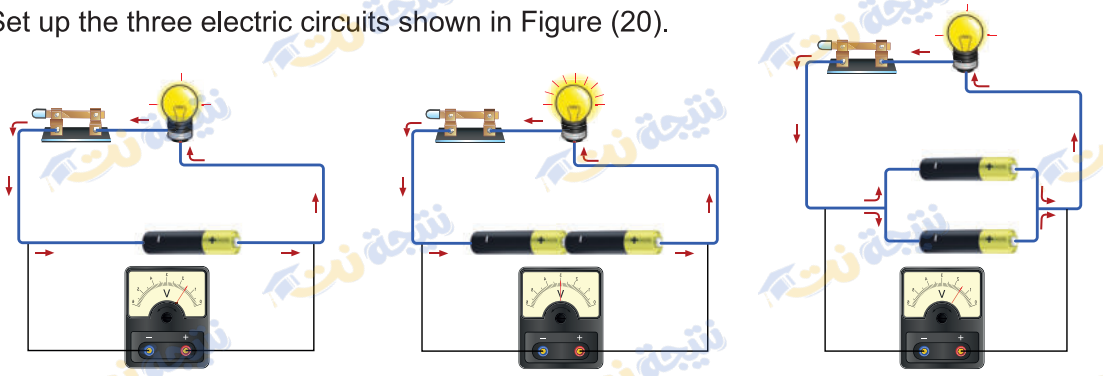
Activity 3 Investigate and Conclude

Materials and Tools:

- Five identical electric cells, electromotive force of each is 1·5 volts.
- Connecting wires.
- Three identical small light bulbs.
- Three voltmeters.
- Three switches.

Steps :

1. Set up the three electric circuits shown in Figure (20).



Circuit (1) **Circuit (2)** **Circuit (3)**

Figure (20)

2. **Describe** and compare the light intensity of the bulbs in circuits (2) and (3) to that of circuit (1).

.....

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3 Record the readings of the voltmeters in the three circuits.

What do you observe? .....

What do you conclude? .....

	Circuit (1)	Circuit (2)	Circuit (3)
Voltmeter reading	.....	.....	.....

A number of identical electric cells can be connected together in two ways:

1 **In series:**
The positive pole of the first cell is connected to the negative pole of the next cell, and so on, as in circuit (2). The electromotive force of the battery equals the sum of the electromotive forces of all the connected cells.

2 **In parallel:**
All positive poles are connected together, and all negative poles are connected together, as in circuit (3). The electromotive force of the battery equals the electromotive force of a single cell.

Technological Applications

1 **Torch:**
The electric cells in a torch are connected in series (Figure 21) to obtain a large electromotive force sufficient to power it.

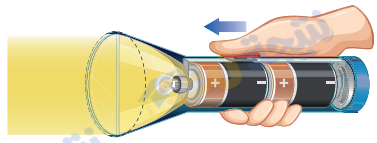


Figure (21)
Connecting electric cells in a torch

2 **Power Bank:**
Some power banks contain several electric cells connected in parallel (Figure 22), allowing a phone to be charged several times without increasing the output voltage.

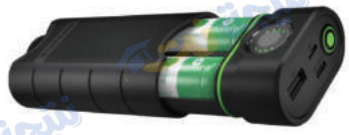


Figure (22)
Connecting electric cells in a power bank

Mathematical Application

Figure (23) shows an electric circuit containing a number of identical electric cells, each has an electromotive force of 3 volts. Calculate the potential difference across the light bulb.

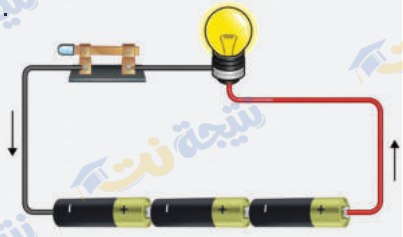


Figure (23)

Solution:
The potential difference across the light bulb equals the total electromotive force in the circuit.

$$V_{(\text{light bulb})} = \varepsilon_{(\text{total})}$$
$$= \varepsilon_{(\text{cell})} \times N_{(\text{number of cells})}$$
$$= 3 \times 3 = 9 \text{ V}$$

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Electric Resistance

Electric resistance is the opposition encountered by electric charges as they move through conductors. A conductor that has a specific electric resistance is called a 'fixed resistor' (Figure 24).



Figure (24)
Fixed resistor

The unit of measuring the electric resistance (R) is the ohm **(Ω).** An ohmmeter is used to measure the resistance of an electrical component. The resistor to be measured is connected between the terminals of the ohmmeter, as shown in (Figure 25).

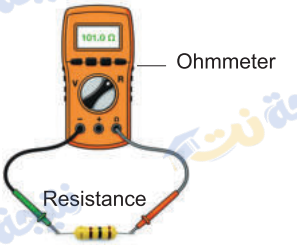


Figure (25)
Measuring resistance

Another type of resistor has an adjustable resistance and is called a variable resistor. One example is the rheostat shown in Figure (26). This type of resistor is used to control the electric current in a circuit by adjusting the slider to change the wire length through which the current flows.

The greater the length of wire through which the current flows, the greater its electric resistance. Therefore, the total resistance of the circuit increases and the electric current intensity through it decreases.

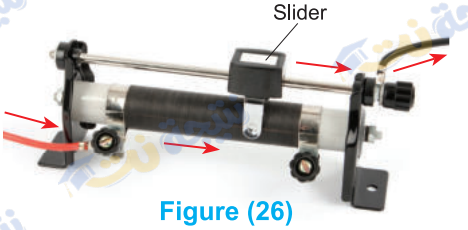


Figure (26)
Rheostat

Life Application

Controlling the volume of a radio:
A rotary knob (Figure 27) is used in radios to control sound volume. Turning the knob changes the electric resistance, which changes the electric current intensity and consequently the sound volume.



Figure (27)
Volume control knob

Check Your Understanding

Write the scientific term indicated by each statement:

(1) The flow of electric charges through a conductor. ( )

(2) The quantity of electric charge that passes through a cross-section of a conductor per second. ( )

(3) The work done to move a charge of one coulomb between two points. ( )

(4) The total work done by an electric source to move a charge of one coulomb through a complete electric circuit. ( )

(5) The opposition encountered by electric charges as they move through conductors. ( )

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Activity 4 Observe and Conclude

Figure (28) shows an incandescent light bulb. Notice that it contains two types of wire: the filament and the connecting wires.

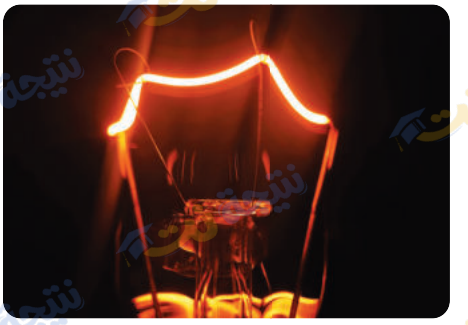


Figure (28)
Incandescent light bulb

1. Are the two types of wire made of the same material?
   .....
2. Do these wires have the same length and thickness?
   .....
3. When electric current flows through them, which type of wire glows?

What do you observe? .....

What do you conclude? .....

Based on the above, we conclude that:

- Every conductor, such as a wire, has electrical resistance. At a given temperature, the conductor resistance increases when:
  1. its length, through which electric current flows, increases.
  2. its cross-sectional area (thickness) decreases.
  3. it is made of a material of higher resistivity (each material has a characteristic value of resistivity).

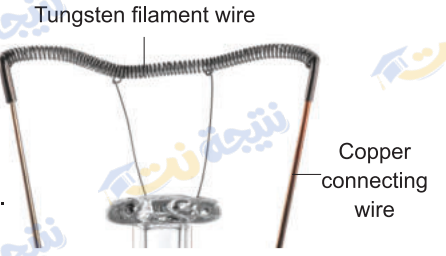


Figure (29)

- For example, in the incandescent light bulb (Figure 29), the filament is made of a thin, long tungsten wire wound into a coil, while the connecting wire is a relatively short, thicker copper wire. Therefore, the electric resistance of the bulb filament is much greater than that of the connecting wire.
- When a given electric current flows through a wire, the higher its electric resistance, the greater the amount of heat generated in the wire.

Scientist Profile

Thomas Edison
(1847–1931)

An American inventor who invented many devices that had a major impact on people's lives all over the world, including the phonograph (sound recorder), the motion picture camera, and the motion picture projector. He also developed a long-lasting incandescent light bulb and contributed to the development of electric power systems. Edison held 1093 U.S. patents, as well as many patents in France and Germany.



Figure (30)
Thomas Edison

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Representing Electric Circuit Components

Many electrical devices around you contain several different components. Designing and maintaining these devices requires a simplified diagram that shows how the components are connected. Therefore, engineers represent the components using standard symbols, as shown in the following table:

Electrical component	Symbol	Electrical component	Symbol
Electric cell		Switch (opened)	
Electric battery		Light bulb	
Fixed resistor		Ammeter	
Variable resistor (Rheostat)		Voltmeter	

Example

Draw a diagram for the electric circuit shown in (Figure 31), using the standard symbols.

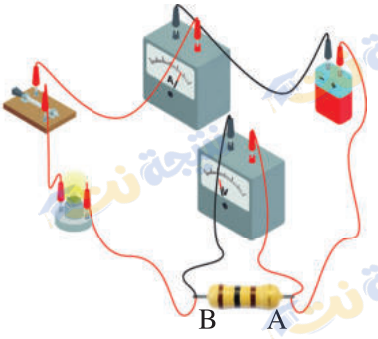


Figure (31)

Solution

1. Select the appropriate symbol for each component from the above table.
2. Ensure that each component in your diagram is connected the same way as in the original circuit.

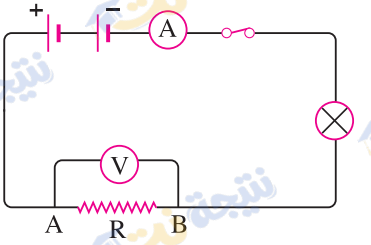


Figure (32)

Check Your Understanding

Draw a diagram of the electric circuit shown in Figure (33), using the standard symbols.

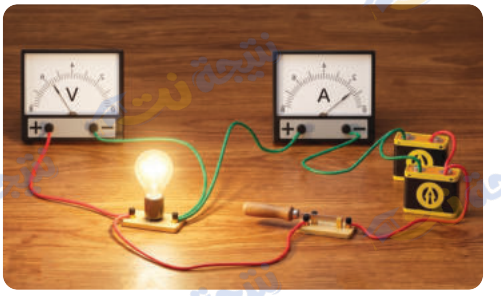


Figure (33)

Information and Communication Technology

You can design various electric circuits using an interactive simulation available on different websites, such as PhET.

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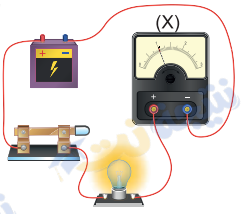
Assessment of Lesson One

1 Choose the correct answer for questions (1)–(5).

(1) Which of the following units is equivalent to joule per coulomb?

(a) Ampere. (b) Volt.
(c) Ohm. (d) Second.

(2) In the opposite electric circuit, what physical quantity does device (X) measure?



(a) Electric resistance of the light bulb.
(b) Electric current intensity in the circuit.
(c) Potential difference across the light bulb.
(d) Electromotive force of the battery.

(3) What is the main role of the electric source in an electric circuit?

(a) Producing electric charges.
(b) Causing electric charges to flow.
(c) Opposing the movement of electric charges.
(d) Completing the path of electric charges.

(4) Four identical electric cells are connected in series, giving a total electromotive force of 6 volts. What is their electromotive force if they are all connected in parallel?

(a) 6 Volt. (b) 4.5 Volt.
(c) 3 Volt. (d) 1.5 Volt.

(5) The figure shows three wires made of the same metal, with resistances R1, R2 and R3. What is the correct order of their resistances?

(a) $R_3 > R_2 > R_1$
(b) $R_1 > R_2 > R_3$
(c) $R_3 > R_1 > R_2$
(d) $R_2 > R_3 > R_1$



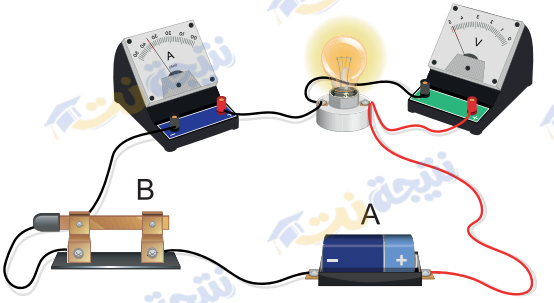
2 What are the conditions required for a direct electric current to flow through an electric circuit?

3 Compare: Ammeter and Voltmeter (in terms of the quantity each measures, the measuring unit, and way of connection during measurement).

4 What is meant by:

(1) the electric current intensity through a wire is 2 amperes?
(2) the potential difference across a conductor is 3 volts?

5 The figure shows an electric circuit containing several components:



(1) What is the function of both components, (A) and (B)?
(2) Draw a diagram of the electric circuit using the standard symbols.

6 Give reasons for:

(1) The potential difference between the battery terminals is usually less than its electromotive force.
(2) In some electric devices, a number of electric cells are connected together in series.
(3) Some power banks contain a number of electric cells connected in parallel.

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Lesson Two

Electric Circuits



Lesson Terminology:

- Ohm's Law
- Series connection
- Parallel connection
- Equivalent resistance
- Energy Efficiency Label
- Electric power
- Electric energy
- Compact Fluorescent Light (CFL)
- Light - Emitting Diode (LED)

Included Skills, Values and Issues :

- **Skills** : Practical – Measurement – Communication – Data Analysis – Mathematical – Evaluating Sources – and Credibility.
- **Values** : Collaboration – Self-Preservation – Communication.
- **Issues** : Financial Awareness – Compliance with the law – Resource Conservation

Cross-Cutting Concepts:

- Cause and Effect.

Lesson Objectives :

By the end of the lesson, students will be able to:

1. Verify Ohm's Law experimentally and represent the relationship between current intensity and potential difference graphically.
2. Compare the two methods of connecting resistors: in series and in parallel.
3. Calculate the equivalent resistance of a number of identical resistors connected in series or in parallel.
4. Define the electric power.
5. Calculate the cost of electical energy consumed at home.
6. Appreciate the importance of safety precautions when handling electricity.

Lesson Introduction



The opposite figure shows some light bulbs lit in a home.

This lesson explores the ideas that will help you answer the questions below:

- What happens to the light bulbs when one of them is switched off or damaged?
- How are household electrical appliances connected together? How does the way of connection affect the electric current intensity and the potential difference in each appliance?
- How can the monthly cost of electric energy consumed at home be estimated?

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In a closed electric circuit, an electric current flows through a conductor if there is a potential difference across its terminals, while its electric resistance opposes this flow. But how can the electric current intensity through the conductor be determined? How can efficient and safe electric circuits be designed and used economically to save energy?

Ohm's Law

Activity Experiment and Analyse Data

Materials and Tools:

- Electric source (battery).
- Fixed resistor.
- Variable resistor (Rheostat).
- Connecting wires.
- Electric switch.
- Ammeter.
- Voltmeter.

Steps:

1. Setup the electric circuit shown in Figure (1).
2. Set the variable resistor to its maximum value to obtain the lowest possible current intensity and protect the circuit components.
3. Close the circuit, then record the voltmeter and ammeter readings.
4. Reduce the value of the variable resistor.
5. Record the voltmeter and ammeter readings.
6. Repeat steps (4) and (5) several times.
7. Record the results in the following table:

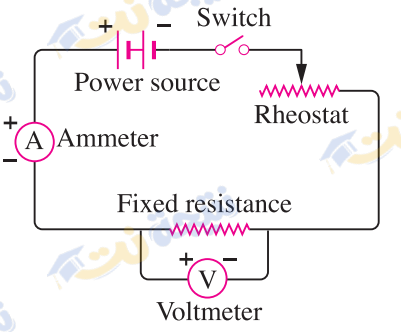


Figure (1)
Ohm's Law circuit

Voltmeter reading (V)	.....	.....	.....	.....
Ammeter reading (A)	.....	.....	.....	.....

8. Plot the relationship between the voltmeter reading (V), representing the potential difference across the fixed resistor, on the horizontal axis, and the ammeter reading (A), representing the electric current intensity through the fixed resistor, on the vertical axis.

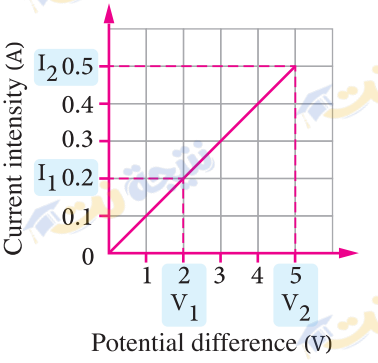


Figure (2)
Graphical representation of Ohm's Law

What do you observe? .....

What do you conclude? .....

When the relationship between the electric current intensity through the fixed resistor and the potential difference across it is represented graphically, a **straight line passing through the origin is** obtained as shown in Figure (2).

Based on the above, Ohm's Law can be formulated as follows:

The intensity of electric current flowing through a conductor (fixed resistor) is directly proportional to the potential difference across its terminals, at constant temperature.

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Ohm's Law is expressed mathematically by the equation shown in Figure (3).

- The value of the fixed resistance can be determined from the graph by calculating:

$$\frac{\text{change in potential difference}}{\text{change in electric current intensity}}$$

$$R = \left(\frac{V_2 - V_1}{I_2 - I_1} \right)$$

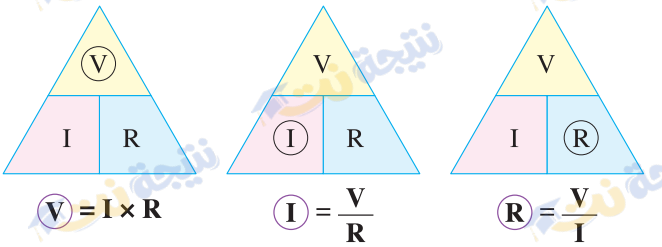


Figure (3)
Mathematical relation of Ohm's Law

Mathematical Understanding

Calculate the electric current intensity through a metallic wire of resistance 2 ohms when the potential difference across it is 6 volts.

Solution:

$$I = \frac{V}{R} = \frac{6}{2} = 3 \text{ A}$$

Scientist Profile

Georg Simon Ohm

(1789–1854)

A German physicist who discovered a law of electricity named after him. He identified the relationship between electric current, voltage, and resistance, and the unit of electrical resistance was named in his honor.



Figure (4)
Georg Simon Ohm

Check Your Understanding

(1) **In an experiment to verify Ohm's Law, identify:**

Dependent variable: .....

Independent variable: .....

Constant factors: .....

(2) **Figure (5) shows the graph that represents the results of an experiment to verify Ohm's Law. Find the value of the fixed resistance.**

.....

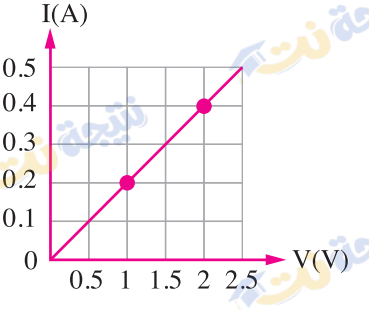


Figure (5)

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Connecting Identical Resistors

In simple electric circuits, we may use a single resistor. In practical applications and devices, however, several resistors are connected together. Resistors can be connected in two main ways:



Circuit (1)
Resistors connected in series

Circuit (2)
Resistors connected in parallel

Figure (6)

Table (1): **Ways of Connecting Resistors**

Type of connection / Point of comparison	In series	In parallel
Way of connection	Resistors form a **single continuous path** for the electric current (Figure 6)	Resistors form **branching paths** for the electric current (Figure 6)
Electric current intensity	The **same** electric current intensity flows through all resistors	**The electric current intensity is distributed** equally among the identical resistors
Potential difference	**The potential difference is distributed** equally across the identical resistors	**The potential difference** across each resistor is equal.
Calculating the equivalent resistance* (R´)	$R` = n \times R$ where (n) is the number of identical resistors	$R` = \frac{R}{n}$ where (n) is the number of identical resistors
Comparing the equivalent resistance with that of a single resistor	The equivalent resistance of a group of resistors is **greater** than the resistance of one resistor	The equivalent resistance of a group of resistors is **less** than the resistance of one resistor
Purpose of connection	Obtaining a **large** equivalent resistance	Obtaining a **small** equivalent resistance

Note:

* **Equivalent resistance (R`)**: The single resistance that produces the same effect on a circuit as that of a group of interconnected resistors.

Life Application

Household appliances are connected **in parallel** so that each appliance can be operated independently. If any appliance is disconnected or damaged, the others can continue operating because each appliance has an independent path with the source, as shown in Figure (7).

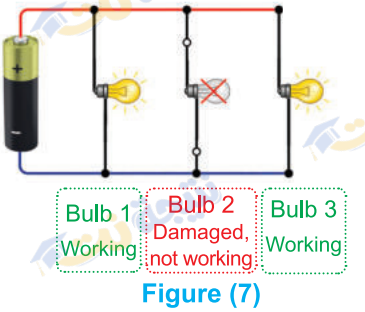


Figure (7)

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Mathematical Understanding

Three identical resistors connected in series to an electric source of electromotive force of 12 volts. If an electric current of 2 amperes flows through the circuit, **calculate** the resistance of each resistor.

Solution:

$$R` = \frac{V}{I} = \frac{12}{2} = 6\ \Omega \qquad R` = n \times R \qquad R = \frac{R`}{n} = \frac{6}{3} = 2\ \Omega$$

Integration with Medicine

Pacemaker:
This device is a practical application that integrates the concepts of "electric circuits" with "human physiology". The device is implanted under the patient's skin and consists of a battery, a smart microchip containing microelectronic circuits to manage the device, and wires connected directly to the heart muscle (Figure 8).
The circuit operates intelligently. If the normal heartbeat becomes irregular, it sends micro-electrical pulses to stimulate the heart muscle to contract regularly, ensuring that blood continues to be pumped efficiently.

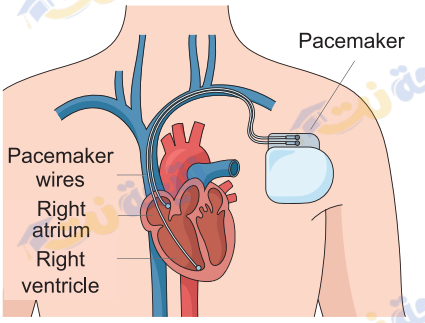


Figure (8)
Pacemaker

Energy and Electric Power

You may have noticed a label attached to a household appliance, like the one shown in Figure (9). What are the most important data recorded on this label?

The energy efficiency label shows the appliance monthly consumption of electric energy and energy efficiency level. This allows consumers to choose products that consume less energy protecting them from low-efficiency products. In Figure (9), the green arrow marked (A) on the label right indicates that this appliance has the highest efficiency and the lowest electric energy consumption.

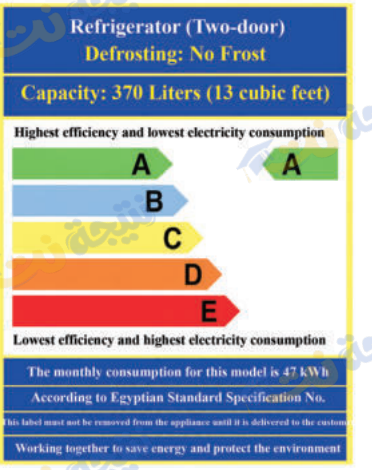


Figure (9)
Energy efficiency label

Many electrical appliances also display data that provide important specifications. **For example:** its electric power and the potential difference required to operate the appliance. Figure (10) shows the packaging box of a LED bulb having power rating of 9 W. **What does this mean?**

Electric power (P) is the rate at which an appliance (the light bulb) consumes electric energy; that is, the amount of electric energy (E) it consumes per second. Electric power is measured in **watts (W)**, and electric energy is measured in **joules (J)**, so one watt is equivalent to one joule per second. **In the light bulb in Figure (10)** consumes 9 J of electric energy when operated for one second.



Figure (10)
LED bulb

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Electric power is calculated using the equation:

$$P = \frac{\text{E (consumed electric energy)}}{\text{t (time of energy consumption)}}$$

The consumed electric energy is calculated using the equation:

Electric energy (J) = power (W) × time (s)

In real-life, the joule is a very small unit of electric energy. Therefore, we use a larger unit called the kilowatt-hour (kW.h).

$$1\ \text{kW.h} \xrightarrow{\times 1000 \times 60 \times 60} = 3.6 \times 10^6\ \text{J}$$

Calculating the Cost of Energy Consumption of Electrical Appliances

To calculate the cost of the electric energy consumed by a household appliance, follow the steps below:

Find:

1. Appliance power in kilowatts (kW) = $\frac{\text{Power in watts (W)}}{1000}$
2. Number of operating hours
3. Consumed energy in (kW.h) = power in (kW) × number of operating hours
4. Consumption cost = consumed energy in (kW.h) × price per kilowatt-hour



Figure (11)
Household meter records electric energy consumption

Mathematical Application

Suppose we have a Compact Fluorescent Light (CFL) bulb with a power rating of 20 watts and an LED bulb with a power rating of 12 watts, both producing approximately the same light intensity.

Compare the monthly cost of each bulb when used for 12 hours per day, assuming that the average price per kilowatt-hour is 1.55 Egyptian pounds.



LED light — Fluorescent lamp

Figure (12)

Solution:

Number of operating hours per month: t = 30 × 12 = 360 h

First: Compact Fluorescent Light (CFL)

- Power in (kW): $P = \frac{20}{1000} = 0.02\ \text{kW}$
- Monthly energy consumption: $E = 0.02 \times 360 = 7.2\ \text{kW.h}$
- Monthly cost = $7.2 \times 1.55 \simeq 11.2$ pounds

Second: LED bulb (LED)

- Power in (kW): $P = \frac{12}{1000} = 0.012\ \text{kW}$
- Monthly energy consumption: $E = 0.012 \times 360 = 4.32\ \text{kW.h}$
- Monthly cost = $4.32 \times 1.55 \simeq 6.7$ pounds

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Based on the above, we conclude that:

LED bulbs consume less electric energy than Compact Fluorescent Light (CFL) bulbs when operated for the same period. This indicates that LED bulbs have **higher efficiency** and are **more energy- and cost-efficient**, thereby conserving financial and environmental resources.

- **Table (2) (For reference only) lists examples of household electrical appliances and their electric power:**

Table (2)

Appliance	Electric power	Appliance	Electric power
Electric heater	1 kW – 2 kW	**Laptop**	50 W
Electric iron	1 kW – 2.5 kW	**Fan**	50 W – 100 W
Air conditioner	1.5 kW – 2.5 kW	**Television**	100 W

It can be observed that:

Air conditioners and heating appliances are among the appliances that consume the most electric energy.

Cross-Cutting Concepts: Cause and Effect

Increasing the operating hours of an electrical appliance (cause). leads to an increase in the consumed electric energy and, consequently, an increase in the consumption cost (effect).

Safety Precautions

- **Avoid overloading:** Do not connect several high-power appliances to a single socket (Figure 13), as the resulting increase in electric current intensity may cause a fire.
- **Insulation:** Make sure that wires are properly insulated to avoid electric shock.
- **Equipment dryness:** Make sure your hands, wires, and all components are dry before closing the circuit because tap water conducts electricity.
- **Disconnecting the electric source:** Do not attempt to modify any part of the circuit or replace a component until the electric current has been completely disconnected.
- Do not use household electrical sources in the experiments presented in this unit.



Figure (13)
Overloading

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Assessment of Lesson Two

1 Choose the correct answer for questions (1)–(5).

(1) In an experiment to verify Ohm's Law using a conductor, the rheostat resistance is changed several times. The constant factor is the .....

(a) potential difference across the conductor.
(b) current intensity through the conductor.
(c) resistance of the conductor.
(d) quantity of charge passing through the cross-section of the conductor.

(2) The unit used to measure the rate at which an appliance consumes electric energy is the .....

(a) ampere. (b) volt.
(c) ohm. (d) watt.

(3) When the potential difference across a resistor was 10 volts and an electric current of 2 amperes passed through it, the value of this resistance was .....

(a) 0.2 ohms. (b) 5 ohms.
(c) 8 ohms. (d) 20 ohms.

(4) Three identical resistors are connected in parallel, and their equivalent resistance is 2 ohms. What would their equivalent resistance be if connected in series?

(a) 2 ohms. (b) 3 ohms.
(c) 6 ohms. (d) 18 ohms.

(5) Two electrical appliances, (x) and (y), have power ratings of 2000 watts and 1000 watts, respectively. If appliance (x) consumes a certain amount of energy when operated for 3 hours, how long must appliance (y) operate to consume the same amount of energy?

(a) 6 hours. (b) 3 hours.
(c) 1.5 hours. (d) 1 hour.

2 What is meant by:

(1) The equivalent resistance of a group of connected resistors is 1 ohm?
(2) The electric power of a fan is 75 watts?

3 In an experiment to verify Ohm's Law, the potential difference across a metallic conductor is doubled. What happens to each of the following:

(1) The resistance of the conductor?
(2) The current intensity through the conductor?

4 You have three identical resistors connected together twice: first in series and second in parallel. In each case, the group of resistors is connected to the same battery:

(1) Draw a schematic diagram for the formed electric circuit.
(2) Compare the current through each resistor with the current through the battery.
(3) Compare the potential difference across each resistor with the electromotive force of the battery.
(4) Show how to calculate the equivalent resistance.

5 Suppose you have two identical resistors, two identical electric cells, and an ammeter. **Draw** a circuit diagram containing these components so that the ammeter gives the highest possible reading.

6 A family uses an electric kettle with a power rating of 1500 watts for half an hour daily to prepare hot drinks. Assuming that the average price per kilowatt-hour is 1.55 Egyptian pounds, calculate the weekly cost of operating the kettle.

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Lesson Three

Electric and Magnetic Forces



Lesson Terminology:

- Electromagnet
- Permanent Magnet
- Magnetic Force
- Electric Motor
- Torque
- Electric Generator

Included Skills, Values and Issues :

- **Skills:** Practical – Modeling – Communication – Critical thinking – Evaluating Sources and Credibility.
- **Values:** Collaboration – Self-Preservation
- **Issues:** Conserving environmental resources – Using clean energy sources.

Cross-Cutting Concepts:

- Cause and Effect – Structure and Function.

Lesson Objectives :

By the end of the lesson, students will be able to:

1. Conclude the magnetic effect of electric current.
2. Explain the structure of an electromagnet, how it works, and some of its applications.
3. Conclude the factors that affect the strength of an electromagnet.
4. Explain the magnetic force acting on a current-carrying wire.
5. Describe the structure of an electric motor, how it works, and some of its applications.
6. Conclude the factors that affect the torque acting on a motor coil.
7. Describe the structure of an electric generator, how it works, and some of its applications.
8. Conclude the factors that affect the electromotive force generated by an electric generator.

Lesson Introduction:

The opposite figure shows an electric fan. This lesson explores the ideas that will help you answer the questions below:

- How does a fan work?
- How does a fan motor convert electrical energy into mechanical energy?
- How can the rotational speed of a fan motor be controlled?



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In scrapyards, a machine like the one shown in Figure (1) is used to move heavy pieces of iron scrap from one place to another. How does this machine work, and how can its strength be controlled?



Figure (1)
Iron scrap lifting machine

Magnetic Effect of Electric Current

Activity 1 Observe and Conclude

Materials and Tools:

- Battery.
- Insulated copper wire.
- Compass.
- Small electric light bulb.
- Switch.

Steps:

1. Place the compass on a horizontal table and wait until it settles.
2. Set up the electric circuit as shown in Figure (2).
3. Place the wire above the compass, parallel to its axis.
4. Close the electric circuit.

What do you observe? .....

What do you conclude? .....

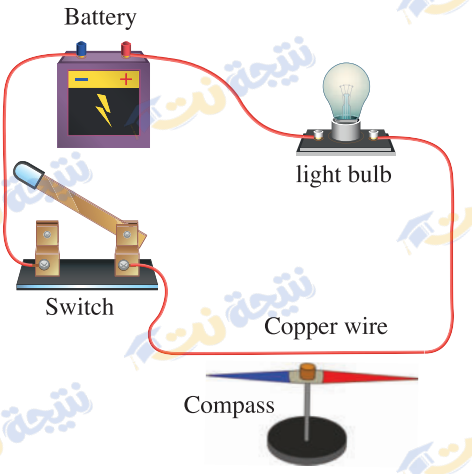


Figure (2)
Oersted's experiment

Hans Oersted discovered that when an electric current passes through a wire, it produces a **magnetic field** around the wire, causing a compass needle to deflect from its original direction. This phenomenon is known as the **magnetic effect of electric current**. This discovery is the foundation of many innovations and inventions based on the relationship between electric and magnetic forces, **for example:** the electromagnet, electric motor, and electric generator.

Cumulative Knowledge

- **Magnetic field:** the region around a magnet where the effects of its magnetic force can be detected.
- **Compass needle:** a small, freely moving magnet that naturally points toward the north under the influence of Earth's magnetic field.

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Electromagnet

An **electromagnet** consists of an insulated copper wire wound around a soft iron core. When an electric current flows through the coil, a magnetic field is produced around it that magnetizes the iron core.

You can make your own electromagnet and investigate how to increase its strength.

Activity 2 Experiment and Conclude

Materials and Tools:

- Long soft iron nail.
- Long insulated copper wire.
- Battery.
- Switch.
- Wooden stand.
- Iron paper clips.
- Rheostat.
- Ammeter.

Steps:

1. Wind the insulated copper wire evenly around the soft iron nail as a coil to make an electromagnet.
2. Secure the nail and the coil in the wooden stand.
3. Connect the two ends of the coil wire to the circuit shown in Figure (3).
4. Place the iron paper clips at a suitable distance (about 1 cm) directly below the nail.
5. Use the switch to close the circuit for a few minutes.
6. Open the switch.

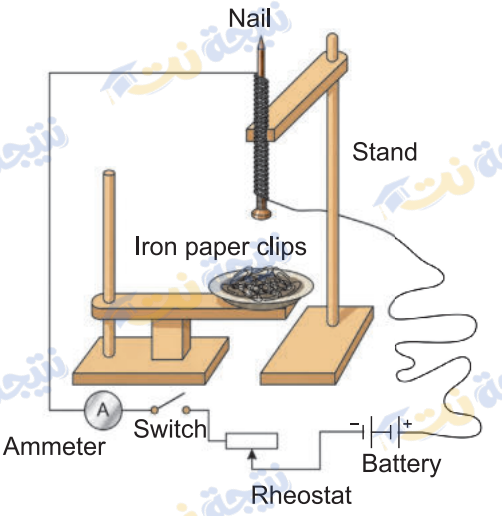


Figure (3)
Electromagnet

What do you observe? .....

What do you conclude? .....

- When an electric current flows through the coil, it produces a magnetic field that magnetizes the soft iron nail, causing it to attract the paper clips.
- When the circuit is opened and the electric current stops flowing, the electromagnet loses its magnetism and the paper clips fall off.
- An electromagnet is characterized by being a **temporary magnet** ; as it can be switched on or off by allowing the electric current to flow through the coil or cutting the current off, respectively. Can you now explain why electromagnets are used to move iron scrap from one place to another?

Research Activity

Research using reference sources, including reliable Internet sources, to learn about the role of electromagnets in sorting metal waste for recycling and how this process helps reduce the energy required to produce new metal products.

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Strength of an Electromagnet

Activity 3 Set Up Variables and Conclude

Using Activity (2) and Figure (3):

1. **How** can you conclude the strength of the electromagnet?

.....

2. **Suggest** some factors that can increase the strength of the electromagnet.

.....

3. Change one of these factors while keeping the other factors constant, and observe what happens to the strength of the electromagnet.

Independent variable: .....

Dependent variable: .....

Controlled variables: .....

4. Investigate another factor that you think affects the strength of the electromagnet.

What do you observe? .....

What do you conclude? .....

The number of paper clips attracted by the electromagnet can be used as an indicator of its strength. The more paper clips it attracts, the stronger the electromagnet.

Information and Communication Technology

You can investigate how to control the strength of an electromagnet using an interactive simulation available on PhET website.

Based on the above, we conclude that:

The strength of an electromagnet **increases:**

- **by increasing** the number of turns in the coil.
- **by increasing** the electric current intensity through the coil.
- **by using a soft iron** core.

Check Your Understanding

Compare a permanent magnet and an electromagnet in terms of:

- One similarity between them.

.....

- One difference between them.

.....

Cross-Cutting Concepts : Structure and Function

The core of an electromagnet coil is made of soft iron (structure) because it is easily magnetized and demagnetized. This makes the electromagnet a temporary magnet (function).

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Technological Application (Enrichment)

Electric bell:

- The operation of an electric bell (Figure 4) is based on the presence of an electromagnet.
- When the bell button is pressed, the circuit is closed and the soft iron core of the electromagnet becomes magnetized and attracts the metal strip toward it. As a result, the hammer strikes the gong, producing a sound.
- At the same moment, the circuit opens as the metal strip moves away from the contact screw, automatically causing the electric current to stop flowing.
- The electromagnet loses its magnetism, so the metal strip returns to its original position due to its elasticity, closing the circuit again. This cycle repeats rapidly, producing a continuous ringing sound.

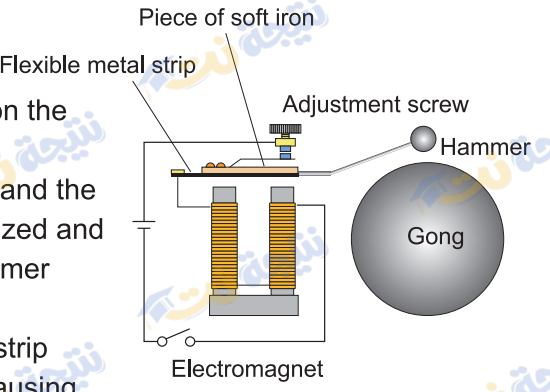


Figure (4)
Diagram of electric bell circuit

Magnetic Force Acting on a Current-Carrying Wire

We have learned that when an electric current flows through a wire, it produces a magnetic field around the wire. What will happen when this wire is exposed to another magnetic field, such as that of a permanent magnet?

Activity 4 Experiment and Conclude

Materials and Tools:

- Cylindrical metal rod.
- Battery.
- Connecting wires.
- Strong U-shaped magnet.
- Two copper rails.
- Switch.

Steps:

1. Arrange the tools to set up the device shown in Figure (5).
2. Connect the two ends of the rails to the battery and the switch to form an electric circuit.
3. Close the electric circuit.

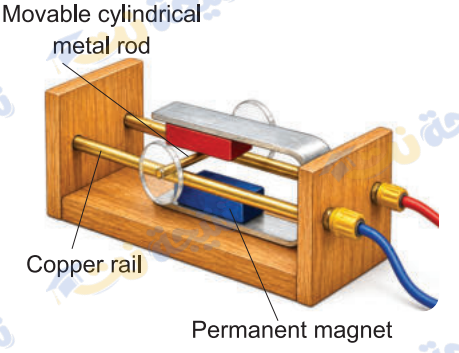


Figure (5)

What do you observe? .....

What do you conclude? .....

Based on the above, we conclude that:

- If a conductor or a straight wire is placed perpendicular to a magnetic field and an electric current flows through it, the wire is affected by a **magnetic force,** in a specific direction, which may cause it to move (Figure 6).

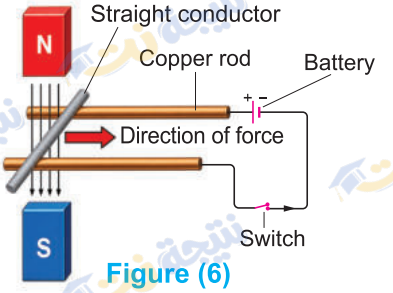


Figure (6)
Magnetic force acting on a straight conductor

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Simple Electric Motor

In Activity (4), what would happen if we placed a coil between the poles of the magnet instead of the wire and an electric current is flowing through it? Would the coil move like the wire did? If so, what would its motion be like?

This principle led to the invention of the "electric motor"

- A direct current (DC) motor consists of a coil of insulated copper wire that is free to rotate between the poles of a strong U-shaped permanent magnet.
- The two ends of the coil are connected to a direct-current electric source (a battery) through a commutator (a metal cylinder split into two mutually insulated halves) and two graphite brushes that act as contact points (in and out) for electric current (Figure 7).

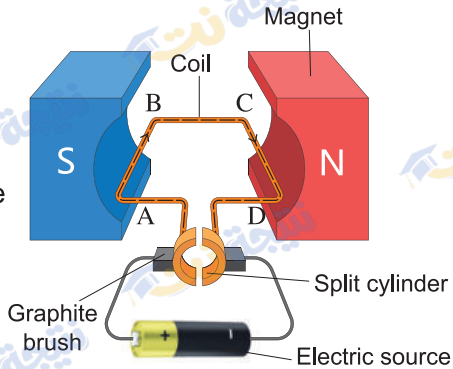


Figure (7)
Direct current motor (DC motor)
(For illustration only)

Operating Principle of an Electric Motor

When an electric current flows through the **motor coil shown in Figure** (7), a magnetic force acts on each of the two long sides (AB) and (CD). The two forces are equal in magnitude, opposite in direction, and act along different lines of action, as shown in Figure (8).The two forces form a couple that causes the coil to rotate.

An example of torque in real-life is turning a steering wheel with both hands, as shown in Figure (9). The two forces acting on the sides of the steering wheel cause it to rotate in the direction intended by the driver.

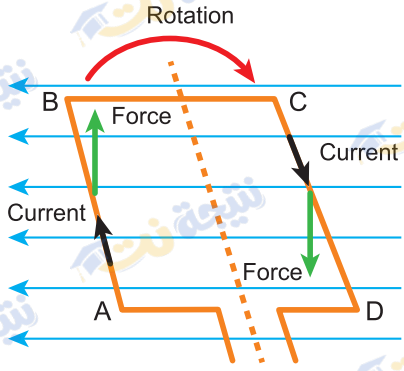


Figure (8)
Torque on a motor coil

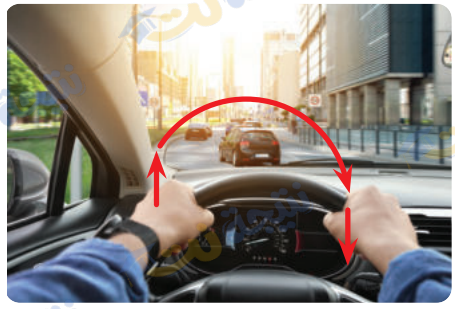


Figure (9)
Torque on a steering wheel

The torque acting on a motor coil, causing it to rotate, increases **by increasing:**

1. the electric current intensity through the coil.
2. the number of coil turns.
3. The area of the coil.
4. the magnetic field strength, which can be increased by using more powerful magnets or a larger number of magnets.

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Critical Thinking

Figure (10) shows an electric motor whose coil rotates in the direction indicated.

Suggest two methods, either of which would reverse the direction of rotation of the coil.

.....

.....

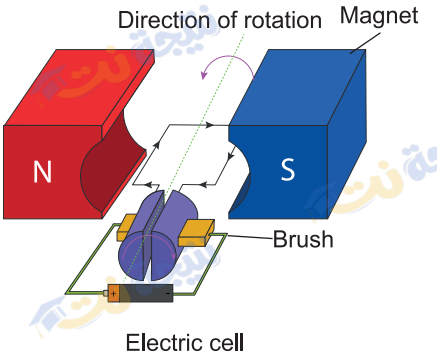


Figure (10)

Information and Communication Technology

You can deepen your understanding of how a motor works and how to control the factors affecting torque through an interactive simulation available on oPhysics website.

Cross-Cutting Concepts: Cause and Effect

Increasing the number of magnets in an electric motor (cause).
leads to an increase in the turning effect (torque) on the motor coil (effect).

- **Applications:** An electric motor converts **electric energy** into **kinetic energy**, making it useful in many applications, including household appliances such as blenders, fans, and washing machines, and transportation systems such as electric cars and the metro (Figure 11).



Figure (11)
Applications of electric motors

Life Application

The electric drill - screwdriver (Figure 12) is a real-life application of controlling the speed of an electric motor to suit different tasks.

- **When loosening or tightening threaded screws,** the motor is set to rotate at a low speed to ensure accuracy and avoid damaging the screw head.
- **When drilling into walls,** the motor is set to rotate at a very high speed providing the energy that enables the drill bit to penetrate the hard surface effectively.



Figure (12)
Electric drill and screwdriver

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Electric Generator

An electric motor is used to generate mechanical (kinetic) energy. What would happen if we rotated the shaft of an electric motor by hand? The process is reversed and the motor would produce electrical energy. This is the operating principle of an **electric generator.**

Activity 5 Experiment and Conclude

Designing an Electric Generator

Materials and Tools:

- Small direct current motor (such as a toy motor).
- LED lamp or a small light bulb.
- Connecting wires.
- Small fan or hand crank.

Steps:

1. Use connecting wires to connect the motor terminals to the LED or small light bulb instead of the battery.
2. Attach the small fan securely to the motor shaft.
3. Secure the motor firmly, then rotate the fan by hand as shown in Figure (13).
4. Rotate the fan slowly, and then rotate it more quickly, and observe the brightness of the bulb.

What do you observe? .....

What do you conclude? .....

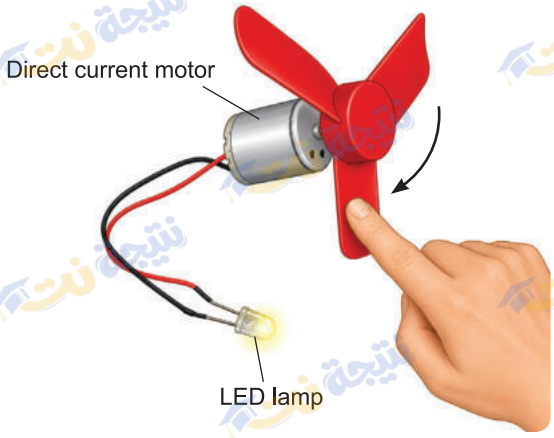


Figure (13)
Converting a motor into a generator

Note:

A LED lamp lights up when electric current flows through it in a particular direction. If it does not light up, try reversing its connection relative to the two terminals of the device.

An electric motor converts electrical energy into mechanical (kinetic) energy. When operated in reverse, by rotating its coil between the poles of a magnet, the device **generates an electromotive force** causing the bulb connected to the graphite brushes to light. A device that converts mechanical energy into electrical energy is called an **electric generator** Figure (14).

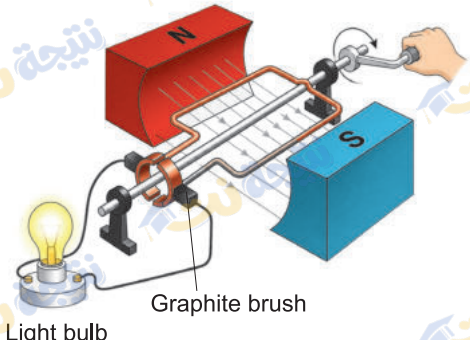


Figure (14)
Direct current generator (DC generator)
(For illustration only)

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Operating Principle of an Electric Generator

The generator coil is rotated between the poles of a magnet by a source of mechanical energy. As the coil cuts through the magnetic field lines, an electromotive force (emf) is generated, causing electric current to flow through the external circuit.

Cumulative Knowledge

Magnetic field lines: imaginary lines that indicate the direction and strength of a magnetic field.

Life Application

Bicycle dynamo:

- The traditional type is mounted on one side of a bicycle wheel.
- As the wheel rotates, friction turns the dynamo shaft, which drives the generator and converts mechanical energy into electrical energy to power the bicycle lights without batteries (Figure 15).
- The electromotive force (emf) produced by the generator increases as its rotational speed increases. Therefore, the brightness of the bicycle lamp powered by a dynamo increases as the bicycle wheel rotates faster.

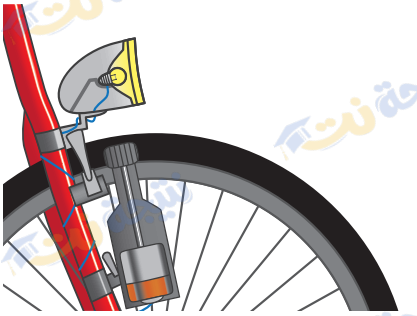


Figure (15)
Bicycle dynamo

Uses of an Electric Generator

An electric generator converts mechanical (kinetic) energy into electrical energy, making it the basis of many applications, most importantly:

1. **Electric Power Stations** (Figure 16):
   - Huge turbines drive coils of large electric generators to generate the electricity needed by cities and factories. These turbines obtain the mechanical energy required for rotation from different sources, **such as:** waterfalls, steam, or wind.
   - The electric generator whose coil terminals are connected to a split-ring commutator, as shown in Figure (14), generates a direct current (DC), which flows through its external circuit in one direction.

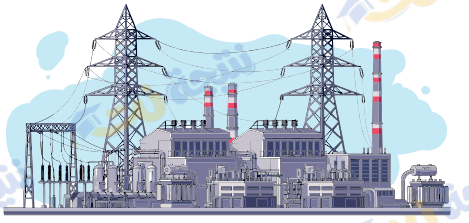


Figure (16)
Electric power station

Electric power stations use a different type of electric generator that produces alternating current (AC), which is the type of the electric current used in homes.

Alternating current (AC) can be transmitted efficiently from power stations to places where electricity is used with relatively low energy losses. It can also be converted into **direct current (DC),** similar to the current supplied by batteries.

2. **Emergency Generators** (Figure 17):
   Generators used in homes, hospitals, and factories to provide electrical power during power outages.



Figure (17)
Emergency generator

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Assessment of Lesson Three

1 Choose the correct answer for questions (1) - (5).

(1) As an electric current flows in a straight wire, it produces ..... around it.

(a) electric potential difference
(b) a magnetic field (c) air currents
(d) electric charges

(2) Which of the following statements correctly describes a property of an electromagnet?

(a) It cannot lift heavy iron objects.
(b) It can attract nonmagnetic materials.
(c) Its magnetic strength cannot be controlled.
(d) It loses its magnetism as soon as the electric current is switched off.

(3) What is the function of the two graphite brushes in an electric motor?

(a) Increasing the circuit resistance.
(b) Passing electric current to the coil.
(c) Generating a magnetic field.
(d) Reducing the coil rotational speed.

(4) An electric motor converts energy from .....

(a) thermal to electrical.
(b) electrical to mechanical.
(c) light to electrical.
(d) mechanical to electrical.

(5) The operating principle of an electric generator is based on .....

(a) the magnetic effect of electric current.
(b) the heating effect of electric current.
(c) production of torque on a current-carrying coil placed in a magnetic field.
(d) generation of an electromotive force in a coil when it is rotated in a magnetic field.

2 Give reasons for:

(1) A compass needle deflects when an electric current flows through a wire parallel to its axis.
(2) Soft iron is used as the core of an electromagnet.
(3) A bicycle lamp lights up when the shaft of the bicycle dynamo rotates.

3 The opposite figure shows a number of paper clips attracted to a nail at a coil core:



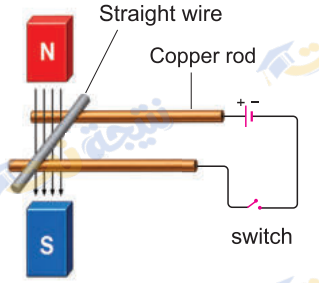
(1) Explain why the paper clips were attracted to the nail.
(2) Describe two ways to increase the number of paper clips attracted to the nail.
(3) State a practical application of this idea.

4 Compare each of the following:

(1) A permanent magnet **and** an electromagnet. (in terms of: possibility to control magnetic strength – one use).
(2) Electric motor **and** electric generator. (in terms of: type of input energy – type of output energy – operating principle)

5 State two advantages of the type of current produced by electric generators in power stations.

6 The figure shows a straight wire between magnetic poles, and the wire is free to move along two copper rods. What happens when:



(1) The switch is closed?
(2) The electric cell connections are reversed and the switch is then closed?

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UNIT 3

Variation of Traits in Living Organisms

Unit Lessons

Lesson one : Heredity and Variation of Traits

Lesson two : Natural Selection and Artificial Selection.



Learning Outcomes:

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

1. Explain dominant and recessive alleles and their role in transmitting inherited traits from parents to offspring.
2. Explain how differences in alleles and their distribution create genetic variation within the same species.
3. Conclude the relationship between marriage between close relatives and inherited diseases.
4. Compare natural selection and artificial selection in changing traits within populations.
5. Design a descriptive diagram explaining that natural selection is a major mechanism for transmitting genes and making living organisms better adapted to changes in the environment and evolution.
6. Write a report on the impact of environmental and genetic factors on the growth of populations in humans and animals (giving only one example in the animal kingdom).
7. Compare modern and traditional techniques for preserving desirable genetic traits in living organisms.

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Lesson **One**

Heredity and Variation of Traits



Lesson Terminology:

- Gene
- Gametes
- Allele
- Dominant Allele
- Recessive Allele
- Genotype
- Phenotype
- Mendel's Laws
- Punnett Square
- Genetic Diversity
- Genetic (Inherited) Diseases
- Deoxyribonucleic Acid (DNA)

Included Skills, Values and Issues

- **Skills:** Explaining phenomena – Analysing relationships – Creative thinking – Analytical thinking – Using models.
- **Values:** Respecting human differences and diversity – Health protection – Making healthy decisions.
- **Issues:** Marriage between close relatives in some communities.

Cross-Cutting Concepts:

- Cause and Effect – Patterns

Lesson Objectives:

By the end of the lesson, students will be able to:

1. Explain the role of dominant and recessive alleles in passing hereditary traits from parents to their offspring.
2. Explain how different alleles and their distribution among individuals create genetic variation within a species.
3. Apply the Punnett square to predict the probability that specific traits will be expressed in the offspring.
4. Link Mendel's laws of inheritance to the passing of traits across generations.
5. Explain how different alleles determine specific human traits.
6. Apply genetic concepts to examples of inherited diseases.
7. Conclude how marriage between close relatives can increase the risk of certain inherited diseases in offspring
8. Recognize the importance of health awareness and genetic screening in reducing the risk of inherited diseases.

Lesson Introduction:



The photo shows members of a family. Look closely at the features of each person. You may notice that the children resemble their parents in some aspects and differ in others.
This lesson explores the ideas that will help you answer the questions below:

- How are traits passed down from parents to their offspring?
- Why do family members share some inherited traits, but differ in others?
- Why do humans differ in many inherited traits?
- How can we prevent or manage certain inherited diseases?

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Family members often share certain inherited traits, while differ in others. **Genetics** is the science that aims to explain these similarities and differences by studying how **genetic information** is passed down from parents to their offspring. Genetic information is stored in human cells as a chemical substance called **genetic material or Deoxyribonucleic Acid (DNA)**.

Activity 1 Observe and Conclude

The figure shows a living cell and the genetic material in it:

1. **Which** part of the cell contains the genetic material?

.....

2. **What** is the relationship between a chromosome and a gene?

.....

3. **What** do genes control in humans?

.....

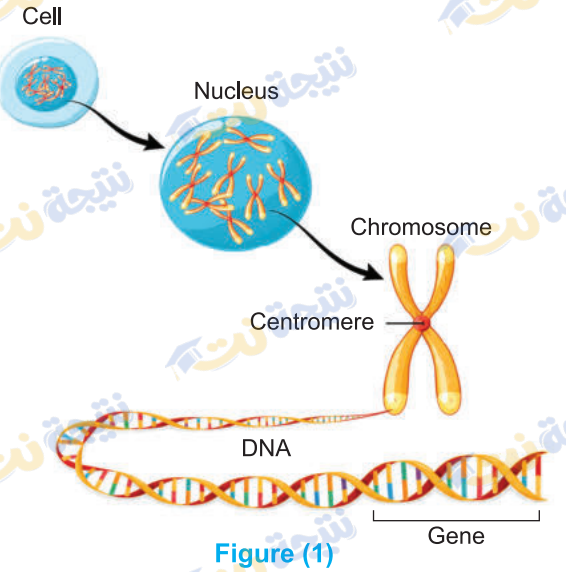


Figure (1)
Genetic material in the cell

The DNA molecule is extremely long. Therefore, it coils around molecules of protein to form thread-like structures called **chromosomes**. The genetic material forming each chromosome is divided into specific segments; each segment is called a **gene** (Figure 1). Therefore, a **gene** is a segment of genetic material that carries the genetic information responsible for a specific inherited trait in humans, such as eye colour, hair texture, or body height.

Inheritance of Traits

- Inherited traits are passed down from parents to their offspring through genes carried by **gametes**.
- Parents produce these gametes (sperm in male and ovum in female) in their gonads through **meiosis.**
- Each gamete contains only **half** of the genetic material. Therefore, it carries only one copy of each gene responsible for an inherited trait (Figure 2).
- During fertilization, the nucleus of father's sperm (male gamete) fuses with the nucleus of the mother's egg (female gamete) resulting in a new individual that carries two copies of each gene for each genetic trait.

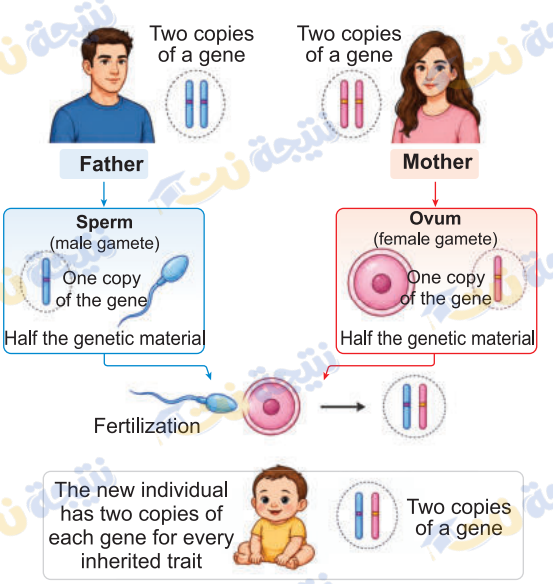


Figure (2)
Transmission of genetic material from parents to offspring

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Activity 2 Analyze The Data and Explain.

Table (1) shows the inheritance of eye colour in some individuals from different families.

Table (1): **Inheritance of eye colour**

Individuals	Gene copy from father	Gene copy from mother	Observable inherited trait
Individual A	Brown	Brown	Brown eyes
Individual B	Brown	Blue	Brown eyes
Individual C	Blue	Brown	Brown eyes
Individual D	Blue	Blue	Blue eyes

1. **What** trait appears when the two gene copies inherited from the parents are identical?

.....

2. **What** trait appears when the two gene copies inherited from the parents are different?

.....

3. **What** do you conclude about the effect of genotype on eye colour in offspring?

.....

From Table (1), we note that the two gene copies inherited by:

- Individual A are homozygous for the brown eye colour trait; therefore, his eyes are brown.
- Individual D are homozygous for the blue eye colour trait; therefore, his eyes are blue.
- Individuals B and C are heterozygous, with two different gene copies: one for brown eye colour and the other for blue eye colour ; therefore, their eyes are brown. Thus, the brown copy of the gene is dominant over the blue copy.

Based on the above, we conclude that :

- The existence of different copies of the same gene leads to variation in how an inherited trait appears.
- Each copy of the same gene is called an **allele**.
- A gene may have more than one allele, as shown in Figure (3).
- For each inherited trait, an individual usually receives two alleles for the gene responsible for that trait: one from the father and one from the mother.
- If an individual has two different alleles for a particular inherited trait (see individuals B in Table 1), the allele that is expressed in the phenotype is called the **dominant allele**, while the allele that is completely masked is called the **recessive allele**.

  When the dominant trait appears and completely masks the contrasting trait, this is known as the **principle of complete dominance**.
- Two individuals may show the same inherited trait (i.e. have the same **phenotype**), such as brown eyes, but they may differ in the two alleles they inherited (i.e. differ in their **genotype**). One individual may have two identical alleles (**homozygous**) , while the other may have two different alleles (**heterozygous**).

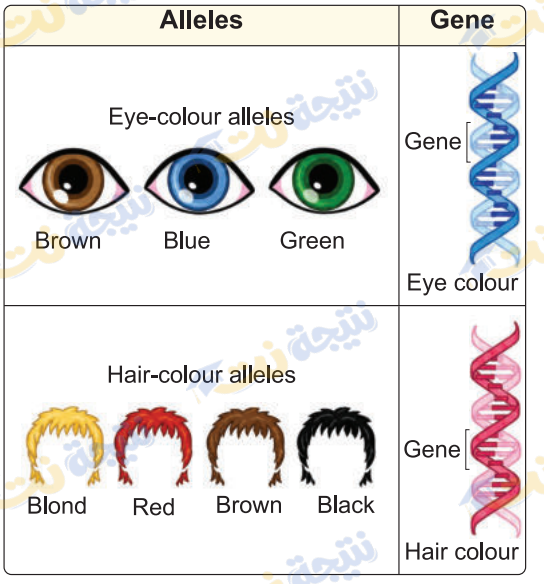


Figure (3)
Gene and its different alleles

Cross-Cutting Concepts: Cause and Effect

A difference in genotype (cause) can result in a different phenotype (effect).

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The **phenotype** refers to the inherited trait that appears in an individual and can be observed, while the **genotype** refers to the genetic makeup of an individual, i.e., the types of alleles he or she carries.

To make it easier to represent the genotype of an inherited trait, the dominant allele is usually represented by a **capital** letter, using the first letter of the trait name in English, while the recessive allele is represented by the corresponding **small** letter.

For example, the dominant allele for Brown eyes is represented by B while the recessive allele for blue eyes is represented by b. Table (2) shows how the genotype for eye colour (brown – blue) can be expressed.

From Table (2), it is clear that:

- The appearance of the brown eye colour trait (dominant) requires only one dominant allele (B); therefore, the individual's genotype can be (BB) or (Bb).

Table (2)

Phenotype	Purity of the trait	Allele type	Genotype
Brown eyes	Homozygous	Dominant + Dominant	BB
Brown eyes	Heterozygous	Dominant + Recessive	Bb
Blue eyes	Homozygous	Recessive + Recessive	bb

- The appearance of the blue eye colour trait (recessive) requires the presence of two recessive alleles (b); therefore, the individual's genotype is (bb).

Mendel and the Discovery of the Laws of Heredity

How do certain inherited traits appear in offspring, while other inherited traits disappear, even though they are present in one of the parents?

Scientists attempted to develop a clear scientific explanation of how inherited traits are transmitted from one generation to another. In the nineteenth century, the scientist **Gregor Mendel** (1822–1884) conducted a series of systematic experiments on pea plants.



Figure (4)
Gregor Mendel

- Mendel chose the pea plant (Figure 5) because it has clear contrasting inherited traits that are easy to distinguish from each other, such as seed colour (yellow–green) and seed shape (round–wrinkled). In addition, pollination between pea plants can be easily controlled.
- Mendel conducted crossing (hybridization) experiments between pea plants that differed in one inherited trait appearing in two contrasting forms, after ensuring that each trait was purebred; for example, plant height (pure tall plants and pure short plants) (Figure 6).
- By analysing the results of these experiments, Mendel concluded that inherited traits do not appear randomly, as was previously believed, but are transmitted according to systematic patterns that can be scientifically explained. These patterns form the foundation of modern genetics.



Figure (5)
Pea plant

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	Stem length	Flower position	Flower colour	Pod shape	Pod colour	Seed shape	Seed colour
Dominant traits	 Tall	 Axial	 Purple	 Inflated	 Green	 Round	 Yellow
Recessive traits	 Short	 Terminal	 White	 Constricted	 Yellow	 Wrinkled	 Green

Figure (6)
Contrasting traits in pea plants

Cross-Cutting Concepts: Patterns

Inherited traits show regular patterns in their transmission from one generation to another, as indicated by the results of Mendel's experiments. These patterns help predict the probability that traits will appear in offspring.

Mendel's Laws of Heredity

Mendel's First Law: Law of Segregation

When two purebred individuals are crossed for a pair of contrasting inherited traits, the individuals of the first generation show only one of the parents' traits (the dominant trait) with a percentage of 100%.

When individuals of the first generation are crossed with each other, both traits appear in the individuals of the second generation in a ratio of: 3 (dominant trait) : 1 (recessive trait).

Example

The seeds of pea plants may be yellow (a dominant trait) or green in colour (a recessive trait). Suppose we denote the allele for the yellow seed trait with a capital letter (Y) and the allele for the green seed trait with a lowercase letter (y). When a cross is made between two plants, one with pure yellow seeds and the other with green seeds (Figure 7), then:

- Each hereditary trait is controlled by a pair of genetic factors (alleles), for example: YY.
- The pair of alleles in each parent segregates during the formation of gametes, so that each gamete carries only one allele, for example: Y.
- During fertilization in plants, when the pollen grain fuses with the ovule, an allele from one parent combines with an allele from the other parent to form a new pair of alleles in the resulting offspring, for example: Yy.

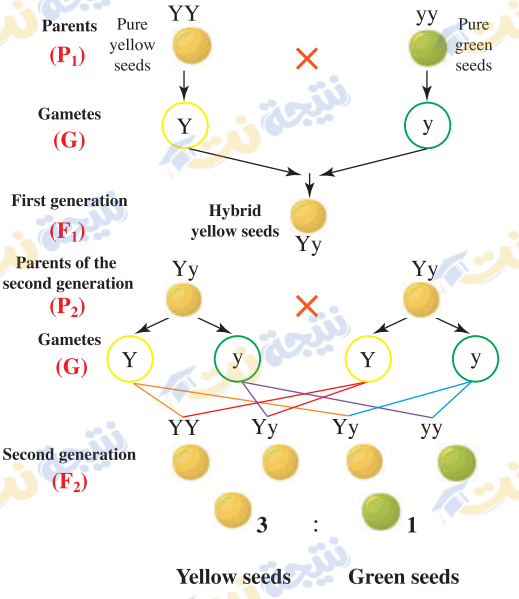


Figure (7)
Example of Mendel's first law

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Table (3): Genetic notations

Table (3)

Term	Male parent	Cross	Female parent	Parents	Gametes	First generation	Second generation
Notation	♂	×	♀	P	G	F_1	F_2

Punnett Square

A **Punnett square** is a scientific tool used to predict the possible **genotypes** and **phenotypes** of offspring resulting from a certain mating.

Table (4): **Punnett square**

G → / ↓	Y	y
Y	YY	Yy
y	Yy	yy

Constructing a Punnett Square

1. Determine the number of cells in the Punnett square by the number of gametes produced by each parent.
2. Draw a grid consisting of rows and columns to represent all possible combinations of gametes during fertilization.
3. Write the gametes of one parent horizontally across the top of the grid, and the gametes of the other parent vertically along the left side.
4. Fill each inner cell by combining an allele from one parent with an allele from the other parent (Table 4). This reveals the possible genotypes of the resulting offspring.

Check Your Understanding

In pea plants, the trait for purple flower colour is dominant over the trait for white flower colour (Figure 8). Let the allele for the dominant trait be represented by the letter (P) and the allele for the recessive trait by the letter (p). If two pea plants are crossed - one with purebred purple flowers and the other with white flowers - use Punnett squares to determine the possible genotypes and phenotypes of the first and second generations.

.....

.....



PP × pp

Figure (8)

Mendel's Second Law: Law of Independent Assortment

If two purebred individuals differing in two or more pairs of contrasting traits are crossed, each pair is inherited independently. When analysed separately, each trait appears in the second generation in a ratio of 3 (dominant trait) to 1 (recessive trait).

Example

Inheritance of seed shape and seed colour in pea plants:

The trait for round seeds is dominant over wrinkled seeds, and the trait for yellow seeds is dominant over green seeds. The alleles for these traits are represented as shown in Table (5).If a cross is made between two pea plants; one with purebred round, yellow seeds, and the other with wrinkled, green seeds. Then:

Table (5)

Trait allele	Symbol
Round seeds	R
Wrinkled seeds	r
Yellow seeds	Y
Green seeds	y

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- During gamete formation in the parents, the alleles for seed shape (round-wrinkled) segregate and are distributed independently of the alleles for seed colour (yellow-green).
- Due to the principle of complete dominance, all seeds of the first generation appear round and yellow, having a hybrid genotype for both traits (RrYy).
- When two plants from the first generation are crossed, each pair of alleles segregates and is distributed to the gametes independently of the other pair. Therefore, each plant produces four types of gametes with equal probability: (RY), (Ry), (rY), and (ry).
- The Punnett square in Figure (9) shows the possible combinations of these gametes to produce the individuals of the second generation.

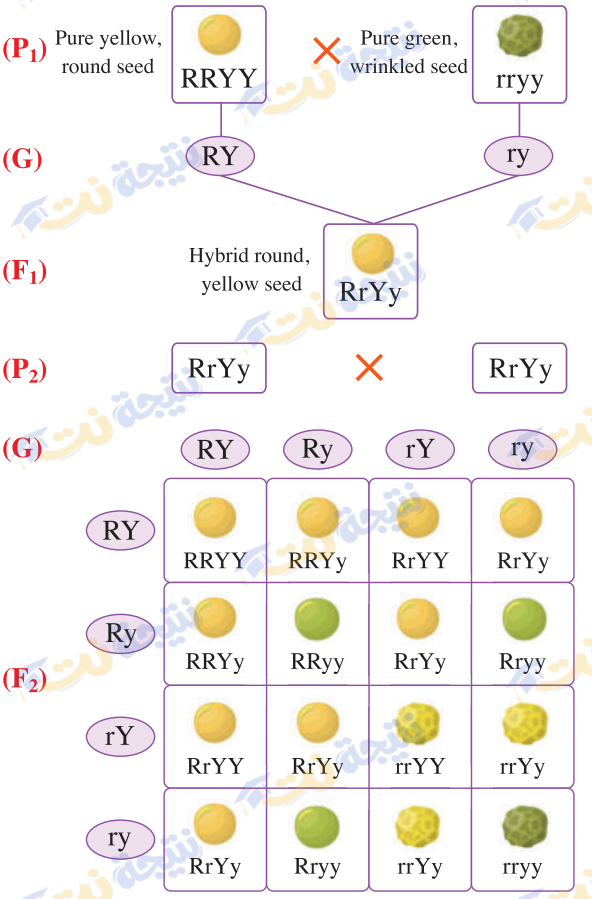


Figure (9)
Inheritance of two pairs of traits in pea plants

Based on the above, we conclude that:

When two **purebred** individuals differing in two or more pairs of contrasting traits are crossed:

1. Each pair of traits is inherited **independently of the other pairs.**
2. The two dominant traits appear in 100% of the first-generation individuals.
3. When two individuals of the first generation are crossed, there are 16 possible combinations of gamete fusion to produce the second generation.
4. The ratio of the probabilities of the phenotypes among the second generation individuals is 9 : 3 : 3 : 1, as distributed in Table (6).

Table (6)

Phenotypes of the Second Generation	Probability of the Two Traits
Both dominant traits (round, yellow seeds)	9 out of 16
First dominant trait with second recessive trait (round, green seeds)	3 out of 16
First recessive trait with second dominant trait (wrinkled, yellow seeds)	3 out of 16
Both recessive traits (wrinkled, green seeds)	1 out of 16

5. The probability distribution of each pair of contrasting traits is as follows:

First: Seed shape (round-wrinkled): There are 12 outcomes for round seeds and 4 outcomes for wrinkled seeds. This simplifies to a ratio of 3 (round): 1 (wrinkled).

Second: Seed colour (yellow-green): There are 12 outcomes for yellow seeds and 4 outcomes for green seeds. This simplifies to a ratio of 3 (yellow): 1 (green).

Therefore, the trait of seed shape is inherited independently of the trait of seed colour meaning each trait appears among the individuals of the second generation in a ratio of 3 (dominant trait) : 1 (recessive trait).

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Check Your Understanding

In pea plants, tall stems are dominant over short stems, and green pods are dominant over yellow pods. The allele symbols are shown in Table (7).

Use a Punnett square to determine the proportion of tall, green-podded plants produced by crossing two plants that are heterozygous for both traits.

.....

.....

Table (7)

Trait allele	Symbol
Tall stem	T
Short stem	t
Green pods	G
Yellow pods	g

Genetic Diversity

Every human has a unique genetic structure that determines his/her inherited traits. This explains the wide genetic variation in the inherited traits observed among humans (Figure 10). This variation helps increase the ability to adapt to different environmental conditions and ensures human survival over time.



Figure (10)
Variation of inherited traits in humans

Inheritance Diseases and Their Transmission

Inherited traits pass down from parents to offspring through genes. In some cases, these genes may carry mutations or genetic disorders that lead to a specific disease in an individual, which are called genetic diseases. These diseases may appear in children from birth, or at later stages of life.

Activity 3 Observe and Conclude

Figure (11) shows a case where both parents appear healthy but are carriers of a genetic disorder; each has one normal allele (R) and one disease-causing allele (r).

Observe the figure, then conclude:

1. **What** is the expected percentage of healthy offspring who are not carriers of the disease?
   .....
2. **What** is the expected percentage of offspring who are carriers of the disease but do not show any symptoms?
   .....
3. **What** is the probability of their child being born with the disease?
   .....

What do you conclude? .....

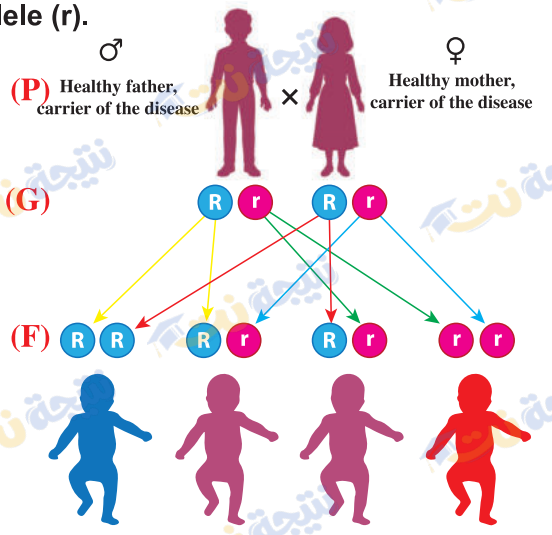


Figure (11)
Transmission of inherited diseases

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In many inherited diseases, the disease-causing allele is recessive. If one parent (either the father or the mother) has one copy of the recessive disease-causing allele and one normal allele in their genotype, the parent appears phenotypically healthy. In this case, the individual is called a carrier of the disease.

In general, a carrier does not show any symptoms of the inherited disease but can pass the disease-causing allele on to his/her children.

A child is affected only if they inherit two disease-causing alleles, one from each parent.

Examples of inherited diseases transmitted in this manner include:

- **Thalassemia (Mediterranean anaemia)**: An inherited disease affecting haemoglobin production and causing anaemia with variable degrees.
- **Galactosemia**: A rare inherited disease in which the body cannot break down galactose, causing health problems in infants such as vomiting, yellow of the skin and eye, and poor growth.

Medical Application

Comprehensive genetic screening:

Today, many advanced medical techniques, such as comprehensive genetic screening, are used to examine thousands of genes simultaneously instead of examining only one gene. This technique helps in the early detection of rare inherited diseases.



Figure (12)
Comprehensive genetic screening

Community Issue
The Relationship between Marriage between Close Relatives and the Risk of Inherited Diseases

Relatives typically share some of the genes inherited from common ancestors. If one of these genes causes an inherited disease, the likelihood that both relatives in a couple will carry the same disease-causing allele is higher than in an unrelated couple. When both partners carry the same recessive allele that causes the disease, the probability of having a child with the disease increases. For this reason, health authorities recommend that couples planning to marry undergo medical screening for certain inherited diseases before marriage. This helps them make informed health decisions and reduces the transmission of these diseases to future generations.

Community Application

Genetic Counseling:

Genetic counseling includes specialized programs that help families evaluate the probability of inheriting genetic diseases. Specialists analyse family medical histories, conduct precise genetic tests, and provide scientific consultations to help couples plan safely for having children. This counseling plays a vital preventive role in protecting the health of community members and reducing the spread of inherited diseases.



Figure (13)
Genetic counselling

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Assessment of Lesson One

1 Choose the correct answer for questions (1)–(6).

(1) What is the DNA segment that carries the genetic information for a specific trait?

(a) Chromosome (b) Gene
(c) Nucleus (d) Protein

(2) The allele for brown eyes (B) is dominant over the allele for blue eyes (b). The genotype of a blue-eyed person is .....

(a) BB (b) Bb
(c) bb (d) No correct answer

(3) Which of the following statements is correct?

(a) A dominant allele causes the recessive trait to appear.
(b) Each individual carries only one allele for each trait.
(c) Inherited traits are transmitted through gametes.
(d) The types of gametes depend on the parents' phenotypes.

(4) When two hybrid pea plants with yellow seeds are crossed, what percentage of the offspring is expected to have green seeds?

(a) 25% (b) 50%
(c) 75% (d) 100%

(5) Which of the following is an inherited disease?

(a) Influenza (b) Thalassemia
(c) Common cold (d) Food poisoning

(6) What is the purpose of comprehensive genetic screening?

(a) Treating damaged genes
(b) Early detection of genetic disorders
(c) Modifying undesirable traits
(d) Producing new genes

2 Define each of the following?

(1) Principle of complete dominance?
(2) Dominant allele?
(3) Genotype? (4) Phenotype?

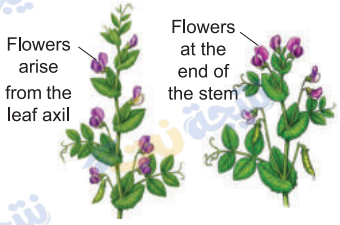
3 Give reasons for :

(1) Siblings may differ in some inherited traits.
(2) A child may be affected by an inherited disease even though both parents appear healthy.
(3) A Punnett square is used in genetics.

4 State one difference between each of the following pairs:

(1) Dominant allele **and** recessive allele.
(2) Mendel's first law **and** Mendel's second law.

5 Pea flowers may be axial (in the leaf axil) or terminal (at the end of the stem).



The axial flower trait is dominant and represented by the allele (A), whereas the terminal flower trait is recessive and represented by the allele (a). If a heterozygous axial-flowered plant is crossed with a terminal-flowered plant. Use a Punnett square to determine the genotypes and phenotypes of the offspring.

6 In humans, curly hair is dominant over straight hair, and brown eyes are dominant over blue eyes. A curly-haired, brown-eyed man (HhBb) marries a straight-haired, blue-eyed woman (hhbb). **Use a Punnett square to determine the expected phenotypic ratios of the offspring.**

7 The probability of inherited diseases increases in marriages between close relatives.

(1) Explain this statement.
(2) Suggest two ways to reduce the transmission of inherited diseases to offspring.

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Lesson **Two**

Natural Selection and Artificial Selection



Lesson Terminology

- Population
- Population Growth
- Carrying Capacity
- Adaptation
- Natural Selection
- Artificial Selection
- Environmental Factors
- Genetic Factors

Included Skills, Values, and Issues :

- **Skills :** Analysing evidence – Explaining changes – Comparison – Creative thinking – Analytical thinking.
- **Value :** Reasonable use of science.
- **Issue :** Artificial selection: Balancing breed improvement and the preservation of genetic diversity.

Cross-Cutting Concepts :

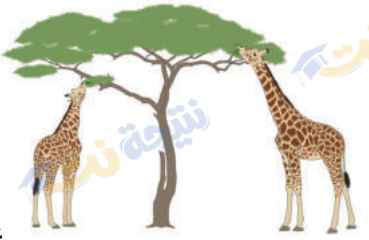
- Patterns – Stability and Change.

Lesson Objectives:

By the end of the lesson, students will be able to :

1. Explain the impact of environmental and genetic factors on the growth of human and animal populations.
2. Use simplified mathematical models to explain the role of natural selection in increasing or decreasing specific traits within populations.
3. Design a descriptive diagram to explain how natural selection increases the probability of passing on genes that make living organisms better adapted to environmental changes and driving evolution over time.
4. Compare the effects of natural and artificial selection on traits within populations.
5. Compare traditional and modern techniques for preserving desirable hereditary traits in living organisms.

Lesson Introduction:



The figure shows two giraffe individuals, one with a short neck and the other with a long neck. This lesson explores the ideas that will help you answer the questions below :

- Why might long-necked individuals be more likely to survive?
- How does the environment affect the increase or decrease of a specific trait within a population?
- Is the variation in growth among individuals within a population due to their genetic traits or to environmental conditions?
- Do humans play a role in changing certain traits of living organisms? How?

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Studying the characteristics of an individual organism alone is not enough to understand its behaviour and activities within an ecosystem. It is also necessary to analyse the populations that exist within that ecosystem. A population is a group of individuals of the same species that can reproduce with one another and live in the same place at the same time.

Population Growth

A characteristic of populations is that they are not static. The number of individuals in some species may remain stable for long periods, while others undergo periods of rapid increase, or experience a sudden collapse may happen in their numbers. This continuous change reflects the interaction between living organisms and various environmental factors.

Example

Suppose a small population of rabbits is introduced into an environment rich in food and free of competitors, as shown in image (1) in Figure (1):

(1) **Initially, the rabbits acclimate to the new environment.**



(2) **The rabbits begin to reproduce.**



(3) **With abundant food, the population increases rapidly.**



(4) **As the population increases, food resources begin to deplete.**



(5) **As competition for resources increases, the population growth rate slows down.**



(6) **The population size reaches a state of relative stability in balance with its environment.**



Figure (1)

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Activity 1 Explain the Data

Graph (2) shows the growth curve of a population of living organisms, which represents a change in the number of individuals over time. Four main phases can be distinguished in this curve.

Study the graph, then answer:

1. In which phase does the number of individuals increase rapidly?

.....

2. What causes the population to enter the growth deceleration phase?

.....

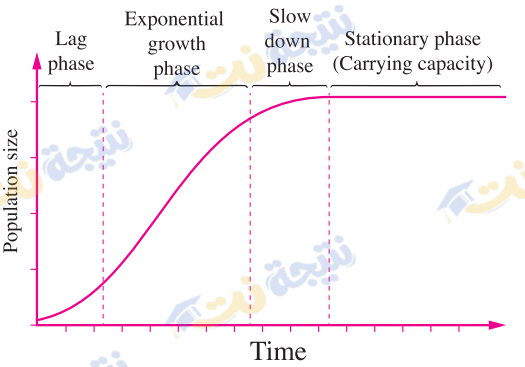


Figure (2)
Growth curve

What do you conclude? .....

- Under ideal conditions, the number of individuals in a population can multiply rapidly. This is called exponential growth, where the number increases from (2 → 4 → 8 → 16 ... and so on). This pattern of growth can be expressed mathematically as an exponential increase as follows: ($2^1 \rightarrow 2^2 \rightarrow 2^3 \rightarrow 2^4$ ... and so on), as shown in Figure (3).
  In nature, population growth does not continue indefinitely because environmental resources, such as food, water, and space, are limited. As the number of individuals increases, environmental factors that limit this growth appear; these factors are known as environmental resistance and include:
  - Depletion of resources.
  - Increased competition among individuals for resources.
  - Rapid spread of diseases and parasites among individuals

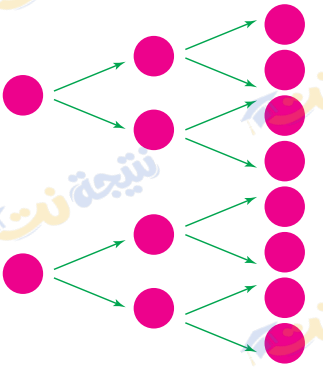


Figure (3)
Exponential growth

Because of the environmental resistance, population growth stops at a certain limit called the carrying capacity, which represents the maximum number of individuals of a particular species that the environment can support continuously without degrading its resources

Check Your Understanding

Why does the number of individuals decrease when a population exceeds the carrying capacity of the environment?

.....

Environmental Application

In nature reserves, determining the carrying capacity is extremely important. Ecologists and biologists monitor the populations of living organisms to intervene when necessary to prevent an excessive increase or a sharp decline in the population size within the reserve, thereby maintaining ecosystem balance.

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Factors Affecting Population Growth

Activity 2 Observe and Classify

Population growth is affected by two main types of factors: **environmental factors and genetic factors**.

The images in Figure (4) show several situations in which population size is affected by one of these types:

Case 1: Abundant growth of wheat plants following a season of heavy rainfall.

Case 2: A decrease in the number of a specific animal species due to the spread of an inherited disease among them.

Case 3: Some birds survive and reproduce because their strong beaks help them crack hard seeds.

Case 4: A decrease in the fish population of a lake due to water pollution.

Case 1



Case 2



Case 3



Case 4



Figure (4)

Answer the following questions:

1. **Classify** the factor that caused population size to change in each case into an environmental factor or a genetic factor.

.....

2. **Explain** how each factor led to an increase or decrease in the number of individuals.

.....

3. **Discuss** which type of factor—environmental or genetic—affects population size more rapidly.

.....

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Based on the above, we conclude that:

Population growth is affected by a variety of factors that control increases or decreases in the number of individuals over time. **These factors are classified as follows:**

1 Environmental factors

Environmental factors include all the biotic (living) and abiotic (non-living) components, within an organism's environment. **The most important factors include** food, water, temperature, diseases, predators, and the available space for its activity. These factors directly affect **population size** because they are essential needs for survival.

- **When the environment flourishes:**
  When resources are abundant, the chances of survival and reproduction increase, leading to an increase in population size. due to an increase in its individual number.
- **When the environment degrades:**
  In situations of resource scarcity or high risk, the population size declines due to reduced reproduction rates, increased mortality rates, or a combination of both.

2 Genetic factors

Genetic factors : They are responsible for the inherited traits passed from parents to offspring affecting an organism's ability to adapt to its environment, survive, and reproduce. Individuals within a population are not identical; they differ in certain inherited traits. This **genetic variation** may give some individuals a greater ability to cope with environmental conditions compared to others. **Examples of inherited traits that affect survival include** fur colour, disease resistance, the ability to tolerate extreme heat or cold, sharp eyesight, and a strong sense of smell.

Check Your Understanding

What is the effect of resource abundance, followed by scarcity, on the size of a population in a particular environment?

.....

Natural Selection

Natural selection is a process that explains how populations evolve over time. Individuals with inherited traits suited to their environment are more likely to survive and reproduce than individuals lacking those traits. These **beneficial** traits are passed to offspring and become more common generation after generation. Natural selection does not mean that the environment gives the organism new traits, but the environment selects, from the traits that individuals initially possess, those that help them survive.

- Individuals with beneficial traits in a particular environment live longer and have a greater opportunity to reproduce, passing their traits on to the next generation.
- Less-adapted individuals are less likely to survive; they may die before reproducing or reproduce at lower rates.
- This process is repeated over successive generations within the same species, **the proportion of beneficial traits increases**, while **the proportion of less beneficial traits decreases.**

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Activity 3 Observe and Explain

Before the Industrial Revolution in Europe, tree trunks were light-coloured and covered with **lichens**, so light-coloured moths were less visible to predators, giving them a greater chance of survival.

Life Application (Lichens and the Environment)

Lichens are organisms formed through a symbiotic relationship between a fungus and a unicellular alga or cyanobacterium. They are used as environmental bioindicators because their presence or absence indicates the quality of air and pollution level, helping assess the health of the environment surrounding agricultural crops.

After the Industrial Revolution, air pollution caused tree trunks to become dark and caused lichens to disappear. Consequently, Light-coloured moths became more visible, while dark-coloured moths were less likely to be eaten. Over time, the number of dark-coloured moths increased whereas the number of light-coloured moths decreased (Figure 5).

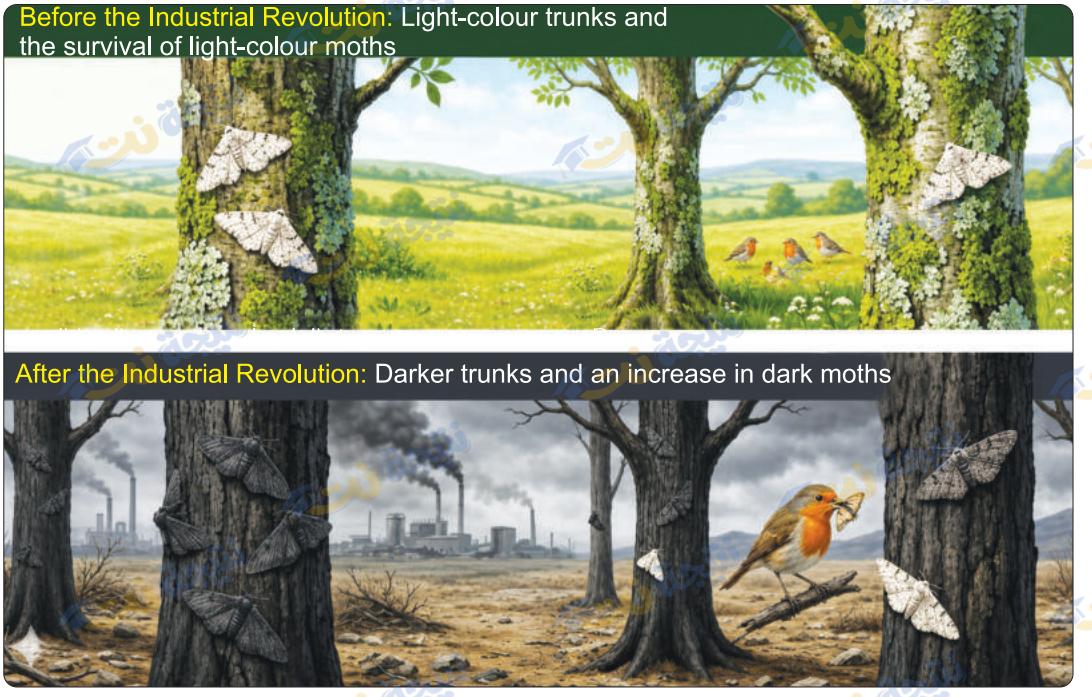


Figure (5)

Answer the following questions:

1. **Explain** how the previous example demonstrates natural selection.

.....

2. **Explain** how an environmental change can make one trait more common and cause another to disappear from a population.

.....

Mathematical Understanding

Assume a population of 100 rabbits: 60 are fast-moving and 40 are slow-moving. After predation, 50 fast rabbits and 10 slow rabbits remain.

What do you conclude from these data in light of natural selection?

.....

.....



Figure (6)

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Based on the above, we conclude that: The greater the ratio of survived individuals carrying a particular trait, the greater the chance that this trait is passed on to future generations. As this process is repeated over time, the trait becomes **more common** within the population. This demonstrates that natural selection is **a cumulative process** that occurs over successive generations and leads to gradual change in population traits.

Artificial Selection

Artificial selection is a process in which humans select plants or animals that have desirable traits and breed or propagate them to produce offspring in which these traits are more pronounced.

For example, if a farmer selects female cows with the highest milk production (Figure 7) and breeds them, their offspring are **more** likely to inherit this trait. Repeating this over successive generations improves the breed and increases the average milk production



Figure (7)
Breeding cows with the highest milk production

Examples of Artificial Selection

Humans use artificial selection in agriculture and animal breeding. **Examples include:**

1. Selecting plants that produce larger fruits.
2. Selecting cattle with higher meat production.
3. Selecting hens with higher egg-laying rates.
4. Selecting dogs with specific physical or behavioural traits.

Cross-Cutting Concepts : Patterns

Observing the recurrence of inherited traits within populations and classifying individuals based on their similarities and differences contributes to explain the processes of natural selection and artificial selection.

Artificial selection differs from **natural selection** in what drives the selection process. In **natural selection**, the **environment** is the factor that allows the best-adapted individuals to survive, and this usually occurs **gradually over long periods**. In **artificial selection**, **humans** select the desirable traits, so change may occur in a relatively short period of time. Natural selection is therefore associated with **survival and adaptation**, while artificial selection is associated **with meeting human needs and interests.**

Check Your Understanding

Complete the following table with the appropriate information to compare natural selection and artificial selection:

Point of comparison	Natural selection	Artificial selection
Factor affecting selection	.....	.....
Purpose	.....	.....
Rate of change	.....	.....
Type of selected traits	.....	.....
Examples	.....	.....

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Cross-Cutting Concepts : Stability and Change

Living organisms retain some inherited traits over time, while other traits change in response to the environment or artificial selection. This concept demonstrates how stability and change coexist in living organisms.

Artificial Selection Techniques

Humans seek to preserve **beneficial inherited traits in plants and animals** because they contribute to improving production, preserving superior breeds, and supporting food security. To achieve this, humans use different techniques classified into two main types:

1. Traditional techniques, such as crossbreeding good breeds and selecting the best plants for cultivation.
2. Modern techniques, such as gamete preservation and tissue culture.

Technological Application

Tissue **culture** helps produce disease-free plants and supports some therapeutic and research applications, while gene banks preserve important gametes, cells, and valuable breeds to support treatment, scientific research, and biodiversity protection.

Research Activity

Use various knowledge sources, including reliable websites, to prepare a report comparing traditional and modern artificial-selection techniques.

Issue for Discussion

Artificial selection can improve breeds and increase production, but it may also reduce genetic diversity.

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Assessment of Lesson Two

1 Choose the correct answer for the questions (1) - (6).

(1) What is meant by the carrying capacity of an environment?

(a) The minimum number of individuals of a species that can survive in the environment.
(b) The maximum number of individuals of a species that the environment can sustainably support.
(c) The reproduction rate of a population.
(d) The number of predators in the environment.

(2) Which of the following is an environmental factor affecting population growth?

(a) Fur colour (b) Beak shape.
(c) Amount of available food.
(d) Genetic diversity.

(3) Which environmental factor prevents exponential growth from continuing indefinitely?

(a) Adaptation.
(b) Environmental resistance.
(c) Increase in resources.
(d) Carrying capacity.

(4) Which of the following traits helps an organism survive in a cold environment?

(a) Thick fur. (b) Short neck.
(c) Sharp eyesight. (d) Ability to swim.

(5) One purpose of artificial selection is .....

(a) increasing agricultural crop production.
(b) reducing the number of predators.
(c) helping less-adapted individuals survive.
(d) increasing genetic variation within a population.

(6) Which of the following is an example of artificial selection?

(a) Increase in the number of dark-coloured moths following environmental pollution.
(b) Breeding cows with the highest milk production.
(c) Bird migration in winter.
(d) Change in the fur colour of certain animals in winter.

2 Define each of the following:

(1) Population.
(2) Exponential population growth.

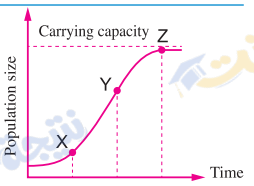
3 Give reasons for the following:

(1) Population growth does not continue at the same rate indefinitely.
(2) Environmental factors can directly affect population size.
(3) The number of individuals carrying beneficial traits increases over generations.

4 Compare each pair of the following:

(1) Natural selection and artificial selection (in terms of the factor that affects selection and the rate of change).
(2) Environmental factors and genetic factors affecting population growth (in terms of their definition and one example of each.).

5 The graph represents the growth of a rabbit population in a new food-rich environment over time:



(1) During which stage, XY or YZ, was the rabbit population growth rate greater?
(2) Explain the difference in the population growth rate between the two stages.
(3) What happens when a population reaches the environment's carrying capacity?

6 In an industrial area with dense trees, two types of moths were observed: light-colour and dark-coloured moths After several years, dark-coloured moths became more common.

(1) Explain this in light of natural selection.
(2) What factor helped the dark-coloured moths survive?

7 Farmers seek to improve certain plant and animal traits:

(1) How does artificial selection help achieve this?
(2) State one potential hazard of reducing genetic diversity.

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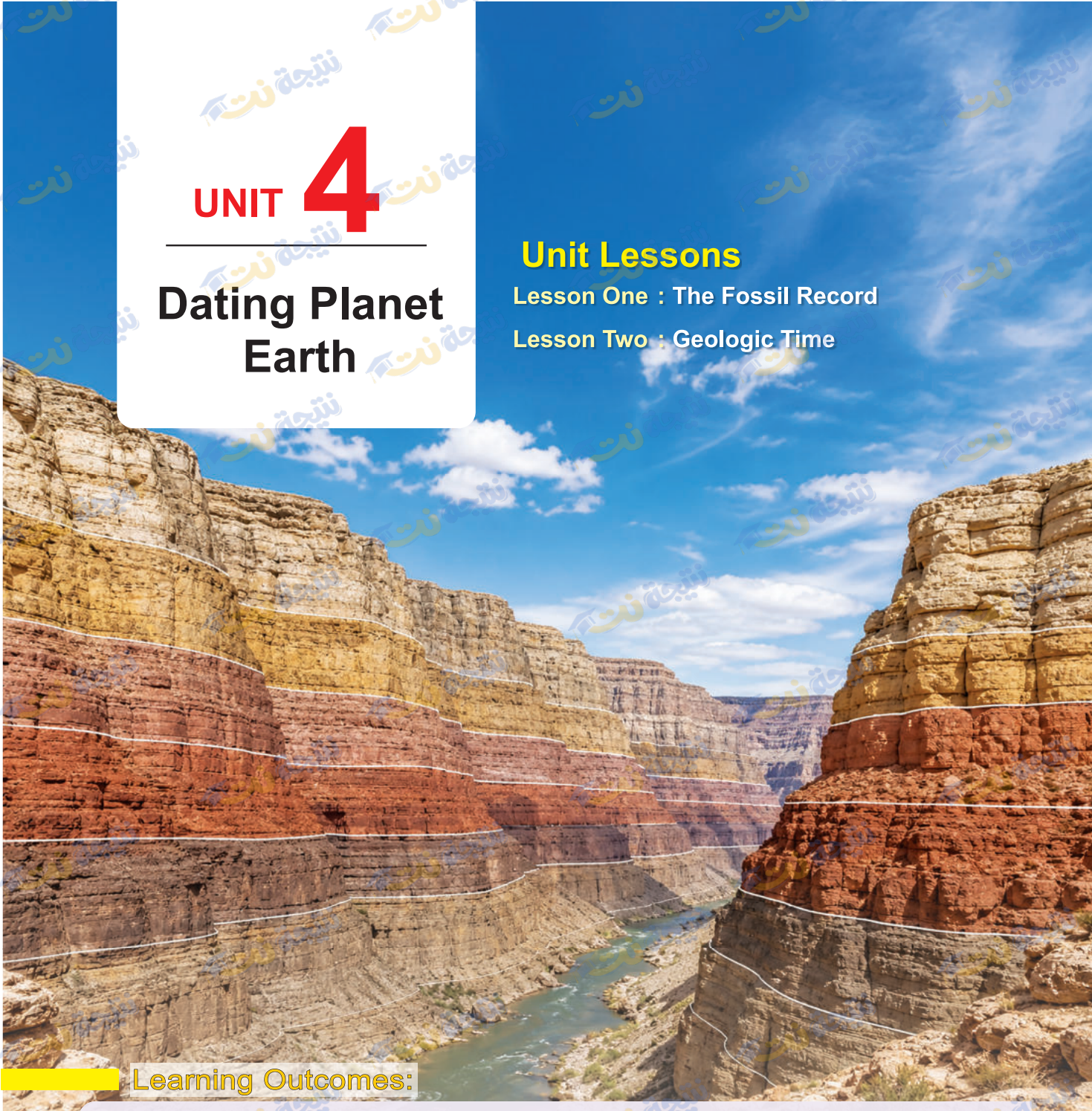
UNIT 4

Dating Planet Earth

Unit Lessons

Lesson One : The Fossil Record

Lesson Two : Geologic Time



Learning Outcomes:

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

1. Define the fossil record and its role in documenting the history of life on Earth.
2. Explain the causes of biodiversity, extinction, and changes in life forms throughout Earth's history in an approximate chronological sequence using the geologic time scale.
3. Explain evolutionary relationships among living organisms through anatomical comparison of similarities and differences between extinct and recent organisms..
4. Classify the major geologic time periods in Earth's history.
5. Explain with an example how scientists use the geologic time scale to trace Earth's history.
6. Analyse data from rock formations and fossils to conclude the sequence of major geological events, such as Earth's formation, the formation of mountain ranges, mass extinctions, and major volcanic eruptions.
7. Explain the methods used to determine the relative age of rocks.
8. Explain how radioactive isotopes are used to determine the absolute age of rocks and fossils.
9. Use digital sources and databases responsibly, citing those sources.

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Lesson One

The Fossil Record



Lesson Terminology :

- Fossils
- Fossil Record
- Mass Extinction
- Evolutionary Relationships
- Natural Selection
- Genetic Mutations
- Geographical Isolation
- Comparative Anatomy
- Homologous Structures
- Analogous Structures
- Transitional Fossils

Included Skills, Values, and Issues

- **Skills :** Communication – Modeling.
- **Values :** Respect for intellectual property.
- **Issues:** Evaluating evidence used for dating Planet Earth.

Cross-Cutting Concepts:

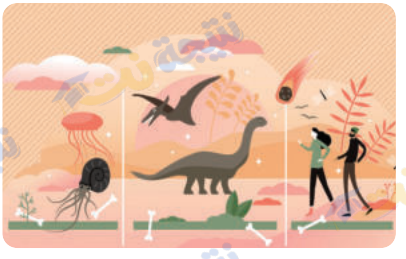
- Change and Stability – Cause and Effect

Lesson Objectives :

By the end of the lesson, students will be able to:

1. Explain the concept of fossils and how they are formed.
2. Distinguish between different types of fossils and give an example of each.
3. Explain the concept of the fossil record and its role in documenting the history of life on Earth.
4. Explain the causes of extinction of certain species of living organisms and the changes in life forms over geologic time.
5. Explain the causes of the appearance of new species of living organisms through geologic time.
6. Conclude the evolutionary relationships between extinct and recent organisms through anatomical comparison and identifying their similarities and differences.

Lesson Introduction



The figure shows organisms that lived during different geologic periods in Earth's history.

This lesson explores ideas that help you answer the questions below:

- How do scientists know that dinosaurs lived millions of years ago?
- How does the fossil record help scientists understand Earth's history?

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Activity 1 Analyse

Figure (1) shows footprints found in sand in a certain area.

Observe and Conclude

1. What types of organisms might have left these footprints?

.....

2. What sequence of events can be inferred from the footprints?

.....

3. What evidence supports your conclusions?

.....

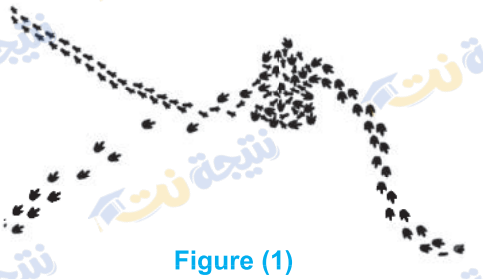


Figure (1)
Footprints

Fossils

Fossils: are the remains or traces of organisms such as plants, animals, and microorganisms that lived in ancient geologic times. These remains were preserved because of special environmental conditions after the organism died. In rare cases, an entire organism is preserved intact.

Fossils usually form when an organism is rapidly buried after its death in a suitable medium that protects it from decomposition (Figure 2), such as:

1. Sediments: are fragments of clay, sand, or limestone.
2. Permafrost: is a frozen layer of ground that remains without melting for prolonged periods.
3. Natural tar: is a form of crude oil.
4. Amber: is a material formed by the hardening of resin, which is a sticky substance secreted by some trees.



Fossil in amber



Fossil in tar



Fossil in ice



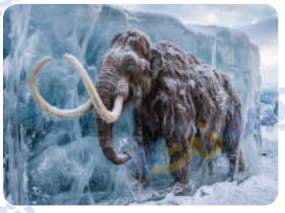
Fossil in sediments

Figure (2)
Fossils in different media

Types of Fossils

1 Body Fossils

Body fossils include parts of an organism's body, such as bones, teeth, shells, tree trunks, leaves, or the whole organism, such as insects trapped in amber and mammoths preserved in ice (Figure 3).



Mammoth fossil in ice



Plant fossil



Insect fossil



Bone and teeth fossil

Figure (3)
Body fossils

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2 Trace Fossils

Trace fossils include footprints, tracks, burrows, or coprolites that indicate an organism's behavior or its feeding habits (Figure 4).



Dinosaur footprint fossil



Burrow trace fossil



Worm-burrow trace fossil

Figure (4)
Trace fossils

3 Mold and Cast Fossils

- Mold: is an impression of the organism's external surface preserved in rock (Figure 5).
- Cast: represents the shape of the internal cavity of an organism's shell. A cast forms when the cavity is filled with mineral solutions such as silica or calcite, or with sand and clay sediments that become consolidated over time (Figure 6).

Example: Mold and cast of ammonites.



Figure (5)
Mold fossil



Figure (6)
Cast Fossil

4 Petrified Fossils

When an organism remains buried in sediments for millions of years, some minerals such as silica or calcium carbonate gradually replace the organic matter in its tissues. The remains of the organism become a solid petrified fossil (Figure 7). Example: the Petrified Forest located in Cairo Governorate.



Figure (7)
Petrified fossil (Tree trunks)

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Activity 2 Designing a Fossil Model

Materials and Tools:

- Plaster.
- A plastic board.
- Modeling clay.
- Safety goggles.
- A seashell.
- Water.

Steps:

1. Spread a lump of clay on the plastic board.
2. Press the surface of the shell into the clay until it is embedded to about half its depth.
3. Carefully remove the shell from the clay to preserve the impression it has made.
4. Leave the clay in the air until completely dry, or expose it to sunlight to speed drying. You now have fossil model (A).
5. Make a medium-consistency plaster mixture (water amount is half the plaster amount) , and pour it into the cavity in the clay made by the shell until it is full (Figure 8), then leave it for 15–20 minutes to harden.
6. Carefully remove the hardened plaster cast from the clay. You now have fossil model (B).



Figure (8)
Making a fossil model

Answer the following questions:

1. **Which** type of fossil is represented by:
   (a) Model (A)? .....
   (b) Model (B)? .....
2. **Can** you make other fossil-shape models?
   .....
3. **What** other tools and materials could you use?
   .....

Project: Fossil Exhibition

Collaborate with classmates to organize a fossil exhibition to display the fossil models you have made.

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Check Your Understanding

From Figure (9), answer:

(1) What type of fossil is shown? .....

(2) How was this fossil formed? .....

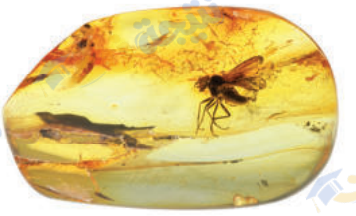


Figure (9)

Enrichment Information

The Geological Museum in Cairo:

The Egyptian Geological Museum contains samples of igneous, metamorphic, and sedimentary rocks as well as fossils of animals and plants that lived in different geologic periods. Notable exhibits include a complete skeleton of an ancient whale. It also contains a Moon-rock sample and a meteorite from Mars, one of the world's rare meteorites.



Figure (10)

Fossil Record

The **fossil record** refers to the collection of all fossils that have been naturally preserved in rock layers or other media such as ice, tar, or amber, and then have been discovered.

Importance of the Fossil Record

1 Tracing the Appearance and Evolution of Life

Studying fossils in an undisturbed **rock sequence** helps trace the emergence and evolution of living organisms on Earth.

Since the deep layers in such rock sequence are older than the surface layers, the organisms whose fossils have been found in deeper rock layers appeared on Earth earlier than those whose fossils have been found in upper layers of the same rock sequence (Figure 11).

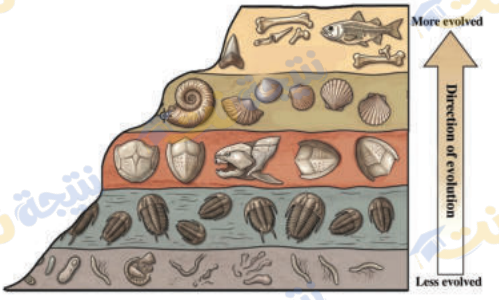


Figure (11)

The fossil record helps trace the Evolution of Life

For example: fossils of **invertebrates** have been found in rock layers deeper than those layers containing fossils of **vertebrates**. This indicates that most **invertebrates** appeared on Earth before **vertebrates.**

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2 Identifying Mass Extinction in Some Organisms

Studying the fossil record has led to discovering what are called mass extinctions in certain periods of geologic time. In a **mass extinction**, a huge number of species die out in a relatively short period of time. For example, the mass extinction that happened about 66 million years ago wiped out approximately 75% of all species on Earth, including most dinosaurs species.



Figure (12)
Mass extinction

Scientists propose several hypotheses to explain these extinctions, **including the occurrence of:**

1. Cosmic **catastrophes** such as meteorite impacts (Figure 12).
2. Severe **climate changes** and shifts in atmospheric composition.
3. Massive **volcanic activity**.
4. Changes in **sea level** and shaping of continents over time.

Cross-Cutting Concept : Cause and Effect

Cosmic catastrophes, severe climate changes, or massive volcanic activity in ancient geologic times (cause) led to the mass extinction of many living organisms (effect).

3 Identifying Evolutionary Relationships between Ancient and Recent Organisms

Palaeontology works together with **anatomy and genetics** to identify the links between ancient organisms and those living today.
This integration shows how different species branched from common ancestors over time.

For example:
The modern Asian elephant is the closest relative to the extinct mammoth (Figure 13), as they both share a common ancestor that lived in ancient times.

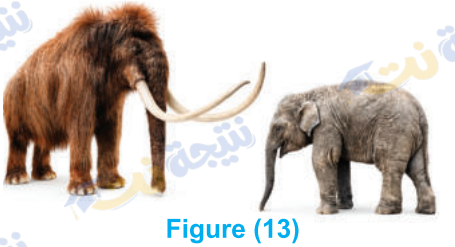


Figure (13)
Evolutionary link between the Asian Elephant and the Mammoth

4 Inferring Ancient Environmental Conditions

The fossil record helps build an accurate picture of changes in Earth's climate and ecosystems.
For example:

1. Fossil skeletons of primitive whales in Wadi Al-Hitan in Fayoum (Figure 14) indicates that the region was once covered by an ancient sea.
2. The Petrified Forest in Cairo (Figure 15) indicates that the region was once a humid forest, and the climate in that region has changed from humid to dry today.



Figure (14)
Wadi Al-Hitan



Figure (15)
The Petrified Forest

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Causes of the Diversity of Life Forms Over Time

Scientists offer several explanations for the diversity of living organisms (Figure 16) and the emergence of new species through geologic time, **including:**

1. **Adaptation** to new and different environments such as the deep sea, forests, and deserts, which led to the evolution of different species, each adapted to its own environmental conditions.
2. Evolution of living organisms through **natural selection**, which may occur gradually over long periods of time or relatively rapidly in some cases.
3. **Accumulated genetic mutations** within a particular class of organisms.
4. **Geographical Isolation:** the separation of a group of organisms from the rest of their species by a natural barrier **such as** a mountain range, wide river, or deep valley. Over time, this may produce different species from a single species, as shown in Figure (19).

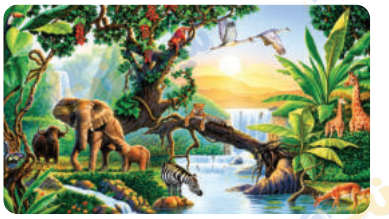


Figure (16)
Diversity of life forms



Figure (17)
Extinct marine reptiles

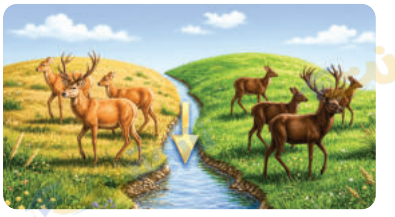


Figure (18)
Geographical isolation

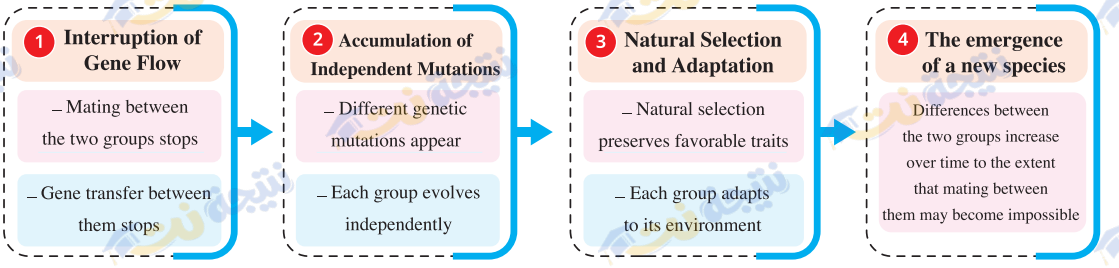


Figure (19)
Geographical isolation and the diversity of life forms over Time

Cross-Cutting Concepts: Change and Stability

Earth and its life forms have undergone many changes through geologic time, while some rock structures and formations remained relatively stable. These geologic layers have recorded some of these ancient events.

Check Your Understanding

(1) Mark (✔) or (✘):

(a) Geographical isolation is one of the main causes of mass extinction. ( )

(b) The fossil record denies any evolutionary link between the Asian elephant and the extinct mammoth. ( )

(2) How can the Petrified Forest east of Maadi help conclude climate change in that region?

.....

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Comparative Anatomy among Organisms

Studying the similarities and differences in the body structures of different species—known as **comparative anatomy**—helps scientists conclude evolutionary relationships among organisms.

Activity 3 Compare and Conclude

Figure (20) shows the anatomical features of the forelimbs of humans, bats, and whales.

1. What are the similarities in the general structure of these forelimbs?

.....

2. Do these forelimbs perform the same function in these three organisms?

.....

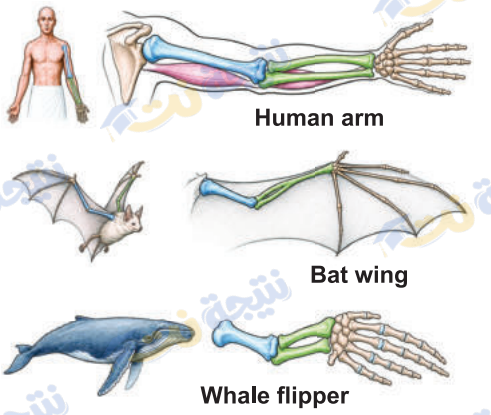


Figure (20)
Forelimbs of Humans, Bats, and Whales

Some organisms have organs that share the same basic structure.
These are called homologous structures.
Their functions may differ because each organism is adapted to a different environment and way of life. Within each species, individuals with traits better suited to their environment survive, and these traits pass to later generations by natural selection.

For example: the similarity in the overall bone structure of the human arm, bat wing, and whale flipper (Figure 20) is evidence that helps scientists classify these organisms as mammals, despite their different functions of these structures.

Some structures may be similar in function but not in structure. They are called analogous structures.

For example: wings found in the pterosaur (an extinct reptile), the bat (a mammal), and the butterfly (an insect) (Figure 21). Although their wings enable flight, their internal structures are completely different.



Figure (21)
Wings of the Pterosaur, Bat, and Butterfly

The wing of a **pterosaur** is supported by a single long finger attached to a skin membrane. A **bat wing is supported by four** long **spread fingers** like umbrella ribs. In **insects the wing is an extension** of the body's exoskeleton **and contains no bones or muscles**. It is moved by **thoracic muscles** (Figure 22).

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Figure (22)

Internal wing structure in the Pterosaur, Bat, and Butterfly

Comparative Anatomy of these wings shows that the presence of a wing does not indicate a shared evolutionary origin; rather, it indicates adaptation to similar environments.

Importance of Comparative Anatomy among Organisms

1. **Identifying common ancestors:** The **more** similar the internal structures of two species are, the **closer** their evolutionary relationship.
   For example, fossils show that **modern birds** share many traits with a group of carnivorous dinosaurs called **theropods** (Figure 23), **including** hollow bones, body posture, and feathers.



Figure (23)

Extinct Theropod

2. **Understanding the Evolutionary Pathways of Organs:**
   Comparative anatomy helps trace how **organs** and body structures evolved over time.
   For example, jaw bones in **reptiles evolved** into middle-ear bones in **mammals.**
3. **Reconstructing Extinct Organisms**
   By comparing the skeleton of an extinct animal with that of animals living today, scientists can visualize what the extinct animal looked like while it was alive on Earth.
   For example: reconstructing **Archaeopteryx** (Figure 24), which went extinct 150 million years ago.



Figure (24)

Extinct Archaeopteryx

Integration with Life Sciences

Transitional Fossils:

The Archaeopteryx fossil shows anatomical structures shared by both reptiles and birds, supporting the concept of a gradual evolutionary transition. It had teeth and a bony tail like reptiles, and feathered wings like birds.

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Assessment of Lesson one

1 Choose the correct answer for questions (1)–(5).

(1) What is a fossil?

(a) The remains of an organism that lived recently.
(b) Preserved remains of organisms that lived in the distant past.
(c) Layers of sedimentary rock.
(d) Minerals found beneath Earth's surface.

(2) Which of the following is an example of homologous structures?

(a) A butterfly wing and a bird wing.
(b) A whale flipper and a human arm.
(c) A bat wing and an insect wing.
(d) A fish fin and a bat wing.

(3) Two different flying organisms have wings. One wing is supported by bones, while the other is an extension of the organism's exoskeleton. What can be inferred about these two organisms?

(a) They have evolutionary links.
(b) They do not share a recent common ancestor.
(c) Both evolved from one species through geographical isolation.
(d) Both evolved from one species through genetic mutations.

(4) Which of the following fossils is the best choice for obtaining an intact soft-tissue sample from an extinct organism?

(a) A mold fossil in limestone.
(b) A footprint fossil in hardened mud.
(c) A petrified fossil of the organism.
(d) An entire body fossil preserved in ice.

(5) Which of the following factors may lead to mass extinction?

(a) Geographical isolation.
(b) Abundant food.
(c) Severe environmental changes.
(d) Increased biodiversity.

2 Define each of the following:

(1) Fossil record.
(2) Homologous structures.

3 Give reasons for:

(1) Some fossils provide evidence for the evolution of living organisms.
(2) Fossils of soft-bodied organisms are rare.
(3) The structural similarity between a whale's forelimb and a human arm is evidence of a common ancestor.

4 Compare between each of the following:

(1) Mold fossil and cast fossil (in terms of how each is formed).
(2) Homologous structures and analogous structures (in terms of similarity of function and structure).

5 State one benefit of anatomical comparison between ancient and recent organisms.

6 Scientists discovered a fossilized organism with both reptile-like and bird-like traits:

(1) What is this type of fossil called?
(2) What does its discovery indicate?
(3) Give an example of this type of fossil.

7 Petrified tree trunks were found in a dry desert region. **Conclude** the climate change that occurred in the region over time.

8 Some ancient organisms became extinct while other species survived:

(1) State two reasons for the diversity of life forms through geologic time.
(2) Explain how scientists inferred that mass extinctions of many ancient organisms occurred.

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Lesson Two

Geologic Time



Lesson Terminology:

- Rock Record
- Geologic Time Scale
- Relative Dating
- Law of Superposition
- Index Fossils
- Absolute Dating
- Radioactivity
- Half-life
- Radioactive Isotopes

Included Skills, Values, and Issues :

- **Skills:** Modeling – Measurement – Mathematical thinking – Data analysis – Critical thinking.
- **Values:** Respect for intellectual property.
- **Issues:** Exploitation of environmental resources and species extinction.

Cross-Cutting Concepts:

- Measurement – Patterns

Lesson Objectives :

By the end of the lesson, students will be able to:

1. Explain the concept of the geologic time scale and the purpose of using it.
2. Arrange the units of geologic time from largest to smallest (eons, eras, periods, and epochs).
3. Design a timeline showing geologic time on Earth.
4. Analyse data from rock layers and fossils to infer the sequence of geologic events.
5. Explain the methods that scientists use to determine the relative age of rocks and fossils.
6. Explain how scientists determine the absolute age of rocks using radioactivity.
7. Compare methods used to estimate the relative and absolute ages of rocks.

Lesson Introduction:

The figure shows a fossil of an animal that once lived on Earth. This lesson explores ideas that will help you answer the questions below:



- How can scientists estimate the age of this fossil?
- What role do radioactive elements play in determining the age of rocks and fossils?

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Have you ever wondered how old Earth is? How can scientists, despite not existing in ancient times,identify major events that occurred long before humans existed?

Scientists have inferred much of Earth's history by studying both:

1. **The fossil record:** all fossils naturally preserved in rock layers (Figure 1), or in other media such as ice or amber, and subsequently discovered.
2. **The rock record:** all rock layers and formations in Earth's crust (Figure 2).

Together, the rock record and the fossil record help scientists infer past environmental and climatic changes on Earth, and organize major geologic events.



Figure (1)
Fossils in rocks



Figure (2)
Rock sequence

Geologic time scale

Just as time is divided into units, (years, → months, → days, → hours) scientists have divided Earth's history into time units based on **rock** and **fossil evidence**. This division is known as **the geologic time scale**, which helps understand the sequence of major events in Earth's history, **such as:**

1. Major geologic changes that occurred over millions of years.
2. The appearance of different living organisms.
3. Major mass extinctions.

Units of the geologic time scale are arranged from **largest** to **smallest**, as follows:

Eons → **Eras** → **Periods** → **Epochs**

• **An eon is the largest** unit of geologic time, and each eon **is divided** into several **eras**.

For example, the **Phanerozoic Eon** is divided into three eras (Figure 3):

1. **Paleozoic Era.**
2. **Mesozoic Era.**
3. **Cenozoic Era.**

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• Each era is divided into several geologic periods, each had distinct climatic conditions. In turn, each period is subdivided into several epochs.

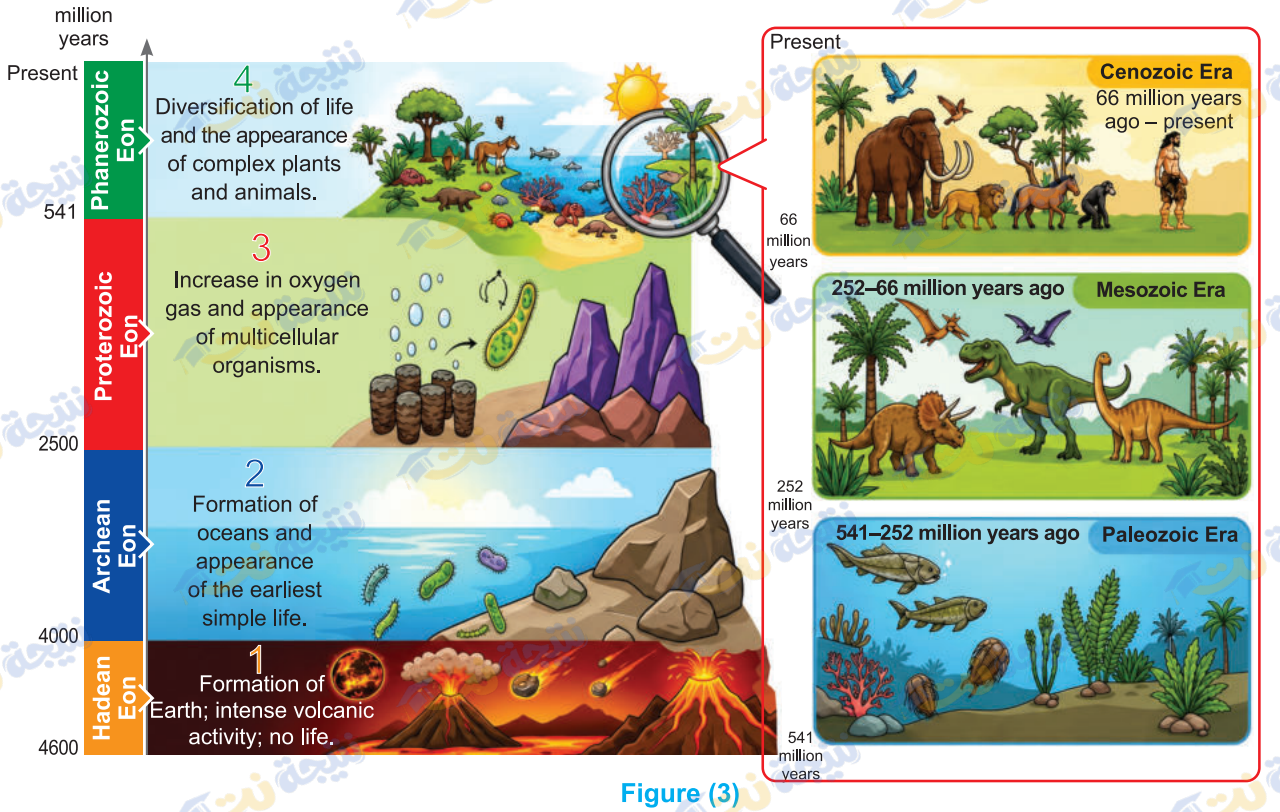


Figure (3)
Geologic time scale (For Reference Only)

Activity 1 Research

Designing a Timeline of Earth's History

Steps:

1. Work with your classmates to design a suitably long timeline (Figure 4) representing Earth's history (about 4.6 billion years). Use a suitable scale for the line length, such as 1 cm = 500 million years.
2. Search reliable websites and scientific references for important events in Earth's history.

Examples of major events in Earth's history:

Event	Eon / Era
Formation of Earth	.....
Appearance of early life forms	.....
Extinction of dinosaurs	.....
Diversity of mammals	.....



Figure (4)
Representing the geologic time scale

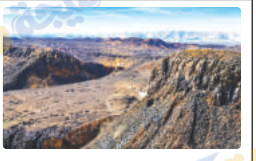
3. Place each event at its appropriate position on the timeline.
4. Discuss with classmates how scientists determined the time of each event.

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Geologic Features and Earth's History

Analysing geologic structures, sequences of rock layers, and fossils help scientists infer past geologic events that occurred on Earth.

Activity 2 Analyse and Conclude

Column (A)		Column (B)
1 Formation of the Red Sea and Uweinat mountains from igneous (granite) and metamorphic rocks.		(a) A sudden global mass extinction, probably caused by a major event such as a meteorite impact or severe climate changes.
2 The basalt rock covering limestone in Abu Rawash.		(b) These mountains were once an ancient sea floor and were uplifted by tectonic plate collision to form mountain ranges.
3 The presence of marine fossils on the high peaks of the Himalayan mountains		(c) These mountains are among the oldest parts of Earth's crust; their rocks formed deep within the Earth.
4 Fossils of extinct organisms, such as dinosaurs, in particular rock layers worldwide.		(d) This area was initially a marine environment, followed by volcanic activity that covered these rocks with basalt.

Rocks, geologic formations, and fossils provide evidence of ancient environments, catastrophes, or tectonic plate movements that reshaped the surface of the planet.

For example:

1. Deep within Earth, **igneous rocks** such as granite form through **cooling of magma**, while **metamorphic rocks** form under **intense heat and pressure**. Thus, the rocks of the **Red Sea and Uweinat mountains** are among the oldest rocks formed on Earth.
2. **Basalt** is an igneous rock that indicates past **volcanic activity**, whereas **limestone** is a sedimentary rock that usually forms on the floor of a **marine environment**. A basalt layer overlying limestone indicates that the area was once covered by sea water that later retreated, followed by volcanic eruptions.
3. **Marine fossils** form only on the floors of seas and oceans. Their presence on mountain peaks indicates that the area was once a sea floor. When tectonic plates collided, this ancient sea floor was uplifted to form mountain ranges, carrying the fossils from the ancient sea floor with it.
4. The presence of a specific fossil type in a particular rock layer worldwide, followed by its complete disappearance from higher layers, indicates the extinction of those organisms.

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Determining the Age of Rocks

Earth science goes beyond studying the form and composition of rocks; it also determines when those rocks formed.

Scientists use two main methods to do this: determining relative age and determining absolute age.

First Relative Age of Rocks

The relative age of a rock determines whether the rock is older or younger than another rock without determining its age in years. This estimate is based on:

1. **Law of Superposition:**

In an undisturbed sequence of sedimentary rock layers, the oldest layers are at the bottom and the youngest are at the top (Figure 5).

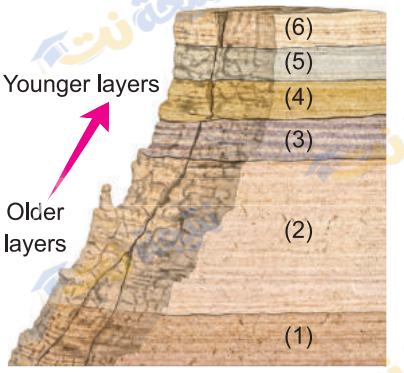


Figure (5)
Law of superposition

2. **Index fossils:**

These are fossils found in some sedimentary rock layers that belonged to organisms that lived for a short period of time and were widely distributed geographically, before becoming extinct and not appearing in later geologic periods. Examples include trilobite fossils (Figure 6) and ammonite fossils.

Index fossils are used to match rock layers in distant areas and determine their relative ages:

- When the same index fossil is found in two distant rock layers, the two layers have the same relative age, even if the rocks above and below them are different.
- The layer containing the index fossil is used as a "reference" within a rock sequence to determine the age of other layers. The layer below it is older, and the layer above it is younger.



Figure (6)
Trilobite fossil

Cross-Cutting Concepts : Patterns

Observing recurring patterns in rocks and fossils helps geologists sequence Earth's history. For example, recurring index fossils in particular layers helps determine the relative age of rock layers.

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Activity 3 Observe and Conclude

Figure (7) shows two rock sequences in two distant areas. Use the figure to answer:

(1) **Which** organisms appeared first on Earth: fossil (X) or fossil (Y)? **Why?**

.....

.....

(2) **What** is the order of rock layers A, B, C, and D from oldest to youngest using the positions of index fossils X and Y?



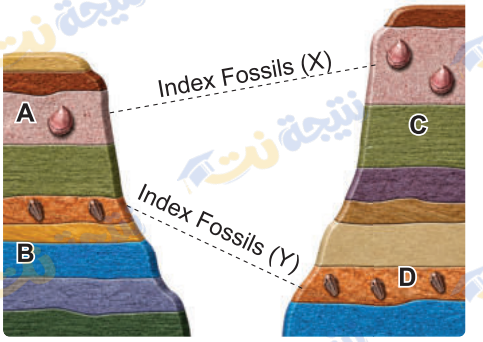


Figure (7)
Two distant rock sequences

Second Absolute Age of Rocks

Scientists can determine the absolute (or actual) age of some rocks and fossils using radioactivity.

Some minerals in rocks contain unstable radioactive elements, such as uranium-238 and carbon-14. Their nuclei emit radiation and transform into more stable elements.

The nuclei of each radioactive element decay gradually at a constant rate that is a characteristic of that element. This rate can be used as a measure of time. The time required for half the quantity of a radioactive element to decay is called its half-life. By measuring the amount of radioactive element remaining in a rock and the quantity of its decay product, scientists can calculate the exact time that has passed since the rock formed until now.

Cross-Cutting Concepts : Measurement

Radioactive decay patterns and half-lives are used to determine the absolute age of rocks and fossils.

Critical Thinking

(1) In what situations must scientists use relative dating instead of absolute dating?

.....

(2) How does using both methods provide a more accurate understanding of Earth's history?

.....

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Check Your Understanding

Complete the table to compare methods for determining the relative and absolute age of a rock.

Point of comparison	Relative age determination	Absolute age determination
Definition	.....	.....
Is the rock age determined in years?	.....	.....
Scientific principle	.....	.....
Purpose of using the method	– Identifying the sequence of geologic events – Determining which is older and which is younger	Determining the absolute age of rocks.

Enrichment Information

Imagine that a tiny grain of sand could hold one of our planet's secrets. Zircon crystals (Figure 8) found in some rocks in the Jack Hills of Australia do exactly that. Their extreme hardness and the uranium they contain, which decays over time into **lead**, make them an accurate geologic clock that can be used to determine their age.

Studies show that some of these crystals are about 4.4 billion years old. Recent studies indicate that Earth is about 4.6 billion years old.



Figure (8)
Zircon crystal

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Assessment of Lesson Two

1 Choose the correct answer for questions (1)–(6).

(1) What is meant by the geologic time scale?

(a) A device used to measure time in the past.
(b) A division of Earth's history into time periods.
(c) A method for determining rock density.
(d) A table showing the order of Earth's layers.

(2) Which of the following is a characteristic of index fossils?

(a) Limited distribution in one region.
(b) Found in layers belonging to several geologic periods.
(c) Wide geographic distribution and a short time range.
(d) Found in igneous and metamorphic rocks.

(3) Which of the following is an accurate method for determining the age of a rock sample in years?

(a) Law of Superposition.
(b) Index fossils.
(c) Radioactive decay.
(d) Comparative anatomy.

(4) In an undisturbed rock sequence, a dinosaur fossil is found in a lower layer (X), and a mammal fossil in an overlying layer (Y). What can be concluded?

(a) Mammals appeared on Earth before dinosaurs.
(b) Rock layer X is older than rock layer Y.
(c) Rock layer Y is older than rock layer X.
(d) Dinosaurs were heavier than mammals.

(5) If a rock sample contains only 50% of the original quantity of a radioactive element, how many half-lives have passed?

(a) One half-life. (b) Two half-lives.
(c) Three half-lives. (d) Four half-lives.

(6) Marine fossils found in a present-day desert indicate that .....

(a) destructive earthquakes occurred in the region.
(b) the region was once covered by water.
(c) Earth's surface has not changed since it formed.
(d) the organisms moved to live in the desert.

2 Define the following:

(1) Half-life. **(2)** Law of Superposition.

3 Arrange the units of the geologic time scale from largest to smallest.

4 Give reasons for:

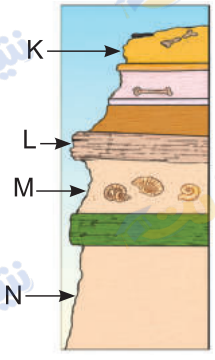
(1) Scientists use carbon-14 to determine the ages of some fossils.
(2) Index fossils help determine the relative age of rock layers.

5 Compare the following:

(1) Relative age **and** absolute age of rocks (in terms of determination methods and the information each provides)
(2) Index fossil **and** transitional fossil (in terms of meaning and scientific importance.)

6 The figure shows an undisturbed rock sequence, with different fossils found in the labeled layers.

(1) Arrange the labeled layers from oldest to youngest.
(2) Which layer is likely to contain fossils of more evolved organisms?
(3) Explain why fossil types differ from one layer to another.



7 Scientists use geologic and fossil evidence to understand Earth's history:

(1) State two benefits of studying the geologic time scale.
(2) Give an example of how sedimentary rocks and fossils help infer ancient environmental conditions.

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Notes

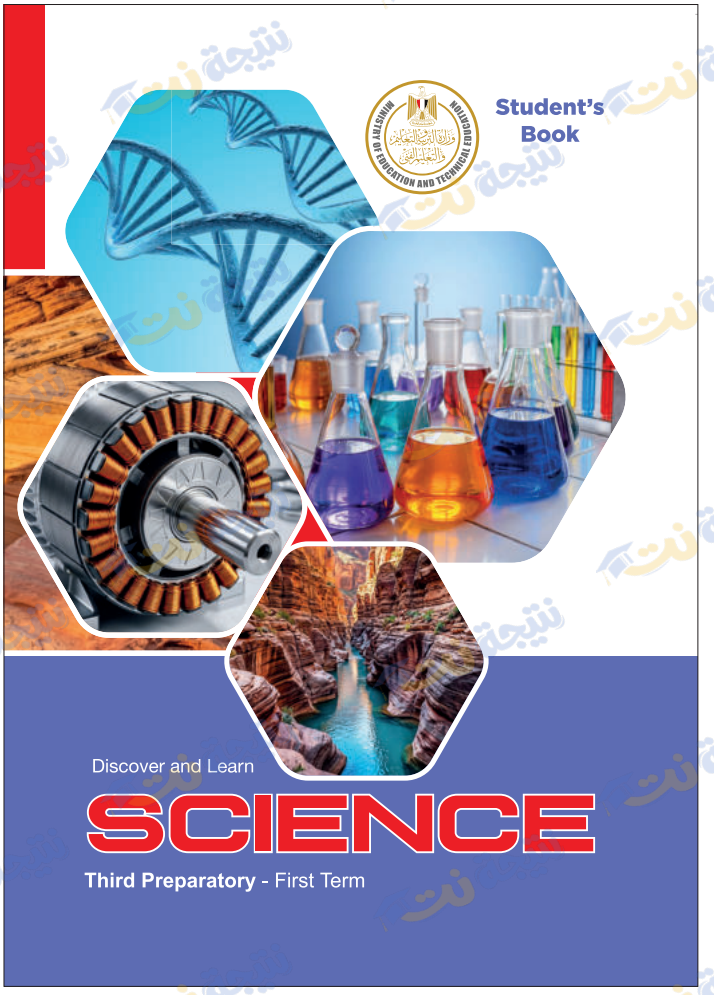
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