



Phase 1 Package

Scientific Track – NSMO

Sciences

Science Scientific Team

Biology

The Contents

Chapter one

Cell Structure and Function

■ The Cell.....	9
■ Characteristics of Living Organisms.....	10
■ Cell Theory.....	11
■ Difference Between Plant and Animal Cells.....	12
■ Components of the Cell.....	13
■ Cellular Structures.....	13
■ Membrane Structure.....	18
■ Transport of Substances Through the Membrane.....	20

Chapter two

Cell Chemistry

■ Cell Chemistry	24
■ What are the elements of living matter?.....	25
■ Macromolecules.....	25
■ Enzymes reduce the activation energy in the reaction.....	25

Chapter Three

Cellular Energy

■ Metabolism.....	31
■ Laws of Thermodynamics.....	31
■ Photosynthesis.....	32
■ Structure of Chloroplasts.....	33
■ Cellular Respiration.....	34

Chapter four

Cell Division

■ Cell Growth.....	40
■ Cell Division in Bacteria.....	41
■ Cell Division in Eukaryotes.....	41
■ Regulation of the Cell Cycle.....	45
■ Normal Cell Cycle.....	45
■ Abnormal Cell Cycle.....	46
■ Programmed Cell Death (Apoptosis).....	46
■ Stem Cells.....	46
■ Meiosis.....	47
■ Stages of Meiosis.....	48

Chapter five

Ecology

Living Organisms and Their Interactions.....	51
Energy Transfer in the Ecosystem.....	52
Cycling of Materials.....	53
Ecological Succession.....	54
Terrestrial Biomes.....	56
Biodiversity.....	57
Animal Behavior.....	58
References.....	76

Index of Figures

Figure 1 Levels of organization in living organisms.....	9
Figure 2 Prokaryotic Cells.....	11
Figure 3 Eukaryotic Cells	11
Figure 4 Animal Cell.....	12
Figure 5 Plant Cell.....	12
Figure 6 Cytoskeleton	13
Figure 7 Phosphocholine lipids	17
Figure 8 Membranous Structure	18
Figure 9 Osmosis.....	19
Figure 10 Shrinkage and swelling of red blood cells and plant cells in solutions of different concentrations.....	20
Figure 11 Simple Diffusion	21
Figure 12 Facilitated Diffusion	22
Figure 13 Active Transport.....	23
Figure 14 Phagocytosis & Pinocytosis.....	23
Figure 15 Exocytosis.....	24
Figure 16 peptide bonds in proteins	29
Figure 17 Enzymes that reduce energy activation and accelerate the reaction..	29
Figure 18 Enzyme binding to the substrate	29
Figure 19 Optimal temperature and pH for enzymes	29
Figure 20 The Energy Molecule – ATP	32
Figure 21 Phosphorylation Cycle.....	33
Figure 22 Chloroplast	33
Figure 23 Light absorption spectra of plant pigments.....	34
Figure 24 Light Reactions.....	34
Figure 25 Light-Independent Reactions	35
Figure 26 Glycolysis.....	36
Figure 27 Conversion of Pyruvic Acid to Acetyl CoA.....	36
Figure 28 Aerobic and Anaerobic Respiration	36
Figure 29 Krebs Cycle.....	37
Figure 30 Electron Transport Chain	38
Figure 31 Total net ATP	38
Figure 32 Alcoholic Fermentation	39
Figure 33 Lactic Acid Fermentation.....	39
Figure 34 Cell Division in Bacteria.....	42
Figure 35 Cell Cycle	43
Figure 36 The cell at the end of interphase	43
Figure 37 The chromosome after replication	43

Figure 38 Cytoplasmic Division	44
Figure 39 Stages of Mitosis	45
Figure 40 Cell Cycle	46
Figure 41 Stages of Meiosis.....	50
Figure 42 Pyramid of Numbers	54
Figure 43 pyramid of Energy	55
Figure 44 Pyramid of Biomass	55
Figure 45 Water Cycle.....	55
Figure 46 Nitrogen Cycle	56
Figure 47 Carbon Cycle	56
Figure 48 Primary succession.....	57
Figure 49 Secondary succession	57

Introduction

This course pack covers a set of fundamental concepts in biology, beginning with the study of the cell as the basic unit of life, moving through the biological processes that provide organisms with energy, and culminating in an understanding of how cells grow, divide, and integrate into complex systems within the human body.

The topics presented aim to provide a comprehensive overview of the essential components of life, the processes that sustain it, and the general structures that regulate the functioning of living organisms. They also explore the interrelationships among living creatures within ecosystems, the transfer of energy across trophic levels, the role of matter cycling in maintaining environmental sustainability, and the characteristics of major terrestrial and aquatic biomes. In addition, the pack examines biodiversity, animal behavior, and the various factors influencing it.

We have carefully designed this material to offer you both scientific content and an integrated vision that begins at the cellular level and extends to large-scale ecological systems. Presented in clear, engaging language, it aims to inspire your curiosity and encourage you to explore further challenges and the joy of learning.

General Objectives

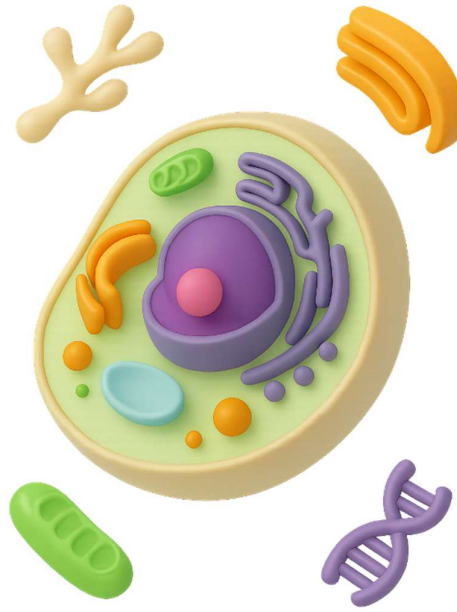
- 1- To build fundamental concepts in biology as a foundation for participation in scientific competitions.
- 2- To prepare students for the continuation of advanced studies in Olympiad-level biology.
- 3- To enrich the field with scientific material that supports and sustains the passion of those interested in Olympiad biology.
- 4- To promote and disseminate the culture of Olympiad participation.

Specific Objectives

- 1- For the student to be able to describe the different types of cells, their structures, and their functions.
- 2- For the student to recognize the chemical composition of the cell.
- 3- For the student to identify the sources of cellular energy and explain the mechanisms of its transfer.
- 4- For the student to explain the vital processes occurring within the cell, such as photosynthesis, cellular respiration, and cell division.

Chapter 1

Cell Structure and Function



Introduction

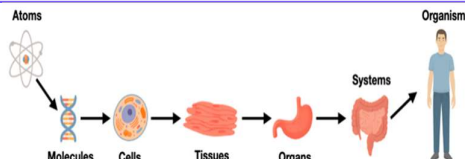
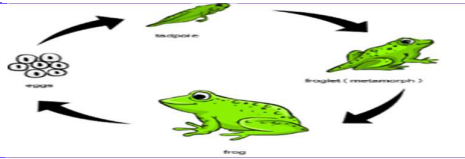
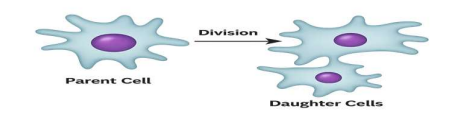
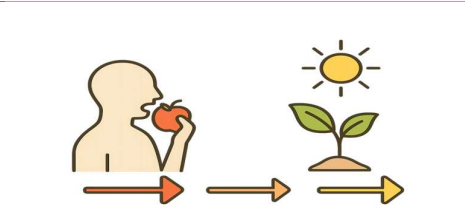
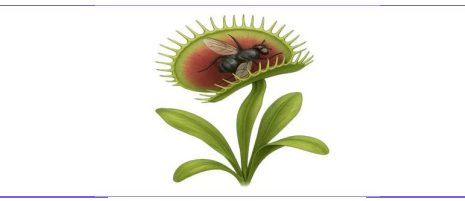
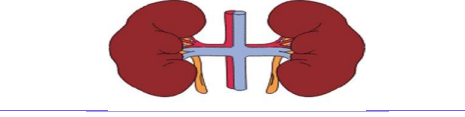
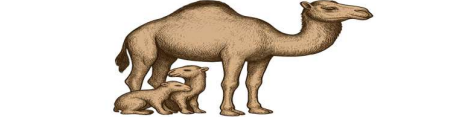
- **The Cell:** It is the structural and functional unit of a living organism
- **Types of cells:**
 - Prokaryotic cells: The genetic material is free and not surrounded by a membrane, such as in bacteria.
 - Eukaryotic cells: The genetic material is enclosed within a nucleus surrounded by a membrane, such as in plants and animals.
- Levels of organization in living organisms begin with the cell as follows:
- Cell → Tissue → Organ → System → Organism
- Tissue: A group of similar cells that perform the same function.
- Organ: A group of specialized tissues that perform specific functions.
- System: A number of organs working together to perform a certain task.
- Organism: May consist of a single cell, a number of tissues, a number of organs, or a number of systems.
- Protoplasm: Refers to what is inside the plasma membrane, including the cytoplasm and the nucleus.



Figure 1 Levels of organization in living organisms

Characteristics of living organisms:

All living organisms, regardless of their sizes, share the following characteristics:

Property	Definition	Example
Organization	Presence of organs, starting from the cell and ending with the organ system.	
Growth	Increase in size and weight.	
Reproduction	Increase in the number of individuals of the species.	
Obtaining Energy	Through direct oxidation of food in heterotrophic organisms. In autotrophic organisms, they produce their own food.	
Response	Sensitivity to internal and external stimuli and producing an appropriate response.	
Excretion	Maintaining homeostasis by eliminating wastes.	
Adaptation	Making structural and behavioral changes to cope with the environment.	

Cell Theory:

The cell theory states that:-

1. All living organisms are composed of one or more cells.
2. The cell is the basic unit of structure and function in living organisms.
3. New cells arise only from pre-existing cells.

Comparison between Prokaryotes and Eukaryotes:

Feature	Prokaryotic Cells	Eukaryotic Cells
Number of Cells	Unicellular <u>only</u>	Unicellular or Multicellular
Nucleus	No true nucleus; DNA is free in cytoplasm	True nucleus enclosed by a nuclear membrane
DNA structure	Circular DNA (plasmid may be present)	Linear DNA organized into chromosomes
Organelles	No membrane-bound organelles	Membrane-bound organelles (mitochondria, ER, etc.)
Cell wall	Usually present (peptidoglycan in bacteria)	In plants (cellulose) and fungi (chitin); absent in animals
Chromosome	Usually one (single circular chromosome)	More than one (multiple linear chromosomes)
Examples	Bacteria, Archaea	Plants, Animals, Fungi, Protists

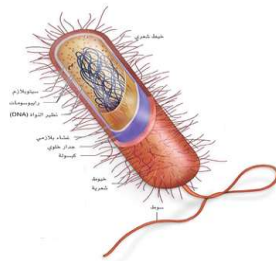


Figure 2 Prokaryotic Cells

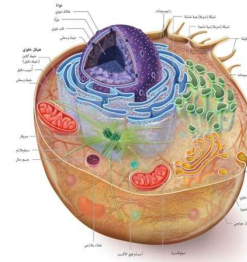


Figure 3 Eukaryotic Cells

Difference between Plant Cell and Animal Cell.

Structure	Plant Cell	Animal Cell
Cell Wall	Present	Absent
Nucleus Location	Peripheral	Central
Plastids	Present	Absent
Centrosome	Absent	Present
Vacuoles	One large vacuole	Several small vacuoles

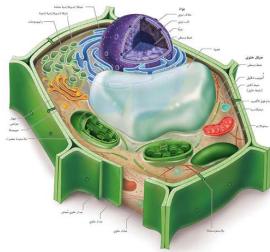


Figure 4 Plant Cell

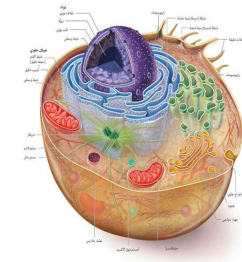
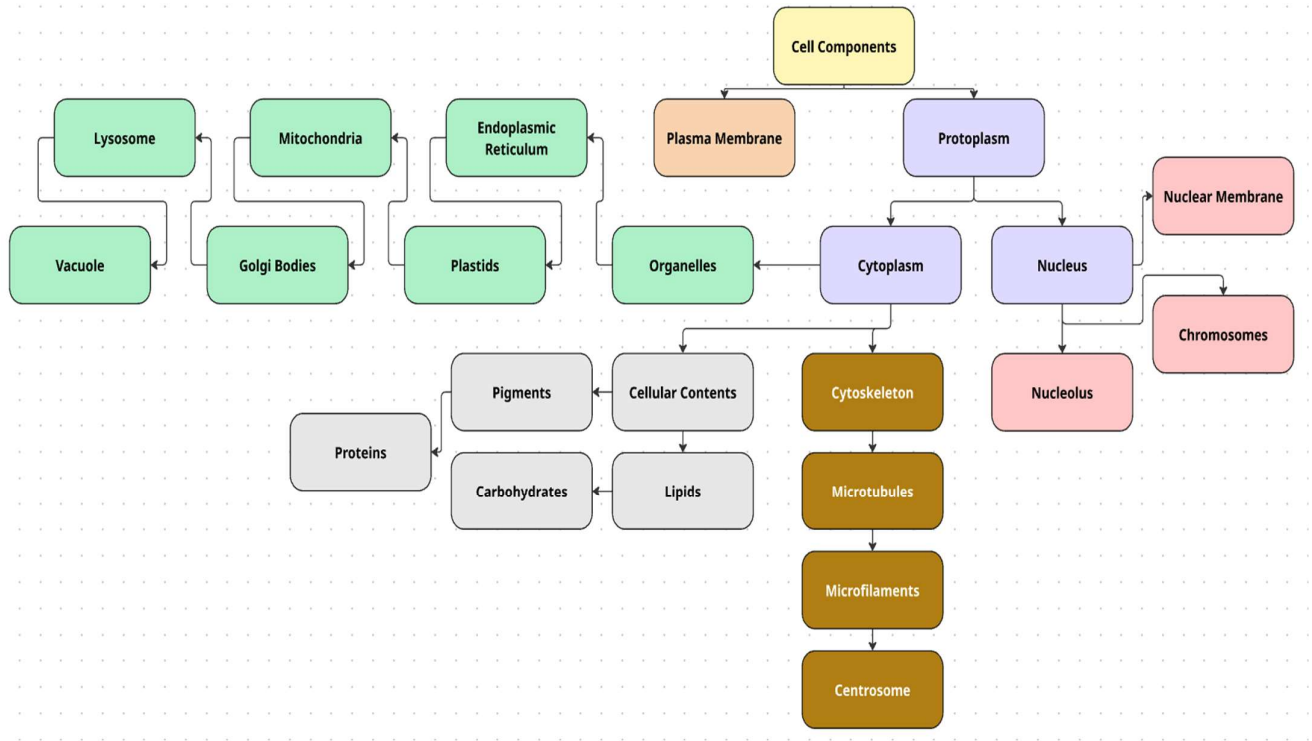


Figure 5 Animal Cell

Cell Contents Concept Map



Cytoskeleton: A network of protein filaments that supports the cell, gives it its shape, anchors organelles inside the cell, and also contributes to regulating the movement of organelles within the cell.

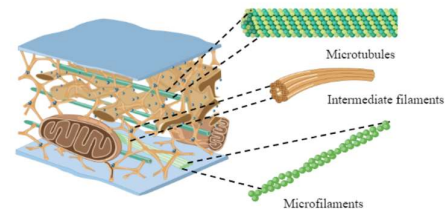
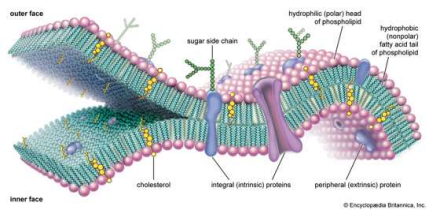
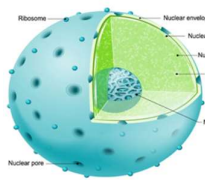
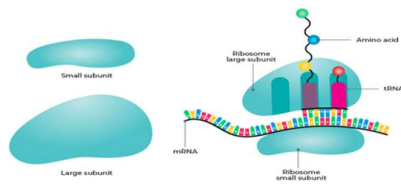
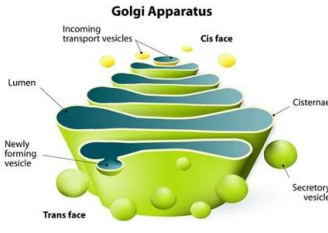
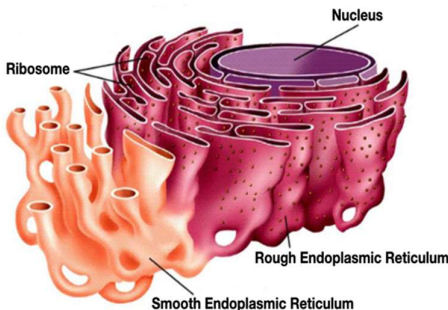
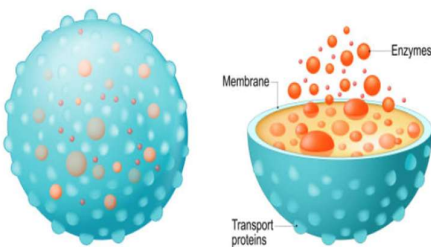


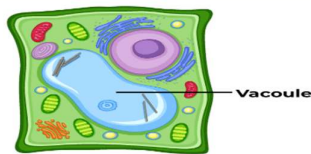
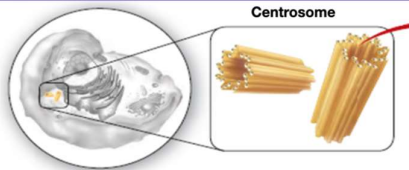
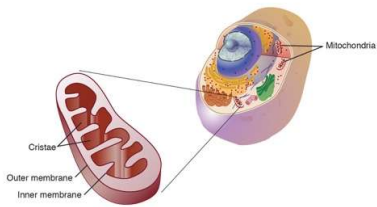
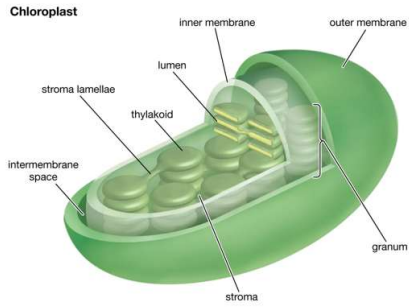
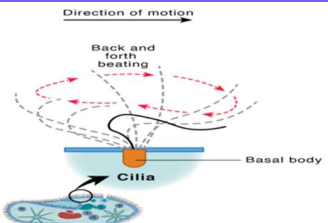
Figure 6 Cytoskeleton

Cell Structures (Organelles):

Structure	Function	Figure
Cell Wall	- A perforated membrane that allows all materials to pass into and out of the cell. - Its function is support and protection. - It is found in all cells except animal cells and their counterparts.	

Cell Membrane	- A double layer of phospholipids and proteins. - Defines the boundaries of the cell and regulates the passage of molecules into and out of the cell (selective permeability).	
Nucleus	- Storage of genetic information - Production of DNA and RNA - Control and command center of the cell	
Ribosome	- Protein synthesis - Found free in the cytoplasm or attached to the endoplasmic reticulum	
Golgi Apparatus	- A system composed of stacked membranes. - It modifies, sorts, and packages materials into sacs called vesicles. - Responsible for the formation of lysosomes.	

Structure	Function	Figure
Endoplasmic Reticulum (ER)	A system consisting of interconnected channels, divided into two types: 1. Rough Endoplasmic Reticulum (RER) - Site of ribosome attachment - Responsible for protein synthesis and transport 2. Smooth Endoplasmic Reticulum (SER) - Lacks ribosome attachment - Responsible for the synthesis of carbohydrates and complex lipids, including phospholipids - In the liver, it detoxifies harmful substances from the body - Transports proteins	 The diagram illustrates the structure of the endoplasmic reticulum. It shows a central purple nucleus surrounded by a network of pink, folded membranes. The rough endoplasmic reticulum (RER) is characterized by the presence of small black dots representing ribosomes. The smooth endoplasmic reticulum (SER) is shown as a network of tubular membranes without ribosomes.
Lysosome	- Originate from the Golgi bodies and the endoplasmic reticulum. - Carry out intracellular digestion (within the cell).	 The diagram shows a lysosome as a spherical organelle with a blue, textured surface. Inside, there are various colored dots representing enzymes and other molecules. A cross-section view shows the internal structure with a membrane and the presence of enzymes and transport proteins.

	-Responsible for programmed cell death (apoptosis).	
Vacuole	-Storage of materials. -Its size in plant cells is larger than in animal cells.	
Centrioles	- A pair of tubules. - Form the spindle fibers. - Play a role in animal cell division	
Mitochondria	- Cellular Respiration - The powerhouse of the cell - Surrounded by two membranes - Contains genetic material	
Chloroplast	- Photosynthesis - Surrounded by two membranes and contains genetic material - Colorless plastids store materials - Colored plastids give flowers and fruits their colors	 © Encyclopædia Britannica, Inc.
Cilia	- Short, numerous, hair-like projections. - Move in coordination to transport substances or aid cell movement.	

	- Made of microtubules (9+2 arrangement).	
Flagella	- Long and few in number (usually 1–2 per cell). - Whip-like motion used mainly for locomotion. - Made of microtubules (9+2 arrangement).	
Cytoplasm	- Gel-like substance that fills the cell. - Composed of water, salts, and organic molecules. - Supports organelles and holds them in place. - Site of many metabolic reactions.	

Membranous Structure (Cell Membrane)

- The cell membrane is defined as the boundary separating the cell's protoplasm from the external environment, controlling the passage of substances into and out of the cell (selective permeability).
- It surrounds the cell externally, as well as the nucleus and organelles.
- It is composed of two layers of lipids (phospholipids) interspersed with proteins and carbohydrates.

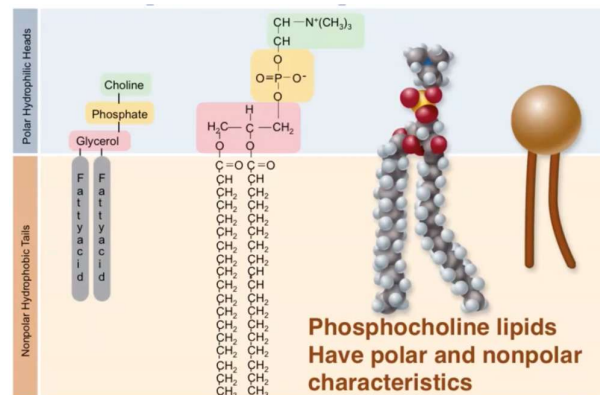


Figure 7 Phosphocholine lipids

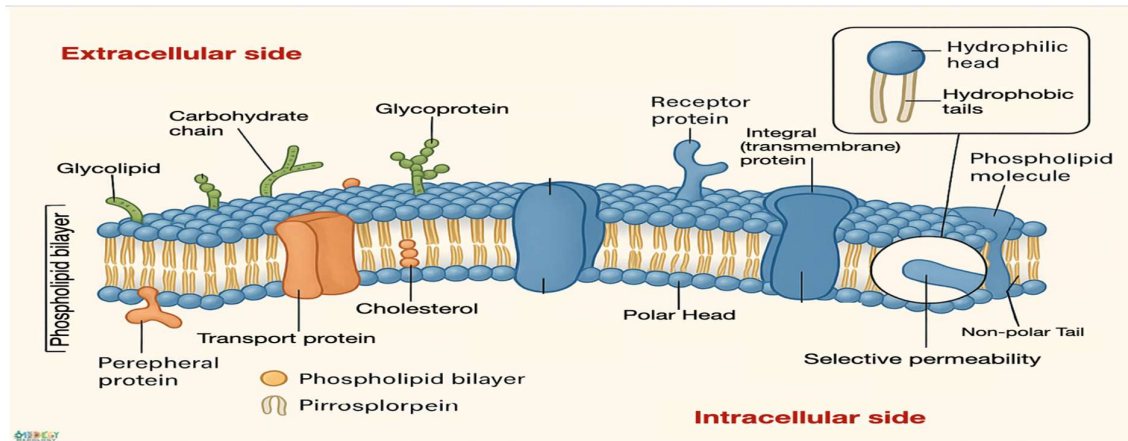


Figure 8 Membranous Structure

Membrane Structure

I. Lipid Molecules	
1) Cholesterol	Regulates the flexibility of the membrane depending on temperature.
2) Hydrophobic phospholipids	Allow the passage of non-polar, water-repelling molecules such as CO ₂ , O ₂ , and hydrocarbons.
3) Hydrophilic phospholipids	Permit the limited passage of polar, water-loving substances, such as small amounts of water through tiny pores between phospholipid molecules.
II. Protein Molecules	
1) Enzyme protein	Some membrane proteins act as enzymes that facilitate chemical reactions within the cell.
2) Transport protein	Helps specific substances pass through the cell membrane.
3) Receptor protein	Recognizes and binds to specific molecules outside the cell.

III. Carbohydrate Molecules	
1) Glycoprotein	A distinctive marker on the cell surface that gives each cell its identity, enabling immune cells to recognize the body's own cells and prevent them from being attacked. (This is the basis for immune rejection in organ transplantation.)
2) Membrane Carbohydrates	• Play a role in hormone reception. • Help in cell adhesion and binding. • Contribute to cell recognition within the same organism. • Therefore, they are important in immune interactions.

Transport of Substances Across the Membrane:

Osmosis

The process of moving solvent molecules (water) from a solution with a lower solute concentration to a solution with a higher solute concentration.

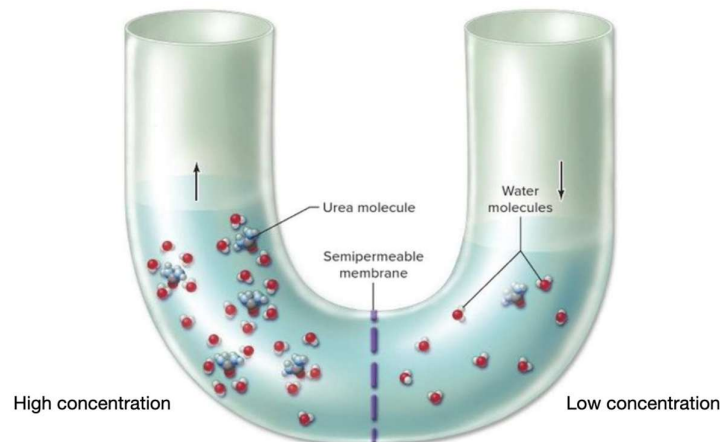


Figure 9 Osmosis

Solutions are classified according to their osmotic concentration into three types, each with a specific effect on the cell:

- Hypertonic solution: A solution with a high concentration of solute (salts).
- Hypotonic solution: A solution with a low concentration of solute (salts).
- Isotonic solution: A solution with an equal solute concentration (salts).

Example 1: Red blood cells placed in solutions of different concentrations

- When red blood cells are placed in a hypertonic solution:
The red blood cells shrink as a result of water leaving the cell.
- When red blood cells are placed in a hypotonic solution:
The red blood cells swell and may burst due to water entering the cell.
- When red blood cells are placed in an isotonic solution:
The red blood cells remain unchanged because the concentrations are balanced.

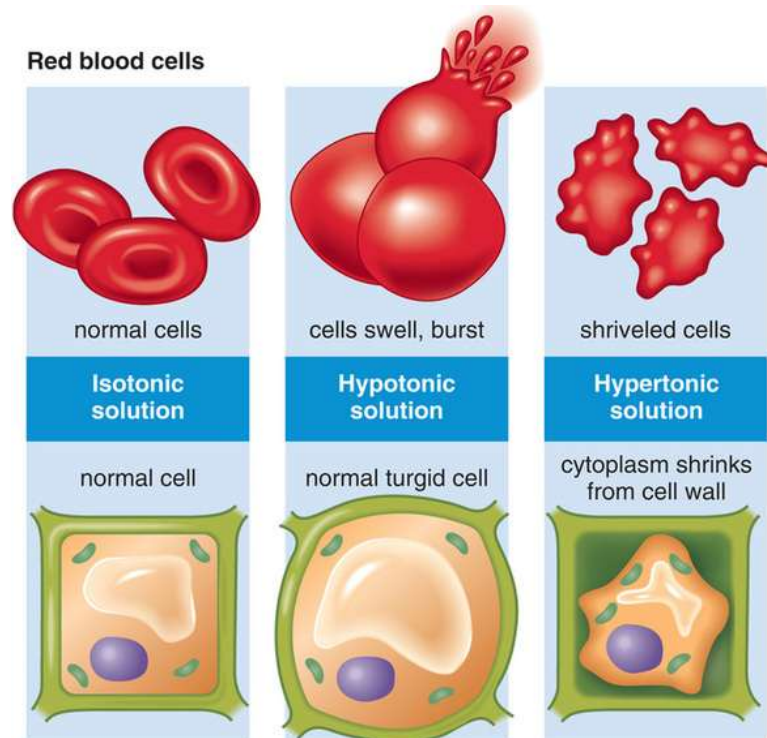


Figure 10 Shrinkage and swelling of red blood cells and plant cells in solutions of different concentrations

Simple Diffusion

The movement of molecules from an area of high concentration to an area of low concentration. This property plays an important role in the exchange of substances between the cell and its surrounding environment. Example: Oxygen, carbon dioxide, and substances that dissolve in lipids.

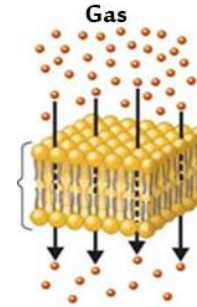


Figure 11 Simple Diffusion

Facilitated Diffusion

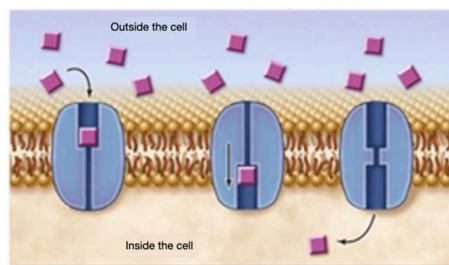
This process occurs along the concentration gradient of the transported substance (from a high concentration to a low concentration). Molecules that do not dissolve in lipids and cannot pass through the cell membrane pores are transported with the help of carrier proteins, known as transport proteins.

There are two main types of these proteins:

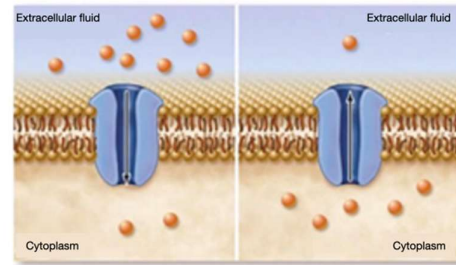
Type I: Forms channels through which certain ions can pass.

Type II: Binds to the molecule to be transported, carries it across the membrane, then releases it inside the cell and returns to its original position to bind to another molecule. This process involves temporary changes in the protein's shape.

Example: The rapid movement of glucose and fructose molecules from outside the cell to inside it.



B. Glucose transport



A. Ion transport

Figure 12 Facilitated Diffusion

Active Transport

The movement of substances from an area of low concentration to an area of high concentration, which requires the expenditure of energy to occur. In this process, the transported substance binds to a component of the cell membrane, which may be a protein or lipid.

Example: Ions

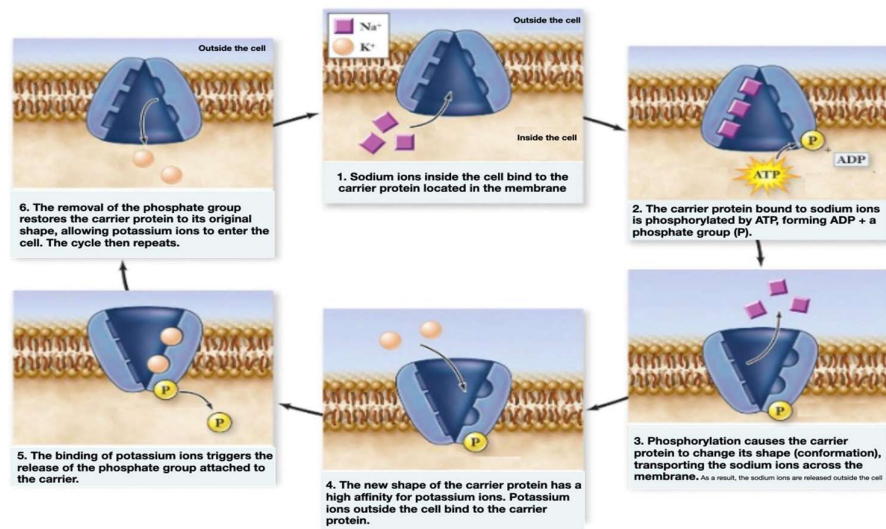


Figure 13 Active Transport

Endocytosis Exocytosis

Endocytosis → The plasma membrane has the ability to fold inward at the region where it contacts large particles, causing these particles to become enclosed within the fold, which gradually transforms into a vesicle within the cytoplasm.

Endocytosis is divided into two types:

Phagocytosis (cell eating) → occurs when the materials ingested by the cell are solid.

Pinocytosis (cell drinking) → occurs when the materials ingested by the cell are liquid.

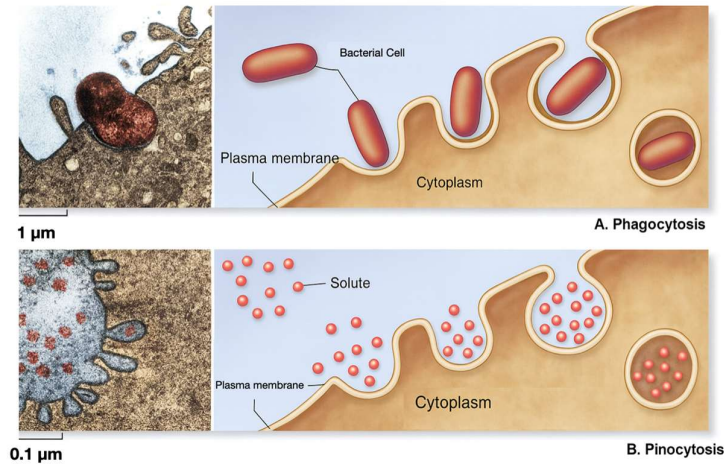


Figure 14 Phagocytosis & Pinocytosis

Exocytosis

The process of expelling materials outside the cell by forming special vesicles or vacuoles within the cell that fuse with the plasma membrane and release their contents outside the cell.

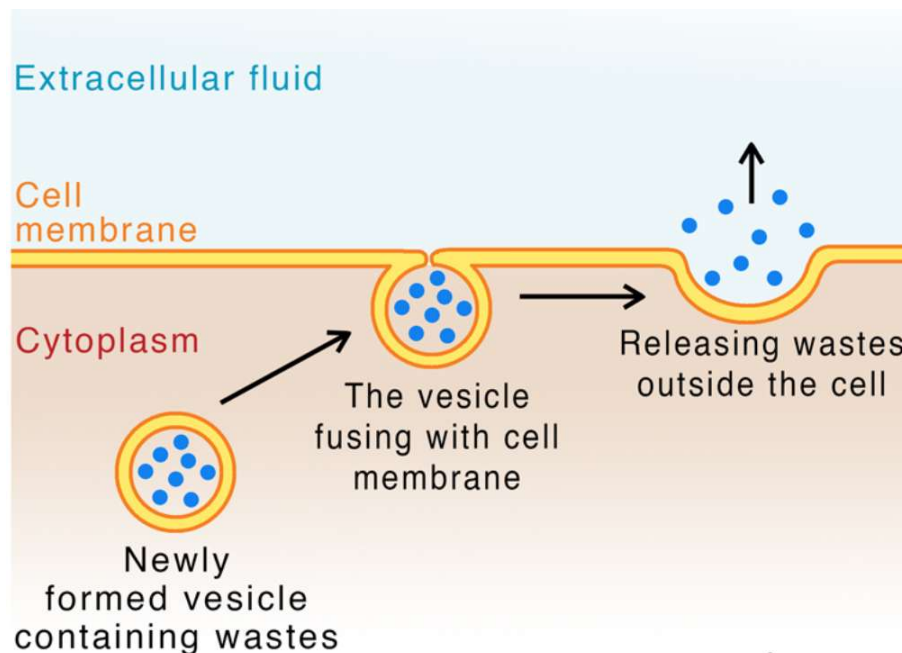
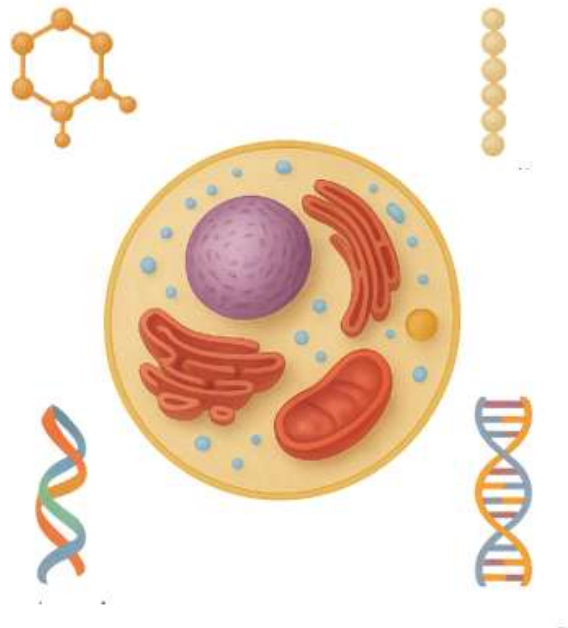


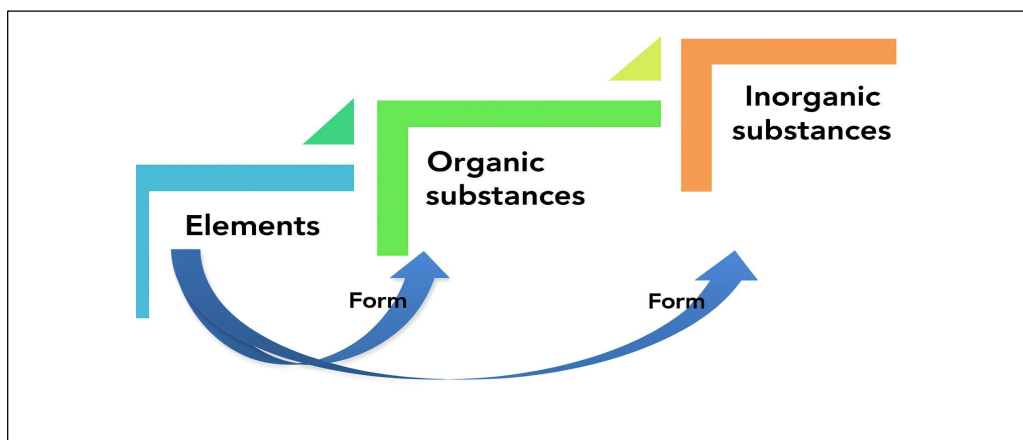
Figure 15 Exocytosis

Chapter Two Cell Chemistry



The Chemistry of The Cell:

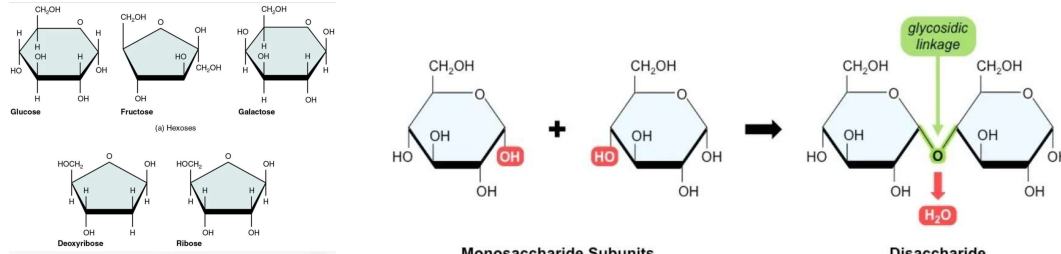
- The cell, with all its components, is composed of chemical elements.
- All biological activities depend on chemical reactions.
- These reactions rely on chemically bonded elements arranged in a coordinated and organized manner.

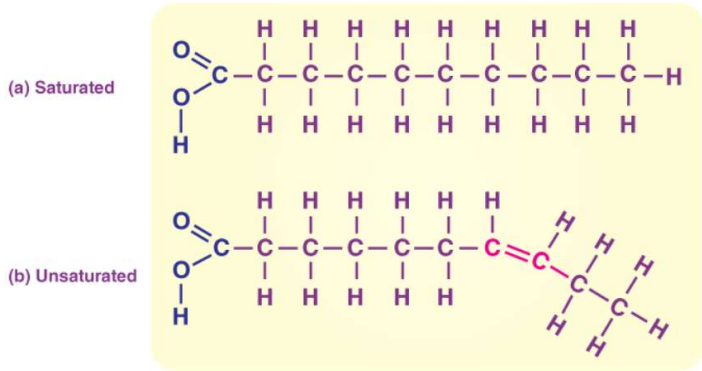
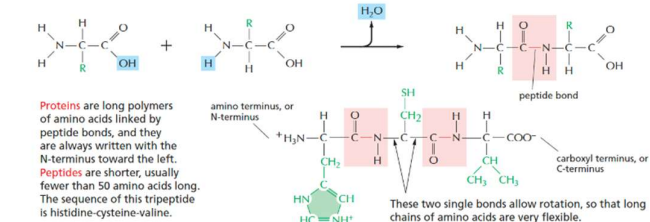


What are the elements of living matter, and how do they exist?

Secondary (Microelements)	Primary 5% (Macroelements)	Major Elements 90%
Iron/ Aluminum/ Chlorine/ Zinc/ Iodine/ Boron/ Manganese/ Sodium	Calcium/ Sulfur/ Magnesium/ Potassium/ Phosphorus	Oxygen/ Hydrogen/ Carbon /Nitrogen

- The major and essential elements are found in all living organisms, whereas the secondary elements are present only in some.
- The major, essential, and secondary elements exist either in a free form or as compounds.
- The cells of living organisms are composed of compounds that contain carbon in their structure, called organic compounds.
- These compounds are known as macromolecules, and they include: carbohydrates, lipids, proteins, and nucleic acids.

1- Carbohydrates	
Structure	Composed of C, H, and O in the ratio 1 : 2 : 1. General formula: $(CH_2O)_n$
Importance	Serve as a source of energy.
Types	- Monosaccharides: single molecule ($C_6H_{12}O_6$) such as glucose and fructose. - Disaccharides: formed by joining two monosaccharide molecules through the removal of a water molecule ($C_{12}H_{22}O_{11}$), such as sucrose and lactose. - Polysaccharides: composed of many monosaccharide units ($(C_6H_{10}O_5)_n$), such as glycogen, starch, and cellulose.
Main characteristics of monosaccharides and disaccharides: • They can pass through cell membranes. • They dissolve in water. Polysaccharides cannot pass through membranes and do not dissolve in water>	
 The diagram illustrates the chemical structures of various monosaccharides and the process of forming disaccharides. At the top left, the structures of Glucose, Fructose, and Galactose are shown, labeled as (a) Hexoses. Below them are the structures of Deoxyribose and Ribose. To the right, a reaction shows two glucose molecules (represented as hexagons) joining to form a disaccharide (maltose). This process involves the removal of a water molecule (H₂O), indicated by a red arrow pointing down from the reaction. The resulting disaccharide is shown with a green arrow pointing to the 'glycosidic linkage' between the two sugar units. Below this, the structures of Cellulose and Starch are shown, both consisting of long chains of glucose units linked by glycosidic bonds. Cellulose is shown as a linear chain, while Starch is shown as a branched chain.	

2- Lipids	
Structure	Composed of C, H, and O.
Importance	Energy storage and protection.
Components	Fatty acids and glycerol.
Types	1. Saturated fats: Solid; contain single bonds between carbon atoms – e.g., animal fats. 2. Unsaturated fats: Liquid; contain double bonds between carbon atoms – e.g., vegetable oils.
	
3- Proteins	
Structure	Composed of C, H, O, and N.
Importance	Building tissues, transporting substances between cells, accelerating chemical reactions, and transmitting signals within the cell.
Components	Made up of 20 different amino acids linked together by peptide bonds to form proteins. Enzymes: Special types of proteins that act as catalysts for chemical reactions in the body. They lower the activation energy required for the reaction and are not consumed during the process. Examples: salivary amylase and pancreatic amylase.
PEPTIDE BONDS In proteins, amino acids are joined together by an amide linkage, called a peptide bond. The four atoms involved in each peptide bond form a rigid planar unit (red box). There is no rotation around the C-N bond.  Proteins are long polymers of amino acids linked by peptide bonds, and they are always written with the N-terminus toward the left. Peptides are shorter, usually fewer than 50 amino acids long. The sequence of this tripeptide is histidine-cysteine-valine. These two single bonds allow rotation, so that long chains of amino acids are very flexible.	
Figure 16 peptide bonds in proteins	

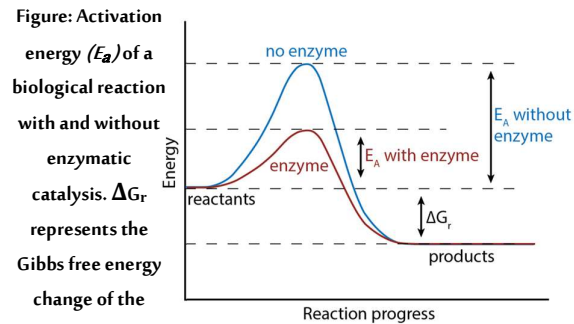


Figure 17 Enzymes that reduce activation energy and accelerate the reaction

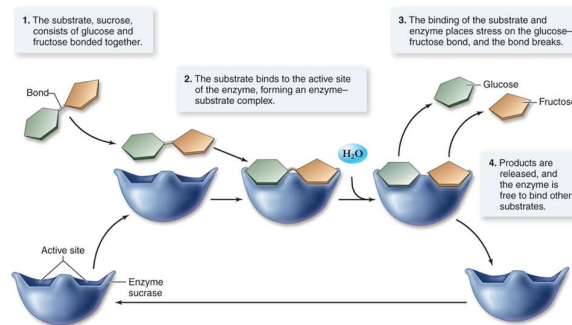


Figure 18 Enzyme binding to the substrate

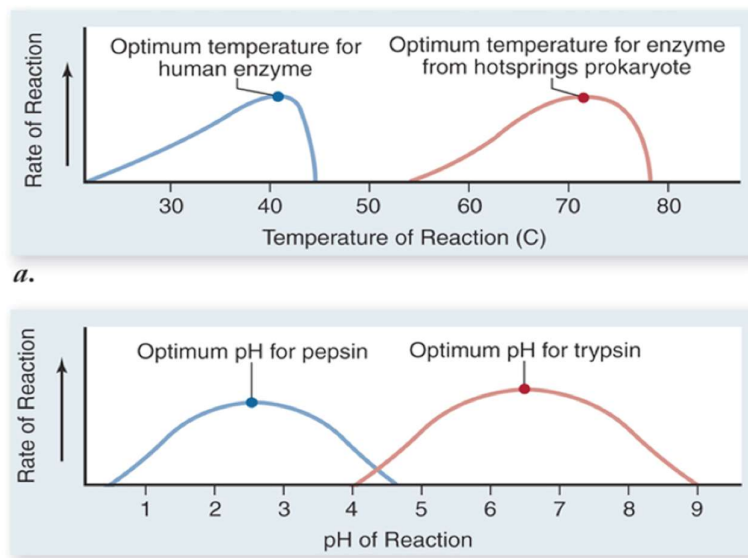
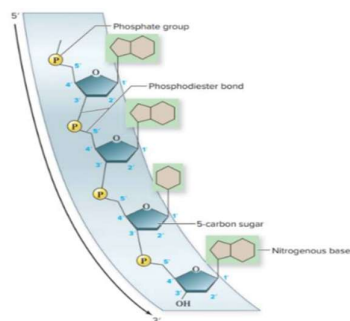
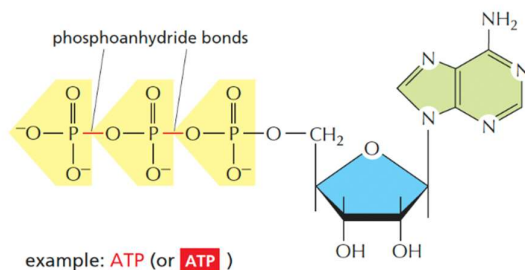


Figure 19 Optimal temperature and pH for enzymes

4- Nucleic Acids

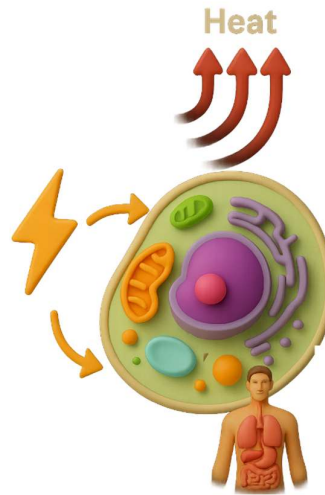
Structure	Composed of C, H, O, N, and P.
Function	Storage and transmission of genetic information.
components	A pentose sugar, a nitrogenous base, and a phosphate group.
Types	DNA and RNA.

As nucleoside di- and triphosphates, they carry chemical energy in their easily hydrolyzed phosphoanhydride bonds.



Nucleotide: The basic unit of nucleic acids, composed of a phosphate group, a nitrogenous base, and a ribose sugar.

Chapter Three Cellular Energy



Metabolism:

Metabolism is the sum of all the biochemical processes that occur within the body of a living organism.

Metabolic processes are divided into:

- Catabolism: releases energy, e.g. digestion and respiration.
- Anabolism: consumes energy, e.g. photosynthesis.

How do living organisms obtain energy?

- Energy is the ability to do work.
- The main source of energy on Earth is the Sun.
- The direct source of energy for living organisms is food (nutrients).

📖 Laws of Thermodynamics:

📖 First Law (Law of Energy Conservation):

- States that energy can be transformed from one form to another, but cannot be created or destroyed except by God's will.
- Example: the energy stored in nutrients is converted to chemical energy when you eat, and then to mechanical energy when you run.

📖 Second Law:

- States that energy is lost whenever it is transformed from one form to another.
- The lost energy is released as heat.
- The food chain is an example of this law.

📖 The Energy Molecule – ATP:

- It is the cellular unit of energy.
- It consists of adenine + ribose sugar + three phosphate groups.
- It stores chemical energy used by cells in their reactions.
- ATP releases energy when the bond between the second and third phosphate groups is broken.
- This produces ADP + a free phosphate group.
- Energy is stored in the phosphate bond when ADP combines with a free phosphate group to form ATP again.

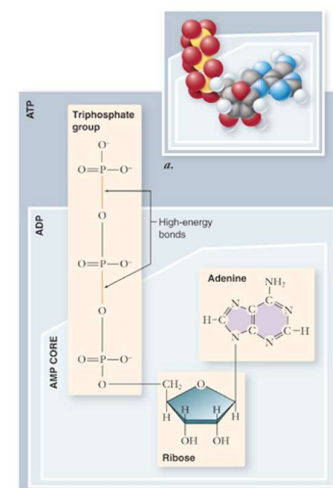


Figure 20 The Energy Molecule – ATP

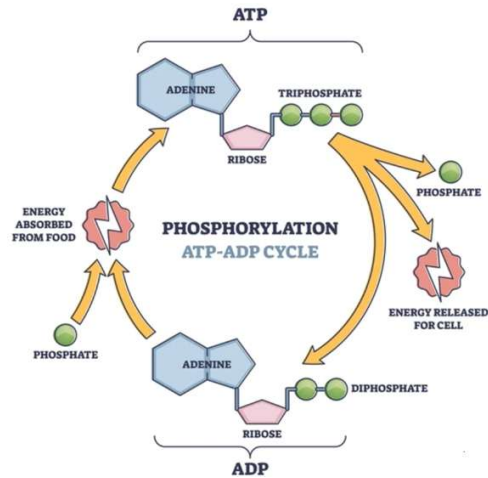


Figure 21 Phosphorylation Cycle

Photosynthesis:

- The process of converting light energy into chemical energy.
- Photosynthesis takes place in the chloroplasts.
- It is a common process among all organisms that contain chloroplasts.
- It occurs through a series of reactions that produce a molecule of glucose.



Chloroplast:

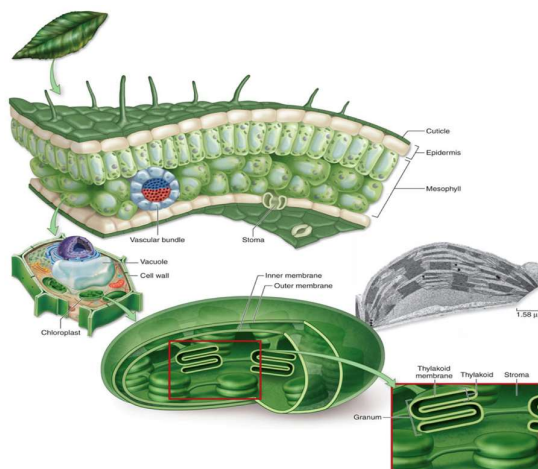


Figure 22 Chloroplast

Structure of the Chloroplast:

- Large, disc-shaped organelles.
- Contain the pigment chlorophyll, which absorbs light energy.
- Composed of:
 1. Thylakoids: stacks of flattened membrane sacs (disc-like structures) that form the grana.
 2. Stroma: the fluid that fills the spaces surrounding the grana.

Pigments:

Colored molecules located in the thylakoid membranes that absorb specific wavelengths of light.

Types:

1. Chlorophyll (a) and (b): the main pigments in plants.
 - Light absorption by chlorophyll a and b is highest in the red and violet regions of the spectrum.
2. Carotenoids: red, yellow, and orange pigments.
 - These pigments become visible in autumn as chlorophyll molecules break down, giving leaves their different colors.

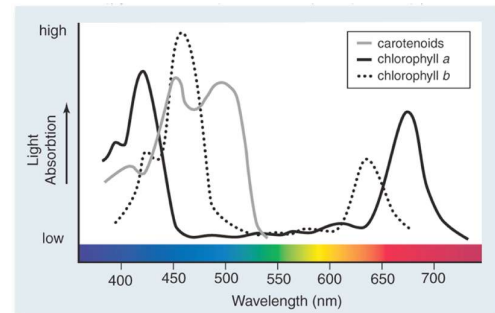


Figure 23 Light absorption spectra of plant

Photosynthesis occurs in two stages:

1. Light Reactions:

- Occur in the grana, where chlorophyll pigments absorb light energy and convert it into chemical energy in the form of NADPH and ATP, which are used to build glucose.
- Oxygen is released as a byproduct due to the splitting of water molecules.

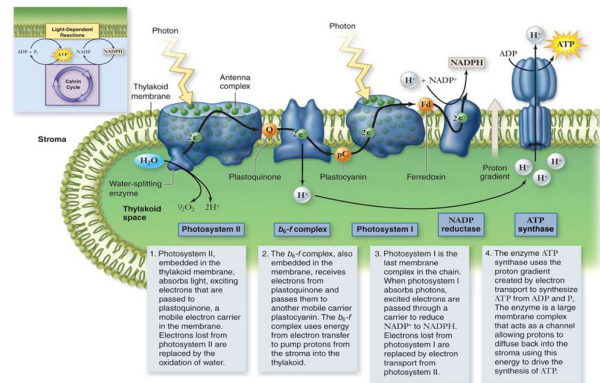


Figure 24 Light Reactions

2. Dark Reactions (Light-Independent Reactions):

- Occur in the stroma, where the energy produced from the light reactions (ATP and NADPH) along with CO_2 is used to form a molecule of glucose.
- Take place through a series of reactions known as the Calvin Cycle.
- Do not require the presence of light.

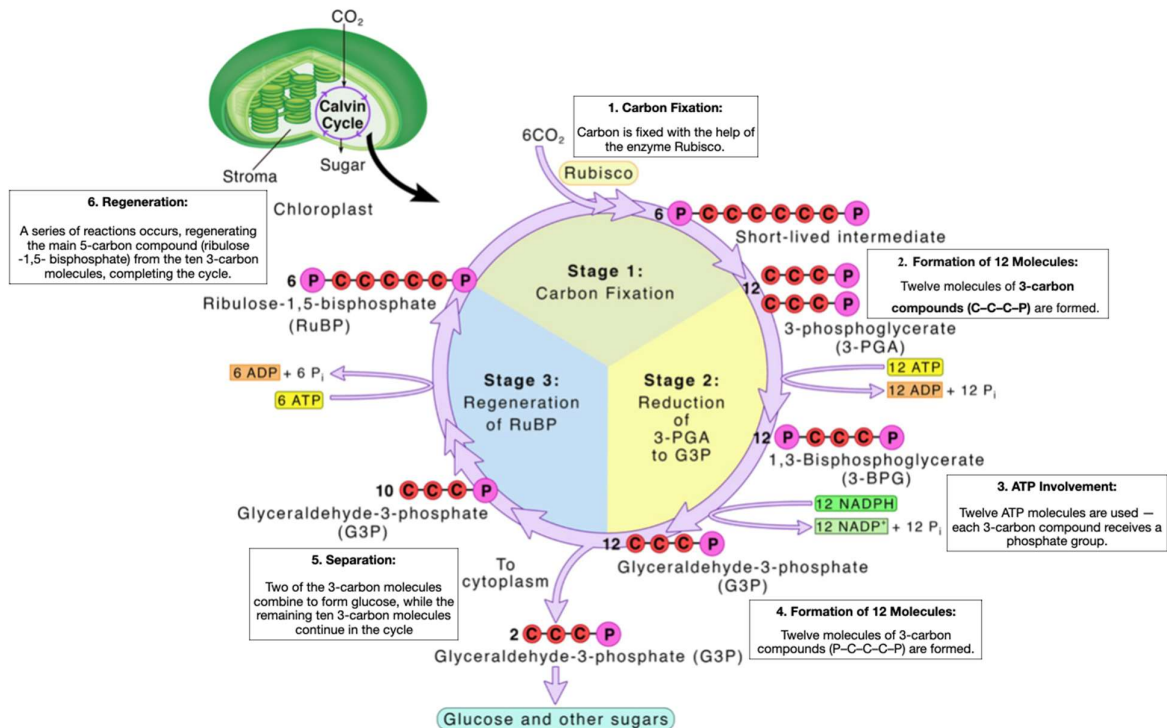


Figure 25 Light-Independent Reactions

Cellular Respiration:

- The process of oxidizing nutrients to obtain energy.
- Involves the intake of O_2 and the release of CO_2 .
- Takes place inside the mitochondria.
- There are two types of respiration: 1. Aerobic respiration: occurs in the presence of oxygen. / 2. Anaerobic respiration: occurs in the absence of oxygen

Aerobic Respiration:



Aerobic respiration goes through four stages:

1. Glycolysis:

- Glucose is broken down in the cytoplasm.
- Two molecules of pyruvic acid are produced.
- The net energy yield from this stage is 2 NADH + 2 ATP.
- The carbon-containing compounds move on to the next stage.
- The energy-carrying molecules proceed directly to the final stage to enter the electron transport chain reactions.

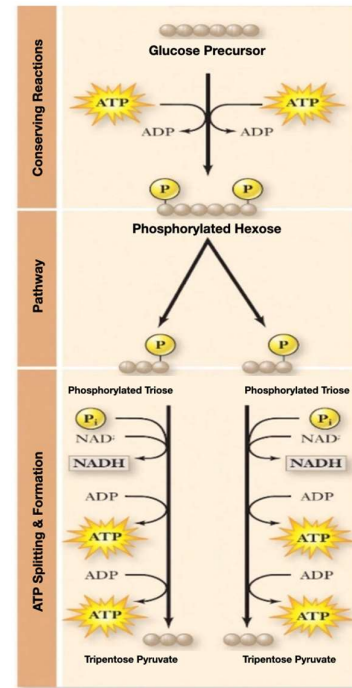


Figure 26 Glycolysis

2- Conversion of Pyruvic Acid to Acetyl CoA:

- This stage occurs in the mitochondrial membrane.
- When oxygen is available, pyruvic acid enters the mitochondrion.
- The acetyl group combines with coenzyme A (CoA) to form acetyl-CoA.
- The products of this stage (from 2 pyruvates) are: 2 Acetyl-CoA + 2 CO₂ + 2 NADH

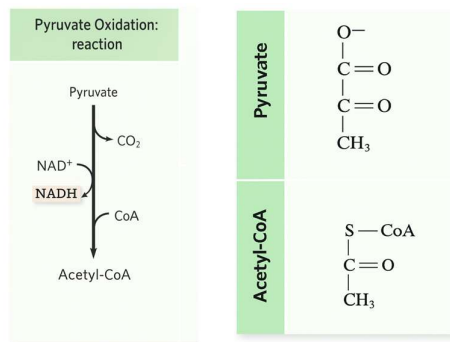


Figure 27 Conversion of Pyruvic Acid to Acetyl CoA

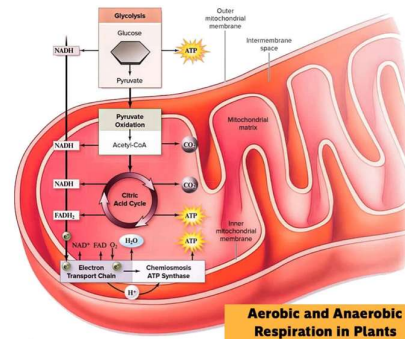


Figure 28 Aerobic and Anaerobic Respiration

3- Krebs Cycle:

Occurs in the mitochondrial matrix.

- The acetyl group from acetyl-CoA combines with a four-carbon compound to form a six-carbon compound (citric acid).
- A series of oxidation reactions and atom rearrangements occur, allowing the cycle to repeat.

Products of this stage:

- From one cycle: $\rightarrow 2 \text{ CO}_2 + 1 \text{ ATP} + 1 \text{ FADH}_2 + 3 \text{ NADH}$
- From two cycles: $\rightarrow 4 \text{ CO}_2 + 2 \text{ ATP} + 2 \text{ FADH}_2 + 6 \text{ NADH}$

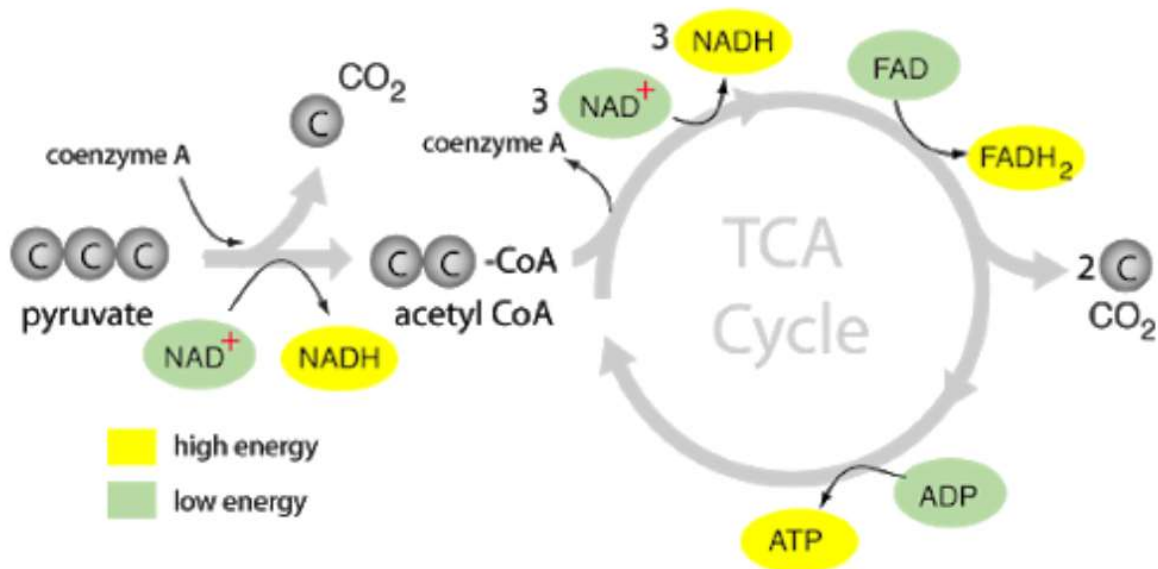


Figure 29 Krebs Cycle

4- Electron Transport Chain:

- Occurs in the mitochondrial membrane.
- It is the final stage of aerobic respiration.
- In this stage, most ATP molecules are produced.
- High-energy electrons from NADH and FADH_2 (generated in the Krebs cycle and during pyruvate formation) are used. The difference in hydrogen ion concentration across the membrane is utilized to convert ADP into ATP.
- Each NADH molecule produces 3 ATP molecules.
- Each FADH_2 molecule produces 2 ATP molecules.

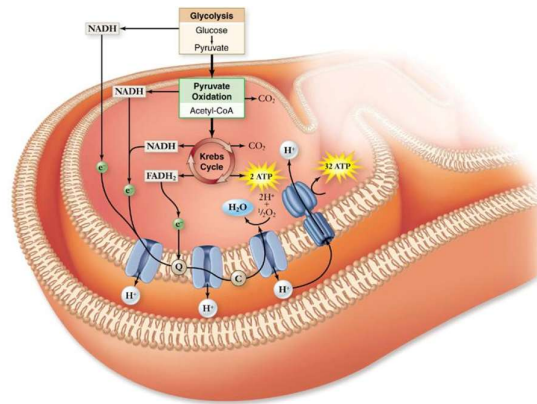


Figure 30 Electron Transport Chain

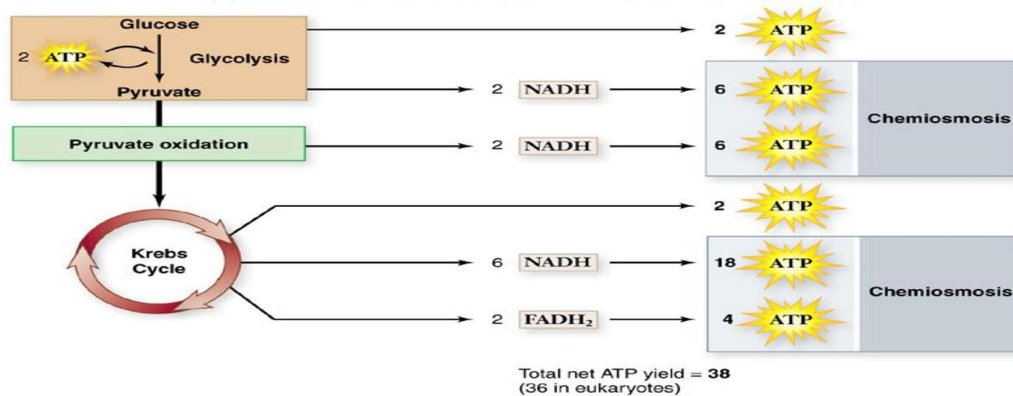


Figure 31 Total net ATP

■ Anaerobic Respiration:

1- Lactic Acid Fermentation:

- Glucose is converted into pyruvate, producing ATP and NADH.
- Through the action of enzymes, pyruvate is converted into lactic acid.
- This process occurs in muscles during fatigue and oxygen deficiency.
- No CO_2 is produced in this process.
- Final products: 2 Lactic acid + 2 ATP

2- Alcoholic Fermentation:

- Glucose is converted into pyruvate, producing ATP and NADH.
- Pyruvate is then converted into ethanol.
- This process occurs in yeast and certain bacteria.
- CO_2 is produced during this process.
- Final products: 2 Ethanol + 2 ATP + 2 CO_2

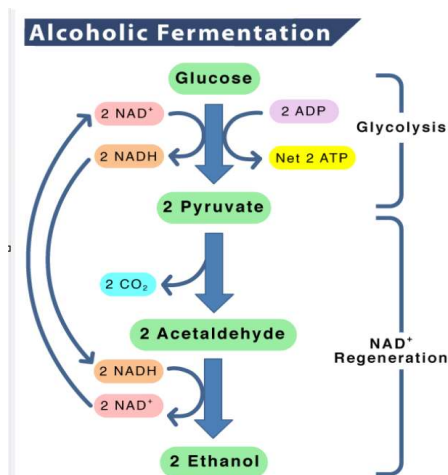


Figure 32 Alcoholic Fermentation

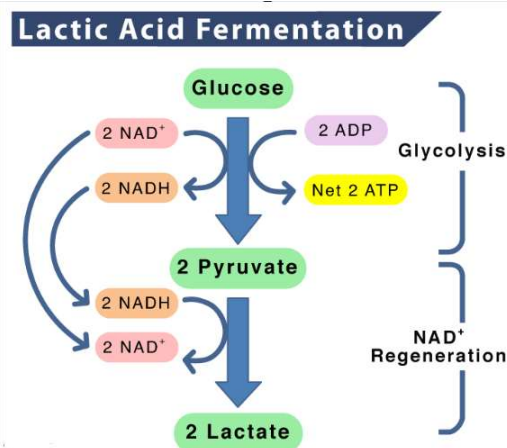
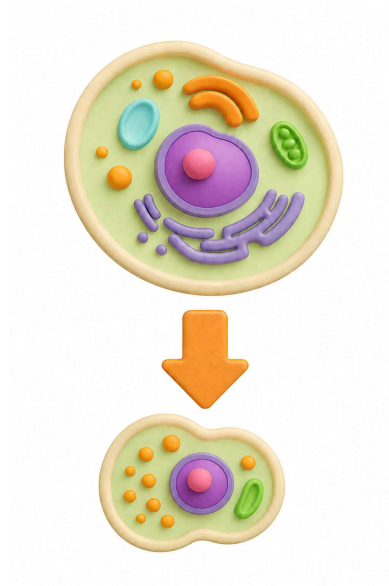


Figure 33 Lactic Acid Fermentation

Chapter Four Cell Division

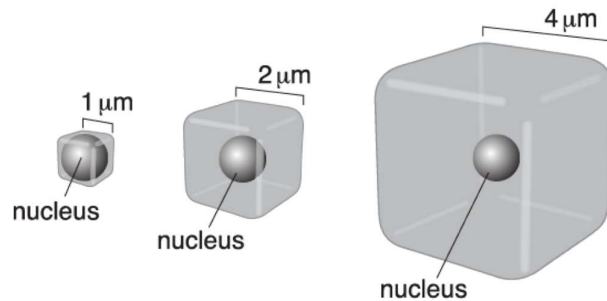


Cell Growth:

- The diameter of most cells is less than $100\ \mu\text{m}$ (1 micrometer = 10^{-6} meter).
- As a cell continues to grow, its volume increases while its surface area decreases, making it harder to obtain nutrients and remove wastes.
- Therefore, it is better for a cell to remain small in order to perform its functions more efficiently.
- As cell size increases, surface area decreases, which in turn reduces the cell's ability to exchange materials with its environment and lowers its activity.
- The main factor determining cell size is the surface area-to-volume ratio. The surface area refers to the area covered by the plasma membrane.

demonstration

Calculate and compare the surface area of a $1\ \mu\text{m}$ cell and a $2\ \mu\text{m}$ cell as shown in the following figure.



Given Data:

- Surface area of the cell = length $\times$ width $\times$ number of faces
- Cell volume = length $\times$ width $\times$ height

Cell Division in Bacteria:

Cell division in bacterial cells is the most common method of reproduction and is called binary fission.

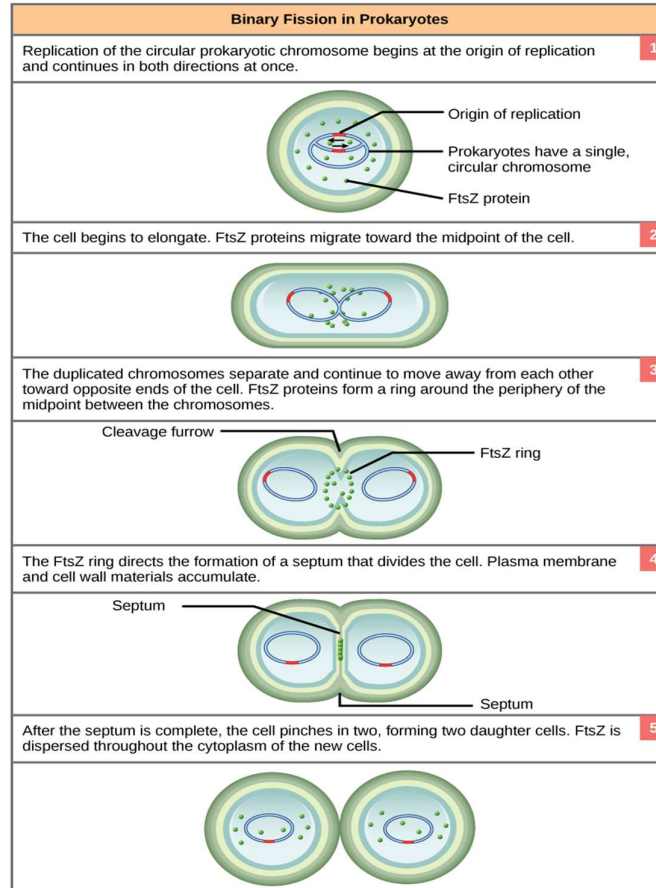


Figure 34 Cell Division in Bacteria

Cell Division in Eukaryotes:

Cell Cycle:

- The time interval between two successive divisions, including all the stages and phases in between.
- The cell cycle passes through three main stages:
 - Interphase
 - Mitosis (Equational Division)
 - Cytokinesis (Cytoplasmic Division)

First. Interphase

1- G₁ Phase (First Growth Phase):

- Begins immediately after cell division.
- The cell grows, organelles double, and it performs its normal functions.
- The cell spends the longest period of its life in this phase.

2- S Phase (DNA Synthesis Phase):

- The cell's genetic material (DNA) is replicated and duplicated.

3- G₂ Phase (Second Growth Phase):

- Proteins are synthesized, and the cell prepares for division.

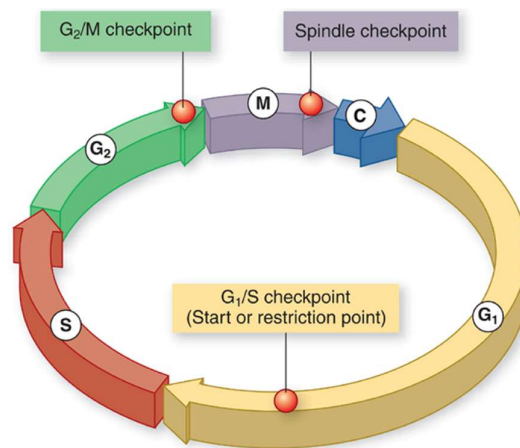


Figure 35 Cell Cycle

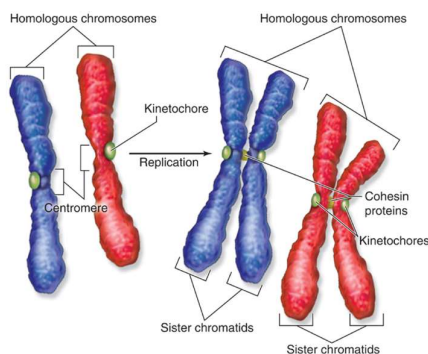


Figure 36 The chromosome after replication

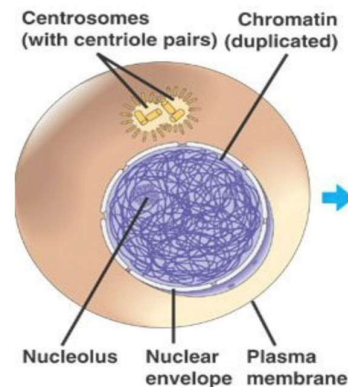


Figure 37 The cell at the end of interphase

Second. Mitosis: The Equational Division

- Occurs in somatic cells ($2n$), meaning diploid cells that contain two sets of chromosomes. The duplicated genetic material separates, and the cell divides into two daughter cells, each having the same number of chromosomes ($2n$).
- The purpose of mitosis is growth and replacement of damaged cells.
- Mitosis occurs in four stages:

1. Prophase:

- The nuclear envelope disintegrates.
- The nucleolus disappears.
- Chromosomes condense and become visible.
- Spindle fibers form between the two poles of the cell.

2. Metaphase:

- Chromosomes attach to the spindle fibers at the centromere.
- Chromosomes align along the equatorial plane of the cell.

3. Anaphase:

- Spindle fibers contract and shorten.
- Sister chromatids are pulled toward opposite poles of the cell.

4. Telophase:

- Chromosomes reach the opposite poles.
- A new nuclear envelope forms around each set of chromosomes.
- The nucleolus reappears.
- Chromosomes uncoil and return to a less condensed state.
- Spindle fibers disappear.

- In all stages of mitosis, the cell remains diploid ($2n$).

Third. Cytokinesis (Cytoplasmic Division):

In animal cells, the cell membrane constricts until the cell splits into two daughter cells, each containing the same number of chromosomes. In plant cells, a cell plate forms between the two newly formed nuclei, and then a cell wall develops, resulting in two genetically identical cells.

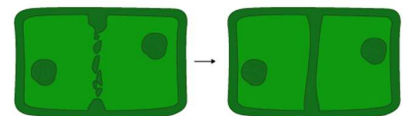
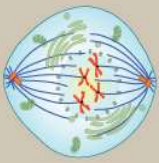
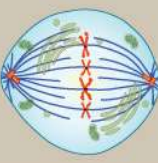
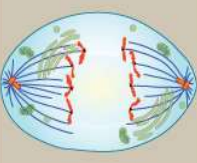
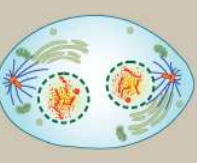
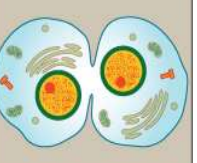
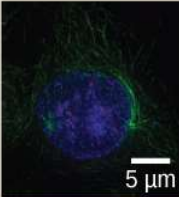
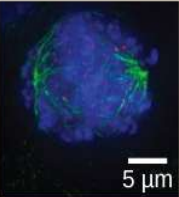
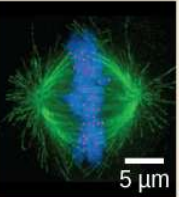
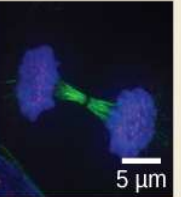
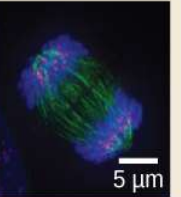


Figure 38 Cytoplasmic Division

Prophase	Prometaphase	Metaphase	Anaphase	Telophase	Cytokinesis
					
- Chromosomes condense and become visible - Spindle fibers emerge from the centrosomes - Nuclear envelope breaks down - Nucleolus disappears	- Chromosomes continue to condense - Kinetochores appear at the centromeres - Mitotic spindle microtubules attach to kinetochores - Centrosomes move toward opposite poles	- Mitotic spindle is fully developed, centrosomes are at opposite poles of the cell - Chromosomes are lined up at the metaphase plate - Each sister chromatid is attached to a spindle fiber originating from opposite poles	- Cohesin proteins binding the sister chromatids together break down - Sister chromatids (now called chromosomes) are pulled toward opposite poles - Non-kinetochore spindle fibers lengthen, elongating the cell	- Chromosomes arrive at opposite poles and begin to decondense - Nuclear envelope material surrounds each set of chromosomes - The mitotic spindle breaks down	- Animal cells: a cleavage furrow separates the daughter cells - Plant cells: a cell plate separates the daughter cells
					

MITOSIS

Figure 39 Stages of Mitosis

Regulation of the Cell Cycle:

- The rate of cell division varies depending on the type of cell.
- Cyclins (regulatory proteins) and kinase enzymes play a vital role in controlling the normal progression of the cell cycle.
- Checkpoints exist after each phase of the cell cycle, and the cycle can be halted if an error occurs.
- When cells fail to respond to the control mechanisms that regulate their life cycle, cancerous cells may result.

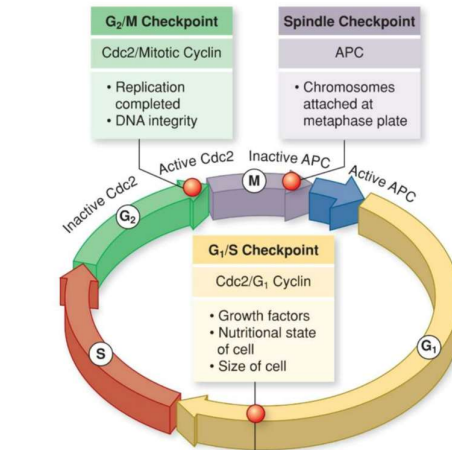


Figure 40 Cell Cycle

- Normal Cell Cycle

Role of Cyclins	Role of Cyclin–CDK Complexes
- Regulate the normal progression of the cell cycle. - Activate the cell cycle in eukaryotic cells when they bind to cyclin-dependent kinases (CDKs), sending a signal to initiate cell division.	- During the G₁ phase of interphase: • Their binding sends a signal to start the cell cycle. - During the cell cycle: • Different cyclin–CDK combinations send signals to initiate other activities, including DNA replication, protein synthesis, and nuclear division. • Another group of cyclins sends a signal to end the cell cycle.

- Abnormal Cell Cycle (Cancer Disease)

Cancer	Uncontrolled and irregular growth and division of cells.
Causes of Cancer	• Mutations or changes in segments of DNA that control the production of proteins responsible for regulating the cell cycle. • Environmental factors and certain substances that cause cancer, known as carcinogens.
Carcinogens	Asbestos, smoking, ultraviolet (UV) radiation, and X-rays.
Genetic Inheritance of Cancer	An individual who inherits one or more genetic mutations from either parent is at a higher risk of developing cancer than someone who does not inherit such changes.

Programmed Cell Death (Apoptosis)

- A process that occurs in certain cells, leading to the death of all cells produced from those divisions.
- It happens when cells shrink and condense in a controlled and organized manner.
- Apoptosis helps protect living organisms from the growth of cancerous cells.

Examples:

- In humans – during the development of the hands and feet, cells occupying the spaces between the fingers and toes die.
- In plants – apoptosis occurs when cells die, causing leaves to fall during autumn.

Stem Cells:

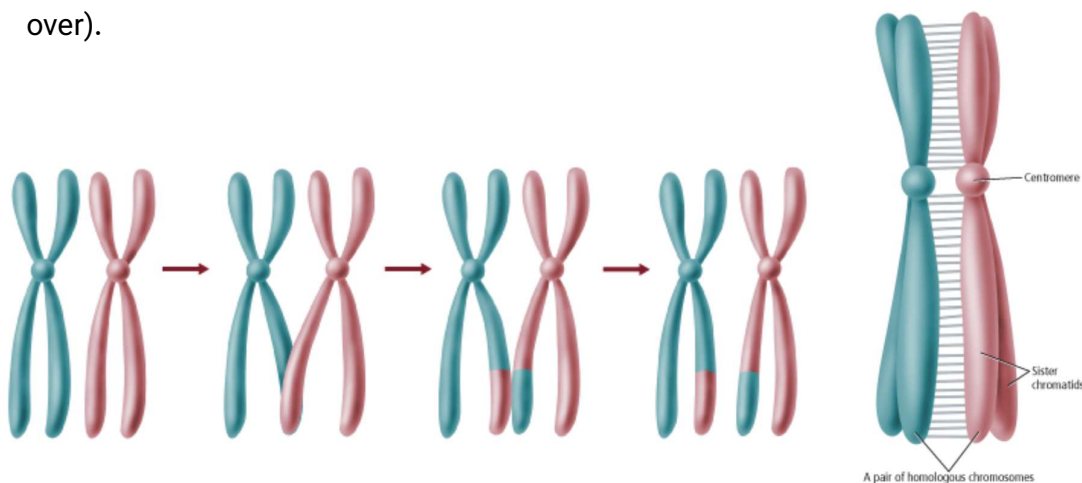
- Undifferentiated cells capable of dividing and developing into specialized cells according to the type of tissue they join.
- Embryonic stem cells are more effective than adult stem cells.
- Stem cells contribute to treating many diseases, such as paralysis and organ dysfunction.

Types of Stem Cells:

1. Embryonic stem cells. / 2. Adult stem cells

Meiosis (Reduction Division):

- Reproductive cells that carry genetic traits from parents to offspring reproduce through meiosis.
- Meiosis produces haploid gametes ($1n$) – cells containing half the number of chromosomes.
- The number of chromosomes in human somatic cells is 46 chromosomes, or 23 pairs – these are diploid ($2n$) cells.
- The number of chromosomes in human gametes is 23 chromosomes, which are haploid ($1n$).
- When a female gamete ($1n$) fuses with a male gamete ($1n$), a zygote is formed containing the full set of chromosomes ($2n$).
- Chromosomes are structures in the nucleus that contain DNA, which is composed of several genes.
- Genes are segments of the DNA strand responsible for expressing specific traits.
- Homologous chromosomes are pairs of chromosomes that have the same length, centromere position, and genes controlling the same inherited traits – one inherited from the father and the other from the mother. These pairs pair up during meiosis in a process called synapsis (crossing over).



📄 Stages of Meiosis:

Meiosis occurs in two successive divisions, ending with the formation of gametes (1n reproductive cells).

First Stage: Meiosis I (Reduction Division I)

This stage includes four phases:

Prophase I – Metaphase I – Anaphase I – Telophase I

What distinguishes these phases:

- In prophase I and metaphase I, the chromosomes appear as homologous pairs.
- In anaphase I and telophase I, the chromosomes appear as duplicated chromosomes.

Cells in all phases of Meiosis I are diploid (2n) because the cell has not yet divided.

Second Stage: Meiosis II (Reduction Division II)

This stage also includes four phases:

Prophase II – Metaphase II – Anaphase II – Telophase II

What distinguishes these phases:

- In prophase II and metaphase II, chromosomes appear as duplicated chromosomes.
- In anaphase II and telophase II, they appear as single chromosomes.

The second meiotic division closely resembles mitosis in somatic cells, except that:

- In Meiosis II, the cells are haploid (1n).
- In Mitosis, the cells are diploid (2n).

Cells in all phases of Meiosis I remain diploid (2n) until division is complete.

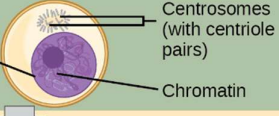
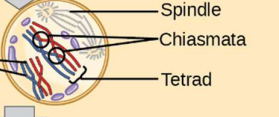
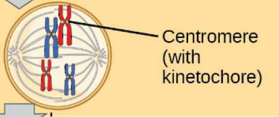
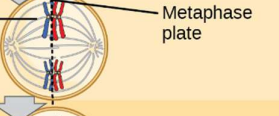
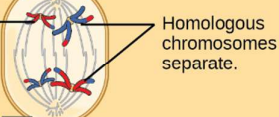
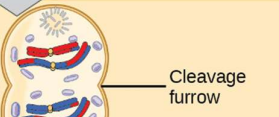
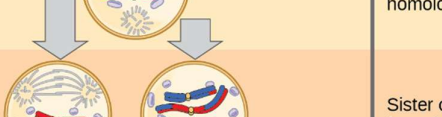
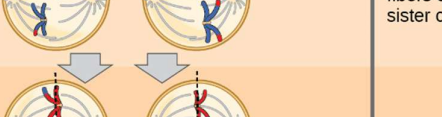
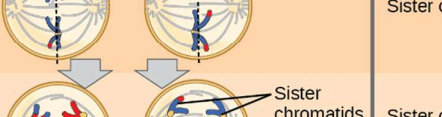
Stage	Event	Outcome
INTERPHASE	S phase 	Chromosomes are duplicated during interphase. The resulting sister chromatids are held together at the centromere. The centrosomes are also duplicated.
	Prophase I 	Chromosomes condense, and the nuclear envelope fragments. Homologous chromosomes bind firmly together along their length, forming a tetrad. Chiasmata form between non sister chromatids. Crossing over occurs at the chiasmata. Spindle fibers emerge from the centrosomes.
MEIOSIS I	Prometaphase I 	Homologous chromosomes are attached to spindle microtubules at the fused kinetochore shared by the sister chromatids. Chromosomes continue to condense, and the nuclear envelope completely disappears.
	Metaphase I 	Homologous chromosomes randomly assemble at the metaphase plate, where they have been maneuvered into place by the microtubules.
	Anaphase I 	Spindle microtubules pull the homologous chromosomes apart. The sister chromatids are still attached at the centromere.
	Telophase I and Cytokinesis 	Sister chromatids arrive at the poles of the cell and begin to decondense. A nuclear envelope forms around each nucleus, and the cytoplasm is divided by a cleavage furrow. The result is two haploid cells. Each cell contains one duplicated copy of each homologous chromosome pair.
	Prophase II 	Sister chromatids condense. A new spindle begins to form. The nuclear envelope starts to fragment.
MEIOSIS II	Prometaphase II 	The nuclear envelope disappears, and the spindle fibers engage the individual kinetochores on the sister chromatids.
	Metaphase II 	Sister chromatids line up at the metaphase plate.
	Anaphase II 	Sister chromatids are pulled apart by the shortening of the kinetochore microtubules. Non kinetochore microtubules lengthen the cell.
	Telophase II and Cytokinesis 	Chromosomes arrive at the poles of the cell and decondense. Nuclear envelopes surround the four nuclei. Cleavage furrows divide the two cells into four haploid cells.

Figure 41 Stages of Meiosis

Chapter five Ecology

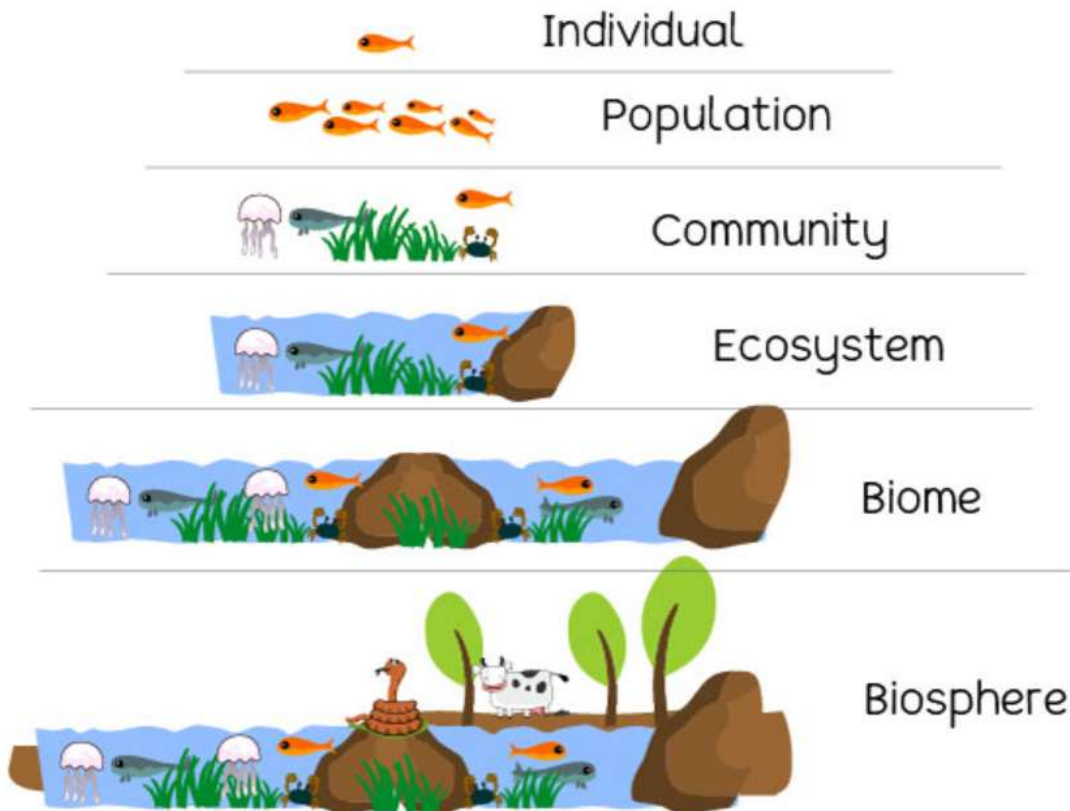


Ecology:

It is the science that studies the relationships between living organisms and their interactions with their environments.

- All living organisms, regardless of their types and habitats, exist within a system called the biosphere.
- The biosphere includes two types of factors: biotic and abiotic.
- Biotic Factors: include all living organisms (plants, bacteria, animals, etc.).
- Abiotic Factors: are the non-living components in an organism's environment (water, air, temperature, etc.).

Level of Organization:



Ecosystem Interaction

Habitat: the area where an organism lives.

Niche: the role an organism plays in its environment.

Community Interactions	
Competition	- Occurs when more than one organism uses the same resources at the same time. - Competition may also be for a mating partner. - Usually, the weaker is eliminated and the stronger survives.
Predation	- The act of one organism consuming another. - Some plants, such as the Venus flytrap, are carnivorous and capture insects to obtain nitrogen.

Symbiosis			
A close relationship in which two or more living organisms live together.			
Type of Relationship	Description		Examples
Beneficial	Mutualism	A relationship between two or more organisms living together where both benefit from each other.	Algae and fungi in lichens, birds and buffalo, clownfish and sea anemones
	Commensalism	A relationship between two organisms where one benefits while the other is neither helped nor harmed.	Birds building nests on trees, lichens growing on plants
Harmful	Parasitism	A symbiotic relationship in which one organism benefits while the other is harmed.	External parasites like ticks, internal parasites like bacteria

Flow of Energy in Ecosystem

- Producers (Autotrophic): self-feeding organisms such as plants and algae.
- Consumers: heterotrophic organisms that depend—directly or indirectly—on plants for their food.
- Decomposers: play an important role in breaking down waste and organic compounds in the ecosystem.

Models of Energy Flow

- Trophic Level represents each step in a food chain or food web.
- The first level is represented by the producers.
- The subsequent levels are represented by the consumers.
- Living organisms at each level obtain their energy from the trophic level below them.
- **Food Chains:** a sequence in which energy is transferred from producers through a series of consumers.
- **Food Web:** a model that represents the interconnecting and diverse food chains within an ecosystem.
- **Ecological Pyramids:** a diagram that shows the relative amounts of energy, biomass, and number of organisms at each trophic level in an ecosystem.

These include:

Pyramid of Numbers

In a pyramid of numbers, each level represents the number of individual organisms consumed by the level above it.

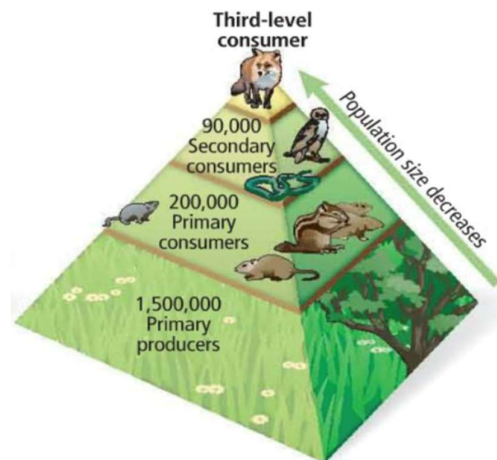


Figure 42 Pyramid of Numbers

Pyramid of Energy

In a pyramid of energy, each level represents the amount of energy that is available to that trophic level. With each step up, there is an energy loss of 90 percent.

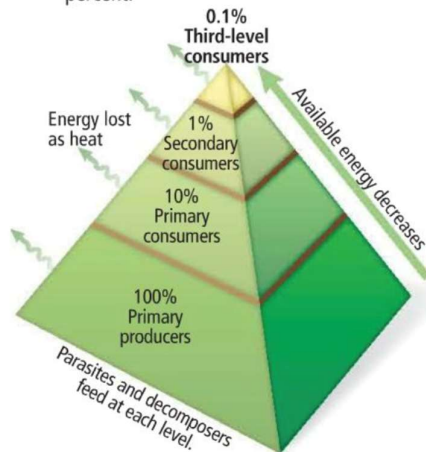


Figure 43 pyramid of Energy

Pyramid of Biomass

In a pyramid of biomass, each level represents the amount of biomass consumed by the level above it.

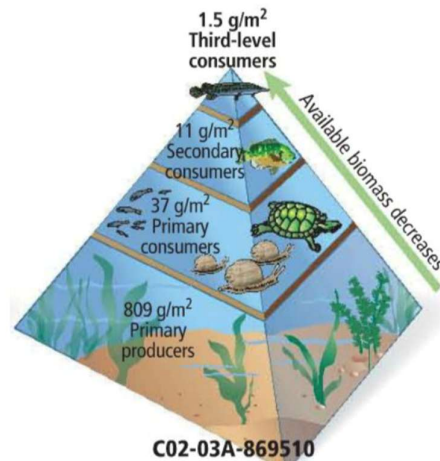


Figure 44 Pyramid of Biomass

Cycling of Matter

Cycles in The Biosphere

- Provide living organisms with the nutrients they need to carry out their functions.
- Nutrient: a chemical substance that an organism must obtain from its environment to carry out life processes and sustain life.
- The bodies of all living organisms are made up of water and nutrients, including carbon and nitrogen

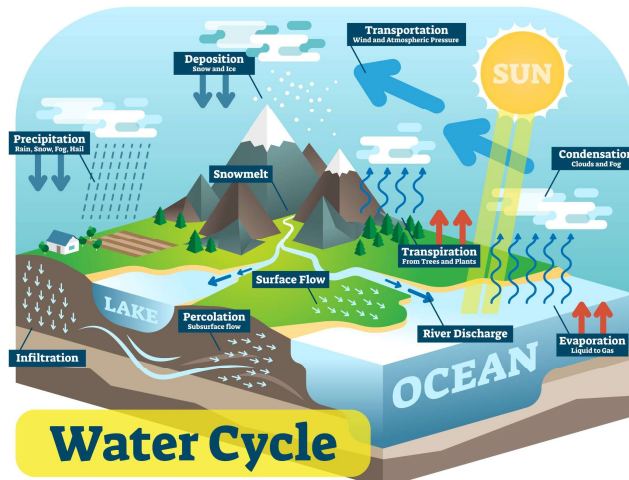


Figure 45 Water Cycle

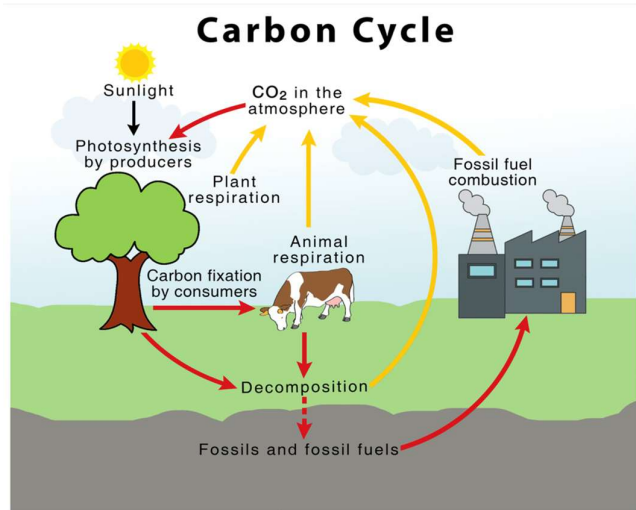


Figure 47 Carbon Cycle

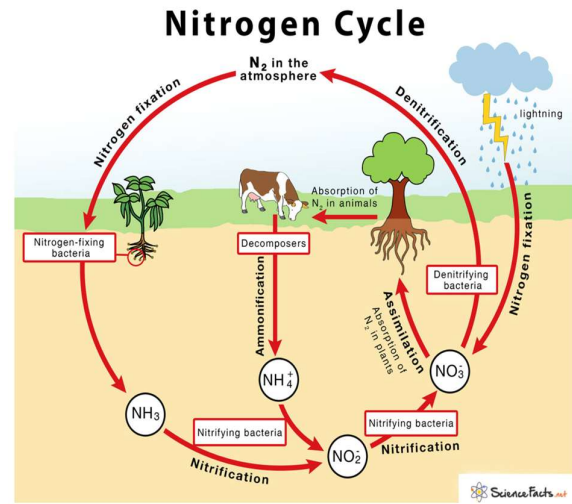


Figure 46 Nitrogen Cycle

Ecological Succession

It occurs when one biological community is replaced by another as a result of changes in biotic and abiotic factors.

Scientific Term in Ecological Succession

Scientific Term	Definition
Primary Succession	occurs after an entire biological community, along with the soil, has been removed.
Secondary Succession	occurs after an entire biological community has been removed, but the soil remains.
Leading Species	appear during primary succession to initiate the formation of a new biological community, such as lichens and mosses.
Climax Community	refers to a stable biological community in which little change occurs.
Weather	the state of the atmosphere at a specific place and time.
Climate	the average weather conditions in a particular region.
Ozone	a protective layer in the atmosphere that absorbs most harmful ultraviolet rays, concentrated mainly above the South Pole.

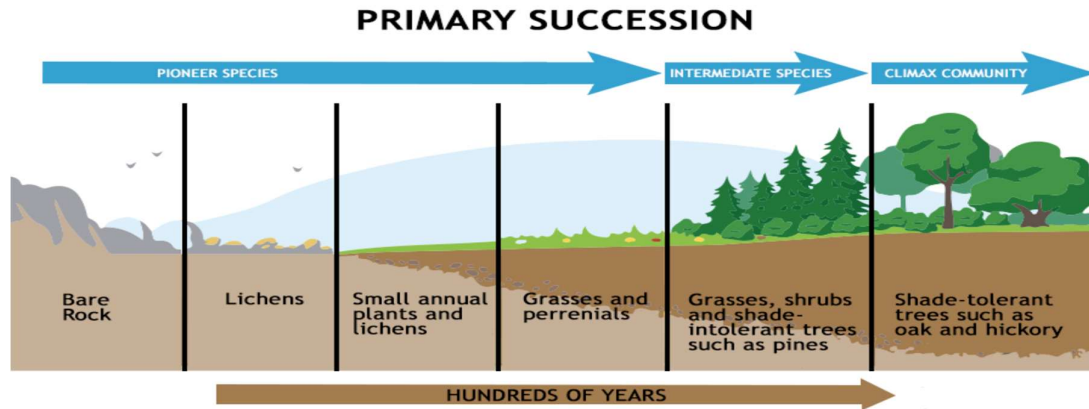


Figure 48 Primary succession

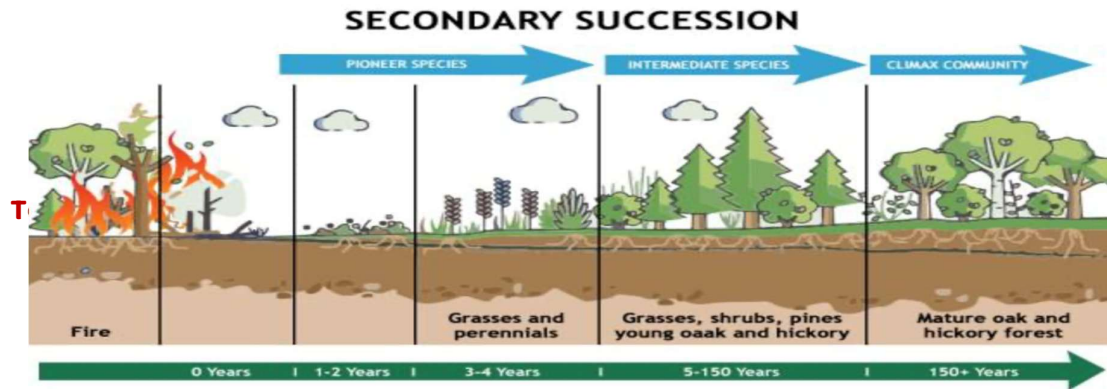
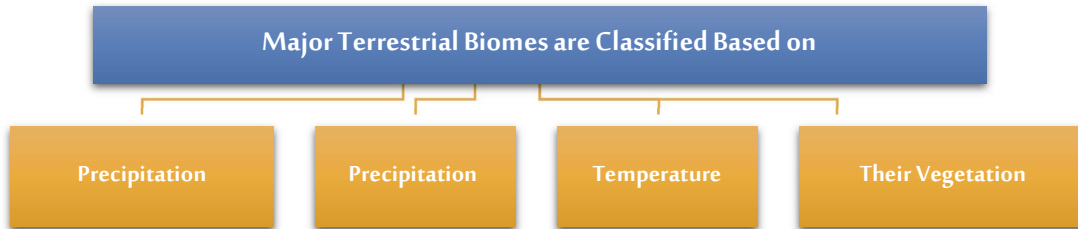


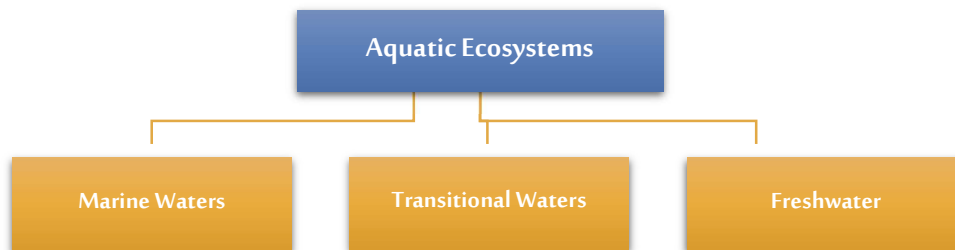
Figure 49 Secondary succession

Terrestrial Biomes

Major Land Biomes:



Aquatic Ecosystems:



Biodiversity

The variety of living organisms found in a particular place that interact with one another is called biodiversity.

Extinction: the disappearance or death of the last individual of a species within the biosphere.

The Importance of Biodiversity

- Stability of the ecosystem.
- Contributes to the quality of the biosphere.
- Has direct economic importance, such as providing food, shelter, medicine, and clothing.
- Has indirect economic value, such as supplying the atmosphere with oxygen, removing carbon dioxide, and maintaining soil fertility.

Factors That Threaten Biodiversity

- 1- Overexploitation
- 2- Habitat Loss.
- 3- Fragmentation of Habitat
- 4- Pollution
- 5- Acid Precipitation
- 6- Biological Magnification
- 7- Eutrophication
- 8- Introduced Species

Conserving Biodiversity

Protecting Biodiversity

It involves reducing consumption, recycling materials, and conserving ecosystems.

Restoring Ecosystem

Ecosystem restoration can be done in two ways:

1. Bioremediation:

The use of living organisms—such as prokaryotes, fungi, or plants—to remove toxic substances from a polluted area.

2. Biological Augmentation:

The introduction of natural predatory organisms into a disturbed ecosystem to help restore its balance.

Animal Behavior

Behavior: A way in which animals respond to a stimulus.

Types of Animal Behavior

Type	Definition
Innate Behavior	Behavior that depends solely on inheritance.
Learned Behavior	Behavior that depends on previous experiences.

Examples of Innate Behavior:

- Some birds sing during mating seasons in response to male hormones.
- Some young animals walk immediately after birth.

Examples of Learned Behavior:

- Swimming.
- Habituation.

Ecological Behaviors

Type	Definition	Example
Competitive Behavior	1. Aggressive behavior: fighting between two individuals of the same species, where the winner gains control over food, territory, and mating partner. 2. Dominance hierarchy: individuals with higher ranks in the group can access resources without conflict with others. 3. Territorial behavior: selecting and defending an area of specific size.	Fighting between male deer or bears. Female chickens or monkeys showing hierarchy. Male birds or leopards marking territory with urine.
Foraging Behavior	The ability of an organism to obtain food and overcome obstacles while searching for it.	Many herbivores such as elephants and buffaloes.
Migratory Behavior	The movement of animals from one place to another in search of survival opportunities.	The migration of salmon for reproduction.

Exercises

1- The bacterial cell is described as prokaryotic because:	
A	It does not have genetic material
B	It does not have a cell wall
C	It cannot be seen with the naked eye
D	Its genetic material is not surrounded by a membrane
2- Which of the following statements does NOT correctly describe the structure?	
A	Performs several functions
B	Composed of a number of specialized cells
C	Composed of tissues that have the same function
D	Has a role in one of the body's systems
3- Which of the following images represents a behavioral adaptation?	
A	Desert plants close their stomata during the day.
B	The presence of hairs on some desert plant leaves
C	Birds that feed on flower nectar have tubular beaks
D	The camel has a hump to store water and fat
4- During the examination of a bacterial cell, the following are expected to be observed:	
A	Nucleus
B	Plastids
C	Mitochondria
D	Ribosomes
5- Which of the following organelles replicate independently?	
A	Nucleus
B	Golgi Apparatus
C	Mitochondria
D	Ribosomes
6- One of the following components controls the elasticity and fluidity of the plasma membrane.:	
A	Phosphorus
B	Proteins
C	Cholesterol
D	Sugars

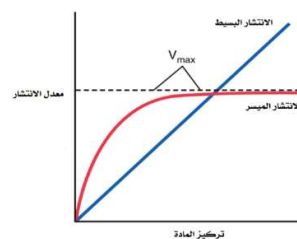
7- The taste of plants differs from one another due to differences in their components of.....

- A succulent vacuoles
- B Cell Wall
- C Plastids
- D Ribosomes

8-A complex and harmonious chemical system, in which all aspects of life during reproduction take place..

- A Cytoplasm
- B Endoplasmic reticulum
- C Vacuoles
- D Nucleic fluid

9-Based on the graph, which of the following statements correctly describes the difference between simple diffusion and facilitated diffusion?



- A Both processes require energy and transport substances against the concentration gradient
- B In simple diffusion, the rate of diffusion increases linearly with concentration, while in facilitated diffusion, it reaches a maximum rate (V_{max}) due to carrier saturation.
- C In facilitated diffusion, substances move faster as concentration increases without limit.
- D Simple diffusion occurs through protein channels, while facilitated diffusion occurs directly through the lipid bilayer

10-How many NADH molecules are produced from the Krebs cycle when 6 glucose molecules are broken down?

- A 6 molecules
- B 12 molecules
- C 16 molecules
- D 36 molecules

11-Which of the following represents the site of O₂ release in photosynthesis?

- I. Thylakoid membrane
- II. Inside the stroma
- III. Light-independent reactions
- IV. After hydrolysis

- | | |
|---|--------------|
| A | I ,II , V |
| B | I , III , IV |
| C | II , IV , V |
| D | III , IV , V |

12-Cellular respiration is a process...

- | | |
|---|-----------------------------|
| A | Anabolism consumes energy. |
| B | Catabolism consumes energy. |
| C | Anabolism produces energy. |
| D | Catabolism produces energy. |

13-A middle lamella is formed in a plant cell due to:

- | | |
|---|--|
| A | Absence of centrioles |
| B | Because the nucleus is lateral |
| C | Because of the large size of the vacuole |
| D | Because of the presence of a cell wall |

14-Which of the following is NOT true regarding mitosis in plant cells?

- | | |
|---|--|
| A | Chromosomes duplicate during interphase. |
| B | Spindle fibers originate from centrioles during prophase. |
| C | A middle plate forms during telophase. |
| D | The cell divides into two cells, each with the same number of chromosomes. |

15-In which phase of mitosis can chromosomes be seen and counted?

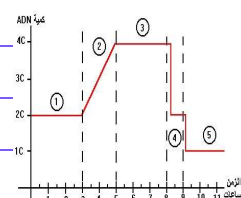
- | | |
|---|-----------|
| A | Prophase |
| B | Metaphase |
| C | Anaphase |
| D | Telophase |

16-How many mitotic divisions are expected to occur in a single cell to produce 128 cells?

- A 7 times
- B 14 times
- C 27 times
- D 32 times

17-In the following diagram, which stage of meiosis does the number 2 represent?

- A G1
- B G2
- C S phase
- D Meiotic I



18-If a germ cell has 32 chromosomes before meiosis, how many chromosomes does it have in anaphase I?

- A 8
- B 16
- C 32
- D 64

19-The genetic crossing over occurs in:

- A Prophase I
- B Prophase II
- C Interphase
- D Prophase of mitosis

20-Which of the following tasks would be performed by an ecologist?

- A Exploring the medical uses of nectar
- B Examining the effect of cyanide on algae
- C Studying and classifying mollusk fossils
- D Vaccinating livestock against a disease

21- What is considered a weakness of traditional food webs when facing complex environmental problems?

- A The food web does not represent all connections in the real ecosystem
- B Food webs do not take invasive species into account.
- C The numerous food chains within a food web make it difficult to use.
- D Trophic levels are not considered when creating a food web.

22-Which of the following processes is an example of mutualism?

- A A male peacock performing courtship rituals for a female.
- B A fish protecting a shrimp that, in return, builds a shared burrow.
- C A shrimp and a minnow resting under the same rock.
- D Two snake species with the same coloration displaying their venom.

23- Which of the following represents the beginning of primary succession?

- A Lichens growing on cooled volcanic lava
- B A forest area developing from grasslands
- C A new plant species growing in a floodplain
- D Trees growing after a forest fire.

24-What explains the low number of animal species living in a fast-flowing river?

- A Cold water reduces dissolved oxygen levels.
- B Strong currents prevent the accumulation of most organic matter.
- C Few animals are adapted to withstand high-speed water.
- D Surface water reflects sunlight away from autotrophic organisms.

25-Which of the following actions would violate the CITES (Convention on International Trade in Endangered Species)?

- A Cutting down rainforests
- B Polluting lakes
- C Selling elephant tusks.
- D Hunting mountain goats.

26-Which of the following is an example of innate behavior?

- A Chirping of chicks after hatching
- B Bears learning to catch fish.
- C A small child pronouncing a few words.
- D Ducks walking together to the pond to feed

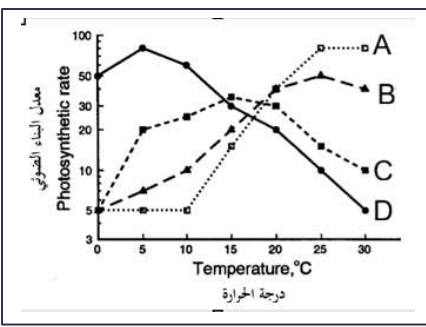
27- Complete the table by placing a (✓) in the appropriate column to identify the type of pollution described in each of the following statements:

A	Fertilizers cause excessive growth of algae, which reduces oxygen levels in the water.			
B	Sulfur dioxide reacts with water in the atmosphere to form sulfuric acid.			
C	Pesticides accumulate in the bodies of organisms at the top of the food chain.			
D	Accumulation of DDT in the tissues of eagles and sea eagles during the 1970s.			

Answer Key Guide

1	2	3	4	5	6	7	8	9	10
D	C	A	D	C	C	A	A	B	D
11	12	13	14	15	16	17	18	19	
A	D	D	B	B	A	C	C	A	
20	21	22	23	24	25	26			
B	A	B	A	B	C	A			
27	A		B		C		D		
	Eutrophication		Acid Rain		Biological Magnification		Biological Magnification		

Challenges

1. When we describe any living organism as autotrophic, this organism can:				
(A)	Get energy from organic sources			
(B)	Convert energy from sunlight into chemical energy			
(C)	Depend on the energy produced by other creatures as an energy source.			
(D)	Live in isolation from other living organisms			
(E)	Use only soil elements			
2. Organisms that have not changed in thousands of years may:				
(A)	Be poorly adapt.			
(B)	Mate more often.			
(C)	Be fierce competitors.			
(D)	live in stable environments.			
(E)	Do not depend on plants.			
3. One of the scientists who experimented with (algae) using ultraviolet rays was able to produce new mutant cells that do not contain chloroplasts. To preserve these cells alive, the scientist had to:				
(A)	Provide them a light with high intensity.			
(B)	Keep them in the dark.			
(C)	Provide them with a sugar solution.			
(D)	Give them chlorophyll.			
(E)	Increase the temperature.			
4. The graph below shows the relationship between photosynthetic rate and temperature. Based on these results, which species from (a to d) is best adapted to arctic conditions where the growth season average temperature does not exceed 8 C°?				
				
A) a	B) b	C) c & d	D) d	E) a & b

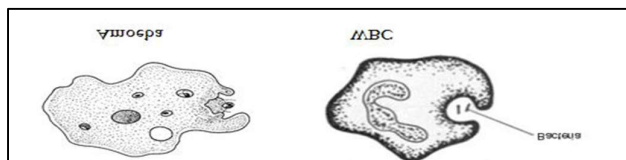
5. Although the function of each organ shown in the attached pictures is different, but they share one principle that makes them more efficient in carrying out their functions. What is this principle?

Gills	Root hairs	Intestinal villi
		
(A)	Resists mechanical shocks.	
(B)	Increase the surface area.	
(C)	The large number of cellular organelles in it.	
(D)	Maintaining the members 'moisture.	

6. One of the following structures is not a common ingredient between a bacterial cell and a plant cell:

(A)	Mitochondria
(B)	Cellular wall
(C)	Chromosomes
(D)	Plasma membrane
(E)	Cytoplasm

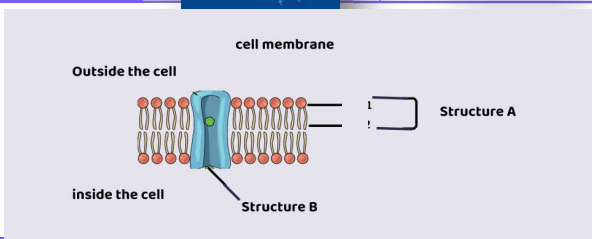
7. We always look at white blood cells and amoebas as similar. Read the following statements about them:



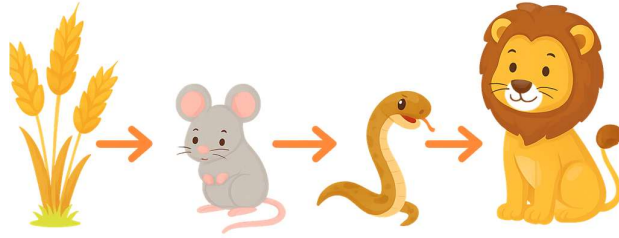
- I. Amoeba and white blood cells do not move.
- II. Amoeba and white blood cell have genetic material.
- III. Amoeba and white blood cells can change their shape.
- IV. Amoeba and white blood cell have a cell membrane.

Which of the previous statements are correct:

(A)	I - II
(B)	II - IV
(C)	I - II - III
(D)	II - III-IV
(E)	I - II - III -IV

8. Which of the substances described in the following forms represent the substances needed by the plant to conduct photosynthesis?			1		2
(A)	1 & 2		3		4
(B)	2 & 3				
(C)	3 & 4				
(D)	1 & 4				
9. What kind of molecule is structure					
(A)	Proteins				
(B)	Carbohydrate				
(C)	Phospholipid				
(D)	Nucleic acid				
(E)	Cholesterol				
10. Within the mitochondria, a series of chemical reactions produces energy. which of the following organs may be more affected when mitochondrial dysfunction?					
(A)	Muscles				
(B)	Skin				
(C)	Teeth				
(D)	Liver				

11. Which of the organisms in the next food chain have more energy transferred?



(A)	Wheat
(B)	Mouse
(C)	Snake
(D)	Lion

12. Natural resources are part of the Earth's environment and provide the necessary materials, used for the survival of living organisms. Which of the following options represents renewable resources?

1	2
3	4

(A)	1
(B)	2 & 3
(C)	3
(D)	1 & 4

13. The insect shown in the picture collects pollen and nectar for food, but at the same time helps to a Plant reproduction. What does this relationship explain?

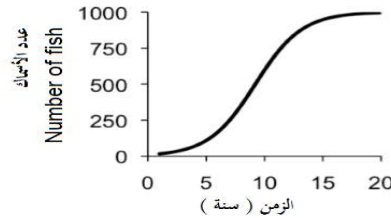


(A)	Predation
(B)	Commensalism
(C)	Mutualism
(D)	Parasitism
(E)	Competition

14. On World Environment Day, attention is drawn to Earth-friendly practices. Among these practices a shopper is strongly advised to bring his cloth bag to carry his purchases. What is the name of this practice?

- (A) Reducing waste
(B) Decrease consumption
(C) Reuse
(D) Trash disposal
(E) Best use

15. The attached graph shows the growth of a population of fish in a pond over time. Selling the fish, you catch from this pond is your livelihood, and you free to harvest as many fish as possible at once. How many fish should you leave in the pond at a time to ensure an increase in the production rate of fish?



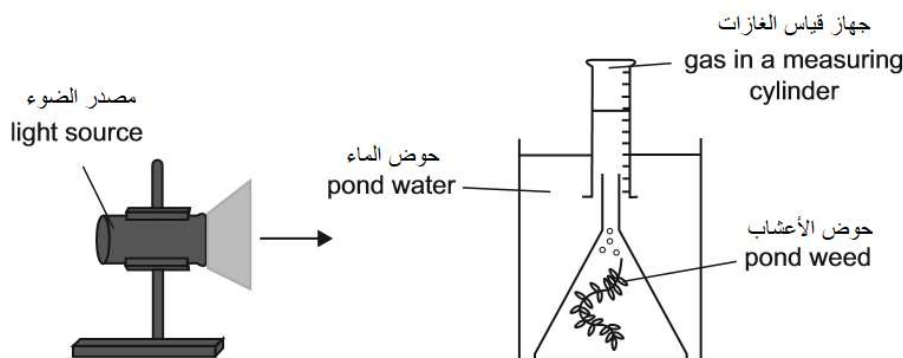
- A) 2 B) 100 C) 500 D) 750 E) 1000

Answer Keys for the Challenging Exercises

1	2	3	4	5	6	7	8	9	10
B	D	C	D	B	A	D	D	C	A
11	12	13	14	15					
B	B	C	B	C					

Mock Exam

1. A student set up an experiment to measure the rate of photosynthesis, as shown in the diagram.



Data was collected and plotted on a graph.

If plotted, which of the following (From 1 To 3) variables would give a gradient that is directly proportional to the rate of photosynthesis?

	x-axis	y-axis
1	Time	volume of CO ₂ released
2	number of gas bubbles released per minute	Time
3	Time	released volume of O ₂

1	A
3	B
1-2	C
2-3	D

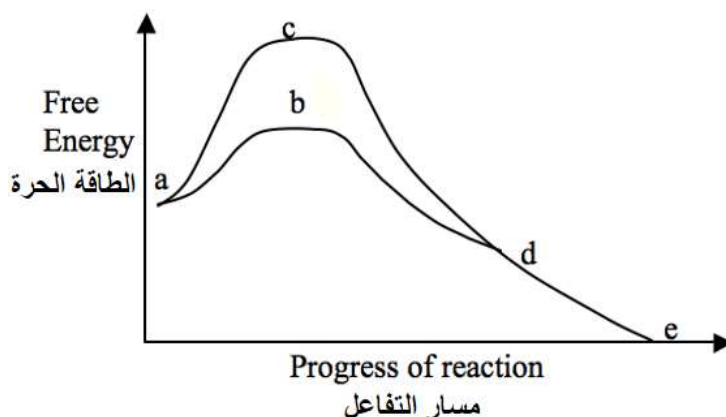
2. Bacteria reproduce asexually by dividing into two by binary fission. If binary fission occurs every 20 minutes, how many cells will be produced in 24 hours?

2^2	A
2^3	B
2^{24}	C
2^{72}	D

3. The molecular formula for glucose is $C_6H_{12}O_6$. What would be the molecular formula for a molecule made by linking three glucose molecules together by dehydration reactions?

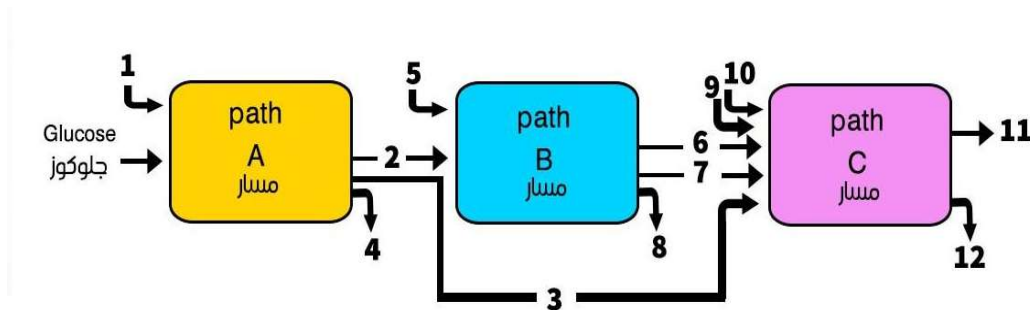
$C_{18}H_{36}O_{18}$	A
$C_{18}H_{32}O_{16}$	B
$C_{18}H_{10}O_{15}$	C
$C_3H_6O_3$	D

4. The graph below compares the rates of protein digestion when catalyzed by the digestive enzyme pepsin and when left uncatalyzed. one curve represents the catalyzed reaction, and the other represents the uncatalyzed reaction. Which point on the graph (a, b, c, d) represents the point in the catalyzed reaction when the reactants have gained their activation energy and the reaction can proceed?



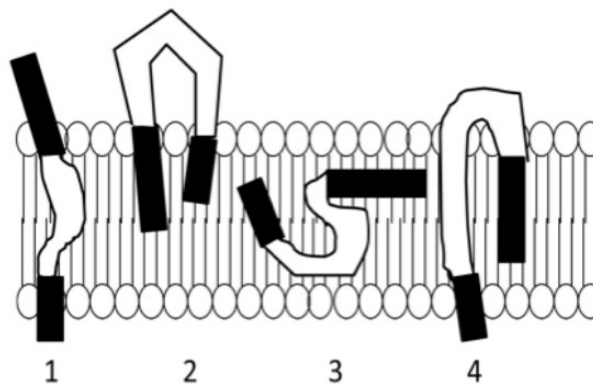
A	A
B	B
C	C
D	D

5. In the attached figure, if path A is glycolysis, path B is a Krebs cycle, and C path is an electron transport chain, then Arrow number 2 represents:



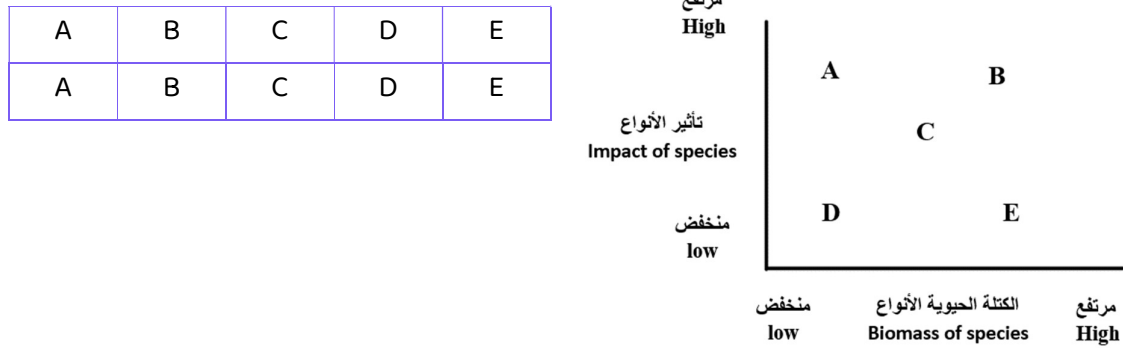
A. Oxygen	B. Pyruvate	C. Water	D. ATP
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6. The diagram at right illustrates five possible arrangements (numbered 1 to 4) of a protein that could associate with a phospholipid bilayer. The black regions of the protein are composed of polar and charged amino acids, and the white region of the protein is composed of nonpolar amino acids. Which arrangement is most likely to occur?

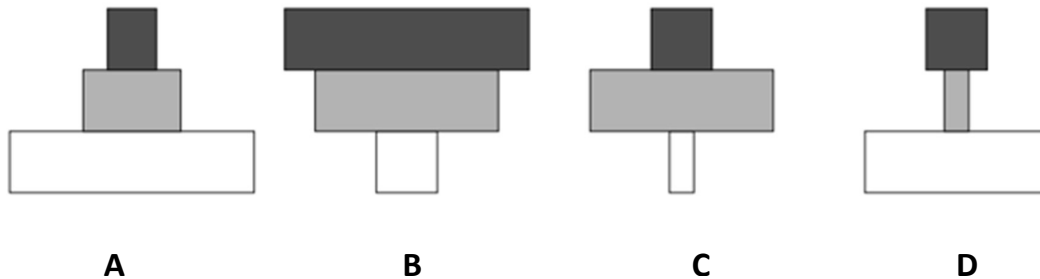


A	B	C	D
1	2	3	4

7. In the figure below, A to E denote five different species in an ecosystem. Which of the species is most likely to be a keystone species



8. An ecological pyramid is a diagrammatic representation of the relationship between various organisms in an ecosystem. These pyramids can be drawn to represent the organic material (biomass), or number, or energy at each trophic level. Which of the following pyramids represents a Number pyramid of an ecosystem consisting of a tree, caterpillars and mynas



Answer Key For the mock Exa

1	2	3	4
B	D	B	B
5	6	7	8
B	A	A	C

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Chemistry

Table of Contents

No.	Subject	Contents	Pages
1	Atomic structure	- Composition of the atom - The Law of Conservation of Mass - The Law of Definite Proportions - The Law of Multiple Proportions - Historical Atomic Models - Atomic Structure - Electron Configuration	3 - 16
2	The Periodic Table and Classification of Elements	- Classification of Elements - Modern construction of the periodic table - Division of the elements of the periodic table	17 - 21
3	Ionic Bonds and Compounds	- Ions - Ionic Bonds - Properties of Ionic Compounds - Steps for Writing the Chemical Formula of Ionic Compounds - Metallic Bond	22 - 28
4	Covalent Bonds and Compounds	- The Covalent Bonding Model - Formation of the Covalent Bond - Properties of the Covalent Bond - Naming Molecules ΔEN (The Electronegativity Difference (ΔEN) and Bond Polarity	29 - 34

01

Atomic Structure

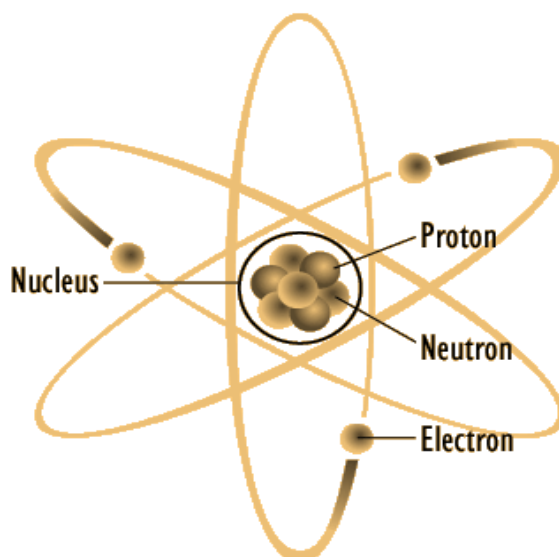
Composition of the atom

If you cut a piece of graphite from the tip of a pencil into smaller and smaller pieces, how far could you go? Could you divide it forever? Would you eventually run into some basic particles that were no longer divisible, not because of their sheer smallness, but because of the nature of matter? This fundamental question about the nature of matter has been asked by thinkers for over two millennia. Their answers have varied over time. On the scale of everyday objects, matter appears continuous, or infinitely divisible. And until about 200 years ago, many scientists thought that matter was indeed continuous—but they were proven wrong. If you were to divide the graphite from your pencil tip into smaller and smaller pieces (far smaller than the eye could see), you would eventually end up with individual carbon atoms. The word atom comes from the Greek atomos, meaning “indivisible”.

You cannot divide a carbon atom into smaller pieces and still have carbon. Atoms compose all ordinary matter. If you want to understand matter, you must begin by understanding atoms.

The Modern Atomic Theory and the Laws it is Based On

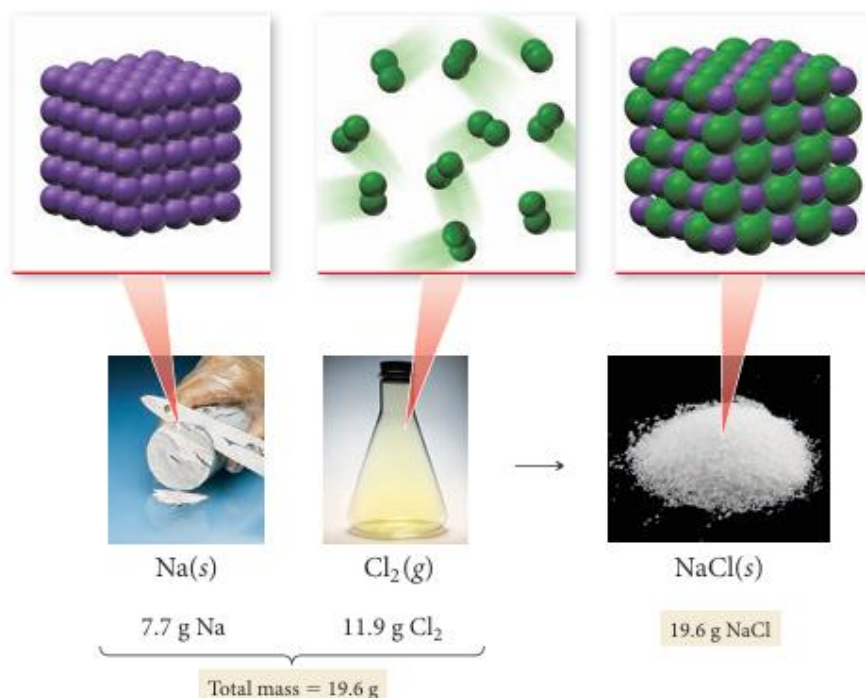
The atomic theory (the idea that all matter is composed of atoms) grew out of observations and laws. The three most important laws that led to the development and acceptance of the atomic theory are the law of conservation of mass, the law of definite proportions, and the law of multiple proportions.



The Law of Conservation of Mass

In 1789, Antoine Lavoisier formulated the law of conservation of mass, which states: In a chemical reaction, matter is neither created nor destroyed.

In other words, when a chemical reaction occurs, the total mass of the substances involved in the reaction does not change. For example, consider the reaction between sodium and chlorine to form sodium chloride. The combined mass of the sodium and chlorine that reacts (the reactants) exactly equals the mass of the sodium chloride that forms (the product) as shown in Figure 1-1. This law is consistent with the idea that matter is composed of small, indestructible particles. The particles rearrange during a chemical reaction, but the amount of matter is conserved because the particles themselves are indestructible (at least by chemical means).



Mass of product = Mass of reactants

Figure 1-1: The reaction of sodium with chlorine

The Law of Definite Proportions

In 1797, the French chemist Joseph Proust made observations on the composition of compounds. He found that the elements composing a given compound always occur in fixed (or definite) proportions in all samples of the compound. In contrast, the components of a mixture can be present in any proportions whatsoever. Proust summarized his observations in the law of definite proportions: samples of a given compound, regardless of their source or how they were prepared, have the same proportions of as their constituent elements.

For example, the decomposition of 18.0 g of water results in 16.0 g of oxygen and 2.0 g of hydrogen, or an oxygen-to-hydrogen mass ratio of:

$$\text{Mass ratio} = \frac{16.0 \text{ g O}}{2.0 \text{ g H}} = 8.0 \text{ or } 8:1$$

This ratio holds for any sample of pure water, regardless of its origin. The law of definite proportions applies to every compound. Consider ammonia, a compound composed of nitrogen and hydrogen. Ammonia contains 14.0 g of nitrogen for every 3.0 g of hydrogen, resulting in a nitrogen to hydrogen mass ratio of 4.7.

$$\text{Mass ratio} = \frac{14.0 \text{ g N}}{3.0 \text{ g H}} = 4.7 \text{ or } 4.7:1$$

Again, this ratio is the same for every sample of ammonia. The law of definite proportions also hints at the idea that matter is composed of atoms. Compounds have definite proportions of their constituent elements because the atoms that compose them, each with its own specific mass, occur in a definite ratio. Since the ratio of atoms is the same for all samples of a particular compound, the ratio of masses is also the same.

Example 1-1

Two samples of carbon dioxide are decomposed into their constituent elements. One sample produces 25.6 g of oxygen and 9.60 g of carbon, and the other produces 21.6 g of oxygen and 8.10 g of carbon. Show that these results are consistent with the law of definite proportions.

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The Law of Multiple Proportions

In 1804, John Dalton published his law of multiple proportions:

When two elements (call them A and B) form different compounds, the masses of element B that combine with 1 g of element A can be expressed as a ratio of small whole numbers.

When two elements A and B combine to form more than one compound, an atom of A combines with either one, two, three, or more atoms of B (AB_1 , AB_2 , AB_3 , etc.). Therefore, the masses of B that react with a fixed mass of A are always related to one another as small whole-number ratios. Let's take the two compounds carbon monoxide and carbon dioxide, which are made of the same two elements: carbon and oxygen. We saw in the previous example that the mass ratio of oxygen to carbon in carbon dioxide is 2.67:1; therefore, 2.67 g of oxygen reacts with 1 g of carbon. In carbon monoxide, however, the mass ratio of oxygen to carbon is 1.33:1, or 1.33 g of oxygen to every 1 g of carbon.

The ratio of these two masses is itself a small whole number.

$$\frac{\text{Mass oxygen to 1 g carbon in carbon dioxide}}{\text{Mass oxygen to 1 g carbon in carbon monoxide}} = \frac{2.67}{1.33} = 2$$

With the help of the molecular models in the figure below, we can see why the ratio is 2:1.

Carbon dioxide contains two oxygen atoms to every carbon atom, while carbon monoxide contains only one. Of course, neither John Dalton nor Joseph Proust had access to any kind of modern instrumentation that could detect individual atoms. Dalton supported his atomic ideas primarily by using the masses of samples.

Carbon dioxide



Mass oxygen that combines
with 1 g carbon = 2.67 g

Carbon monoxide



Mass oxygen that combines
with 1 g carbon = 1.33 g

Example 1-2

Nitrogen forms several compounds with oxygen, including nitrogen dioxide and dinitrogen monoxide. Nitrogen dioxide contains 2.28 g oxygen to every 1.00 g nitrogen, while dinitrogen monoxide contains 0.570 g oxygen to every 1.00 g nitrogen. Show that these results are consistent with the law of multiple proportions.

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Example 1-3

73 g of HCl gas is passed through a solution containing 158 g of sodium thiosulfate, resulting in 117 g of table salt, 64 g of SO₂ gas, 32 g of sulfur, and 18 g of water. Do the results support the law of conservation of mass?

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Dalton's Atomic Theory

In 1808, John Dalton explained the laws we just discussed with in his atomic theory:

- Matter is made up of very small particles called atoms.
- Atoms are indivisible and indestructible.
- The atoms that make up an element are similar in size, mass, and chemical properties.
- Atoms of one element differ from atoms of other elements.
- Different atoms combine in a simple numerical ratio to form compounds.
- In chemical reactions: atoms separate, combine, or rearrange.

The Evolution of the Atom

The atom represents the basic building block of matter, and understanding its composition is key to understanding the chemical and physical properties of elements and their interactions. The concept of the atom has evolved from the idea of an "indivisible particle" (Dalton) to the modern model based on quantum mechanics.

Historical Atomic Models

The following diagram in Figure 1-2 shows the historical sequence of the development of our understanding of the structure of the atom:

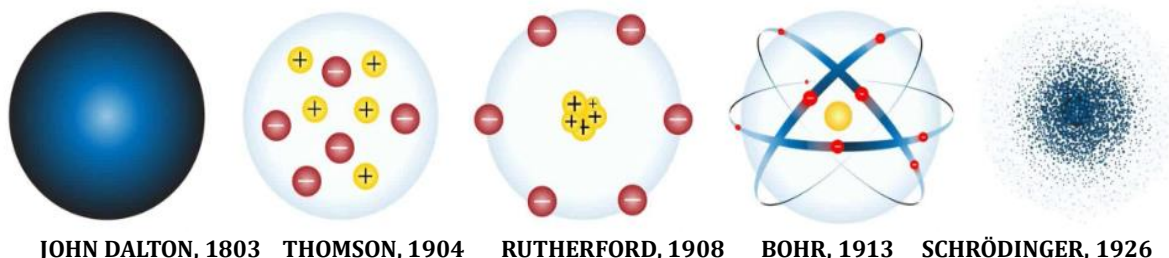


Figure 1-2: The historical sequence of the development of the structure of the atom.

The model	Discovery	Basic Concept
Dalton's model	The first scientific atomic theory	An atom is a solid, indivisible sphere.
Thomson's model	Discovery of the electron	Peach pie: a positive sphere interspersed with negative electrons.

Rutherford's model	Discovery of the proton.	An atom is mostly empty space, and the mass and positive charge are concentrated in the nucleus.
Bohr's model	Atomic emission spectrum of hydrogen	Electrons revolve in fixed orbits with specific quantized energy levels.
Quantum mechanical model	Principles of quantum mechanics	Orbitals are described as probability regions (electron clouds) for the presence of an electron.

Atomic Structure and Subatomic Particles

An atom consists of two main regions: the nucleus and the electron cloud.

The Nucleus

It is the center of the atom. It has a high density and a positive charge, and contains most of the atom's mass.

Subatomic Particles

An atom consists of three fundamental particles: protons, neutrons, and electrons.

Particle	Symbol	Location	Relative Charge	Relative Mass (approximately)
Proton	p^+	Nucleus	+1	1 amu
Neutron	n^0	Nucleus	0	1 amu
Electron	e^-	Electron cloud	-1	$\frac{1}{1840}$ amu

Completing the Atom Model: All atoms are made up of three basic subatomic particles: the electron, the proton, and the neutron. An atom is spherical in shape, containing a small, dense nucleus composed of positive charges surrounded by one or more negatively charged electrons. Most of the atom's volume is empty space containing fast-moving electrons, which move around the nucleus. The electrons are bound to the atom by attraction to the positive charges in the nucleus. The nucleus is composed of neutral neutrons (except for the nucleus of a hydrogen atom, which contains only one proton and no neutrons) and positively charged protons. The nucleus constitutes more than 99.97% of the atom's mass and occupies about

0.0001% of the atom's volume. Because the atom is electrically neutral, the number of protons in the nucleus equals the number of electrons surrounding it. Figure 1-3 shows the components of an atom.

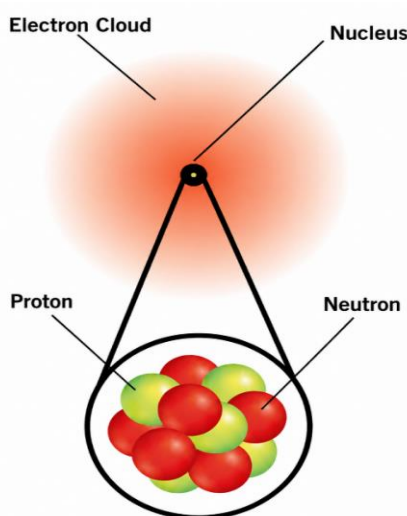
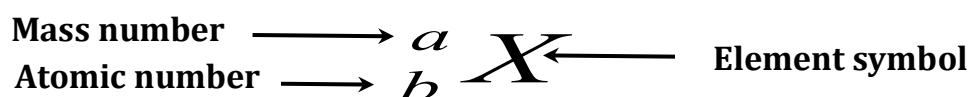


Figure 1-3: An atom consists of a nucleus containing protons and neutrons surrounded by a cloud of electrons.

The components of an atom continue to be of interest to many modern scientists. In fact, scientists have determined that protons and neutrons have their own composition, consisting of particles called quarks. Chemical behavior is explained by the electrons of an atom, as you will study later.

Atomic number and mass

العدد الذري والعدد الكتلي
number



Atomic number = number of protons in an atom = number of electrons

Mass number = number of protons + number of neutrons

Number of neutrons = mass number – number of protons

Number of protons = mass number – number of neutrons

Isotopes

All atoms of a given element have the same number of protons; however, they do not necessarily have the same number of neutrons. Since the mass of neutron is approximately equal to the mass of proton (one atomic unit), this means that not all atoms of a given element have the same mass. For example, all hydrogen atoms have one proton, but they may have 0, 1, or 2 neutrons. All three types of hydrogen(protium, deuterium, and tritium) atoms exist,

each with a slightly different mass. Atoms with the same number of protons but different numbers of neutrons are known as isotopes.

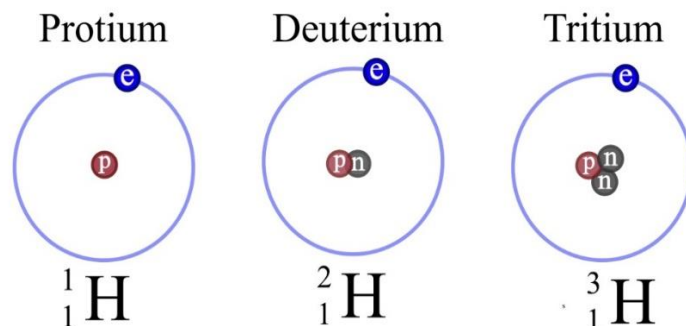


Figure 1-4: Hydrogen isotopes

Some elements, such as beryllium (Be) and aluminum (Al), have only one naturally occurring isotope, while other elements, such as neon (Ne) and chlorine (Cl), have two or more.

The relative amount of each different isotope in a naturally occurring sample of a given element is roughly constant. For example, in any natural sample of neon atoms, 90.48 % of them are the isotope with 10 neutrons, 0.27% are the isotope with 11 neutrons, and 9.25% are the isotope with 12 neutrons. These percentages are the natural abundance of the isotopes. Each element has its own characteristic natural abundance of isotopes.

Example 1-4

Complete the following two tables: (Use the periodic table)

Element name	Element symbol	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons	Isotope name	Isotope symbol
								$^{70}_{30}\text{Zn}$
Calcium	Ca	20	46					

Mass of Atoms

The mass of a proton and a neutron is approximately 1.67×10^{-27} kg, and the mass of an electron is much smaller, about $\frac{1}{1840}$ the mass of a proton or neutron.

Atomic Mass Unit

Because these masses are so small and difficult to manipulate, scientists developed a new method for measuring the mass of an atom relative to the mass of a standard atom. This standard atom is carbon, which has an atomic mass of 12. Therefore, the atomic mass unit (amu) is $\frac{1}{12}$ the mass of a carbon-

12 atom. Therefore, an atomic mass unit is approximately equal to the mass of one proton or one neutron.

Atomic Mass

Because the mass of an atom depends primarily on the number of protons and the number of neutrons in it, and because the mass of both a proton and a neutron is close to 1 amu, you might expect that the atomic mass of an element would always be a whole number! But this is not true; the atomic mass of an element is the average of the masses of its isotopes. Because isotopes have different masses, the average atomic mass is will not be always a whole number. The figure 1-5 shows the calculation of the atomic mass of chlorine.

Chlorine occurs in nature as a mixture of 75.78% chlorine-35 and 24.22 % chlorine-37. The atomic mass of chlorine is 35.453 amu.

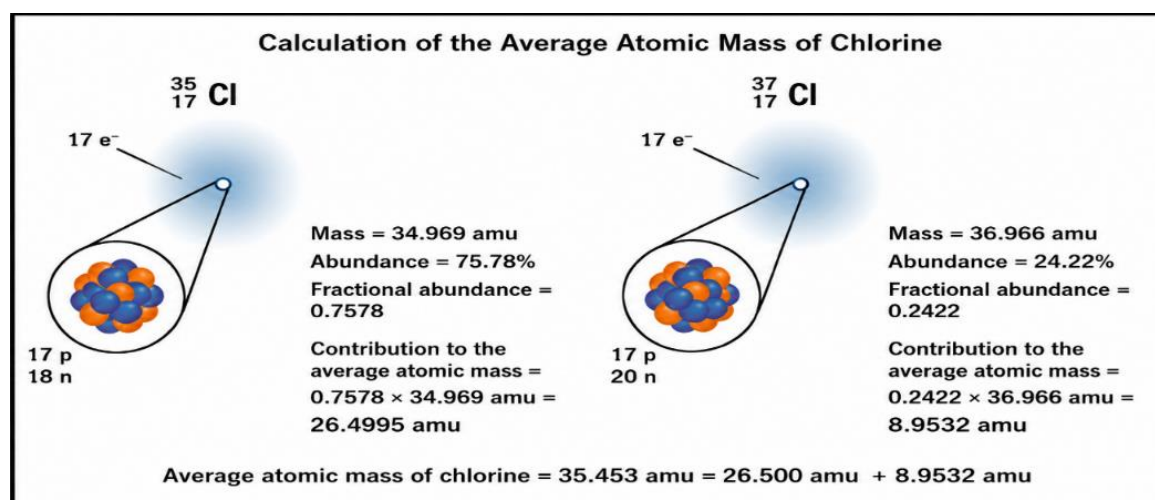


Figure 1-5: Calculating the average atomic mass of the element chlorine

Electron Configuration

Ground -State Electron Configuration

The arrangement of electrons in an atom is called electron configuration. Because lower-energy systems are more stable than higher-energy systems, electrons tend to adopt an arrangement that gives the atom the lowest possible energy. The arrangement of electrons in the lowest, most stable energy position is called the electron configuration in the element's ground state. Principles or rules—including the Aufbau principle, the Pauli principle, and Hund's rule—govern how electrons are arranged in atomic levels.

The Aufbau principle (building upward) states that every electron occupies the lowest energy level. Therefore, determining the ground state electron configuration requires knowing the arrangement of sublevels according to

their increasing energy. This sequence is known as the Aufbau diagram, and is illustrated in the Figure 1-6, where each box in the figure represents a sublevel.

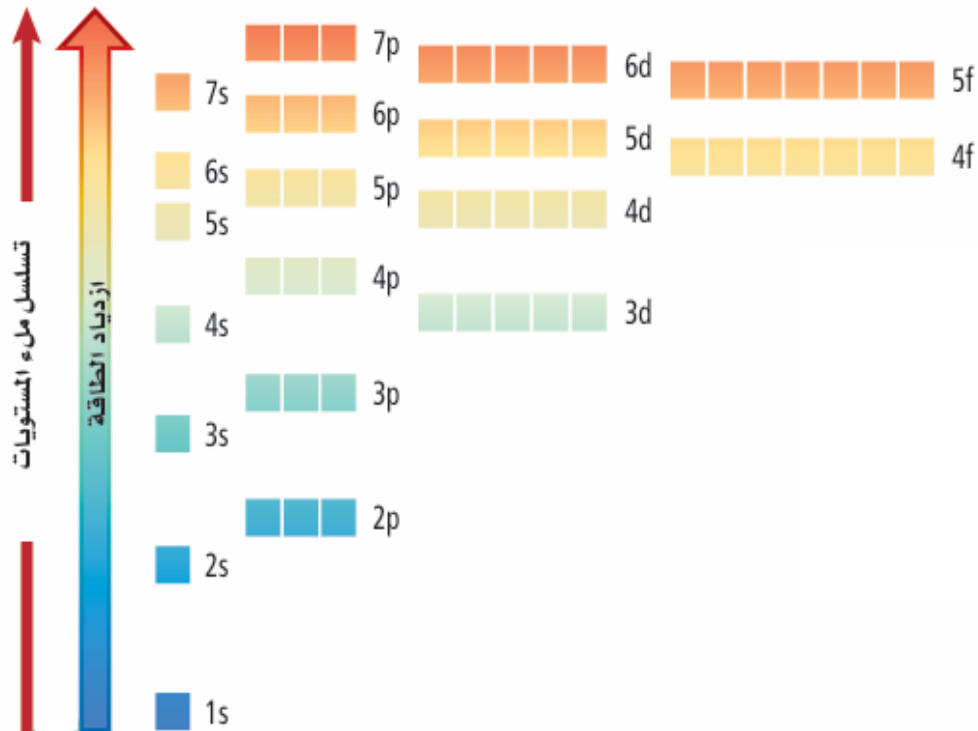


Figure 1-6: Aufbau drawing

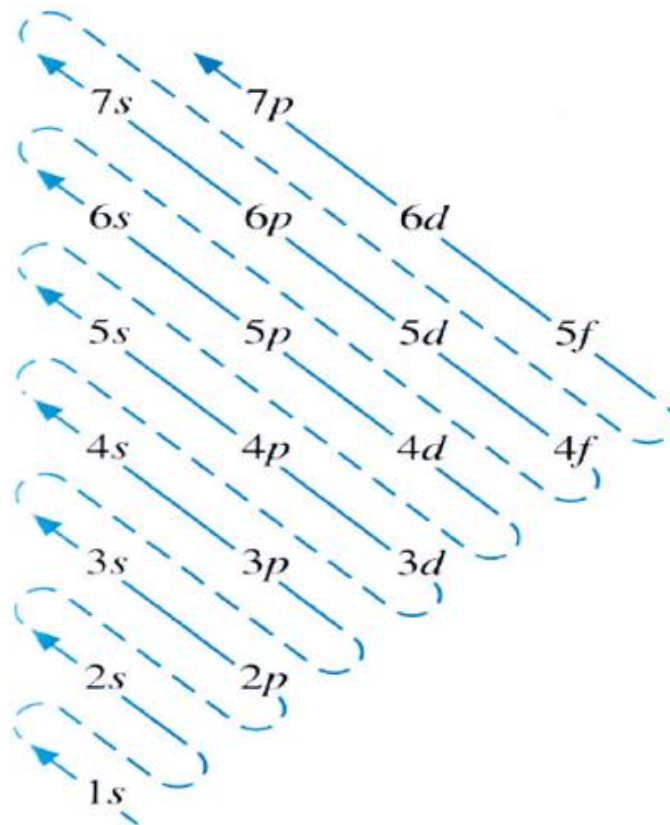


Figure 1-7: Order of filling levels with electrons

The following table shows the properties of the Aufbau diagram:

Example	Feature
All three 2p orbitals are of equal energy.	All orbitals related to an energy sublevel are of equal energy.
The three 2p orbitals are of higher energy than the 2s orbital.	In a multi-electron atom, the energy sublevels within a principal energy level have different energies.
If $n=4$, then the sequence of energy sublevels is 4s, 4p, 4d, and 4f.	In order of increasing energy, the sequence of energy sublevels within a principal energy level is s, p, d, and f.
The orbital related to the atom's 4s sublevel has a lower energy than the five orbitals related to the 3d sublevel.	Orbitals related to energy sublevels within one principal energy level can overlap orbitals related to energy sublevels within another principal level.

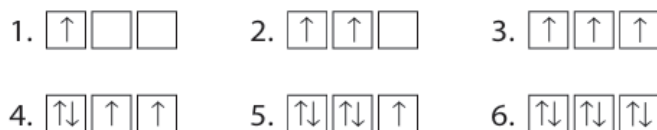
Pauli's Principle: Pauli's principle states that no two electrons in an atom can have the same four quantum numbers .

Sublevels can be represented by squares or circles, and electrons within levels can be represented by arrows within the squares. Each electron has an associated spin direction, with an upward arrow $\uparrow$ representing the electron's spin in one direction, and a downward arrow $\downarrow$ representing the electron's spin in the opposite direction.

An empty square $\square$ represents a vacant sublevel, a square with one arrow pointing up $\uparrow$ represents a sublevel with one electron, and a square with two arrows, one pointing up and one down $\uparrow\downarrow$, represents a filled sublevel.

Hund's Rule: The fact that negatively charged electrons repel each other has a significant effect on the configuration of electrons into equal-energy sublevels. Hund's rule states that electrons are distributed in equal-energy sublevels so that they maintain the same spin orientation before additional electrons with the opposite spin orientation occupy the same levels. For example, the three 2p orbitals are filled with single electrons, and then

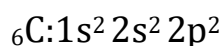
pairing occurs. The following figure illustrates the sequence of six electrons entering the p sublevels.



Methods for representing the electron configuration

You can represent the electron configuration of an atom in one of the following ways: electron notation, Orbital diagram, or noble gas notation.

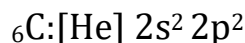
1- Electron Notation:



2- Orbital Diagram:



3- Noble Gas Notation:



Example 1-5

Write the electronic Configuration of magnesium ${}_{12}\text{Mg}$ in three ways?

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Electron configuration of positive and negative ions

When an atom loses electrons, it forms a positive ion, and when it gains electrons, it forms a negative ion. The following table shows the electron configuration of some atoms and their ions

H: $1s^1$	H ⁻ : $1s^2$ or [He]
F: $1s^2 2s^2 2p^5$	F ⁻ : $1s^2 2s^2 2p^6$ or [Ne]
O: $1s^2 2s^2 2p^4$	O ²⁻ : $1s^2 2s^2 2p^6$ or [Ne]
N: $1s^2 2s^2 2p^3$	N ³⁻ : $1s^2 2s^2 2p^6$ or [Ne]
Na: $1s^2 2s^2 2p^6 3s^1$	Na ⁺ : $1s^2 2s^2 2p^6$ or [Ne]
Ca: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	Ca ²⁺ : $1s^2 2s^2 2p^6 3s^2 3p^6$ or [Ar]
Al: $1s^2 2s^2 2p^6 3s^2 3p^1$	Al ³⁺ : $1s^2 2s^2 2p^6$ or [Ne]

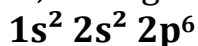
Isoelectronic

When different atoms or ions possess the same total number of electrons and the same electron configuration in the ground state, we say they are isoelectronic.

Examples of electronic isomorphism:

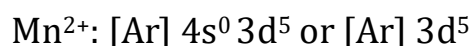
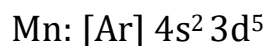
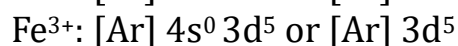
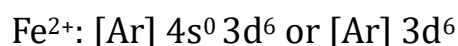
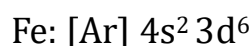
- The oxide ion O^{2-} has 10 electrons.
- The fluoride ion F^{-} has 10 electrons.
- The neon atom Ne has 10 electrons.
- The sodium ion Na^{+} has 10 electrons.

These species are all isoelectronic, having the same electron configuration.



Transition Element Ions

For transition elements, they first lose two electrons from the **s** orbital, then from the **d** orbital.



Exceptions to predicted configuration

You can use the aufbau diagram to write correct ground-state electron configurations for all elements up to and including vanadium, atomic number 23. However, if you were to proceed in this manner, your configurations for Chrome, $[Ar] 4s^2 3d^4$, and copper, $[Ar] 4s^2 3d^9$, would be incorrect. The correct configurations for these two elements are $[Ar] 4s^1 3d^5$ for Chrome and $[Ar] 4s^1 3d^{10}$ for copper. The electron configurations for these two elements, as well as those of several other elements, illustrate the increased stability of half-filled and filled sets of s and d orbitals.

Example answers

Example 1-1

For the first sample:

$$\frac{\text{Mass oxygen}}{\text{Mass carbon}} = \frac{25.6}{9.60} = 2.67 \text{ or } 2.67:1$$

For the second sample:

$$\frac{\text{Mass oxygen}}{\text{Mass carbon}} = \frac{21.6}{8.10} = 2.67 \text{ or } 2.67:1$$

The ratios are the same for the two samples, so these results are consistent with the law of definite proportions.

Example 1-2

$$\frac{\text{Mass oxygen to 1 g nitrogen in nitrogen dioxide}}{\text{Mass oxygen to 1 g nitrogen in dinitrogen monoxide}} = \frac{2.28}{0.570} = 4$$

The ratio is a small whole number (4); these results are consistent with the law of multiple proportions.

Example 1-3

Total mass of the reactants = 158 g + 73 g = **231 g**

Total mass of the products = 117 g + 64 g + 32 g + 18 g = **231 g**

This is consistent with the **Law of Conservation of Mass**.

Example 1-4

Complete the following two tables: (Use the periodic table)

Element name	Element symbol	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons	Isotope name	Isotope symbol
Zinc	Zn	30	70	30	30	40	Zinc-70	$^{70}_{30}\text{Zn}$
Calcium	Ca	20	46	20	20	26	Calcium-46	$^{46}_{20}\text{Ca}$

Example 1-5

1- electron notation : $_{12}\text{Mg}:1s^2 2s^2 2p^6 3s^2$

2- Orbital diagram :



3- gas notation : $_{12}\text{Mg}:[\text{Ne}]3s^2$

02

The Periodic Table and Classification of Elements

Classification of Elements

Many attempts have been made to classify elements into tables:

- To facilitate the study of elements with similar properties in one group.
- Berzelius' attempt to divide the elements into metals, non-metals, and metalloids.
- Mendeleev arranged the elements in his first periodic table in increasing order of atomic mass, and by doing so he was able to predict the existence of elements that had not yet been discovered. Moseley later demonstrated that the correct arrangement should be based on atomic number, which is the principle used in the modern periodic table.

Modern construction of the periodic table

1) **It consists of periods:** horizontal rows starting from the first period to the seventh.

2) **It consists of groups:** vertical columns numbered from 1 to 18, and each group contains elements that share a common number of valence electrons; thus, their properties are similar.

[illegible]

Division of the elements of the periodic table:

- **Metals:** Most elements are of this type.
- **Non-metals:** are the elements found on the right side of the periodic table.
- **Metalloids:** There are 7 elements found between metals and non-metals in a zigzag row.

The diagram illustrates the classification of elements into three categories: Metals (blue), Non-metals (green), and Metalloids (yellow). The periodic table is represented by a grid of colored squares. The legend on the right indicates that blue squares represent Metals, green squares represent Non-metals, and yellow squares represent Metalloids. The diagram shows a large block of blue elements on the left, a small block of green elements on the right, and a diagonal line of yellow elements separating them.

Important notes:

- The elements of main groups 1, 2, 13 to 18 are referred to as the representative elements.
- Elements in groups 3 to 12 are referred to as transition elements.
- Group 1 elements (except hydrogen) are called alkali metals.
- Group 2 elements are called alkaline earth metals.
- Transition elements are divided into transition metals and inner transition metals.
- The inner transition metals are known as the lanthanide and actinide series.
- The elements in group 17 are known as halogens.

- The elements in group 18 are known as the noble gases.

Physical states of the elements of the periodic table:

- Gases: F_2 , O_2 , N_2 , H_2 , Cl_2 , which are non-metals.
- Liquid: Bromine Br_2 (non-metal), Mercury Hg (the only metal that is liquid at room temperature).
- Solid elements: the rest of the elements in the periodic table (mostly metals).
- The inert gases are He, Ne, Ar, Kr, Xe, and Rn. They have several uses, especially in the manufacture of lamps. They are called this because they are chemically inert (their final level is completely full).

Physical properties of metals, nonmetals and metalloids:

Metals	Nonmetals	Metalloids
Solid at room temperature except mercury	Including gas, liquid, and solid	Generally, have properties intermediate between those of metals and non-metals.
Their melting points are high.	Its melting and boiling points are low.	
It has a shine and luster.	It has no shine	
conductor of heat and electricity	Non-conductive to heat and electricity	
Malleable and ductile.	The steel is brittle and easy to break.	

Exercises

(2-1)

Fill in the blanks based on the following:

A	B	C	D	E
Metals	Nonmetals	Metalloids	Noble elements	Neither of them

- 1) It always exists in the gaseous state under normal conditions.....
- 2) It exists as a solid or liquid under normal conditions.....
- 3) It may exist in the gaseous state under normal conditions.....
- 4) It has a shine and lustre.....
- 5) Their melting points are low.....
- 6) It has the properties of metals and non-metals.....

- 7) Including oxygen and iodine.....
- 8) Including iron and gold.....

(2-2)

Based on the following figure of the periodic table containing the following hypothetical elements, answer the following questions?

[illegible]

- 1) Identify an element that is in the third period and group 13?
- 2) What is the transition element found in the fourth period?
- 3) How many protons does element Q have?
- 4) Which of the elements in the previous table is :an alkali metal.....
An alkaline earth metal.....A halogen..... An inert gas.....
- 5) Write the electronic configuration of element B
- 6) The elements that may exist in the gaseous state at room temperature are

Exercise answers	
(2-1)	
D	(1
A	(2
B, D	(3
A	(4
B, D	(5
C	(6
B	(7
A	(8
(2-2)	
D	(1
C	(2
17	(3
A, B, Q, Z	(4
$_{18}[\text{Ar}] 4s^2$	(5
G, Q, Z	(6

03

Ionic Bonds and Compounds

Ions

Ions are atoms of elements but that carrying charges.

(Anions) negative

(Cations) positive

Simple ions

consist of a single element. Their charge equals the number of valence electrons gained, such as O^{2-} .

Polyatomic

It consists of two or more atoms covalently bonded, carries an overall negative charge, and behaves as a single unit in chemical reactions, such as SO_4^{2-} .

Simple ions

consist of
a single element.
Their charge equals
the number of
valence electrons lost
such as Na^+

Polyatomic +

It consists of two or more atoms bonded covalently, carries an overall positive charge, and behaves as a single unit in chemical reactions, such as NH_4^+ .

[illegible]

*Remember



CATS ARE GOOD
(POSITIVE)



ONIONS
ARE
BAD
(NEGATIVE)

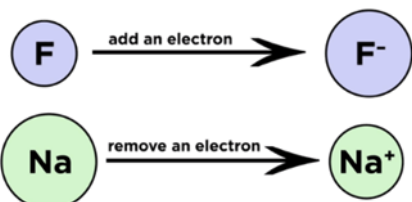
Anions are negatively charged ions

Cations are positively charged ions.

Major Cations and Anions

	Strontium	Barium	Calcium	Magnesium	Silver	Potassium	Sodium	Lithium	Hydrogen	Zinc	Ion
Symbol	Sr^{2+}	Ba^{2+}	Ca^{2+}	Mg^{2+}	Ag^+	K^+	Na^+	Li^+	H^+	Zn^{2+}	Positive Ions (Cations)
	Ammonium	Aluminum	Chromium III	Chromium II	Iron III	Iron II	Copper II	Copper I	Zinc		
Symbol	NH_4^+	Al^{3+}	Cr^{3+}	Cr^{2+}	Fe^{3+}	Fe^{2+}	Cu^{2+}	Cu^+	Zn^{2+}		Negative Ions (Anions)
	Cyanide	Hydroxide	Nitrid	Sulfide	Oxide	Iodide	Bromide	Chloride	Fluoride	Ion	
Symbol	CN^-	OH^-	N^{3-}	S^{2-}	O^{2-}	I^-	Br^-	Cl^-	F^-	Symbol	Negative Ions (Anions)
	Silicate	Perchlorate	Chlorate	Chlorite	Hypochlorite	Permanganate	Bicarbonate	Nitrate	Nitrite	Ion	
Symbol	SiO_3^{2-}	ClO_4^-	ClO_3^-	ClO_2^-	ClO^-	MnO_4^-	HCO_3^-	NO_3^-	NO_2^-	Symbol	

Remember: Size of Ions



Note: The size of ions varies. An anion is larger than its neutral atom, while a cation is smaller. This change is due to electron loss or gain.

Exercises

(3-1)

Write the names of the following compounds, indicating the number of oxygen atoms in each compound.

$\text{Al}(\text{NO}_3)_3$	$\text{Ca}(\text{OH})_2$	Na_2CO_3	Compound
			Name
			Number of oxygens

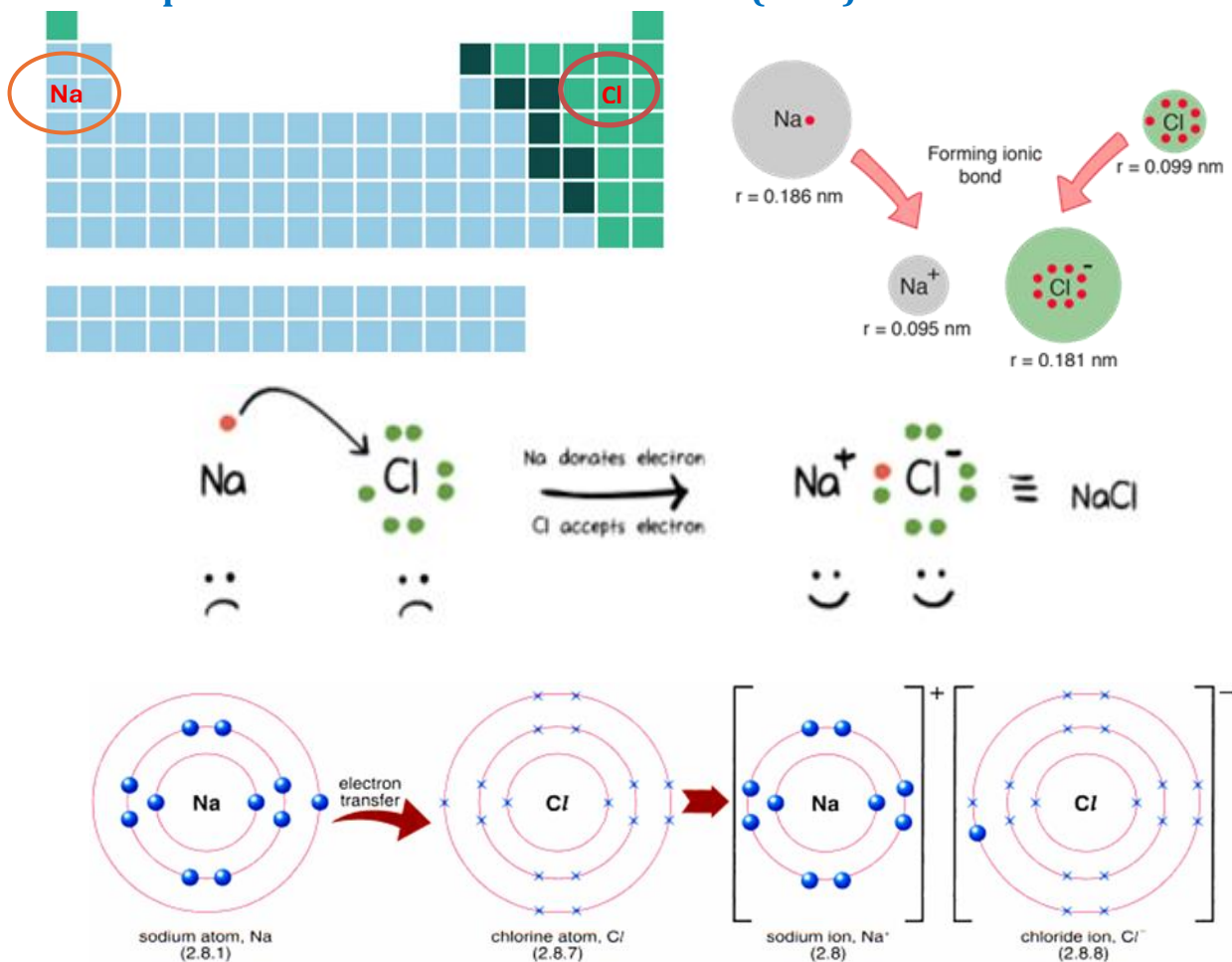
Chemical bond

A chemical bond is the attractive force that arises between two or more atoms through electron loss, gain, or sharing.

Ionic Bonds

Ionic bonds are formed between a metal and a non-metal due to the electrostatic attraction of oppositely charged ions, resulting in ionic compounds.

Example: how is sodium chloride formed (NaCl)



A metal atom loses its valence electrons until it stabilizes and forms a positive ion.

A nonmetal atom gains Electrons until it stabilizes and forms a negative ion

Negative and positive ions attract each other, The number of atoms is such that the overall charge of the compound is zero

Properties of Ionic Compounds

1. Solid at room temperature.
2. High melting and boiling points.
3. Mostly soluble in water and dissociate into ions.
4. They conduct electricity in the molten state or in aqueous solution, but not in the solid state.
5. Ionic crystals are hard, brittle, and strong.

Lattice Energy of Ionic Compounds

Definition: The energy required to separate one mole of an ionic solid into gaseous ions. It reflects the strength of electrostatic forces between cations and anions.

Factors:

1. Ion charge: Higher charges → stronger attraction → higher lattice energy.
Example: $\text{MgO} > \text{NaCl}$ because Mg^{2+} and O^{2-} carry higher charges.
2. Ion size: Smaller ionic radius → stronger attraction.
Example: $\text{NaF} > \text{NaI}$ because fluoride is smaller than iodide.

Importance:

- Explains hardness and high melting points.
- Explains solubility: if lattice energy is too high, solubility decreases.
- Directly related to density and thermal resistance.

Illustrative Examples

The lattice energy of MgO is higher than that of NaF , making MgO more solid and having a higher melting point.

Compounds such as SrCl_2 or AgCl vary in energy depending on the size and charge of their constituent ions.

Steps for Writing the Chemical Formula of Ionic Compounds

Example

Write the chemical formula of the ionic compound formed from chloride ion and magnesium ion.

Solution

Must follow these steps:

First: Write the symbol of the positive ion on the left and the negative ion on the right.

Mg

Cl

Second: Write the charge of each ion below it (without the positive or negative sign)



Third: We exchange between charge numbers



Charges are in their simplest ratio, so abbreviations may be necessary.

For example: The formula for silicon oxide is SiO₂, not Si₂O₄.

If the number of charges is equal, it is not written.

For example: The formula for calcium oxide is CaO, not Ca₂O₂.

If the number of charges is +1 or -1, it is not written.

For example: The formula for magnesium chloride is MgCl₂, not Mg₁Cl₂.

Polyatomic ions are enclosed in parentheses.

For example: The formula for barium hydroxide is Ba(OH)₂, not BaOH₂.

Exercises

(3-2) Write the chemical formula for the following compounds.

IronII sulfide	Sodium silicate	Sodium sulfate	IronIII sulfate	Calcium hydroxide

(3-3) Based on the ions in the following table, write the chemical formulas of the compounds, then write the name of each compound below Formula.

Ions	OH ⁻	O ²⁻	PO ₄ ³⁻	NO ₃ ⁻	SO ₄ ²⁻	SO ₃ ²⁻
Ca ²⁺						
NH ₄ ⁺						

(3-4) Based on the following elements, fill in the blanks in the table and then answer the subsequent questions.

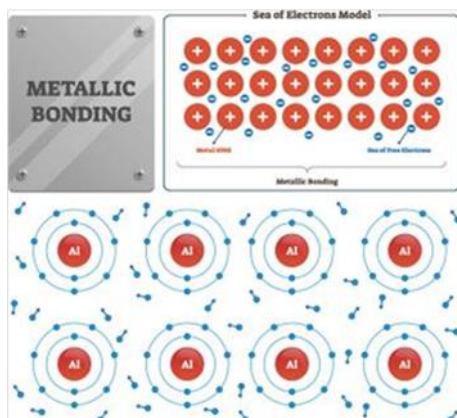
$_{19}\text{K}$	$_{17}\text{Cl}$	$_8\text{O}$	$_7\text{N}$	$_{12}\text{Mg}$	Element
					Symbol of Ion
					Number of Bonds

- The type of bond between (O, N) is
- The type of bond between (Mg, O) is
- The type of bond between (Mg, Cl) is.
- The formula of the compound formed by the bonding of (Mg, N) is.....
- The formula of an oxygen molecule is.
- Which has the higher boiling point, KCl or Cl_2O

Metallic Bond

A force of attraction between positive metal ions and the surrounding sea of electrons.

The sea of electrons is responsible for many of the distinctive properties of metals.



Factors Affecting the Strength of a Metallic Bond:

- Number of free electrons.
- Amount of positive charge in the nucleus.
- Size of the metal atom.

The Metals

"They are chemical elements that lose electrons to form positive ions. They are mainly located in the left and center of the periodic table, including Groups 1 and 2, most transition metals, and some Group 13 elements."

Properties of Metals:

- They are shiny and have a luster.
 - They are ductile and malleable.
 - They have a high melting point.
 - They are solid and have a high density.
 - They are good conductors of electricity and heat.
 - They are chemically active, reacting with oxygen to form metal oxides.
- Their chemical activity also varies.

Exercise answers

(3-1)

$\text{Al}(\text{NO}_3)_3$	$\text{Ca}(\text{OH})_2$	Na_2CO_3	Compound
Aluminum nitrate	Calcium hydroxide	Sodium carbonate	Name
9	2	3	Number of oxygen atoms

(3-2)

Iron(II) sulfide	Sodium silicate	Sodium sulfate	Iron(III) sulfate	Calcium hydroxide
FeS	Na_2SiO_3	Na_2SO_4	$\text{Fe}_2(\text{SO}_4)_3$	$\text{Ca}(\text{OH})_2$

(3-3)

Ions	OH^-	O^{2-}	PO_4^{3-}	NO_3^-	SO_4^{2-}	SO_3^{2-}
Ca^{2+}	$\text{Ca}(\text{OH})_2$ Calcium hydroxide	CaO Calcium oxide	$\text{Ca}_3(\text{PO}_4)_2$ Calcium phosphate	$\text{Ca}(\text{NO}_3)_2$ Calcium nitrate	CaSO_4 Calcium sulfate	CaSO_3 Calcium sulfite
NH_4^+	NH_4OH Ammonium hydroxide	$(\text{NH}_4)_2\text{O}$ Ammonium oxide	$(\text{NH}_4)_3\text{PO}_4$ Ammonium phosphate	NH_4NO_3 Ammonium nitrate	$(\text{NH}_4)_2\text{SO}_4$ Ammonium sulfate	$(\text{NH}_4)_2\text{SO}_3$ Ammonium sulfite

(3-4)

^{19}K	^{17}Cl	^8O	^7N	^{12}Mg	Element
K^+	Cl^-	O^{2-}	N^{3-}	Mg^{2+}	Symbol of Ion
1	1	2	3	2	Number of Bonds

- a) covalent
- b) ionic
- c) ionic
- d) Mg_3N_2
- e) O_2
- f) KCl

04

Covalent Bonds and Compounds

The Covalent Bonding Model

Covalent bonds form when atoms share electrons, and they appear in everything from simple molecules like H_2 to complex biological macromolecules and polyatomic ions. Electron sharing is the one of the main ways atoms bond.

Hydrogen exists as H_2 because two atoms are more stable together than alone. As they approach, the system's potential energy decreases—the attraction between electrons and nuclei outweighs repulsion. At the optimal distance, called the bond length, a covalent bond forms (Figure 4.1), creating the stable H_2 molecule instead of separate atoms.

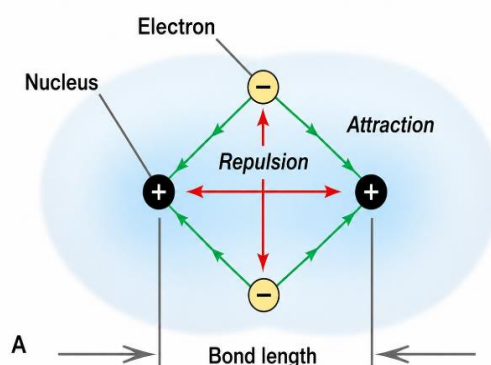


Figure 4.1 Covalent bond formation in H_2

The Formation of the Covalent Bond

Hydrogen gas exists as H_2 because two atoms are more stable bonded together.

Covalent bond results from the balance of attractive and repulsive forces, with greater electron density between the nuclei holding the atoms together (Figure 4.2).

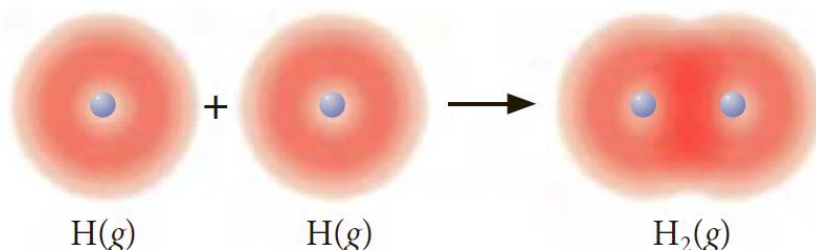
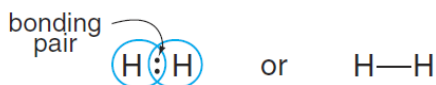


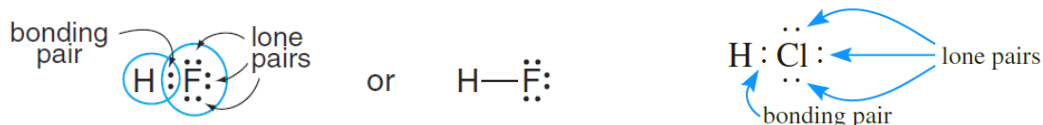
Figure 4.2 The electron probability distribution for the H_2 molecule

Bonding Pairs and Lone Pairs

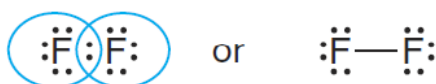
The **shared pair**, or **bonding pair**, is represented by a pair of dots or a line:



An outer-level electron pair that is not involved in bonding is called a **lone pair**, or **unshared pair**. The bonding pair in HF or HCl fills the outer level of the H atom and, together with three lone pairs, fills the outer level of the F atom as well.



In F₂ the bonding pair and three lone pairs fill the outer level of each F atom.

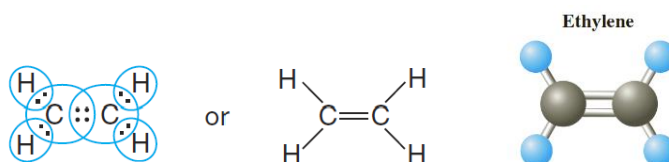


Properties of the Covalent Bond: Order, Energy, and Length

1. Bond Order

The number of electron pairs shared between two atoms.

- **Single bond:** 1 shared pair → bond order = **1** (e.g., H₂, HF, F₂).
- **Double bond:** 2 shared pairs → bond order = **2** (e.g., C=C in ethylene, C₂H₄).



- **Triple bond:** 3 shared pairs → bond order = **3** (e.g., N≡N and C≡C in acetylene, C₂H₂).



2. Bond Energy

The energy required to break one mole of bonds in the gas phase.

- Higher bond order → stronger bond → higher bond energy.
- Triple bonds > double bonds > single bonds.

3. Bond Length

The average distance between the nuclei of bonded atoms.

- Higher bond order → shorter bond length.
 $C \equiv C$ (shortest), $C = C$ (intermediate), $C - C$ (longest)
 - Within a group:** Larger atoms → longer bonds → weaker bonds.
 $C - I > C - Br > C - Cl$ (length), but $C - Cl > C - Br > C - I$ (energy)
 - Within a period:** Smaller atoms → shorter bonds → stronger bonds
 $C - N > C - O > C - F$ (length), but $C - F > C - O > C - N$ (energy).
- Relationship Between the Three Properties:
- As bond order increases → bond length decreases and bond energy increases.
 - Stronger, shorter bonds = greater stability, but often less reactive.

Exercises (4-1):

Rank the bonds in each set in order of decreasing bond length and decreasing bond strength.

(a) S-F, S-Br, S-Cl (b) C=O, C-O, $C \equiv O$

.....

.....

.....

.....

Naming Molecules

Binary molecular compounds are those that contain only two different elements. In naming such compounds, given their formulas, the rules below are followed.

- Name the first element in the formula first, using its element name, unchanged.
- Name the second element, using the root of its name and adding the suffix-ide.
- Use the following prefixes, given the number of each type of atom present: 1, mono-; 2, di-; 3, tri-; 4, tetra-; 5, penta-; 6, hexa-; 7, hepta-. Mono- is not used as a prefix for the name of the first element.

Examples:

CO → carbon monoxide

CO₂ → carbon dioxide

NO → nitrogen monoxide

NO₂ → nitrogen dioxide

N₂O₅ → dinitrogen pentoxide

$\text{PCl}_3 \rightarrow$ phosphorus trichloride

$\text{SF}_6 \rightarrow$ sulfur hexafluoride

$$\text{Cl}_2\text{O}_7 \rightarrow \text{dichlorine heptoxide}$$

Electronegativity (EN)

Electronegativity (EN) is the ability of atoms in a molecule to attract electrons to itself. On the periodic chart (Figure 4.4) , electronegativity increases as you go from left to right across a row. from the bottom to the top of a column.

1 H 2.20																				
3 Li 0.98	4 Be 1.57															5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44	9 F 3.98
11 Na 0.93	12 Mg 1.31												13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58	17 Cl 3.16			
19 K 0.82	20 Ca 1.00	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96				
37 Rb 0.82	38 Sr 0.95	39 Y 1.22	40 Zr 1.33	41 Nb 1.6	42 Mo 2.16	43 Tc 2.10	44 Ru 2.2	45 Rh 2.28	46 Pd 2.20	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.96	51 Sb 2.05	52 Te 2.1	53 I 2.66				
55 Cs 0.79	56 Ba 0.89	57 La 1.10	72 Hf 1.3	73 Ta 1.5	74 W 1.7	75 Re 1.9	76 Os 2.2	77 Ir 2.2	78 Pt 2.2	79 Au 2.4	80 Hg 1.9	81 Tl 1.8	82 Pb 1.8	83 Bi 1.9	84 Po 2.0	85 At 2.2				
87 Fr 0.7	88 Ra 0.9	89 Ac 1.1																		

Metal

Metalloid

Nonmetal

Figure 4.3 The Pauling electronegativity

The Electronegativity Difference (ΔEN) and Bond Polarity

The difference between the electronegativity values of the bonded atoms is directly related to the polarity of the bond. It ranges from 0.0 non-polar covalent bond in a diatomic element, such as H_2 , O_2 , or Cl_2 , all the way up to 3.3, the difference between the most electronegative atom, F (4.0), and the most electropositive, Cs (0.7), in the ionic compound CsF.

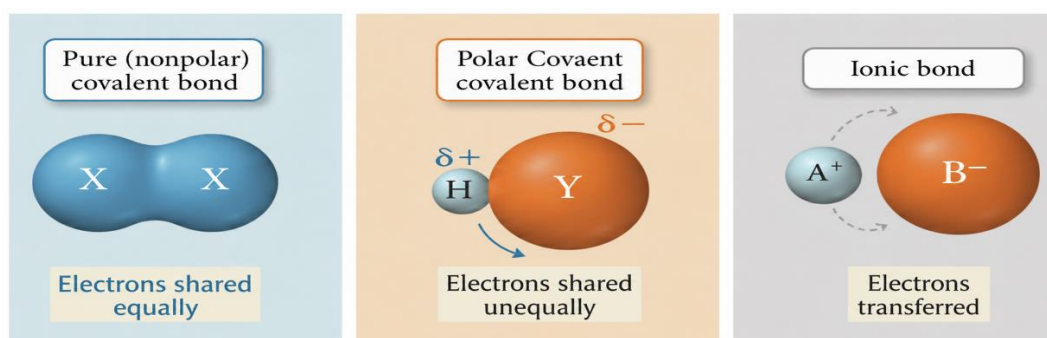
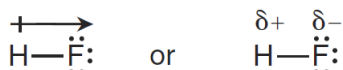


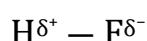
Figure 4.4 The Electronegativity difference (ΔEN) and types of bonds

Nonpolar covalent bonds: When identical atoms bond (H_2 , F_2 , Cl_2), electron sharing is equal.

Polar covalent bond: Whenever atoms of different electronegativities form a bond, such as H (2.1) and F (4.0) in HF, the bonding pair is shared unequally. This unequal configuration of electron density results in a polar covalent bond. It is depicted by a polar arrow ($\rightarrow$) pointing toward the partially negative atom or by the symbols δ^+ and δ^- . A greater ΔEN leads to larger partial charges and higher ionic character.



Example 2: HF



δ^+ and δ^- symbols show partial positive and negative charges.

Example 3: Use electronegativity values (Figure 4.3) to arrange the following bonds in order of increasing polarity.

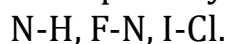


(EN): P-H, 0.0; H-O, 1.4; C-Cl, 0.5:

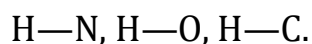


Exercises (4-2):

(a) Use a polar arrow to indicate the polarity of each bond:



(b) Rank the following bonds in order of increasing polarity and decreasing percent ionic character.



.....
.....
.....
.....

Coordinate Covalent Bond

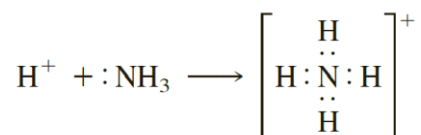
A coordinate bond (also called a dative covalent bond) is a covalent bond (a shared pair of electrons) in which **both** electrons come from the same atom.

Example 4: Ammonium Ion NH_4^+

H^+ has no electrons

N has lone pair

Can still get 2 e^- s shared between them



Exercise answers

1. (a) Bond length: S-Br > S-Cl > S-F
Bond strength: S-F > S-Cl > S-Br

(b) Bond length: C-O > C=O > C≡O
Bond strength: C≡O > C=O > C-O

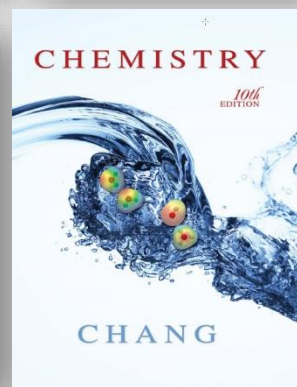
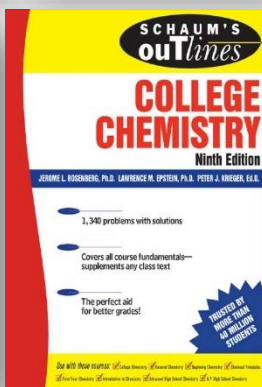
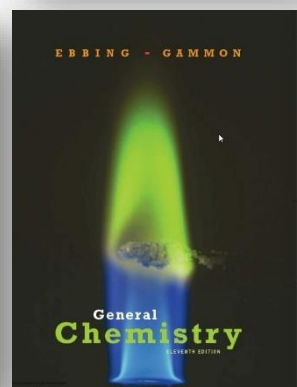
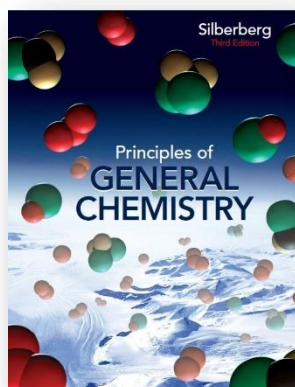
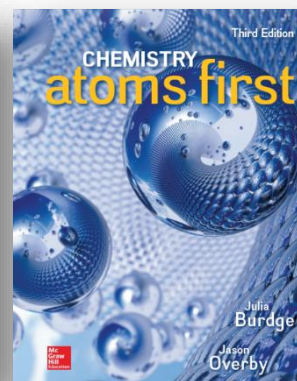
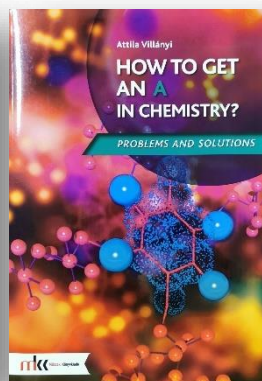
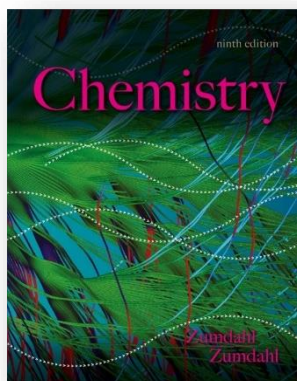
2. (a) $\overleftarrow{\text{N}-\text{H}^+}$, $\overleftarrow{\text{F}-\text{N}^+}$, $\overrightarrow{\text{I}^+-\text{Cl}}$

(b) H-C < H-N < H-O
H-O > H-N > H-C

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
PERIODIC TABLE																	
VIII. A																	
2 He 4.0																	
III. A IV. A V. A VI. A VII. A																	
5 B 10.8 6 C 12.0 7 N 14.0 8 O 16.0 9 F 19.0 10 Ne 20.2																	
13 Al 27.0 14 Si 28.1 15 P 31.0 16 S 32.0 17 Cl 35.5 18 Ar 40.0																	
I. B II. B																	
VIII. B																	
I. A II. A																	
1 H 1.0 2 He 4.0 3 Li 6.9 4 Be 9.0 5 B 10.8 6 C 12.0 7 N 14.0 8 O 16.0 9 F 19.0 10 Ne 20.2																	
11 Na 23.0 12 Mg 24.3 13 Al 27.0 14 Si 28.1 15 P 31.0 16 S 32.0 17 Cl 35.5 18 Ar 40.0																	
19 K 39.1 20 Ca 40.1 21 Sc 45.0 22 Ti 47.9 23 V 50.9 24 Cr 52.0 25 Mn 54.9 26 Fe 55.8 27 Co 58.9 28 Ni 58.7 29 Cu 63.5 30 Zn 65.4 31 Ga 69.7 32 Ge 72.6 33 As 74.9 34 Se 79.0 35 Br 79.9 36 Kr 83.8																	
37 Rb 85.5 38 Sr 87.6 39 Y 88.9 40 Zr 91.2 41 Nb 92.9 42 Mo 95.9 43 Tc 98.0 44 Ru 101.1 45 Rh 102.9 46 Pd 106.4 47 Ag 107.9 48 Cd 112.4 49 In 114.8 50 Sn 118.7 51 Sb 121.8 52 Te 127.6 53 I 126.9 54 Xe 131.3																	
55 Cs 132.9 56 Ba 137.3 57 La 138.9 58 Ce 140.1 59 Pr 140.9 60 Nd 144.2 61 Pm 145.0 62 Sm 150.4 63 Eu 152.0 64 Gd 157.3 65 Tb 158.9 66 Dy 162.5 67 Ho 164.9 68 Er 167.3 69 Tm 168.9 70 Yb 173.0 71 Lu 175.0																	
87 Fr 223 88 Ra 226 89 Ac 227 90 Th 232.0 91 Pa 231.0 92 U 238.0 93 Np 237 94 Pu 244 95 Am 243 96 Cm 247 97 Bk 247 98 Cf 251 99 Es 252 100 Fm 257 101 Md 258 102 No 259 103 Lr 262																	
* EN: electronegativity																	

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Physics

Contents

1	Physics and Its Nature	3
1.1	What is physics?	3
1.2	Physics And Natural Phenomena	4
1.3	Physics And Other Sciences	5
1.4	Physics and math	5
1.5	Introduction to the Basics of Mathematics	6
1.5.1	First-Degree Equations	7
1.5.2	Second-Degree Equations	7
1.5.3	Systems of Equations	8
1.6	Basic and Derivative Physics Quantities	8
1.7	Units In Physics	9
1.7.1	Conversion of Units	11
1.7.2	Prefixes	11
1.8	significant digits	13
1.9	Exercises	13
2	Introduction to Fluids	15
2.1	What are Fluids?	15
2.2	Mass, Volume, and Density	16
2.2.1	Definition of Density:	16
2.3	Pressure	18
2.3.1	Definition of Pressure	18
2.3.2	Pressure in Fluids	19
2.4	The exposure of the atmosphere	20

2.5	Pascal's Principle.....	21
2.5.1	Hydraulic Press	21
2.6	Archimedes' Principle	22
2.6.1	Experiment to verify Archimedes' Principle:	22
2.6.2	Exercises.....	23
3	Motion in one dimension	24
3.1	Scalar and Vector Quantities.....	25
3.2	Vector Quantities in Three Dimensions.....	25
3.3	Motion.....	25
3.3.1	Position	26
3.3.2	Distance and Displacement	26
3.3.3	Speed and velocity	28
3.3.4	Acceleration.....	29
3.4	Graphics Calculations	30
3.4.1	The position-time graph.....	30
3.4.2	The speed-time graph	31
3.4.3	The velocity-time graph	31
3.4.4	The acceleration-time graph.....	32
3.5	Equations of Motion	33
3.5.1	Problem-solving skills using equations of motion	34
3.6	Free Fall	34
3.6.1	Exercises.....	35

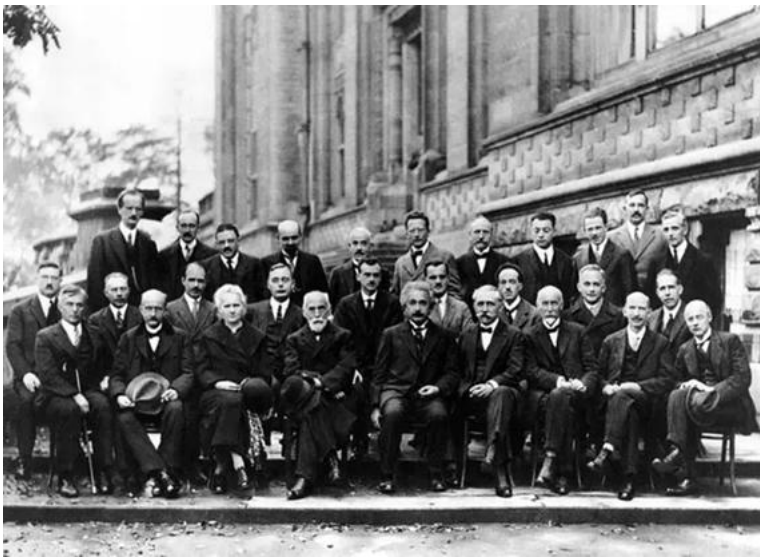
1 PHYSICS AND ITS NATURE

The ancient human tried early to understand and control the natural phenomena around him, such as the motion of objects and the ignition of fire, and he devised tools that help him move heavy objects and ways to ignite fire and benefit from it, and he made tools that help protect him from predators and in catching prey and in accomplishing his work and facilitate his life.

Simply put, what he did is physics in its broadest sense. In this chapter, you will learn about physics and its nature.

1.1 WHAT IS PHYSICS?

What comes to your mind when you hear the word "physics"? Perhaps you imagine a blackboard with many physical mathematical equations written on it, or you may remember pictures of famous physicists that you have heard a lot about, such as Isaac Newton or Albert Einstein, and you may think about the many technical applications developed by physics, such as the laptop computer and modern communication devices, artificial satellites and many others.



The smartest picture in history, taken at the Solvay Conference in 1927, gathered a large number of the most famous physicists, such as Einstein, Marie Curie, Dirac, Heisenberg, Pauli, Schrödinger, Bohr, Compton, and others.



In fact, what you imagined is correct to some extent and shows important aspects of physics, but physics in its broadest sense is: a branch of science concerned with the study of the natural world, matter and energy, and how they are related.

Think

What do we mean by matter, and what do we mean by energy? Give examples of them. Could you list some differences between them?

The word physics is derived from a Greek word " φύσις " (Physica), which means "nature". So, physics is one of the most important aspects of our lives. Whatever we do, there is physics. We apply the principles of physics in our everyday life activities.

1.2 PHYSICS AND NATURAL PHENOMENA

The connection of matter with energy appears in the natural phenomena around us, such as the motion of objects, lightning, thunderbolts, magnetic attraction of things, water waves, and many others. Physics is mainly aimed at:

1. Understanding and explaining these phenomena through the development of laws and theories. An example of this is what the scientist Isaac Newton did in developing equations and laws of motion, which helped us a lot in the mathematical calculation of the speed of an object after a certain period of time had passed, and in calculating the net force acting on it.
2. Utilising understanding of natural phenomena in making modern applications. Such as making cars, planes, spacecraft, lightning rods, and others.
3. Predicting natural phenomena and their future results. Example: predicting the times of eclipses, earthquakes, the structure of the universe, and others.

Exercise: We mentioned earlier that physics studies the relationship between matter and energy. In his famous experiment, Newton studied the decomposition of the white light spectrum using a glass prism. What matter did Newton study, what energy, and how was the connection between them?



1.3 PHYSICS AND OTHER SCIENCES

For more than two thousand years, physics, chemistry, biology, and certain branches of mathematics were part of natural philosophy, but during the scientific revolution of the seventeenth century, these sciences became separated but closely linked. Physics is the basic science because it studies nature in general and provides the basis for all other sciences. It also manufactures measuring devices and invents technical applications that benefit these sciences. Be proud of your study of physics.

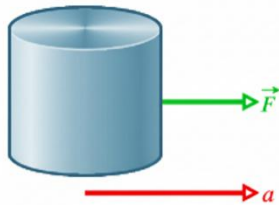
Quantum technology has become at the forefront of the most important and exciting fields that bring together sciences such as physics, biology, chemistry, engineering, and many other fields. This technology gave great hope for scientific revolutions in the near future, as it will change the direction of technology in many applications.

1.4 PHYSICS AND MATH

Physics is closely related to mathematics, and the relationship between them can be briefly described as follows: Mathematics is the language of physics in accurately expressing its description and interpretation of natural phenomena.

This Correlation appears in several forms, the most important of which are:

1. Physics uses mathematical equations to clarify the relationship between the physical quantities, or to calculate unknown quantities, for example:

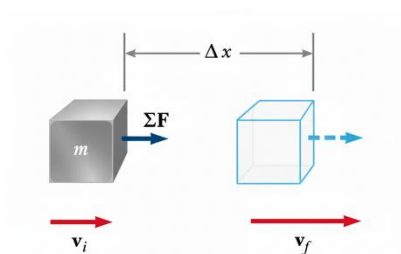


A. $\sum F = ma$

Newton's second law of motion

It states: the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

Note: acceleration means how much the velocity change in each second.

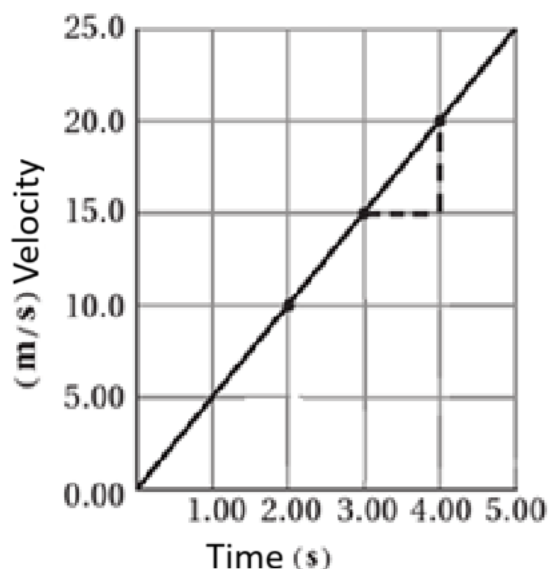


B. $v_f = v_i + a_x t$

Equation of motion in a straight line

It is an important equation that helps us to find the instantaneous velocity of an object v_f at a specific time t in terms of its initial velocity v_i and its acceleration a_x .

- Physics uses mathematical graphs a lot, in order to accurately describe some phenomena and situations, for example the corresponding graph determines how the velocity v of an object moving in a straight line changes with time t , and through the graph you can calculate the velocity of the object at each time moment shown in graph, and also conclude that the relationship between them is proportional (they increase together regularly).



1.5 Introduction to the Basics of Mathematics

One of the important skills in mathematics is solving arithmetic equations, which are used in most life applications and certainly in various sciences.

An equation is a mathematical expression in which the quantity on the left side of the equals

sign (=) is the same as the quantity on the right side. One of the quantities in the equation may be unknown, usually represented by the symbol x .

Let's simplify things with the following example:

$$x + 2 = 8$$

1.5.1 First-Degree Equations

Solving an equation means finding the value of the unknown variable x . To find its value, we must isolate it on one side. To keep the equation balanced, we must do the same operation on both sides. For example, if we add or subtract a value from one side, we must do the same to the other side.

Exercise:

Find the value of x in the following equations:

$$x + 2 = 8$$

$$2x + 2 = 10$$

$$2x + 2 = 10 - 2x$$

$$2x = -10$$

1.5.2 Second-Degree Equations

There is another type of equation called second-degree equations, which require a special method to solve them. The general method we will use is the discriminant (quadratic formula), whose rule is:

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Exercise:

Find the values of x in the following equations:

$$x^2 + 3x + 2 = 0$$

$$x^2 + 3x - 2 = 0$$

$$x^2 - 3x + 2 = 0$$

$$2x^2 - 7x - 5 = 0$$

$$3x^2 + 5x + 7 = 0$$

1.5.3 Systems of Equations

A system contains two equations, each with two unknowns, and it can be solved using one of the following methods:

- Substitution Method
- Elimination Method

Exercise:

Find the solution to the following systems of equations:

$$3x - 5y = 2 \quad ; \quad x + 2y = 3$$

$$2x - 7y = 1 \quad ; \quad 3x + 5y = -6$$

$$2x - 3y = 2 \quad ; \quad 6x - 9y = 7$$

$$3x - 5y = 7 \quad ; \quad 6x - 10y = 14$$

$$3x - 5y = 0 \quad ; \quad 6x + 10y = 14$$

1.6 BASIC AND DERIVATIVE PHYSICS QUANTITIES

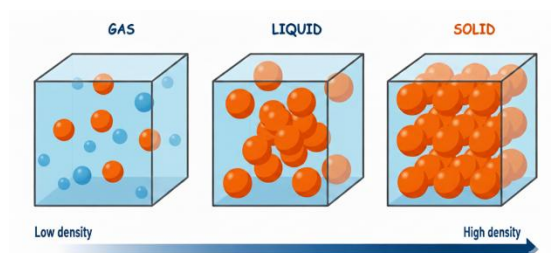
Physics studies the properties of matter, which we call "**Physical Quantities**".

Physical quantities are of two types:

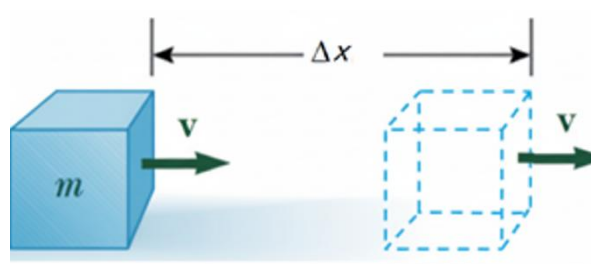
Derivative Quantities	Basic Quantities
They are the quantities defined by other basic quantities.	They are the quantities defined by themselves and are the basis for the derivation of other quantities.
Ex: velocity, density.	Ex: length (distance), mass, temperature

Exercise: Try to define velocity and density in terms of other basic quantities

Density



Velocity



1.7 UNITS IN PHYSICS

Suppose your friend asked you about the distance between your home and your grandfather's home, and you answered that it is 200. Is this answer sufficient to understand the distance between them accurately? Of course not, the distance could be 200 meters (200 *m*), 200 kilometres (200 *km*), or 200 miles (200 *miles*). We call meters, kilometres, and miles units of measure, and they are necessary, as you noted, to accurately determine the distance. In fact, this is a fundamental difference between mathematics and physics. Mathematics deals with abstract numbers, while physics is concerned with writing the unit of the numerical value of any measurement.

It was agreed to establish an international system of measurement called “the International System of Units” with the aim of unifying units of measurement worldwide, and it was referred to by the symbol (SI). This system identified seven basic quantities in physics with the definition of their units of measurement, and these quantities are:



Basic Quantity		Basic Unit	
Name	Symbol	Name	Symbol
Length	ℓ	Meter	m
Mass	m	Kilogram	kg
Time	t	Second	s
Electric Current	I	Ampere	A
Temperature	T	Kelvin	K
Amount of Substance	n	Mole	mol
Luminous intensity	E	Candela	Cd

Note that symbols of physical quantities are written in italicised letters, and symbols of physical units are written in non-italicised letters.

Fun Fact

In A.D. 1120, the king of England decreed that the standard of length in his country would be named the yard and would be precisely equal to the distance from the tip of his nose to the end of his outstretched arm. Similarly, the original standard for the foot adopted by the French was the length of the royal foot of King Louis XIV. This standard prevailed until 1799, when the legal standard of length in France became the meter.

Non-fundamental physical quantities are derived quantities, and their units are composed of two or more basic physical units, such as velocity (ms^{-1}), acceleration (ms^{-2}), density ($\text{kg} \cdot \text{m}^{-3}$) and many others.

Some units of derived quantities are relatively long, and for their abbreviation they are named after the names of the scientists who contributed to their development, then the first letter of the scientist's name in the English language was taken in the capital letter to express that unit, for example, the unit of force measurement was named "Newton" relative to the scientist Newton, and it was abbreviated like this (N).

Exercise: An electric heater is used to boil water. When the switch is turned on, the electric current in the heating element produces heat energy. The temperature of the water increases steadily until it starts to boil after 15 minutes. If another heater with a greater power is used, the time taken to boil the same volume of water would be less than 15 minutes. From the above description, identify the physical quantities. Then, classify these quantities into base quantities and derived quantities.

1.7.1.1 Conversion of Units

The basic idea of the conversion is to multiply by the conversion factor, which is a fraction whose value is one, and is written to allow units to be shortened. Example: conversion factors between kilograms and grams, minutes and seconds:

$$1 = \frac{1000\text{g}}{1\text{kg}}, 1 = \frac{1\text{kg}}{1000\text{g}}$$

$$1 = \frac{1\text{ min}}{60\text{ s}}, 1 = \frac{60\text{ s}}{1\text{ min}}$$

Exercise: Convert the following:

500g to kg.

24 minutes to seconds.

30 ms⁻¹ to km h⁻¹.

1.7.1.2 Prefixes

In physics, we sometimes need to write some values of quantities using prefixes, especially very large or very small values, in order to make it easier to write and understand them more clearly.

For example, 30000 m is in meters, we can write it in kilometres as follows: 30 km.

Also, 0.000001 s in the second unit, we can write it in the unit of microseconds as follows:

1 μ s

The table shows some of the prefixes used in physics:

Small Prefixes		
Value	Symbol	Name
10^{-2}	c	Centi
10^{-3}	m	Milli
10^{-6}	μ	Micro
10^{-9}	n	Nano

large Prefixes		
Value	Symbol	Name
10^3	k	kilo
10^6	M	Mega
10^9	G	Giga

To write values with or without prefixes, we use the conversion factor:

1. To add the prefix: $\frac{\text{prefix that we want to write}}{\text{prefix value}}$

2. To remove the prefix: $\frac{\text{prefix value}}{\text{prefix that we want to omit}}$

Exercise:

Write 2 μ s in the unit of seconds.

Write $6.7 \times 10^{-8} g$ in the unit of (ng).

Write 0.7ng in the unit of (kg).

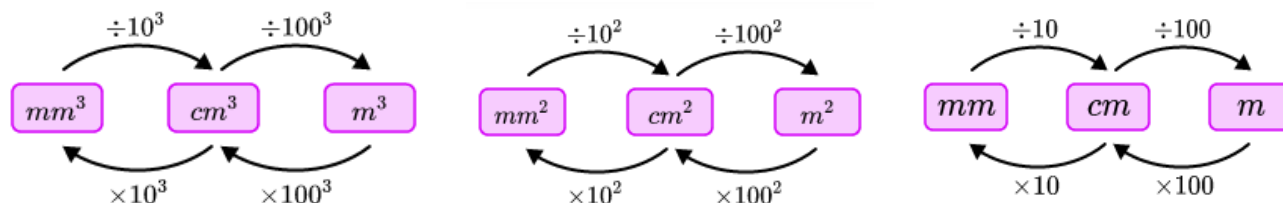
It is also useful to familiarise yourself with the rules for converting between units of length, area and volume:

Length units: $1\text{m}=10^2\text{cm}=10^3\text{mm}$

Area units: $1\text{m}^2 = 10^4\text{cm}^2 = 10^6\text{mm}^2$

Volume units: $1\text{m}^3 = 10^6\text{cm}^3 = 10^9\text{mm}^3$

The litre: $1\text{L}=10^3\text{cm}^3 = 10^{-3}\text{m}^3$



1.8 SIGNIFICANT DIGITS

Measurements resulting from the use of tools and devices are approximate, so they are written in the form of significant digits, and the last number on the right in the measurement result is uncertain. To clarify, “significant” digits are the numbers that are reliable in a measurement.

For example, to measure an object, a one-meter ruler gives a measurement that can be expressed as 24.5cm. However, from a more precise ruler, we can express the measurement as 24.45cm. The extra digit is not arbitrary but does have a meaning; this means that in physics 20m and 20.0m are not the same!

When multiplying or dividing multiple quantities, the result should have the same number of significant figures as the measurement with the lowest significant figures.

1.9 EXERCISES

1. A car travels at 90kmh^{-1} . Convert this speed to m s^{-1} .

2. Write 5L in units of mm^3
3. How many micrometres make up 1.0 km?
4. The density of water is 1 g cm^{-3} . What is this density in kg m^{-3} ?
5. Write the value 0.0056 m using a suitable SI prefix.
6. Perform the calculation and round to the correct number of significant figures:
 $12.45 \text{ m} \times 3.2 \text{ m}$.
7. Perform the calculation and round to the correct number of significant figures:
 $105.4 \text{ g} \div 25.2 \text{ mL}$. Also, answer in kg m^{-3} .
8. The area of a rectangle is found by multiplying its length by its width.
If length = 5.0 cm and width = 3.00 cm, what is the area with the correct number of significant figures?
9. If the side of a cube is **0.50 m**, what is the volume in both m^3 and L?
10. Earth is approximately a sphere of radius $6.37 \times 10^6 \text{ m}$. What are (a) its circumference in kilometres, (b) its surface area in square centimetres, and (c) its volume in litres?

2 INTRODUCTION TO FLUIDS

The crown of King Hiero: the king of Syracuse had given a craftsman a certain amount of gold to be made into an exquisite crown. When the project was completed, a rumour surfaced that the craftsman had substituted a quantity of silver for an equivalent amount of gold, thereby devaluing the crown and defrauding the king. Archimedes was tasked with determining if the crown was pure gold or not. The Roman architect Vitruvius relates the story: While Archimedes was considering the matter, he happened to go to the baths. When he went down into the bathing pool, he observed that the amount of water which flowed outside the pool was equal to the amount of his body that was immersed. Since this fact indicated the method of explaining the case, he did not linger, but moved with delight, he leapt out of the pool, and going home naked, cried aloud that he had found exactly what he was seeking. For as he ran, he shouted in Greek: Eureka! Eureka!

Archimedes came up with one of the most important fluid principles, which was named "Archimedes' principle". In this chapter, you will learn about other concepts, principles and laws in fluids.

2.1 WHAT ARE FLUIDS?

The word fluids refers to every substance that has the property of flowing or diffusion, and thus includes: liquids and gases. The origin of the word fluid is from fluidity, which is physically: not maintaining a constant shape. The basic properties common to liquids and gases are:

1. It has no constant shape.
2. Its particles are far apart.
3. Its molecules move freely:
 - a. In liquids: molecules move translationally within the volume of the liquid.
 - b. In gases: molecules move freely, in any size available.

Exercise: Can you name important differences between the properties of liquids and gases?

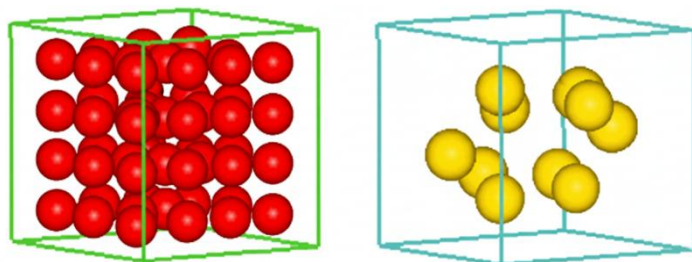
2.2 MASS, VOLUME, AND DENSITY

Mass, volume, and density are distinctive properties of any sample of matter, and it is very important to be aware of their meaning.

Density	Volume	Mass
Mass of a unit volume of a sample It is measured in kg/m^3	The portion of space that a sample of matter occupies. It is measured in m^3	The amount of matter in a sample of it. It is measured in kg

If the particles of a substance are closer to each other, then it is denser.

Exercise: Which of the two samples is denser?



2.2.1.1 Definition of Density:

Density is defined as the mass per unit of volume, which can be expressed by the equation

$$\rho = \frac{m}{V}$$

where:

m is the mass(Kg)

V is the volume (m^3)

ρ is the density (kg/m^3)

Density is a characteristic of any pure substance; that is, each type of substance has its own density, such as iron, copper, gold, etc.

The table shows the densities of some substances at standard situations:



Substance	Density (kg/m ³)	المادة
Air	1.29	الهواء
Ice	0.917×10^3	الثلج
Aluminum	2.70×10^3	الألومنيوم
Iron	7.86×10^3	الحديد
Benzene	0.879×10^3	البنزين
Lead	11.3×10^3	الرصاص
Copper	8.92×10^3	النحاس
Mercury	13.6×10^3	الزئبق
Oak	0.710×10^3	خشب البلوط
Fresh water	1.00×10^3	الماء العذب
Oxygen gas	1.43	غاز الأكسجين
Glycerin	1.26×10^3	الجلسرين
Pine	0.373×10^3	خشب الصنوبر
Gold	19.3×10^3	الذهب
Platinum	21.4×10^3	البلاتين
Helium gas	1.79×10^1	غاز الهيليوم
Seawater	1.03×10^3	ماء البحر
Hydrogen gas	8.99×10^{-2}	غاز الهيدروجين
Silver	10.5×10^3	الفضة

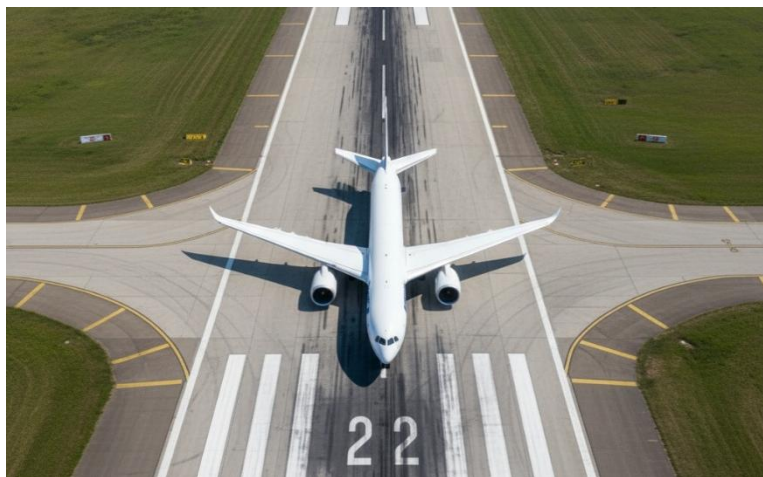
Exercise: What is the volume of helium (density $0.179 \text{ kg} \cdot \text{m}^{-3}$). that has the same mass as 5.0 m^3 of nitrogen (density $1.25 \text{ kg} \cdot \text{m}^{-3}$).

Exercise: Arrange these iron solid objects ascending a) according to their densities b) according to their masses.

- A ball of radius r
- A cube of side length r
- A cylinder of height r and radius r
- A cuboid of length r , width $2r$, and height $0.5r$

2.3 PRESSURE

The plane shown in the figure is standing on a runway of an airport, and the plane weight within 420 tonnes. Intuitively, this weight is distributed over the runway area, and we call the part of its weight affecting on each unit area (1m^2) of the runway: pressure.



2.3.1.1 Definition of Pressure

When a force acts on a surface, we can say that the force is exerting pressure on it. In physics, pressure is defined as the perpendicular force on the surface per unit area, and it can be calculated by the equation:

$$P = \frac{F}{A} \quad (1)$$

Where:

F is the force (N)

A is the area (m^2)

P is the pressure ($\text{Nm}^{-2}=\text{Pa}$) (Pascal)

Exercise: Why do skaters use special shoes instead of regular shoes?



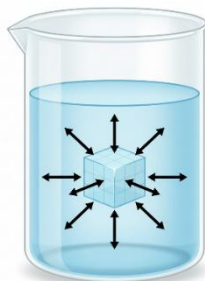
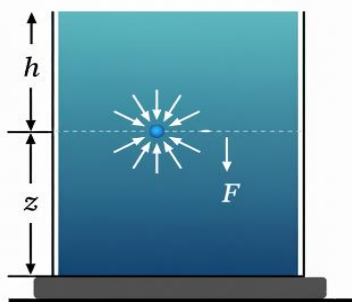
Exercise: Explain why the guy in the figure is not harmed despite being stretched out on a layer of nails.



2.3.2 Pressure in Fluids

Have you tried scuba diving? The diver feels that water exerts pressure on all parts of his body, and his feeling of pressure increases if he dives deep. This can also be witnessed when climbing a mountain, where the higher you go, the lower the pressure you feel.

In fact, all fluids (liquids and gases) exert pressure on objects immersed in them. The pressure of the fluid affects in all directions on an object that immersed in it.



Experimentally, it was found that the pressure of a fluid at a point increase with the increase of:

- The depth of the point below the surface of the fluid h .
- the density of the fluid ρ_f .

Therefore, the fluid pressure at a point is calculated by the equation:

$$P_f = \rho_f h g \quad (2)$$

Where:

P_f is the pressure of fluid (Pa)

ρ_f is the density of the fluid ($\text{kg}\cdot\text{m}^{-3}$)

h is the depth of the point below the surface (m)

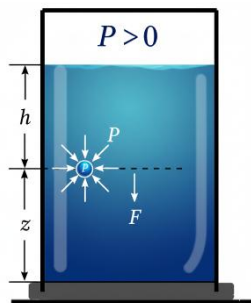
2.4 THE EXPOSURE OF THE ATMOSPHERE

When the fluid is exposed to the atmosphere, then the atmosphere will exert pressure on it, this is true for all fluids too, where fluids can exert pressure on each other.

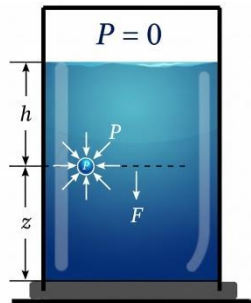
Exercise:

Calculate the total (absolute) pressure at the point P :

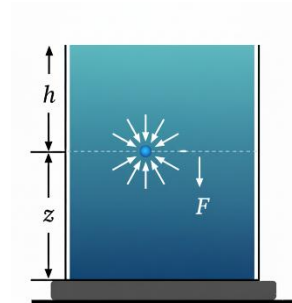
fluid is not exposed to the atmosphere and pressure above it: $P > 0$



fluid is not exposed to the atmosphere and pressure above it: $P = 0$



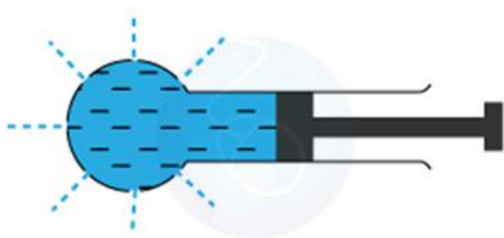
fluid exposed to the atmosphere



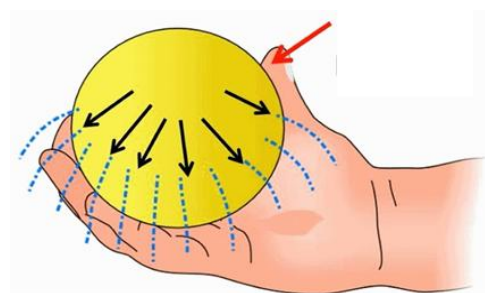
2.5 PASCAL'S PRINCIPLE

Pascal's law (also Pascal's principle or the principle of transmission of fluid-pressure) is a principle in fluid mechanics given by Blaise Pascal that states that a pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere. The law was established by French mathematician Blaise Pascal in 1653 and published in 1663.

For example, when the plunger is pushed in, the water squirts equally from all the holes. This shows that the pressure applied to the plunger has been transmitted uniformly throughout the water.



Also, when you press your finger on a balloon filled with air, the pressure on the surface of the balloon increases by the same value in all directions.



2.5.1 Hydraulic Press

The hydraulic press operates according to Pascal's principle. We see it in our daily life, such as a car lift used in a service station. When a force F_1 is applied to the small piston, the piston is affected by pressure: $P = F_1/A_1$. This pressure is transmitted through the fluid in the lever and exerts the same pressure on the large piston: $P = F_2/A_2$. So:

$$F_1/A_1 = F_2/A_2 \quad (3)$$

Then:

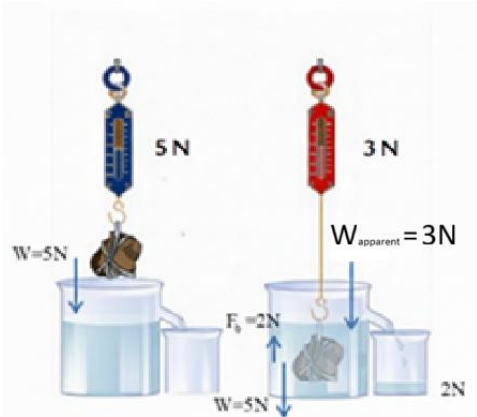
$$F_2 = F_1 \frac{A_2}{A_1} \quad (4)$$

So, A large force is created that affects the large piston, and it is capable of lifting heavy objects such as cars. The quantity (A_2/A_1) is called: mechanical advantage or force multiplication coefficient.

2.6 ARCHIMEDES' PRINCIPLE

From our daily observations, objects appear to be lighter under water. For example, it is difficult for us to lift a heavy rock from the surface of the earth, while we can do so easily if it is submerged under water. This indicates that it is affected by an upward force that reduces its weight, called the Buoyant force and symbolised by F_B . The discovery of the principle is attributed to Archimedes (212-287) BC.

2.6.1 Experiment to verify Archimedes' Principle:



The basin is filled to the edge with water. We weigh the object in the air (reading of the scale):
 $W = 5N$



When the object is immersed in water, Water flows into the trough. The weight of the object inside the water (reading of the scale): $W_{apparent} = 3N$. This means that the buoyant force is:

$$F_B = W - W_{apparent} \quad (5)$$

We can see that the weight of the displaced water is equal to the buoyant force. The volume of the displaced water is equal to the volume of the whole object. Therefore, by the displaced fluid we always mean: the weight of a volume of the fluid equal to the volume of the immersed part of the object.

Statement: Any object, totally or partially immersed in a fluid or liquid, is buoyed up by a force equal to the weight of the fluid displaced by the object.

$$F_B = \rho_{fluid} \times V_{displaced} \times g \quad (6)$$

Where:

F_B is the buoyant force (N).

ρ_{fluid} is the density of the fluid ($kg \cdot m^{-3}$).

$V_{displaced}$ is the volume of fluid displaced by the object (m^3).

g is acceleration due to gravity (ms^{-2}).

2.6.2 Exercises

11. A block of wood has a mass of 120 g and a volume of 150 cm^3 . Find its density in $g \cdot \text{cm}^{-3}$ and $kg \cdot m^{-3}$. Would it float in water?
12. A force of 300 N acts on an area of 0.15 m^2 . Find its pressure.
13. The pressure at a certain point in water is $3.0 \times 10^5 \text{ Pa}$. If the water density is $10^3 \text{ kg} \cdot m^{-3}$, find the depth of that point below the surface.
14. A 2 m^3 block of wood is completely submerged in water (density = $10^3 \text{ kg} \cdot m^{-3}$). Calculate the buoyant force acting on it.

15. An object weighs 40 N in air and 35 N when completely immersed in water. Find the buoyant force and the volume of the displaced water. (Water density = $10^3 \text{ kg} \cdot \text{m}^{-3}$)
16. A hydrometer sinks deeper in oil than in water. What does this tell you about the densities of the two liquids?
17. A piece of wood immersed one-third of its volume if placed in water (the density of water is $10^3 \text{ kg} \cdot \text{m}^{-3}$), While immersed half of its volume if put in oil, find the density of oil?
18. An object with mass 17 kg displaces 85 liters of fresh water. find the buoyant force acting on it.
19. A solid cylinder with a density of $2.0 \times 10^3 \text{ kg} \cdot \text{m}^{-3}$ and a weight of 400 N in air, we immersed it in oil, so its weight became 300 N. find the density of the oil.
20. A solid metal cylinder weighs 400 N in air, after immersing it in fresh water, its weight is 300 N. Calculate the volume of the cylinder. (Water density = $10^3 \text{ kg} \cdot \text{m}^{-3}$)
21. The total (absolute) pressure at the bottom of a swimming pool is 151,325 Pa. If the atmospheric pressure is 101,325 Pa, find the depth of the swimming pool.
22. An iceberg of density $9.2 \times 10^2 \text{ kg} \cdot \text{m}^{-3}$ floats in seawater of density $1.03 \times 10^3 \text{ kg} \cdot \text{m}^{-3}$. If the total volume of the iceberg is 2000 m^3 , find the volume of ice above the water surface.

3 MOTION IN ONE DIMENSION

To describe an event in nature, we express it using physical quantities, such as temperature, pressure, speed, and force. The effect of some of these quantities cannot be determined without knowing their direction, while others cannot be described by a direction. This distinction allows us to divide physical quantities into two types: scalar quantities and vector quantities.

3.1 SCALAR AND VECTOR QUANTITIES

Scalar quantities are physical quantities that are fully described by their magnitude (value) only, and no direction can be assigned to them. Examples include temperature and time. It makes no sense to say "the temperature is 30° upward" or "I waited for you for two hours toward the north."

Vector quantities are quantities that require both a magnitude and a direction to be fully described, such as force and displacement. Suppose a force of 5N acts on a stationary object. Will the object move up or down? Or will it move right or left? And if another force of 5N also acts, will the object move with greater acceleration, or will the two forces balance each other so the object doesn't move? Without knowing the direction, we cannot describe the effect of these physical quantities.

Important note: Vector quantities are written with an arrow or in bold to differentiate between them and the scalar quantities, ($\vec{A}$, A). The magnitude of the vector is written with the normal font $A = |\vec{A}|$.

3.2 VECTOR QUANTITIES IN THREE DIMENSIONS

We live in a three-dimensional world, which means vector quantities exist in three dimensions. Fortunately, we can describe any vector quantity as the sum of three vector quantities, each lying along one of the three dimensions (axes). We can then study each vector independently of the others. At this stage, the requirement will be to study vector quantities in one dimension, and we will leave the analysis of vectors in multiple dimensions for later stages.

3.3 MOTION

The movement of objects – such as a football, a car, and even the sun and moon – is a clear part of our daily lives. The modern concept of motion became clear in the 16th and 17th centuries AD, with significant contributions from Galileo Galilei (1564-1642) and Isaac Newton (1642-1727), who helped formulate the modern understanding of motion.

The study of the motion of objects and the concepts related to force and energy includes a field called Mechanics, which is usually divided into two branches:

Kinematics

Describes the motion of objects in terms of position and time without considering their causes.

Dynamics

Describes the motion of objects by the effect of their causes, such as forces.

We will now discuss the translational motion of objects without rotation, specifically in one dimension (on a straight line).

3.3.1.1 Position

To describe the motion of an object well, physicists need to know several physical quantities about it, such as its position, displacement, velocity, and acceleration, which we will study successively, and we will start by knowing what we mean by position.

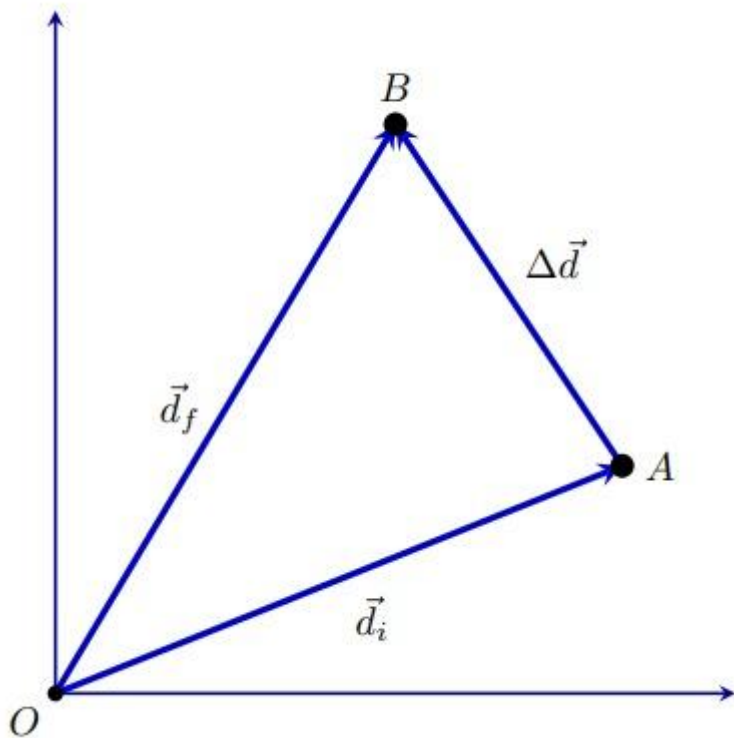
Position is defined as the location of an object at a particular moment relative to a reference point, often called the origin.

3.3.1.2 Distance and Displacement

	Distance	Displacement
Concept	The actual length of the path of the object's motion; it is a scalar quantity.	The change in the position of the body in a specific direction; it is a vector quantity.

Displacement is a vector connecting the endpoints of the path of an object. The displacement does not depend on the path taken, and it can be calculated by the equation:

$$\Delta \vec{d} = \vec{d}_f - \vec{d}_i \quad (7)$$



Where:

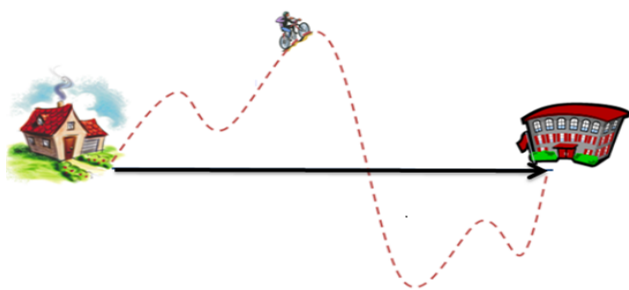
$\Delta \vec{d}$ is the displacement (m).

$\vec{d}_f$ is the final position vector (m).

$\vec{d}_i$ is the initial position vector (m).

Note that in the graph, the path wasn't taken into consideration, only the end points of the path (the start and the end points). While the distance " s " can be calculated only by calculating the length of the path taken by the object.

Exercise: A cyclist moves from his home to his school as shown in the figure. How do we distinguish between distance and displacement?



Exercise: A runner ran around a circle with a radius $r = 10.0 \text{ m}$. a) After he finished the first round, what was his displacement and distance? b) What will his displacement and distance be if he ran 10 rounds? c) What was his displacement and distance at a quarter round? d) And at half round? e) And at 3-quarters?

3.3.2 Speed and velocity

Velocity and speed measure how fast the object is moving, with the speed being a scalar quantity and velocity as a vector. So, we can define the following:

Average speed: is the rate of change of distance with respect to time. And can be calculated by the equation

$$\bar{v} = \frac{s}{t} \quad (8)$$

Where:

$\bar{v}$ is the average speed (ms^{-1}).

s is the total distance (m).

Δt is the time interval (s).

Average velocity: is the rate of change of position with respect to time. And can be calculated by the equation:

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{\vec{d}_f - \vec{d}_i}{\Delta t} \quad (9)$$

Where:

$\vec{v}$ is the average velocity (ms^{-1}).

d_i is the initial position (m).

d_f is the final position (m).

$\Delta \vec{d}$ is the displacement (m).

Δt is the time interval (s).

Exercise: If the runner in the last example completed the round in 12.5 s, what is his average speed and his average velocity?

3.3.3 Acceleration

Acceleration is the rate of change of velocity. It is a vector quantity, and its direction gives us insight into the object's motion. If it is in the same direction as the velocity, then the object is accelerating (speeding up), and if it is in the opposite direction, then the object is decelerating (slowing down).

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \quad (10)$$

Where:

$\vec{a}$ is the average acceleration (ms^{-2}).

$\vec{v}_i$ is the initial velocity (ms^{-1}).

$\vec{v}_f$ is the final velocity (ms^{-1}).

$\Delta \vec{v}$ is the change of velocity (ms^{-1}).

Δt is the time interval (s).

Exercise: A rabbit runs along the x-axis. What is the sign of its acceleration if it is moving (a) in the positive direction with increasing speed, (b) in the positive direction with decreasing speed, (c) in the negative direction with increasing speed, and (d) in the negative direction with decreasing speed?

3.4 GRAPHICS CALCULATIONS

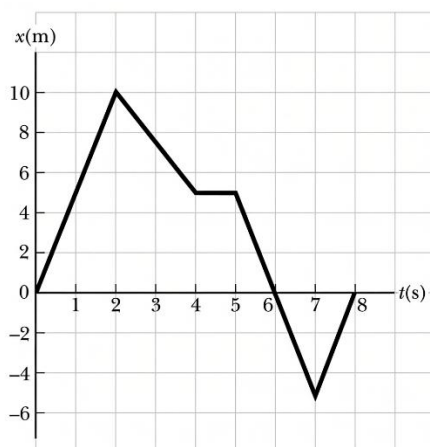
Algebraic equations are essential tools for solving problems in kinematics, yet graphical analysis offers a more intuitive and visually rich understanding of motion. By interpreting the slopes and areas of graphs, we can derive fundamental quantities such as displacement, velocity, and acceleration, and see how they relate to one another.

3.4.1 The position-time graph

This graph shows how the position of the object changes with time. From this graph, it is easy to extract the distance and displacement based on their definitions. Where the displacement only requires the endpoints, and the distance is calculated by summing all the distances travelled by the object.

Velocity is the rate of change of the position, which is the slope of the position-time graph.

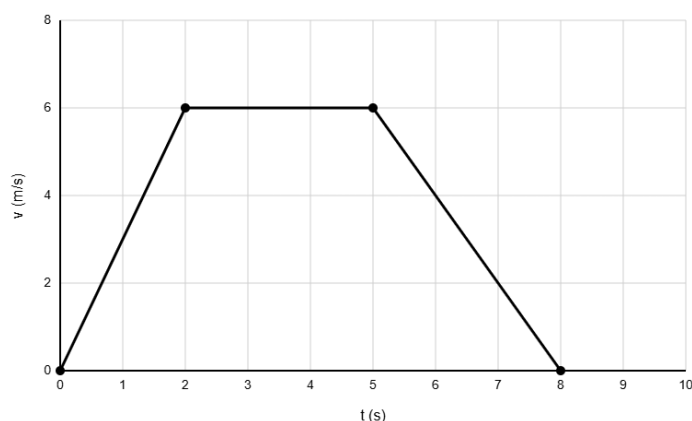
Exercise: In the following graph, a) determine the position at $t = 7.0 \text{ s}$ b) determine the average velocity in the interval between $t = 2.0 \text{ s}$ and $t = 4.0 \text{ s}$. c) determine the average velocity in the interval between $t = 2.0 \text{ s}$ and $t = 6.0 \text{ s}$.



3.4.2 The speed-time graph

This graph shows how the speed changes with time. In this graph, the distance can be obtained by calculating the area under the graph (the area is speed times time, which is the equation to calculate distance).

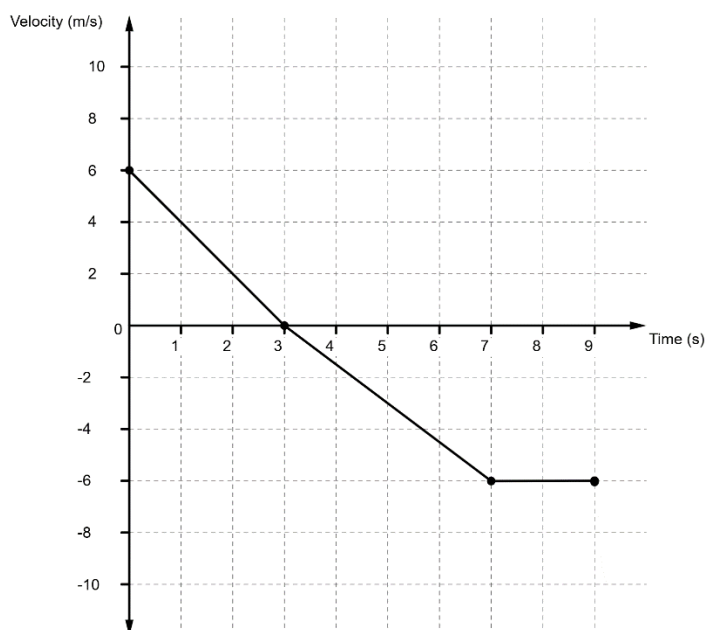
Exercise: The following graph shows the speed of an object versus time. From this graph, a) determine the speed at $t = 4.0 \text{ s}$. b) Determine the distance travelled from $t = 0.0 \text{ s}$ to $t = 8.0 \text{ s}$. c) Determine the distance travelled when the speed was constant.



3.4.3 The velocity-time graph

Similar to the speed-time graph, we can see the velocity and how it changes with time. This time, the area under the graph is the displacement. In addition, the slope of the graph is the change of velocity divided by the time interval, which is exactly the acceleration.

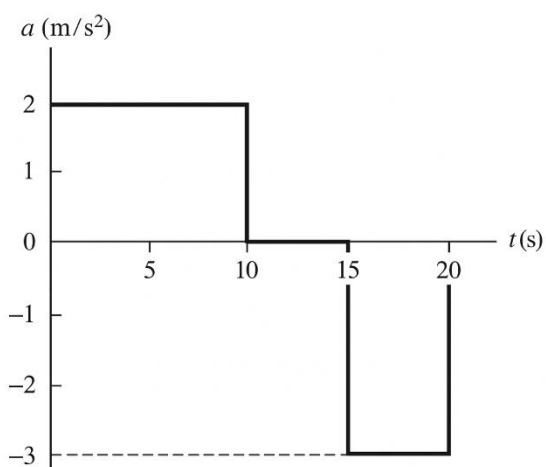
Exercise: The following graph shows the velocity of an object versus time. From this graph, a) Determine the velocity at $t = 1.0 \text{ s}$. b) At what second did the object change its direction? c) Determine the value and the direction of the average acceleration for the interval from $t = 0.0 \text{ s}$ to $t = 10.0 \text{ s}$. d) Determine the total displacement of the object for the interval from $t = 0.0 \text{ s}$ to $t = 7.0 \text{ s}$.



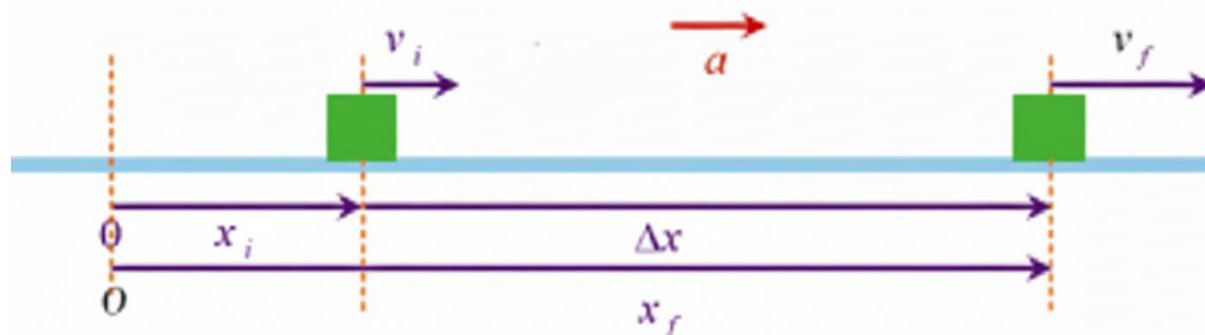
3.4.4 The acceleration-time graph

The acceleration-time graph shows how the acceleration changes with time, and the area under the curve gives the velocity difference.

Exercise: From the acceleration versus time graph, a) determine the direction and value of the acceleration at $t = 7.0 \text{ s}$. b) Calculate the change in the velocity from $t = 0.0 \text{ s}$ to $t = 20.0 \text{ s}$. c) When was the velocity constant?



3.5 EQUATIONS OF MOTION



How can we describe the motion of the object in the figure above, which moves in a straight line from the position on the left to the position on the right toward the axis with constant acceleration? We can describe the motion of this object using the following equations of motion.

$$v_f = v_i + at \quad (11)$$

$$\Delta x = v_i t + \frac{1}{2} at^2 \quad (12)$$

$$\Delta x = v_f t - \frac{1}{2} at^2 \quad (13)$$

$$v_f^2 = v_i^2 + 2a\Delta x \quad (14)$$

$$\Delta x = \left(\frac{v_f + v_i}{2}\right)t \quad (15)$$

Where:

O is the origin.

Δx is the displacement in the x-axis (it can be any axis) (m).

x_f is how far the object is from the origin initially (m).

x_i is how far the object is from the origin initially (m).

v_i is the initial velocity (ms^{-1}).

v_f is the final velocity (ms^{-1}).

a is the acceleration (ms^{-2})

t is the time interval (s).

3.5.1 Problem-solving skills using equations of motion

- 1) If the motion is in one direction: Consider it the positive direction of motion, whatever it is. And the signs of displacement, velocity, and acceleration are positive in this direction and negative in the other direction.
- 2) If the motion is in more than one direction on one line: Consider one of the directions as positive (e.g., to the right or upward) and the other negative (to the left or downward). And the signs of displacement, velocity, and acceleration are positive in the positive direction and negative in the other direction.
- 3) Use the appropriate equation in which all quantities are known except the quantity to be calculated. Note that you need to know 3 variables to determine the other 2.
- 4) If the problem contains several accelerations, apply the equations for each acceleration stage separately.
- 5) You need the number of equations to equal the number of unknowns.

Exercise: A truck covers 40.0 m in 8.50 s while smoothly slowing down to a final speed of 2.80 ms^{-1} . (a) Find its original speed. (b) Find its acceleration.

3.6 FREE FALL

Free fall is considered one of the examples of one-dimensional motion with a constant acceleration in nature, and it is defined as the motion of an object under the influence of Earth's gravity only, with the ignorance of air resistance, in a line perpendicular to the reference surface (the ground).

We usually consider the upward direction as the positive one. The value of the acceleration is: $g = 9.8\text{ ms}^{-2}$ during ascent and descent.

The displacement and velocity of the body can be calculated at any moment during the period of ascent or descent, by utilizing the equations of motion and considering the acceleration in the equations of motion as $a = -g$:

$$v_f = v_i - gt \quad (16)$$

$$\Delta y = v_i t - \frac{1}{2}gt^2 \quad (17)$$

$$\Delta y = v_f t + \frac{1}{2} g t^2 \quad (18)$$

$$v_f^2 = v_i^2 - 2g\Delta y \quad (19)$$

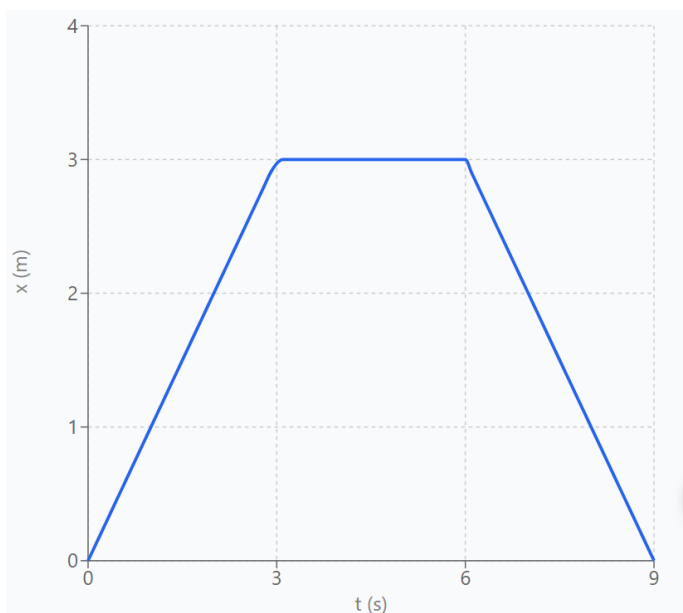
$$\Delta y = \left(\frac{v_f + v_i}{2}\right)t \quad (20)$$

It is also helpful to remember that the velocity at the highest point is $v = 0$. Otherwise, it will go even higher.

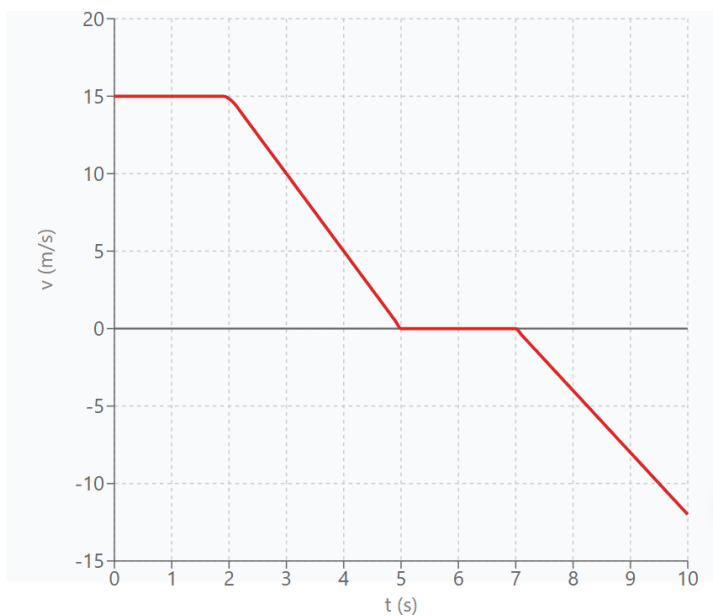
Exercise: A ball was thrown next to a building, and a man in the building saw the ball from his window. After 3 seconds, he saw it again. Was the ball's speed larger in the ascending or descending? And find the velocity in both cases.

3.6.1 Exercises

23. A person walks 4 km East, then 3 km North. Calculate the total distance travelled and the magnitude of his displacement.
24. A car travels from city A to city B with a constant speed of 100 km/hr in one hour, and then back to city A with a constant speed 80 km/hr. Calculate its average speed and average velocity for the entire trip.
25. A car accelerates from 20ms^{-1} to 30ms^{-1} in 5 seconds. What is its acceleration? And what was its displacement?
26. A cyclist slows down from 10ms^{-1} to a stop in 5 seconds. What is his acceleration? And what was his displacement?
27. An object's motion is described by the position-time graph below. Describe its motion in words (e.g., constant speed, at rest, etc.) for each segment.



28. An object's motion is described by the velocity-time graph below. Find (a) the acceleration in each segment, and (b) the total displacement.



29. A ball is thrown vertically upward with an initial velocity of 20ms^{-1} . How high does it go? How much time does it take to reach its maximum height?

30. A truck moving at 25ms^{-1} applies its brakes and comes to a stop in 10 seconds. What is its acceleration, and how far does it travel during this time?



31. A car accelerates uniformly from rest and covers a distance of 100 m in 5 seconds.
Find its acceleration and its final velocity.
32. A stone is dropped from a cliff. It hits the ground after 3 seconds. What is the height of the cliff?
33. A ball is thrown vertically upwards with a speed of 15ms^{-1} from the ground. Calculate the time it takes to return to the ground.
34. A train decelerates uniformly from 40ms^{-1} to 20ms^{-1} over a distance of 200 m . Find the acceleration and the time taken.
35. Sketch a velocity-time graph for an object that accelerates from rest, then moves at constant velocity, then decelerates to a stop.
36. On the moon, gravity is 1.6ms^{-2} . If an astronaut drops a hammer from a height of 2 m , how long does it take to hit the ground?

Simulation test

Q1. Which of the following is a reasonable size for a grain of sand?

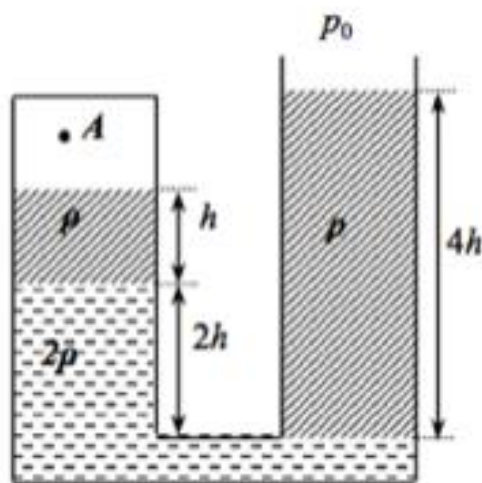
- A) $1m$
- B) $1cm$
- C) $1mm$
- D) $1\mu m$

Q2. An object floats with $1/4$ part of its volume outside the liquid when put in liquid A and $1/2$ part of its volume outside the liquid when put in liquid B. The density of liquid A is ρ_A . Find the density of liquid B.

- A) $\rho_B = \frac{1}{2} \rho_A$
- B) $\rho_B = 2\rho_A$
- C) $\rho_B = \frac{3}{2} \rho_A$
- D) $\rho_B = \frac{2}{3} \rho_A$

Q3. Determine the air pressure above the surface of the liquid at point A inside the closed section of the curved tube. The values are $\rho = 800 \text{ kg/m}^3$, $h = 20 \text{ cm}$, $g = 10 \text{ m/s}^2$. Liquids with densities ρ and 2ρ do not mix with each other. The air pressure above the vessel is $p_0 = 10.0 \text{ kPa}$.

- A) 24.4 kPa
- B) 8.4 kPa
- C) 3.6 kPa
- D) 11.6 kPa



Q4. An ice cube of pure water floats in a glass of salt water. How will the water level in the glass change after the ice melts?

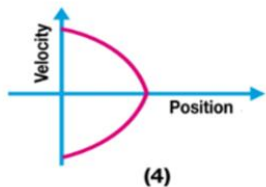
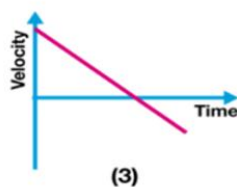
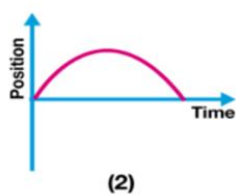
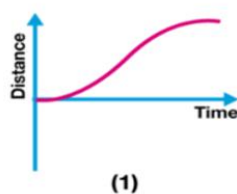
- A) water level increase
- B) water level decrease
- C) water level remains the same
- D) it depends on ice cube volume

Q5. When measuring the pressure in the sea, the following results were found. The pressure at a distance of 50 m from the bottom is 3 times greater than the pressure at a depth of 50 m. Find the depth of the sea. Neglect atmospheric pressure.

- A) 100 m
- B) 200 m
- C) 450 m
- D) 650 m

Q6. All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up.

- A) 1
- B) 2
- C) 3
- D) 4



Q7. A person standing on the edge of a fire escape simultaneously launches two stones, one straight up with a speed of 7 m/s and the other straight down at the same speed. How far apart are the two stones 2s after they were thrown, assuming that neither has hit the ground?

- A. 14 m
- B. 20 m
- C. 28 m
- D. 34 m

Q8. A projectile is thrown upward with speed v . By the time its speed has decreased to $v/2$, it has risen a height h . Neglecting air resistance, what is the maximum height reached by the projectile?

- A. $5h/4$
- B. $4h/3$
- C. $3h/2$
- D. $2h$

Simulation test answers

question	answer
1	C
2	C
3	B
4	B
5	B
6	A
7	C
8	B