أولمبياد الموهبة الوطني
NATIONAL GIFTED OLYMPIAD

Phase 2 Package

Scientific Track – NSMO

Sciences

Science Scientific Team

Biology

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TAXONOMY

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Introduction

Taxonomy represents the cornerstone for understanding the immense diversity of living organisms on Earth. With millions of species differing in form, structure, and lifestyle, there arose a need for an accurate system that facilitates the study of these organisms, determines their relationships, and traces their evolution through time. This science is based on a fundamental principle: all living things, despite their differences, are related to one another to varying degrees and can be organized into groups that reflect these relationships.

Taxonomy provides the scientific framework that enables us to comprehend and organize the vast diversity of life on our planet. Although organisms vary in shape, size, and mode of life, they share patterns of similarity that indicate common relationships and group them into larger categories. Classification helps arrange organisms in a way that clarifies their relationships and evolutionary origins, making the study of life more precise and insightful.

The study of taxonomy begins with identifying prokaryotic organisms and extends to protists, which exhibit a higher level of complexity. Protists include groups that resemble animals, plants, and fungi. The field further encompasses the animal kingdom, both vertebrates and invertebrates. By analyzing the shared and unique traits of each group, scientists can trace the evolution of body plans and understand how species adapt to different environments.

This integration among living groups provides a comprehensive view of the history of life on Earth and helps students connect the characteristics of organisms with their ecological roles, behaviors, and adaptive strategies.

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Objectives:

1. Understand the general principles of biological classification, including taxonomic levels and the fundamentals of naming organisms.
2. Explain the differences among the kingdoms of life by tracing the origin of each group and understanding how shared and unique characteristics emerged.
3. Identify the structures of prokaryotic and eukaryotic cells and compare their main forms and methods of reproduction.
4. Analyze the ecological importance of fungi and their roles in decomposition, symbiosis, and the production of food and medicine.
5. Identify the general characteristics of animals and relate them to feeding patterns, movement, and reproduction.
6. Classify invertebrates into their main groups and describe the characteristics of each.
7. Distinguish the characteristics of vertebrates in terms of structure, reproduction, and habitat.

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CHAPTER ONE

TREE OF LIFE



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Origin of Life :

The cell is the basic unit of life. Life began on Earth about 4.5 billion years ago.

The first cell originated in primitive environments such as:

- Oceans
- Hydrothermal vents

These environments provided simple molecules such as:

- Amino acids
- Nucleotides

From these building blocks, larger molecules were formed:

- Proteins
- Nucleic acids

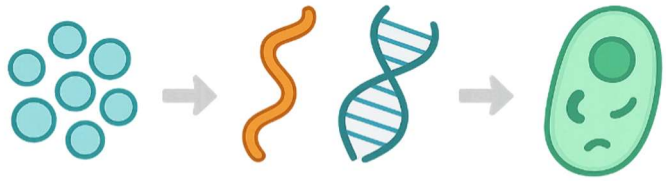


Figure 1: Illustrates the origin of the first cell in primitive

Classification of Living Organisms

Classification:

It is the process of placing living organisms into groups based on their characteristics.

Taxonomy:

Taxonomy is the branch of science specialized in organizing living organisms and arranging them into groups called:

- Taxon (singular)
- Taxa (plural)

Basic rules:

- No two species can have the same name.
- Therefore, the Binomial Nomenclature system was established so that each organism has a unique universal name.

Scientific Name

The scientific name usually consists of two words:

1. The first refers to the Genus.
2. The second refers to the Species.

Examples:

- Human: *Homo sapiens* (abbreviated as *H. sapiens*).
- Dinosaur: *Tyrannosaurus rex* (abbreviated as *T. rex*).

First: Aristotle's System (394–322 BC)

- Divided living organisms into Animals and Plants.

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-

Second: Carl Linnaeus's System (1707–1778 AD)

- Faced the problem of multiple names used to describe the same species (Polynomial nomenclature).
- Established the Binomial Nomenclature system:
  - Composed of two names:
  - Genus name (capitalized). - Species name(lowercase).

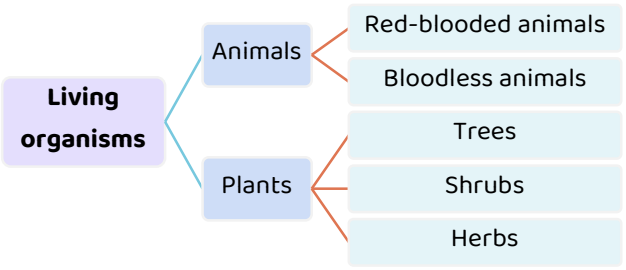


Figure 2: Living Organisms

Third: Whittaker's System (1969)

- Divided living organisms into five kingdoms within three levels of organization:

1. First level: Kingdom Monera – Prokaryotes.
2. Second level: Kingdom Protista – Unicellular eukaryotes.
3. Third level: Multicellular organisms, including:
   - Kingdom Fungi
   - Kingdom Plantae
   - Kingdom Animalia

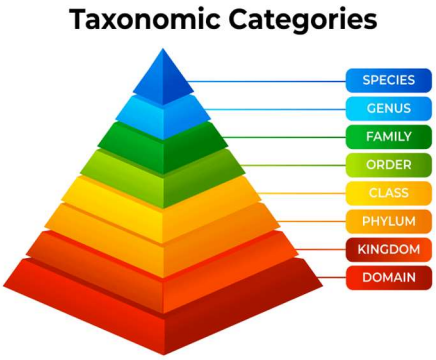


Figure 3: Classification hierarchical system

Taxonomy Categories

Classification is based on a hierarchical system that moves from the most general to the most specific:

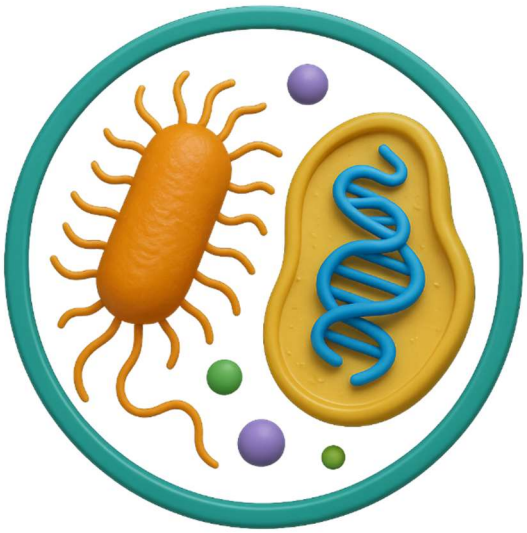
Domain > Kingdom > Phylum > Class > Order > Family > Genus > Species

Notes:

- The highest level (Domain) includes the largest number of organisms with the least similarity.
- The lowest level (Species) includes organisms that are more closely related and share greater similarity in characteristics, morphology, and reproduction.

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Chapter Two
Bacteria and Archaea



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Structure of the Prokaryotic Cell

- Main groups:
  - *Bacteria*.
  - *Archaea*.
- Environments: Soil, oceans, and extreme environments such as:
  - Highly saline waters.
  - Deep hydrothermal vents.
- Size: Ranges between 0.3 – 28 µm.
- Capabilities: Great diversity in form, structure, and functions, with adaptation to multiple conditions.
- Extremophiles: Capable of tolerating:
  - Heat up to 435°C.
  - Acidic or alkaline environments.

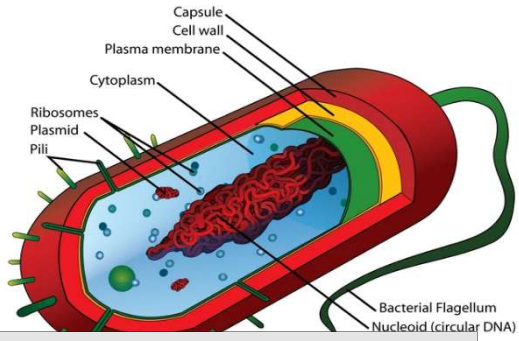


Figure 4 Components of Prokaryotic Cells

Components of Prokaryotic Cells:

Component	Function	Location in the Cell
Plasma membrane	Separates the cell from the external environment and regulates material passage	Inner boundary of the cell, beneath the cell wall
Cytoplasm	Contains enzymes and molecules essential for biochemical reactions	Fills the inside of the cell
Nucleoid	Region containing circular DNA not surrounded by a membrane	Within the cytoplasm
Plasmids	Extra DNA molecules carrying genes that provide special traits or resistance	Floating in the cytoplasm
Ribosomes	Responsible for protein synthesis	Scattered in the cytoplasm
Cell wall	Provides support and protection – differs between Gram-positive and Gram-negative	Surrounds the plasma membrane
Pili	Help the cell adhere to surfaces	Extend outward from the cell surface
Flagella	Enable cell movement	Project outward from the cell surface

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The most common shapes of prokaryotes:

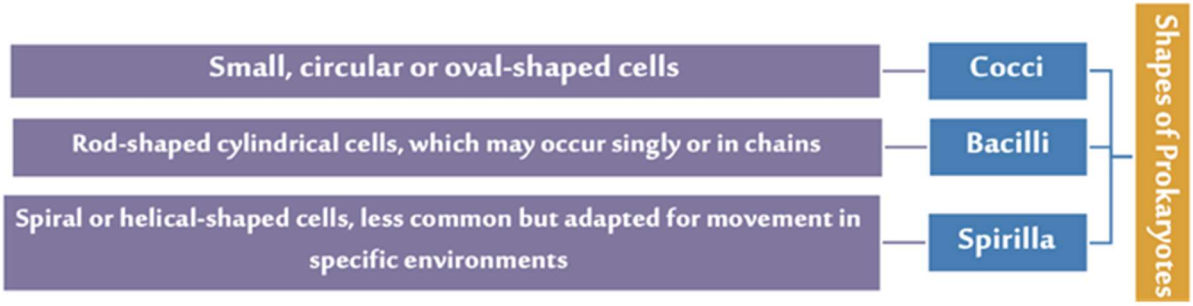


Figure 6: the shapes of prokaryotes

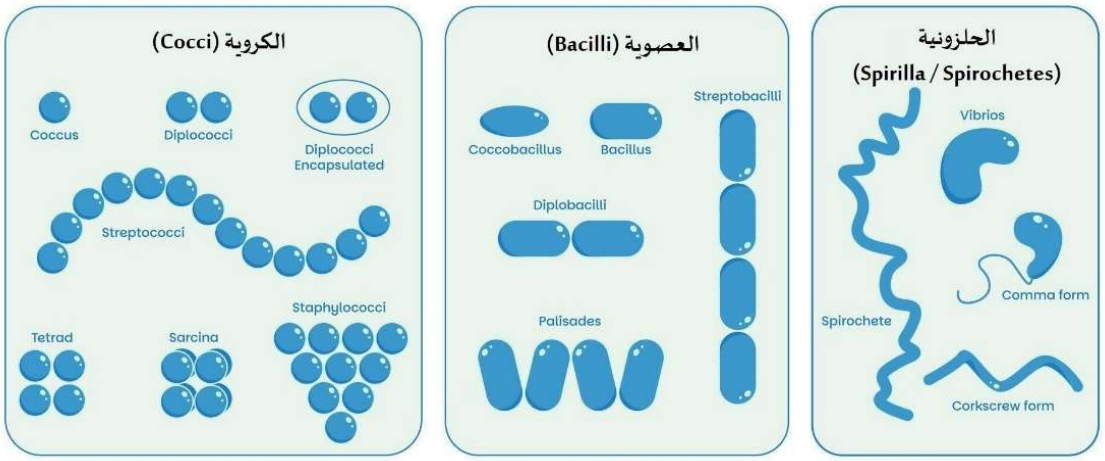


Figure 5: shows the shapes of prokaryotes

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Bacterial Cell Characteristics:

First. Morphological characteristics of bacteria Shape and Arrangement

Second. Growth and Reproduction

Growth

The growth process occurs through:

1. Cell growth: Increase in the amount of protoplasm.
2. Cell division: Increase in the number of cells, forming colonies.

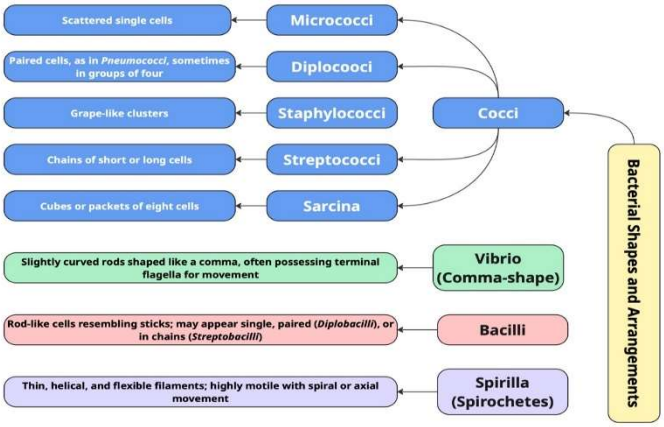


Figure 7: Bacterial shapes and arrangments

- Under favorable environmental and nutritional conditions, bacteria reproduce very rapidly; the population may reach 10–15 billion cells per milliliter in a short period.
- Some species, such as Actinomycetes, reproduce by fragmentation or budding.

Reproduction Methods:

Nutritional Factors

Sexual Reproduction (Genetic Recombination)	Spore Formation (Endospore Formation)
It is the conjugation of two bacterial cells in which genetic material is transferred from a donor cell to a recipient cell through a hollow pilus, aiming to acquire new genetic traits.	It is the process by which bacteria form internal spores under unfavorable conditions to ensure survival of the species.

Types:

1. **Autotrophs:** Use inorganic compounds such as H_2, CO_2, and nitrates through photosynthesis or chemosynthesis.
2. **Heterotrophs**: Obtain their energy from the breakdown of organic compounds via fermentation or oxidation.

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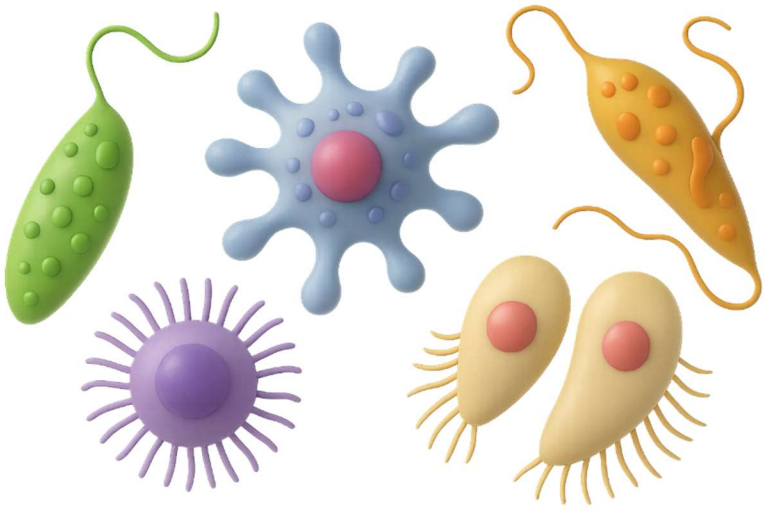
Gram-Positive and Gram-Negative Bacteria:

Gram stain: A method used to distinguish between two types of bacteria.

Structure	Composition	Function	Importance
Cell Wall (Gram + / -)	- Gram-positive: Thick layer of peptidoglycan. - Gram-negative: Thin layer of peptidoglycan. - outer membrane containing LPS.	- Determines cell shape. - Protection from osmotic pressure.	- Gram-positive: Retains purple stain. - Gram-negative: More resistant to antibiotics due to the outer membrane.
Surface Layer (S-layer)	Protein or glycoprotein, crystalline or mesh-like surface.	- Reinforces the cell. - Adheres to surfaces. - Protection against enzymes and harsh conditions.	Present in some archaea and bacteria, provides additional resistance.
Capsule	Gelatinous layer outside the cell wall.	- Protection against desiccation. - Adherence to cells and surfaces. - Avoidance of immune response.	Increases pathogenic bacteria's ability to cause disease.
Flagella	Long, thin protein structures (3–12 μm length, ≤20 nm thick).	Movement in liquid environments.	Helps bacteria migrate in search of nutrients or escape unfavorable conditions.
Pili	Short, thin protein filaments (7.5–10 nm).	- Adherence to surfaces and other cells. - Contributes to genetic exchange.	Important for biofilm formation and gene transfer between bacteria
Endospores	Protective coat containing genetic material and essential proteins.	- Enter dormancy under harsh conditions. - Regrow when conditions improve.	Provide extreme resistance to heat, desiccation, and chemicals; may survive for decades or centuries.

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Chapter Three
Protists



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Definition	Forms
Eukaryotes that live in moist soil, saltwater, and freshwater. Some are parasitic on other organisms, including humans.	1. Unicellular. 2. Multicellular 3. Colonies
Common Examples	**Structure**
1. *Golgi bodies,* 2. *Amoeba* 3. *Plasmodium* 4. *Paramecium* 5. *Euglena* 6. Algae such as *Spirogyra*	Possess a **true nucleus** and organelles such as: • Mitochondria • Plastids • Endoplasmic reticulum, • Golgi bodies.

General Characteristics of Protists

Property	Type
Nutrition	1. **Autotrophic** – Photosynthesis 2. **Heterotrophic** – Absorption or ingestion 3. **Mixotrophic** – Depending on conditions
Respiration	1. **Aerobic** – Common 2. **Anaerobic** – In the absence of oxygen
Reproduction	1. **Asexual** – Binary fission 2. **Sexual** – Cellular conjugation 3. **Encystment** – For protection

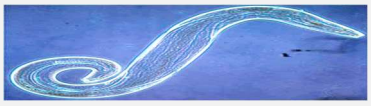
Definition of Encystment:

- Occurs under unfavorable conditions (lack of nutrients, oxygen, moisture, or unsuitable temperature).
- A cyst with a thick covering is formed. Provides the organism with the ability to survive for a long period and later emerge into the vegetative stage.

Movement:

Protists possess specialized structures for movement, which may be:		
Form	**Example**	**Mode of Movement**
	*Paramecium*	Cilia
	*Euglena*	Flagella

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	*Amoeba*	Pseudopodia
	*Plasmodium*	No locomotory organ (move by gliding within host fluids)

Scientific Classification of Protists

Protists are classified based on their nutrition into two main groups:			
Comparison Aspect	**Algal (Plant-like Protists)**	**Protozoa (Animal-like Protists)**	**Fungus-like-Protists**
Nutrition	Autotrophic (Producers)	Heterotrophic (Consumers)	Heterotrophic (Consumers)
Description	Some are unicellular, others are multicellular	Unicellular	Some are unicellular, others are multicellular
Divisions	Include six divisions: 1. Euglenophyta (Euglenoids) 2. Chrysophyta (Golden algae) 3. Pyrrophyta (Dinoflagellates) 4. Chlorophyta (Green algae) 5. Phaeophyta (Brown algae) 6. Rhodophyta (Red algae)	Include four divisions: 1. Mastigophora (Flagellates) 2. Sarcodinae (Amoeboids) 3. Apicomplexa (Sporozoans) 4. Ciliophora (Ciliates)	Include three divisions: 1. Slime molds 2. Water molds 3. Downy mildews

First. Algal (Plant-like Protists)

Characteristics:

- Simple thallus organisms not differentiated into roots, stems, or leaves.
- Contain chlorophyll and are autotrophic through photosynthesis.
- Their life cycle is characterized by alternation of generations between a sexual gametophyte stage and an asexual sporophyte stage.

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1. Phylum Euglenophyta (Euglenoid Algae)

- Represents a link between animals and plants.
- Reproduces very rapidly until it covers the water surface with a characteristic green scum.

Food Storage

- Stores food in the form of:
  - Lipids
  - A carbohydrate compound known as paramylon, which resembles starch but differs.





Figure 8: green Alagea

2. Division: Green Algae (Chlorophyta)

Definition

- Contain:
  - Chlorophyll a & b
  - Xanthophyll
  - Carotene
- Cell wall composed of cellulose.

Form

- Unicellular
- Colonial
- Filamentous (branched or unbranched)
- Thalloid / leaf-like

3. Phylum Chrysophyta (Golden Algae)

Definition:

- The most famous group: Diatoms.

Distinctive Characteristics:

- Plastids contain:
  - Carotene.
  - Fucoxanthin (in higher proportion than Chlorophyll).

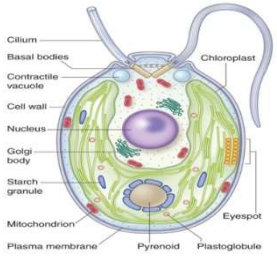


Figure 9: Unicellular

Stored Food:

- Not stored as starch.
- Stored in the form of:
  - Leucosin.

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4. Dinoflagellates (Phylum Pyrrophyta / Dinophyta)

Definition:

- They are named so because some species emit light in the dark, a phenomenon known as bioluminescence, making the water appear as if it is glowing with fire.

Habitat:

- Found in marine waters and freshwater.
- Some species live in symbiotic association with corals.

Pigments:

- Contain:
  - Carotene
  - Xanthophyll
  - Chlorophyll

Important Groups:

- Dinoflagellates (Dinophyceae)



Figure 10 Bioluminescence phenomenon produced by some dinoflagellates, where the sea displays a natural blue glow at night

5. Brown Algae (Phylum Phaeophyta)

Definition:

- Considered among the most advanced algae, showing high complexity in both internal and external structure.

Form:

- Multicellular.
- The thallus is usually large, with a leathery or rubbery texture.
- Structurally composed of:
  - Holdfast (foot).
  - Stipe (stem/neck).
  - Blade (flattened lamina) – its function is photosynthesis and spore production.



Figure 11 : Image of a brown alga

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6. Red Algae (Phylum Rhodophyta)

Motility: Non-motile.

Pigments:

- Dominant pigment: Phycoerythrin (red).
- Secondary pigment: Phycocyanin (blue, in small amounts).

Cell Wall:

- Composed of cellulose and pectin.
- In multicellular species: Possess cross walls with pits that allow cytoplasmic connections, similar to higher plants.

Reproduction:

- Asexual: By fragmentation or division.
- Sexual: Through alternation of generations between:
  - Gametophyte stage.
  - Sporophyte stage.
- Both stages live independently of each other.

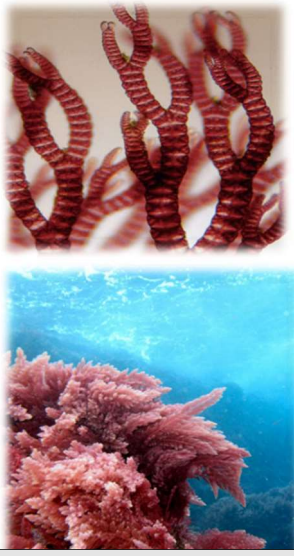


Figure 11: Marine red algae showing their filamentous structure and distinctive colors resulting from phycoerythrin pigments, forming large colonies in marine environments

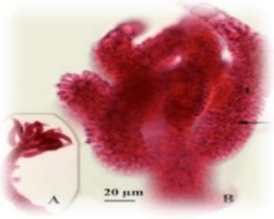


Figure 12: Polysiphonia

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The Economic Importance of Algae in Human Life

The Importance of Algae

- **Food**
  - Used as food in some coastal regions around the world
  - Represent a primary food source for many aquatic and terrestrial animals
  - Form the base of the food chain.
- **Fertilizers**
  - Brown algae are dried and used as fertilizers because they contain high amounts of nitrogenous compounds.
- **Industrial compounds**
  - From brown and red algae, two important substances are extracted:
    - Iodine
    - Agar
  - Used in the food industry and in scientific laboratories.
- **Oxygen production**
  - Contribute to the production of 50–70% of the Earth's oxygen through photosynthesis.
- **Wastewater treatment**
  - Provide oxygen for bacteria that oxidize organic matter.
- **Industries**
  - Used in various **industries**
    - Ice cream
    - Toothpaste
    - Skin cleansers
    - Deodorants
    - Nail polishes
    - Cosmetics
- **Medicine**
  - Some algae yield **chemical compounds** that are utilized in the formulation of **medicines**.
- **Science**
  - Algae have contributed to the **development of many sciences**

Second. Animal-like Protists (Protozoa)

Characteristics:

- Most are microscopic organisms.
- All are unicellular.
- Usually live individually, sometimes in colonies.
- The cytoplasm is differentiated into:
  - Ectoplasm: A clear outer layer.
  - Endoplasm: A granular inner layer.
- The body is covered by a plasma membrane or a thin pellicle.

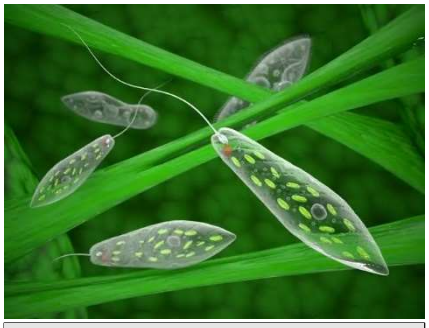


Figure 13: Protozoa

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Locomotion:

- By pseudopodia.
- By flagella.
- By cilia.
- Some species lack locomotory organelles.

Osmoregulation:

- Most possess contractile vacuoles to remove excess water.

Respiration:

- Mostly aerobic respiration through the plasma membrane.
- A few are anaerobic.

Excretion:

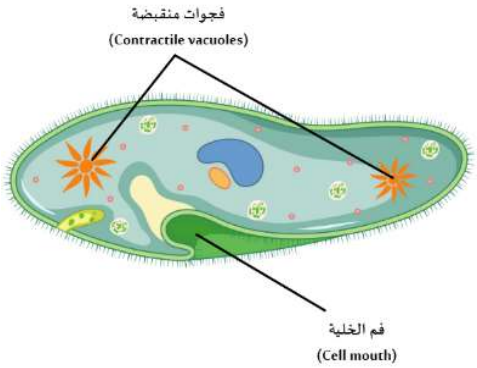
- Occurs by diffusion across the body surface

Reproduction:

- **Asexual:** By simple binary fission or multiple fission.
- **Sexual:** By the formation of gametes or through conjugation.
- **Encystment:** Formation of a cyst to protect the organism under unfavorable conditions.

Nutrition:

- Heterotrophic: By ingesting bacteria, algae, and other microorganisms.
- Saprophytic: Feeding on decomposed organic matter.
- Autotrophic: Due to the presence of green or colored plastids.
- Pinocytosis: Absorption of liquid droplets through minute vacuoles at the surface.



First: Rhodophyta	Second: Mastigophora
Habitat: • Live free-living in freshwater and marine environments, e.g., Amoeba proteus. • Some species live as parasites, such as Entamoeba histolytica, which inhabits the human intestine and causes dysentery. **Locomotion:** • Move by means of pseudopodia, which are constantly forming and disappearing. • These pseudopodia are also used in feeding. •	**Habitat:** • Free-living in fresh and marine waters, moving by means of flagella. • Some live symbiotically with other organisms, such as flagellates inhabiting the intestines of termites. • Some are parasitic and cause diseases, e.g., the protozoan Trypanosoma sp.

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Third: Ciliophora	Fourth: Sporozoa
This subphylum includes protozoans that move by means of cilia. They are characterized by having two nuclei: a large meganucleus and a small micronucleus. They feed by ingestion and reproduce both sexually and asexually. Examples of this subphylum include Paramecium and Balantidium	Sporozoans are protozoan organisms that lack organs of locomotion. They reproduce by forming spores and have a life cycle that includes both sexual and asexual stages. One of the most well-known examples is the malaria parasite (Plasmodium).

Importance of Protozoa:

- From an important part of the food chain for some aquatic organisms (they feed on aquatic plants, and in turn, are consumed by other aquatic animals).
- Play a key role in maintaining ecological balance in some communities (saprophytic species feed on bacteria, decomposed materials, and some fungi that break down organic matter).
- Cause diseases in humans and animals as obligate parasites living inside the host's body.

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Chapter Four

Fungi



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Mycota (Kingdom of Fungi):

Fungal Characteristics:

- Fungi are eukaryotic organisms that belong to a distinct biological kingdom known as the Kingdom Fungi.
- They are thalloid organisms, meaning they lack true roots, stems, or leaves.
- Their bodies may be unicellular (as in yeasts) or filamentous, composed of thread-like structures called hyphae that interweave to form a mycelium, which constitutes the main body of the fungus.
- Fungal cells possess a rigid cell wall primarily composed of chitin, cellulose, and glucans.
- They store food as glycogen, similar to animals.
- Fungi lack chlorophyll and are therefore non-photosynthetic.

Nutrition in Fungi

Modes of Nutrition in Fungi:

- Saprophytic: Fungi that obtain nutrients from decaying organic matter, playing a vital role in decomposition.
- Parasitic: Fungi that derive nutrients from living hosts, often causing diseases in plants, animals, or humans.
- Symbiotic: Fungi that live in mutually beneficial associations with other organisms, such as mycorrhizae (associations between fungal hyphae and plant roots) and lichens (associations between fungi and algae or cyanobacteria).

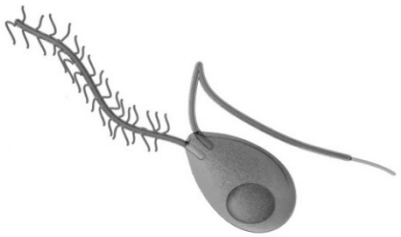
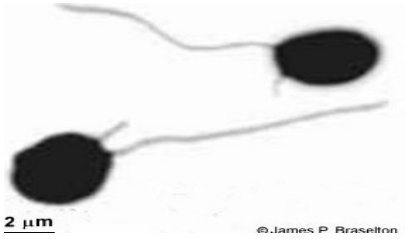
Fungi are classified according to their mode of nutrition as follows:	
Group of Fungi	Description
Obligate Parasitic Fungi	These fungi live parasitically in nature on specific suitable hosts. If the appropriate host is not available, they enter a dormant stage or die.
Facultative Parasitic Fungi	These fungi are normally saprophytic in natural conditions but are capable of becoming parasitic under certain circumstances.
Obligate Saprophytic Fungi	These fungi live exclusively on decomposing organic matter, whether of plant or animal origin.

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Facultative Saprophytic Fungi	These fungi are usually parasitic, but when a suitable host is not available, they switch to a saprophytic lifestyle.
Symbiotic Fungi	These fungi live in a symbiotic relationship, exchanging mutual benefits with other living organisms.

Movement in Fungi

- Fungi are generally non-motile organisms, although exceptions exist.
- Some fungi produce motile reproductive units, usually equipped with flagella that enable movement.
- There are two types of flagella, and a fungus may possess one or both types.

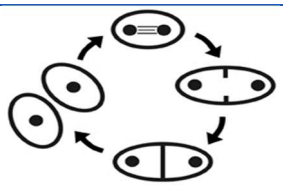
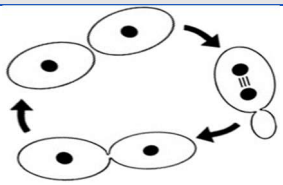
Tinsel Flagella	Whiplash Flagella
Consist of a long axis with numerous hair-like lateral projections extending along its sides	Consist of a long basal part and a short, flexible terminal segment
	

Reproduction in Fungi

- **Asexual Reproduction:** This mode of reproduction commonly occurs through spores, such as conidia or zoospores in certain aquatic fungi. It may also take place through fragmentation or budding, as seen in yeast.
- **Sexual Reproduction:** Characterized by the fusion of nuclei (karyogamy) and the formation of specialized reproductive structures, including:
    - Zygosporangium in zygomycetous fungi (Zygomycetes).
    - Ascus in ascomycetous fungi (Ascomycetes).
    - Basidium in basidiomycetous fungi (Basidiomycetes).
    - Parasexual or Imperfect Reproduction (Parasexuality – Deuteromycetes): Observed in certain fungi that lack an observable sexual phase, such as Penicillium and Aspergillus.

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First: Asexual Reproduction

	Method	Description	Example
Asexual Reproduction Methods	**Fragmentation**	The mycelium breaks into separate units, each capable of developing into a new mycelium.	Common in filamentous fungi
	Transverse Fission	The parent cell divides into two identical daughter cells.	 Figure 15 Yeast fungi
	Budding	A small bud forms on the parent cell, grows, and then separates to form a new individual.	 Figure 16 Yeast
	Oidia (Arthrospores)	The fungal hyphae divide into separate cells that function as spores.	 Figure 17 Some parasitic fungi
	Sclerotia	Formation of hard, thick-walled structures that survive harsh conditions and germinate when conditions improve.	 Figure 18 Certain fungi
	Chlamydospores	Thick-walled cells formed within or between hyphae that act as resting spores.	Some *Candida* species

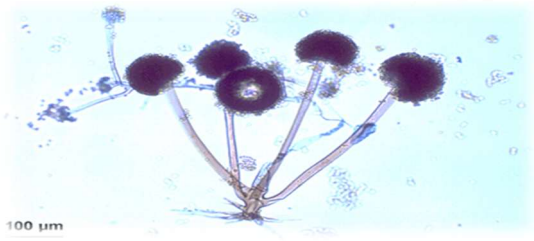
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	Spore Formation	The most common method; spores may be: – Endospores (e.g., *Sporangiospores*, *Zoospores*) or – Exospores (e.g., *Conidia*).	Endospores and Conidia

Spores are classified according to their mode of formation and the way they are borne into two main groups:

- **Endospores** – internal spores
- **Exospores** – external spores

Endospores are formed inside a sporangium or sac, and they occur in several forms:

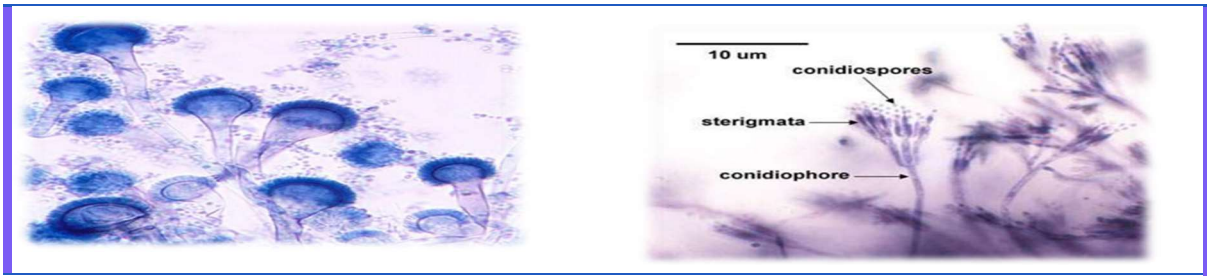
Sporangiospores	**Zoospores**
Formed within non-motile sporangia that are enclosed by a cell wall. Their dispersal depends on the wind, and the sporangia are borne on specialized hyphae called sporangiophores.	Formed inside a zoosporangium and found in aquatic or moist fungi. They possess flagella that enable swimming, with variations in the number and position of the flagella (anterior, posterior, or lateral).
	

Exospores

Conidial spores (Conidia) are non-motile spores that are formed externally on specialized structures called conidiophores, which may be branched (as in *Penicillium*) or unbranched (as in *Aspergillus*).

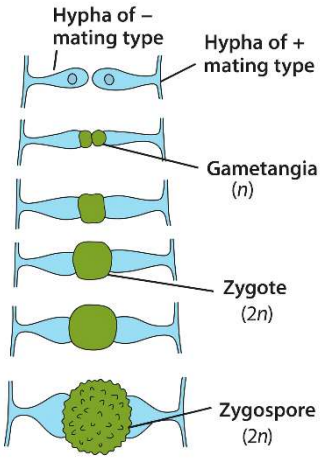
- The shape, size, and color of conidia vary greatly.
- They may occur singly or in chains, and these morphological characteristics are often used in the classification of many fungal species.

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Second: Sexual Reproduction

There are three distinct stages in the sexual reproduction process of fungi, which usually occur in sequence and can be summarized as follows:



1. Plasmogamy

Also called cellular fusion, it involves the fusion of the cytoplasm between two cells, allowing the nuclei to come close together within the same cell.

2. Karyogamy

In this stage, the haploid nuclei (n) fuse to form a diploid nucleus (2n).

3. Meiosis

Following karyogamy, the diploid nucleus undergoes meiotic division to produce haploid nuclei, each forming gametangia or spores enclosed by a cell wall and cytoplasm, leading to the formation of sexual spores.

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Classification of Fungi

1. Division: Gymnomycota (Slime Molds)

Class: Myxomycetes (Slime Molds)

These organisms represent an intermediate link between fungi and animals.



Figure 19 Gymnomycota

- **Life Cycle:** Consists of two main stages a fungal stage (sporangium) and an animal-like stage (plasmodium).
- **Habitat:** Saprophytic, living on decaying wood and leaves, or parasitic on algae and plants.

Distinctive Features:

1. The vegetative body is a plasmodium a naked, multinucleate mass of protoplasm capable of amoeboid movement.
2. The vegetative stage differs from that of true fungi: here it is a plasmodium, whereas in true fungi it consists of hyphae.
3. They form distinct fruiting bodies, and their spores are haploid, enclosed by a cellulose cell wall.

2. Division: Mastigomycota (Flagellated Fungi)

Also known as the Lower Fungi because they produce motile spores that live and move in water.

Class: Oomycetes (Water Molds)

- Habitat: Saprophytic in water and soil, or parasitic on plants, causing diseases such as downy mildew.

Characteristics:

1. The mycelium is coenocytic (multinucleate and non-septate).
2. Asexual reproduction: by motile zoospores possessing two unequal flagella.
3. Sexual reproduction: involves distinct oogonia (female organs) and antheridia (male organs) that fuse to form an oospore.
4. The mycelium is often intercellular, producing haustoria that penetrate host cells for nutrient absorption.



Figure 20 Mastigomycota

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3. **Division: Amastigomycota (Non-Flagellated Fungi)**

- This is the largest and most advanced division of fungi.
- Habitat: Can be saprophytic or parasitic, including both microscopic forms and large fruiting bodies such as mushrooms.
- Distinctive Feature: Absence of motile (flagellated) spores; reproduction occurs either by conidia (asexual spores) or by sexual spores such as zygospores, ascospores, and basidiospores.

Economic Importance of Fungi

Benefits

1. Decompose complex organic materials into simpler compounds, thereby enhancing soil fertility.
2. Improve agricultural soils through their continuous activity in breaking down organic matter.
3. Some species are used in food industries, such as in cheese production (*Penicillium* sp.).
4. Certain fungi are consumed as food, either fresh or dried, such as mushrooms.
5. Produce antibiotics, notably penicillin derived from *Penicillium*.
6. Produce vitamins, especially members of the vitamin B complex.
7. The yeast fungus (Saccharomyces sp.) is used in the production of alcoholic beverages and in fermenting dough for bread making.

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Chapter Five
Plant Diversity



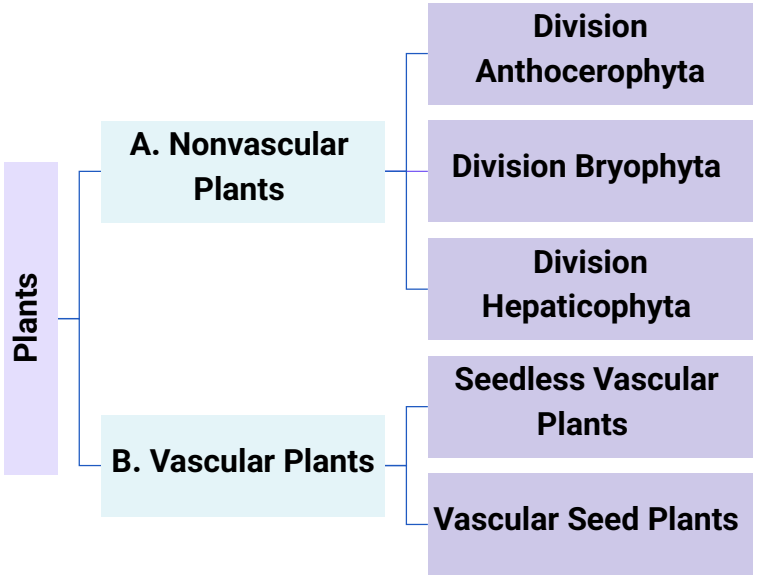
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Plant Diversity

Characteristics of the Plant Kingdom (Plantae)

- Their individuals possess specialized organs and systems
- They contain reproductive organs specialized in the production of gametes
- They exhibit an embryonic stage that follows the zygote (Zygote)
- All members are autotrophic, carrying out photosynthesis (Photosynthesis) to produce their own food
- All are non-motile (Non-motile)

Plant Classification:



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Plant Life Cycle

1. Sporophyte Stage (2n)	2. Spores (n)
This is the diploid stage. It produces haploid spores (n) through meiosis.	These are haploid cells. They grow by mitotic division to form the gametophyte stage.
3. Gametophyte Stage (n)	**4. Gametes (n)**
This is the haploid stage. It produces gametes (male and female) through mitosis.	They fuse during fertilization to form a zygote (2n).
5. Zygote (2n)	
The diploid cell that results from fertilization. It grows by mitotic division to develop into a new sporophyte plant.	

Section I. Non-vascular plants:

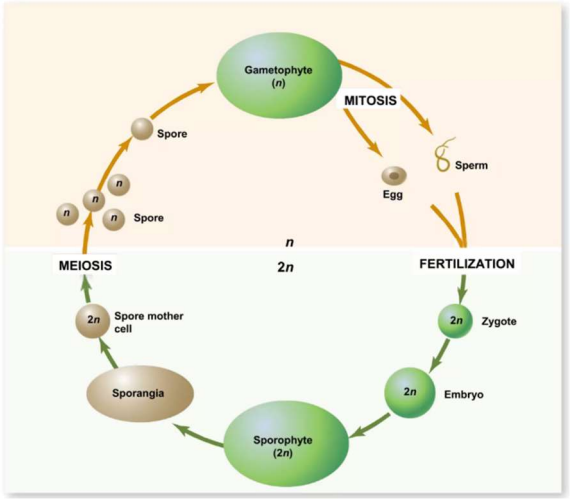
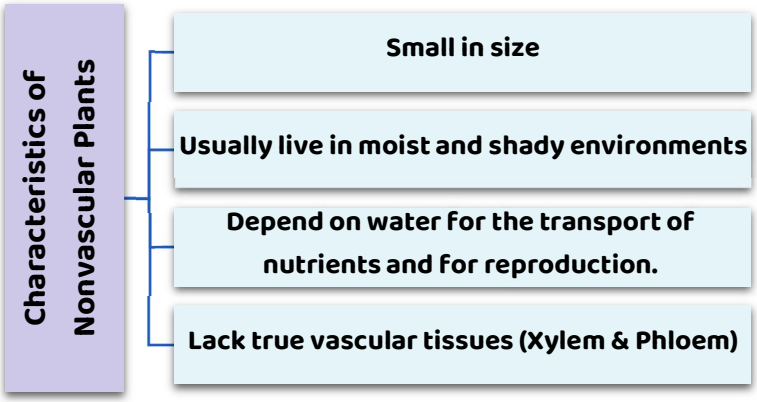


Figure 21 The Life Cycle of Multicellular Plants



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Examples of Nonvascular Plants:

(Mosses)	**Moss (Sphagnum)** • Grows in moist places such as swamps and along stream banks. • Lacks true vascular tissues; water is transported by osmosis and diffusion. • Possesses leaf-like structures one cell layer thick and multicellular rhizoids. • **Importance:** Forms layers of *peat*, which are used as a source of fuel and as agricultural soil.	 Figure 22 The Sphagnum Moss
(Liverworts)	**Liverwort (Marchantia sp.)** • Lives in moist, shady places such as riverbanks and stream edges. • The gametophyte is the dominant stage and grows flattened on the soil surface. • The body is divided into an upper surface containing air chambers and chloroplasts, and a lower colorless surface for storage. • Anchored by unicellular rhizoids. • Reproduces asexually by special structures called *gemmae*, and sexually by *antheridia* (male organs) and *archegonia* (female organs).	 Figure 23 The Marchantia Liverwort

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(Hornworts)	**Hornwort (Anthoceros sp.)** • One of the smallest divisions of nonvascular plants. • The sporophyte is horn-shaped and grows elongated above the gametophyte. • Its cells contain a single large chloroplast. • The sporophyte produces most of the food for both the gametophyte and sporophyte. • Its tissue contains mucilaginous cavities inhabited by *cyanobacteria* in a symbiotic relationship for nitrogen fixation.	 Figure 24 The Anthoceros Hornwort

Section II. Vascular Plants:

Characteristics of Vascular Plants

- Presence of vascular tissues (Xylem & Phloem)
- Possess specialized organs (roots – stems – leaves)
- Reproduce by spores or seeds
- Adapt to the environment through a cuticle and stomata

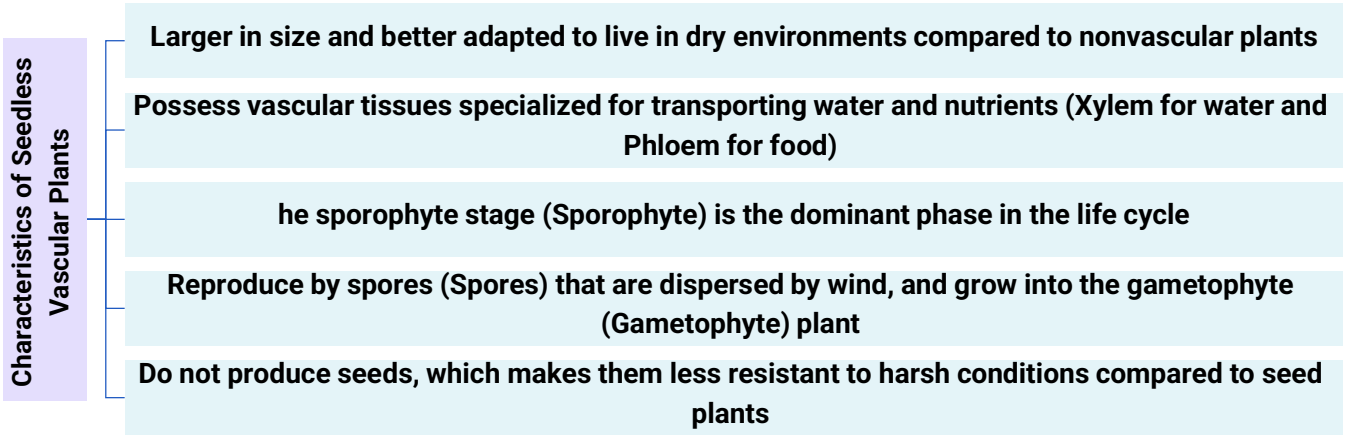
Comparative Overview of Vascular Plant Divisions

Feature	Seedless Vascular Plants	Seed Vascular Plants
Size	Larger than nonvascular plants; diverse in form and size	Large and diverse, ranging from small herbs to giant trees
Dominant Stage	Sporophyte stage (*Sporophyte*)	Sporophyte stage (*Sporophyte*)
Leaves	Simple leaves, small or large, not complex	True, complex leaves that vary in shape and size
Roots	True roots arising from the stem	Well-developed, deep roots for absorbing water and minerals
Transport	Vascular tissues (*Xylem & Phloem*); transport by	Highly developed vascular tissues with efficient transport systems

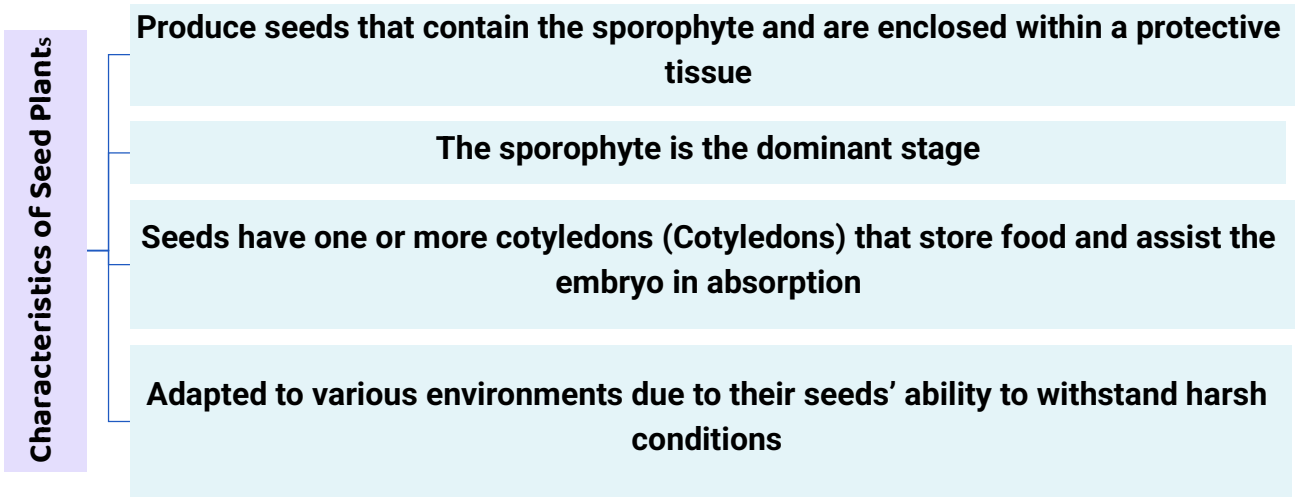
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	osmosis and diffusion in simpler species	
Habitat	Moist environments; some tolerate drought	Diverse habitats: deserts, forests, and agricultural lands
Examples	Ferns and horsetails	*Conifers* and *Angiosperms* (flowering plants)
Importance	- The first vascular plants adapted to life on land- Help in soil formation	- Sources of food, timber, and medicine- Form the basis of ecosystems and agriculture

Section III: Seedless Vascular Plants



Section IV: Seed Plants (Vascular Seed Plants)



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The Cotyledon in Seed Plants

- The cotyledon is a part of the seed that functions as a food storage organ.
- It represents the first embryonic leaf (or leaves) of the plant and provides nutrients to the young sporophyte until it begins independent growth.

Number of Cotyledons

- Monocotyledons / Monocots: Seeds contain one cotyledon. Examples: rice, corn, wheat.
- Dicotyledons / Dicots: Seeds contain two cotyledons. Examples: beans, peas, most fruit trees.

Importance of the Cotyledon in Seeds

- Stores food within the seed (starch, proteins, and fats).
- Assists the young sporophyte in absorbing nutrients during the early stages of germination.

Division	Characteristics	Examples
(Cycadophyta)	- Live in tropical and subtropical regions. - Male and female cones are borne on separate plants. - Have soft stems rich in storage tissues. - Resemble palms, but differ in their reproductive structures.	 Figure 25 Cycad
(Gnetophyta)	- Have long lifespans (1,500–2,000 years). - Consist of three main genera: *Ephedra*, *Gnetum*, and *Welwitschia.* - Adapted to desert and arid environments.	 Figure 26 Ephedra, Gnetum and Welwitschia
(Ginkgophyta)	- A small division containing only one species. - Have fan-shaped leaves. - Dioecious plants (male and female plants separate). - Tolerant to pollution.	 Figure 27 Ginkgo biloba
(Coniferophyta)	- The largest division of gymnosperms. - Male and female cones are usually found on the same plant. - Have needle-like or scale-like leaves. - Live in temperate and cold regions.	 Figure 28 Pinus

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		 Figure 29 Fir (Abies)
(Angiosperms)	- Seeds are enclosed within the ovary of the flower. - Represent the most widespread group of plants. - Divided into monocots (Monocots) and dicots (Dicots). - Possess a wide variety of flowers and fruits. - Exhibit annual, biennial, and perennial life cycles.	 Figure 30 Rice, Corn, Beans and Fruit trees

Comparison of Seed-Bearing Vascular Plants: Angiosperms vs. Gymnosperms

Feature	Gymnosperms (Naked Seed Plants)	Angiosperms (Flowering Plants)
Definition	Vascular seed plants whose seeds are not enclosed by an ovary (naked seeds).	Vascular seed plants whose seeds are enclosed within the ovary of the flower (covered seeds).
Reproductive Organs	Reproduce by male and female cones.	Reproduce by flowers that contain stamens (male) and carpels/pistils (female).
Seeds	Exposed on the scales of cones.	Enclosed within an ovary that develops into a fruit after fertilization.
Examples	*Pine*, *Juniper*, *Cycad*, *Ginkgo*.	*Wheat*, *Rice*, *Bean*, *Apple*, *Grape*, *Rose*, fruit trees.
Habitat	Commonly found in cold and temperate regions.	Widespread in most environments (terrestrial and aquatic).
Pollination	Usually by wind.	By wind, insects, or water.
Importance	Source of timber, resins, and certain medicines.	Provide major food sources, as well as fibers and oils.

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Chapter Six
Animal Diversity



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Animal Diversity

General Characteristics of Animals

Multicellular organisms:

Animal bodies are composed of many specialized cells that perform different functions.



Figure 31 Eukaryotic Cell

Eukaryotic:

Their cells contain a well-defined nucleus and membrane-bound organelles.

Heterotrophic:

They obtain their food from other organisms through ingestion and internal digestion.

Specialized tissues:

They possess muscle and nervous tissues that enable movement and response to stimuli.

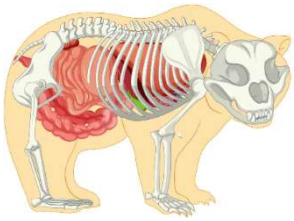


Figure 32 Body Cavity

Symmetry:

Most animals exhibit bilateral symmetry, while some show radial symmetry.

Body cavity:

Present in most animals, providing space for internal organs and allowing their growth and movement.

Developmental stages:

Their life begins from a fertilized egg (zygote) that undergoes cell divisions and transformations until maturity.

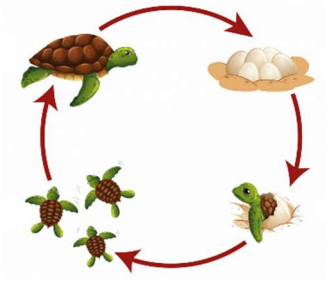


Figure 33 Stages of Growth and Development

Movement:

Most animals are capable of active movement at some stage of life due to the presence of muscles and nerves.

Sexual reproduction:

Most animals reproduce sexually, involving the fusion of different reproductive cells (gametes).

Body organization:

Many animals show segmentation—division of the body into regions or segments—which enhances efficiency in movement and function.

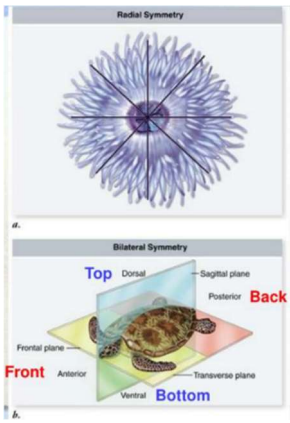


Figure 34 illustrates the difference between radial symmetry and bilateral symmetry.

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Evolution of the Animal Body Plan

This evolution can be traced through five main stages that illustrate how animal bodies developed from simple to complex forms.

First: Tissues

All animals possess tissues except sponges, which lack true tissue organization.

Second: Body Symmetry (Symmetry)

- Bilateral symmetry: The body can be divided into two identical halves, each mirroring the other.
- Radial symmetry: The body can be divided into two or more identical parts radiating from a central axis.

Third: Body Cavity (Coelom)

As animal body complexity increased, the need arose for an internal cavity that allows the growth, movement, and independence of organs from the body wall.

This feature evolved through three major stages:

1. Acoelomates:

Animals without a true body cavity; their bodies are completely filled with tissues, as in flatworms.

2. Pseudocoelomates:

Animals with a false body cavity, partially lined with mesoderm, as seen in roundworms.

3. Coelomates:

The most advanced animals, possessing a true coelom fully lined with mesoderm, found in annelids, arthropods, and vertebrates. The presence of this cavity allows for better organ organization, greater movement, and functional specialization.

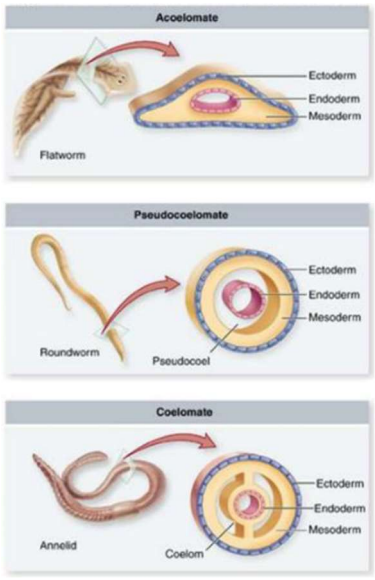


Figure 35 Shows the different stages of development

Fourth: Embryonic Development (Development)

During embryonic stages, an early opening called the blastopore forms, and its developmental fate distinguishes two main groups of animals:

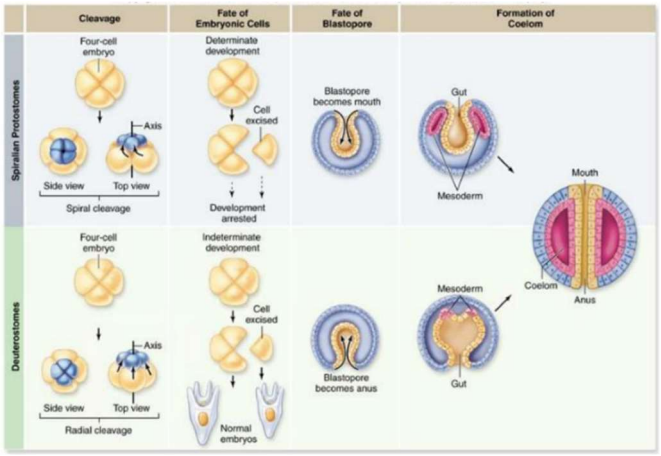


Figure 36 Illustrates embryonic development in protostomes and deuterostomes.

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1- Protostomes:

The mouth develops first from the blastopore. Examples include arthropods, mollusks, and annelids.

2. Deuterostomes:

The anus develops first from the blastopore, and the mouth forms later. This group includes echinoderms and all vertebrates.

Fifth: Segmentation (Segmentation)

Segmentation allows animals to have greater flexibility of movement and to distribute vital functions among body segments, providing enhanced efficiency and adaptability.

Invertebrates are among the oldest and most widespread organisms in the animal kingdom, representing the majority of known species on Earth. They are characterized by the absence of a vertebral column, unlike vertebrates, which possess an internal bony or cartilaginous skeleton.

Sponges (Porifera):

They are aquatic animals that lack true tissues.

Structure	Composed of two layers: a. Outer layer: Made up of collar cells (choanocytes) with flagella. b. Inner layer: Consists of epithelioid-like cells that provide protection to the sponge.
Feeding and Digestion	- Feeding: Food enters through lateral pores (a process known as filter feeding). - Digestion: Occurs within the cells (intracellular digestion).
Excretion	Through the osculum (exhalant opening).
Movement	Adult sponges are sessile, meaning they are attached to rocks and form colonies.
Support	Internal, composed of spicules, spongin fibers, or both.
Reproduction	- Asexual: By fragmentation or budding. - Sexual: Through male and female gametes.
Response	They lack a nervous system; epithelial cells are responsible for response to stimuli.
Habitat	May be free-living or symbiotic.

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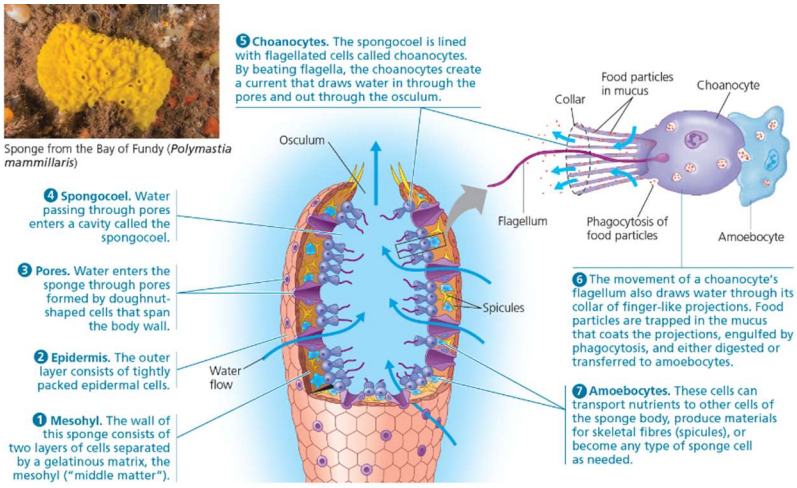


Figure 37 Anatomy of a sponge. In the main diagram, portions of the front and back wall are cut away to show the sponge's internal structure.

Cnidarians (Coelenterates):

Aquatic animals that possess tissues and exhibit radial symmetry, some of which are distinguished by bright colors and beautiful shapes.

Aspect	Description
Structure	Composed of two layers: a. Outer layer: Provides protection and contains stinging cells (cnidocytes). b. Inner layer: Forms the gastrovascular cavity, responsible for digestion
Feeding and Digestion	- Feeding: Through tentacles; stinging cells paralyze prey, and tentacles move it to the mouth. - Digestion: Extracellular, occurring in the gastrovascular cavity with the help of digestive enzymes.
Excretion	Through the mouth opening, which serves a dual function.
Movement	Slow and can occur in all directions.
Support	External, provided by stinging capability.
Reproduction	- Asexual: By budding. - Sexual: Life cycle includes two stages an asexual polyp stage and a sexual medusa stage.
Habitat	Free-living forms such as jellyfish; colonial forms such as corals and sea anemones; some live in symbiotic relationships with other marine organisms.

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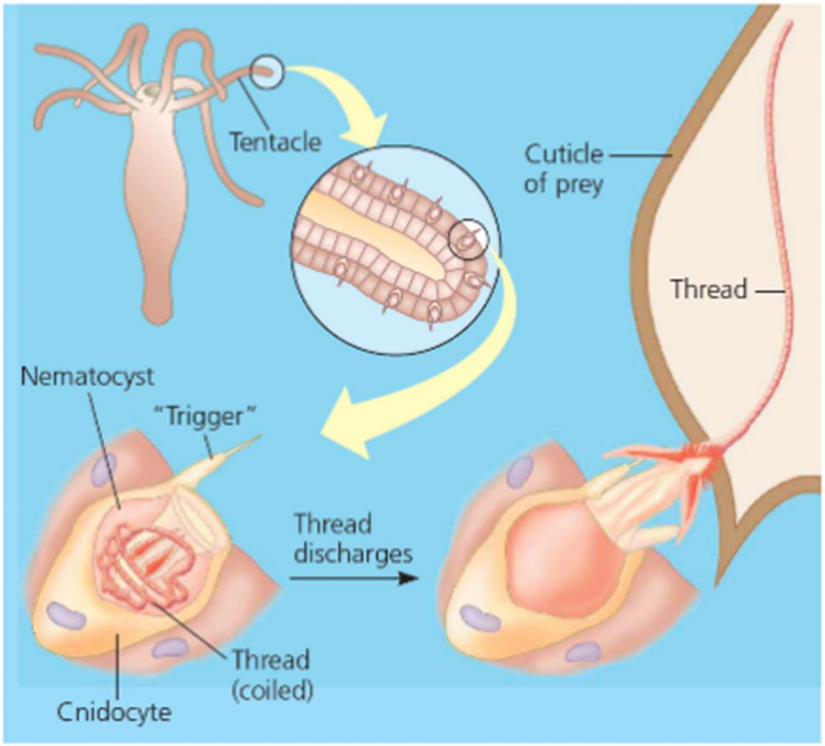


Figure 38 Cnidocyte of a hydra. This type of cnidocyte contains a stinging capsule called a nematocyst, which holds a coiled thread. When the "trigger" is stimulated by touch or specific chemicals, the thread shoots out, piercing the prey's cuticle and injecting toxins into it.

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Flatworms (Platyhelminthes):

Bilaterally symmetrical animals lacking a body cavity (acoelomates).

Aspect	Description
Structure	Flattened in shape, consisting of a head region and a group of internal organs.
Feeding and Digestion	- Feeding: Free-living flatworms feed through a pharynx, while parasitic flatworms use suckers and hooks to obtain nutrients. - Digestion: Extracellular digestion.
Respiration, Circulation, and Excretion	- Respiration and circulation: Occur by diffusion. - Excretion: Carried out by flame cells.
Movement	- Free-living species: Move by gliding. - Parasitic species: Move by muscle contraction.
Response	The nervous system consists of two longitudinal nerve cords connected to lateral nerve ganglia. Possess eyespots that detect light.
Reproduction	- Asexual: By regeneration, where a separated body part can reform missing parts and develop into a new individual. - Sexual: Occurs when two worms meet, each exchanging sperm with the other.
Habitat	Can be free-living or parasitic.

Roundworms (Nematodes):

They possess a pseudocoelom and have an unsegmented cylindrical body.

Aspect	Description
Structure	Possess a pseudocoelom and a cylindrical, unsegmented body.
Feeding	- Can be free-living or parasitic. - Digestion: External digestion in both free-living and parasitic forms. Have a simple digestive system.
Respiration and Circulation	Occur by diffusion.
Excretion	Through flame cells.
Response	Possess a nervous system.
Reproduction	Sexes are separate (male and female); reproduction is sexual with internal fertilization.
Movement	By muscle contraction.

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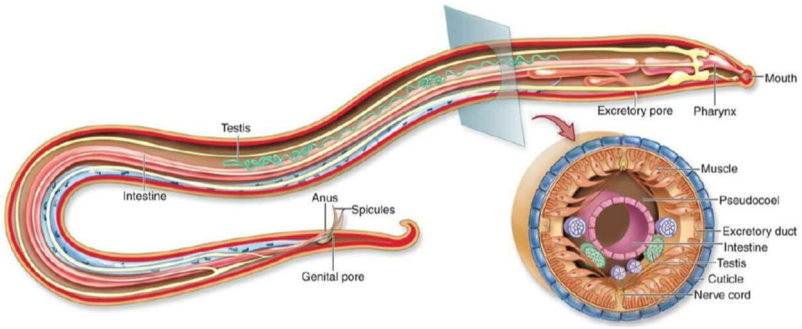




Figure 39 Structure of Roundworms

Mollusks (Phylum Mollusca):

Mollusks are soft-bodied invertebrates, many of which are protected by a hard external shell. They have a muscular foot for movement, a visceral mass containing internal organs, and a mantle that may secrete the shell. Examples include snails, clams, and octopuses.

Aspect	Description
Structure	Have a soft, true body usually protected by a shell (mantle) and possess a muscular foot. The shell (mantle) is formed by a membrane that secretes calcium carbonate.
Feeding and Digestion	- Feeding: Through a mouth equipped with rows of teeth on a rasping structure called a radula; some also have tentacles. - Digestion: Extracellular, occurring within a complex digestive system.
Respiration	- Aquatic mollusks: Through gills. - Terrestrial mollusks: Through the lining of the mantle cavity.
Circulation	- Slow-moving mollusks: Have an open circulatory system (e.g., snail, clam). - Fast-moving mollusks: Have a closed circulatory system (e.g., octopus, squid).
Excretion	Through nephridia (ciliated excretory tubes).
Movement	- Slow species: Move using the muscular foot (e.g., snail, clam). - Fast species: Move using a siphon, as in octopuses and squids the siphon is an internal cavity that expels water forcefully, propelling the animal at high speed.
Reproduction	- Aquatic mollusks: Sexual reproduction with external fertilization. - Terrestrial mollusks: Sexual reproduction with internal fertilization.

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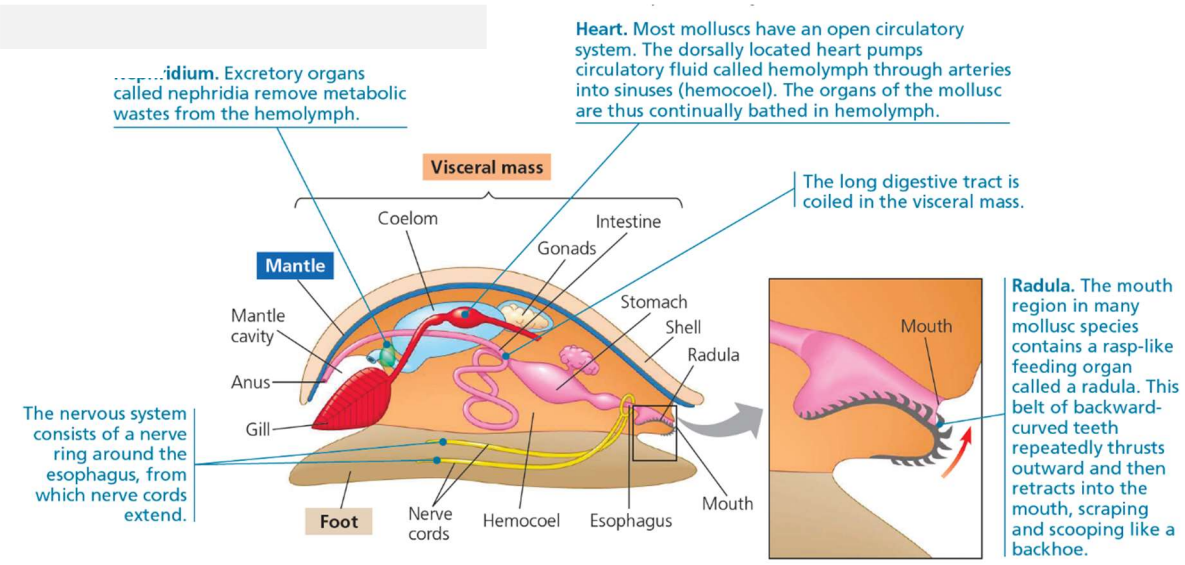


Figure 40: Visceral mass

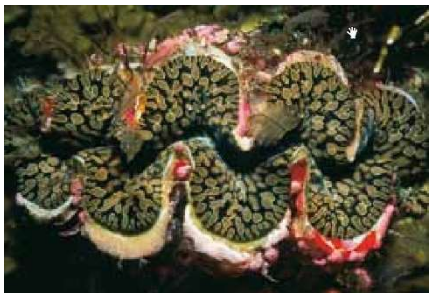


Figure 41 Giant Clam

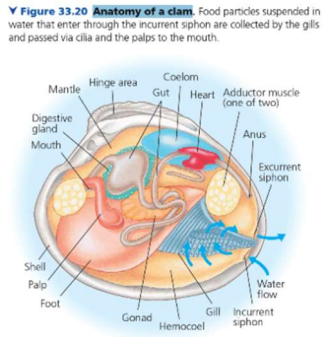


Figure 42 Anatomy of a clam

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Annelids (Segmented Worms)

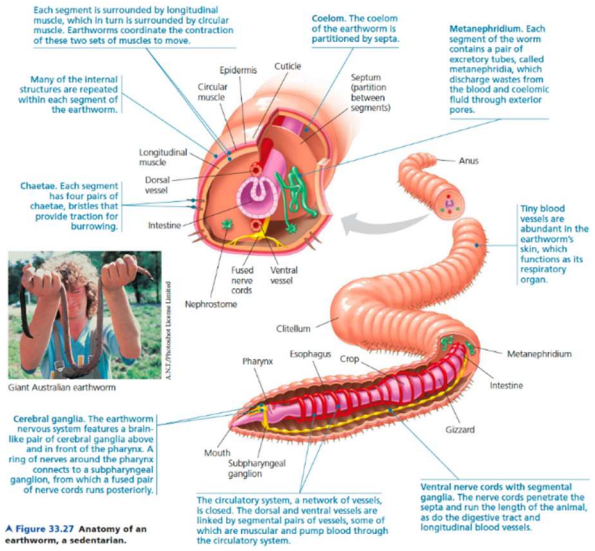


Figure 43 Anatomy of an earthworm, a sedentarian

Aspect	Description
Structure	Cylindrical body divided into segments, each containing structures for movement, digestion, and excretion. Some body segments are specialized for functions such as sensation and reproduction. Most annelids are hermaphroditic.
Feeding and Digestion	- Feeding: Through the mouth. - Digestion: Extracellular, within a complex digestive system. Some annelids possess crop chambers for storage and a gizzard for grinding food.
Respiration	Terrestrial annelids: Through diffusion across the body surface. Aquatic annelids: Through gills.
Circulation	Have a closed circulatory system.
Excretion	By means of nephridia (ciliated excretory tubes).
Movement	Through muscle contraction.
Response	Possess a nervous system concentrated in the anterior body segments.
Reproduction	- Asexual: By regeneration. - Sexual: Internal fertilization occurs from the clitellum region.

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Arthropods:

Arthropods are invertebrate animals with segmented bodies, jointed appendages, and a hard exoskeleton made of chitin.

Aspect	Description
Structure	- Body divided into: 1. Head, Thorax, Abdomen or 2. Cephalothorax, Abdomen. - Possess a hard external skeleton (exoskeleton) made of chitin, which gives body support and shape. - Have jointed appendages (legs and antennae), which is why they are called arthropods. - Undergo molting (shedding the old exoskeleton and forming a larger new one).
Feeding and Digestion	- Feeding: Varies among species but all have a mouthpart called the mandible, used for biting, cutting, or grasping food. - Digestion: Extracellular, within a complex digestive system.
Respiration	- Gills (e.g., lobsters). - Tracheal tubes (e.g., beetles). - Book lungs (e.g., spiders).
Circulation	Have an open circulatory system.
Excretion	Through Malpighian tubules.
Movement	Walking, swimming, jumping, or flying depending on the species.
Response	Possess compound eyes for vision and tympanum (eardrum) for hearing.
Reproduction	Sexual reproduction with internal fertilization.

Echinoderms:

They are marine invertebrates with radial symmetry, a spiny skin, and an internal calcium-based skeleton.

Aspect	Description
Structure	Marine organisms with bodies covered in spines, an internal supporting skeleton, and radial symmetry.
Water Vascular System	A unique system in echinoderms consisting of water-filled canals that begin at the madreporite and end at the tube feet.

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Feeding and Digestion	- Feeding: Through the mouth, using various methods depending on the species. - Digestion: Extracellular, within a digestive tract.
Respiration	Through the tube feet.
Circulation	Via the water vascular system.
Excretion	By diffusion through the tube feet.
Response	Controlled by the nervous system.
Reproduction	- Asexual: By regeneration. - Sexual: By external fertilization.

Invertebrate Chordates:

They are animals that have a notochord (a flexible supporting rod) at some stage of their life but lack a backbone.

Aspect	Description
Characteristics	- Dorsal notochord. - Post-anal tail. - Dorsal tubular nerve cord. - Pharyngeal pouches (gill slits). - Primitive thyroid gland.
Types	1. Lancelets (*Cephalochordates*). 2. Tunicates (*Urochordates*).

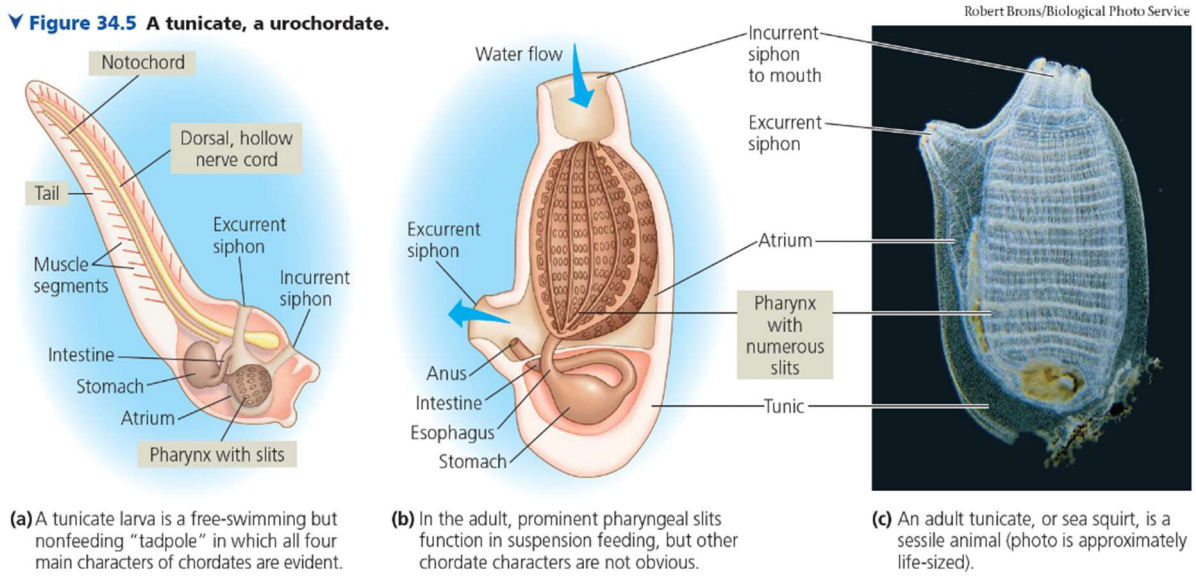


Figure 44: A Tunicate , aurochorodate

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Characteristics of Vertebrates:

1. Internal skeleton (Endoskeleton): Provides support, protection, and aids in movement.
2. Well-developed nervous system: Includes a brain and spinal cord.
3. Specialized sensory organs: Enable response to environmental stimuli.
4. Integrated internal systems: Such as a closed circulatory system, respiratory system, and excretory system.
5. Reproductive diversity: Includes both internal and external fertilization, and reproduction may be oviparous (egg-laying) or viviparous (live-bearing).



Figure 45: Fishes

1. Fishes

Fishes are the oldest and most numerous vertebrates in the animal kingdom. They are adapted to aquatic life through the presence of gills for respiration and fins for movement.

A. Body Structure	
Aspect	**Description**
External Form	The body is streamlined, helping in swimming and reducing water resistance. It is usually divided into three main regions: 1. Head 2. Trunk 3. Tail
Body Covering	The external skin is covered with scales, which vary in shape and structure depending on the class: - In cartilaginous fishes (Chondrichthyes): rough placoid scales resembling teeth. - In bony fishes (Osteichthyes): smooth and flexible cycloid or ctenoid scales. The skin also contains mucous glands that secrete a slimy substance to reduce water friction.
Endoskeleton	Provides support, protection, and aids in movement. Its composition differs by fish type: - Cartilaginous skeleton in sharks, rays, and skates. - Bony skeleton in bony fishes like tilapia and tuna. The vertebral column consists of distinct vertebrae.
Fins	External appendages used for movement and balance in water. Types:

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	1. Paired fins: pectoral and pelvic fins. / 2. Unpaired fins: dorsal, anal, and caudal fins.
Muscular System	Composed of strong segmented muscles. Sequential contraction from head to tail produces wave-like motion for swimming.
Respiratory System	Fish breathe using gills. Water enters through the mouth, passes over the gills where oxygen is absorbed and carbon dioxide is released.
Circulatory System	A closed circulatory system with a two-chambered heart: - Atrium - Ventricle The heart pumps blood to the gills for oxygenation, then to the rest of the body.
Nervous System	Fairly well-developed, consisting of a small forebrain and a spinal cord extending through the vertebral column. Specialized sensory organs include: - Lateral line detects vibrations and water movement. - Eyes adapted for underwater vision. - Olfactory and taste organs for smell and taste.
Swim Bladder	Found in most bony fishes, it helps control buoyancy in water. Absent in cartilaginous fishes, which rely on continuous swimming to avoid sinking.
Digestive and Excretory Systems	The digestive tract is complete, extending from mouth to anus. Fish possess kidneys that remove liquid wastes and regulate salt and water balance in the body.
Feeding Method	Fish vary in their diet depending on their environment and mouth structure: - Carnivorous fishes (e.g., *sharks*) have sharp teeth for tearing flesh. - Herbivorous fishes feed on plants and algae. - Filter-feeding fishes absorb food particles from water, as seen in some bony fishes. The digestive system is complete, starting from the mouth and ending at the anus, and is adapted to the type of food consumed.
Reproduction	Most fishes are dioecious (separate sexes) and undergo external fertilization in water, where females lay eggs and males fertilize them. Some species, such as sharks, exhibit internal fertilization. Modes of reproduction vary:

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	- Oviparous: Eggs are laid outside the body. - Viviparous: Embryos develop inside the female's body until birth.

2. Amphibians:

Creatures that **begin their life in water** and later **live on land** after completing their development.

Aspect	Description
Feeding and Digestion	- Feeding: Free-living. - Digestion: External; they possess a complex digestive system that ends in a cloaca, a chamber that receives digestive wastes, urine, and reproductive cells (eggs or sperm) before leaving the body.
Excretion	- Waste materials are filtered from the blood through the kidneys, releasing ammonia or urea as byproducts of cellular metabolism.
Brain and Senses	- The nervous system consists of a spinal cord and a brain (as in other vertebrates). The lateral line system helps detect movement and vibrations in water.
Respiration	- Larvae: Breathe through skin or gills. - Adults: Breathe through lungs, moist skin, or the lining of the mouth cavity.
Circulatory System	- Have a double circulatory system: 1. First circuit: Deoxygenated blood moves from the heart to the lungs. 2. Second circuit: Oxygenated blood moves from the lungs to the body. - The heart has three chambers: two atria and one undivided ventricle.
Brain and Sensory Organs	- Possess a brain and are ectothermic (cold-blooded). - Have a nictitating membrane, a transparent eyelid that protects the frog's eyes in water and on land. - Amphibians also possess a tympanic membrane (eardrum) for hearing.
Reproduction and Development	- External fertilization. - Eggs are: ▪ Without shells or protective coverings, making them prone to drying out.

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	▪ Covered with a jelly-like substance that helps them adhere to aquatic plants. ▪ The developing embryo feeds on the yolk until it hatches into a tadpole stage.

3. Reptiles:

They are cold-blooded vertebrates covered with dry, scaly skin that helps prevent water loss.

Aspect	Description
Amniotic Egg (Structure and Layers)	Layers of the egg from inside to outside: a) **Amnion:** Provides protection for the embryo. b) **Allantois:** Stores metabolic waste. c) **Chorion:** Allows oxygen exchange. d) **Yolk sac:** Stores nutrients. e) **Leathery shell:** Protects the egg from drying out.
Dry, Scaly Skin	- **Importance:** Prevents water loss and protects against dehydration. - **Issue:** The tough skin limits growth, so reptiles like snakes periodically shed their skin.
Feeding and Digestion	- **Feeding type:** Mostly carnivorous, some herbivorous or omnivorous. - **Digestion:** The digestive system is similar to that of amphibians and fishes.
Excretion	Excrete semi-solid wastes (uric acid) through the kidneys to conserve water.
Respiration	- **Organ:** Lungs. - **Mechanism:** Air is inhaled through inspiration and exhaled through expiration.
Circulatory System	- The heart consists of three chambers, except in crocodiles, which have four chambers, allowing separation of oxygen-rich and oxygen-poor blood. - Reptiles are ectothermic (cold-blooded).
Brain and Senses	- The brain is larger than that of amphibians. - Vision is the primary sense. Some reptiles lack eardrums. - Snakes possess Jacobson's organs in the mouth to detect smells.

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Movement	Some reptiles have limbs for locomotion, while others move by muscular contractions during slithering.
Reproduction	Internal fertilization. Most females lay eggs in soil, while some snakes and lizards retain eggs inside their bodies until hatching.

4. Birds:

are warm-blooded vertebrates covered with feathers, possessing wings, beaks, and lightweight bones adapted for flight.

Aspect	Description
Feathers	- Specialized skin outgrowths made of keratin protein. - Functions: Enable flight and provide thermal insulation (aided by oil secreted from the tail gland, which is spread along feathers with the beak to restore structure and resist water). - Types: a) Contour feathers: Have a central shaft with barbs and barbules linked by hooks; cover the wings, body, and tail. b) Down feathers: Soft feathers beneath contour feathers that trap air and keep the body warm.
Bones	- Lightweight due to air cavities and bone fusion for increased rigidity. - Large chest muscles (about 30% of body weight). - The sternum (breastbone) is large and has a keel for the attachment of flight muscles.
Respiration	Birds have high oxygen consumption required for flight. Their respiratory system features: - Larger air capacity than reptiles. - One-way airflow through the lungs. - Air sacs that allow breathing even during flight.
Circulation	Heart has four chambers (like crocodiles). Birds are warm-blooded (endothermic), unlike reptiles.
Feeding and Digestion	- Feeding: With a beak, using methods such as piercing, sucking, scooping, crushing, or hunting no teeth for chewing. - Have a crop for food storage. - Possess a gizzard containing small stones to grind food with the help of strong muscles.

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Excretion	- Kidneys convert nitrogenous wastes into uric acid (as in reptiles). - Possess a cloaca that reabsorbs water. - No urinary bladder, reducing weight for flight.
Brain and Senses	- The brain is large relative to body size. Birds have excellent hearing owls can detect even the faintest sounds in darkness. - Vision is highly developed; eyes face forward to enhance depth perception.
Reproduction	- Internal fertilization. - Activities include territory selection, mate choice, courtship behavior, nest building, egg incubation, and feeding chicks. - The ostrich is the largest bird. - Some birds, like penguins and ducks, have adaptations for swimming.

5. Mammals:

are warm-blooded vertebrates that have hair or fur covering their bodies, breathe through lungs, and nourish their young with milk produced by mammary glands.

Aspect	Description
Feeding and Digestion	- Mammals can be herbivores, insectivores, carnivores, or omnivores. - Herbivores have a longer digestive tract and a larger cecum than carnivores because digesting fibers is more difficult than digesting meat.
Excretion	The kidneys are responsible for: - Removing metabolic wastes. - Maintaining fluid balance. - Filtering blood from urea. - Regulating water levels in body fluids, especially in desert mammals.
Respiration	Characterized by the presence of a diaphragm, a muscular sheet below the lungs separating the thoracic and abdominal cavities.
Circulation	The heart has four chambers (as in birds and crocodiles), allowing complete separation of oxygenated and deoxygenated blood.
Brain	The brain is large and highly developed.

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	a) Cerebrum: The outer folded cortex increases surface area for neural connections, coordinating conscious activities, memory, and learning. b) Cerebellum: Responsible for balance and movement coordination.
Movement	- Movement helps mammals find food, shelter, and escape predators. - Examples: Running (wolf), jumping (kangaroo), swimming (dolphin), flying (bat).
Glands	Groups of specialized cells that secrete substances used in other parts of the body (e.g., mammary glands, sweat glands, oil glands).

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Chapters' Exercises

1) The various taxonomic levels (viz, genera, classes, etc.) of the hierarchical classification system differ from each other on the basis of	
A	How widely the organisms assigned to each are distributed throughout the environment
B	The body sizes of the organisms assigned to each
C	Their inclusiveness.
D	The relative genome sizes of the organisms assigned to each.
2) Which of the taxonomic ranks cannot include multiple species?	
A	Genus.
B	Species.
C	Family.
D	Phylum.
3) Regarding prokaryotic reproduction, which statement is correct?	
A	Prokaryotes form gametes by meiosis.
B	Prokaryotes feature the union of haploid gametes, as do eukaryotes
C	Prokaryotes exchange some of their genes by conjugation, the union of haploid gametes, and transduction.
D	Mutation is a primary source of variation in prokaryote populations.
4) If new genetic variation in the experimental populations arose solely by spontaneous mutations, then the most effective process for subsequently increasing the prevalence of the beneficial mutations in the population over the course of generations is	
A	Transduction
B	binary fission.
C	Conjugation
D	Transformation
5) Which of the following use light energy to synthesize organic compounds from CO_2?	
A	Photoautotrophs
B	Photoheterotrophs
C	Chemoautotrophs
D	Chemoheterotrophs that perform decomposition
6) Protists are alike in that all are:	
A	Unicellular

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B	Eukaryotic
C	Symbionts
D	Monophyletic
7) An individual mixotroph loses its plastids, yet continues to survive. Which of the following most likely accounts for its continued survival?	
A	It relies on photosystems that float freely in its cytosol.
B	It must have gained extra mitochondria when it lost its plastids
C	It engulfs organic material by phagocytosis or by absorption.
D	It has an endospore.
8) Which process results in genetic recombination, but is separate from the process wherein the population size of Paramecium increases?	
A	Budding
B	Meiotic division
C	Mitotic division
D	Conjugation
9) Which of the following most closely represents the male gametophyte of seed-bearing plants?	
A	Ovule
B	Microspore mother cell
C	Pollen grain interior
D	Embryo sac
10) Gymnosperms differ from both extinct and extant ferns because they	
A	Are woody
B	Have macrophylls
C	Have pollen
D	Have sporophylls
11) Generally, wind pollination is most likely to be found in seed plants that grow	
A	Close to the ground
B	In dense, single-species stands
C	In relative isolation from other members of the same species
D	In well-drained soils.
12) Which of the following do all fungi have in common?	
A	Meiosis in basidia
B	Coenocytic hyphae
C	Sexual life cycle

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D	Absorption of nutrients
13) If all fungi in an environment that perform decomposition were to suddenly die, then which group of organisms should benefit most, due to the fact that their fungal competitors have been removed?	
A	Plants
B	Protists
C	Prokaryotes
D	Animals
14) Which of the following is a characteristic of hyphate fungi (fungi featuring hyphae)?	
A	They acquire their nutrients by phagocytosis.
B	Their body plan is a unicellular sphere.
C	Their cell walls consist mainly of cellulose microfibrils.
D	They are adapted for rapid directional growth to new food sources.
15) Both animals and fungi are heterotrophic. What distinguishes animal heterotrophy from fungal heterotrophy is that only animals derive their nutrition	
A	From organic matter
B	By preying on animals
C	By ingesting it
D	By using enzymes to digest their food
16) Which of the following is (are) unique to animals?	
A	Cells that have mitochondria
B	The structural carbohydrate, chitin
C	Nervous conduction and muscular movement
D	Heterotrophy
17) Soon after the coelom begins to form, a researcher injects a dye into the coelom of a deuterostome embryo. Initially, the dye should be able to flow directly into the	
A	Blastopore
B	Blastocoel
C	Archenteron
D	Pseudocoelom
18) Which of the following is true of members of the phylum Cnidaria?	
A	They are not capable of locomotion because they lack true muscle tissue.
B	They are primarily filter feeders.

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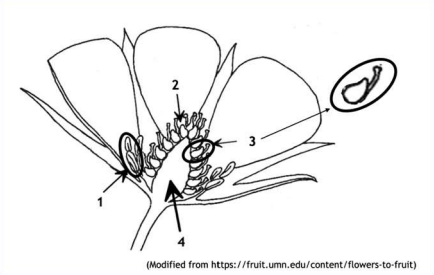
C	They may use a gastrovascular cavity as a hydrostatic skeleton.
D	They are the simplest organisms with a complete alimentary canal
19) Many of which of the following annelid classes are parasites?	
A	Oligochaeta
B	Polychaeta
C	Hirudinea
D	All three of these
20) Nematode worms and annelid worms share which of the following features?	
A	Use of fluid in the body cavity as a hydrostatic skeleton
B	Ecdysis
C	Presence of a circulatory system
D	Presence of segmentation
21) Which of the following is a shared characteristic of all chordates?	
A	Scales
B	Jaws
C	Vertebrae
D	Dorsal, hollow nerve cord
22) The endoskeletons of most vertebrates are composed of calcified	
A	Cartilage
B	Silica
C	Chitin
D	Dentin
23) Which of these characteristics added most to vertebrate success in relatively dry environments?	
A	The amniotic egg
B	Two pairs of appendages
C	Claws
D	A four-chambered heart

Answer keys for exercises

1	2	3	4	5	6	7	8	9	10	11	12
C	B	D	B	A	B	C	D	C	C	B	D
13	14	15	16	17	18	19	20	21	22	23	
C	D	C	C	C	C	C	A	D	A	A	

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Exam



(Modified from https://fruit.umn.edu/content/flowers-to-fruit)

According to their development, type of flower, and the number of ovaries, fruits are classified into 3 types:

1. Simple fruit, which develops from a solitary flower with a single carpel or several fused carpels.
2. Aggregate fruit, which develops from a solitary flower with more than one separate carpel, each forming a fruit.
3. Multiple fruit, which develops from an inflorescence with many dense florets, and the ovary walls are fused together into one fruit.

1. If the flower shown in the diagram is fertilized, which type of fruit will be developed?
(1: stamen, 2: carpel, 3: pistil, 4: receptacle)

A simple fruit	A
An aggregate fruit	B
A multiple fruit	C
A fruit with many seeds	D

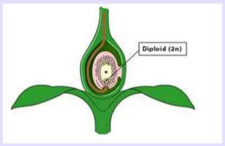
2. Identify the Corn borer stages of development below by inserting the following letters:



Larva	A
Pupa	B
Adult female	C
Egg	D
Adult male	E

3. Sexual reproduction in plants and animals involves the union of two gametes to form a single cell called a zygote. Gametes include the egg and sperm cells. The zygote is formed after the sperm fertilizes the egg, resulting in a diploid (2n)

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chromosome number. The zygote develops into …(Hint: The following figure indicates a fertilized egg.) 	
Embryo	A
Endosperm	B
Carpel	C
Ovule	D
4. The various taxonomic levels (viz, genera, classes, etc.) of the hierarchical classification system differ from each other on the basis of	
How widely the organisms assigned to each are distributed throughout the environment.	A
The body sizes of the organisms assigned to each.	B
Their inclusiveness	C
The relative genome sizes of the organisms assigned to each.	D
5. Which two structures play direct roles in permitting bacteria to adhere to each other, or to other surfaces? 1. Capsules 2. Endospores 3. Fimbriae 4. Plasmids 5. Flagella	
1 and 2	A
1 and 3	B
2 and 3	C
3 and 4	D
6. An individual mixotroph loses its plastids, yet continues to survive. Which of the following most likely accounts for its continued survival?	
It relies on photosystems that float freely in its cytosol.	A
It must have gained extra mitochondria when it lost its plastids.	B
It engulfs organic material by phagocytosis or by absorption.	C
It has an endospore.	D
7. Which feature of cycads makes them similar to many angiosperms? 1. They have exposed ovules. 2. They have flagellated sperm.	

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3. They are pollinated by animals.	
1 only	A
2 only	B
3 only	C
2 and 3	D
8. A biologist is trying to classify a newly discovered fungus on the basis of the following characteristics: filamentous appearance, reproduction by asexual spores, no apparent sexual phase, and parasitism of woody plants. If asked for advice, to which group would you assign this new species?	
Deuteromycota	A
Zygomycota	B
Ascomycota	C
Basidiomycota	D
9. A student encounters an animal embryo at the eight-cell stage. The four smaller cells that comprise one hemisphere of the embryo seem to be rotated 45° and lie in the grooves between larger, underlying cells (**spiral cleavage**). This embryo may potentially develop into a(n)	
Turtle	A
Earthworm	B
Sea star	C
Fish	D
10. What distinguishes complete metamorphosis from incomplete metamorphosis in insects?	
Presence of wings in the adult, but not in earlier life stages	A
Presence of sex organs in the adult, but not in earlier life stages	B
Radically different appearance between adults and earlier life stages	C
Only A and B	D

Answer keys for the practice exam

1	2	3	4	5	6	7	8	9	10
B		A	C	B	C	C	A	B	C

1	2	3	4	5
D	A	B	E	C

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Ecology & Ethology



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Introduction

Ecology is defined as a branch of the biological sciences concerned with the study of interactions among living organisms and between organisms and their physical environments. This field seeks to understand species distribution and abundance, the flow of energy within ecosystems, and the cycling of matter that sustains life on Earth. Ecologists examine how biotic factors—such as competition, predation, and symbiosis—and abiotic factors—such as temperature, light, water, and nutrient availability—shape the structure and function of ecological communities.

Modern ecology integrates concepts from physiology, behavior, evolution, and environmental sciences to explain how organisms adapt to their environments and respond to natural or human-induced changes. At the population level, ecology focuses on patterns of growth, reproduction, and survival. At the community level, it investigates interspecific interactions and the processes that maintain biodiversity. At the ecosystem level, it analyzes energy flow, primary productivity, food webs, and biogeochemical cycles.

Ecology is central to addressing global environmental challenges such as climate change, habitat fragmentation, pollution, invasive species, and biodiversity loss. Through an understanding of ecological principles, scientists can develop sustainable strategies for natural resource management, design effective conservation programs, and predict how ecosystems respond to environmental disturbances.

Overall, ecology provides a framework for understanding the complex and dynamic relationships linking organisms to one another and to the Earth's physical systems. Its insights form a cornerstone for maintaining ecosystem health, supporting human well-being, and ensuring the long-term sustainability of natural environments.

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Objectives

1. Understand how Earth's climate varies with latitude and seasons, and examine the factors contributing to rapid contemporary climate change.
2. Analyze the role of climate and environmental disturbances in regulating the distribution, structural characteristics, and functional properties of terrestrial biomes.
3. Describe the diversity, structure, and ecological roles of aquatic ecosystems, and explain why they are considered dynamic systems that cover most of the Earth's surface.
4. Explain how species distributions are constrained by interactions between organisms and the physical environment, and how this influences the formation of ecological niches.
5. Examine the interaction between environmental change and evolutionary processes, and its role in shaping populations and biological communities over both short and long timescales.
6. Link global climate patterns to patterns of biodiversity and understand how environmental gradients influence species adaptation and distribution.
7. Evaluate the ecological significance of natural and human-induced disturbances—such as fires, storms, and human activities—in shaping ecosystem structure and function.

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Chapter One

Species distribution and design dynamics



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Interactions between organisms and the environment

Interactions between organisms and the environment limit the distribution of species

Dispersal and Distribution:

One of the major factors contributing to the global distribution of organisms is dispersal - the movement of individuals or gametes away from their areas of origin or from centers of high population density.

Behavior and Habitat Selection:

- When individuals appear to avoid certain habitats, even when those habitats are suitable, the distribution of the organism may be limited by habitat selection behavior.
- For example, larvae of the European corn borer can feed on a variety of plants but are found almost exclusively on maize, because egg-laying females are attracted to the odors produced by this plant.
- Clearly, habitat selection behavior restricts this insect to geographical locations where maize occurs.

Biotic Factors:

Negative interactions with predators (organisms that kill their prey) or herbivores (organisms that eat plants or algae) often limit a species' ability to survive and reproduce.

Abiotic Factors:

- Temperature
- Water and Oxygen
- Salinity
- Sunlight
- Rocks and Soil

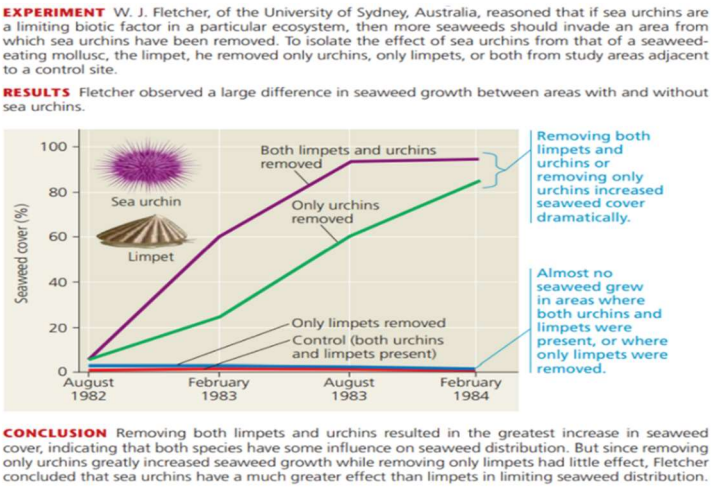


Figure 46: **Impact of urchin and limpet removal on seaweed cover.**

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Dynamic biological processes

Dynamic biological processes influence population density, dispersion, and demographics:

Density and Dispersion:

- **Density of a population** is the number of individuals per unit area or volume. Example: The number of oak trees per square kilometer.
- **Dispersion** is the pattern of spacing among individuals within the boundaries of a population.
- **Density** is not a fixed property; it changes as individuals are added to or removed from the population (see figure).

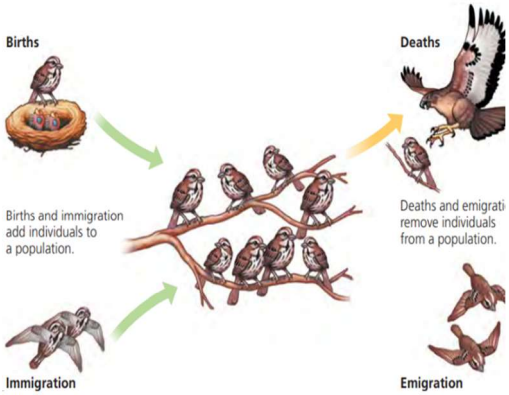


Figure 47: Factors that add or remove individuals from a population.

- Additions occur through **birth** (all forms of reproduction) and **immigration**, the influx of new individuals from other areas.
- Factors that remove individuals from the population include **death (mortality)** and **emigration**, the movement of individuals out of the population to other locations.

Patterns of Dispersion:

1) Clumped
2) Uniform
3) Random

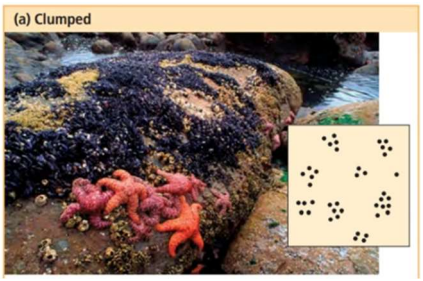


Figure 49: clumped pattern

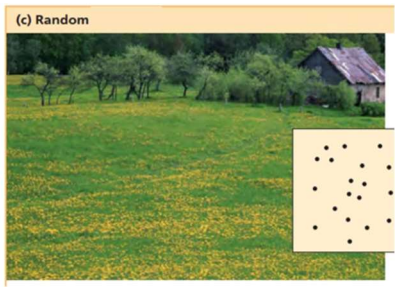


Figure 48: random pattern

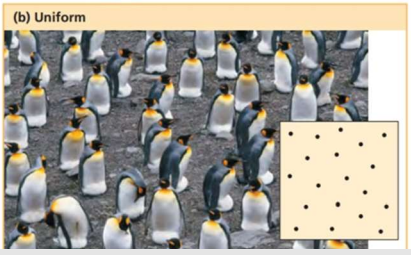
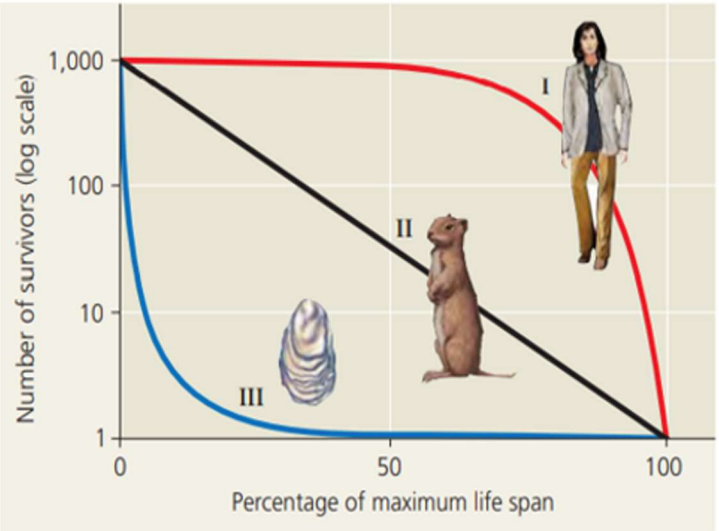


Figure 50: uniform pattern

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Survivorship Curves:



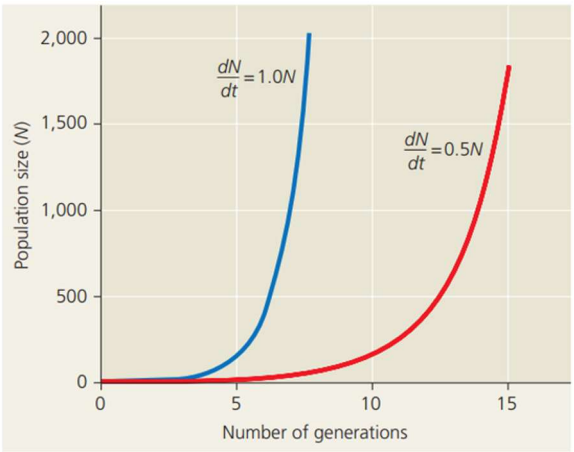
Idealized Growth Curves: Types I, II, and III.

The **y-axis** is logarithmic, and the **x-axis** is on a relative scale, allowing species with widely varying life spans to be shown together on the same graph.

Figure 51: Survivorship curves: Types I, II, and III

The exponential model :

The exponential model describes population growth in an idealized, unlimited environment: A population that grows exponentially increases in size at a constant rate, eventually producing a J-shaped growth curve when population size is plotted over time (as shown in the following figure).



Population growth as predicted by the exponential model. This graph compares the growth of two populations with different values of r_{max}.

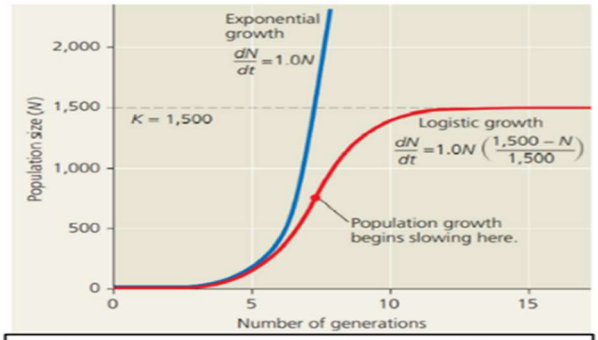
Although the maximum rate of increase remains constant, the population adds more new individuals per unit of time when it is large than when it is small; thus, the curves in the figure become steeper over time.

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The logistic model:

The logistic model describes how a population grows more slowly as it nears it is carrying capacity:

- The growth of some small animal populations that can be raised in laboratories—such as beetles and crustaceans—and some microorganisms, such as bacteria, Paramecium, and yeasts, tends to fit an S-shaped (sigmoid) curve fairly well under conditions of limited resources (as shown in the figure).
- These populations grow in a stable environment with no predators and no competing species that might reduce their growth, and such conditions are very rarely found in nature.



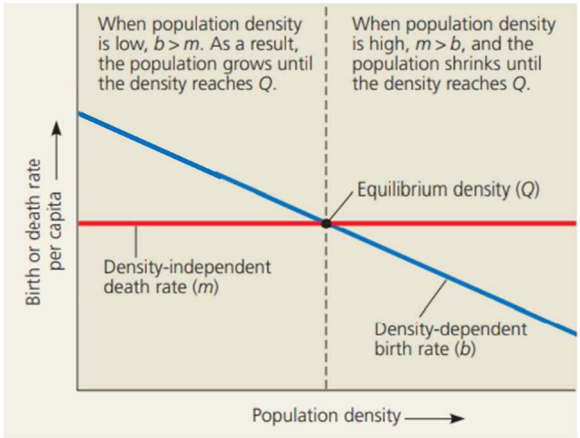
Population growth as predicted by the logistic model: The population's growth rate decreases as its size (N) approaches the environment's **carrying capacity (K)**. The red curve shows population growth with $r_{max} = 1.0$ and $K = 1500$.

Figure 53: Exponential vs. logistic population growth.

Many factors that regulate population growth are density dependent:

What environmental factors prevent populations from growing indefinitely? Why are some populations relatively stable in size, while others are not?

Population Change and Population Density:
If emigration and immigration are equal, a population increases in size when the birth rate exceeds the death rate, and decreases when the death rate exceeds the birth rate.



Determining population density equilibrium: This simple model considers only **birth and death rates** (assuming that **immigration and emigration rates are zero or equal**). In this example, the birth rate changes with population density, while the death rate remains constant. At the **equilibrium density (Q)**, the birth and death rates are equal.

Figure 54: Birth and death rates determining equilibrium density.

- A birth rate or death rate that does not change with population density is said to be density independent.
- In contrast, a death rate that rises with increasing population density is said to be density dependent, as is a birth rate that falls with increasing density.

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Mechanisms of Density-Dependent Population Regulation:

As population density increases, many density-dependent factors act to slow or stop population growth by reducing birth rates or increasing death rates:

1. Competition for Resources
2. Toxic Wastes
3. Predation
4. Intrinsic Factors
5. Territoriality
6. Disease

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Chapter Two
Community Ecology



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Community Ecology

Community interactions are classified by whether they help, harm or have no effect on the species involved:

- The main relationships in an organism's life are its interactions with individuals of other species in the community. These interspecific interactions include competition, predation, herbivory, and symbiosis (which encompasses parasitism, mutualism, and commensalism).
- We use the symbols + and – to indicate how each interaction affects the survival and reproduction of the two species involved.
- For example, predation is a –/+ interaction, having a positive effect on the survival and reproduction of the predator population and a negative effect on the prey population.
- Mutualism is a +/+ interaction, because the survival and reproduction of both species are increased in the presence of the other.
- A 0 indicates that the population is unaffected by the interaction in any known way.
- Historically, most ecological research has focused on interactions that have a negative effect on at least one species, such as competition and predation. However, positive interactions are widespread, and their contributions to community structure are now being extensively studied.

Competition:

- Interspecific competition is a (–/–) interaction that occurs when individuals of different species compete for a resource that limits their growth and survival. Weeds growing in a garden compete with garden plants for soil nutrients and water. Grasshoppers and cattle on the Great Plains compete for grass, which both consume. Lynx and foxes in the northern forests of Alaska and Canada compete for prey such as hares.
  - Competitive Exclusion
  - Ecological Niches and Natural Selection

  As a result of competition, the fundamental niches of species — the potential niches they could occupy — often differ from their realized niches, which are the portions of their fundamental niches that they actually occupy in a particular environment.

Character Displacement: As shown in the figure, finches have similar beak sizes when they live in different habitats. However, on islands where their habitats overlap (they live together), the species have evolved different beak sizes, with one adapted to eat larger seeds and the other to eat smaller seeds. Such character displacement plays an important

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role in reducing competition and promoting adaptation to different parts of the environment.

Experiment ecologist **Joseph Connell** studied two barnacle species-**Chthamalus stellatus** and **Balanus balanoides**-that have a stratified distribution on rocks along the coast of Scotland. **Chthamalus** is usually found higher on the rocks than **Balanus**. To determine whether the distribution of **Chthamalus** is the result of interspecific competition with **Balanus**, Connell removed **Balanus** from the rocks at several sites.

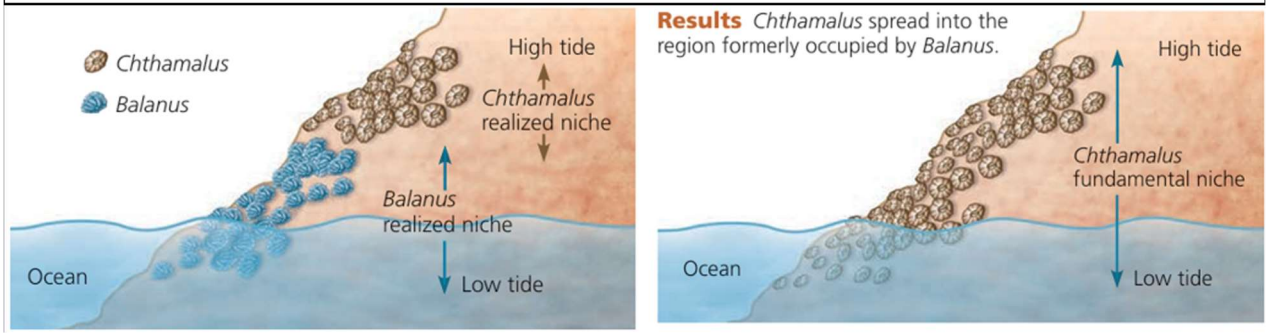


Figure 55: Competitive exclusion in barnacle niches

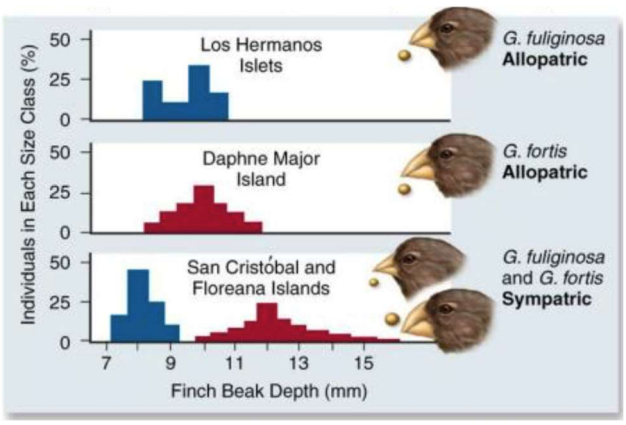


Figure 56: Character Displacement in Geospiza Finches: Two species of finches (Geospiza) have beaks of similar length when they live in different habitats, but they develop different beak sizes when they live together in the same habitat.

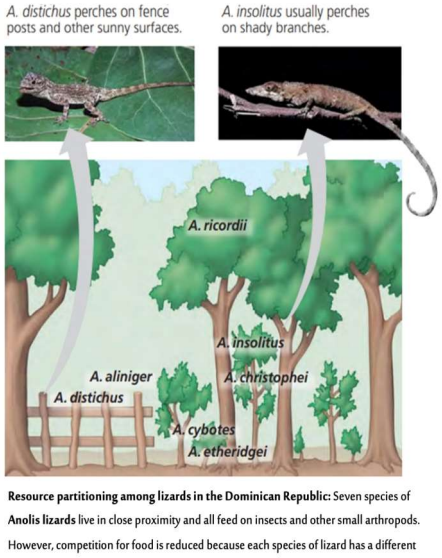


Figure 57: Habitat partitioning among Dominican Anolis lizards.

Predation:

Predation refers to a +/– interaction between species in which one species, the predator, kills and eats the other, the prey.

Herbivory

Ecologists use the term herbivory to describe a +/– interaction in which an organism eats parts of a plant or alga.

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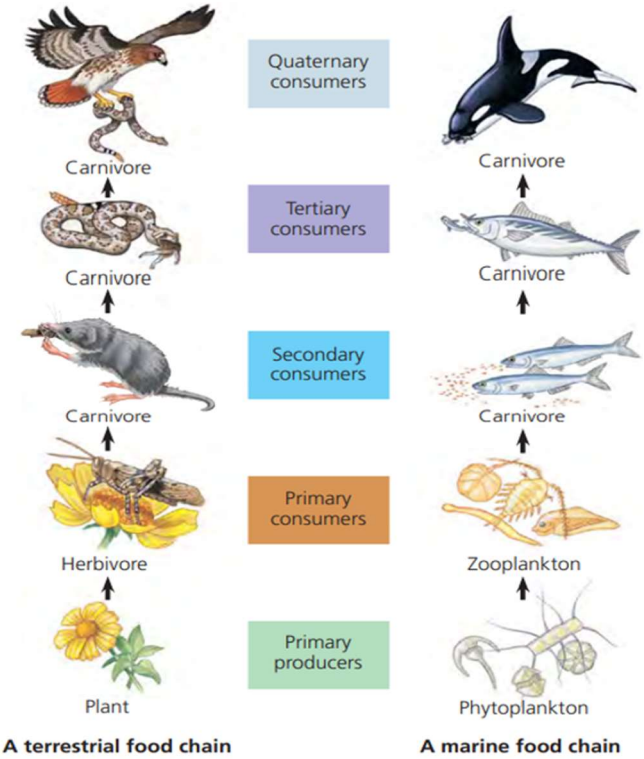
Symbiosis

When individuals of two or more species live in direct and close association with one another, their relationship is called symbiosis, whether the interaction is harmful, helpful, or neutral.

- Parasitism (+ / –)
- Mutualism (+ / +)
- Commensalism (+ / 0)
- Facilitation (+ / + or 0 / +)
- Amensalism (0 / –

Trophic Structure:

- **The composition and dynamics of a community** also depend on the feeding relationships among organisms — the trophic structure of the community.
- The transfer of food energy through trophic levels — from its source in plants and other autotrophic organisms (primary producers), through herbivores (primary consumers), to carnivores (secondary, tertiary, and quaternary consumers), and finally to decomposers — is referred to as the food chain.



Examples of terrestrial and marine food chains: The arrows trace the flow of energy and nutrients through the trophic levels of the community as living organisms feed on one another. **Decomposers**, which feed on organisms from all trophic levels, are not shown here.

Figure 58 Terrestrial and marine food chains across trophic levels.

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Food Webs:

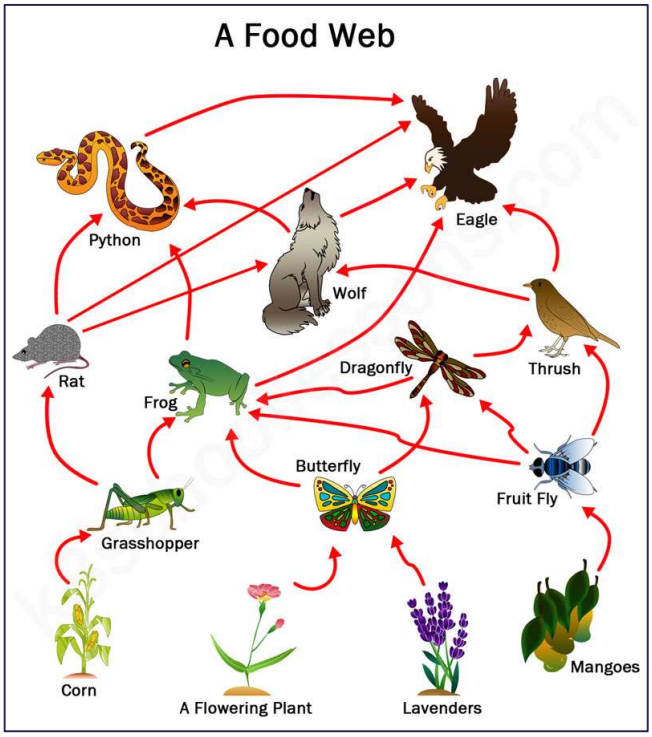


Figure 59: A simplified terrestrial food web

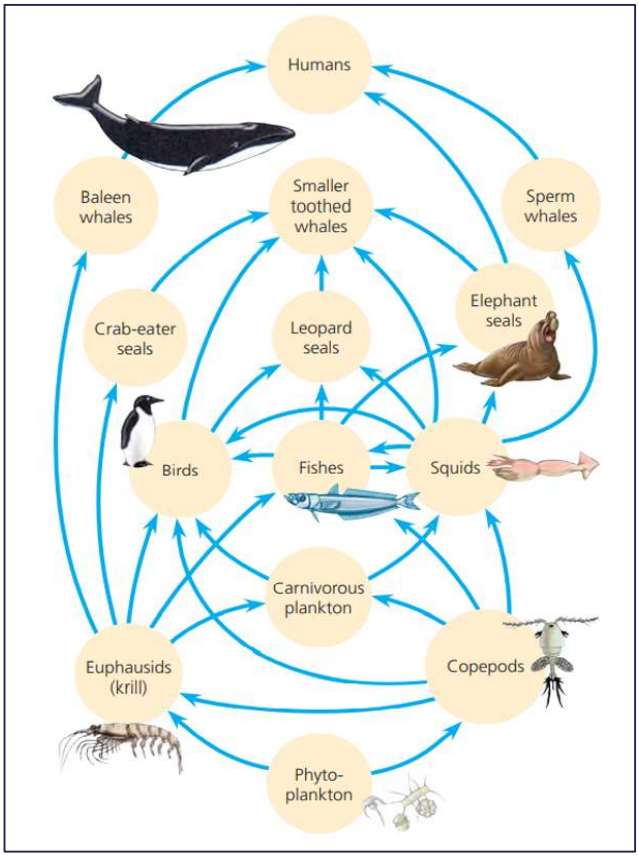


Figure 60: A simplified Antarctic marine food web

Limits on Food Chain Length:

Most food webs studied so far contain chains consisting of five links or fewer.

• Why are food chains relatively short?

The reason lies in the energetic hypothesis, which states that the length of a food chain is limited by the inefficiency of energy transfer along the chain. Only about 10% of the energy stored in organic matter at each trophic level is converted into organic matter at the next level. Thus, a producer level consisting of 100 kg of plant material can support about 10 kg of herbivore biomass (the total mass of all individuals in a population) and only 1 kg of carnivore biomass.

Species with a Large Impact:

Some species have an especially large impact on the composition of entire communities because they are extremely abundant or play a pivotal role in community dynamics.

The influence of these species is expressed through their feeding interactions and their effects on the physical environment. 1. Dominant Species

2. Keystone Species 3. Ecosystem Engineers

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Disturbance influences species diversity and composition:

Disturbances can be of high intensity or low intensity. High-intensity disturbances such as wildfires, droughts, and floods can have large-scale effects. Animals can also cause major disruptions — for example, gypsy moths, which are capable of destroying an entire forest, or deer populations that grow explosively and devastate forests through overgrazing. In contrast, low-intensity disturbances affect small areas, such as a tree falling in a forest or an animal digging a hole near a plant's roots. The intermediate disturbance hypothesis states that moderate levels of disturbance promote greater species diversity than either low or high levels of disturbance.



(a) Soon after fire. The fire has left a patchy landscape. Note the unburned trees in the far distance.

(b) One year after fire. The community has begun to recover. A variety of herbaceous plants, different from those in the former forest, cover the ground.

Figure 61: Fire recovery stages.

Ecological Succession:

Changes in the composition and structure of terrestrial communities are most evident after severe disturbances, such as a volcanic eruption or glacial retreat, which remove all existing vegetation. The disturbed area may then be colonized by a variety of species, which are gradually replaced by others — a process known as ecological succession.

• Primary Succession: This process begins in a virtually lifeless area where soil has not yet formed, such as a newly formed volcanic island or on the rubble left behind by a retreating glacier.

• Secondary Succession: This occurs when an existing community is cleared by a disturbance that leaves the soil intact, such as after a fire.

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Chapter Three
Ecosystems and Restoration Ecology



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Energy, Mass, and Trophic Levels:

- Ecologists group species in an ecosystem into trophic levels based on their feeding relationships.
- The trophic level that ultimately supports all others consists of autotrophs, also called the primary producers of the ecosystem, such as photosynthetic organisms and chemosynthetic prokaryotes.
- Herbivores are the primary consumers.
- Carnivores that eat herbivores are the secondary consumers.
- Carnivores that eat other carnivores are the tertiary consumers.
- Consumers that obtain their energy from detritus (nonliving organic matter) are the detritivores and decomposers.

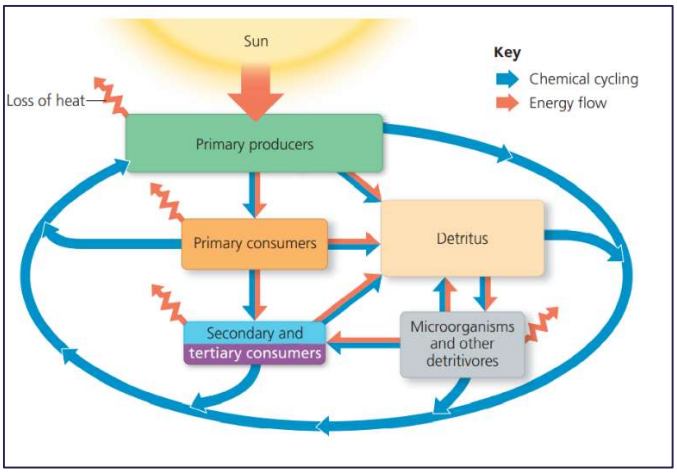


Figure 62: Energy flow and chemical cycling in an ecosystem

Energy Transfer Between Trophic Levels:

Energy Transfer Between Trophic Levels is Typically Only 10%Efficient

Production efficiency:

- We begin by examining secondary production in a single organism — a caterpillar.
- When the caterpillar feeds on a leaf, only 33 joules out of 200 joules (or one-sixth of the leaf's potential energy) are used for secondary production, or growth (see figure).
- The caterpillar stores some of the remaining energy in organic compounds that will be used for cellular respiration, while the rest passes out in its feces.
- The energy in the feces remains temporarily within the ecosystem, but most of it is eventually lost as heat after being consumed by detritivores.
- The energy used for the caterpillar's respiration is also ultimately lost from the ecosystem as heat.
- Only the chemical energy stored by herbivorous animals as biomass—through growth or reproduction—is available as food for secondary consumers.
- We can measure the efficiency of animals as energy converters using the following equation:

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$$\text{Production efficiency} = \frac{\text{Net secondary production} * 100\%}{\text{Assimilation of primary production}}$$

- Net secondary production is the energy stored in biomass that represents growth and reproduction.
- Assimilation consists of the total amount of energy consumed and used for growth, reproduction, and respiration.
- Thus, production efficiency is the percentage of assimilated energy that is stored in food used for growth and reproduction, rather than lost as respiration.
- For the caterpillar in the previous figure, the production efficiency is 33%;
- 67 joules out of 100 joules of assimilated energy are used for respiration.
- (The 100 joules of undigested energy lost as feces are not included in assimilation.)

$$\text{Production efficiency كفاءة الانتاج} = \frac{33 * 100\%}{100}$$

- Production efficiency is typically low in endothermic (warm-blooded) animals, because they use much of their energy to maintain body temperature — usually only 1–3%.
- Insects and microorganisms are more efficient, with average production efficiencies of 40% or more.

Trophic Efficiency and Ecological Pyramid:

- Trophic efficiencies range from about 5% to 20% across different ecosystems, but on average, they are only around 10%.
- In other words, 90% of the energy available at one trophic level is not transferred to the next level. This loss is compounded along the food chain.
- If 10% of the available energy from primary producers is transferred to primary consumers (such as caterpillars), and 10% of that energy is then transferred to secondary consumers (carnivores), only 1% of the net primary production is available to secondary consumers (10% of 10%).
- This progressive loss of energy along the food chain limits the abundance of carnivores at higher trophic levels that an ecosystem can support.
- Only about 0.1% of the chemical energy fixed by photosynthesis passes all the way through the food web to a tertiary consumer, such as a snake or a shark.
- This explains why most food webs contain only four or five trophic levels.

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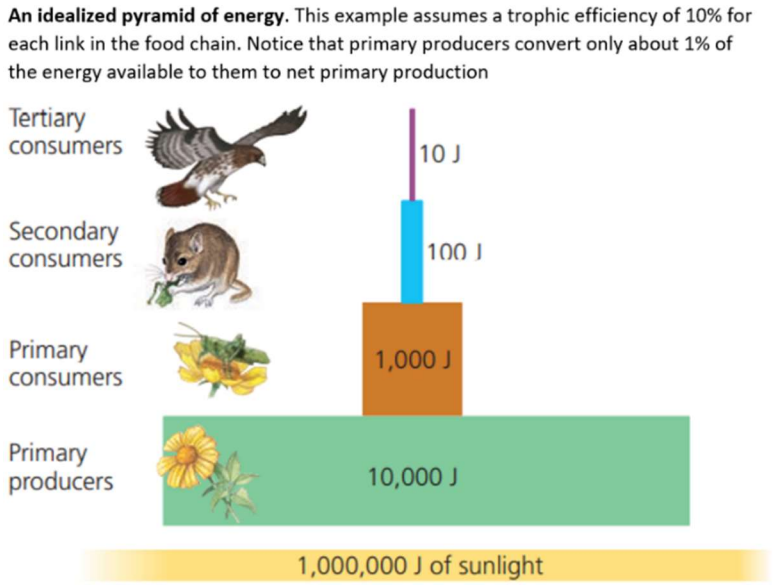
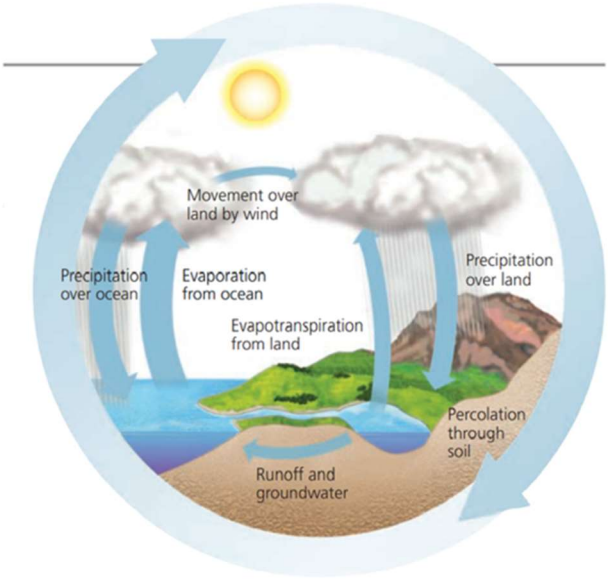


Figure 63: An idealized energy pyramid showing trophic energy loss.

Biological and Geochemical Processes :

Biological and Geochemical Processes Cycle Nutrients and Water in Ecosystems Because nutrient cycles involve both biotic and abiotic components, they are called biogeochemical cycles.

Water cycle



Biological importance Water is essential to all organisms, and its availability influences the rates of ecosystem processes, particularly primary production and decomposition in terrestrial ecosystems.

Forms available to life All organisms are capable of exchanging water directly with their environment. Liquid water is the primary physical phase in which water is used, though some organisms can harvest water vapor. Freezing of soil water can limit water availability to terrestrial plants.

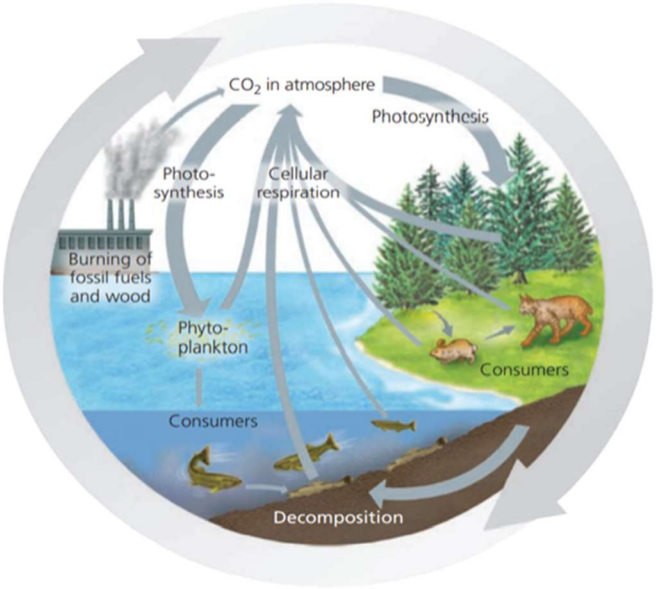
Reservoirs The oceans contain 97% of the water in the biosphere. Approximately 2% is bound in glaciers and polar ice caps, and the remaining 1% is in lakes, rivers, and groundwater, with a negligible amount in the atmosphere.

Key processes The main processes driving the water cycle are evaporation of liquid water by solar energy, condensation of water vapor into clouds, and precipitation. Transpiration by terrestrial plants also moves large volumes of water into the atmosphere. Surface and groundwater flow can return water to the oceans, completing the water cycle.

Figure 64: Water Cicle

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Carbon cycle



Biological importance Carbon forms the framework of the organic molecules essential to all organisms.

Forms available to life Photosynthetic organisms utilize CO_2 during photosynthesis and convert the carbon to organic forms that are used by consumers, including animals, fungi, and heterotrophic protists and prokaryotes.

Reservoirs The major reservoirs of carbon include fossil fuels, soils, the sediments of aquatic ecosystems, the oceans (dissolved carbon compounds), plant and animal biomass, and the atmosphere (CO_2). The largest reservoir is sedimentary rocks such as limestone; however, carbon remains in this pool for long periods of time. All organisms are capable of returning carbon directly to their environment in its original form (CO_2) through respiration.

Key processes Photosynthesis by plants and phytoplankton removes substantial amounts of atmospheric CO_2 each year. This quantity is approximately equal to the CO_2 added to the atmosphere through cellular respiration by producers and consumers. The burning of fossil fuels and wood is adding significant amounts of additional CO_2 to the atmosphere. Over geologic time, volcanoes are also a substantial source of CO_2.

Figure 65: Carbon Cycle

Nitrogen cycle

Biological importance Nitrogen is part of amino acids, proteins, and nucleic acids and is often a limiting plant nutrient.

Forms available to life Plants can assimilate (use) two inorganic forms of nitrogen—ammonium (NH4 +) and nitrate (NO3 –)—and some organic forms, such as amino acids. Various bacteria can use all of these forms as well as nitrite (NO2 –). Animals can use only organic forms of nitrogen.

Reservoirs The main reservoir of nitrogen is the atmosphere, which is 80% free nitrogen gas (N2). The other reservoirs of inorganic and organic nitrogen compounds are soils and the sediments of lakes, rivers, and oceans; surface water and groundwater; and the biomass of living organisms.

Key processes The major pathway for nitrogen to enter an ecosystem is via nitrogen fixation, the conversion of N2 to forms that can be used to synthesize organic nitrogen compounds. Certain bacteria, as well as lightning and volcanic activity, fix nitrogen naturally. Nitrogen inputs from human activities now outpace natural inputs on land. Two major contributors are industrially produced fertilizers and legume crops that fix nitrogen via bacteria in their root nodules. Other bacteria in soil convert nitrogen to different forms. Examples include nitrifying bacteria, which convert ammonium to nitrate, and denitrifying bacteria, which convert nitrate to nitrogen gas. Human activities also release large quantities of reactive nitrogen gases, such as nitrogen oxides, to the atmosphere

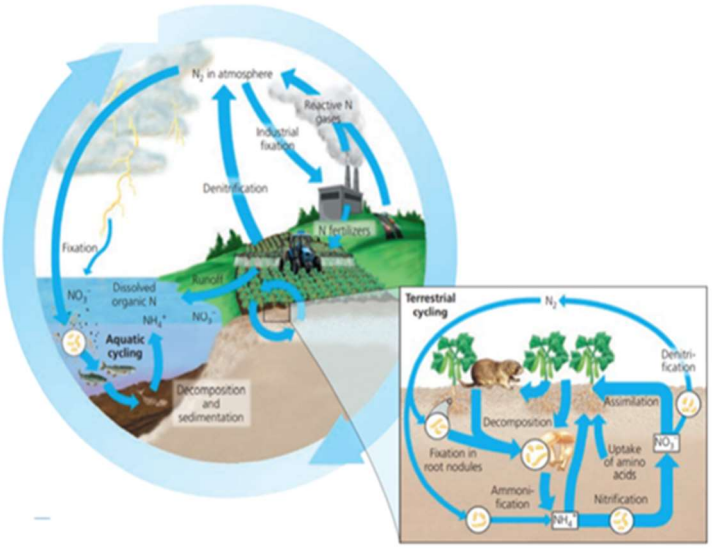
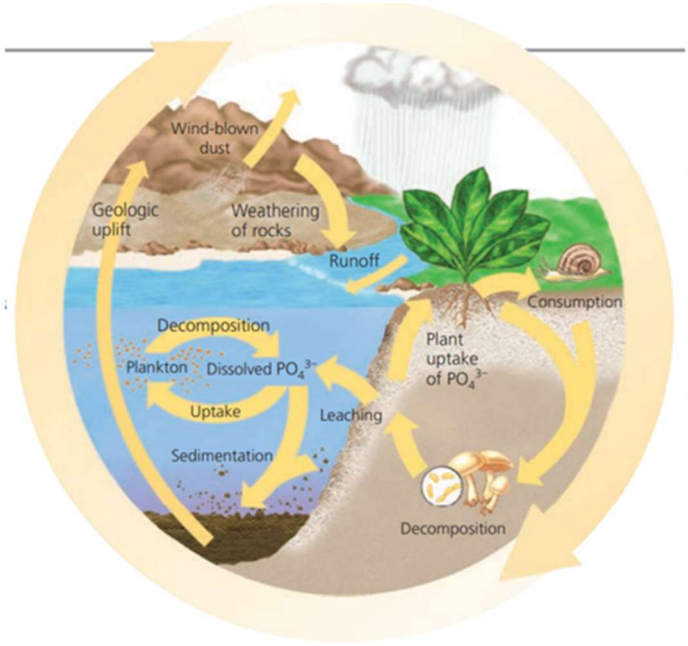


Figure 66: Nitrogen Cycle

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The Phosphorus Cycle



Biological importance Organisms require phosphorus as a major constituent of nucleic acids, phospholipids, and ATP and other energy-storing molecules and as a mineral constituent of bones and teeth.

Forms available to life The most biologically important inorganic form of phosphorus is phosphate (PO_4^{3-}), which plants absorb and use in the synthesis of organic compounds.

Reservoirs The largest accumulations of phosphorus are in sedimentary rocks of marine origin. There are also large quantities of phosphorus in soil, in the oceans (in dissolved form), and in organisms. Because soil particles bind PO_4^{3-}, the recycling of phosphorus tends to be quite localized in ecosystems.

Key processes Weathering of rocks gradually adds PO_4^{3-} to soil; some leaches into groundwater and surface water and may eventually reach the sea. Phosphate taken up by producers and incorporated into biological molecules may be eaten by consumers. Phosphate is returned to soil or water by either decomposition of biomass or excretion by consumers. Because there are no significant phosphorus-containing gases, only relatively small amounts of phosphorus move through the atmosphere, usually in the forms of dust and sea spray.

The role of Restoration Ecologists

Restoration Ecologists Return Degraded Ecosystems to a More Natural State: Scientists around the world often use two main strategies: bioremediation and biological augmentation.

Bioremediation:

The use of living organisms, usually prokaryotes, fungi, or plants—to detoxify polluted ecosystems, is known as bioremediation. It is a strategy aimed at removing harmful substances from an ecosystem.

Biological Augmentation:

Biological augmentation uses living organisms to add essential materials to a degraded ecosystem. For example, adding mycorrhizal fungi to the soil can enhance the growth of many plants in that environment.

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Chapter Four
Human Activities Threaten Earth's Biodiversity



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Human Activities Threaten Earth's Biodiversity:

Extinction is a natural phenomenon that has occurred since life first evolved; however, the increased rate of extinction today is responsible for the current biodiversity crisis.

There are three levels of biodiversity:

Genetic Diversity:

- Genetic diversity includes not only individual genetic variation within a population, but also genetic differences between populations, often associated with adaptations to local conditions.
- If one population becomes extinct, the species may lose some of the genetic diversity that makes microevolution possible.
- This erosion or reduction of genetic diversity in turn diminishes the species' adaptive potential.

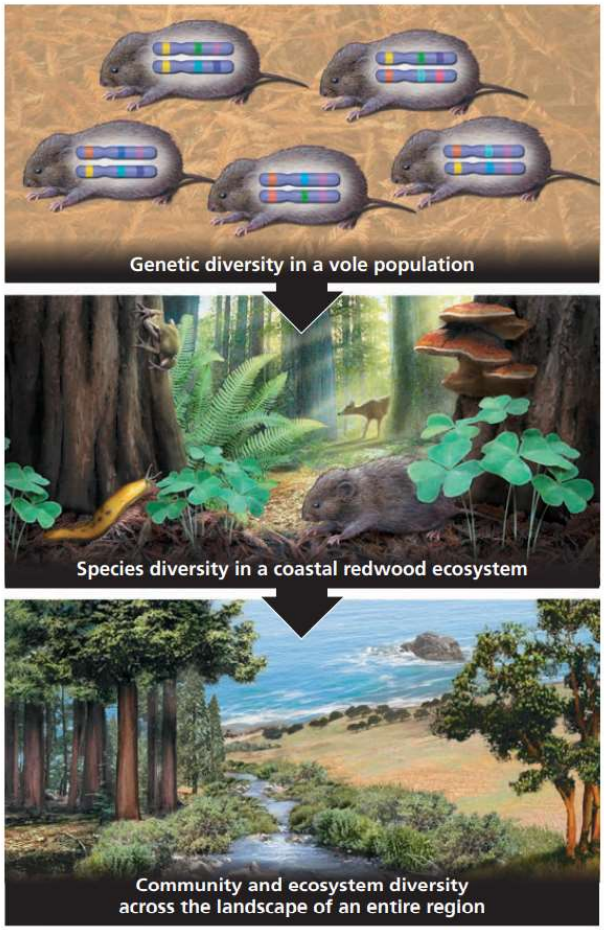


Figure 68: Levels of biodiversity: genetic, species, and ecosystem diversity

Species Diversity

- Public concern about the biodiversity crisis is often focused on species diversity, meaning the number of species in an ecosystem.
- The global extinction of a species means its loss from all ecosystems in which it once lived.

Ecosystem Diversity:

- The diversity of ecosystems on Earth represents the third level of biodiversity.
- Because of the many interactions among different species within an ecosystem, the extinction of populations of one species can have negative effects on other species in the same ecosystem.

Threats to Biodiversity

- Habitat Loss
- Introduced Species
- Overharvesting
- Global Change

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Chapter Five
Animal Behavior



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Animal Behavior–the how and why of animal activity:

- Animal behavior, whether individual or group-based, fixed or variable, depends on physiological systems and processes.
- An individual behavior is an action performed by muscles under the control of the nervous system in response to a stimulus.
- Examples include animals making sounds, releasing scents to mark their territory, or waving their claws.
- Behavior is an essential part of acquiring nutrients and finding a mate for sexual reproduction. Behavior also contributes to homeostasis - in short, all aspects of an animal's physiology contribute to its behavior, and an animal's behavior affects all of its organ functions.

simple and complex behaviors

Discrete sensory inputs can stimulate both simple and complex behaviors

- What approach do biologists use to determine how behaviors arise and what functions they serve?
- The Dutch scientist Niko Tinbergen, a pioneer in the study of animal behavior, proposed that understanding any behavior requires answering four key questions, summarized as follows:
    1. What stimulus triggers the behavior, and what physiological mechanisms mediate the response?
    2. How do an animal's experiences during growth and development influence the response?
    3. How does the behavior aid survival and reproduction?
    4. What is the evolutionary history of the behavior?
- How the behavior occurs — this refers to the proximate causation of behavior. To analyze the proximate cause of a behavior, scientists might measure hormone levels or record nerve activity. For example, a male songbird may sing during the breeding season because rising levels of the male sex hormone testosterone bind to receptors in the brain, triggering the singing behavior. This explanation describes the proximate cause of male bird song.
- Why the behavior occurs — this refers to the ultimate causation of behavior. To study ultimate causation, scientists aim to determine how the behavior influences survival or reproductive success. A male songbird sings to defend his territory from other males and to attract a female mate, which represents the ultimate explanation for male bird song.

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Fixed Action Patterns

- The scientist Niko Tinbergen conducted an experiment in which he kept aquariums containing three-spined stickleback fish (*Gasterosteus aculeatus*). Male sticklebacks with red bellies attack other males that invade their territories.
- Tinbergen observed that the male sticklebacks also behaved aggressively when he placed a red model in front of their tanks. He noticed that the red coloration on the underside of any intruding object was
- what triggered the attack behavior. Thus, a male stickleback will not attack a fish that lacks a red underside (note that female sticklebacks never have red bellies), but it will attack even unrealistic models if they contain

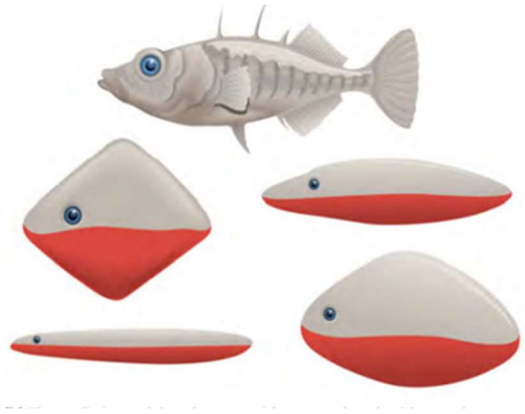


Figure 69: red-colored areas



Figure 70: Red-bellied intruder triggers aggressive behavior in male stickleback."

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Migration:

Many migratory animals travel through environments they have never previously visited. How, then, do they find their way in these new places? What mechanisms have scientists proposed for how animals detect Earth's magnetic field?



Figure 71: Migration of animals and birds

Animal Signaling and Communication:

A stimulus that is transmitted from one organism to another is called a signal. The sending and receiving of signals among animals constitutes communication, which often plays a direct role in triggering behavior. The four common types of communication in animals are:

- Visual
- Chemical
- Tactile (touch)
- Auditory (sound)

Most terrestrial mammals are nocturnal, making visual displays relatively ineffective. Instead, these species rely on auditory and olfactory (smell) signals, which work just as well in the dark as in the light. In contrast, most birds are diurnal (active mainly during the daytime) and communicate primarily through visual and auditory signals.

Pheromones:

Animals that communicate through smell or taste emit chemical substances called pheromones. Pheromones are especially common among mammals and insects and are often associated with reproductive behavior.

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Learning (Acquired Behavior):

In some species, the ability of offspring to recognize and identify a parent is essential for survival. In young animals, this learning often takes the form of imprinting, which is the establishment of a long-lasting behavioral response to a specific individual or object. Imprinting can occur only during a specific developmental period, known as the sensitive period.

Associative Learning

- These studies usually involve either classical conditioning or operant conditioning.
- In classical conditioning, a random (neutral) stimulus becomes associated with a particular outcome. The Russian physiologist Ivan Pavlov conducted early experiments on classical conditioning, showing that if a bell was always rung before feeding a dog, the dog would eventually salivate at the sound of the bell, expecting food.
- In operant conditioning, also known as trial-and-error learning, an animal learns to associate one of its behaviors with a reward or punishment and then tends to repeat or avoid that behavior accordingly.

Cognition and Problem Solving

- The most complex forms of learning involve cognition—the process of knowing, which includes awareness, reasoning, memory, and judgment.
- Although it was once believed that only primates and some marine mammals possessed higher-level thinking processes, many other groups of animals—including insects—have demonstrated cognitive abilities in laboratory studies.

Social Learning:

Many animals learn to solve problems by observing the behavior of other individuals. This type of learning through observation is called social learning.



Figure 72: Social learning in chimpanzees.

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Mating Behaviors and Mate Choice:

Just as foraging behavior is essential for individual survival, mating behavior and mate choice play a key role in determining reproductive success. These behaviors include seeking or attracting mates, choosing among potential partners, competing for mates, and caring for offspring.

Mating Systems and Sexual Dimorphism:



In monogamous species, such as these western gulls (Larus occidentalis), males and females are often difficult to distinguish using external characteristics only.

Among polygynous species, such as elk (Cervus canadensis), the male (right) is often highly ornamented.

In polyandrous species, such as these red-necked phalaropes (Phalaropus lobatus), females (right) are generally more ornamented than males.

Figure 73: Examples of monogamy, polygyny, and polyandry in animals.

Sexual Selection and Mate Choice:

Sexual dimorphism results from sexual selection, a form of natural selection in which differences in reproductive success among individuals arise from differences in their mating success.

Altruism:

Another example of altruistic behavior occurs in honeybee societies, where the workers are sterile. The workers themselves never reproduce but labor on behalf of a single fertile queen. Moreover, the workers sting intruders, a behavior that helps defend the hive but results in the death of the workers themselves.

Reciprocal Altruism:

Some animals sometimes behave altruistically toward nonrelatives. For example, a baboon may help an unrelated companion in a fight, or a wolf may share food with another wolf even though they are not kin. Such behavior can be adaptive if the aided individual later reciprocates the favor.

- Reciprocal altruism is rare among animals and is largely limited to species (such as chimpanzees) with stable social groups, where individuals have many opportunities to exchange acts of aid.

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- It is generally thought to occur when individuals are likely to meet again, and when there are negative consequences for failing to return favors to those who have helped in the past — a pattern of behavior scientists refer to as “cheating.”

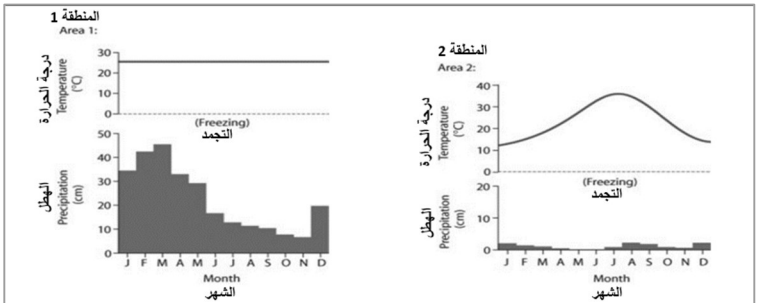
Since cheating can provide great benefits to the cheater, how can reciprocal altruism evolve? Game theory offers a possible answer in the form of a behavioral strategy known as “tit for tat.”

- In the tit-for-tat strategy, an individual treats another in the same way it was treated during their previous interaction.
- Individuals following this strategy are always altruistic or cooperative in their first encounter with another and remain so as long as their altruism is reciprocated.
- When cooperation is not returned, individuals using the tit-for-tat principle retaliate immediately, but they return to cooperative behavior once the other individual resumes cooperation.

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Chapters' Exercises

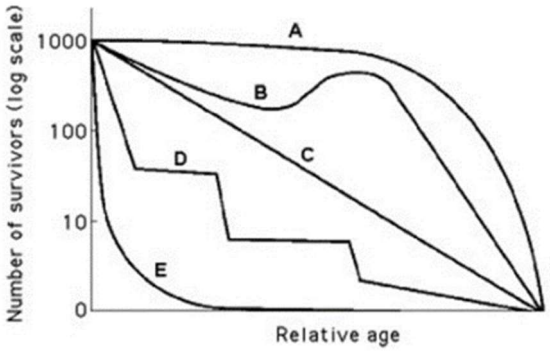
1-	Based on the data in the figures, which of the following statements are correct?



I	Area 1 would be considered a desert because of its high average temperature air temperatures driven by precipitation
II	Area 1 has more average precipitation than Area 2.
III	Area 2 would be considered a desert because of its low average precipitation.
IV	Area 2 has a larger annual temperature variation.

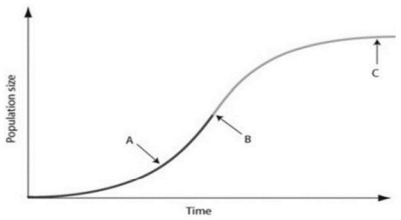
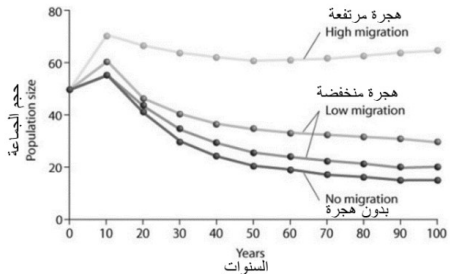
A	B	C	D
only I and III	only II and IV	only I, II, and IV	only II, III, and IV

2-	Which curve best describes survivorship in elephants?

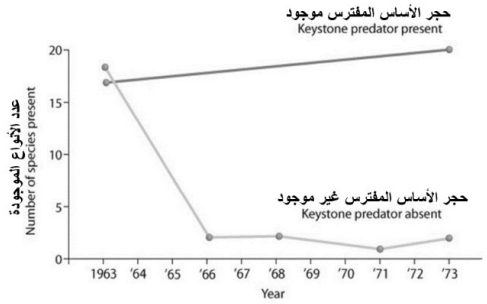


A	B	C	D
A	B	C	E

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3-	In the figure, which of the arrows represents the carrying capacity?		
			
A	B	C	D
A	B	C	cannot be found in the figure
4-	Looking at the figure, what factor is contributing significantly to stabilizing the population size over time? I) no migration II) low migration III) high migration		
			
A	B	C	D
only I	only II	only III	only II & III
5-	As you study two closely related predatory insect species, the two spot and the three-spot avenger beetles, you notice that each species seeks prey at dawn in areas without the other species. However, where their ranges overlap, the two-spot avenger beetle hunts at night and the three-spot hunts in the morning. When you bring them into the laboratory and isolate the two different species, you discover that the offspring of both species are found to be nocturnal. You have discovered an example of _____.		
A	mutualism		
B	character displacement		
C	Batesian mimicry		

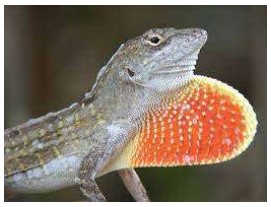
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D	resource partitioning
6-	What does the graph tell you about the effect of a keystone species?
	
A	A keystone species has little interaction with other species in an environment
B	Removing a keystone species from the community drastically reduces species richness.
C	Adding a keystone species to the community will make it more diverse.
D	Removing a keystone species from the community will eventually allow for the invasion of a new species.
7-	Dwarf mistletoes are flowering plants that grow on certain forest trees. They obtain nutrients and water from the vascular tissues of the trees. The trees derive no known benefits from the dwarf mistletoes, nor are they negatively affected by this interaction. Which of the following best describes the interactions between dwarf mistletoes and trees?
A	Mutualism
B	Commensalism
C	Competition
D	Facilitation
8-	If two species are close competitors, and one species is experimentally removed from the community, the remaining species would be expected to._____
A	change its fundamental niche
B	expand its realized niche
C	become the target of specialized parasites
D	decline in abundance
9 -	The symbols +, -, and 0 are used to show the results of interactions between individuals and groups of individuals. The symbol + denotes a positive interaction, denotes a negative interaction, and 0 denotes

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	interactions in which individuals are not affected. The first symbol refers to the first organism mentioned. What interactions exist between a lion pride and African wild dogs, if the dogs are found to typically avoid areas with lions?

A	B	C	D
+/+	+/-	0/0	-/-

10-	A stickleback fish will attack a fish model as long as the model has red coloring. What animal behavior idea is manifested by this observation?
A	sign stimulus.
B	cognition.
C	imprinting.
D	classical conditioning.
11-	A lizard's bobbing dewlap (a colorful flap of skin hanging from an Anolis lizard's throat) is an example of a(n)__
	
A	stimulus.
B	reflex
C	signal
D	innate releasing mechanism.
12-	Listed are several examples of types of animal behavior. Choose the letter of the correct term (A-E) that matches each example in the following questions.
	A operant conditioning B. classical conditioning C. innate behavior D. imprinting E. altruistic behavior

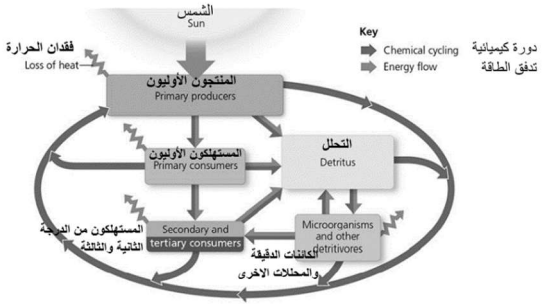
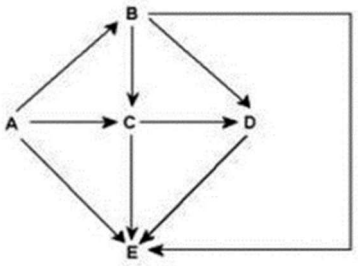
Through trial and error, a rat learns to run a maze without mistakes to receive a food reward.

A	B	C	D

A human baby performs a sucking behavior perfectly when it is put in the presence of the nipple of its mother's breast

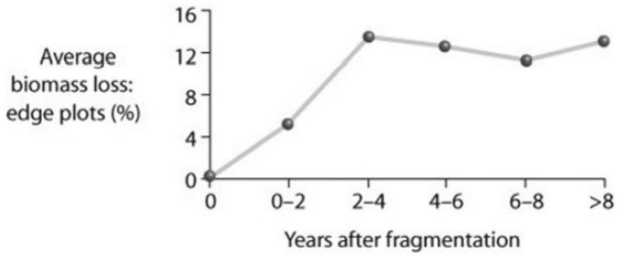
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A	B	C	D
A mother goat can recognize its own kid by smell.			
A	B	C	D
A cat runs to its food dish when it hears the sound of a can opener			
A	B	C	D

13-	To recycle nutrients, an ecosystem must have, at a minimum._____ ,
A	producers.
B	producers and decomposers..
C	producers, primary consumers, and decomposers.
D	producers, primary consumers, secondary consumers, and decomposers.
14-	In the figure, what could the jagged arrow leaving microorganisms and other detritivores represent?
	
A	organic compounds broken down by bacteria.
B	energy consumed by bacteria.
C	energy lost from a worm during cellular respiration.
D	CO2 and heat loss from decomposing materials due to the effects of solar radiation and precipitation.
15-	Food web for a particular terrestrial ecosystem (arrows represent energy flow and letters represent species) Which pair of species could be omnivores?
	

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C	D	C	D
C and D	C and E	C and D	C and E

16-	Which of the following organisms is correctly paired with its trophic level?
A	cyanobacterium—primary consumer
B	grasshopper—secondary consumer
C	phytoplankton—primary producer
D	fungus—primary consumer
17-	Which of the following would be considered an example of bioremediation?
A	adding nitrogen-fixing microorganisms to a degraded ecosystem to increase nitrogen availability
B	using a bulldozer to regrade a strip mine
C	dredging a river bottom to remove contaminated sediments
D	adding fertilizer to soil poor in nutrients to increase plant growth
18-	What is the biological significance of genetic diversity between populations?
A	Genes for traits conferring an advantage to local conditions are unlikely.
B	The population that is most fit would survive by competitive exclusion.
C	Genetic diversity reduces the probability of extinction.
D	Diseases and parasites are not spread between separated populations.
19-	Which of the following criteria have to be met for a species to qualify as invasive?
A	endemic to the area, spreads rapidly, and displaces foreign species.
B	introduced to a new area, spreads rapidly, and displaces native species.
C	introduced to a new area, spreads rapidly, and displaces other invasive species.
D	endemic to the area, spreads slowly, and displaces native species.
20-	Looking at the figure showing the results of forest fragmentation, what can be said about edge effects?
	

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A	Biomass declines along edges of forest fragments
B	Biomass increases along the edges of forest fragments
C	Species diversity decreases along the edges of forest fragments.
D	Fragmentation does not affect biomass

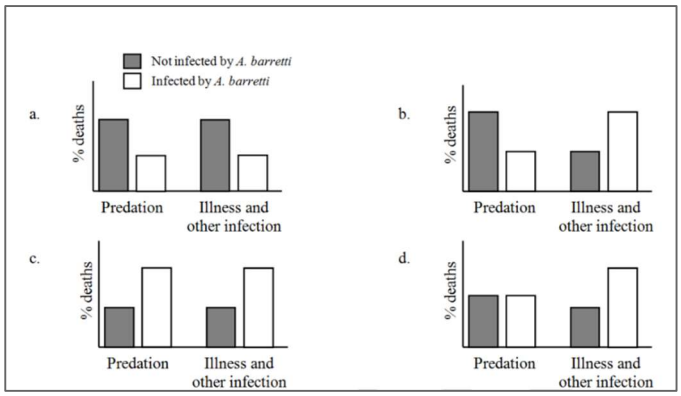
Answer keys for exercises

1	D	11	C				
2	A	12	1	2	3	4	
			A	C	D	B	
3	C	13	B				
4	A	14	C				
5	D	15	D				
6	B	16	C				
7	B	17	A				
8	B	18	C				
9	D	19	B				
10	A	20	A				

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Exam

1- In Northern American swamps, predatory adult mosquito Toxorhynchites rutilus (T. rutilus) preys on the larvae of Aedes triseriatus (A. triseriatus) that are foraging for food. Larvae forage for food by thrashing the water around it, but this makes them more vulnerable to detection by T. rutilus. Data has shown that thrashing behaviour is strongly correlated with larval health and fitness. The parasite Ascogregarina barrette (A. barretti) infects A. triseriatus in the larval stage and completes its life cycle in the pupal stage. This results in weakening of the larval muscles causing the larvae to thrash less for food – thus making them unhealthy. Larval deaths were recorded and categorized into two causes –
(i) predation by T. rutilus
(ii) illness and other infections.
Which graph is most likely to represent the scenario described above?



2- Codling moth Cydia pomonella is a serious pest in agriculture. From time to time, favorable environmental conditions can cause population outbreaks. In an experiment, the minimum and maximum values for the survival to different heat and humidity conditions of codling moth pupa were studied (Tables 1, 2).
Analyze the risk of mass bursts of large numbers of codling moths on the basis of these data in the coordinate space of the two-dimensional ecological niches formed in the zones marked with the letters X and Y (Figure 1). Table 1. 100% mortality of codling moth pupae is observed in the case of the following combinations of temperature and humidity.
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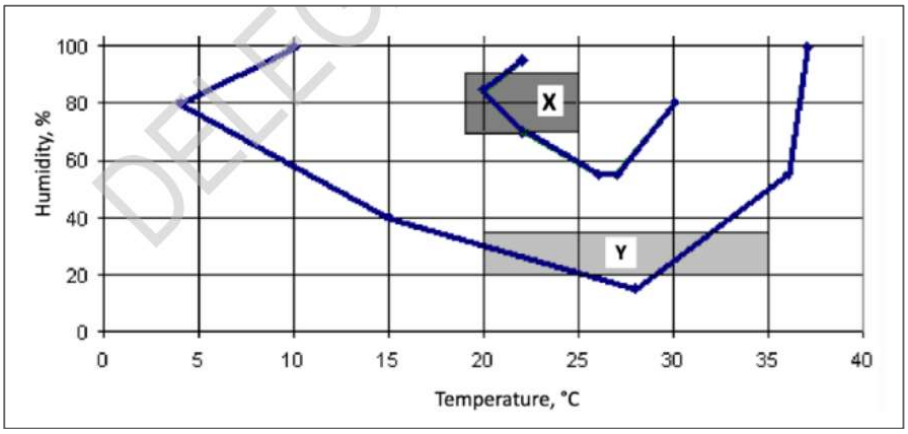
+37	+36	+28	+15	+4	+10	Temperature, C
100	55	15	40	80	100	Humidity, %

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Table 2 The lowest mortality of codling moth pupae (less than 10%) is observed in these combinations of temperature and humidity

+30	+22	+26	+27	+22	+20	Temperature, C
80	70	55	55	95	85	Humidity, %

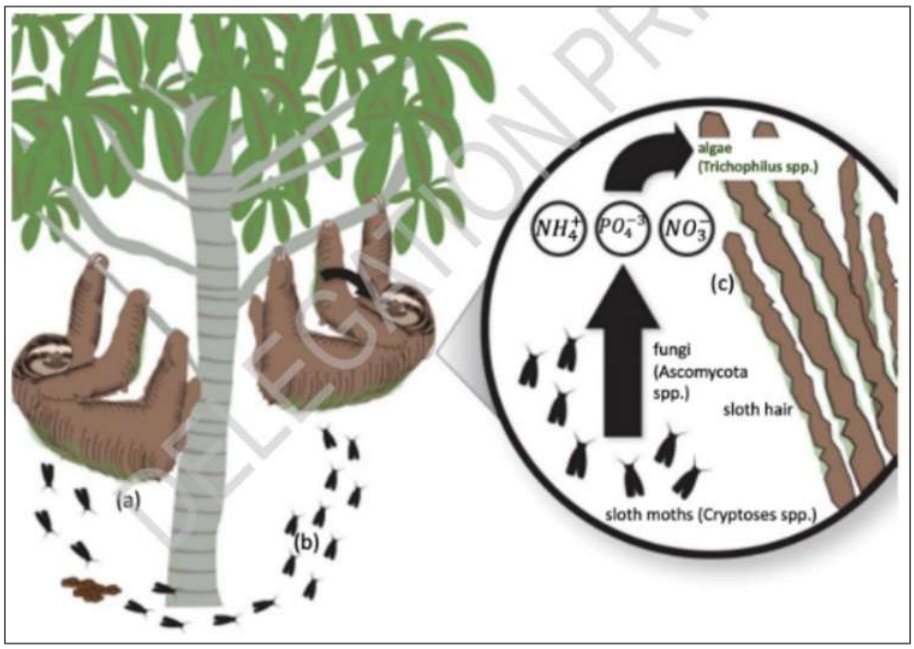
Using this information, which of the following options is correct?



A	Viability of codling moth pupae is low in zone X
B	Zone Y corresponds to the range of 18 – 25 °C air temperature, and 70 – 90% humidity
C	The mortality rate of codling moth pupae is high in area Y
D	20 – 30 °C is optimal for survival of moth pupae if the air humidity is lower than 40%

3- Three-toed sloths Bradypus sp., found in South and Central America, are sluggish animals that spend their entire lives in the foliage of trees (Figure 1), descending to the ground only once a week to defecate Cryptoses choloepi moths live in the fur of sloths (a) and this defends them from the attacks of insectivorous birds. In addition, they move with sloths and lay their eggs on the feces of sloths. The larvae that hatch from the eggs feed on the feces. Adult moths (b) climb up on sloths again. In addition to moths, algae of the genus Trichophyllus(c) grow in the fur of sloths, which when in large quantities, serve as food for sloths. The algae turn the sloth fur color to greenish, making the sloth inconspicuous to enemies, when in the foliage. Ascomycota fungi also grow in the fur of sloths, decomposing dead moth bodies, and producing nutrition for the algae.

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Using this information, which of the following options is correct?

A	The interaction between the sloth and moths is mutualism.
B	moths and fungi, living in sloth fur, have a commensal relationship with the sloth
C	Algae, living on sloth fur, and sloths are amensal.
D	Algae and fungi, living in the fur of sloths, have a Competitive relationship with each other.

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4- An ecologist found a small water body on an isolated island and observed the various organisms present in it. He classified the organisms based on different trophic levels as shown in the table:

Trophic level المستوى الغذائي	Name of Trophic level اسم المستوى الغذائي	Organisms found الكائنات الموجودة
Level 1	Producers منتجات	Phytoplankton عوالق نباتية
Level 2	Primary consumers مستهلكات أولية	Zooplankton عوالق حيوانية
Level 3	Secondary consumers مستهلكات ثانوية	Small planktivorous fish الأسماك الصغيرة آكلة اللحوم

For studying the interactions between the organisms, the ecologist introduced a population of a carnivorous fish (which feed only on other small fish) in the waterbody.

Which of the following statements is correct regarding the long-term consequence of this introduction?

A. There will be an increase in the biomass of autotrophs

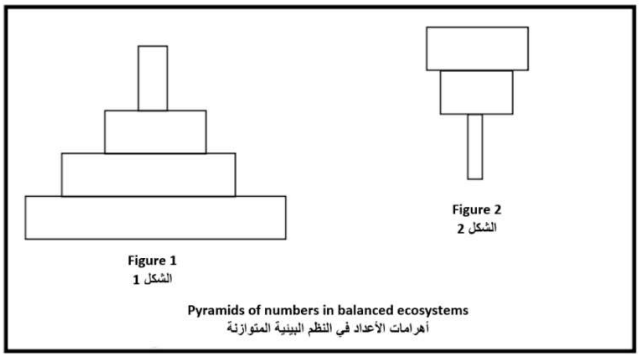
B. There will be a decrease in the biomass of both autotrophs and herbivores

C. There will be an increase in the biomass of herbivores

D. There will be a decrease in the biomass of herbivores and an increase in the biomass of autotrophs

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5- The following ecological pyramids represent the number of organisms involved in feeding relationships:



Choose the LETTER (A, B, C or D) which is most likely to represent the organisms in each of the figures.

	Figure 1 الشكل ١	Figure 2 الشكل ٢
A.	grass → locust → snake → frog ضفدع → ثعبان → جراد → عشب	grass → locust → frog ضفدع → جراد → عشب
B.	tree → ant → spider → lizard سحلية → عنكبوت → نمل → شجرة	tree → bird → parasites طفيليات → طير → شجرة
C.	grass → locust → frog → snake ثعبان → ضفدع → جراد → عشب	phytoplankton → zooplankton → fishes أسماك → عوالق حيوانية → عوالق نباتية
D.	snake → frog → locust → grass عشب → جراد → ضفدع → ثعبان	tree → ant → spider عنكبوت → نمل → شجرة

6-The following statements describe the alarm calls made by animals: Indicate which of the following statements are true using the letter T or false using the letter F

1- Alarm calls put the caller at increased risk of predation by drawing attention to its location.

2- Animals that use alarm calls their genes benefit by allowing others in the group to survive

3- Animals that use alarm calls usually live in colonies with large family groups

4- Alarm calls may be favored by kin selection.

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7- In ecosystems, rate of energy flow and nutrient cycling can determine ecosystem productivity and biodiversity. Which of the following organisms is considered to be effective in both processes

A	Mushroom
B	Camel
C	Date palm
D	Insects

8- the following examples describes a behavioral pattern of animals. Put the appropriate number 1 or 2 under the letter of each behavior pattern.

A) The canary bird sings because the high concentration of testosterone pushes it to do so

B) A male sheep fights with another male because it helps to improve its social position.

C) A male robin attacks a red tennis ball because it confuses it with an encroaching male who will steal his territory..

D) A cat tries to scratch someone who is trying to hold it because the nerve center stimulates the voluntary muscles that move the fingers so that it causes them to scratch..

E) A cat kills a mouse to obtain nutrition

1- *proximate causation* *المسبب القريب*

2- *ultimate causation* *المسبب النهائي*

A	B	C	D	E

9- Suppose that mercury (Hg) is present as a pollutant in an aquatic lake and the following food chain is found:

Phytoplankton → zooplankton → small fish (species X) → larger fish (species Y) → largest fish (species Z) → Aquatic Bird.

Your friend wants to purchase one kg of fresh fish and requests your advice about the least toxic one, which species you will recommend to your friend?

A	B	C	D
(النوع) Species Y	(النوع) Species Z	(النوع) Species X	All have similar toxicity

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10- During a field trip, an instructor touched a moth resting on a tree trunk. The moth raised its forewings to reveal large eyespots on its hind wings. The instructor asked why the moth lifted its wings. One student answered that sensory receptors had fired and triggered a neuronal reflex culminating in the contraction of certain muscles. A second student responded that the behavior might frighten predators. Which statement best describes these explanations?

A	The first explanation is correct, but the second is incorrect.
B	The first explanation refers to proximate causation, whereas the second refers to ultimate causation.
C	The first explanation is testable as a scientific hypothesis, whereas the second is not
D	Both explanations are reasonable and simply represent a difference of opinion.

Answer keys

1	B				
2	C				
3	B				
4	C				
5	C				
6	T	T	T	T	
7	A				
8	A	B	C	D	E
	1	2	2	1	2
9	C				
10	B				

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Chemistry

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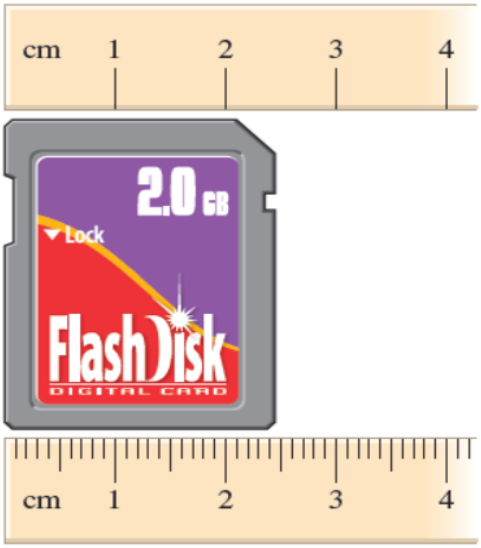
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2	**Chemical Reactions**	• Representing chemical reactions • Word chemical equations • Symbolic chemical equations • Types of Chemical Reactions • Reactions in aqueous solutions • Dissolution of ionic compounds in solutions	12 - 27
3	**Measuring Matter**	• Mass and mole • Relationships between the mole and the chemical formula of compounds • Empirical formula • Molecular formula • Formulas of Hydrates • Naming of Hydrates	28 - 35

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01 Elementary Principles

Significant Figures

An inexact number must be reported in such a way as to indicate the uncertainty in its value, this is done using significant figures. Significant figures are the meaningful digits in a reported number.



Consider the measurement of the memory card "in the adjacent figure" using the ruler above it, The card's width is between 2 and 3 cm. We may record the width as 2.5 cm, but because there are no gradations between 2 and 3 cm on this ruler, we are estimating the second digit. Although we are certain about the number 2 in 2.5, we are not certain about the number 5.

The last digit in a measured number is referred to as the uncertain digit; and the uncertainty associated with a measured number is generally considered to be ± 1 in the decimal place of the last recorded digit. Thus, when we report the width of the memory card to be 2.5 cm, we are implying that its width is 2.5 ± 0.1 cm, and that its actual width may be as low as 2.4 cm or as high as 2.6 cm. Each of the digits in a measured number, including the uncertain digit, is a significant figure. The reported width of the memory card, 2.5 cm, contains two significant figures.

A ruler with millimeter gradations would enable us to be certain about the second digit in this measurement and to estimate a third digit. Now consider the measurement of the memory card using the ruler below it. We may record the width as 2.45 cm. Again, we estimate one digit beyond those we can read. The reported width of 2.45 cm contains three significant figures. Reporting the width as 2.45 cm implies that the width is 2.45 ± 0.01 cm.

Rules of significant figures

(A) Rules for determining how many significant figures are in a number:

(1) Non-Zero digits (1 – 9) and Zeros that are in between two non-zero digits are always significant.

(2) Leading zeroes are never significant.

(3) Trailing zeroes are only significant if a decimal point is present in the number.

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*Examples

	a. 809,231	b. 0.00456	c. 2300	d. 130.00
The explanation	Zero in between DOES count	Leading zeroes do NOT count	Trailing zeros do NOT count	Trailing zeros DO count befor the decimal
The number of significant figures	6	3	2	5

(B) Rules for performing Addition / Subtraction:

The final answer is written so that it has the same number of decimal places as the measurement that has the fewest decimal places.

*Examples

	a. 420.03 + 299.270 + 99.068	b. 504.09 – 246.8 – 119.32
The explanation	This number is the least precise (2 decimal places). So the answer MUST BE rounded to 2 decimal places.	Least Precise
Answer	818.37	138.0

(C) Rules for performing Multiplication / Division:

The final answer is written so that it has the same number of Significant Figures as the measurement with the fewest Significant Figures.

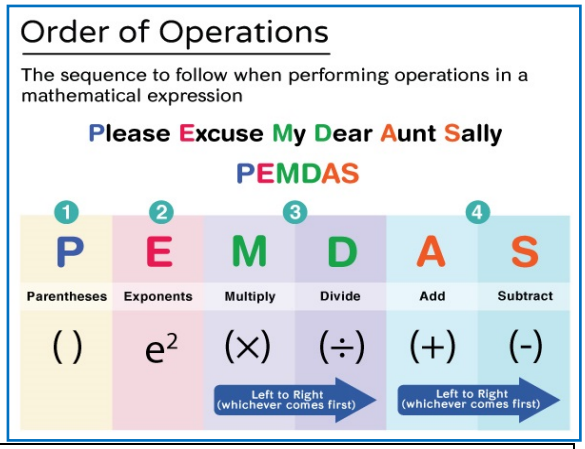
*Examples

	a. (2400)(3.45)(16.21)	b. 0.9935 × 10.48 × 13.4
The explanation	This number only has 2 Significant Figures , so the answer must be rounded to 2 Significant Figures .	Only has 3 Significant Figures, so answer needs rounded to 3 Significant Figures.
Answer	130000 or 1.3×10^5	140. or 1.40×10^2

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(D) Rules for Performing a Combination of Operations:

The previous rules listed for A/S and M/D still apply along with incorporating the rules for order of operations (PEMDAS). Be cautious, however, that you do not round the answer too early.

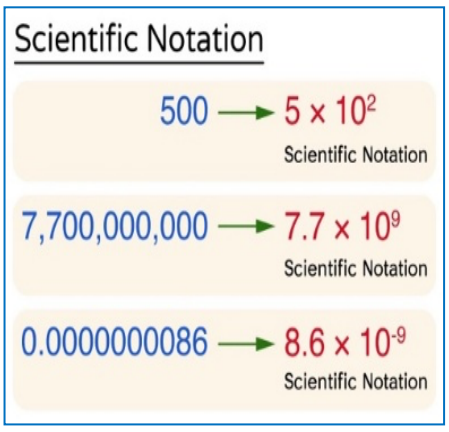


*Example

1.4 × 2.639 + 117.25	
Step 1: Multiply (1.4 × 2.639) + 117.25 (3.6946) + 117.25 Because this is multiplication, the answer to this part can only have 2 Significant Figures (3.7). Make note of this, but do NOT round yet.	(1.4 × 2.639) + 117.25 (3.7) + 117.25 Rounded too early. Should have been left as 3.6946
Step 2: Addition 3.6946 + 117.25 = 120.9946 = 120.9 1 2 decimal place	

Scientific notation

Chemists often deal with numbers that are either extremely large or extremely small. For example, in 1 g of the element hydrogen there are roughly 602,200,000,000,000,000,000,000 hydrogen atoms. Each hydrogen atom has a mass of only 0.00000000000000000000000166 g. These numbers are cumbersome to handle, and it is easy to make mistakes when using them in arithmetic computations. Consequently, when working with very large and very small numbers, we use a system called scientific notation. Regardless of their magnitude, all numbers can be expressed in the form: $N\ 10^n$



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Rounding Off

It is usually necessary to round off the final answer so that it has the proper number of significant figures. To round off a number, follow the procedure below.

Determine the desired number of significant figures

Look at the first digit after the last significant figure

If this digit is less than 5, all the numbers after the last significant figure are dropped

5.6 ≈5.6201

If this digit is equal to 5

5.6501

If this digit is greater than 5, all the numbers after the last significant figure are dropped and the last significant figure is increased by one

5.7 ≈5.6801

If the last significant figureis an odd number, the lastsignificant figureis increased by one

5.8 ≈5.7501

If the last significant figure is an even number, the last significant figure is left unchanged. (Note that zero is considered to be an even number)

5.6 ≈5.6501

If it is followed by additional digits (1-9), the last significant figure is increased by one

5.7 ≈5.6541

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Fundamental and derived units of measurement



International System of Units (SI):

The International System of Units (SI) is the most widely used system of measurement units in the world.

*Examples of Fundamental Units

Quantity	SI unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Amount of substance	mole	mol
Luminous intensity	candela	cd

*Examples of Derived Units

Quantity	SI unit	Symbol
Area	square meter	m^2
Volume	cubic meter	m^3
Density	kilogram per cubic meter	kg/m^3
Force	newton	$N = kg.m/s^2$
Energy	joule	J = N.m



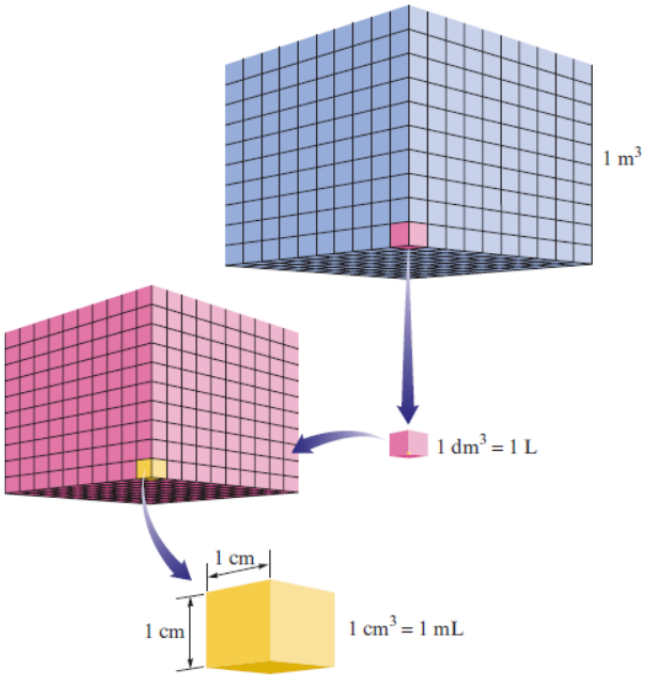
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Prefixes Used in the SI System

Prefix	Symbol	Meaning	Exponential Notation*
exa	E	1,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
—	—	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}

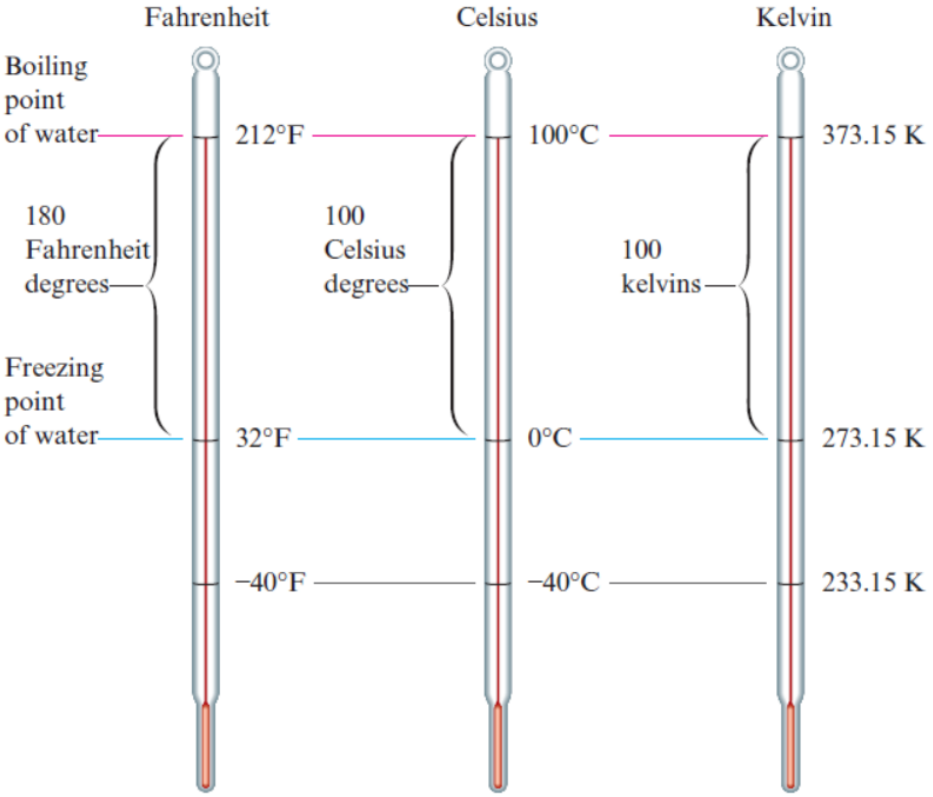
The most commonly encountered prefixes are shown in blue

$1\ L = 1\ (dm)^3 = (10\ cm)^3 = 1000\ cm^3$



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$K = °C + 273.15$



***Examples:**

Example 1-1: convert 2.3 cm^3 to m^3 unit.

$2.3\ cm^3 = 2.3\ (cm)^3 = 2.3\ (10^{-2}\ m)^3 = 2.3 \times 10^{-6}\ m^3$

Example 1-2: convert 5000 μs^{-1} to s^{-1} unit.

$5000\ \mu s^{-1} = 5000\ (\mu s)^{-1} = 5000\ (10^{-6}\ s)^{-1} = 5 \times 10^{9}\ s^{-1}$

Example 1-3: Speed of sound = 330 m/s, convert the unit to km/h.

$$330\ m/s = 330\ \frac{\cancel{m}}{\cancel{s}} \times \frac{1\ km}{1000\ \cancel{m}} \times \frac{3600\ \cancel{s}}{1\ h} = 1188\ km/h$$

Exercises

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(1-1)

State the number of significant digits in each measurement:

1) 2804 m
.....

2) 2.84 km
.....

3) 5.029 m
.....

4) 0.003068 m
.....

5) 4.6×10^{5} m
.....

6) 4.6×10^{-5} m
.....

(1-2)

Round the following numbers as indicated:

3.682417	21.860051	375.6523	112.511	45.4673
.....	.....	.....	.....	.....

(1-3)

Express the following numbers in their equivalent scientific notation:

1) 123,876.3
.....

2) 0.000000000000211
.....

(1-4)

Perform the following mathematical operation and express the result to the correct number of Significant Figures.

$$\frac{(1.00866 - 1.00728)}{6.02205 \times 10^{23}} = \text{.....}$$

(1-5)

The density of Mercury is 13.6 g/cm^3. Convert its unit to Mg/mm^3.

.....

.....

.....

.....

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Exercise answers

(1-1)

1) 2804 m ……4……..

2) 2.84 km ……3……..

3) 5.029 m ……4……..

4) 0.003068 m ……4……..

5) 4.6×10^5 m ……2……..

6) 4.06×10^{-5} m ……3……..

(1-2)

3.682417	21.860051	375.6523	112.511	45.4673
3.682	21.86	375.7	112.5	45.47

(1-3)

1) 123,876.3
1.238763×10^5

2) 0.000000000000211
2.11×10^{-13}

(1-4)

$$\frac{(1.00866 - 1.00728)}{6.02205 \times 10^{23}} = 2.29 \times 10^{-27}$$

(1-5)

1 Mg = 10^6 g , 1 cm^3 = $(10\ mm)^3$ = $10^3\ mm^3$

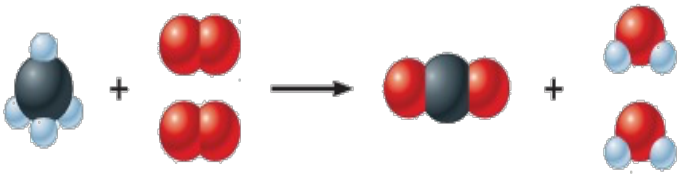
$$13.6\ g/cm^3 = 13.6\ \frac{\cancel{g}}{\cancel{cm}^3} \times \frac{1\ Mg}{10^6\ \cancel{g}} \times \frac{1\ \cancel{cm}^3}{10^3\ mm^3} = 13.6 \times 10^{-9}\ Mg/mm^3$$

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02

Chemical Reactions

A chemical reaction is a process in which a set of starting materials (reactants) is converted into new materials (products) that are completely different in their chemical and physical properties from the original materials.
For example, when methane burns, the chemical bonds in the reactant molecules are broken, and new chemical bonds are formed to rearrange the atoms and produce the product molecules. The key point is that the types of atoms do not change (a carbon atom remains carbon, and a hydrogen atom remains hydrogen); what changes is how they are bonded to one another.



Signs of a Chemical Reaction:

1) **Qualitative evidence (observed by the senses or simple experiments).**

a) Color change.

- Example: When potassium permanganate solution is mixed with some reducing agents, the purple color disappears.
- Explanation: A change in the composition of ions/molecules results in a difference in light absorption.

b) It smells new or different.

- Example: The sulfurous smell resulting from the reaction of some sulfides with acids (H_2S).
- Explanation: Production of gases or volatile compounds with a distinctive odor.

c) gas formation (gas release).

- Example: Effervescence occurs when sodium bicarbonate is mixed with acid, forming CO_2. This can be detected by passing the gas through limewater ($Ca(OH)_2$), where a white turbidity is formed, indicating the presence of CO_2.
- Explanation: The formation of gaseous molecules resulting from the rearrangement of atoms.

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d) Precipitate (a solid that settles out).

- Example: Mixing sodium sulfate solution with sodium chloride solution does not produce a precipitate, but mixing sodium sulfate with barium nitrate produces a white precipitate ($BaSO_4$).
- Explanation: Formation of a new compound with low solubility.

e) Change in energy (change in heat, light, sound).

- Example: Emission of light or sparks: Combustion or strong oxidation reactions.
- Explanation: Change in bond energy — forming new bonds releases energy or absorbing energy to break bonds.

f) Change in electrical conductivity.

- Example: Dissolving an acid or base or a reaction that results in the formation of ions increases or decreases the electrical conductivity of the solution.
- Explanation: The number of Ions in the solution changes.

2) Quantitative evidence.

a) Mass change measurement.

- In a mass-closed reaction, the total mass does not change (law of conservation of mass).
- In open experiments: a loss of mass indicates the release of a gas; a gain in mass may indicate the absorption of a gas (e.g., a metal absorbing oxygen from the air in an oxidation reaction).

b) Heat of reaction measurements.

- Using a calorimeter, the heat released or absorbed can be accurately measured, confirming that an energy transfer has occurred associated with the formation or breaking of bonds.

c) Concentration measurements.

- Tracking the decrease in concentration of one substance and the formation of another using spectroscopy, chromatography, or electrical conductivity measurement provides strong evidence that a reaction has occurred, showing the amount of product produced and the rate of the reaction.

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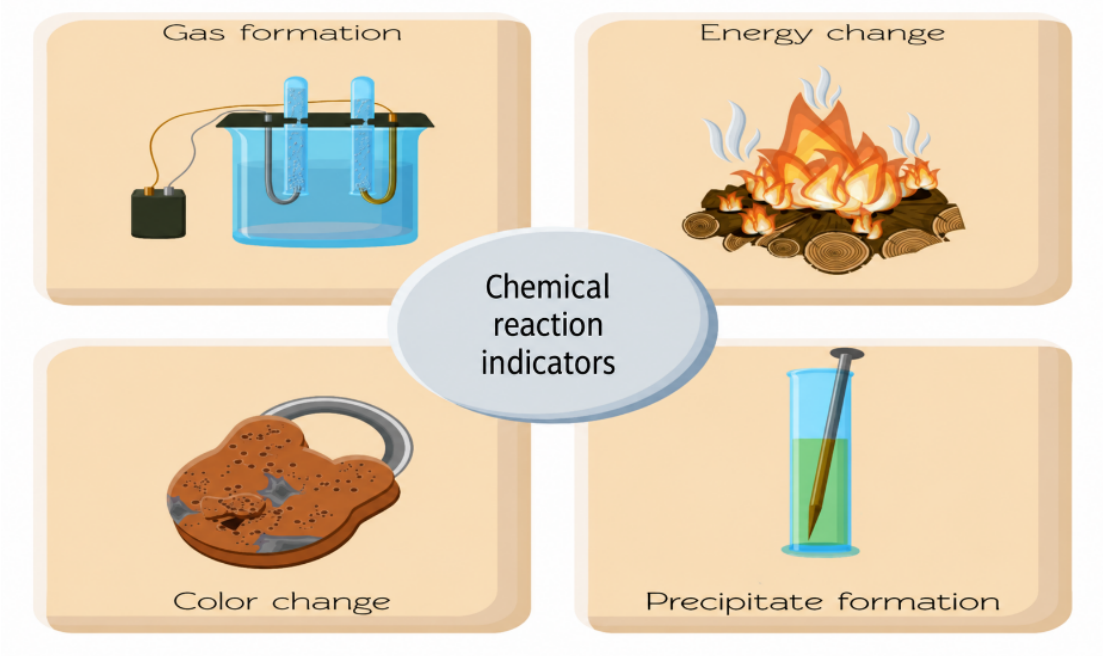


Figure 2-1: Some examples of chemical reactions

Representing chemical reactions

Chemical equations are the basic and most effective tool for representing chemical reactions. They are a universal and concise language used by chemists to describe what happens at the molecular level during a reaction.

The purpose of representing a chemical reaction is:

Representing a chemical reaction is writing a symbolic description of what happens during a reaction, using element symbols, chemical formulas, and arrows instead of writing the reaction out in words.

The basic components of a chemical equation

1) **Reactants**

   These are the starting materials that start the reaction. They are written to the left of the arrow (or to the left of the equal sign in some cases).

2) **Products**

   The new substances that result from the reaction. They are written on the right side of the arrow (or to the right of the equal sign in some cases).

3) **Arrow**

   The arrow (⟶) points from reactants to products, and is usually read as "produces" or "reacts to give."

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Symbols used in equations

Symbol	Meaning	Example
→	Produces or gives. Separates reactants from products and indicates an irreversible, one-way reaction.	A + B → C
⇌	Reversible reaction. Indicates that the reaction reaches equilibrium and occurs in both forward and reverse directions.	A + B ⇌ C + D
+	Reacts with or in addition to. Separates reactants and/or products.	H_2 + O_2
(s)	Refers to the solid state.	NaCl(s)
(l)	Refers to the liquid state.	H_2O(l)
(g)	Refers to the gaseous state.	CO_2(g)
(aq)	Refers to an aqueous solution.	HCl(aq)
Δ or heat	Placed above the arrow. Indicates that the reaction requires heating to occur.	$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
Pressure or pressure value	Placed above the arrow. Indicates that the reaction requires a specific pressure .	$N_2 + 3H_2 \xrightarrow{200\ atm} 2NH_3$
Catalyst, such as Pt	Placed above the arrow. Indicates the use of a catalyst to speed up the reaction without being consumed.	$C_2H_4 + H_2 \xrightarrow{Pt} C_2H_6$
↓ (Precipitate)	Placed after a chemical formula. Indicates the formation of a precipitate, an insoluble solid, in the products.	AgCl↓
↑ (Gas evolved)	Placed after a chemical formula. Indicates the evolution of a gas in the products.	CO_2↑

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Word chemical equations

A word equation is an expression written in words to show the reactants and products of a chemical reaction without using chemical symbols or formulas.

reactant (1) + reactant (2) ⟶ product(1) + product(2)

Example 1:

Methane reacts with oxygen to produce water and carbon dioxide.

Methane +oxygen ⟶ carbon dioxide + water

Exercise (2-1):

Write the word equation for the reaction of bromine gas with hydrogen to produce hydrogen bromide gas. ……

Exercise (2-2):

Write the word equation for the heat decomposition of ammonium nitrate to form nitrous oxide (laughing gas) and water vapor.

.....

Symbolic chemical equations

Symbolic chemical equations are the most accurate and scientific way to represent chemical reactions. These equations use symbols and formulas for elements and compounds, along with numbers written before them called coefficients, to show what is happening at the molecular level.

Coefficient: The number written before a reactant or product. Coefficients are usually integers and are not written if the value is one. Coefficients describe the simplest whole number ratio of the quantities of the reactants and products.

Balancing chemical equations

Balancing chemical equations means making the number of atoms of each element equal on both sides of the equation (reactants and products), so that the law of conservation of mass is achieved, which states that mass can neither be created nor destroyed, but rather is transformed from one form to another.

The importance of balancing

The most important property of a symbolic equation is that it must be balanced. Figure 2-2 shows the steps for balancing chemical equations.

- **Definition:** Balancing an equation means adjusting the coefficients to ensure that the number of atoms of each element is equal on both sides of the equation (the reactants and the products).
- **Goal:** To achieve the law of conservation of mass, which states that mass is neither created nor destroyed in a chemical reaction.
- **Method:** Only the coefficients are changed; subscripts in the formula must not be changed, as this changes the identity of the substance.

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Steps for balancing chemical equations

Steps for Balancing Chemical Equations

Step	Process	Example
1	**Write the unbalanced chemical equation.** Make sure to include the correct formulas for all reactants and products. Identify the different elements and count the number of atoms of each element in the reactants and products.	$H_{2(g)} + Cl_{2(g)} \rightarrow HCl_{(g)}$ Hydrogen molecule, Chlorine molecule, Hydrogen chloride molecule
2	**Count the atoms of each element in the reactants.** In this example, 2 hydrogen atoms and 2 chlorine atoms.	$H_2 + Cl_2 \rightarrow$ 2 H atoms, 2 Cl atoms
3	**Count the atoms of each element in the products.** In this example, 1 hydrogen atom and 1 chlorine atom.	HCl 1 H atom, 1 Cl atom
4	**Change the coefficients to make the number of atoms of each element the same on both sides of the equation.** Do not change the subscripts in the chemical formulas, as this would change the identity of the substance.	$H_2 + Cl_2 \rightarrow 2HCl$ 2 H atoms, 2 Cl atoms, 2 H atoms + 2 Cl atoms 2 H atoms + 2 Cl atoms → 2 H atoms, 2 Cl atoms
5	**Write the balanced equation with the smallest possible whole-number coefficients.** The coefficients should be in the simplest possible ratio. In this example, $2HCl : 1Cl_2 : 1H_2$ is already the simplest ratio, because it cannot be divided further without making the coefficients non-integers.	$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ $1H_2 : 1Cl_2 : 2HCl$ $1 : 1 : 2$
6	**Check your work.** Make sure the chemical equation is balanced correctly and that the number of atoms of each element is the same on both sides.	$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ 2 H atoms, 2 Cl atoms, 2 H atoms, 2 Cl atoms The number of hydrogen atoms and chlorine atoms is the same on both sides of the equation.

Figure 2-2: Steps for balancing chemical equations

Exercise (2-3):

Write the word equation and the symbol chemical equation for the following reaction: When solid potassium chlorate is heated, solid potassium chloride and oxygen gas are produced.

……

……

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Exercise (2-4):

Express the following word equations as balanced symbolic equations:

calcium carbonate + hydrochloric acid → calcium chloride + water + CO_2 ……
potassium hydroxide + sulfuric acid → potassium sulfate + water ……
tin (Ⅱ) sulfate + potassium phosphate → tin (Ⅱ) phosphate + potassium sulfate ……
aluminum + hydrochloric acid → aluminum chloride + hydrogen gas ……

Exercise (2-5):

Balance the following equations:

1) .....$C_2H_4O_2$ + ...O_2 → .....CO_2 + ...H_2O
2) .....$Mn(NO_2)_2$ + ...$BeCl_2$ → .....$Be(NO_2)_2$ + ...$MnCl_2$
3) .....$AgBr$ + ...$GaPO_4$ → .....Ag_3PO_4 + ...$GaBr_3$
4) .....H_2SO_4 + ...$B(OH)_3$ → .....$B_2(SO_4)_3$ + ...H_2O
5) .....$NaNO_3$ + ...PbO → .....$Pb(NO_3)_2$ + ...Na_2O
6) .....$Ca_3(PO_4)_2$ + ... H_2SO_4 → .....$CaSO_4$ + ...H_3PO_4
7) .....Al + ...H_2SO_4 → .....$Al_2(SO_4)_3$ + ... H_2

Types of Chemical Reactions

Chemical reactions vary into several main types, including:

1) **Combustion reactions:** It is a type of rapid chemical reaction that occurs between a reactant and an oxidizing agent (usually atmospheric oxygen), producing energy.

Example 2: the complete combustion of methane (natural gas)

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{Energy}$$

2) **Formation reactions:** the combination of two or more substances to form a new compound.

   The product is always just one compound. This is the clearest indication that a reaction is a synthesis reaction. These are often reactions that release energy in the form of heat and light. This makes sense because bond formation is often accompanied by the release of energy.

General form of the equation:

$$A + B \longrightarrow AB$$

Formation reactions can occur between:

- Two elements to form a compound:

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Example 3: Hydrogen reacts with oxygen to form water.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$$

- Element and compound combine to form a new compound:

Example 4: Sulfur dioxide reacts with oxygen to form sulfur trioxide.

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

- Two compounds combine to form a new, more complex compound.

Example 5: Calcium oxide (quicklime) reacts with water to form calcium hydroxide (slaked lime).

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(s)}$$

3) **Decomposition reactions:** It is a chemical reaction in which one compound breaks down into two or more simpler substances (either elements or simpler compounds). Simply put, it is a "breaking" or "decomposition" reaction.

General form of the equation:

$$AB \longrightarrow A + B$$

Because decomposition reactions involve the breaking of chemical bonds, they often require the addition of energy. This energy can take various forms, such as heat, light, or electricity.

Example 6: Ammonium nitrate decomposes into nitrous oxide and water.

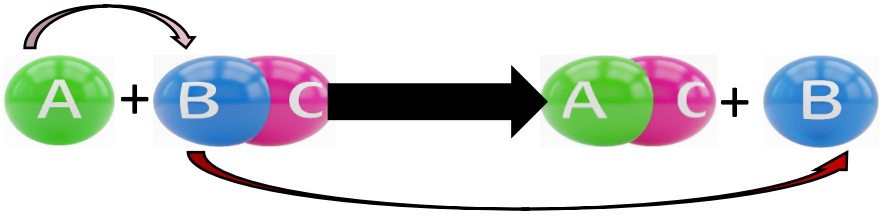
$$NH_4NO_{3(s)} \longrightarrow N_2O_{(g)} + 2H_2O_{(g)}$$

4) **Simple substitution reactions:** substitution of one element for another in a compound.

General form of the equation:

$$A + BC \longrightarrow AC + B$$

In this type of reaction, an active (more reactive) element reacts with a compound, replacing one of the components of that compound (the less reactive element). The result is the formation of a new compound and a free element.



Types of simple substitution reactions:

- **Substitution of one metal for another:**

  It occurs when the free metal is more reactive than the metal in the compound.

Example 7:

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

- **Substitution of hydrogen from acids by a metal:**

Some active metals displace hydrogen in acids.

Example 8:

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

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- **Substitution of a nonmetal for another nonmetal:**

It often occurs among halogens (e.g., F_2, Cl_2, Br_2, I_2).

Example 9:

$$Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$$

A reaction only occurs if the free element is more reactive than the element it will replace. The order of reactivity is known as the chemical activity series. As shown in Figure 2-3.

Metal activity series																				
The lowest		→																	**The highest**	
Au	**Ag**	**Cu**	**Pb**	**Sn**	**Ni**	**Co**	**Fe**	**Cr**	**Zn**	**Mn**	**Ti**	**Al**	**Mg**	**Na**	**Ca**	**Sr**	**Ba**	**Cs**	**K**	**Rb**	**Li**
Nonmetal activity series																				
The lowest		→																	**The highest**	
																	I_2	**Br_2**	**Cl_2**	**F_2**

Figure 2-3: Activity sequence of some elements

Exercise (2-6):

Predict whether each of the following reactions will occur, indicate the products formed, and then weigh them:

1)	$Mg_{(s)} + ZnCl_{2(aq)} \rightarrow$
2)	$F_{2(g)} + 2HCl_{(aq)} \rightarrow$
3)	$Al_{(s)} + AlCl_{3(aq)} \rightarrow$
4)	$Fe_{(s)} + Na_3PO_{4(aq)} \rightarrow$
5)	$2Al_{(s)} + 3Pb(NO_3)_{2(aq)} \rightarrow$

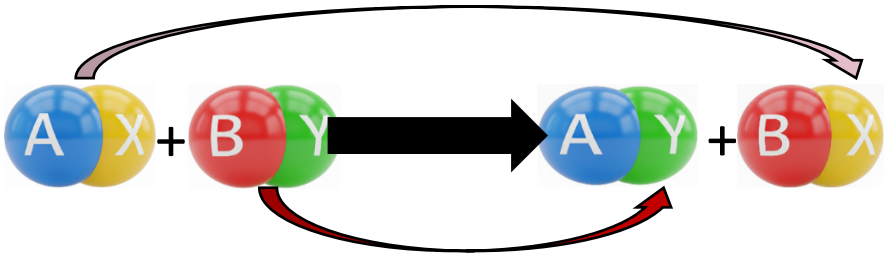
5) Double replacement reactions: the exchange of ions between two compounds to form two new compounds.

General form of the equation:

$$AX + BY \rightarrow AY + BX$$

Where A and B are cations (positive ions) and X and Y are anions (negative ions). In this reaction, both cations exchange places with the corresponding anions to form new compounds.

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Example 10:

$$2NaOH_{(aq)} + CuCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + Cu(OH)_{2(s)}$$

Basic steps for writing balanced chemical equations for double replacement reactions:

Step		Example
1	Write the chemical formula for the reactants.	$Ba(NO_3)_2 + H_2SO_4$
2	Identify the positive and negative ions in each compound.	$Ba(NO_3)_2$ contains Ba^{2+} and NO_3^-. H_2SO_4 contains H^+ and SO_4^{2-}.
3	Match each positive ion with the negative ion in the other compound.	SO_4^{2-} pairs with Ba^{2+}. NO_3^- pairs with H^+.
4	Write the chemical formulas of the products using step 3.	$BaSO_4$ and HNO_3
5	Write the complete chemical equation for the double replacement reaction.	$Ba(NO_3)_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + HNO_{3(aq)}$ Check solubility to confirm that the reaction occurs.
6	Balance the equation.	$Ba(NO_3)_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2HNO_{3(aq)}$

Figure 2-4: Steps for writing double replacement equations

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Exercise (2-7):

Classify the following reactions according to the types you have studied:

	The Equation	Classification
1)	Sulfur trioxide + water → sulfuric acid	
2)	Magnesium + iron(III) chloride → magnesium chloride + iron	
3)	When oxygen fluoride gas is heated, oxygen gas and fluorine gas are produced.	
4)	Hydrogen and oxygen are obtained from water by electrolysis.	
5)	Table salt is obtained from the reaction of sodium and chlorine.	

Reactions in aqueous solutions

Aqueous solution reactions are chemical reactions that occur when the reactants (solutes) are dissolved in water. In these reactions, water acts as the solvent and is the largest component of the solution.

Classification of substances in water:

Compounds dissolved in water are classified based on their ability to dissociate into ions (conductivity of electricity).

Type	Properties	Example
Strong electrolytes	They dissociate or ionize completely in water to form a large number of ions. Most soluble ionic compounds, strong acids, and strong bases are included.	**NaCl** (table salt) **HCl** (hydrochloric acid)
Weak electrolytes	They partially ionize in water to form a small number of ions. Includes weak acids and bases.	CH_3COOH (acetic acid)
Non-electrolytes	They dissolve in water but do not ionize or dissociate into ions, and remain in the form of molecules.	$C_{12}H_{22}O_{11}$ (table sugar)

Dissolution of Molecular Compounds in Aqueous Solutions:

Molecular (or covalent) compounds are substances composed of atoms held together by covalent bonds. When these compounds dissolve in an aqueous solution, they behave in one of two main ways:

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1) Dissolving without ionization (formation of non-electrolytes):

This is the most common behavior of ordinary molecular compounds, especially those not classified as strong acids or bases. As shown in Figure 2-5.

Example 11:

Sugar (sucrose):

$$C_{12}H_{22}O_{11(s)} \xrightarrow{H_2O} C_{12}H_{22}O_{11(aq)}$$

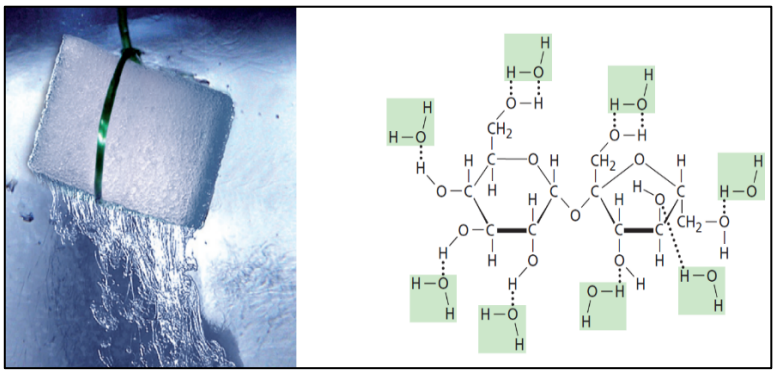


Figure 2-5: Dissolving sugar in water

2) Dissolution with ionization (formation of electrolytes):

In special cases, some polar molecules react with water molecules to form ions. This process is called ionization. As shown in Figure 2-6.

Example 12:

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

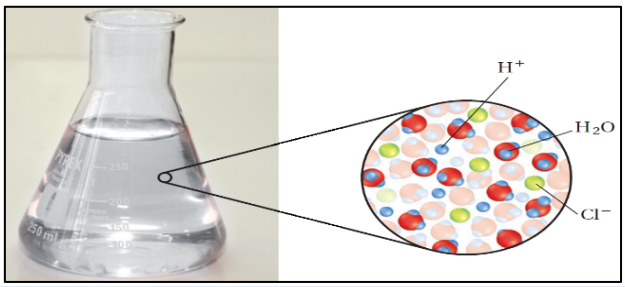


Figure 2-6: Electrolyte solubility in water

Dissolution of Ionic Compounds in Aqueous Solutions

Ionic compounds dissolve in polar solutions (such as aqueous solution) by dissociating into freely moving positive and negative ions. This process is known as dissolution or hydration when the solvent is water. Figure 2-7 shows the process of dissolving table salt in water.

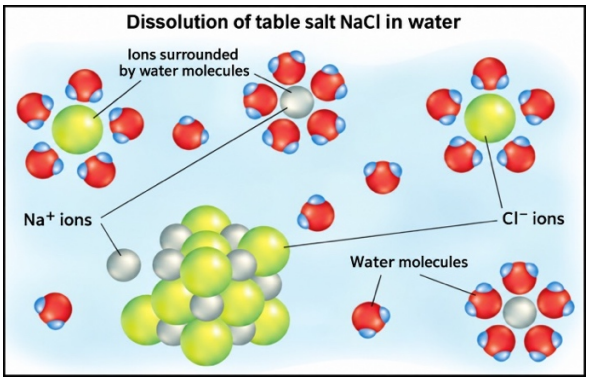


Figure 2-7: Dissolution of ionic compounds in water

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Describing reactions with ionic equations:

Ionic equations are used to describe reactions in aqueous solutions more accurately, especially for strong electrolytes.

1) **Complete (overall) ionic equation:** All strong electrolytes dissolved in water are shown as dissociated ions, while the precipitate, water, or gas (or weak electrolyte) is written in its molecular formula.

Example 13:

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

Write the complete ionic equation for this reaction as follows:

$$Ag^{+}_{(aq)} + NO_3^{-}{}_{(aq)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + Na^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$$

2) **Net (final) ionic equation:** It is obtained by eliminating spectator ions, which are ions that appear unchanged on both the reactant and product sides and do not actually participate in the chemical reaction.

Example 14:

$$Ag^{+}_{(aq)} + NO_3^{-}{}_{(aq)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + Na^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$$

To write the net ionic equation for this reaction, remove the spectator ions:

$$\cancel{Ag^{+}_{(aq)}} + \cancel{NO_3^{-}{}_{(aq)}} + \cancel{Na^{+}_{(aq)}} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)} + \cancel{Na^{+}_{(aq)}} + \cancel{NO_3^{-}{}_{(aq)}}$$

Final result: النتيجة النهائية:

$$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$$

Spectator ions: ions present on both sides of an ionic equation (reactants and products) without undergoing any change in their chemical or physical state.

Types of reactions in aqueous solutions:

A double replacement reaction occurs and is considered complete only if some of the ions are removed from the solution to form one of the following products:

1) **Precipitate formation (Precipitation reactions):**

This is the most common type. The positive and negative ions combine to form an insoluble ionic compound (solid) that separates from the solution. Figure 2-8 shows the process of precipitation of copper(II) hydroxide.

Example 15:

$$2NaOH_{(aq)} + CuCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + Cu(OH)_{2(s)}$$

The complete ionic equation:

$$2Na^{+}_{(aq)} + 2OH^{-}_{(aq)} + Cu^{2+}_{(aq)} + 2Cl^{-}_{(aq)} \rightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + Cu(OH)_{2(s)}$$

Net ionic equation:

$$\cancel{2Na^{+}_{(aq)}} + 2OH^{-}_{(aq)} + Cu^{2+}_{(aq)} + \cancel{2Cl^{-}_{(aq)}} \rightarrow \cancel{2Na^{+}_{(aq)}} + \cancel{2Cl^{-}_{(aq)}} + Cu(OH)_{2(s)}$$

$$2OH^{-}_{(aq)} + Cu^{2+}_{(aq)} \rightarrow Cu(OH)_{2(s)}$$

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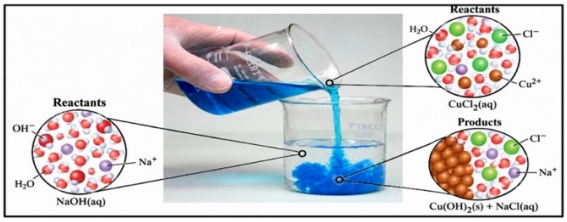


Figure 2-8: Precipitation Reactions

2) Formation of a water molecule (neutralization reactions):

It occurs between an acid and a base. The positive hydrogen ion (H^+) from the acid combines with the negative hydroxide ion (OH^-) from the base to form a neutral water molecule (H_2O). Figure 2-9 shows the process of water formation.

Example 16:

$$HBr_{(aq)} + NaOH_{(aq)} \rightarrow NaBr_{(aq)} + H_2O_{(l)}$$

The complete ionic equation:

$$H^+_{(aq)} + Br^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Br^-_{(aq)} + H_2O_{(l)}$$

Net ionic equation:

$$H^+_{(aq)} + Br^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Br^-_{(aq)} + H_2O_{(l)}$$

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

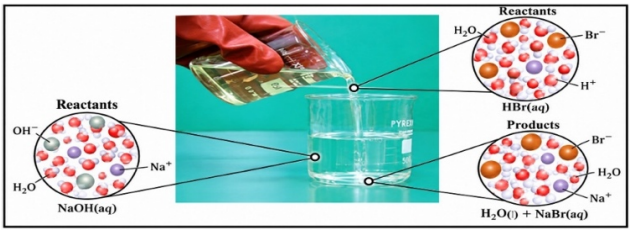


Figure 2-9: Neutralization reactions

3) Gas formation:

One of the products is a gas that leaves the solution. This gas often results from the decomposition of an unstable intermediate compound, such as acetic acid with baking soda (sodium hydrogen carbonate), to produce CO_2 gas.

Example 17:

Chemical equation:

$$NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

The reaction takes place in two stages:

1. $NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2CO_{3(g)}$
2. $H_2CO_{3(g)} \rightarrow H_2O_{(l)} + CO_{2(g)}$

$$NaHCO_{3(aq)} + HCl_{(aq)} + H_2CO_{3(g)} \rightarrow H_2CO_{3(g)} + NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

The complete ionic equation:

$$Na^+_{(aq)} + HCO_3^-{}_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Net ionic equation:

$$Na^+_{(aq)} + HCO_3^-{}_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$HCO_3^-{}_{(aq)} + H^+_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)}$$

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Exercise answers

Exercise (2-1):

Bromine+ hydrogen ⟶ Hydrogen Bromide

Exercise (2-2):

Ammonium nitrate $\xrightarrow{\Delta}$ nitrous oxide + water

Exercise (2-3):

Solid potassium chlorate ⟶Solid potassium chloride + Oxygen gas

$$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$$

Exercise (2-4):

calcium carbonate + hydrochloric acid ⟶ calcium chloride + water + CO_2 $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$
potassium hydroxide + sulfuric acid ⟶ potassium sulfate + water $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$
tin(Ⅱ) sulfate + potassium phosphate ⟶ tin(Ⅱ) phosphate + potassium sulfate $3SnSO_4 + 2K_3PO_4 \rightarrow Sn_3(PO_4)_2 + 3K_2SO_4$
aluminum + hydrochloric acid ⟶ aluminum chloride + hydrogen gas $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

Exercise (2-5):

1) $C_2H_4O_2 + 2O_2 \rightarrow 2CO_2 + 2H_2O$
2) $Mn(NO_2)_2 + BeCl_2 \rightarrow Be(NO_2)_2 + MnCl_2$
3) $3AgBr + GaPO_4 \rightarrow Ag_3PO_4 + GaBr_3$
4) $3H_2SO_4 + 2B(OH)_3 \rightarrow B_2(SO_4)_3 + 6H_2O$
5) $2NaNO_3 + PbO \rightarrow Pb(NO_3)_2 + Na_2O$
6) $Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$
7) $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

Exercise (2-6):

1)	$Mg_{(s)} + ZnCl_{2(aq)} \rightarrow MgCl_{2(aq)} + Zn_{(s)}$
2)	$F_{2(g)} + 2HCl_{(aq)} \rightarrow Cl_{2(g)} + 2HF_{(aq)}$
3)	$Al_{(s)} + AlCl_{3(aq)} \rightarrow NR$
4)	$Fe_{(s)} + Na_3PO_{4aq)} \rightarrow NR$
5)	$2Al_{(s)} + 3Pb(NO_3)_{2(aq)} \rightarrow 3Pb_{(s)} + 2Al(NO_3)_{3(aq)}$

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Exercise (2-7):

	The Equation	Classification
1)	Sulfur trioxide + water → sulfuric acid	Formation
2)	Magnesium + iron(III) chloride → magnesium chloride + iron	Simple substitution
3)	When oxygen fluoride gas is heated, oxygen gas and fluorine gas are produced.	Decomposition
4)	Hydrogen and oxygen are obtained from water by electrolysis.	Decomposition
5)	Table salt is obtained from the reaction of sodium and chlorine.	Formation

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03 Measuring Matter

In chemistry, the term "measurement of matter" refers to the precise determination of the amount of a substance, especially when dealing with chemical reactions that require specific ratios of reactants and products. Because atoms and molecules are so small that they cannot be counted individually, chemists adopted the mole as the basic unit of measurement for "amount of matter" in the International System of Units (SI).

Mole: The standard unit for counting particles (atoms, molecules, ions, or chemical formula units) in chemistry.

Particles	Example
Atoms	Atoms of elements (Fe, Cu, Ag, etc.)
Molecules	Elemental molecules (O_2, F_2, P_4, etc.) and compound molecules (H_2O, CO_2, etc.)
Ions	Monatomic ions (Cl^-, Cr^{2+}, etc.) and polyatomic ions (OH^-, NH_4^+, etc.)
Chemical formula units	Covalent network compounds (SiO_2) and ionic compounds (NaCl, Al_2O_3)

A mole is also defined as the amount of a substance that contains the same number of particles as 12 g of the carbon-12 isotope. This constant is called Avogadro's number (N_A).

$$N_A = 6.02 \times 10^{23}$$

The relationship between moles and the number of particles

Avogadro's number can be used to convert between moles and the number of particles according to the following relationship:

Mathematical relationship:

$$n = \frac{N}{N_A} = \frac{\text{Number of Particles}}{\text{Avogadro Number}}$$

Example 1:

How many moles are there in 5.75×10^{24} atoms of aluminum?

$n = \frac{N}{N_A}$

$n = \frac{5.75 \times 10^{24}}{6.02 \times 10^{23}}$

$n = 9.55$ mol

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Exercise (3-1):

Which of the following options contains the largest number of oxygen atoms?

a) 10.0 mol O_3
b) 3.0 mol O_2
c) 16.0 mol O_2
d) 16.0 mol H_2O

Mass and mole

The mass of one mole is the mass of one mole of a substance, that is, the mass of a sample containing Avogadro's number of particles.

Molar mass (M_m)

The molar mass of an element is the mass of one mole of atoms of that element (g/mol).

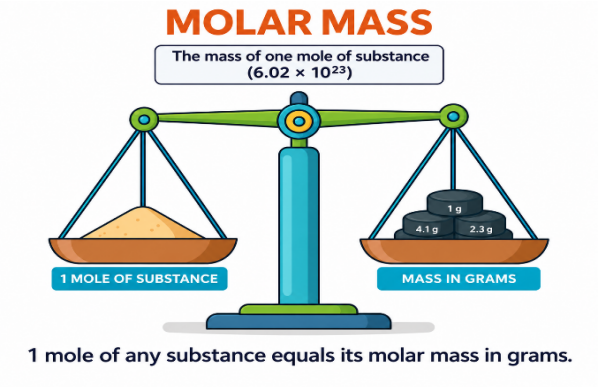


Figure 3-1: Molar mass representation

The molar mass of an element is equal to the relative atomic mass of that element (as found in the periodic table), but in g/mol rather than atomic mass units (amu).

Example 2:

molar mass O_2:

O : 2×16.00 g/mol = 32.00 g/mol

molar mass (M) = 32.00 g/mol

Exercise (3-2):

Which of the following cannot be considered one mole?

a) 65.34 g Zn
b) 26.0 g Fe
c) 6.02×10^{23} Ag atom
d) 6.02×10^{23} O_2molcule

Mathematical relationship:

$$\text{Number of moll} = \frac{mass}{\text{molar mass}}$$

$$n = \frac{m}{M}$$

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Example 3:

Calculate the mass in grams of aluminum Al which has 3.75 mol?

Solution

m = n × M

m = 3.75mol × 27g/mol

m = 101.25g

Exercise (3-3):

What is the molar mass of $C_8H_9NO_2$?

a) 162 g/mol
b) 76 g/mol
c) 151 g/mol
d) 70 g/mol

The relationship between the number of particles and mass

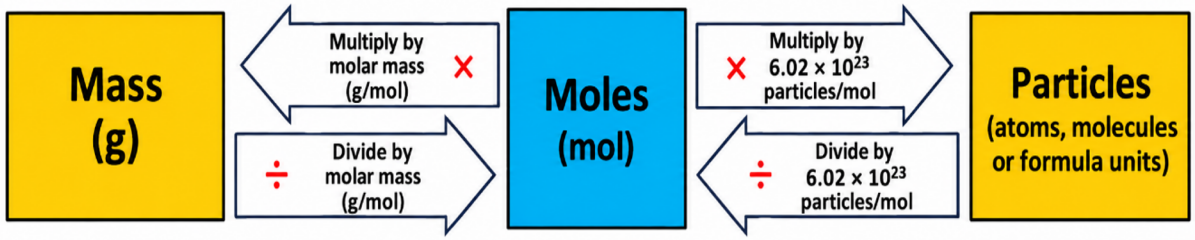


Figure 3-2: Some moles relationships

Example 4:

How many atoms are in 11.5 g of mercury Hg?

Solution

$N = \frac{m}{M} \times 6.02\times10^{23}$

$N = \frac{11.5}{200.6} \times 6.02\times10^{23}$

$N = 3.45\times10^{22}$ atom

Exercise (3-4):

How many moles of ions are present in 2 mol of sodium fluoride NaF?

a) 2 mol
b) 0.5 mol
c) 4 mol
d) 1 mol

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Relationships between the mole and the chemical formula of compounds

The relationship between the mole and the chemical formula of compounds is based on three basic concepts.

- **Molar mass and its relationship to the chemical formula of compounds**

The chemical formula of a compound is used to determine the number of atoms of each element, and then the molar mass of the compound is calculated by adding the atomic masses of all the atoms that make it up as they appear in the formula.

Example 5:

To calculate the molar mass of water (H_2O).

$$H : 2\times1.008 = 2.016 \text{ g/mol}$$

$$O : 1\times16.00 = 16.00 \text{ g/mol}$$

$$M = 2.016 + 16.00 = 18.016 \text{ g/mol}$$

- **Avogadro's number and its relationship to the chemical formula of compounds**

A chemical formula represents the ratio of the number of particles (or moles) of the elements that make up a compound.

Example 6:

1 mole of methane gas (CH_4) contains 6.02×10^{23} molecules of methane. Based on the formula, this mole also contains:

1 mole of carbon (C) atoms (6.02×10^{23} atoms). Because there is only one carbon atom in the formula.

4 moles of hydrogen atoms (H) ($4\times6.02\times10^{23}$ atoms). Because there are only four hydrogen atoms in the formula.

- **Molar ratios and their relationship to the chemical formula of compounds**

The subscripts in a chemical formula indicate the number of moles of atoms per mole of the compound.

Example 7:

What is the molar ratio of carbon dioxide (CO_2)?

The mole ratio of carbon to oxygen is 1 mole to 2 moles per 1 mole of CO_2.

Relative percentage composition of the chemical formula

Percent composition is the percentage by mass of each element in a compound or sample. This percentage is constant for a pure compound, regardless of the sample size.

Mathematical relationship:

$$\text{Mass percentage of an element} = \frac{\text{Mass of element in compound}}{\text{Molar mass of the compound}} \times 100$$

or

$$\text{Percentage by mass} = \frac{\text{Number of atoms of the element} \times \text{Molar mass of the element}}{\text{Molar mass of the compound}} \times 100$$

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Important Note: The sum of the mass percentages of all the elements in a compound must be equal to or very close to 100%.

Example 8:

Determine the percentage composition of carbon dioxide CO_2?

M = (1×C) + (2×O)

M = (1×12.01) + (2×16.00)

M = 44.01g/mol

C% = $\frac{12.01}{44.01}$ × 100

C% = 27.29%

O% = $\frac{2\times16.00}{44.01}$ × 100

O% = 72.71%

Empirical formula

It is a chemical formula that expresses the simplest whole number ratio of the atoms of the elements that make up a compound. It does not represent the actual number of atoms in a molecule. It is often derived from empirical data (observation or experiment). The empirical formula may be the same as the molecular formula of some compounds, such as water (H_2O) and carbon dioxide (CO_2). Figure 3-3 shows a simplified step in the process of finding the initial formula.

Steps to find the empirical formula

	Steps
1	If the data are mass percentages, assume you have a sample with a mass of 100 g. This conversion simplifies the calculations, as the percentage of an element becomes equal to its mass in grams.
2	Convert the masses of elements obtained (either from direct data or after conversion in step 1) to moles. Use the atomic mass of the element to convert its mass to the number of moles.
3	Determine the simplest mole ratio by dividing the number of moles of each element (which you obtained in step 2) by the smallest number of moles between them.
4	If the results in step 3 are integers, skip this step. If they contain decimals, convert them to integers by multiplying all values by the smallest integer that makes them all integers.
5	Write the empirical formula using the integers from steps 3 or 4 as subscripts for the elements in the chemical formula in order.

Figure 3-3: Steps to find the empirical formula

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Example 9:

An organic compound consisting of 40.0% carbon (C), 6.7% hydrogen (H), and 53.3% oxygen (O). (Atomic masses: C = 12.0, H = 1.0, O = 16.0).

Element	Mass (Step 1)	Number of Moles (Step 2)	Mole Ratio (Step 3)	Integers (Step 4)
C	40.0 g	40.0 / 12.0 = 3.33	3.33 / 3.33 = 1.0	1
H	6.7 g	6.7 / 1.0 = 6.7	6.7 / 3.33 = 2.01	2
O	53.3 g	53.3 / 16.0 = 3.33	3.33 / 3.33 = 1.0	1

Since the integers are C = 1, H = 2, O = 1, the empirical formula is CH_2O.

Molecular formula

It is the formula that shows the true composition of the compound, i.e. the number of atoms of each element in the molecule, not the simple ratio between them.

The difference between molecular formula and empirical formula

Comparison	Empirical formula	Molecular formula
Definition	Show the simplest integer ratio between atoms.	Shows the actual number of atoms in a molecule.
Example	CH_2O	$C_6H_{12}O_6$
The relationship between them	Molecular formula = (n × empirical formula)	

How to find the molecular formula:

a) Calculate the empirical formula of the compound.
b) Calculate the molar mass of the empirical formula.
b) Calculate the following ratio:

$$n = \frac{The\ actual\ molar\ mass\ of\ the\ compound}{Molar\ mass\ of\ the\ empirical\ formula}$$

d) Multiply the empirical formula symbols by n to get the molecular formula.

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Example 10:

A compound has the empirical formula CH_2 and a molar mass of 56.12 g/mol. What is its molecular formula?

a) Molar mass of the empirical formula CH_2:

$$(1\times12.01) + (2\times1.01) = 14.03 \text{ g/mol}$$

b) Number of repetition units n:

$$n = \frac{56.12}{14.03} \approx 4$$

c) Molecular formula:

$$(CH_2)\times4 = C_4H_8$$

Formulas of Hydrates

A hydrated salt is a solid ionic compound that contains a specific, definite number of water molecules trapped within its crystal lattice. These water molecules are called "water of crystallization."

An anhydrous salt is the same salt but with all of the water of crystallization molecules removed from it (usually by heating).

The presence of water of crystallization gives the hydrated salt different properties from the anhydrous salt, including color (e.g., copper sulfate changes from aqueous blue to anhydrous white as shown in Figure 3-4).

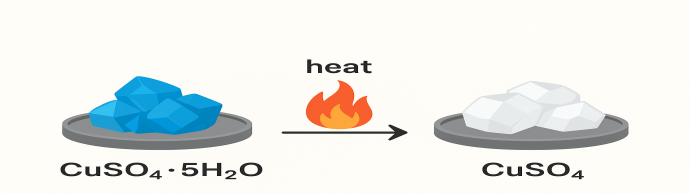


Figure 3-4: Copper sulfate changes from aqueous blue to anhydrous white

The formula for a hydrated salt is written by combining the formula for the anhydrous salt with water molecules, separated by a dot (·).

General formula:

$$\text{anhydrous salt}.\ xH_2O$$

where:

Hydrated salt: The chemical formula of an ionic compound (salt).

x: is an integer (molar) that represents the number of moles of water molecules associated with each mole of salt.

Example 11:

$CuSO_4{\cdot}5H_2O$ Copper(II) Sulfate Pentahydrate

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Naming of hydrates

1. Naming an ionic (anhydrous) salt is the usual way (name the cation then name the anion).
2. Add a syllable to indicate the number of water molecules associated with it using Greek prefixes.
3. Ending the name with the word "water" or "hydrate".

Prefix	Number of Water Molecules	Formula	Name
Monohydrate	1	$(NH_4)_2C_2O_4 \cdot H_2O$	Ammonium oxalate monohydrate
Dihydrate	2	$CaCl_2 \cdot 2H_2O$	Calcium chloride dihydrate
Trihydrate	3	$NaC_2H_3O_2 \cdot 3H_2O$	Sodium acetate trihydrate
Tetrahydrate	4	$FePO_4 \cdot 4H_2O$	Iron(III) phosphate tetrahydrate
Pentahydrate	5	$CuSO_4 \cdot 5H_2O$	Copper(II) sulfate pentahydrate
Hexahydrate	6	$CoCl_2 \cdot 6H_2O$	Cobalt(II) chloride hexahydrate
Heptahydrate	7	$MgSO_4 \cdot 7H_2O$	Magnesium sulfate heptahydrate
Octahydrate	8	$Ba(OH)_2 \cdot 8H_2O$	Barium hydroxide octahydrate
Decahydrate	10	$Na_2CO_3 \cdot 10H_2O$	Sodium carbonate decahydrate

Figure 3-5: Examples of hydrated salts

Exercise answers

Exercise (3-1):

c) 16.0 mol O_2

Exercise (3-2):

b) 26.0 g Fe

Exercise (3-3):

c) 151g/mol

Exercise (3-4):

c) 4mol

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PERIODIC TABLE

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
	I.A																	VIII. A
1.	2.1 **1** **H** 1.0	II. A											III. A	IV. A	V. A	VI. A	VII. A	**2** **He** 4.0
2.	1.0 **3** **Li** 6.9	1.5 **4** **Be** 9.0											2.0 **5** **B** 10.8	2.5 **6** **C** 12.0	3.0 **7** **N** 14.0	3.5 **8** **O** 16.0	4.0 **9** **F** 19.0	**10** **Ne** 20.2
3.	0.9 **11** **Na** 23.0	1.2 **12** **Mg** 24.3	III. B	IV. B	V. B	VI. B	VII. B	VIII. B			I. B	II. B	1.5 **13** **Al** 27.0	1.8 **14** **Si** 28.1	2.1 **15** **P** 31.0	2.5 **16** **S** 32.0	3.0 **17** **Cl** 35.5	**18** **Ar** 40.0
4.	0.8 **19** **K** 39.1	1.0 **20** **Ca** 40.1	1.3 **21** **Sc** 45.0	1.5 **22** **Ti** 47.9	1.6 **23** **V** 50.9	1.6 **24** **Cr** 52.0	1.5 **25** **Mn** 54.9	1.8 **26** **Fe** 55.8	1.8 **27** **Co** 58.9	1.8 **28** **Ni** 58.7	1.9 **29** **Cu** 63.5	1.6 **30** **Zn** 65.4	1.6 **31** **Ga** 69.7	1.8 **32** **Ge** 72.6	2.0 **33** **As** 74.9	2.4 **34** **Se** 79.0	2.8 **35** **Br** 79.9	**36** **Kr** 83.8
5.	0.8 **37** **Rb** 85.5	1.0 **38** **Sr** 87.6	1.3 **39** **Y** 88.9	1.4 **40** **Zr** 91.2	1.6 **41** **Nb** 92.9	1.8 **42** **Mo** 95.9	1.9 **43** **Tc** [98]	2.2 **44** **Ru** 101.1	2.2 **45** **Rh** 102.9	2.2 **46** **Pd** 106.4	1.9 **47** **Ag** 107.9	1.7 **48** **Cd** 112.4	1.7 **49** **In** 114.8	1.8 **50** **Sn** 118.7	1.9 **51** **Sb** 121.8	2.1 **52** **Te** 127.6	2.5 **53** **I** 126.9	**54** **Xe** 131.3
6.	0.7 **55** **Cs** 132.9	0.9 **56** **Ba** 137.3	1.1 **57** **La** 138.9	1.3 **72** **Hf** 178.5	1.5 **73** **Ta** 180.9	1.7 **74** **W** 183.8	1.9 **75** **Re** 186.2	2.2 **76** **Os** 190.2	2.2 **77** **Ir** 192.2	2.2 **78** **Pt** 195.1	2.4 **79** **Au** 197.0	1.9 **80** **Hg** 200.6	1.8 **81** **Tl** 204.4	1.8 **82** **Pb** 207.2	1.9 **83** **Bi** 209.0	2.0 **84** **Po** [209]	2.2 **85** **At** [210]	**86** **Rn** [222]
7.	0.7 **87** **Fr** [223]	0.9 **88** **Ra** [226]	1.1 **89** **Ac** [227]	**104** **Rf** [261]	**105** **Db** [262]	**106** **Sg** [266]	**107** **Bh** [264]	**108** **Hs** [269]	**109** **Mt** [268]	**110** **Ds** [271]	**111** **Rg** [272]	**112** **Cn** [285]	**113** **Nh** [284]	**114** **Fl** [289]	**115** **Mc** [289]	**116** **Lv** [293]	**117** **Ts** [294]	**118** **Og** [294]

EN*
atomic number
Chem. symbol
relative atomic mass

1.1 **58** **Ce** 140.1	1.1 **59** **Pr** 140.9	1.1 **60** **Nd** 144.2	1.1 **61** **Pm** [145]	1.2 **62** **Sm** 150.4	1.2 **63** **Eu** 152.0	1.2 **64** **Gd** 157.3	1.2 **65** **Tb** 158.9	1.2 **66** **Dy** 162.5	1.2 **67** **Ho** 164.9	1.2 **68** **Er** 167.3	1.2 **69** **Tm** 168.9	1.1 **70** **Yb** 173.0	1.2 **71** **Lu** 175.0
1.3 **90** **Th** 232.0	1.5 **91** **Pa** 231.0	1.4 **92** **U** 238.0	1.3 **93** **Np** [237]	1.3 **94** **Pu** [244]	1.3 **95** **Am** [243]	1.3 **96** **Cm** [247]	1.3 **97** **Bk** [247]	1.3 **98** **Cf** [251]	1.3 **99** **Es** [252]	1.3 **100** **Fm** [257]	1.3 **101** **Md** [258]	1.3 **102** **No** [259]	1.3 **103** **Lr** [262]

* EN: electronegativity

المصادر والمراجع العلمية

- وزارة التعليم . سلسلة مقررات الكيمياء في المرحلة الثانوية (نظام المسارات) ، المملكة العربية السعودية ، 2025 .

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Physics

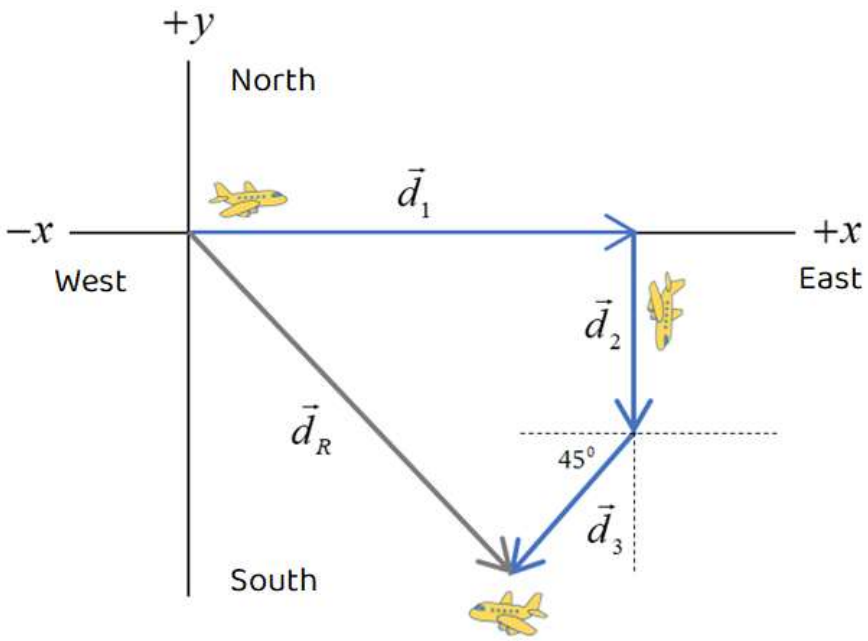
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1 CHAPTER 1: VECTORS



Imagine a plane that makes a trip in three stages, as shown in Fig. First, it flies 400 km east. Then it flies 175 km south. Finally, it flies 170 km at 45° south of west.

Where does the plane end up? If another plane wanted to fly directly from the same starting point to the final position, how far would it need to travel, and in which direction?

Knowing the distances alone is not enough to answer these questions. If we only know that the plane flew 400 km, 175 km, and 170 km, we cannot tell where it ended up. We also need to know the direction of each stage.

Quantities that need both a size (called the magnitude) and a direction are called **vectors**. The change in an object's position, called **displacement**, is one example. In Fig., the displacement of each stage is drawn as an arrow: the length of the arrow represents the magnitude, and the arrowhead shows the direction. The small arrow above a symbol tells us that the quantity is a vector. The gray arrow represents the **resultant displacement**, which is the direct path from the starting point to the final position.

Displacement is not the only vector quantity. Velocity, acceleration, and force are also vectors, and you will meet them throughout physics.

In this chapter, you will learn the basic concepts of vectors and how to work with them. Later in the chapter, we will return to the plane and calculate its resultant displacement.

1.1 SCALAR QUANTITIES

Some physical quantities, such as time, temperature, mass, density, and distance, are completely described by a numerical value and an appropriate unit. These quantities are called **scalar quantities**.

Example: If the outdoor temperature is 25 °C, no direction is required to describe it.

Operations on Scalar Quantities

Scalar quantities of the same type can be combined using ordinary algebraic operations, such as addition and subtraction.

For example: A box contains 2 kg of sugar. If 1 kg of sugar is added, the total mass becomes 3 kg. If 0.5 kg is then removed, 2.5 kg of sugar remains.

1.2 VECTOR QUANTITIES

Some physical quantities cannot be completely described by magnitude alone; their direction must also be specified. These quantities are called **vector quantities**. Examples include displacement, velocity, acceleration, and force.

Example: Knowing the speed of an airplane tells us how fast it is moving, but not the direction of its motion. To describe its motion completely, we use **velocity**, which has both magnitude and direction.

Another example: A force is a push or a pull that affects an object. To describe a force completely, both its magnitude and direction must be specified. For example, stating that a force of 10 N acts on an object is not sufficient unless the direction of the force is also given.

Operations on Vector Quantities

Vector quantities are combined according to the rules of **vector addition**. The resultant vector depends on both the magnitudes and the directions of the vectors.

When two forces act in the same direction, their magnitudes are added. When they act in opposite directions, the smaller magnitude is subtracted from the larger one. If the forces act at an angle to each other, their magnitudes cannot be simply added or subtracted; their directions must also be considered.

Case 1



Case 2

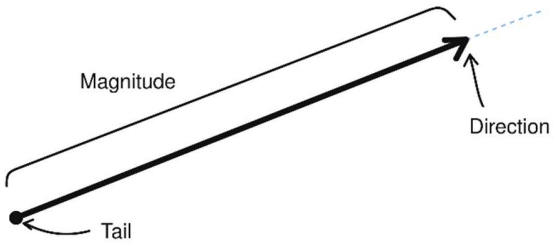


We summarize the difference between scalar and vector quantities in the following table:

Scalar Quantities	Vectors Quantities
Described by a single number and unit.	Described by a magnitude and a direction and unit.
For example: length, mass, time, temperature, and work.	For example: velocity, acceleration, force and displacement.
Follows normal algebraic rules	Requires vector algebra for operations

1.3 VECTOR QUANTITIES REPRESENTATION

Vector quantities such as displacement, force, acceleration, etc. can be represented by an arrow whose length indicates the magnitude, its head to the direction, and its tail marks the starting point of the arrow, as shown in the figure.



The length of the arrow is proportional to the magnitude of the vector quantity. We usually choose an appropriate scale; for example, when representing forces, we might choose one centimeter to represent a force of 5 Newtons. Therefore, if the force is 15 Newtons, the arrow would be 3 cm long.

The direction can be determined using the known cardinal directions: north, east, south, and west, or by using angles.

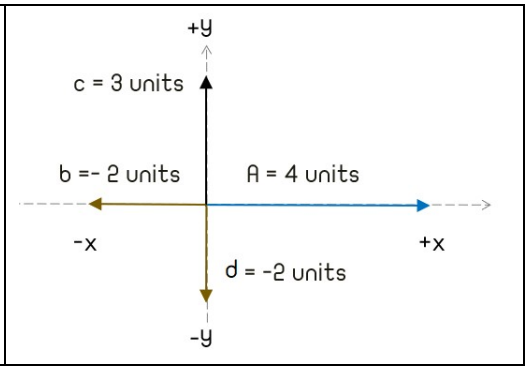
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1.4 VECTOR QUANTITY NOTATION

We usually denote a vector quantity with a letter surmounted by an arrow $\vec{A}$ or with a letter that is typed in bold $\mathbf{A}$. When we put the vector symbol between vertical bars, it means the magnitude of the vector: for example, $|\mathbf{A}| = |\vec{A}| = 5\ units$

Or we write the symbol in italic: for example, $A = 5\ units$

1.5 VECTORS SIGNS.

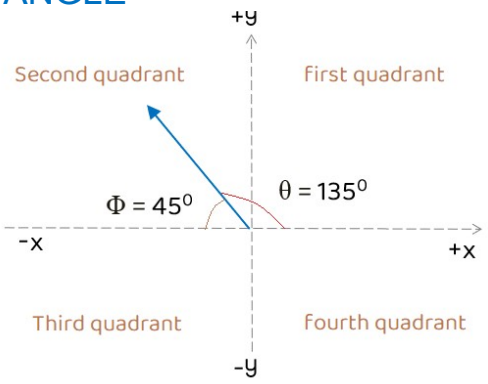
In the xy coordinate plane, the vector is: -with positive sign when it is in the direction of +x or +y -With negative sign when it is in the direction of -x or -y -Without a sign when it is not in the direction of either axis.	

1.6 STANDARD ANGLE AND REFERENCE ANGLE

An angle is usually given for a vector along with its magnitude, without specifying the axis from which it is measured or the direction of rotation. In this case, the angle is called a standard angle.

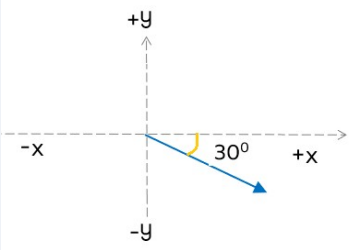
Standard Angle θ: Measured from the +x axis counterclockwise.

Reference Angle Φ: Measured between the vector and one of the axes.



Note the difference between the standard angle and the reference angle for the vector shown in the figure. Note that the standard angle is measured between the vector and the -x axis. The quadrants of the coordinate plane are named as shown in the figure.

Example 1-1



Find the following for the vector shown in the figure

(a) The standard angle.

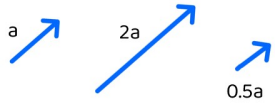
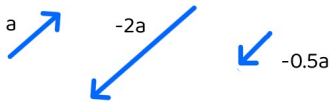
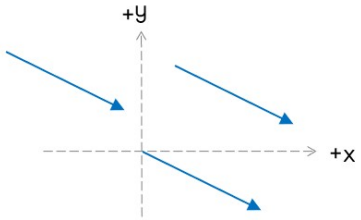
(b) The reference angle with respect to the -y axis.

Solution:

(a) $\theta = 360^0 - 30^0 = 330^0$ (b) $\Phi = 90^0 - 30^0 = 60^0$

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1.7 SOME PROPERTIES OF VECTORS

Multiply a vector by a positive number	Multiply a vector by a negative number
	
The resulting vector: with the same direction but a different magnitude.	The resulting vector: with opposite direction and a different magnitude.
Negative of a Vector	**Vector transport**
	
a and - **a** have the same magnitude as the original vector, but in the opposite direction.	A vector can be moved from one location to another as long as its length and direction remain unchanged. All vectors in the figure above are equal even though they have different starting points.

Example 1-2

Represent each of the following displacement vectors on the coordinate grid. Use the scale:

1 grid square = 1 cm

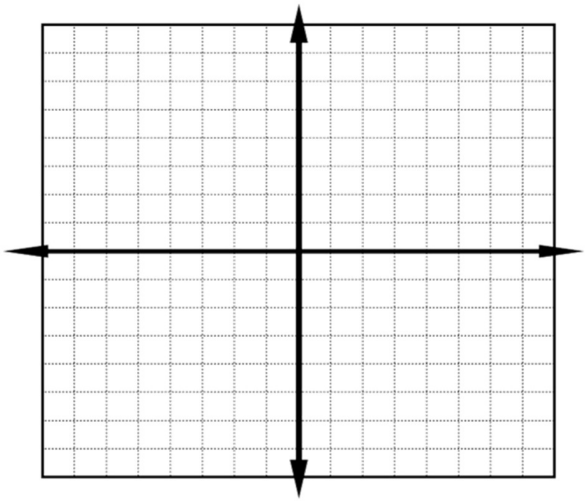
(a) $\boldsymbol{d_1} = 3$ cm eastward.

(b) $\boldsymbol{d_2} = 2$ cm southward.

(c) $\boldsymbol{d_3} = 4$ cm northeastward.

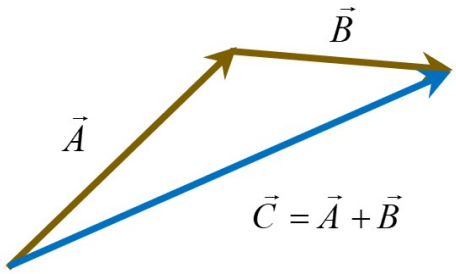
(d) $\boldsymbol{d_4} = 3$ cm, directed $30°$south of east.

(e) $\boldsymbol{d_5} = 2$ cm, with a direction angle of $210°$, measured counterclockwise from the positive x-axis.



1.8 ADDING VECTORS

Suppose an object first moves through displacement $\vec{A}$ and then through displacement $\vec{B}$. The result will be as if it moved straight from the starting point to the end point which represents the vector $\vec{C}$ (the final displacement). The resultant connects the original starting point directly to the final point.



We call the vector $\vec{C}$ the resultant vector or the sum, the resultant can be written as follows: $\vec{C} = \vec{A} + \vec{B}$

We cannot generally add the magnitudes directly.

1.9 ADDING VECTORS IN ONE DIMENSION (COLLINEAR VECTORS)

It is easy to calculate the resultant of a set of vector quantities when their direction is on the same dimension (line), whether they are in the same direction or in opposite directions, provided that they are of the same type, for example: successive displacements made by one object, or a set of forces acting on one object at the same time.

Adding Collinear Vectors

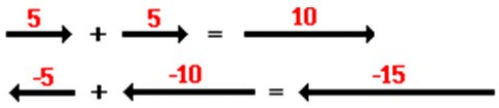
- Vectors in the Same Direction

Resultant magnitude:

The sum of the magnitudes of the vectors.

Resultant direction:

The same direction as the original vectors.



- Vectors in Opposite Directions

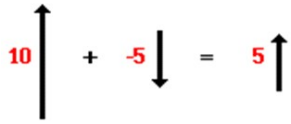
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Resultant magnitude:

The difference between the larger and smaller magnitudes.

Resultant direction:

The direction of the vector with the greater magnitude.



If the vectors have equal magnitudes, the resultant is zero.

- Algebraic Addition

To add collinear vectors algebraically, first choose a positive direction. Assign a positive sign to vectors pointing in that direction and a negative sign to vectors pointing in the opposite direction. Then add the signed values.

The magnitude of the resultant is the absolute value of the algebraic sum, while its sign indicates its direction.

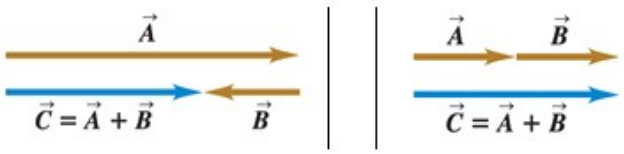
Alternatively:

- For vectors in the same direction, add their magnitudes.
- For vectors in opposite directions, subtract the smaller magnitude from the larger one. The resultant points in the direction of the vector with the greater magnitude.

Tow vectors $\vec{A}$ and $\vec{B}$ in one dimension

Note that the resultant $\vec{C}$ is always written as follows:

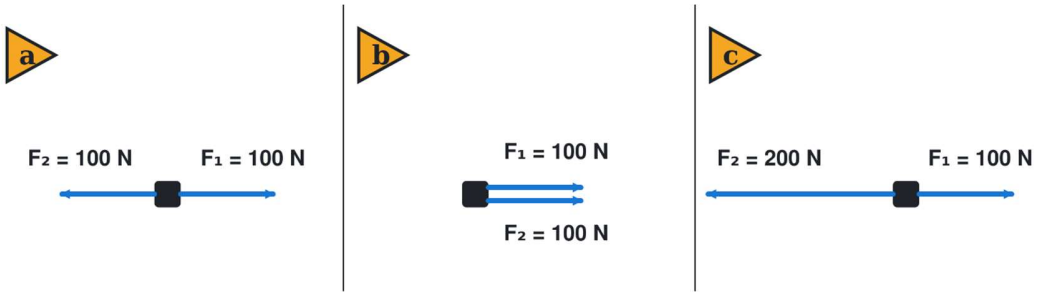
$$\vec{C} = \vec{A} + \vec{B}$$



While the method of calculating its value differs in both cases.

Example 1-3

Three pairs of forces act on an object in three different cases. find the magnitude and direction of the resultant force in each case.

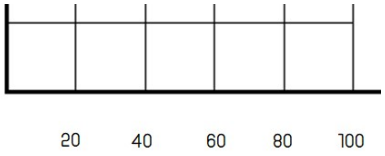


Solution:

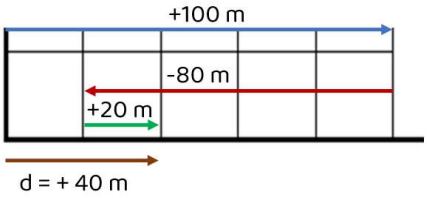
Case	Resultant
a	∑F = 100 – 100 = 0. A zero resultant has no defined direction.
b	∑F = 100 + 100 = 200 N The resultant sign is positive; therefore, the direction is positive (east).
c	∑F = 100 - 200 = -100 N The resultant sign is negative; therefore, the direction is negative (west).

Example 1-4

A whale swims 100 m eastward, then 80 m westward, then 20 m eastward. Calculate its final displacement (resultant displacement).



Solution: By representing the displacements on the diagram, and considering the eastward direction as positive and the westward direction as negative, the final displacement can be calculated as:



d = 100 – 80 + 20 = 20 + 20 = 40 m. Since the sign of the resultant displacement is positive, its direction is eastward.

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Example 1-5

Two forces of magnitudes 10 N and 20 N act on a single object. Which of the following could be the value of their resultant?

(a) 7 N (b) 9 N (c) 13 N (d) 32 N (e) Answers B and C

Solution:

The highest possible value of the resultant force: when the two forces are in the same direction:

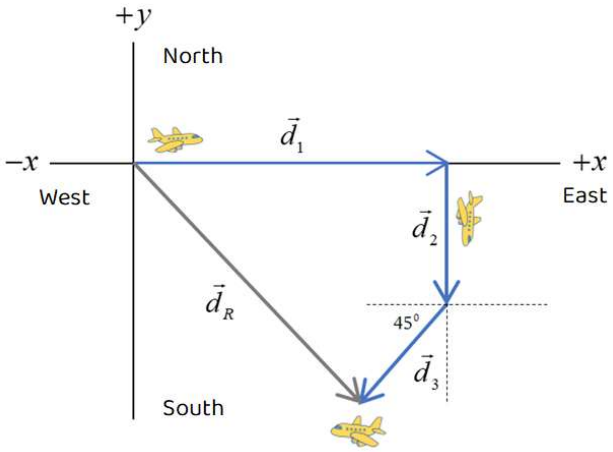
20 N + 10 N = 30 N . The lowest possible value of the resultant force: when the two forces are in opposite directions: 20 N - 10 N = 10 N . Possible values of the resultant force: from 10 N to 30 N, meaning the correct answer is: C

When the resultant force is greater than 10 N and less than 30 N, it means that the two forces do not act at the same dimension (line).

1.10 ADDING VECTORS IN TWO DIMENSIONS

In many cases, the vector quantities whose sum we want to find do not act in one dimension; that is, their directions are not along the same line.

For example, consider the airplane flight we discussed at the beginning of the chapter.



Note that the airplane made three displacements, and the resultant of these displacements, or the final displacement, can be defined as follows:

- A straight vector from the starting point of the motion to its endpoint.
- Or: A vector from the tail of the first displacement arrow to the head of the last displacement arrow, provided that the tail of each displacement arrow starts from the head of the preceding displacement arrow. We write the resultant displacement $\overrightarrow{d_R}$ as follows: $\overrightarrow{d_R} = \overrightarrow{d_1} + \overrightarrow{d_2} + \overrightarrow{d_3}$

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However, this does not mean that the magnitude of $\overrightarrow{d_R}$ is simply the algebraic sum of the three displacements.

By using an appropriate scale, we can determine the magnitude and direction of the resultant displacement (the sum of displacements). This method of adding vectors is known as the graphical method of vector addition.

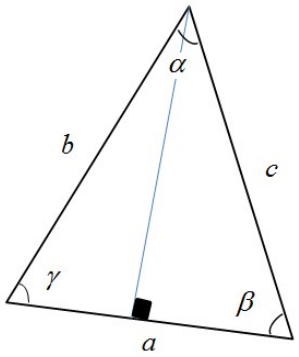
1.11 TRIANGLE

The lengths of the sides and angles of the triangle are shown in the figure. The relationship between the angles of the triangle: $\alpha + \beta + \gamma = 180^0 = \pi\, rad$

The relationships between the lengths of the sides of the triangle: $a < b + c$ $b < a + c$ $c < a + b$

The perimeter of the triangle: $C = a + b + c$

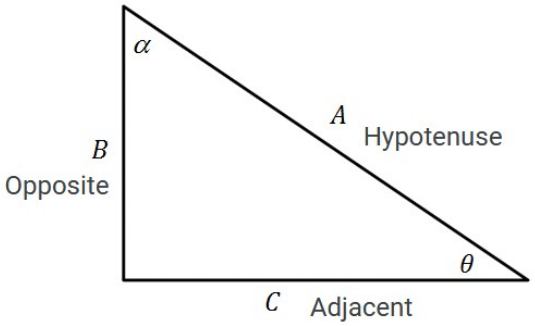
The area of the triangle: $A = \frac{1}{2}ah$, where h is the height.



1.12 TRIGONOMETRIC FUNCTIONS

We use the Pythagorean theorem to find the length of the third side of a right-angled triangle in terms of the lengths of the other two sides, using the formula: The square of the length of the hypotenuse = the sum of the squares of the length of the other two sides:

$A^2 = B^2 + C^2$ Remember that the hypotenuse is the longest side of a right-angled triangle and corresponds to the 90° angle



But can we use the length of a side and an angle to find the lengths of the remaining sides of the triangle? We can do this simply using trigonometric functions, which we will write for the angle θ shown in the figure: where the sides are labeled as follows: B: opposite because it is opposite angle θ; C: adjacent because it is adjacent to angle θ. The hypotenuse A is not called an adjacent. The basic trigonometric functions are:

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Sine function	Cosine function	Tan function
$sin\theta = \frac{Opposite}{Hypotenuse} = \frac{B}{A}$	$cos\theta = \frac{Adjacent}{Hypotenuse} = \frac{C}{A}$	$tan\theta = \frac{Opposite}{Adjacent} = \frac{B}{C}$

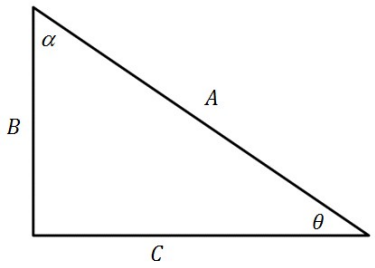
Note that: $tan\theta = \frac{sin\theta}{cos\theta}$

Concept check: Write the trigonometric functions of the angle in figure.

Basic angles

	0^0	90^0	180^0	270^0	30^0	60^0	45^0
$\sin\theta$	0	1	0	–1	$\frac{1}{2}$	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$
$\cos\theta$	1	0	–1	0	$\frac{\sqrt{3}}{2}$	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$
$\tan\theta$	0	∞	0	∞	$\frac{\sqrt{3}}{3}$	$\sqrt{3}$	1

Example 1-6



B = 6 cm ، $\theta = 30^0$ Find the length of the sides A and C if

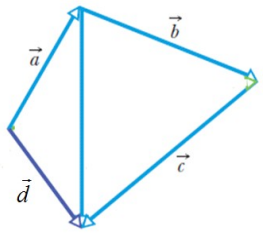
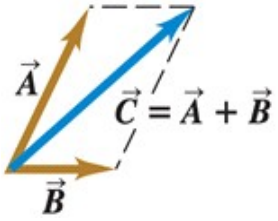
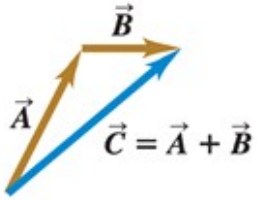
Solution:

$$sin\theta = \frac{Opposite}{Hypotenuse} = \frac{B}{A} \qquad A = \frac{B}{sin\theta} = \frac{6}{0.5} = 12\ cm$$

$$C^2 = A^2 - B^2 = 144 - 36 = 108 \qquad C = \sqrt{108} = 10.4\ cm$$

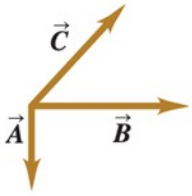
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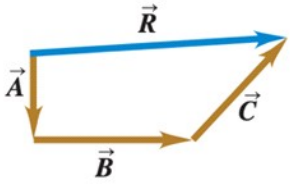
1.13 GRAPHICAL ADDITION OF VECTORS

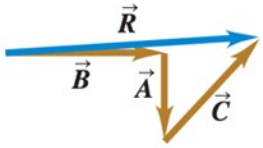
Polygonal Method	Parallelogram Method	Tail to Head Method
		
$\vec{d} = \vec{a} + \vec{b} + \vec{c}$ We draw the vectors sequentially so that the tail of each vector starts from the head of the preceding vector. The resultant vector is a vector from the first tail to the last head.	We draw the two vectors $\vec{A}$ and $\vec{B}$ so that they have a common tail and complete the parallelogram. The resultant $\vec{C}$ is the diagonal of a parallelogram with the same tail.	Draw the tail of the second vector $\vec{B}$ from the head of the first vector $\vec{A}$, The resultant is $\vec{C}$: a vector from the first tail to the last head.

Think: in Previous figure, what if vector $\vec{A}$ starts from head of vector$\vec{B}$, do we get a different resultant vector?

Think: figures show two methods that can be used to find the resultant $\vec{R}$ of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ Note that the way the vectors are ordered does not change the final resultant.



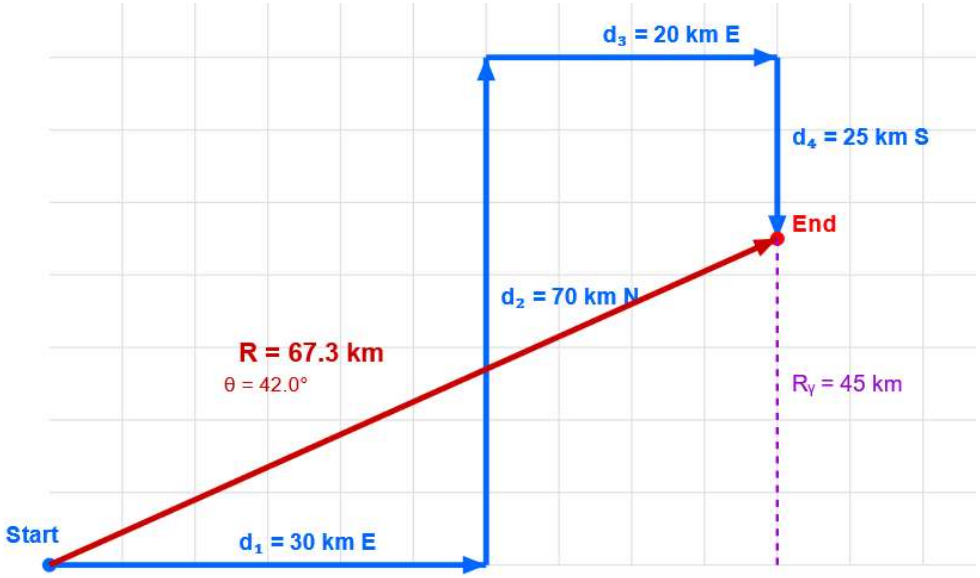




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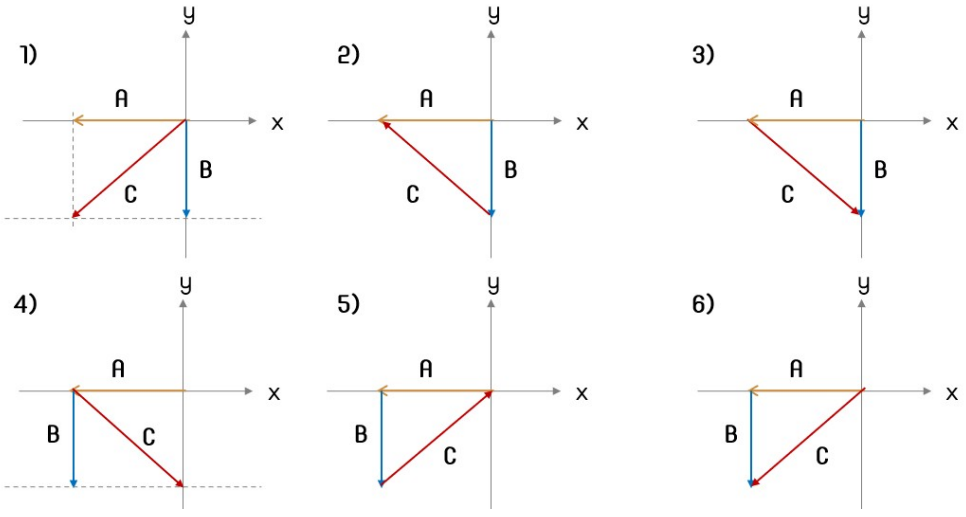
Example 1-7

A car moved 30.0 km east, then turned 70.0 km north, then turned east again and moved 20.0 km, then headed 25.0 km south. Use the coordinate plane to represent the motion of the car and then find the displacement.



Example 1-8

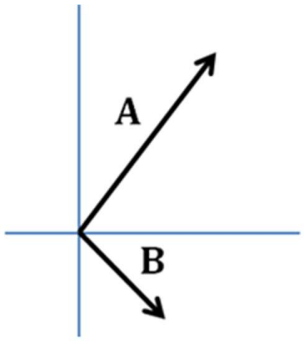
Which of the following diagrams is correct in finding the resultant?



Solution: Choice 1: Parallelogram Method and choice 6: tail to head Method.

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Concept check: In Fig. draw: $\boldsymbol{A+B}$ and $\boldsymbol{A-B}$

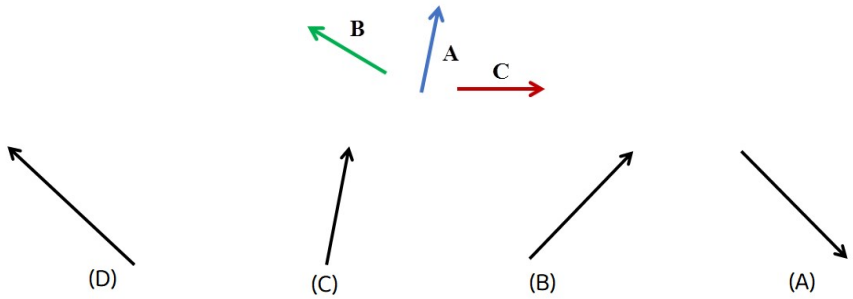


Concept check:

What is the relationship between two vectors $\boldsymbol{A}$ and $\boldsymbol{B}$ IF: $|\boldsymbol{A+B}| = |\boldsymbol{A-B}|$?

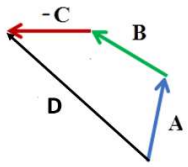
Example 1-9

if $\mathbf{D = A + B - C}$, Which of the following figures represents vector $\boldsymbol{D}$?



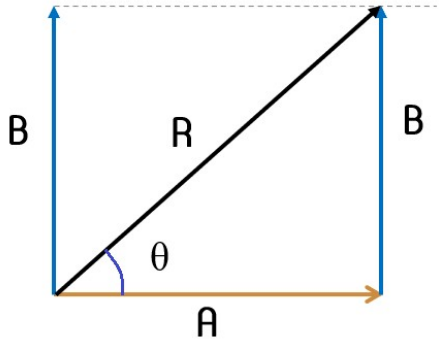
Solution:

By using the polygon method, the correct choice is D. Note in the diagram that vetor -**C** has the same magnitude as vector **C** but in the opposite direction.



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1.14 ADDING PERPENDICULAR VECTORS



When we have two perpendicular vectors **A** and **B**, meaning the angle between them is 90°, note that the resultant vector **R** forms the hypotenuse of a right-angled triangle, whose two right sides are vectors **A** and **B**.

We use the following to find the resultant vector:

The value (from the Pythagorean theorem):

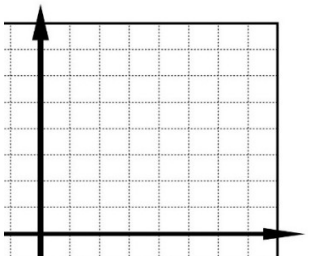
$$R = \sqrt{A^2 + B^2}$$

Direction: From trigonometric functions:

$$tan\theta = \frac{\text{المقابل}}{\text{المجاور}} = \frac{B}{A}$$

Example 1-10

A car travel 3.0 km east and then 4.0 km north. Find the resultant displacement. Illustrate with a drawing



Solution:

Let the eastward displacement be $\vec{A} = 3.0$ km(east), and the northward displacement be $\vec{B} = 4.0$ km(north).

Resultant: $\vec{R} = \vec{A} + \vec{B}$.

1) Magnitude: Since the displacements are perpendicular:

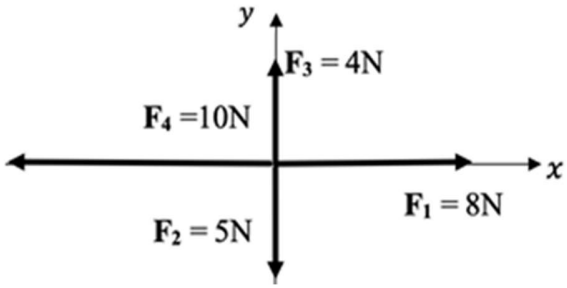
$$R = \sqrt{A^2 + B^2} = \sqrt{(3.0\text{ km})^2 + (4.0\text{ km})^2} = 5.0\text{ km}$$

2) Direction: Angle measured north of east:

$$\theta = \tan^{-1}\left(\frac{B}{A}\right) = \tan^{-1}\left(\frac{4.0\text{ km}}{3.0\text{ km}}\right) \approx 53.1°$$

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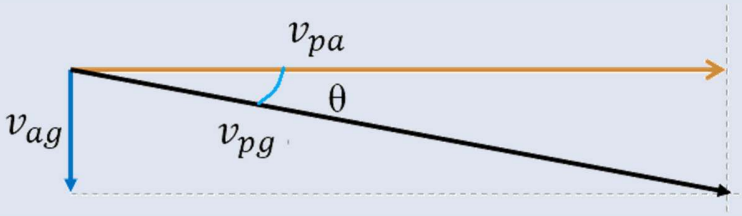
Exercise: Find the resultant of the coplanar force system shown in Fig.



Example 1-11

An airplane is flying due east at 500.0 km/h relative to the air. A wind is blowing due south at 90.0 km/h. Find the airplane's speed and direction relative to the ground.

Solution



The airplane's velocity relative to the ground is the vector sum of its velocity relative to the air and the velocity of the air relative to the ground:

$$\vec{v}_{pg} = \vec{v}_{pa} + \vec{v}_{ag}$$

Since the two velocities are perpendicular, the airplane's speed relative to the ground is:

$$v_{pg} = \sqrt{(v_{pa}^2 + v_{ag}^2)}$$
$$v_{pg} = \sqrt{(500.0^2 + 90.0^2)}$$
$$v_{pg} = 508 km/h$$

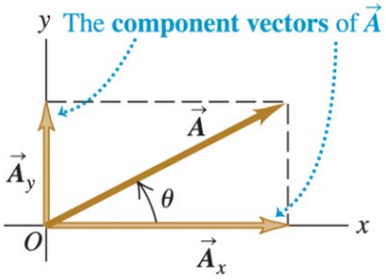
The ground velocity makes an angle θ south of east:

$$tan\theta = v_{ag}/v_{pa}$$
$$\theta = tan^{-1}(90.0/500.0)$$
$$\theta = 10.2°$$

Therefore, the airplane is moving relative to the ground at: 508 km/h, 10.2° south of east.

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1.15 COMPONENTS OF A VECTOR



Any vector, such as vector $\vec{A}$ in the figure, can be resolved into its components, which are its projections onto the axises.

How do we plot the components of vector $\vec{A}$?

From the head of vector $\vec{A}$, we project a line perpendicular to the x-axis. The x-component of vector $\overrightarrow{A_x}$ is a vector from the tail of vector $\vec{A}$ to the point where the perpendicular line intersects the x-axis.

From the head of vector $\vec{A}$, we project a line perpendicular to the y-axis. The y-component of vector $\overrightarrow{A_y}$ is a vector from the tail of vector $\vec{A}$ to the point where the perpendicular line intersects the y-axis.

The components can be calculated by trigonometric functions, noting that vector $\vec{A}$ makes a standard angle θ with the x-axis:

$$cos\theta = \frac{A_x}{A} \qquad A_x = Acos\theta$$

$$sin\theta = \frac{A_y}{A} \qquad A_y = Asin\theta$$

This is a general method; if θ is the standard angle, the negative and positive signs of the components are automatically produced. However, if a reference angle θ is given, i.e., calculated relative to a specific axis, the following method is easier to use: The Golden Rule of Vector Analysis:

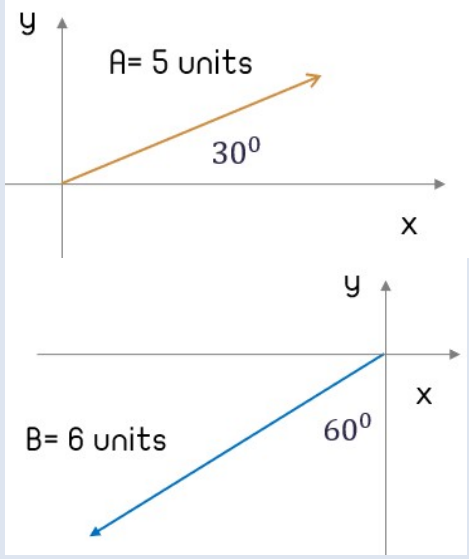
value of the component = ± value of the original vector x

cosθ (If the component is the side adjacent to the angle)

sinθ (if the component is the side opposite the angle)

Example 1-12

Analyze the vectors A and B.



The standard angle is equal to the reference angle. $\theta = 30^0$

$$A_x = A\cos\theta = 5\cos 30^0 = 4.33\ unists$$

$$A_y = A\sin\theta = 5\sin 30^0 = 2.5\ unists$$

Analysis using the standard angle $\theta = 210^0$

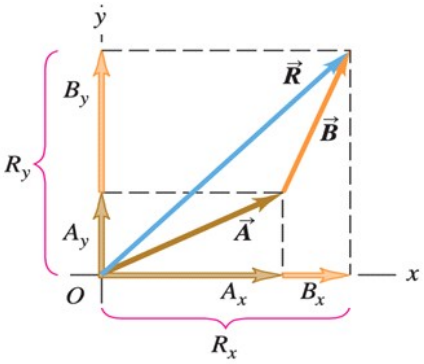
$$A_x = A\cos\theta = 6\cos 210^0 = -5.2\ unists$$
$$A_y = A\sin\theta = 6\sin 210^0 = -3\ unists$$

Analysis using the reference angle $\Phi = 60^0$

$$A_x = -A\sin\Phi = -6\sin 60^0 = -5.2\ unists$$
$$A_y = -A\cos\Phi = -6\cos 60^0 = -3\ unists$$

1.16 ADDING VECTORS BY COMPONENTS

To determine the result of vectors by the component method, the following procedure is employed:
Given two vectors $\vec{A}$ and $\vec{B}$, their resultant $\vec{R}$ is shown in the figure.



The resultant $\vec{R}$ has two components given by:

$$\boldsymbol{R_x = A_x + B_x} \qquad \boldsymbol{R_y = A_y + B_y}$$

The magnitude of the resultant: $R = \sqrt{{R_x}^2 + {R_y}^2}$

The direction of the resultant: $\tan\theta = \frac{R_y}{R_x}$

For a greater number of vectors, this procedure is simply repeated using the same method

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Example 1-13

Compute algebraically the resultant of following coplanar displacements:
$20.0\text{m at } 30.0^o$,$40\text{m at } 120.0^o$, $25.0\text{m at } 180.0^o$, $42.0\text{m at } 270^\circ$, and $12\text{m at } 315.0^\circ$.

Solution:

Let angles be measured counter $-$ clockwise from the $+x$ axis.

Horizontal component:

$$R_x = (20.0\text{ m})cos30° + (40\text{ m})cos120° + (25.0\text{ m})cos180° + (42.0\text{ m})cos270° + (12\text{ m})cos315°$$
$$R_x = -19.1942\text{ m}$$

Vertical component:

$$R_y = (20.0\text{ m})sin30° + (40\text{ m})sin120° + (25.0\text{ m})sin180° + (42.0\text{ m})sin270° + (12\text{ m})sin315°$$
$$R_y = -5.8443\ m$$

Magnitude

$$|\vec{R}| = \sqrt{R_x^2 + R_y^2} = \sqrt{(-19.1942\text{ m})^2 + (-5.8443\text{ m})^2}$$
$$= \sqrt{368.43\text{ m}^2 + 34.17\text{ m}^2} = \sqrt{402.60\text{ m}^2}$$
$$= 20.06\text{ m.} = 20.1m$$

Direction

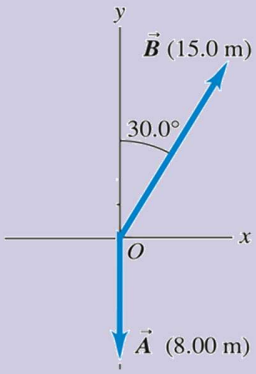
$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{-5.8443\text{ m}}{-19.1942\text{ m}}\right) = -163.07°.$$

In standard form, $\theta = 196.93°$.

Exercise: A vector in first quadrant of the plane xy, the value of its component on +x axis is equal 3, and the value of its component on +y axis is equal 6, if the vector rotates clockwise in the first quadrant, and its component in +x axis is multiplied , find the value of its component on +y axis.

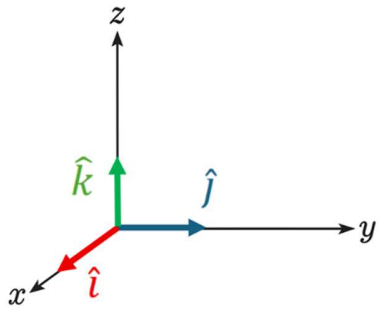
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Exercise: find magnitude and direction and draw: $\vec{A} - \vec{B}$



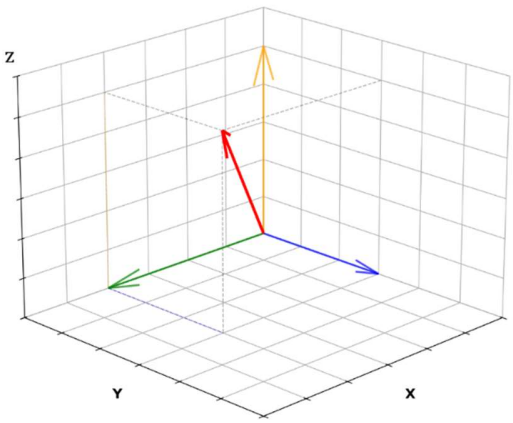
1.17 VECTOR ADDITION USING THE UNIT VECTOR METHOD

Unit vectors are three vectors $\hat{\imath}$ ، $\hat{\jmath}$ ، $\hat{k}$ with magnitudes of 1 and oriented in the directions: $+x$, $+y$ and $+z$ respectively. Any vector can be expressed in terms of unit vectors, which facilitates the handling of vectors when performing vector operations on them. Each unit vector has a magnitude of 1 and specifies a direction.



For example, the vector $[\vec{A}]$ shown in the figure can be written in terms of unit vectors as follows:

$$\vec{A}_x = A_x\hat{\imath}$$
$$\vec{A}_y = A_y\hat{\jmath}$$
$$\vec{A}_z = A_z\hat{k}$$
$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}$$

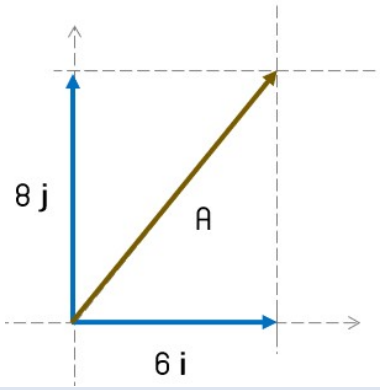


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Example 1-14

Draw and calculate the magnitude of the vector: A = 6 i + 8 j

Solution:



The figure shows the representation of vector **A** on the coordinate plane.

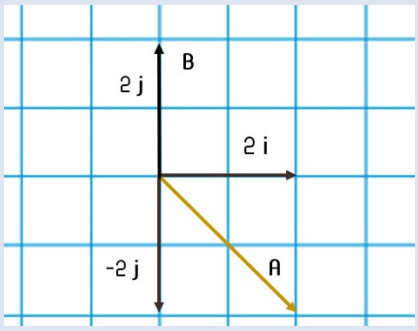
We use the Pythagorean theorem to find the value of vector **A**:

$$A = \sqrt{6^2 + 8^2} = \sqrt{100} = 10$$

Example 1-15

Calculate the resultant of the two vectors: $\vec{A} = 2\hat{\imath} - 2\hat{\jmath}$ and $\vec{B} = 2\hat{\jmath}$ in terms of unit vectors.

Solution:



you simply add the corresponding components (i, j, and k) of each vector separately:

$$\vec{C} = \vec{A} + \vec{B} = (2 + 0)\hat{\imath} + (-2 + 2)\hat{\jmath} = 2\hat{\imath}$$

Example 1-16

The perpendicular components of the vector acceleration are: $a_x = 6.00\ \text{m/s}^2$, $a_y = 4.00\ \text{m/s}^2$, $a_z = 9.00\ \text{m/s}^2$, Find the vector expression for $\vec{a}$ and its value.

Solution:

$$\vec{a} = [6.00\hat{\imath} + 4.00\hat{\jmath} + 9.00\hat{k}]\ (\text{m/s}^2)$$

$$|\vec{a}| = a = \sqrt{(6^2 + 4^2 + 9^2)} \approx 11.5\ \text{m/s}^2$$

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Example 1-17

A vector $\vec{A}$ has magnitude 4.20 m at an angle $55.0°$above the $+x$-axis. Another vector $\vec{B}$ has magnitude 2.80 m at an angle $-35.0°$(i.e., $35.0°$below the $+x$-axis).

Let $\vec{C} = 2.50\,\vec{A} - 3.20\,\vec{B}$.

(a) Write $\vec{A}$ and $\vec{B}$ in unit-vector form.

(b) Find $\vec{C}$ in unit-vector form.

(c) Find the magnitude and direction (from $+x$, counterclockwise) of $\vec{C}$.

Solution:

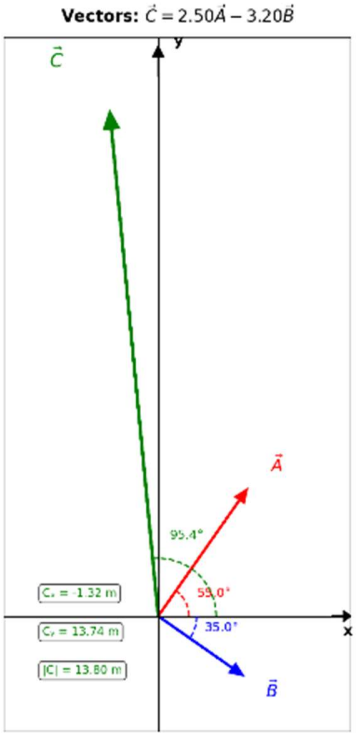
(a) Resolve $\vec{A}$ and $\vec{B}$ into components:

$$\vec{A} = (4.20cos55.0°)\hat{i} + (4.20sin55.0°)\hat{j}$$

$$\vec{A} = (2.409\hat{i} + 3.440\hat{j})m$$

$$\vec{B} = [2.80cos(-35.0°)]\hat{i} + [2.80sin(-35.0°)]\hat{j}$$

$$\vec{B} = (2.294\hat{i} - 1.606\hat{j})m$$



(b) Calculate $\vec{C}$: $\vec{C} = 2.50\vec{A} - 3.20\vec{B}$

$$\vec{C} = [2.50(2.409) - 3.20(2.294)]\hat{i} + [2.50(3.440) - 3.20(-1.606)]\hat{j}$$

$$\vec{C} = (-1.317\hat{i} + 13.740\hat{j})m$$

$$\vec{C} \approx (-1.32\hat{i} + 13.7\hat{j})m$$

(c) Magnitude and direction:

$$|\boldsymbol{C}| = \sqrt{[(-1.317)^2 + (13.740)^2]}$$

$$|\boldsymbol{C}| = 13.8m$$

Since $C_x < 0$ and $C_y > 0$, **C** lies in the second quadrant.

$$\alpha = tan^{-1}(13.740/1.317) = 84.5°$$

$$\theta = 180° - 84.5° = 95.5°$$

Therefore: $\vec{C} = (-1.32\hat{i} + 13.7\hat{j})m$

$|\vec{C}|$ = 13.8 m, θ = 95.5° counterclockwise from the positive x-axis.

Exercise: If $\boldsymbol{A} = 2\hat{\imath} - 3\hat{\jmath} + 5\hat{k}$ mm and $\boldsymbol{B} = -\hat{\imath} - 2\hat{\jmath} + 7\hat{k}$ find in component form:
(a) $2\boldsymbol{B} - \boldsymbol{A}$ (b) Vector **C** such that $\boldsymbol{A} + \boldsymbol{B} + \boldsymbol{C} = 0$

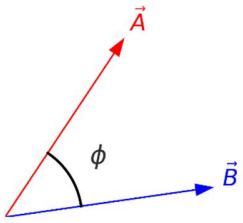
Exercise: Find the angle between two vectors of equal magnitude: $5.0\ units$, such that the resultant is $[6.0\hat{\jmath}]units$.

1.18 SCALAR PRODUCT (DOT PRODUCT)

The dot product between two vectors **A** and **B** is a scalar quantity given by:

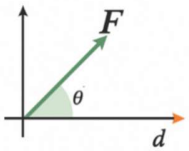
$\boldsymbol{A} \cdot \boldsymbol{B} = |\boldsymbol{A}||\boldsymbol{B}|\cos(\theta)$,

where θ is the angle between the vectors.



A physical example: work is the resultant of the dot product of force and displacement W = **F** · **d**

$W = Fd\cos\theta$



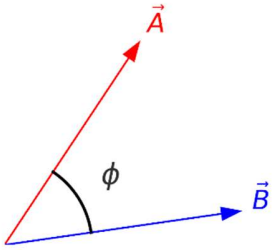
Concept check: How does the angle affect the result of the dot product?

Solution:

- The dot product is positive when 0° < θ < 90°.
- The dot product is zero when θ = 90° (vectors are perpendicular).
- The dot product is negative when 90° < θ < 180°.
- The maximum positive value occurs at θ = 0°.
- The maximum negative value occurs at θ = 180°.

1.19 VECTOR PRODUCT (CROSS PRODUCT)

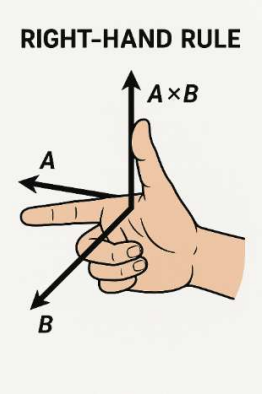
- yields a vector quantity $|\vec{C}| = |\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}|\sin\phi$
- ϕ The smaller angle between the vectors.
- Direction of the resultant vector: The direction is determined by the right-hand rule and is perpendicular to the plane formed by the two vectors.



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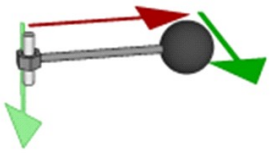
The right-hand rule is used to determine the direction of the cross product of two vectors, **A** × **B**.

Using your right hand, curl your fingers in the direction from the first vector toward the second vector, your thumb will then point in the direction of the resultant vector ($\vec{C}$).



Physics Example: Torque:

$$\boldsymbol{\tau} = r\, f\, sin\theta$$



Example 1-18

Two vectors, A=2 units and B=5 units, form an angle of 60^0 between them. Calculate their dot product and the magnitude of cross product.

Solution:

$$\boldsymbol{A}\cdot\boldsymbol{B} = |\boldsymbol{A}||\boldsymbol{B}|cos(\theta) = (2)(5)cos60^0 = 5$$

$$|\vec{C}| = |\vec{A}\times\vec{B}| = |\vec{A}||\vec{B}|\,sin\,\phi = (2)(5)sin60^0 = 8.66$$

Example 1-19

Two vectors, **A** and **B**, are equal in magnitude and have an angle of 60° between them. If their dot product is 4.5, calculate the magnitude of vector **A**.

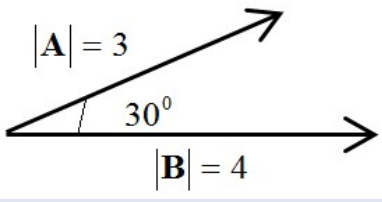
Solution:

$$\boldsymbol{A}\cdot\boldsymbol{B} = |\boldsymbol{A}||\boldsymbol{B}|cos(\theta) \qquad 4.5 = A^2 cos60^0 \qquad A^2 = \frac{4.5}{0.5} = 9 \qquad A = 3$$

Example 1-20

The direction of the cross product vector of the two vectors shown in the figure is:

(a) Up (b) Down (c) Inwards (d) Outwards



Solution:

Applying the right-hand rule, the correct choice is c

2 CHAPTER2: PROJECTILE MOTION



A projectile is an object that is given an initial velocity and then moves, after its release, under the influence of the gravitational force alone, with air resistance neglected. Projectile motion can be analyzed as two independent and simultaneous motions:

- Horizontal motion at constant velocity, because the horizontal acceleration is zero.
- Vertical motion with constant downward acceleration of magnitude g.

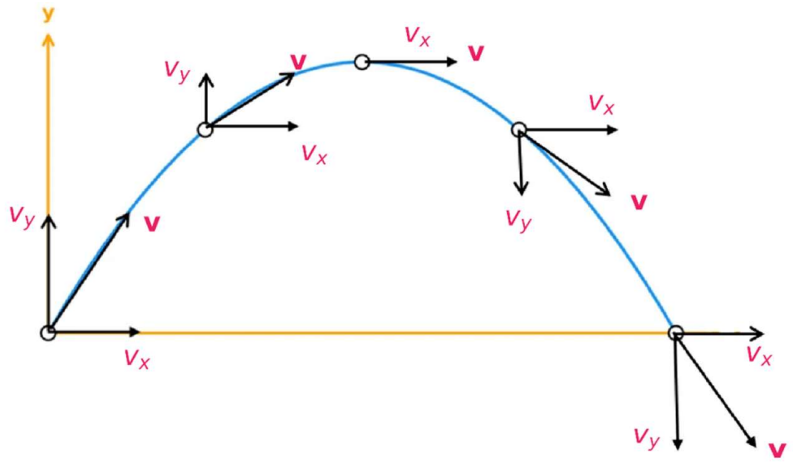
The horizontal motion does not affect the vertical motion, and the vertical motion does not affect the horizontal motion. However, both motions occur over the same time interval.

If a projectile is launched with an initial speed v_i at an angle θ above the horizontal, the horizontal and vertical components of its initial velocity are:

$$v_{xi} = v_i \cos\theta$$
$$v_{yi} = v_i \sin\theta$$

Thus, the projectile's motion can be analyzed independently along the horizontal and vertical axes, using the same time t for both motions.

We shall neglect air resistance in our analysis of projectile motion and assume that it is launched with an initial velocity v_i at an angle θ with the horizontal.



Motion Along the y-Axis:

Vertical acceleration: $a_y = -g$

Initial vertical velocity:

$v_{yi} = v_i sin\theta$

Vertical velocity is variable: it decreases during ascent until it becomes zero at maximum height, then increases during descent.

Vertical velocities are positive during ascent and negative during descent.

Vertical displacement at time t :

$\Delta y = v_{yi}t - \frac{1}{2}gt^2$ or $\Delta y = \frac{v_{yf}+v_{yi}}{2}t$

Motion Along the x-Axis:

Horizontal acceleration: $a_x = 0$

Initial horizontal velocity: $v_{xi} = v_i cos\theta$

Horizontal velocity (constant):

$v_x = v_{xi} = v_i cos\theta$

Horizontal displacement at any instant t:

$x(t) = v_{xi}t = (v_i cos\theta)t$

Horizontal displacement at time t:

$\Delta x = v_i cos\theta \cdot t$

Range: $R = v_{xi}$T where T = time of flight (total flight time)

Important notes:

- We apply the equations of free fall to calculate vertical motion quantities, where the vertical acceleration is $a_y = -g$when the upward direction is positive.
- The horizontal and vertical motions occur during the same time interval t.
- When an object is projected horizontally from the top of a cliff, it follows part of a parabolic trajectory.

Guidelines for solving projectile motion problems:

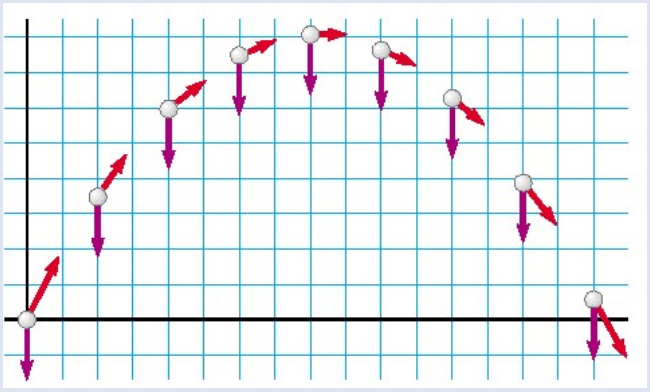
- Choose a coordinate system and resolve the initial velocity vector into its x and y components

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- Follow the methods used for solving constant velocity problems to analyze the horizontal motion and follow the methods for solving constant acceleration problems to analyze the vertical motion.
- The motions in the x- and y-directions occur during the same time interval.

Example 2-1

A ball is launched such that its vertical and horizontal components of velocity are 40.0 m/s and 20 m/s respectively. Calculate the total flight time and the distance at which the ball falls, measured from its starting point.



Time to reach maximum hight:

$$t_{1/2} = \frac{v_{yf} - v_{yi}}{-g} = \frac{0 - 40}{-9.80} = 4.08\ \text{s}$$

Total flight time:

$$t = 2\,t_{1/2} = 2(4.08) = 8.16\ \text{s}$$

Horizontal distance (range):

$$R = v_x t_f = (20)(8.16) = 163.2\ m$$

Example 2-2

A kicked football leaves the ground at an angle $\theta_o = 37.0^{\text{o}}$ with a velocity of 20.0 m/s, Calculate:

(a) the maximum height, (b) the time of travel before the football hits the ground. (c) horizontal range.

(d) Velocity vector at maximum height.

(e) acceleration vector at maximum height

Assume the ball leaves the foot at ground level and ignore air resistance and rotation of the ball.

Solution: Given & Components

Initial speed $v_i = 20.0\,\mathrm{m/s}$, launch angle $\theta^0 = 37.0°, g = 9.80\mathrm{m/s^2}$.

$$v_{xi} = v_i cos\theta = 15.973\,m/s = 16.0\,\mathrm{m/s}$$

$$v_{yi} = v_i\, sin\theta = 12.036\,m/s = 12.0\,\mathrm{m/s}$$

(a) Maximum Height

$$H_{\max} = \frac{v_{yf}^2 - v_{yi}^2}{-2g} = \frac{0 - (12.036)^2}{-2 \times (9.80)} = 7.39\,\mathrm{m}$$

(b) Time of Flight

$$T = \frac{2(0 - v_{yi})}{-g} = \frac{2 \times (-12.036)}{-9.80} = 2.46\,\mathrm{s}$$

(c) Horizontal Range

$$R = v_{xi} \times T = 15.973 \times 2.456 = 39.2\,\mathrm{m}$$

(d) Velocity at Maximum Height

At the top, $v_y = 0$ (instantaneously); v_x is unchanged (no air drag).

$\boldsymbol{v}_{\mathrm{top}} = 16.0\hat{\imath} + 0.0\hat{\jmath}(\mathrm{m/s}) \rightarrow$ purely horizontal to $+x$

(e) Acceleration at Maximum Height

Acceleration is constant and equal to gravity everywhere.

$\rightarrow \boldsymbol{a} = 0.0\hat{\imath} + -9.80\hat{\jmath}(\mathrm{m/s^2}) \rightarrow$ downward

Exercise2-1: Suppose the football in the previous exercise was punted and left the punter's foot at a height of 1.00 m above the ground. How far did the football travel before hitting the ground?

Exercise2-2: Derive the following equations:

$$R = \frac{v_i^2\, sin\, 2\theta_i}{g} \qquad h_{max} = \frac{v_i^2\, sin^2\, \theta_i}{2g}$$

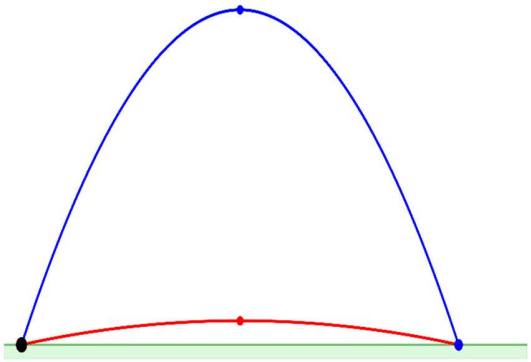
Note: (We substitute in both (g) with a positive sign)

Think: What is the angle that gives the maximum range of the projectile?

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Important Note:

When air resistance is neglected and the landing level is the same as the launch level, the same horizontal range can be obtained with the same initial speed at complementary launch angles, such as $15°$and $75°$. However, the maximum height and the total time of flight are different.

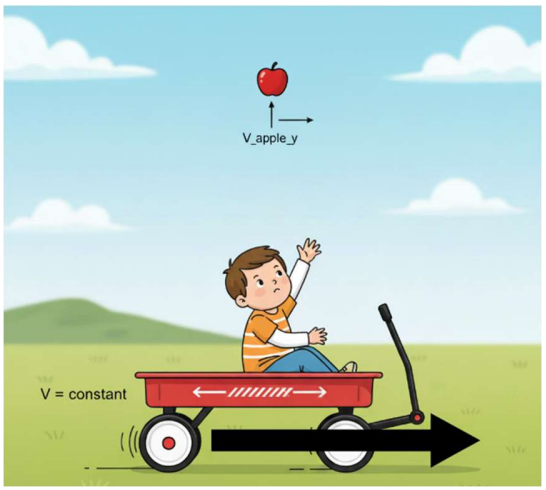


Think 2-1: Which flight takes longer, throw with an angle 15^o or75^0 ,and why?

Concept check 2-1: You are to launch a projectile from just above the ground with one of the following initial velocity vectors: (1)$\vec{v}_i = 20\hat{\imath} + 70\hat{\jmath}$, (2)$\vec{v}_i = -20\hat{\imath} + 70\hat{\jmath}$, (3)$\vec{v}_i = 70\hat{\imath} - 20\hat{\jmath}$. Rank the vectors according to the time of flight of the projectile. Greatest first.

Concept check 2-2:

A child sits upright in a wagon, which is moving to the right at constant speed as shown in Fig. The child extends her hand and throws an apple straight upward (from her own point of view) while the wagon continues to travel forward at constant speed. If air resistance is neglected, will the apple land (a) behind the wagon, (b) in the wagon, or (c) in front of it.



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Example 2-3

A stone is thrown upward from the top of a 45.0 m-high building at an angle of 30.0°above the horizontal and with an initial speed of 20.0 m/s.

(a)How long does it take to reach the ground?

(b)What is the speed of the stone just before it strikes the ground?

Solution

Given Data:

$$\text{Initial speed}, v_i = 20.0\ \text{m/s}$$

$$\text{Launch angle}, \theta = 30.0°$$

$$\text{Height of building}, h = 45.0\ \text{m}$$

$$\text{Gravitational acceleration}, g = 9.8\ \text{m/s}^2$$

(a) Time to reach the ground

Using the vertical motion equation:

$$y = v_{iy}t - (1/2)gt^2$$

At the ground: $y = -45.0\text{m}$ (taking the top of the building as $y_0 = 0$)

$$v_{iy} = v_i\, sin(30°) = 20 \times 0.5 = 10.0\ \text{m/s}$$

Substitute: $-45.0 = 10.0t - 4.9t^2$

$$\Rightarrow 4.9t^2 - 10.0t - 45.0 = 0$$

Using the quadratic formula:

$$t = 10 \pm \frac{\sqrt{10^2 + (4 \times 4.9 \times 45)}}{2 \times 4.9}$$

$t = 4.23s$ (neglecting negative root. Why?)

(b) Speed just before striking the ground

Vertical velocity: $v_{fy} = v_{iy} - gt = 10.0 - 9.8 \times 4.23 = -31.45\text{m/s}$ (downward)

$$Horizontal\ velocity\ (constant): v_x = v_i\, cos(30°) = 20 \times 0.866 = 17.32\ \text{m/s}$$

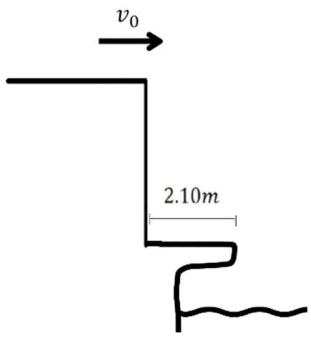
Total speed: $v = \sqrt{(v_x^2 + v_{fy}^2)} = \sqrt{(17.32^2 + 31.45^2)} = 35.9\text{m/s}$

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Exercise 2-3: A particle is projected horizontally while another particle is released from rest at the same instant and from the same height. Neglecting air resistance, prove that both particles reach the ground at the same time.

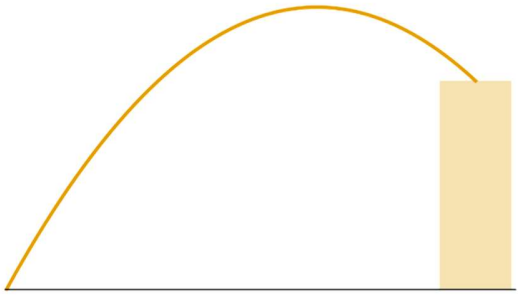
Concept check 2-3: If two balls roll on a table's top at two different speeds, and then fall off the table's top at the same time, which one will hit the ground first?

Exercise 2-4: A swimmer dives off a cliff with a running horizontal leap, as shown in Figure. What must his minimum speed be as he leaves the top of the cliff so that he misses the lower ledge, which is 2.10 mwide and 8.00 m below the upper ledge?



Exercise 2-5:

A small projectile is launched from street level toward a tall building with an initial speed of $38.0\ m/s$ at an angle $\theta_0 = 55.0°$ above the horizontal. The stone lands on the flat roof, $4.80\ s$ after launch. Neglect air resistance. Find:



(a) the roof height above the street,

(b) the speed of the stone just before it touches the roof.

(c) the maximum height the stone reaches above the street.

Exercise 2-6: A basketball player stands 8.0 m from the basket. If he throws the ball at an angle 35^0above the horizontal from a height 2.2m, what initial velocity is needed for the ball to pass directly through the basket hoop at a height of 3.0 m?

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3 ADDITIONAL PROBLEMS

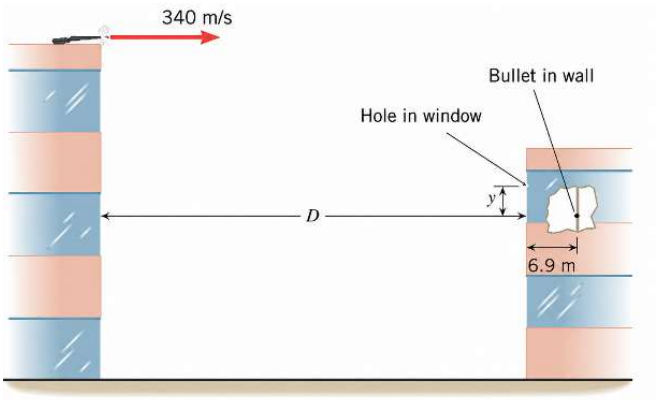
Question 1: A hostile ship is located 450 m from a coastal cannon at sea level. The cannon fires cannonballs with an initial speed: $v_0 = 75$ m/s.

(a) At what angle θ_0 from the horizontal must the cannon be fired to hit the ship?
(b) What is the maximum range of cannonballs?



Question 2: A bullet is fired horizontally at a speed of 340 m/stoward a building opposite. It enters one of the building's windows after 2.50 s. It then crosses a room 6.9 mwide and strikes the opposite wall. Neglect air resistance. Determine:

1. The horizontal distance between the two buildings.
2. The vertical distance the bullet drops while crossing the room.

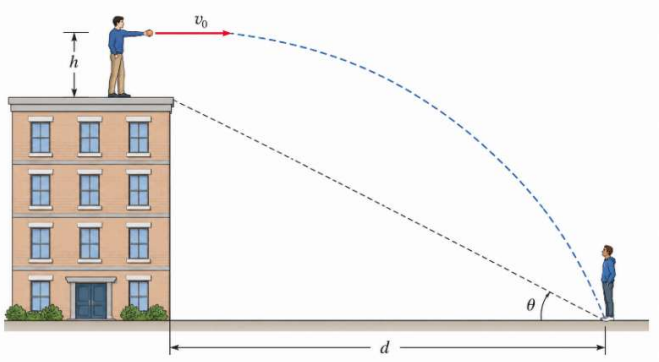


Question 3: An observer stands on the ground at a horizontal distance of 18 mfrom the base of a building. The straight line connecting the observer's position to the edge of the building's roof makes an angle of $45°$with the horizontal. A person standing at the edge of the roof holds

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a ball 2.0 mabove the roof and throws it horizontally toward the observer. Neglect air resistance and use $g = 9.8$ m/s^2. Determine:

1. The initial speed required for the ball to land at the observer's feet.
2. The magnitude and direction of the ball's velocity just before it hits the ground.



Question4: A firefighter directs a stream of water from a hose that is elevated $1.20\ m$ above the ground. The water leaves the nozzle at a speed of $24.0\ m/s$ at an angle of $35°$ above the horizontal. A building wall is located $10.0\ m$ horizontally from the nozzle. At what height above the ground will the water strike the wall?

Question 5: Two projectiles are launched simultaneously at angles of $30°$and $60°$. What is the ratio of their initial speeds if they travel the same horizontal distance in the same time?

Question 6: A boy can throw a ball at a maximum horizontal distance of $40.0\ m$ on a level field. How far can he throw the same ball vertically upward? Assume that his muscles give the ball the same speed in each case.

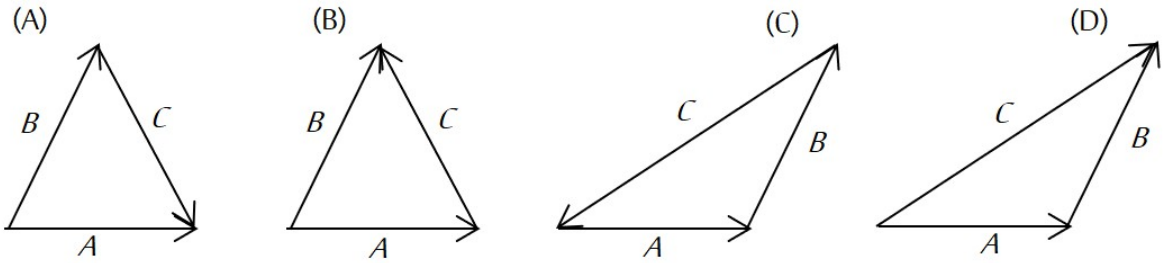
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4 SIMULATION TEST

Q1) If $\vec{A} = \vec{B} + \vec{C}$ and the magnitude of $\vec{A}$, $\vec{B}$ and $\vec{C}$ are 5, 4 and 3 units respectively, then the angle between $\vec{A}$ and $\vec{C}$ is:

A. 90^0
B. 53.1^0
C. 36.9^0
D. 27.6^0

Q2) Three vectors related by the relation $\vec{C} = -\vec{A} - \vec{B}$. Which of the following diagrams represents the correct relationship between them?

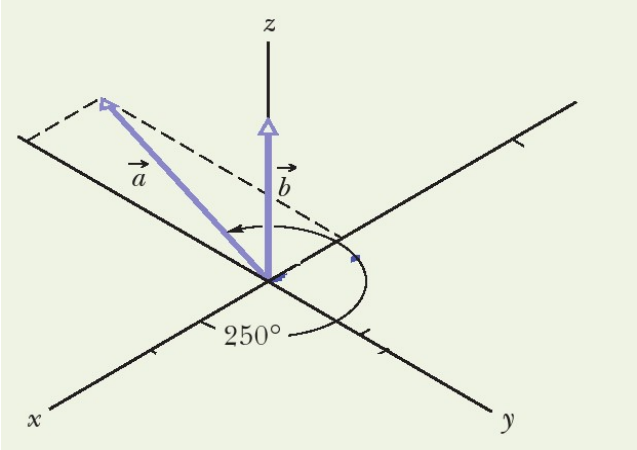


Q3) The range of a projectile launched at an angle of 15^0 to the horizontal is 1.5 km. What will be its range if it is projected at an angle of $45^0$to the horizontal with the same initial speed?

A. 0.75 km
B. 3.0 km
C. 1.5 km
D. 6.0 km

Q4) In the figure, vector $\vec{a}$ lies in the xy plane, has a magnitude of 18 units and points in direction $250^0$from the positive direction of the x-axis. Also, vector $\vec{b}$ has a magnitude of 12 units and points in the positive direction of the z-axis.
If $\vec{c} = \vec{a} \times \vec{b}$, The angle that vector $\vec{c}$ makes with the x-axis is equal to:

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A. 210^0
B. 160^0
C. 90^0
D. 0

Q5) The speed of a projectile at the maximum height is half of its initial speed u
Its horizontal range is:

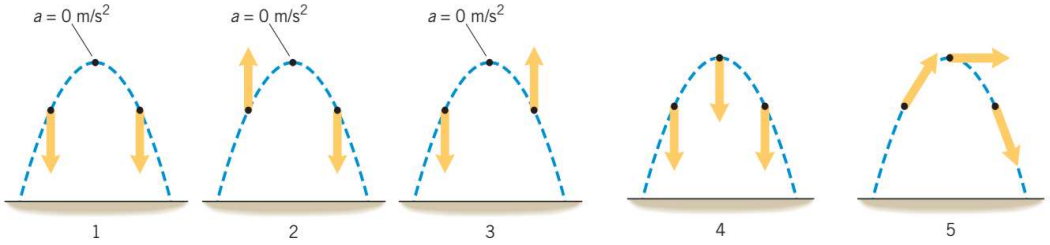
A. $\frac{u^2}{\sqrt{3}g}$
B. $\frac{2u^2}{\sqrt{3}g}$
C. $\frac{\sqrt{3}u^2}{2g}$
D. $\frac{\sqrt{3}u^2}{g}$

Q6) A grasshopper can jump a maximum horizontal distance of $0.2\ m$. If it continues to jump in this manner, spending negligible time on the ground, then its average forward speed is approximately:

A. $1\ \mathrm{m/s}$
B. $2\ \mathrm{m/s}$
C. $3\ \mathrm{m/s}$
D. $4\ \mathrm{m/s}$

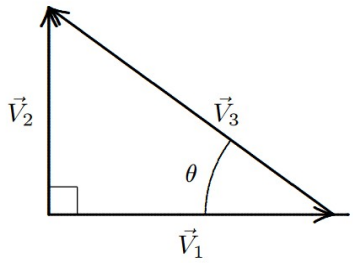
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Q7) Each drawing shows three points along the path of a projectile, one on its way up, one at the top, and one on its way down. The launch point is on the left in each drawing. Which drawing correctly represents the acceleration a of the projectile at these three points?



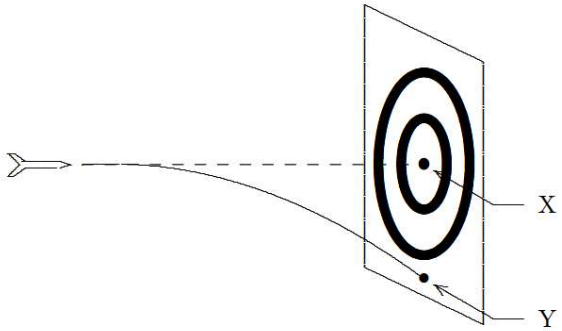
A. 1
B. 2
C. 3
D. 4
E. 5

Q8) The vector $\vec{V}_3$ in the figure is equal to:



A. $\vec{V}_1 - \vec{V}_2$
B. $\vec{V}_1 + \vec{V}_2$
C. $\vec{V}_2 - \vec{V}_1$
D. $\vec{V}_1 \cos\theta$

Q9) An arrow is launched by horizontally velocity 20 m/s towards point X. After a time of 0.1 s, the arrow hits point Y. The distance XY is: g=10 m/s^2



A. 2 m
B. 1 m
C. 0.5 m
D. 0.05 m

Q10) Two forces have equal magnitudes. The magnitude of their resultant is one-third the magnitudes of either force. What is the angle between the two forces?

A) 62^0 B) 80.4^0 C) 124^0 D) 160.8^0

Answers to the Simulation test:

1)	B	2)	C	3)	B	4)	B	5)	C
6)	A	7)	D	8)	C	9)	D	10)	D

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