أولمبياد الموهبة الوطني
NATIONAL GIFTED OLYMPIAD

Phase Two Pack

Science Track "Biology "

Biology Specialization

Biology Scientific Team

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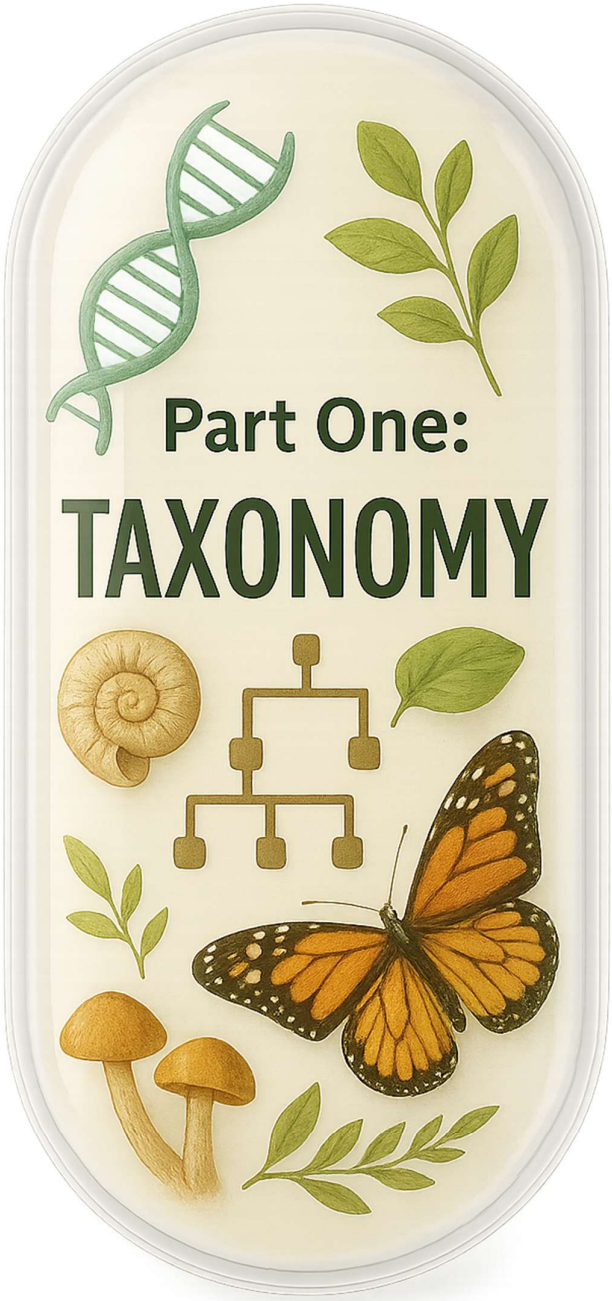
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Introduction to Taxonomy

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.

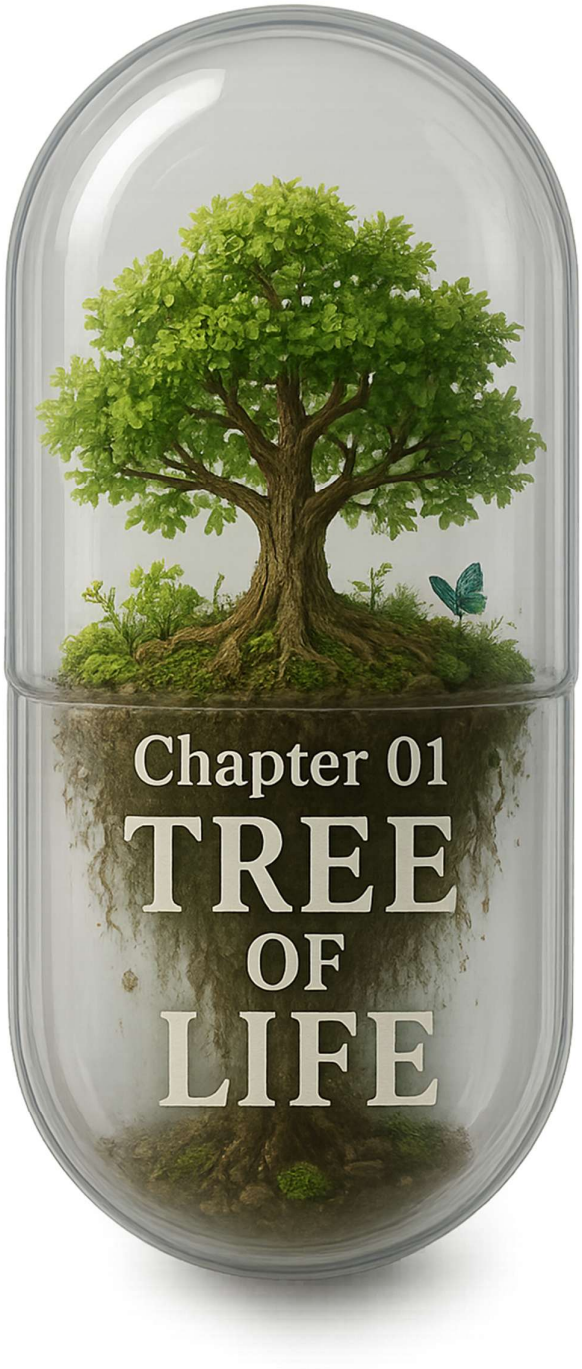
This integration among living groups provides a comprehensive view of the history of life on Earth and helps students connect the characteristics of organisms with their ecological roles, behaviors, and adaptive strategies.

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Objectives:

- ✓ Understand the general principles of biological classification, including taxonomic levels and the fundamentals of naming organisms.
- ✓ Explain the differences among the kingdoms of life by tracing the origin of each group and understanding how shared and unique characteristics emerge.
- ✓ Identify the structures of prokaryotic and eukaryotic cells and compare their main forms and methods of reproduction.
- ✓ Analyze the ecological importance of fungi and their roles in decomposition, symbiosis, and the production of food and medicine.
- ✓ Identify the general characteristics of animals and relate them to feeding patterns, movement, and reproduction.
- ✓ Classify invertebrates into their main groups and describe the characteristics of each.
- ✓ Distinguish the characteristics of vertebrates in terms of structure, reproduction, and habitat.
- ✓ Analyze the evolution of major organ systems in vertebrates—such as the respiratory, circulatory, and muscular systems—and relate them to different modes of life.

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1. 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

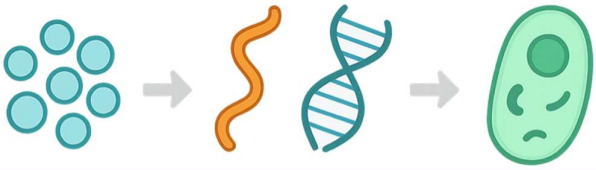


Figure 1: Illustrates the origin of the first cell in primitive environments

These environments provided simple molecules such as:

- Amino acids
- Nucleotides

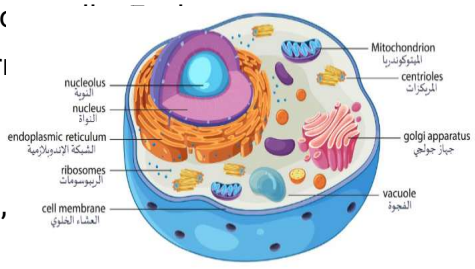
From these building blocks, larger molecules were formed:

- Proteins
- Nucleic acids

Shared Characteristics of Living Organisms

- Cellular Organization:

  All living organisms are composed of one or mo
  cell consists of organized molecules and is surr
  cell membrane.



membrane and internal organization

- Sensitivity / Response to Stimuli:

  All living organisms respond to external stimuli, methods of response vary from one organism to another.

- Growth and Metabolism:

  Living organisms can produce the energy required for life and growth. Plants, algae, and some bacteria utilize sunlight in photosynthesis to convert light energy into chemical energy.

- Embryonic Development:

  Both unicellular and multicellular organisms undergo processes of growth and differentiation controlled by genes.

- Reproduction:

  All living organisms reproduce, transmitting genetic information from one generation to the next.

- Regulation:

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Living organisms possess mechanisms to control and regulate internal processes.

- Homeostasis:
  Living organisms maintain stable internal conditions despite changes in the external environment.
- Heredity:
  Living organisms depend on a genetic system based on DNA (Deoxyribonucleic Acid), which is responsible for passing traits and driving evolution across generations.

2. Conditions on Early Earth

Scientific evidence indicates that Earth's early atmosphere was composed of a mixture of gases, mainly: Carbon dioxide (CO_2), Nitrogen (N_2), Water vapor (H_2O), Possibly hydrogen (H_2).

It was also rich in substances such as: Ammonia (NH_3), Hydrogen sulfide (H_2S), Methane (CH_4), Carbon monoxide (CO)

This composition is known as the Reducing Atmosphere, which provided a suitable environment for chemical reactions that led to the formation of complex organic compounds, paving the way for the emergence of life.

Geological studies suggest that Earth formed about 4.6 billion years ago. During that era, Earth's surface was a harsh environment characterized by high temperatures (49–88 °C / 120–190 °F), intense volcanic activity, magma flows, and thick gas emissions.

The early oceans covered wide areas of the surface, and hydrothermal vents appeared in the deep seas. These events are believed to have provided the ideal environment for the first chemical reactions associated with life.

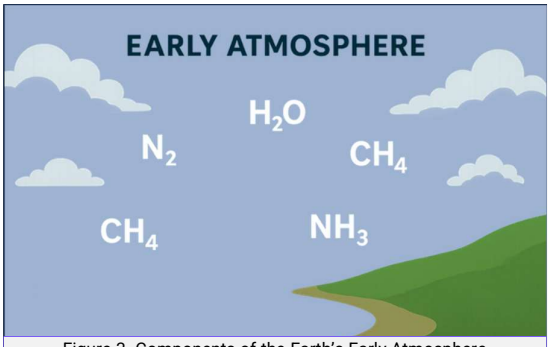


Figure 3: Components of the Earth's Early Atmosphere

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Organic Compounds on Primitive Earth

First experiment to study the origin of organic compounds: Miller–Urey Experiment (1953):

- Objective: Simulate the conditions of primitive Earth and its reducing atmosphere.
- Significance: Demonstrated the possibility of forming organic compounds, which contributed to the emergence of prebiotic chemistry.

Experimental Steps

1. Formation of a reducing atmosphere rich in hydrogen (H_2) and free of oxygen (O_2).
2. Placing the gas mixture above liquid water (H_2O).
3. Maintaining the mixture at a temperature below 100 °C.
4. Releasing electrical sparks to simulate lightning.

Miller–Urey Experiment (1953)

In 1953, Miller and Urey conducted an experiment to simulate the conditions of primitive Earth and test the possibility of forming organic molecules. They used a closed apparatus consisting of glass tubes and two chambers:

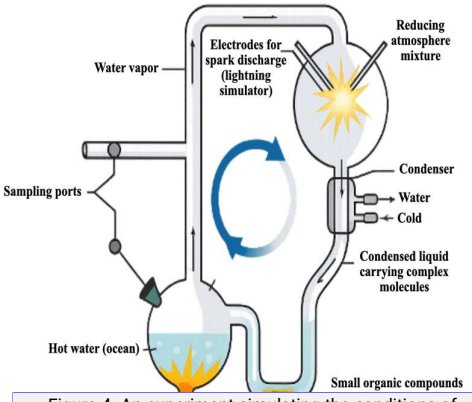


Figure 4: An experiment simulating the conditions of primitive Earth.

- The upper chamber contained a gas mixture representing the early atmosphere (H_2O, N_2, NH_3, CO_2, CO, CH_4, H_2).
- The gases passed through electrodes, generating an electrical spark to simulate lightning.
- The vapor was condensed by a condenser, then returned to the lower chamber containing hot water, representing the “ocean.”

After a week of continuous cycling, organic molecules such as amino acids were detected, supporting the idea that life may have originated from chemical reactions under early Earth conditions.

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Results

- Within one week: About 15% of the carbon was converted into simple organic compounds.
- Among the most important were formaldehyde (CH_2O) and hydrogen cyanide (HCN).
- These compounds later reacted to producing amino acids, which are the building blocks of proteins.

3. Classification of Living Organisms

Classification:

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

Importance of Classification

- Helps organize organisms into groups according to shared traits.
- Facilitates the study of relationships among them.
- Enables clearer and more accurate exchange of scientific information.

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*).

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

- Divided living organisms into Animals and Plants.
  - Classified animals into:
    1. Red-blooded animals
    2. . 2.Bloodless animals
  - He also divided them according to their mode of reproduction:
    1) Oviparous (egg-laying). 2) Viviparous (live bearing)
  - Proposed an ecological classification:
    1) Aquatic. 2) Terrestrial. 3) Aerial
  - As for plants, he classified them into: Trees, Shrubs, and Herbs.

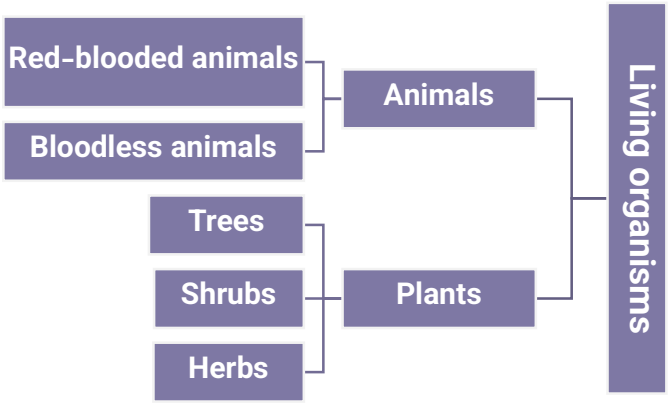


Figure 5. This diagram shows the **early classification of living organisms** into two main groups: **Animals** and **Plants**

Second: Muslim Scholars

Muslim scholars translated Greek sciences, expanded upon them, and developed classification systems. They were the first to make **structure and function** the basis of classification.

Third: John Ray's System (1627–1705 AD)

- Based classification on general morphological traits.
- Introduced two definitions that are still in use today:
  - Species: A group of organisms with similar traits capable of interbreeding and producing fertile offspring.
  - Genus: A group of organisms that share multiple traits but do not interbreed.

Fourth: 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's name (capitalized). - Species name (lowercase).
    - Example: *Apis mellifera* (honeybee).

- This contributed to the unification of organism names worldwide, and his system remains the foundation of modern taxonomy.

Fifth: 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

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.

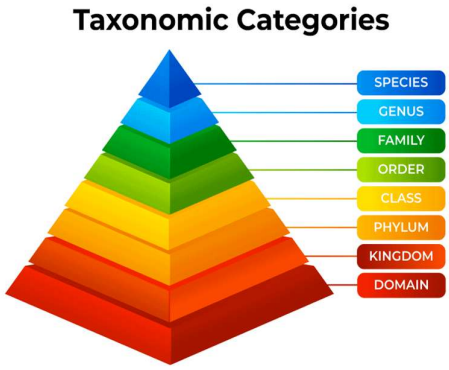


Figure 6. This pyramid illustrates the **taxonomic hierarchy**, showing the levels of biological classification

4. Classification of Living Organisms into Groups (Kingdoms and Domains)

The Kingdom System is considered one of the most important classification systems in biology, as it divides living organisms into major groups known as Kingdoms.

1. In the old classification, there were only two kingdoms:
    - Animals
    - Plants

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2. With scientific progress and the development of methods to study microorganisms, it became clear that this system was insufficient, which led to its development and the addition of new kingdoms.
3. One of the earliest scientists to propose a comprehensive model of the Six-Kingdom System was Carl Woese from the University of Illinois.
4. As scientific evidence grew stronger, scientists adopted a newer system known as the Domain System, which is a higher level above kingdoms.
5. This system is divided into three domains:
    - Domain Archaea (Ancient bacteria)
    - Domain Bacteria
    - Domain Eukarya (Eukaryotes)

The Six Kingdoms: Diversity and Different Origins:

Kingdom	Cell Type	Mode of Nutrition	Examples
Animalia	Eukaryotic – Multicellular	Heterotrophic	Human, Lion
Plantae	Eukaryotic – Multicellular	Autotrophic – Photosynthesis	Tree
Fungi	Eukaryotic – Unicellular/Multicellular	Absorptive (organic material)	Yeast, Mold
Protista	Eukaryotic – Unicellular/Multicellular	Diverse (Photosynthesis / Predation)	Amoeba, Paramecium
Archaea	Prokaryotic	Diverse – thrive in extreme environments	Methanogens, Thermophiles
Bacteria	Prokaryotic	Diverse – beneficial or pathogenic	*E. coli*, *Lactobacillus*

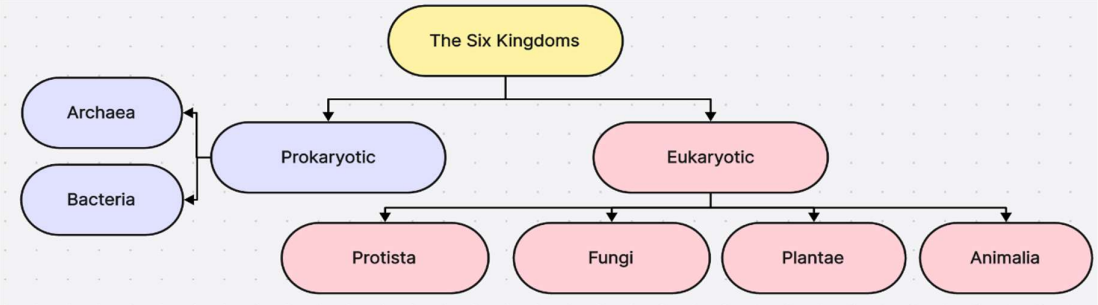
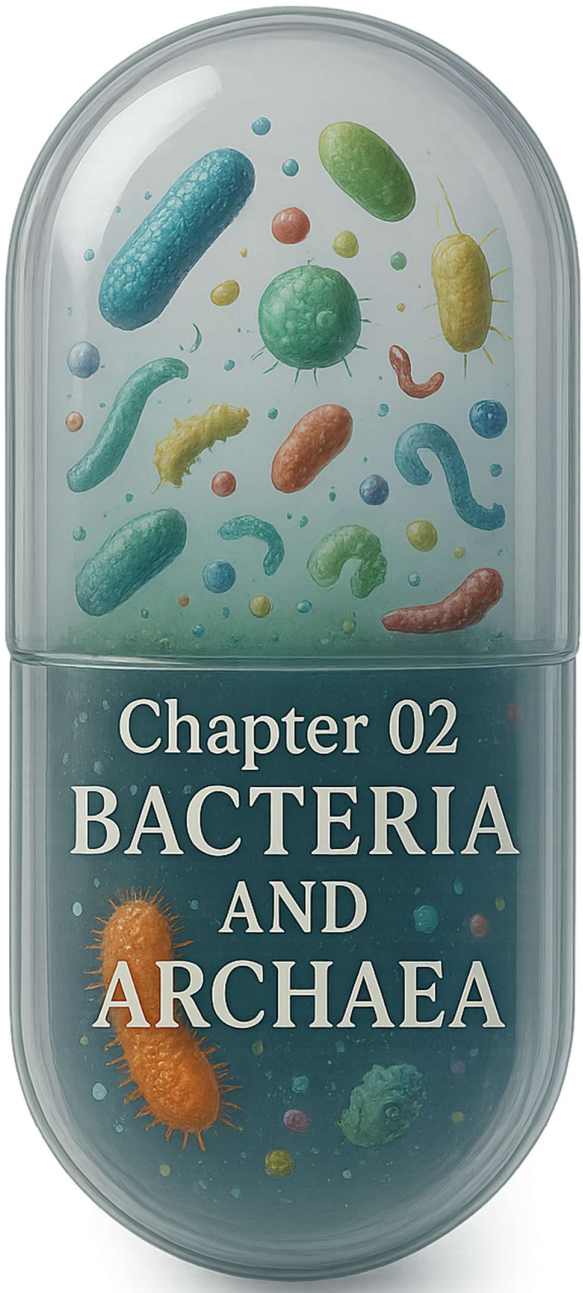


Figure 7: Illustration of the Six-Kingdom Classification



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1. Structure of the Prokaryotic Cell

- Microfossils: Indicate that the earliest cells were *prokaryotic cells*.
- Age: Microscopic structures were found in rocks dating back 3.5 – 3.8 billion years.
- Discovery Sites:
  - Craton – Kaapvaal region, South Africa.
  - *Pilbara* region, Australia.
- Significance: These structures resemble cells and support the hypothesis of the origin of early life in primitive environments.
- Unicellular microbes: Represent an important part of biodiversity.

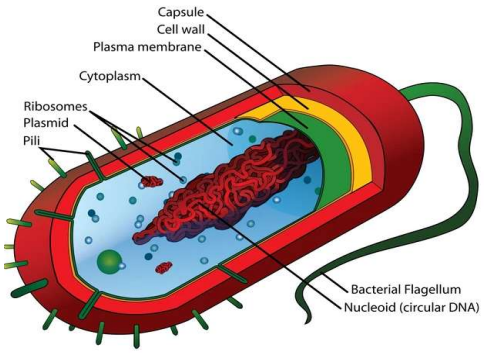


Figure 8: Components of Prokaryotic Cells

- 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.

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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

The flagellum consists of three parts:

1. The filament
2. The hook
3. The basal body, which anchors the flagellum to the cell wall and plasma membrane

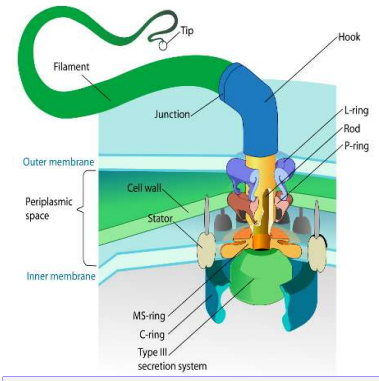


Figure 9. Shows the components of the flagellum

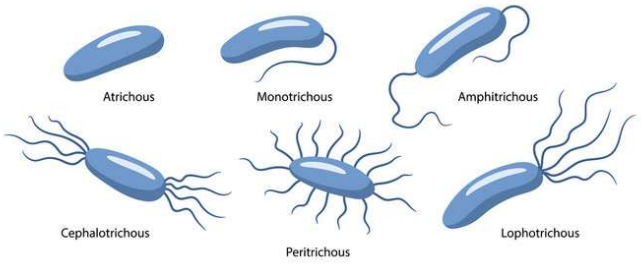


Figure 10. Shows the types of flagella

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2. The most common shapes of prokaryotes

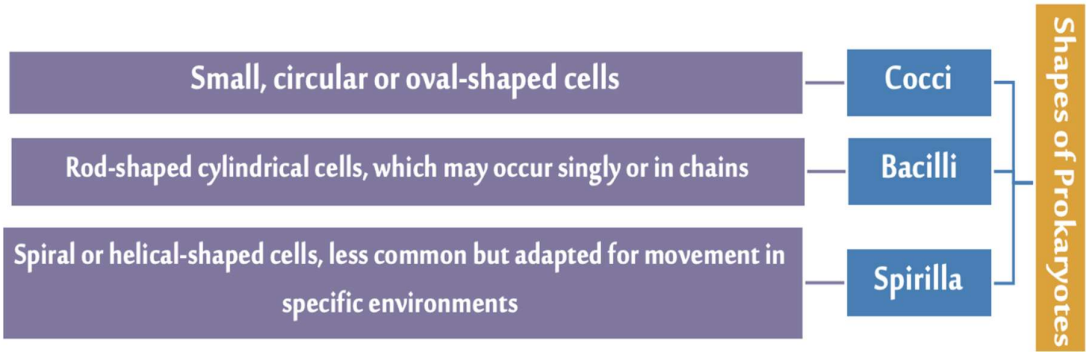


Figure 11. This diagram shows **the three main shapes of prokaryotes**

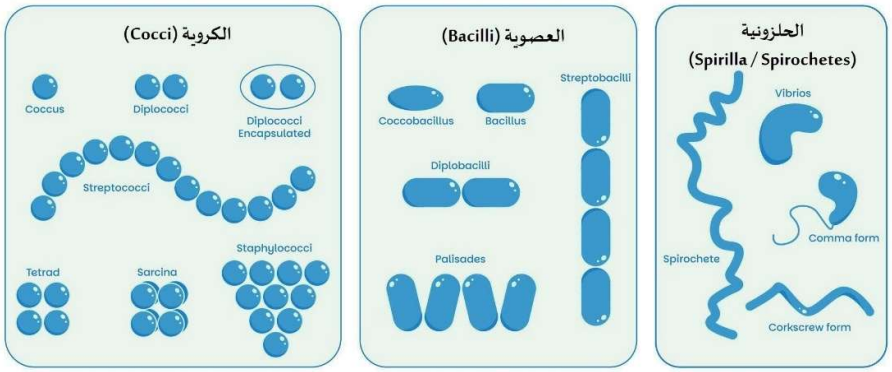


Figure 12: Shows the shapes of prokaryotes

3. Gram-Positive and Gram-Negative Bacteria

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

Gram-Positive Bacteria

- Thick cell wall.
- Retains the purple color when stained.
- Mainly composed of a thick layer of **peptidoglycan**.

Gram-Negative Bacteria

- Thinner cell wall.
- Does not retain the color and appears red or pink.
- Contains a thin layer of **peptidoglycan** between the inner and outer membranes.
- The **outer membrane** contains **lipopolysaccharides (LPS)**.
- More resistant to antibiotics compared to Gram-positive bacteria.

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Characteristics of Gram-Positive and Gram-Negative 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.	Help 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.

Structure of the Cell Wall in Gram-Positive and Gram-Negative Bacteria

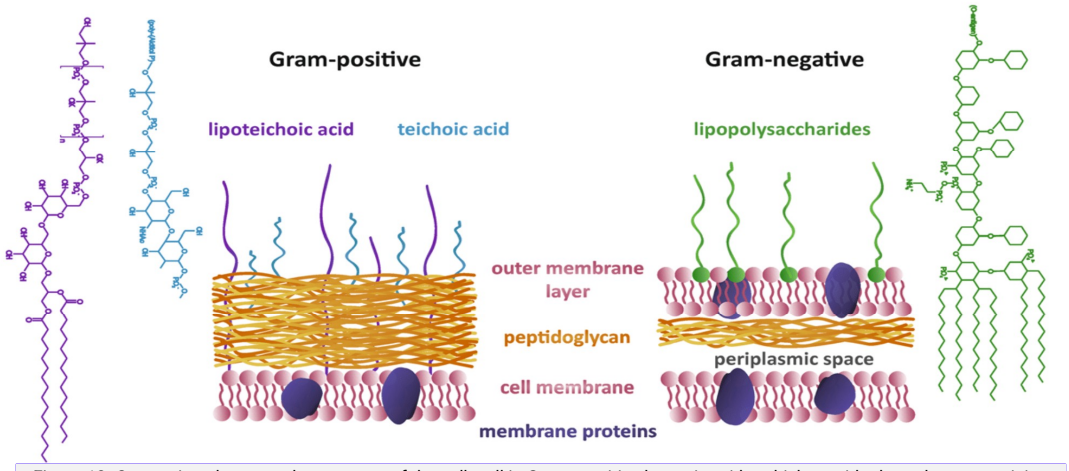


Figure 13: Comparison between the structure of the cell wall in Gram-positive bacteria, with a thick peptidoglycan layer containing teichoic acids, and Gram-negative bacteria.

Bacterial Cell Characteristics

First. Morphological characteristics of bacteria

Shape and Arrangement

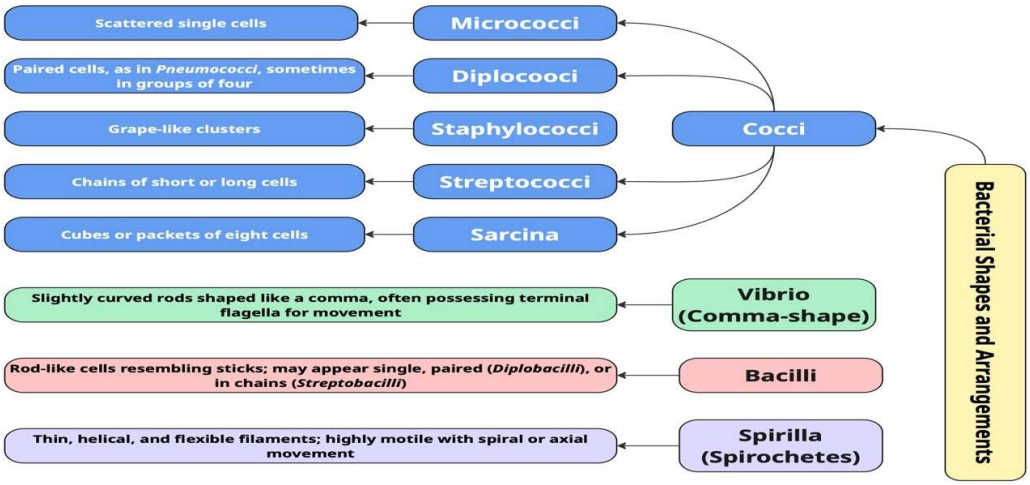


Figure 14. A chart showing different bacterial shapes and arrangements, including cocci, bacilli, spirilla, and vibrio, with examples of how the cells group or align.

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Size

The size of a bacterial cell is measured in microns (1 micron = 1/1000 mm).

- Most cocci have a diameter of about 1 μm.
- Bacilli, such as *Escherichia coli*, may reach up to 500 μm in length.
- Size varies depending on factors such as cell age, growth temperature, and nutrient availability.

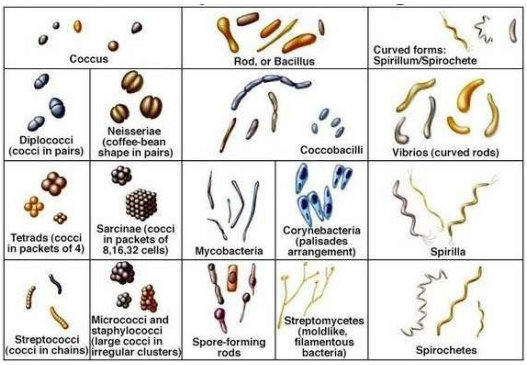


Figure 15: Shows the shapes of bacteria

Gram Staining Reaction

- Gram-positive bacteria (G+ve): Retain the violet stain.
- Gram-negative bacteria (G-ve): Do not retain the primary stain and appear red after counterstainin

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.

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

Sexual Reproduction (Genetic Recombination)	Spore Formation (Endospore Formation)
Definition	
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.

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Steps	
1. The donor and recipient bacterial cells come close, and the pilus of the donor attaches to the recipient. 2. The donor chromosome splits, and one part is transferred to the recipient through the pilus. 3. The two cells separate.	1. The chromosome begins to divide. / 2. One of the chromosomes moves to the end of the cell. / 3. The protoplasmic portion separates from the rest of the cell, each surrounded by its own membrane. / 4. The protoplast completely encloses the terminal portion. / 5. A spore is formed, surrounded by two membranes (inner and outer). / 6. Each plasma membrane secretes a cell wall. / 7. A layer called the **cortex** forms between the two walls

Vegetative Reproduction		
Types		
Fragmentation	Budding	Binary Fission
Steps		
1. Bacteria begins as branched filaments that are not fragmented. 2. These filaments break into shorter units. 3. The short units are divided into smaller ones. 4. Under suitable conditions, each unit grows into a new filament. 5. The new filaments develop into branched filaments that fragment again.	1. A protrusion (bud) forms at one end of the cell. 2. The bud grows gradually. 3. DNA is replicated and added into the bud. 4. Cytoplasm and cellular components are added. 5. The bud separates from forming a new cell.	1. Duplication of all cellular components, including the genetic material (genome). 2. Cell elongation and distribution of components to opposite poles. 3. Formation of a transverse wall that separates the cell into two parts. 4. Two identical daughter cells are produced, which may either separate or remain attached.

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Bacterial Growth Curve

Growth and Reproduction

Growth

The growth process occurs through:

1. Cell growth: Increase in the amount of protoplasm.
2. Division: Increase in the number of cells and the formation of colonies.

- Under favorable environmental and nutritional conditions, bacteria reproduce at an extremely rapid rate. The population can reach 10–15 billion cells per milliliter in a short period of time.
- Some species, such as Actinomycetes, reproduce by fragmentation or by budding.

Practical Impact

The rapid growth of certain bacteria, such as *Salmonella*, leads to food spoilage and poisoning within a short period of time.

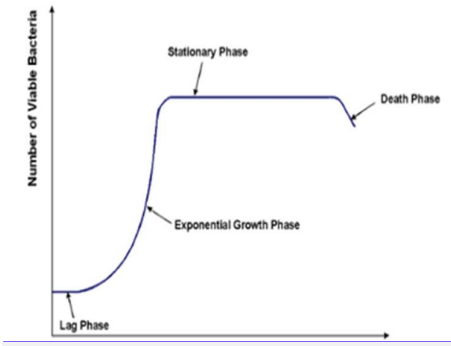


Figure 16. Graph of the bacterial colony growth rate

Factors Determining the Nature of Bacterial Colony Growth

- Nutritional factors
- Physical factors

Growth Rate Calculation

The growth rate of a bacterial colony can be calculated using a graph that shows the relationship between:

- The number of bacteria (colony growth)
- The time required (duration)

Phase	Description
Lag phase	No increase in cell number – increase in cell size and synthesis of structures for division
Log phase	Rapid and regular growth – highest rate of reproduction
Stationary phase	Cell number remains constant – balance between growth and death
Decline (Death) phase	Rapid increase in cell death compared to growth

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Nutritional Factors

Bacteria require: Energy source (proteins, carbohydrates), carbon, hydrogen, nitrogen, vitamins, water (constitutes about 80% of the cell's mass)

- 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.

Physical Factors

- pH: Most bacteria grow in a neutral medium (6.8–7.2).

- Special types:

1. Acidophilic bacteria: e.g., *Lactobacilli*, grow at pH less than 4.
2. Alkaliphilic bacteria: e.g., *Vibrio cholerae*, grow in alkaline media

Aeration (Oxygen Requirement)

Bacteria are divided into three main groups according to their oxygen needs: (to be completed: obligate aerobes, obligate anaerobes, facultative anaerobes).

Type	Oxygen Requirement	Energy Production Method
Aerobic	Require oxygen	Aerobic respiration
Anaerobic	Die in the presence of oxygen	Anaerobic fermentation
Facultative anaerobic	Can live with or without oxygen	Aerobic respiration when oxygen is present / Anaerobic fermentation when absent

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Temperature

Bacteria are classified according to temperature tolerance into three types:

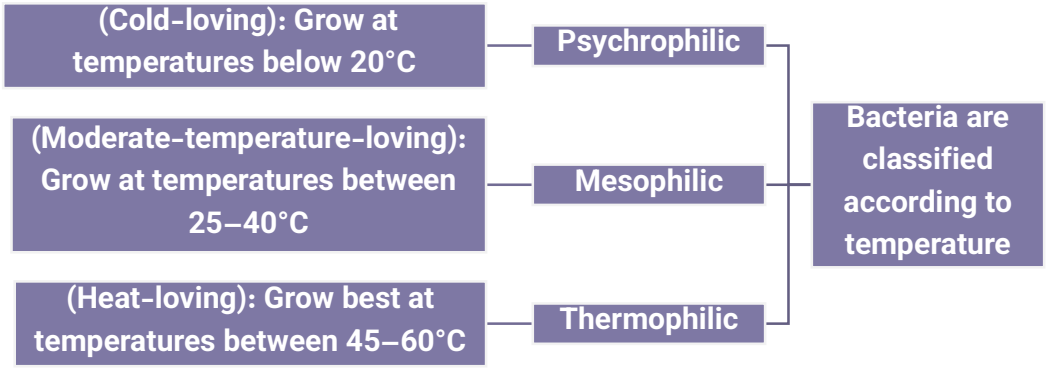


Figure 17. A chart showing different bacterial shapes and arrangements, including cocci, bacilli, spirilla, and vibrio, with examples of how the cells group or align.

Osmotic Pressure

Type	NaCl Concentration	Adaptation
Normal bacteria	~1%	Balanced osmotic pressure
Halophobic	>1%	Regulates salts to cope with high concentration
Halophilic	<1%	Regulates salts to cope with low concentration

4. Prokaryotic Inheritance

Traits are usually transmitted from parents to offspring in sexually reproducing communities. Prokaryotes, however, do not reproduce sexually; yet they are still capable of exchanging genetic material between different cells. This is known as horizontal gene transfer, in which genes move from one cell to another through three main mechanisms:

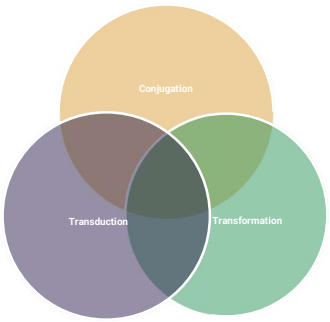


Figure 18. A Venn diagram showing the three methods of bacterial gene transfer

1. Conjugation: Requires direct contact between two cells to exchange genetic material.
2. Transformation: Some bacteria can take up genetic material directly from their surrounding environment and incorporate it into their own genome.
3. Transduction: Occurs through viruses that transfer genetic material from one cell to another during bacterial infection.

These processes have been observed more clearly in true bacteria, while their study in archaea remains limited and challenging due to the inability to culture most of their species in the laboratory. Therefore, early studies focused mainly on *Escherichia coli* (E. coli), which has been extensively researched to clarify these mechanisms in greater detail.

Conjugation depends on the presence of a conjugative plasmid

Plasmids: Additional genetic elements within the bacterial cell that replicate independently of normal cell division.

Functions: They carry traits that provide extra advantages, such as antibiotic resistance.

Conjugative plasmids: Essential for the transfer of genetic material from one cell to another.

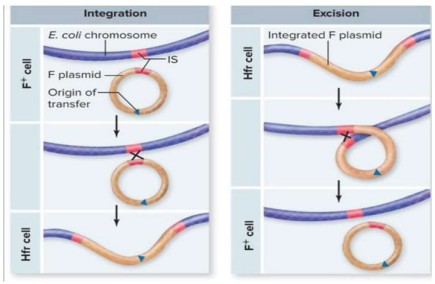


Figure 19: Illustrates the integration of the F plasmid with the E. coli chromosome to form an Hfr cell, and the process of excision and cutting that may restore the F plasmid either as a free element or carrying chromosomal fragments.

Main example – The Fertility Plasmid (F plasmid):

- Grants the cell the ability to perform conjugation.
- Cells that contain it are called F^+ cells.
- Cells that lack it are called F^- cells.
- All conjugative plasmids contain a genetic sequence that enables transfer.

Significance: The F plasmid not only transfers genes but also contributes to enhancing genetic diversity.

Transfer of the F Fertility Factor

Genetic structure:

- The F plasmid carries genes associated with DNA.
- It also contains additional genes that regulate its transfer between cells.



Figure 20: Illustrates the conjugation bridge.

Formation of the conjugation bridge:

- These genes encode specialized small proteins that assemble on the cell surface.
- The F^+ (donor) cell connects to the F^- (recipient) cell via the conjugation bridge.

Transfer mechanism:

- Occurs through rolling-circle replication.
- The plasmid DNA is nicked at the origin of transfer.

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- A single DNA strand separates and gradually moves into the F^- cell through the conjugation bridge.
- At the same time, a complementary DNA strand is synthesized in both the donor and the recipient cell.

Result:

- The process ends with a complete copy of the F plasmid in each cell.
- The F^- cell becomes F^+ and gains the ability to perform conjugation.

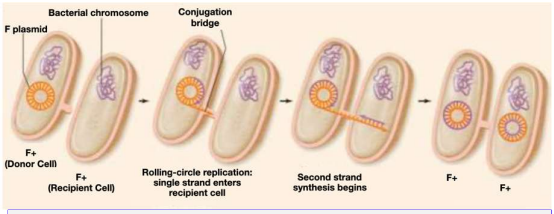


Figure 21: Illustrates the process of bacterial conjugation, which is one form of asexual reproduction.

Genetic recombination between the F plasmid and the host chromosome:

- Integration of the F plasmid: Sometimes, the fertility plasmid (F plasmid) integrates into the bacterial chromosome.
- Outcome: A special type of cell is formed, known as a High-frequency recombination cell (Hfr cell).
- Conjugation process:
  - During conjugation, the plasmid transfers along with portions of the donor cell's chromosome.
  - This allows for extensive exchange of genetic material.
- **Significance:**
  - Leads to major genetic diversity.
  - Strongly resembles genetic recombination that occurs during meiosis in eukaryotes.

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5. Antibiotic Resistance

Resistance Plasmids (R plasmids):

- Some conjugation-associated plasmids acquire genes that confer resistance to antibiotics.
- These are known as resistance plasmids (R plasmids).
- They are characterized by the ability to carry resistance genes to multiple types of antibiotics at the same time.
- The rapid transfer of these plasmids among bacteria has led to the emergence and spread of multidrug-resistant strains.
- They are particularly dangerous in medical settings, as they cause drug-resistant infections.

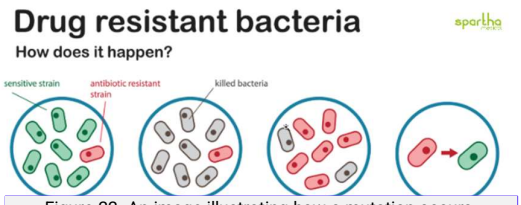


Figure 22: An image illustrating how a mutation occurs.

E. coli:
- A single mutation may occur in every 200 cells.
- When the population reaches 5,000 cells, about 25 new mutations may arise. The accumulation of mutations leads to the emergence of new strains with different capabilities.

Mutations as a Mechanism of Diversity

Mutations are random changes in the genetic material (DNA). They may provide bacteria with new traits, such as drug resistance or adaptation to new environments.

Nutritional mutations and their role in survival:

- Bacteria lose the ability to synthesize essential compounds for growth.
- They require special supplements such as amino acids.
- They are detected using the replica plating technique, by comparing colony growth.

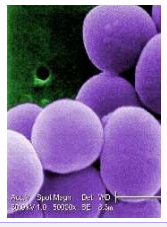


Figure 24. Scanning electron micrograph showing a strain of Staphylococcus aureus taken from a vancomycin-resistant



Figure 23. Scanning electron micrograph of a neutrophil engulfing a methicillin-resistant Staphylococcus aureus (MRSA).

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Multidrug-resistant bacteria:

Among the most notable clinical examples of mutations leading to dangerous bacterial strains are:

- **MRSA (Methicillin-resistant Staphylococcus aureus):**
  - Strong resistance to the antibiotic methicillin.
  - Commonly spread in hospitals and healthcare centers.
- **VRSA (Vancomycin-resistant Staphylococcus aureus):**
  - Developed resistance to the antibiotic vancomycin.
  - Resulted from mutations or gene transfer through plasmids or bacterial transformation.
  - Represents a major threat, as it may become resistant to nearly all available antibiotics.

6. Metabolism of Prokaryotes

Prokaryotes are characterized by an astonishing diversity in their methods of obtaining nutrients and energy, with each type having its own system to meet its needs. Some are autotrophic, while others are heterotrophic, and each group has its own distinctive subtypes.

Type	Energy Source	Carbon Source	Examples / Notes
Photoautotrophs	Light	CO_2	Purple and green bacteria – nutrient recycling
Chemolithoautotrophs	Inorganic reactions (sulfur, H_2, iron)	CO_2	Ammonia- and nitrite-oxidizing bacteria – thrive in extreme environments
Photoheterotrophs	Light	Organic compounds	Require fatty acids or alcohols to build their biomass
Chemoheterotrophs	Complex organic compounds	Organic compounds	Most widespread – includes pathogenic prokaryotes

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7. Benefits of Bacteria

Archaea and bacteria play pivotal roles in sustaining ecosystems through chemical recycling, symbiotic relationships, and bioremediation.

Biogeochemical cycles:

- **Carbon cycle:** CO_2 fixation by photoautotrophs, oxygen production by cyanobacteria, and carbon recycling through heterotrophs.
- **Nitrogen cycle:** Conversion of N_2 into ammonia, formation of amino acids and proteins, and denitrification returning nitrogen to the atmosphere; *nif* enzymes are oxygen sensitive.
- **Sulfur & phosphorus cycles:** Sulfur oxidation and conversion of phosphorus into usable forms to enhance soil fertility.
- **In aquatic environments:** Prokaryotes such as *Anabaena* and *Nostoc* fix nitrogen through heterocyst cells.

Symbiosis:

- **With plants:** *Rhizobium* in root nodules of legumes, and *Frankia* in alder roots.
- Other forms:
  - **Mutualism:** Cellulose digestion in ruminants.
  - **Commensalism:** Bacteria living on the human surface.
  - **Parasitism:** Pathogenic bacteria infecting plants or animals.

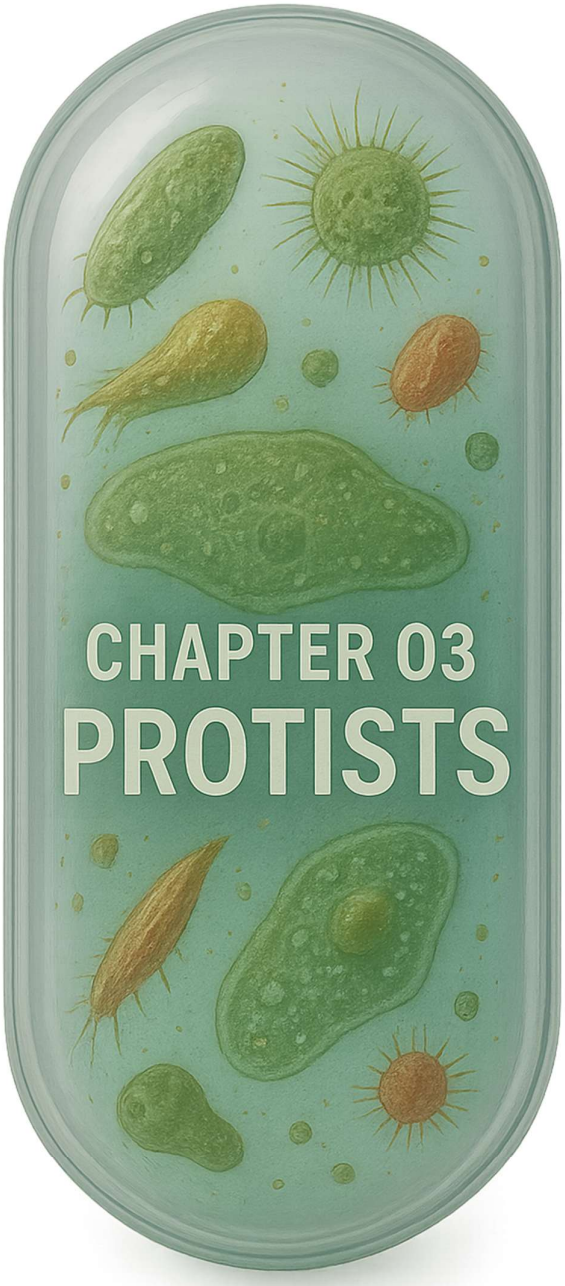
Applications:

- **Wastewater treatment:** Production of CH_4 gas.
- **Oil spill treatment:** Degradation of hydrocarbons.
- **Heavy metals removal:** Uranium removal by *Geobacter*.
- **Halorespiration:** Utilization of chlorinated compounds as an energy source.

Bioremediation:

Breaking down pollutants and converting them into less harmful compounds.

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1. Introduction

Definition	Forms
Eukaryotes that live in **moist soil**, **saltwater**, and **freshwater**. Some are **parasitic** to other organisms, including humans.	- Unicellular. / Multicellular/ - Colonies
Common Examples	**Structure**
Golgi bodies, Amoeba, Plasmodium, Paramecium, Euglena, 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.

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Movement

Protists possess specialized structures for movement, which may be:		
Form	**Example**	**Mode of Movement**
	*Paramecium*	Cilia
	*Euglena*	Flagella
	*Amoeba*	Pseudopodia
	*Plasmodium*	No locomotory organ (move by gliding within host fluids)

2. Scientific Classification of Protists

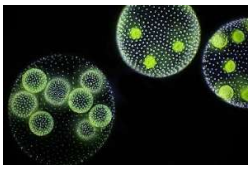
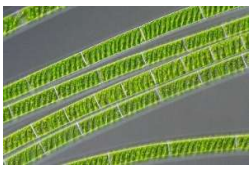
Protists are classified based on their nutrition into two main groups:			
Comparison Aspect	**Algal (Plant-like Protists)**	**Protozoa (Animal-like Protists)**	**Fungus-like-Protists**
Nutrition	Autotrophic (Producers)	Heterotrophic (Consumers)	Heterotrophic (Consumers)
Description	Some are unicellular, others are multicellular	Unicellular	Some are unicellular, others are multicellular
Divisions	Include six divisions : Euglenophyta (Euglenoids) 1. Chrysophyta (Golden algae) 2. Pyrrophyta (Dinoflagellates) 3. Chlorophyta (Green algae) 4. Phaeophyta (Brown algae) 5. 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

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First. Algal (Plant-like Protists)

Characteristics

- Spread in moist and shaded environments, or in freshwater and saltwater; some may live on soil surfaces or with fungi forming lichens.
- Tolerate varying conditions of temperature (up to 80°C) and salinity (up to 2.5%).
- Simple thallus organisms do not differentiate into roots, stems, or leaves.
- Chlorophylls are autotrophic through photosynthesis.
- Their life cycle is characterized by alternation of generations between a sexual gametophyte stage and an asexual sporophyte stage.
- Display diverse colors: green, blue-green, yellowish, red, yellow, orange, olive, brown.
- Sizes vary from microscopic unicellular types to large forms such as kelp, which may reach up to 60 meters in length and live in cold oceans.

The structure of the thallus in algae varies according to their genera and orders; it may consist of:		
Form of the Organism	**Example**	**Thallus Structure**
	*Chlamydomonas*	Single cell
	*Volvox*	Colony of unicellular organisms
	*Spirogyra*	Unbranched filament divided into cells
	*Vaucheria*	Branched filament not divided into cells

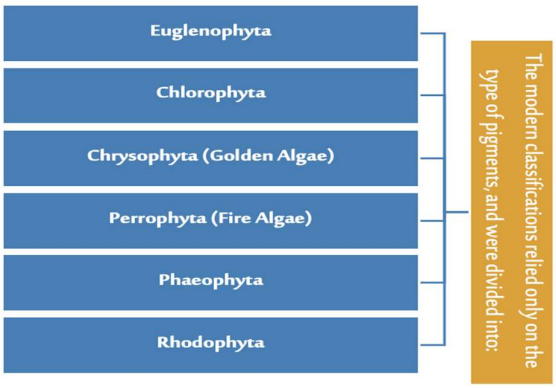
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	*Fucus*	Specialized tissues performing different functions

The classification of algae into their groups depends on the following characteristics:

Type of pigments present.

- Type of stored food in their cells.
- Structure of the cell wall.
- Type of reproductive structures.
- Mode of movement.



1. Phylum Euglenophyta (Euglenoid Algae)

- It includes about 450 species.
- Represents a link between animals and plants.
- Resembles protozoa by having:
  - An eyespot.
  - A gullet.
  - The ability to sometimes feed like animals.
- Classified among algae because it contains pigments that enable it to carry out photosynthesis.
- Reproduce very rapidly until it covers the water surface with a characteristic green scum.



Figure 25. Example of Euglenoid Algae (Euglena sp.)

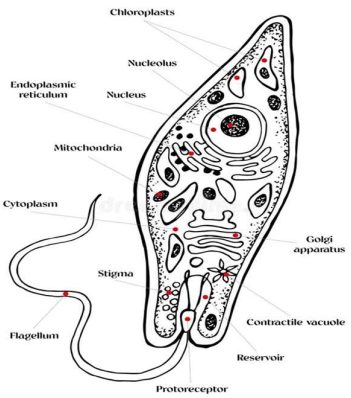
Habitat

- Found in aquatic environments rich in organic matter, such as:
  - Ponds
  - Swamps
  - Rice fields

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Food Storage

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

Example of Euglenoid Algae: Genus Euglena (Euglena sp.)	
Structure	• Composed of a single spindle-shaped cell with a blunt end. • Contains a funnel-shaped opening called the gullet, leading to a spherical reservoir. • It has a single flagellum that originates from a basal granule at the bottom of the reservoir and extends from the anterior opening along the body.  Figure 26. Diagram of Euglena • The outer part of the cytoplasm is denser than the rest and is called the periplast, which changes shape during movement. • The cytoplasm contains a distinct nucleus. • The cytoplasm also contains pigments: chlorophyll, carotene, and xanthophyll. • Possesses a light-sensitive eyespot at the base of the canal. • A contractile vacuole is located near the reservoir for excretion.
Movement	• Rapid spiral motion using the long flagellum. • Slow spiral motion by flexing its body.
Reproduction	• Binary fission under favorable conditions. • Encystment under unfavorable conditions.
Nutrition	• Three modes of nutrition: 1. Autotrophic (plant-like). 2. Membrane diffusion. 3. Heterotrophic (animal-like).

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	• Waste gases from metabolic processes diffuse across the body surface. • Small radial vacuoles collect excess water; once full, they contract into the reservoir, which then expels the contents outside.

2. Division: Green Algae (Chlorophyta)

Definition

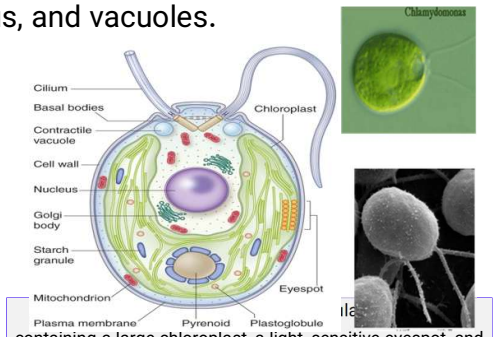


Figure 27: Green algae of different types; filamentous algae at the top, and thalloid/leaf-like algae (Ulva or sea lettuce) at the bottom, both carrying out photosynthesis.

- Includes about 7,000 species.
- Vary in form and size.
- Contain:
  - Chlorophyll a & b
  - Xanthophyll
  - Carotene
- Cell walls are composed of cellulose.
- Protoplast consists of cytoplasm, a true nucleus, and vacuoles.

Habitat

- Most live in freshwater.
- Some live in:
  - Moist soil
  - Rocks or damp tree trunks
  - Inside the vacuoles of some protozoa or invertebrates in symbiotic association
  - With fungi to form lichens



containing a large chloroplast, a light-sensitive eyespot, and two anterior flagella for movement.

Example of Green Algae: Genus Chlamydomonas sp.	
Structure	• Unicellular microscopic alga that lives in ponds and swamps. • Possesses a cellulose cell wall and a cup-shaped chloroplast for starch storage. • Contains a light-sensitive eyespot that helps it move toward suitable light for photosynthesis or away from intense light.
Movement	• Moves using two anterior flagella, each guided by a contractile vacuole located at its base.
Reproduction	• Asexual: Binary fission under favorable conditions. • Sexual: Formation of a zygote under unfavorable conditions.

3. Phylum Chrysophyta (Golden Algae)

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Distinctive Characteristics:

- Plastids contain:
  - Carotene.
  - Fucoxanthin (in higher proportion than Chlorophyll).
- This pigment distribution gives them a golden-yellow coloration.
- They vary in size and form:
  - Microscopic.
  - Macroscopic.
  - Some are motile.



Figure 29: A collection of diatoms with intricate, glass-like geometric shapes viewed under a microscope.

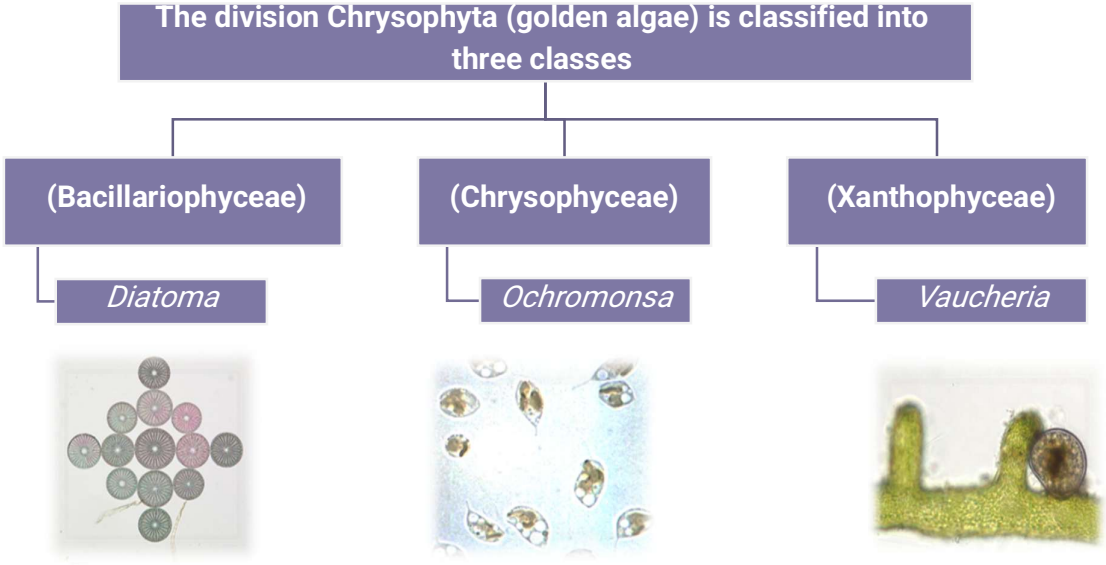


Figure 30: A chart showing the classification of golden algae (Chrysophyta) into three classes

Example of Golden Algae: Phylum Diatoms	
Characteristics	• Diatoms may exist as single cells, gelatinous colonies, or sedentary forms attached to mud and stones. • Their cell walls are composed of silica and pectin, intricately ornamented with distinctive patterns. • They are recognized for their delicate wall structure, making them among the most beautiful microscopic organisms.
Habitat	• Found in freshwater, marine, stagnant, and running waters.

	• Usually, plants exist as plankton (floating) or attached to filamentous algae or other plants. • Serve as an important food source for fish.
Stored Food	• Diatoms store their reserve materials in the form of oils and leucosin.
Reproduction	• Asexual reproduction by binary fission. • Sexual reproduction through motile gametes.
Pennate Structure	• The cell wall of diatoms consists of two valves: an upper one (*epitheca*, lid) and a lower one (*hypotheca*, box), which overlap like a capsule. • The junction where the two valves meet is called the girdle. • The nucleus is usually central and connected to the cytoplasm by cytoplasmic threads (bridges).

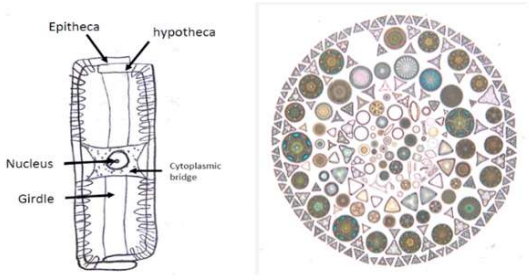
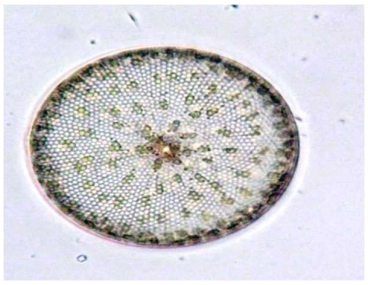


Figure 31. Diatoms Illustration of their cellular structure (upper and lower valves, nucleus) and the diversity of their ornate geometric shapes formed by the siliceous frustule.

Diatoms are classified according to their symmetry into		
Centric Diatoms	Pennate Diatoms	**Aspect of Comparison**
Radial symmetry (discoid)	Bilateral symmetry (elongated/pennate)	**Symmetry**

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		**Form**

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



Figure 32: 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.

Habitat:

- Marine algae, living in seas and oceans.
- Attached to rocks, stones, or rocky plants.
- Fixed by holdfasts, therefore they are non-motile.

From:

- Multicellular.

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- 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 33: Image of a brown alga

Pigments:

- The dominant pigment: Fucoxanthin.
- Present in larger amounts than Chlorophyll and Carotene.
- Gives the characteristic brown coloration.

6. Red Algae (Phylum Rhodophyta)

Habitat:

- Marine algae.
- Found in deep marine environments (oceans and seas).





Figure 34: Marine red algae.

Form:

- Highly diverse:
    - Unicellular.
    - Simple or filamentous branched forms.
    - Parenchymatous structures, which may reach up to a meter in length.

Motility: Non-motile.

Pigments:

- Dominant pigment: Phycoerythrin (red).
- Secondary pigment: Phycocyanin (blue, in small amounts).
- Also contain Carotene and Chlorophyll.

Stored Food:

- Floridean starch.

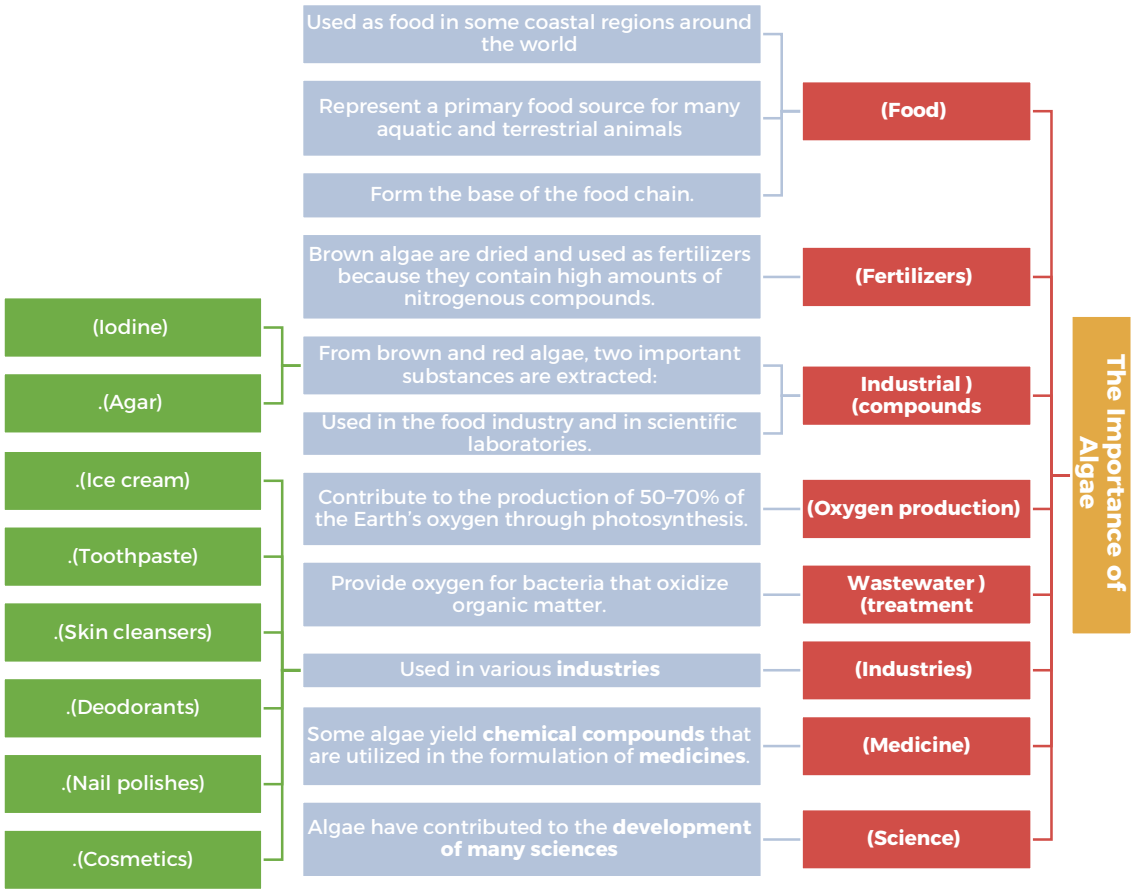
Cell Wall:

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

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Reproduction:

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



3. The Economic Importance of Algae in Human Life



Figure 35. Growth of green algae in aquatic environments causing the phenomenon of algal bloom.

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Second. Animal-like Protists (Protozoa)

Characteristics:

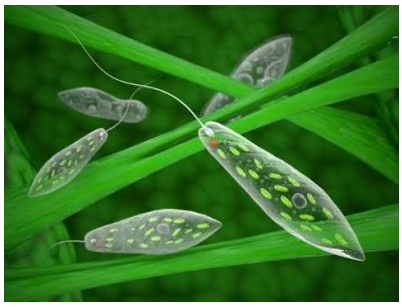


Figure 36. Protozoa

- Most are microscopic organisms.
- All are unicellular.
- Usually live individually, sometimes in colonies.
- Typically contain a single nucleus, though a few species have two nuclei.
- 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.

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.

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.

Excretion:

- Occurs by diffusion across the body surface (since no cell wall is present).

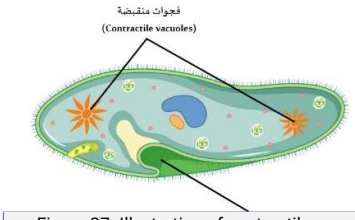


Figure 37. Illustration of contractile vacuoles

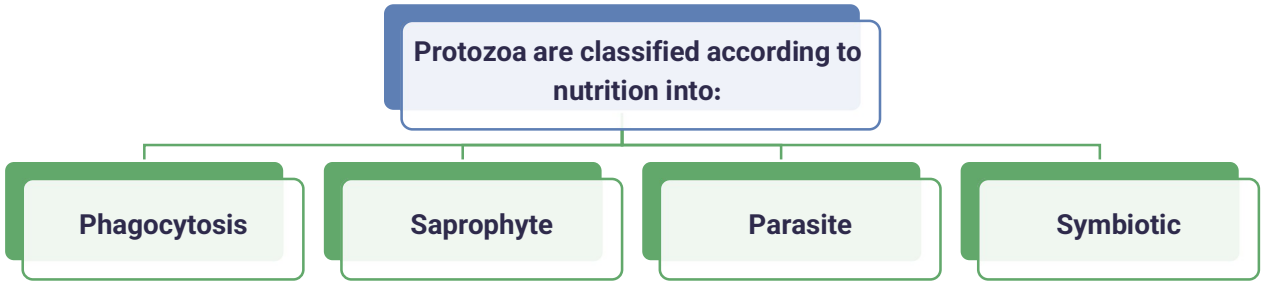
Reproduction:

- 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.

Move by pseudopodia	Sacradina
Move by flagella	Mastigophora
Move by cilia	Ciliophora
Lack locomotory structures	Sporozoa

Protozoa are classified into four subphyla according to the type of locomotory structures they use.

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First: Subphylum Sarcodina (Amoebozoa)

Habitat:

- Live free-living in freshwater and marine environments, e.g., *Amoeba proteus*.
- Some species are parasitic, such as *Entamoeba histolytica*, which inhabits the human intestine and causes dysentery (amoebic dysentery).

Locomotion:

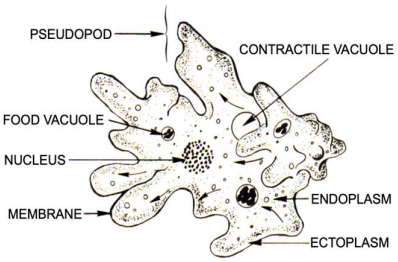
- Move by means of pseudopodia, which are constantly forming and disappearing.
- These pseudopodia are also used in feeding, as the organism engulfs its prey in a process called phagocytosis.



Figure 38. Amoeba proteus with pseudopodia

Example of Phylum Sarcodina: Free-living Amoeba sp.	
Description	A microscopic protoplasmic mass with a diameter ranging between 127–340 microns. The largest species may reach about ½ mm, appearing to the naked eye as shining dots in water.
Habitat	Freshwater in ponds, swamps, and wells.

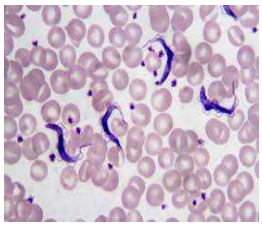
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Form	Variable and non-fixed; its cell is surrounded by a thin, flexible membrane.
Respiration and Excretion	By diffusion through the membrane.
Reproduction	• Asexually by binary fission. • Sexually by conjugation, though rarely. • Capable of encystment under unfavorable conditions.
Structure	Unicellular organisms contain a nucleus and cytoplasm with organelles such as mitochondria, Golgi apparatus, endoplasmic reticulum, and ribosomes. It also contains contractile vacuoles and food vacuoles of various sizes.  Figure 39. A diagram of Amoeba

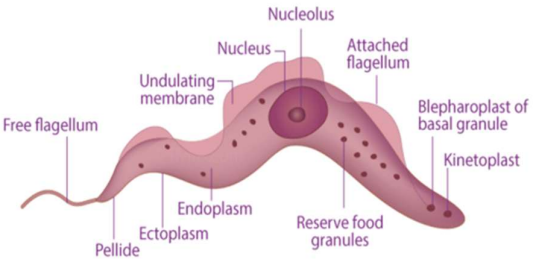
Secondly: Subphylum Mastigophora

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.

Example of Subphylum Mastigophora: Genus Trypanosoma sp.	
Characteristics	Parasitic zooflagellates found in the blood or tissues of many vertebrates, including humans. The life cycle of this parasite involves, in addition to the vertebrate host, another host from blood-sucking invertebrates (such as certain species of flies, fleas, or bugs).  Figure 40. Microscopic image showing Trypanosoma parasites among red blood cells
Locomotion	They swim in the plasma of the vertebrate host's blood by the undulating movement of the flagellum and the undulating membrane. Locomotion is also aided by the sequential contraction and relaxation of body parts.

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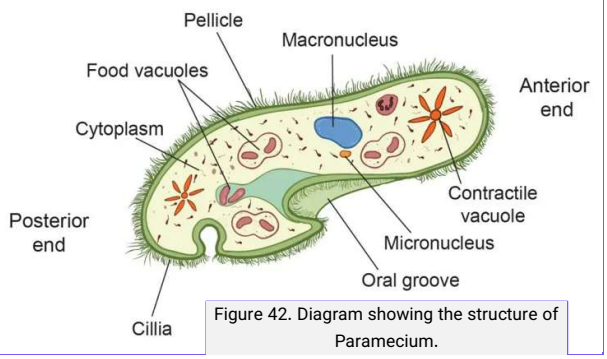
Nutrition	Able to ingest tiny drops of blood plasma at the cell surface, a process known as **saprozoic feeding (pinosome drinking / "sucking")**.
Reproduction	Asexually by binary fission.
Structure	• The body is spindle-shaped, pointed at both ends, and rigid due to the presence of a pellicle covering it externally. • The internal structure includes cytoplasm containing a large oval nucleus, a flagellum, an undulating membrane (the part of the flagellum attached to the body), a basal granule at the base of the flagellum, and posterior to it lies the kinetoplast (kinetosome).  Figure 41. A labeled Trypanosoma cell with its key structures.

Third: Subphylum Ciliophora

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*.

Example of Subphylum Ciliophora: Genus Paramecium sp.	
Habitat	*Paramecium* lives in freshwater ponds and swamps rich in decaying vegetation.
Osmoregulation	The contractile vacuole system functions to remove excess water from the cytoplasm.
Respiration and Excretion	• Oxygen and carbon dioxide are exchanged by simple diffusion through the body surface. • Nitrogenous waste materials are also excreted by the same method.

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Nutrition	It feeds by ingesting unicellular microorganisms as prey. When the organism approaches an area rich in food, the cilium of the oral groove becomes active, driving food particles toward the mouth opening. The food enters through the cytostome (mouth) along with a drop of water to form a **food vacuole** in the cytoplasm. The food vacuole circulates along a definite path in the cytoplasm, where digestive enzymes act upon it. The digested materials are absorbed, and the remaining undigested matter is expelled through the **anal pore (cytoproct)** when the vacuole reaches it.
Reproduction	• Asexually by binary fission. • Sexually by conjugation or by autogamy (division of one of its nuclei).
Structure	• The body is shaped like a slipper, with the dorsal surface convex and the ventral surface flattened. • The body is covered by a firm **pellicle**, which in turn is lined with rows of regular cilia. • On the ventral side lies the **oral groove**, which extends inward to form a wide canal called the **vestibule** ending at the **mouth (cytostome)**; this leads to the **gullet (cytopharynx)**. The oral groove and vestibule are lined with long cilia that help in collecting and directing food. The **anal pore (cytoproct)** is located on the ventral surface just behind the cytopharynx. • It possesses two nuclei — a large **macronucleus** that controls the vegetative functions and a small **micronucleus** responsible for reproduction. The cytoplasm contains many food vacuoles and two sets of contractile vacuoles.  Figure 42. Diagram showing the structure of Paramecium.

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Fourth: Subphylum Sporozoa

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*).

Example of Phylum Sarcodina: Free-living Amoeba sp.	
Habitat	*Plasmodium* lives as a parasite, depending on two hosts during its life cycle. It resides in the wall of the digestive tract of the female *Anopheles* mosquito and in various tissues of its body, causing rupture of the intestine which may lead to the mosquito's death. When transmitted to humans, *Plasmodium* becomes parasitic on liver cells and red blood cells.
Locomotion	*Plasmodium* lacks locomotory organs and moves by gliding within the blood plasma.
Nutrition	It feeds by absorbing surrounding fluids such as the contents of liver cells, red blood cells, or mosquito body cells through diffusion across its entire body surface.
Nutrition	By diffusion through the membrane.
Reproduction	• Asexually by binary fission. • Sexually by conjugation, though rarely. • Capable of encystment under unfavorable conditions.
Structure	• **Asexual reproduction:** by binary fission. • **Sexual reproduction:** occurs inside the stomach of the mosquito.

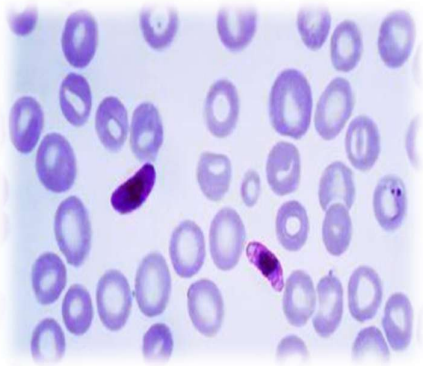


Figure 43. Microscopic image of red blood cells infected with the Plasmodium parasite, the causative agent of malaria.

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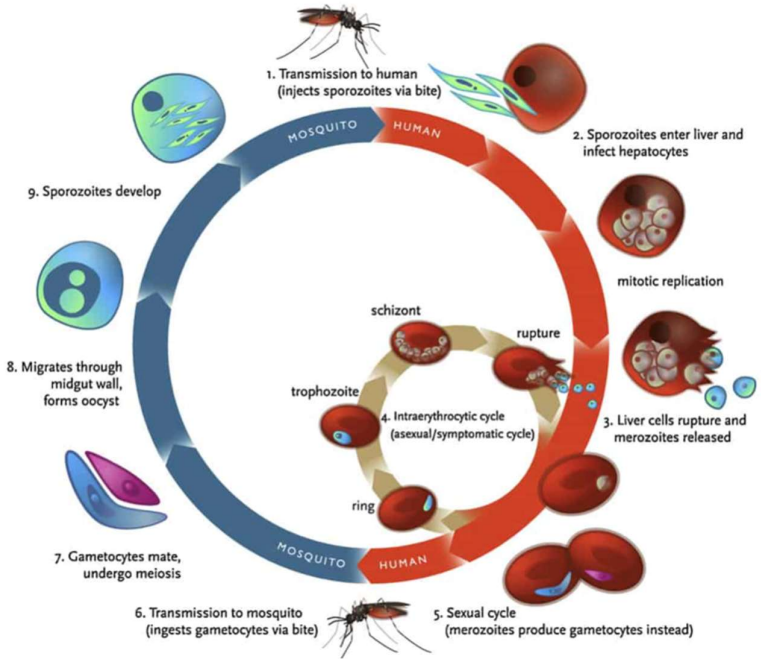
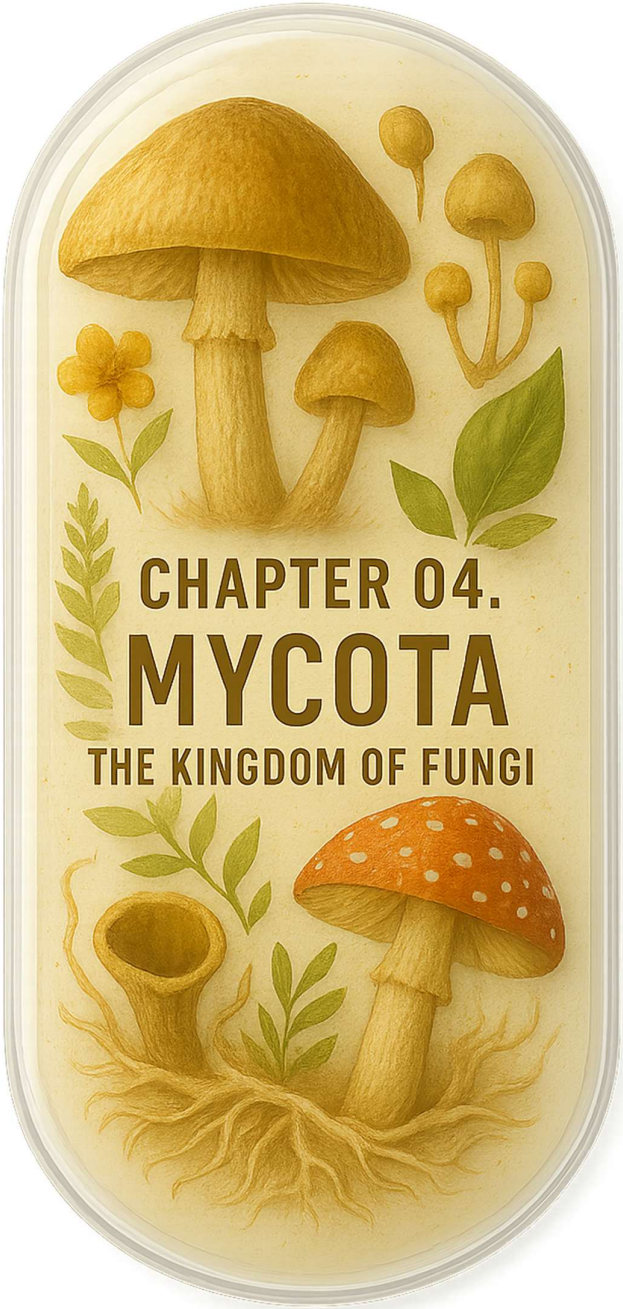


Figure 44: The life cycle of Plasmodium.

3. Importance of Protozoa

- Form 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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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.
- Fungi are widely distributed across diverse environments.
- 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, like animals.
- Fungi lack chlorophyll and are therefore non-photosynthetic; they obtain nutrients through alternative modes such as saprophytism, parasitism, or symbiosis.

Nutrition in Fungi

- Modes of Nutrition in Fungi

- Saprophytic: Fungi that obtain nutrients from decaying organic matter, plays 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).

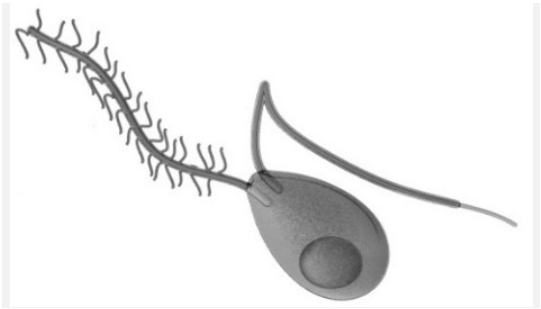
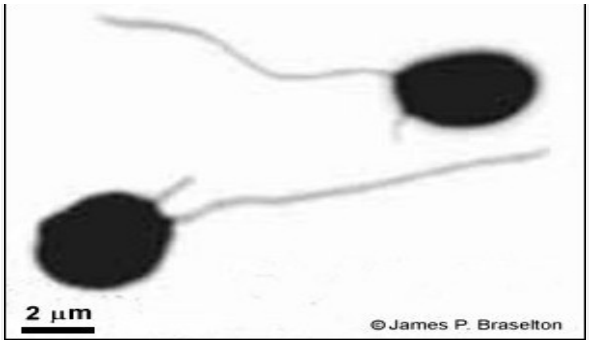
Fungi are classified according to their mode of nutrition as follows:	
Group of Fungi	**Description**
Obligate Parasitic Fungi	These fungi live parasitically in nature on specific suitable hosts. If the appropriate host is not available, they enter a dormant stage or die.
Facultative Parasitic Fungi	These fungi are normally saprophytic in natural conditions but can become 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.

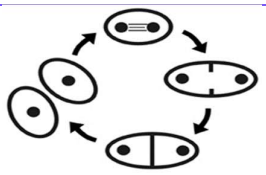
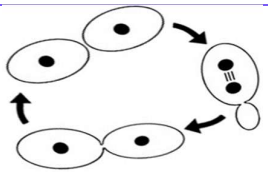
Tinsel Flagella	Whiplash Flagella
Consist of a long axis with numerous hair-like lateral projections extending along its sides	Consists of a long basal part and a short, flexible terminal segment
	

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.

First: Asexual Reproduction

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

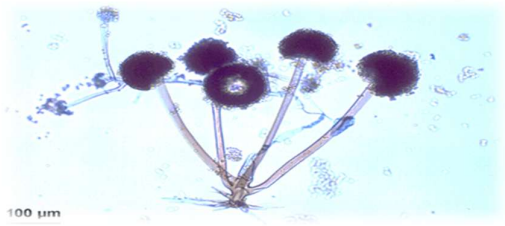
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	Spore Formation	The most common method: spores may be: – Endospores (e.g., *Sporangiospores*, *Zoospores*) or – Exospores (e.g., *Conidia*).	Endospores and Conidia

- 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

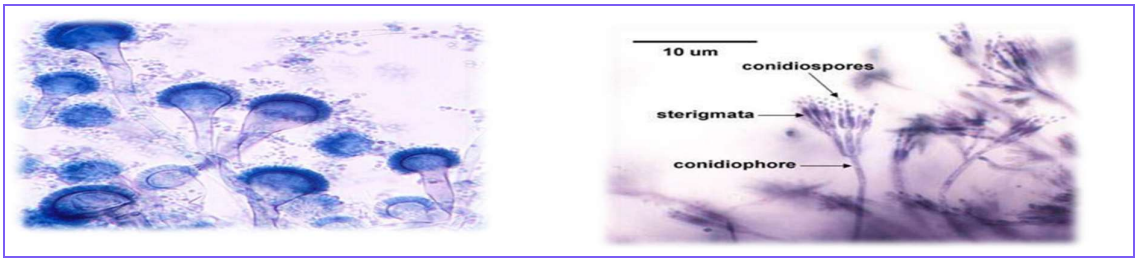
Endospores are formed inside a sporangium or sac, and they occur in several forms:

Sporangiospores	**Zoospores**
Formed within non-motile sporangia that are enclosed by a cell wall. Their dispersal depends on the wind, and the sporangia are born 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).
	

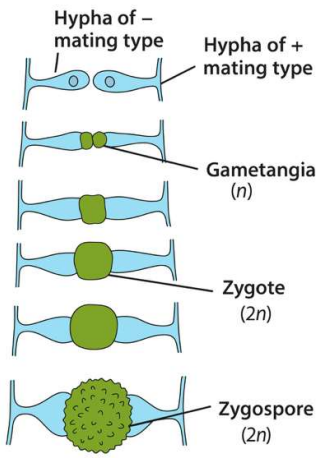
Exospores

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.



Second: Sexual Reproduction



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.

Figure 45. A diagram showing the three stages of fungal sexual reproduction: plasmogamy, karyogamy, and meiosis.

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

Classification of Fungi

1-Division: Gymnomycota (Slime Molds)

Class: Myxomycetes (Slime Molds)

These organisms represent an intermediate link between fungi and animals.

- 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.



Figure 46. Bright orange slime mold fruiting bodies.

Distinctive Features:

1. The vegetative body is a plasmodium, a naked, multinucleate mass of protoplasm capable of amoeboid movement.

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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 penetrates host cells for nutrient absorption.



Figure 47. Symptoms of Fungal Diseases on Plants

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.
- This division is further classified into four main classes.

Economic Importance of Fungi

First: Benefits

1. Decompose complex organic materials into simpler compounds, thereby enhancing soil fertility.
2. Contribute to the carbon cycle by releasing CO_2, which plants utilize in photosynthesis.
3. Improve agricultural soils through their continuous activity in breaking down organic matter.
4. Some species are used in food industries, such as in cheese production (*Penicillium* sp.).
5. Certain fungi are consumed as food, either fresh or dried, such as mushrooms.
6. Produce antibiotics, notably penicillin derived from *Penicillium*.
7. Synthesize organic acids, such as citric acid and acetic acid, using *Aspergillus* fungi.
8. Produce vitamins, especially members of the vitamin B complex.

Symbiotic Fungi (The Symbiotic Fungi)

Symbiosis is a relationship between two living organisms in which both partners benefit, often involving a microorganism. One of the most important examples is the association between fungi and the roots of vascular plants, known as mycorrhiza. Mycorrhizae are considered one of the most widespread and significant forms of symbiosis in nature.



Figure 48. A plant showing fungal mycorrhizae surrounding its roots.

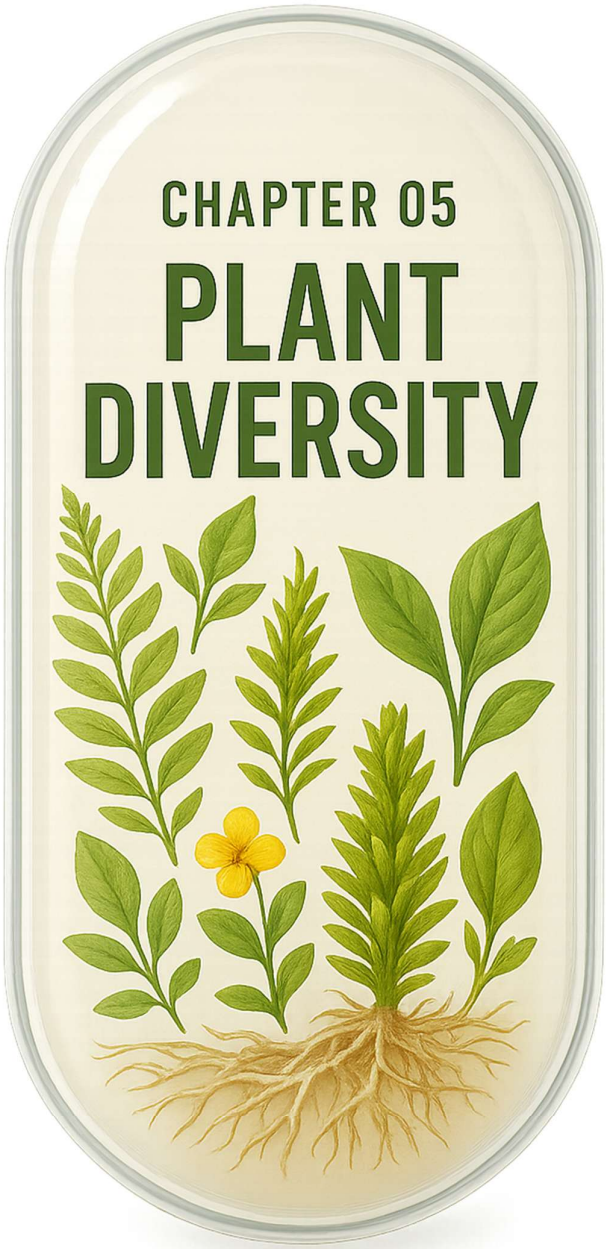
Benefits of the Relationship:

- Fungi help plant roots absorb water and essential nutrients from the soil through their powerful hydrolytic enzymes.
- In return, the plant roots supply the fungus with organic compounds and nutrients produced during photosynthesis.

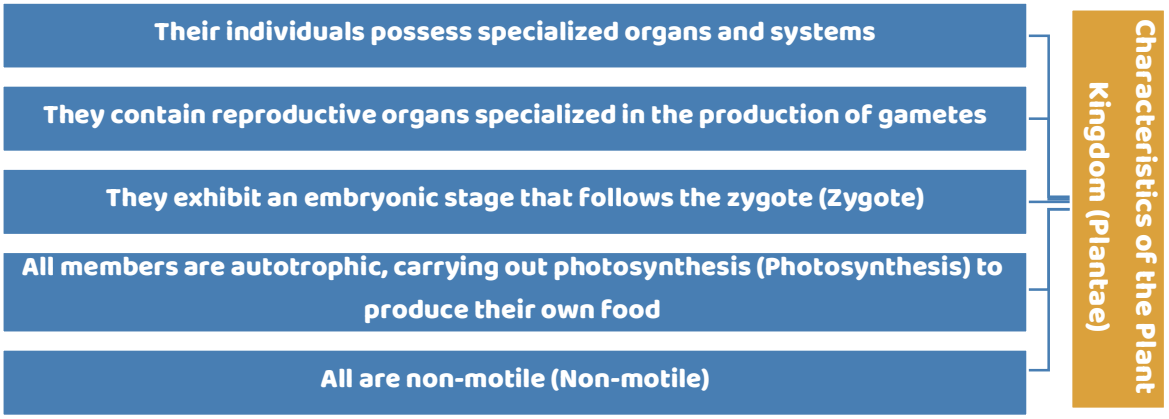
Lichens

- Lichens are organisms that result from a symbiotic association between a fungus and an alga, where neither can survive independently in its natural environment.
- The fungus secretes enzymes and acids that break down the surfaces on which it grows, allowing it to absorb water and mineral salts, which are then supplied to the alga.
- The alga performs photosynthesis, producing food for both it and the fungus, maintaining their mutualistic relationship.

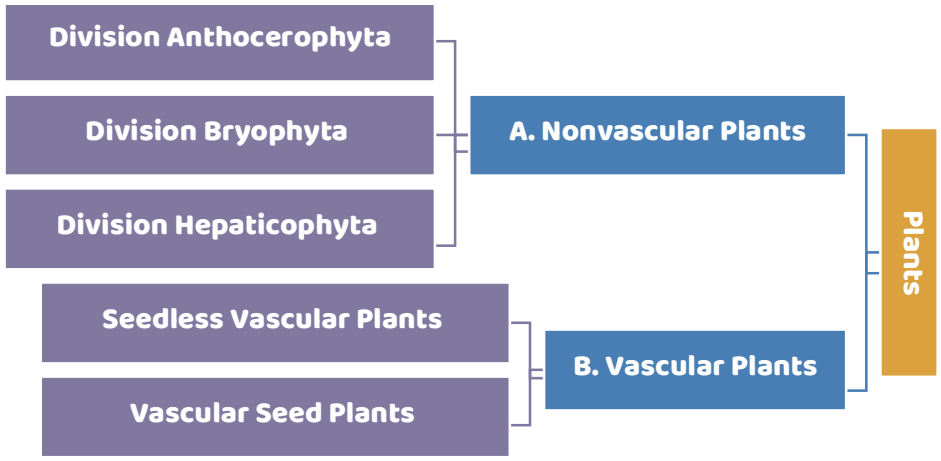
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Plant Classification:



Plant Life Cycle

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

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Hence, the life cycle proceeds through a continuous alternation between the diploid sporophytic phase (2n) and the haploid gametophytic phase (n).

Section I. Non-vascular plants

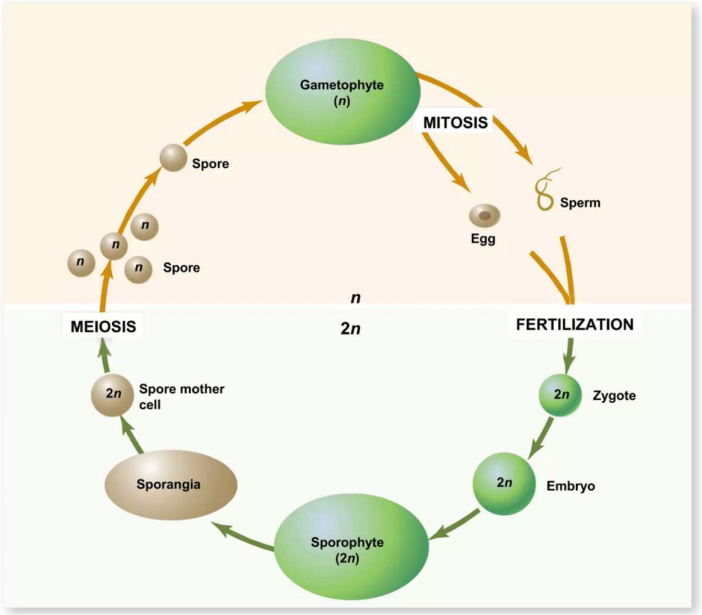


Figure 49. A diagram showing plant classification into nonvascular and vascular groups.

Characteristics of Nonvascular Plants

- Small in size
- Usually live in moist and shady environments
- Depend on water for the transport of nutrients and for reproduction.
- Lack true vascular tissues (Xylem & Phloem)

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Examples of Nonvascular Plants

<table>
<tr>
<td>
Figure 50: The Sphagnum Moss</td>
<td>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.
• Can tolerate long periods of desiccation and resumes growth when moisture becomes available.
• Importance: Forms layers of peat, which are used as a source of fuel and as agricultural soil.</td>
<td>(Mosses)</td>
</tr>
<tr>
<td>
Figure 51: The Marchantia Liverwort</td>
<td>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).</td>
<td>(Liverworts)</td>
</tr>
</table>

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Figure 52: The Anthoceros Hornwort

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.

(Hornworts)

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

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Transport	Vascular tissues transport by osmosis and diffusion in simpler species	Highly developed vascular tissues with efficient transport systems
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

Characteristics of Seedless Vascular Plants

- **Larger in size and better adapted to live in dry environments compared to nonvascular plants**
- **Possess vascular tissues specialized for transporting water and nutrients (Xylem for water and Phloem for food)**
- **he sporophyte stage (Sporophyte) is the dominant phase in the life cycle**
- **Reproduce by spores (Spores) that are dispersed by wind, and grow into the gametophyte (Gametophyte) plant**
- **Do not produce seeds, which makes them less resistant to harsh conditions compared to seed plants**

Fern:

represents the largest group of seedless vascular plants.

1. Sporophyte Stage	2. Sporangia
- The dominant stage in ferns; large, multicellular, and diploid (2n). - Represents the familiar plant with long feathery leaves.	- Form on the underside of the leaves in clusters called sori. - Inside them are spore mother cells.
3. Formation of Spores	**4. Gametophyte Stage (Prothallus)**
The spore mother cells undergo meiosis to produce small, haploid spores (n)	- When the spores germinate, they develop into small, heart-shaped, thin green gametophytes containing chlorophyll. - They live independently and are capable of photosynthesis.

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5. Fertilization	6. Development into a New Sporophyte
- The sperm swims through water to reach the egg inside the archegonium. - Fertilization occurs, forming a zygote (2n).	- The zygote divides mitotically into a new sporophyte plant. - A new sporophytic generation begins, and the life cycle continues by alternating between the sporophyte and gametophyte stages.

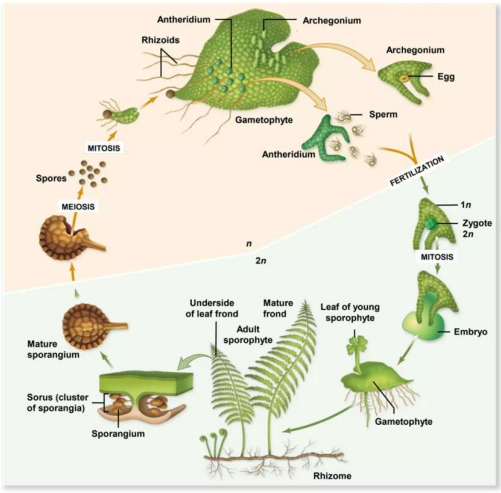


Figure 53. Diagram of the Fern Life Cycle

Section IV: Seed Plants (Vascular Seed Plants)

Characteristics of Seed Plants

- Produce seeds that contain the sporophyte and are enclosed within a protective tissue
- The sporophyte is the dominant stage
- Seeds have one or more cotyledons (Cotyledons) that store food and assist the embryo in absorption
- Adapted to various environments due to their seeds' ability to withstand harsh conditions

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.

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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.

Examples	Characteristics	Division
 *Cycad*	- Live in tropical and subtropical regions. - Male and female cones are borne on separate plants. - It has soft stems rich in storage tissues. - Resemble palms but differ in their reproductive structures.	**(Cycadophyta)**
 *Ephedra*, *Gnetum* and *Welwitschia*	- Have long lifespans (1,500–2,000 years). - Consists of three main genera: *Ephedra*, *Gnetum*, and *Welwitschia.* - Adapted to desert and arid environments.	**(Gnetophyta)**
 *Ginkgo biloba*	- A small division containing only one species. - Have fan-shaped leaves. - Dioecious plants (male and female plants separate). - Tolerant of pollution.	**(Ginkgophyta)**

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 *Pinus*  Fir (*Abies*)	- The largest gymnosperm division. - Male and female cones are usually found on the same plant. - Have needle-like or scale-like leaves. - Live in temperate and cold regions.	**(Coniferophyta)**
 Rice, Corn, Beans and Fruit trees	- 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.	**(Angiosperms)**

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.

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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.

Pine (Pinus)

Pine is a vascular seed plant classified as a gymnosperm.

1. Sporophyte	2. Male Cones
- The large tree (*pine*) represents the dominant stage. - It bears both male cones and female cones.	- Produce pollen grains that contain the male gametes. - These are carried by the wind to the female cones.
3. Female Cones	**4. Fertilization**
- Contain ovules. - After pollination, a pollen tube grows to allow the sperm cell to reach the ovule.	The male sperm cell fuses with the egg to form a zygote.
5. Seed Formation	**6. Seed Germination**
- The zygote develops into an embryo inside the seed. - The seeds are exposed (not enclosed by an ovary), hence the name gymnosperms.	Under suitable conditions, the seed germinates to produce a new sporophytic plant (pine tree).

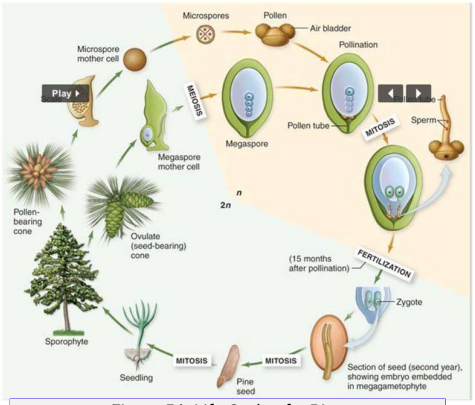


Figure 54. Life Cycle of a Pine

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Life Cycle of Angiosperms (Flowering Plants)

1. Flower Stage	2. Pollination
- The flower is the reproductive organum It consists of: • Sepals (Calyx). • Petals (Corolla). • Stamens is the male reproductive organ, containing the anther, which produces pollen grains. • Carpels (Pistils) is the female reproductive organ, consisting of the stigma, style, and ovary.	- The transfer of pollen grains from the other to the stigma. Two types: • Self-pollination occurs within the same flower or between flowers on the same plant. • Cross pollination occurs between flowers of different plants of the same species. Pollination may occur through wind, insects, water, or animals.
3. Double Fertilization	**4. Seed Formation**
- A unique feature of angiosperms. - The pollen tube grows through the style into the ovary. Two fusions occur: • One male nucleus fuse with the egg → forming the zygote, which develops into the embryo. • Another male nucleus fuses with two polar nuclei → forming the endosperm, which stores food.	- The ovule develops into a seed containing: • The embryo. • One or two cotyledons. • A seed coat for protection
5. Fruit Formation	**6. Germination**
- The ovary develops into a fruit that surrounds and helps in the dispersal of seeds.	- When suitable conditions are available (water, oxygen, appropriate temperature): • The seed germinates and develops into a new sporophytic plant. - Types of germination: • Hypogeal germination – cotyledons remain below the soil. • Epigeal germination – cotyledons appear above the soil surface.

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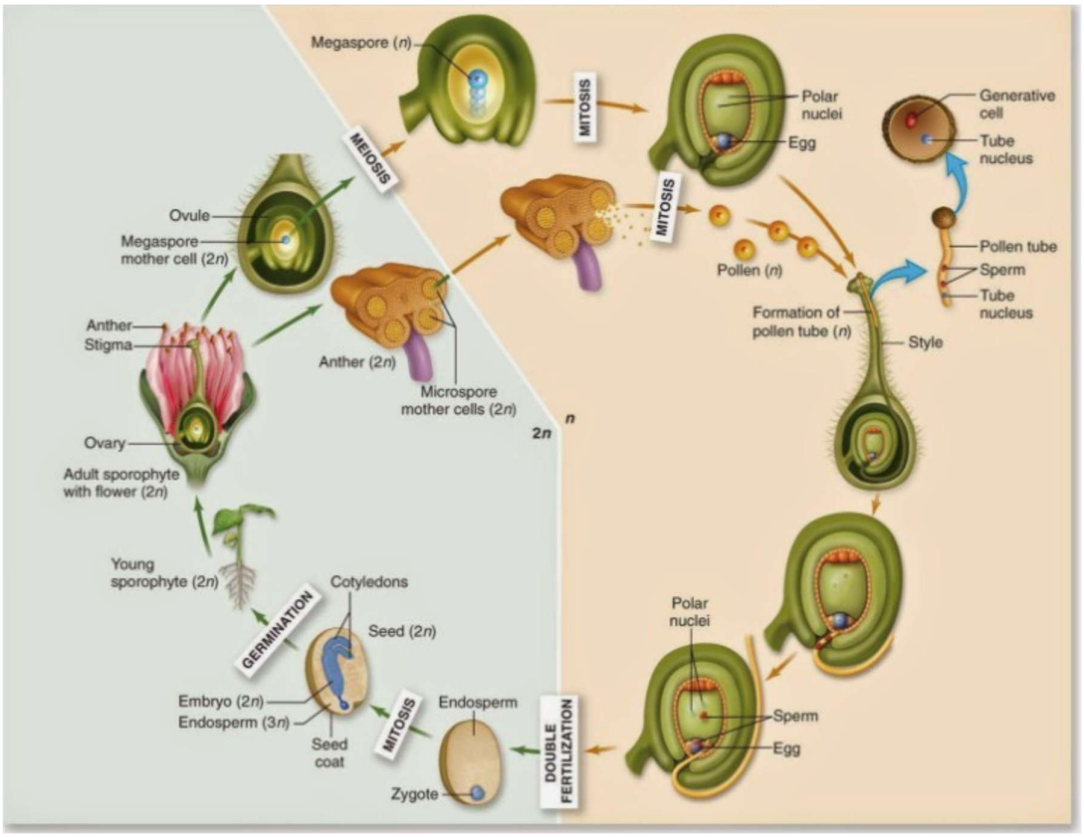


Figure 55: Life Cycle of an Angiosperm

Types of Fruits

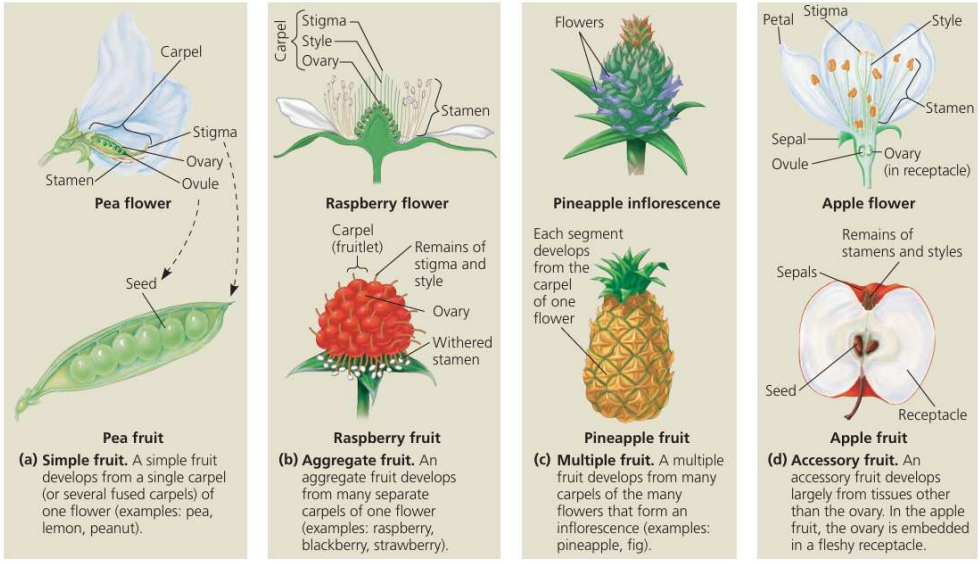
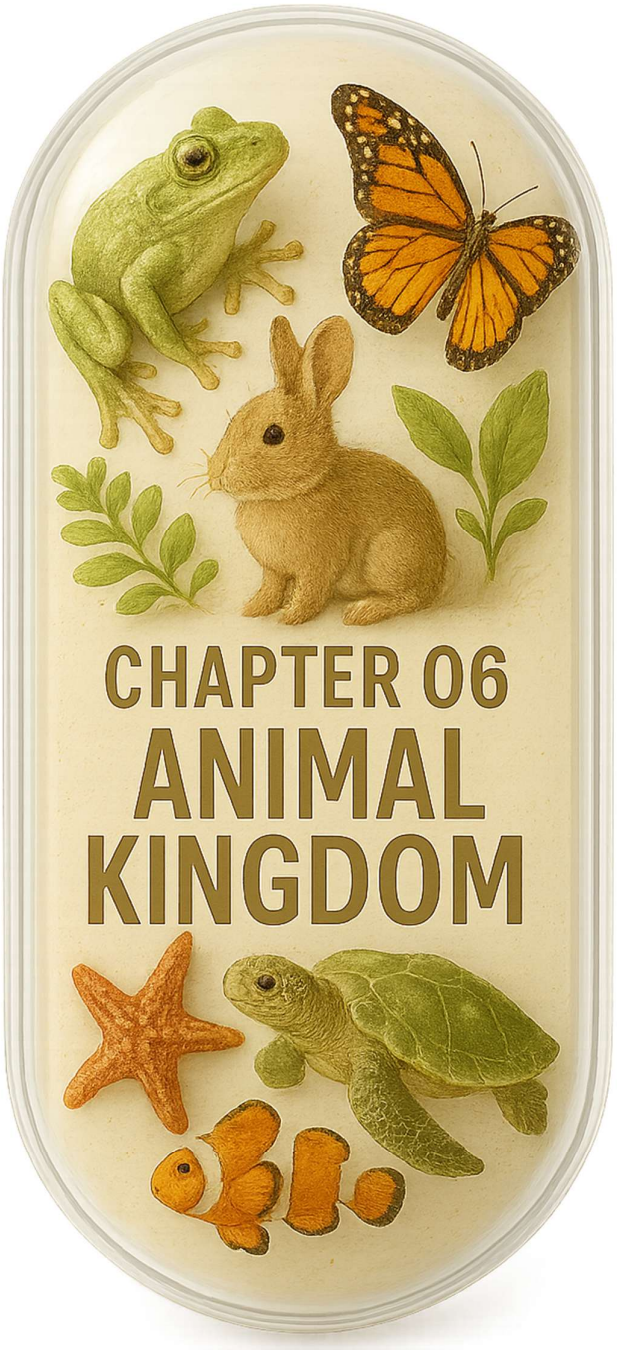


Figure 56: Representative fruit types

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General Characteristics of Animals

- **Multicellular organisms:**

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

- **Eukaryotic:**

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



Figure 57: Eukaryotic Cell

- **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.

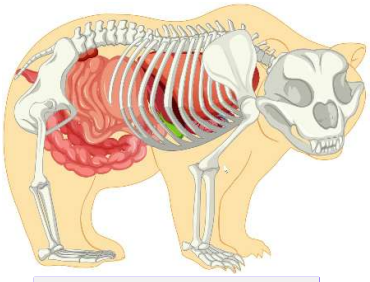


Figure 58: Body Cavity

- **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 with a fertilized egg (zygote) that undergoes cell divisions and transformations until maturity.

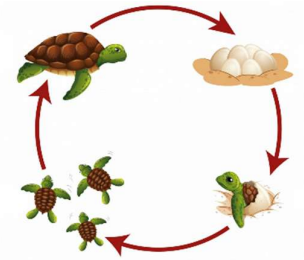


Figure 59: Stages of Growth and Development

- **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.

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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

Second: Symmetry

Third: Body Cavity

Fourth: Embryonic Development

Fifth: Segmentation

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.

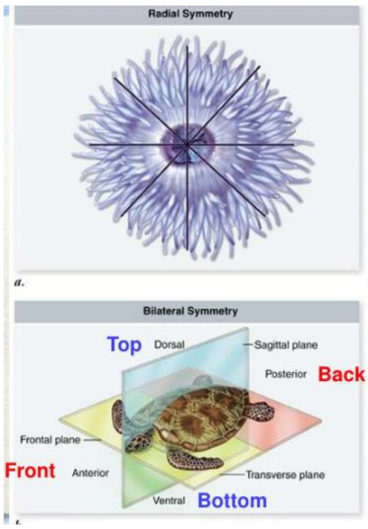


Figure 60: Illustrates the difference between radial symmetry and bilateral symmetry.

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Third: Body Cavity (Coelom)

As animal body complexity increases, 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 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.

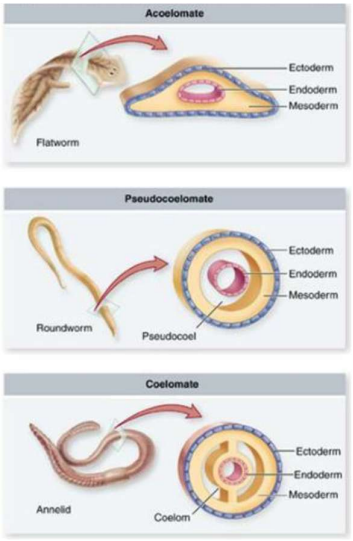


Figure 61. Shows the different stages of development.

Fourth: Embryonic Development (Development)

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

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.

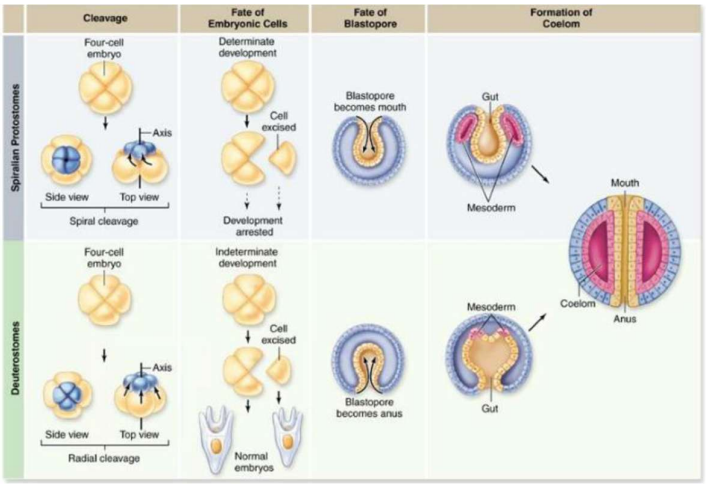


Figure 62. Illustrates embryonic development in protostomes and deuterostomes.

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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

Invertebrates are among the oldest and most widespread organisms in the animal kingdom, representing most 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: Consists of epithelioid-like cells that provide protection to the sponge. b. Inner layer: Made up of collar cells (choanocytes) with flagella.
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.

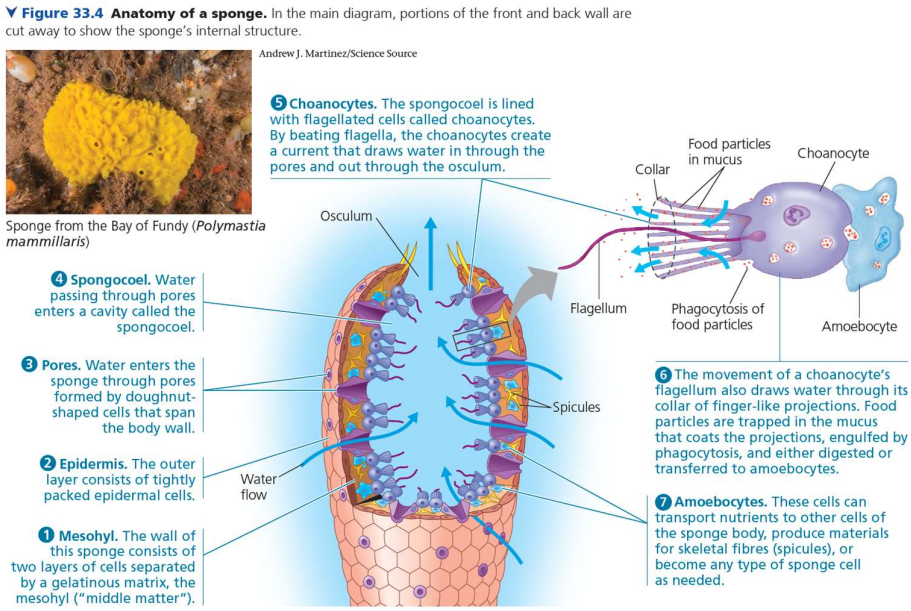


Figure 63. Anatomy of a sponge. In the main diagram, portions of the front and back wall are cut away to show the sponge's internal structure.

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.

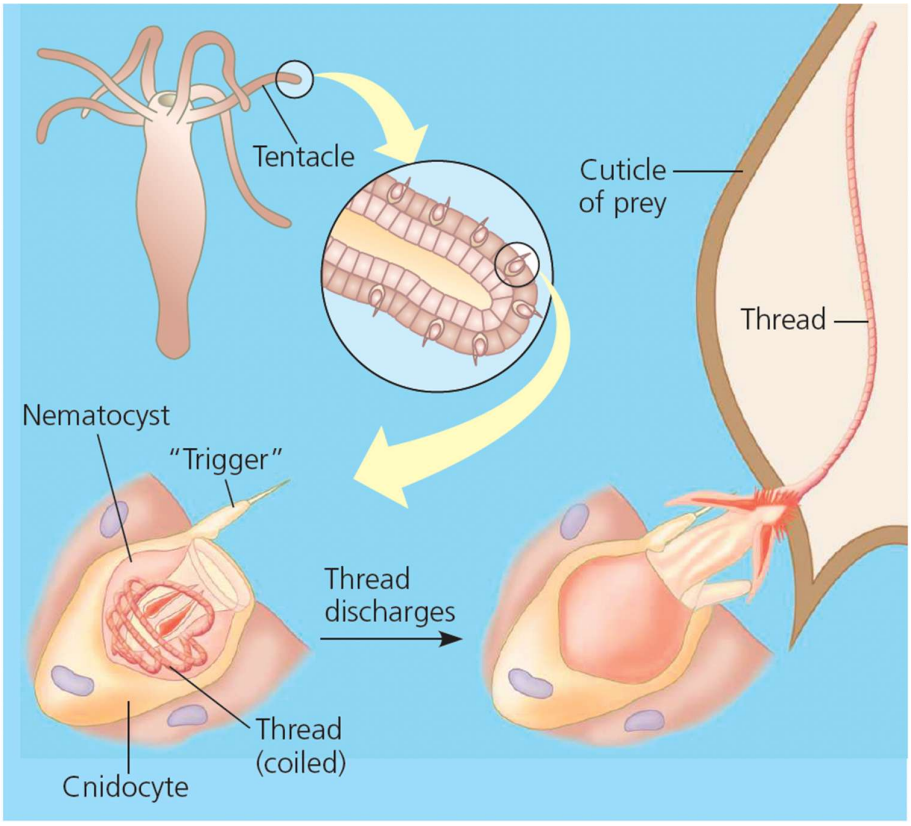


Figure 64. cnidocyte of a hydra. This type of cnidocyte contains a stinging capsule called a nematocyst, which holds a coiled thread. When the "trigger" is stimulated by touch or specific chemicals, the thread shoots out, piercing the prey's cuticle and injecting toxins into it.

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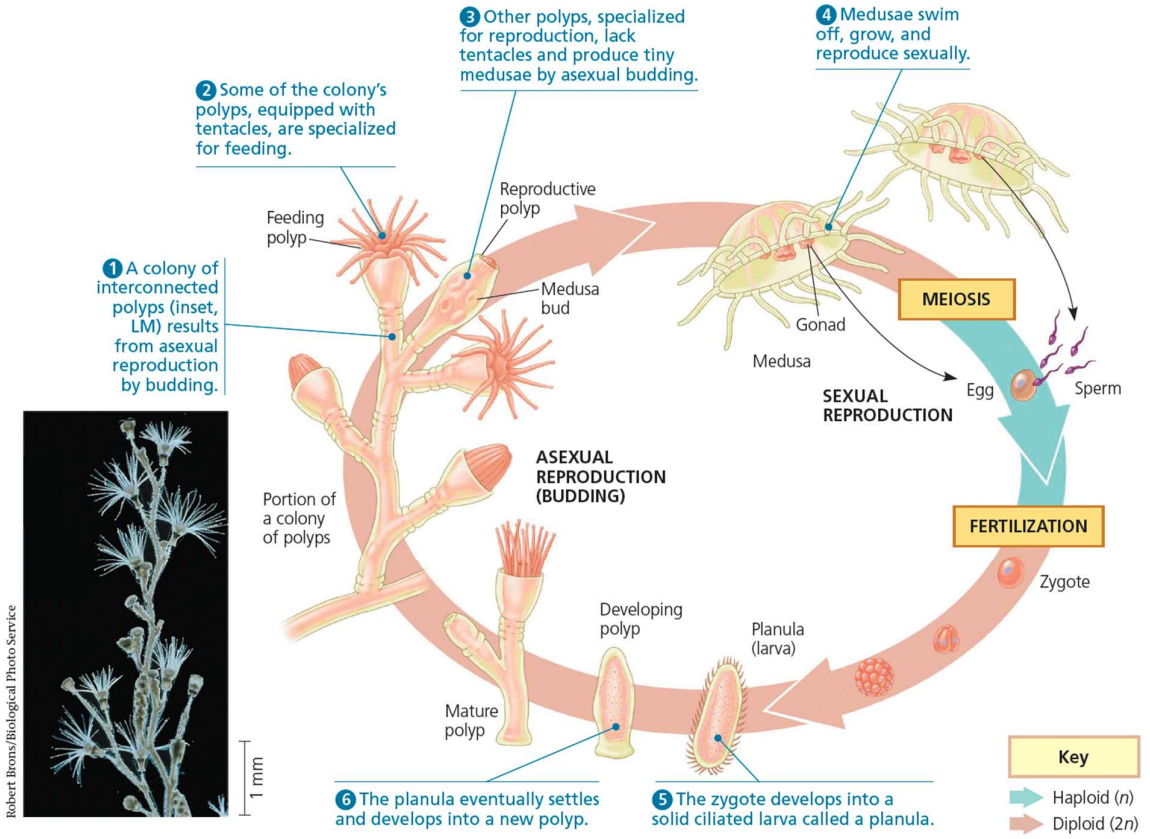


Figure 65. The life cycle of the hydrozoan Obelia. The polyp stage reproduces asexually, while the medusa stage reproduces sexually, releasing eggs and sperm. These two stages alternate, with each stage producing the other.

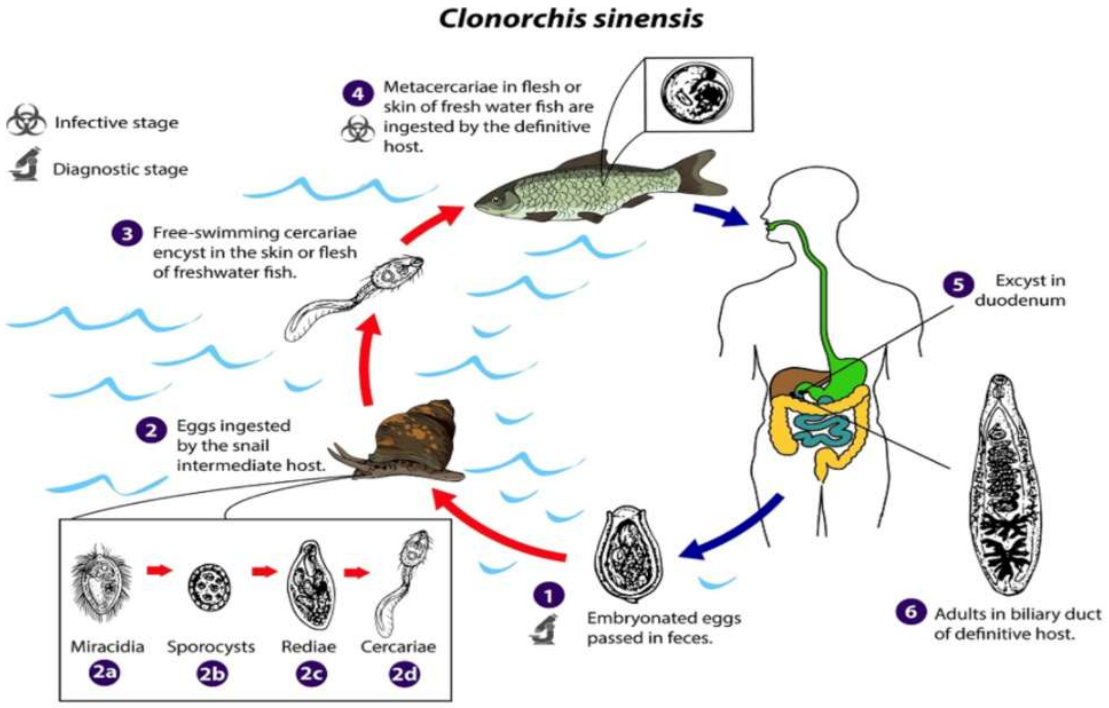
Flatworms (Platyhelminthes):

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.

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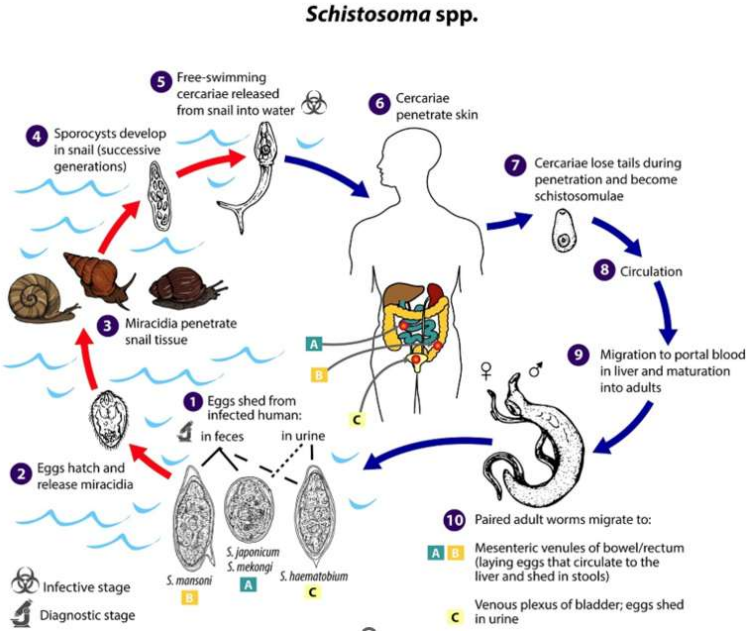
Response	The nervous system consists of two longitudinal nerve cords connected to lateral nerve ganglia. Possess eyespots that detect light.
Reproduction	- Asexual: By regeneration, where a separated body part can reform missing parts and develop into a new individual. - Sexual: Occurs when two worms meet, each exchanging sperm with the other.
Habitat	It can be free-living or parasitic.

Life Cycle of the Oriental Liver Fluke (Clonorchis sinensis)

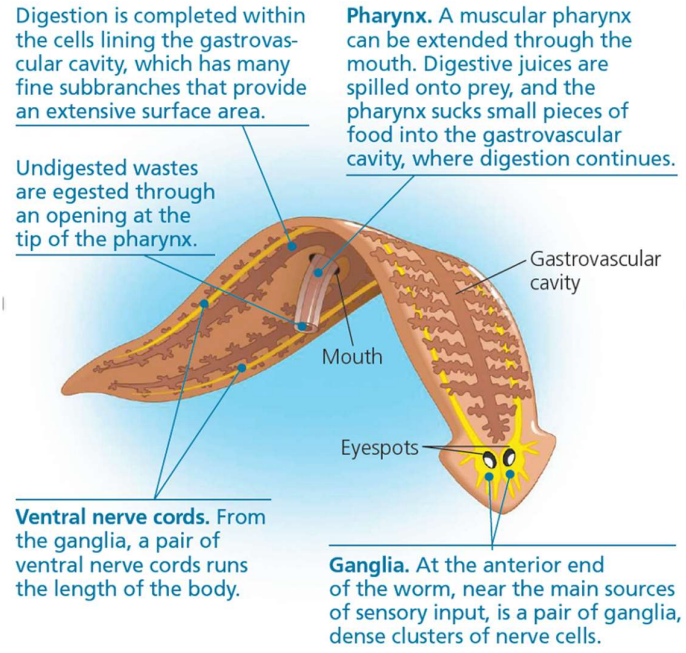


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Life Cycle of Schistosoma (Blood Fluke)



Life Cycle of Planaria (Planarian Worm)



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General Classification of Flatworms (Platyhelminthes)

Class	Habitat	Distinctive Characteristics	Examples
Turbellaria	Free-living in freshwater or marine environments	Body covered with cilia; possesses a ventral mouth and a muscular protrusible pharynx	Planaria
Trematoda	Endoparasites or ectoparasitic	Possess strong suckers for attachment to the host; have a complex life cycle	Liver fluke
Cestoda	Parasitic inside the intestines of vertebrates	Body divided into segments (proglottids); lacks a digestive system; absorbs nutrients directly from the host's intestine	Tapeworm

Roundworms (Nematodes):

They possess a pseudocoelom and have an unsegmented cylindrical body	
Aspect	**Description**
Structure	Possess a pseudocoelom and a cylindrical, unsegmented body.
Feeding	- It 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.
Example	• Whipworm • Ascaris (Roundworm) • Pinworm • Filariasis Worm (Filarial Worm)

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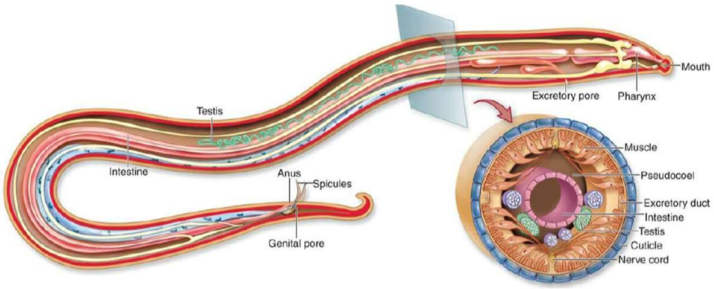


Figure 67. Structure of Roundworms



Figure 66. Trichinella (Thread-like Roundworm)

Mollusks (Phylum Mollusca):

Mollusks are soft-bodied invertebrates, many of which are protected by a hard external shell.	
Aspect	**Description**
Structure	Having a soft, true body is usually protected by a shell (mantle) and possesses 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.
Example	• Chitons • Snails and Slugs • Octopus, Squid, and Nautilus • Dentalium • Caudofoveata (Chaetodermomorpha) / Chaetoderma

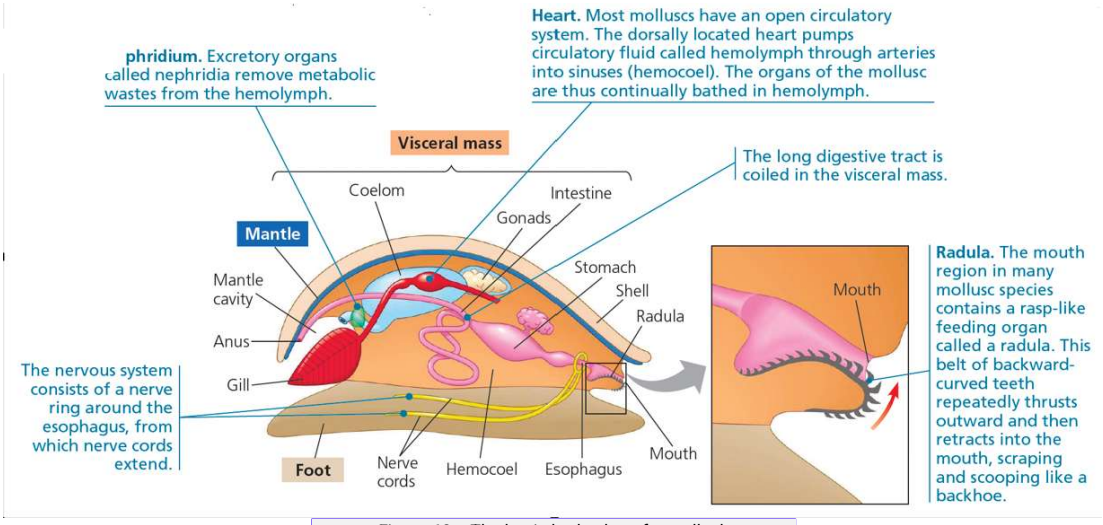


Figure 68a: The basic body plan of a mollusk

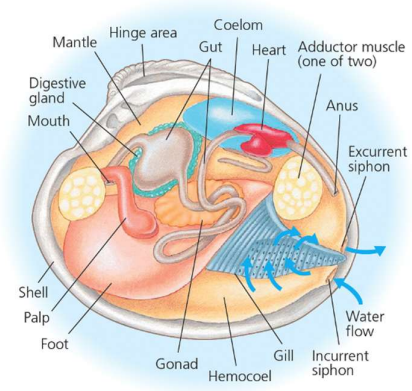


Figure 68b: Anatomy of a clam



Figure 69. Giant Clam

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Annelids (Segmented Worms)

Aspect	Description
Structure	Cylindrical body is 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.

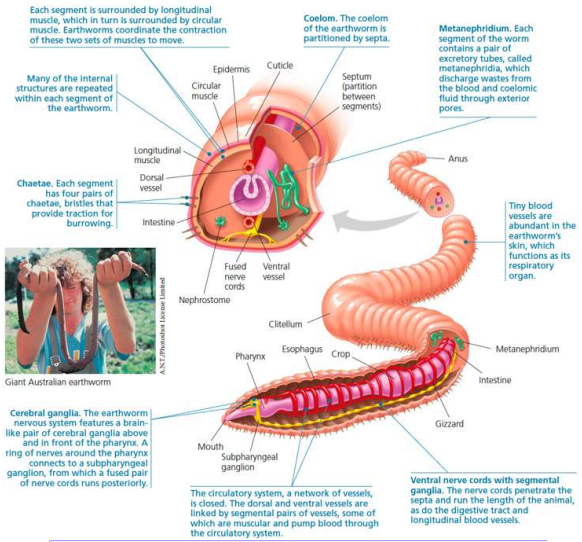


Figure 70. Anatomy of an earthworm, a sedentarian

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Arthropods:

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.

General Classification of Arthropods:

Class	Habitat	Distinctive Characteristics	Examples
Arachnida	Terrestrial	- Body divided into cephalothorax and abdomen. - Have four legs. - Lack antennae. - Possess chelicerae (fang-like mouthparts) for grasping or injecting venom.	Spider, scorpion, tick

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Crustacea	Aquatic (marine or freshwater)	- Have many jointed appendages. - It Possess two pairs of antennae. - Breathe through gills. - Body protected by a hard chitinous exoskeleton.	Crab, shrimp, lobster
Insecta	Terrestrial and aerial	- Body divided into three regions: head, thorax, and abdomen. - I have three pairs of legs. - Most are capable of flight.	Butterfly, bee, ant

Holometabolous Vs. Hemimetabolous Life Cycle:

Feature	Complete Metamorphosis	Incomplete Metamorphosis
Definition	A type of metamorphosis where the organism goes through four life stages: egg, larva, pupa, and adult.	A type of metamorphosis where the organism goes through three life stages: egg, nymph, and adult.

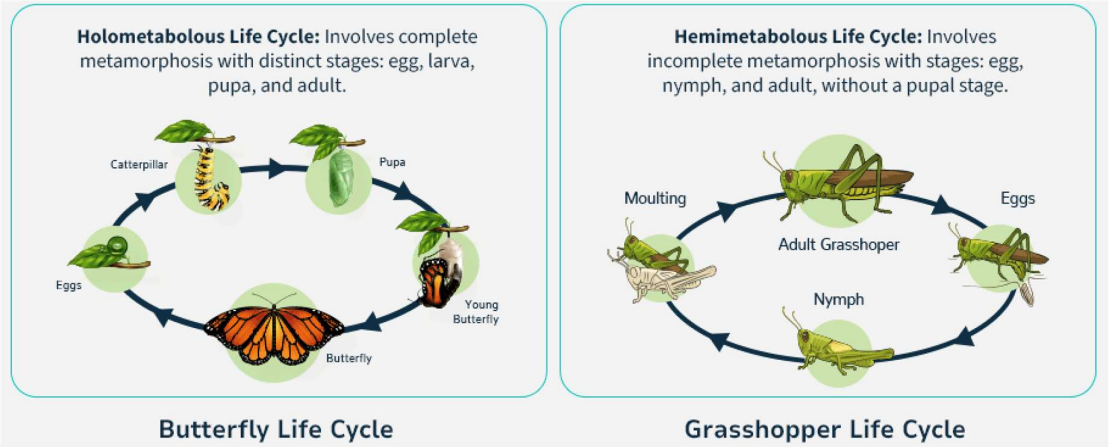


Figure 71. A comparison of butterfly and grasshopper life cycles—complete vs. incomplete metamorphosis.

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Mouthparts:

1. Chewing	2. Sponging	3. Tubular (Siphoning)	4. Piercing
Grasshopper	Fly	Butterfly	Mosquito
			

Echinoderms:

are marine invertebrates with radial symmetry, 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.
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.

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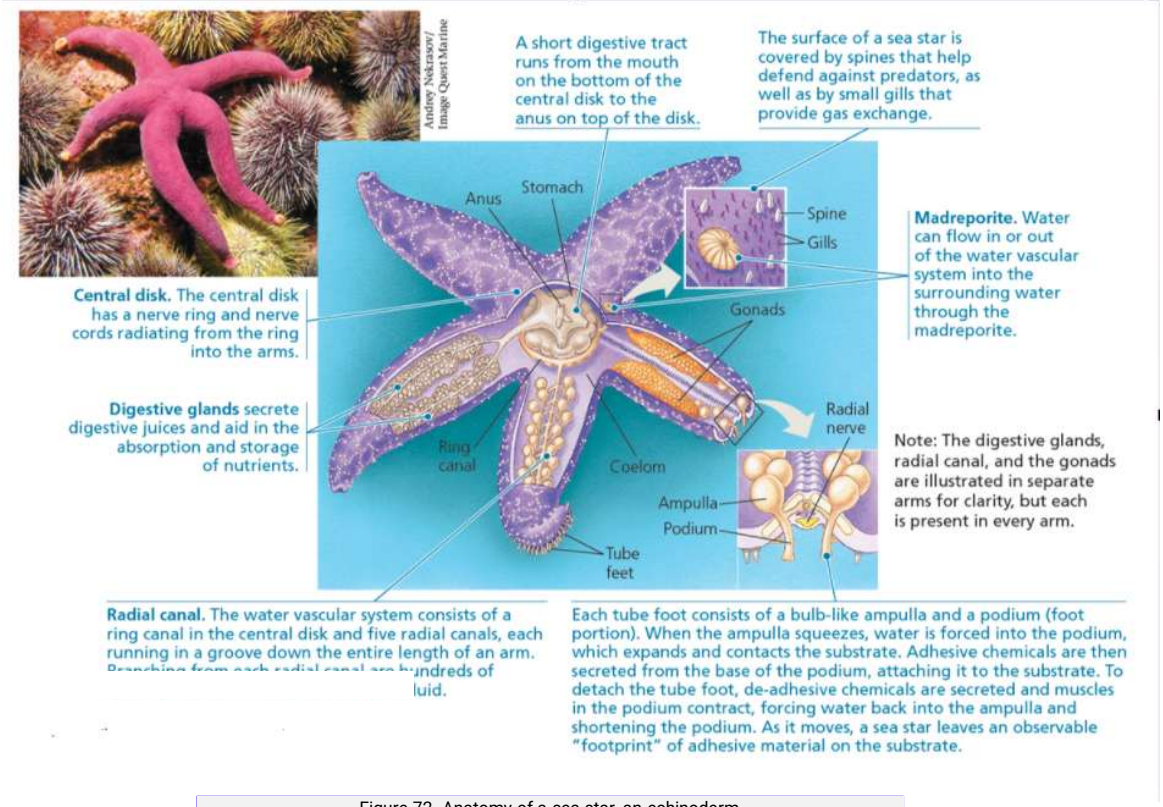


Figure 72. Anatomy of a sea star, an echinoderm

Invertebrate Chordates:

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*).

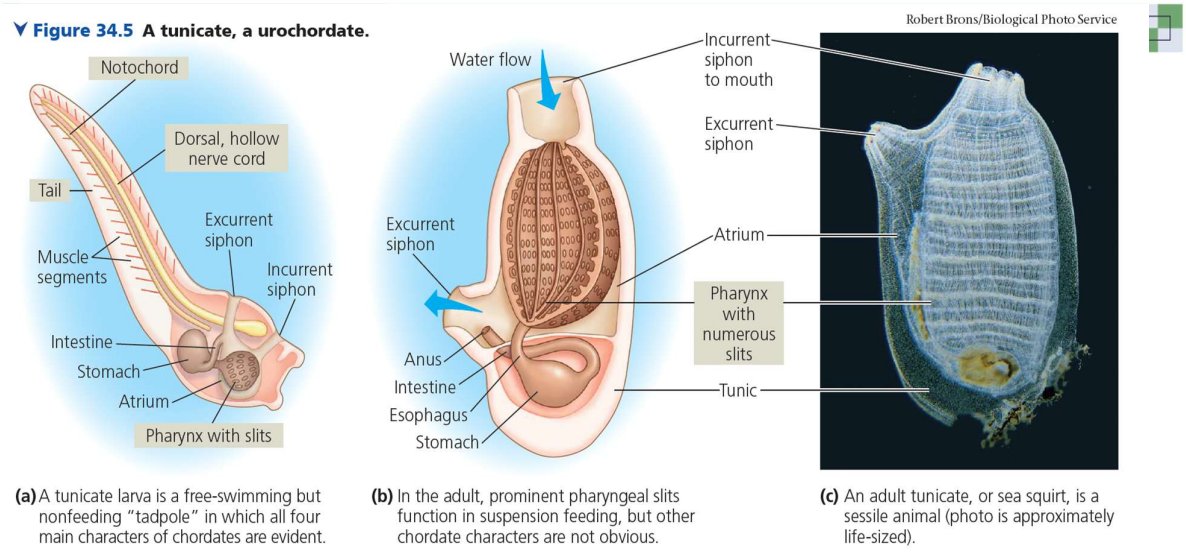


Figure 73. A tunicate, a urochordate

Vertebrates

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. 74. Fishes

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.

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A. Body Structure	
Aspect	**Description**
1. 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
2. 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.
3. 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.
4. Fins	External appendages used for movement and balance in water. Types: 1. Paired fins: pectoral and pelvic fins. / 2. Unpaired fins: dorsal, anal, and caudal fins.
5. Muscular System	Composed of strong segmented muscles. Sequential contraction from head to tail produces wave-like motion for swimming.
6. Respiratory System	Fish breathe using gills. Water enters through the mouth, passes over the gills where oxygen is absorbed and carbon dioxide is released.
7. 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.

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8. 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.
9. 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.
10. 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.
11. 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.
12. 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: - Oviparous: Eggs are laid outside the body. - Viviparous: Embryos develop inside the female's body until birth.

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General Classification of Fishes:

Class	Distinctive Characteristics	Group and Examples
Agnatha (Jawless Fishes)	- Lack jaws, scales, paired fins, and a true bony skeleton. - Possess a notochord that remains throughout life. - Have gills for respiration.	Hagfish, Lamprey
Chondrichthyes (Cartilaginous Fishes)	- Skeleton made of cartilage (for flexibility) reinforced with calcium salts (for strength). - Most have a streamlined body, pointed head, and upturned tail. - Tough skin covered with placoid scales.	Shark, Skate, Ray
Osteichthyes (Bony Fishes)	- Have a bony skeleton. - Covered with cycloid or ctenoid scales. - Possess an operculum (gill cover). - Have a swim bladder for buoyancy. - Fins are thin and membranous, supported by bony rays.	Salmon, Tuna (Ray-finned fishes)

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.

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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	- 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. - 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. ▪ 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.

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Reptiles

Are cold-blooded vertebrates covered with dry, scaly skin that help 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 like that of amphibians and fishes.
Excretion	Excrete semi-solid waste (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.
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.

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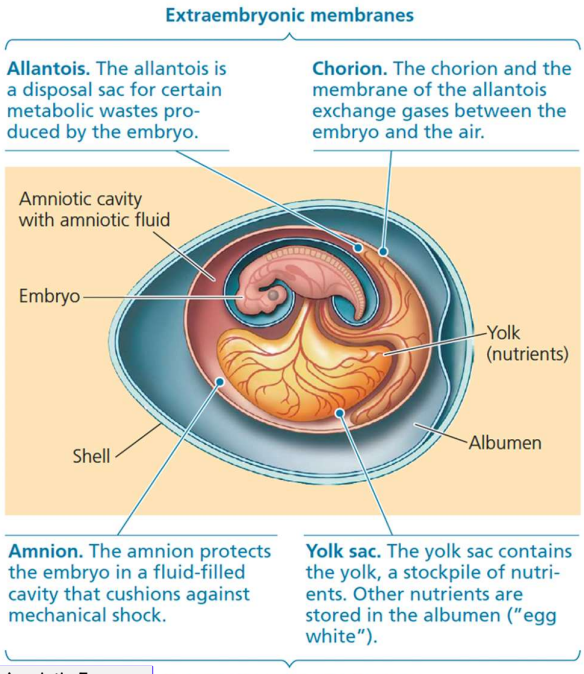


Figure 75: The Amniotic Egg

Birds

Are warm-blooded vertebrates covered with feathers, possessing wings, beaks, and lightweight bones adapted for flight.	
Aspect	**Description**
Feathers	- Specialized skin outgrowths are 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.

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	- 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. - It poses a gizzard containing small stones to grind food with the help of strong muscles.
Excretion	- Kidneys convert nitrogenous waste 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.

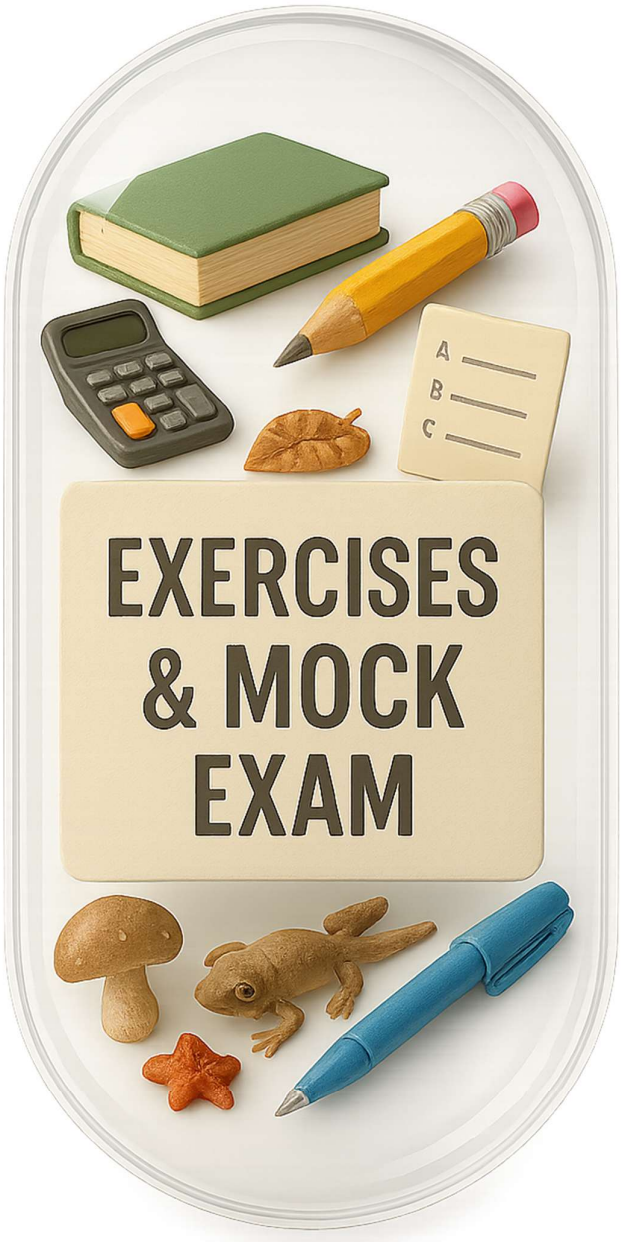
Mammals

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 waste. - Maintaining fluid balance. - Filtering blood from urea. - Regulating water levels in body fluids, especially in desert mammals.

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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. 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).

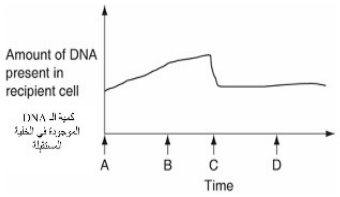
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Exercises

1) What is true of the amino acids that might have been delivered to Earth within carbonaceous chondrites (Carbonaceous chondrites)?	
A	They had the same proportion of L and D isomers as Earth does today.
B	The proportion of the amino acids was like those produced in the Miller–Urey experiment.
C	There were fewer kinds of amino acids on the chondrites than are found in living organisms today.
D	They were delivered in the form of polypeptides.
2) Which of the following is the correct sequence of these events in the origin of life? I. Formation of protobionts II. Synthesis of organic monomers III. Synthesis of organic polymers IV. Formation of DNA-based genetic systems	
A	I, II, III, IV
B	II, III, I, IV
C	IV, III, I, II
D	III, II, I, IV
3) Which of these observations fails to support the endosymbiotic theory for the origin of eukaryotic cells?	
A	The existence of structural and molecular differences between the plasma membranes of prokaryotes and the internal membranes of mitochondria and chloroplasts
B	The existence of size differences between the cytosolic ribosomes of eukaryotes and the ribosomes within mitochondria and chloroplasts
C	The existence of size differences between some prokaryotic cells and mitochondria
D	The existence of rRNA sequence differences between the cytosolic ribosomes of eukaryotes and the ribosomes within mitochondria and chloroplasts
4) During which two times can the recipient accurately be described as "recombinant" due to the sequence of events portrayed in Figure?	



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A	During Times C and D
B	During Times A and C
C	During Times B and C
D	During Times A and B
5) How is the recipient cell different at Time D than it was at Time A?	
A	It has a greater number of genes
B	It has a greater mass of DNA
C	It has a different sequence of base pairs.
D	It contains bacteriophage DNA.
6) Many physicians administer antibiotics to patients at the first sign of any disease symptoms. Why can this practice cause more problems for these patients, and for others not yet infected?	
A	The antibiotic administered may kill viruses that had been keeping the bacteria in check.
B	Antibiotics may cause other side effects in patients.
C	Overuse of antibiotics can select for antibiotic-resistant strains of bacteria.
D	Patients may be allergic to the antibiotic
7) If one were to apply the most recent technique used to fight potato late blight to the fight against the malarial infection of humans, then one would	
A	Increase the dosage of the least expensive antimalarial drug administered to humans
B	Increase the dosage of the most common pesticide used to kill Anopheles mosquitoes
C	Introduce a predator of the malarial parasite into infected humans.
D	Use a "cocktail" of at least three different pesticides against Anopheles mosquitoes.
8) A large seaweed that floats freely on the surface of deep bodies of water would be expected to lack which of the following?	
A	Thalli
B	Bladders
C	Blades
D	Holdfasts
9) According to the endosymbiotic theory of the origin of eukaryotic cells, how did mitochondria originate?	
A	From infoldings of the plasma membrane, coupled with mutations of genes for proteins in energy–transfer reactions
B	From engulfed, originally free-living prokaryotes

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C	By secondary endosymbiosis
D	From the nuclear envelope folding outward and forming mitochondrial membranes
10) The result of heterospory is	
A	The existence of male and female sporophytes.
B	The existence of male and female gametophytes.
C	The absence of sexuality from both plant generations.
D	Both (A) and (B) above.
11) The hydrolytic digestion of which of the following should produce monomers that are aminated (i.e., have an amine group attached) molecules of beta-glucose?	
A	Insect exoskeleton
B	Plant cell walls
C	Fungal cell walls
D	A and C only
12) When a mycelium infiltrates an unexploited source of dead organic matter, what is most likely to appear within the food source soon thereafter?	
A	Fungal haustoria
B	Soredia
C	Fungal enzymes
D	Larger bacterial populations
13) What do fungi and arthropods have in common?	
A	Both groups are commonly coenocytic.
B	The haploid state is dominant in both groups.
C	The protective coats of both groups are made of chitin.
D	Both groups have cell walls.
14) In individual insects of some species, whole chromosomes that carry larval genes are eliminated from the genomes of somatic cells at the time of metamorphosis. A consequence of this occurrence is that	
A	We could not clone a larva from the somatic cells of such an adult insect.
B	Such species must reproduce only asexually.
C	The descendants of these adults do not include a larval stage.
D	Metamorphosis can no longer occur among the descendants of such adults.

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15) Soon after the coelom begins to form, a researcher injects 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
16) At which developmental stage should one be able to first distinguish a diploblastic embryo from a triploblastic embryo?	
A	Fertilization
B	Cleavage
C	Gastrulation
D	Coelom formation
17) What would be the most effective method of reducing the incidence of blood flukes in the human population?	
A	Reduce the mosquito population
B	Reduce the freshwater snail population
C	Purify all drinking water
D	Avoid contact with rodent droppings
18) If a lung were to be found in a mollusc, where would it be located?	
A	Mantle cavity
B	Coelom
C	Foot
D	Visceral mass
19) Which Molluscan class includes members that undergo embryonic torsion?	
A	Chitons
B	Bivalves
C	Gastropods
D	Cephalopods
20) The ray-finned fishes are characterized by	
A	A bony endoskeleton, operculum, and usually a swim bladder
B	A cartilaginous endoskeleton.
C	An amniotic egg.
D	Teeth that are replaced regularly

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21) 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
22) Which of these would a paleontologist be most likely to do to determine whether a fossil represents a reptile or a mammal?	
A	Look for the presence of milk-producing glands.
B	Because mammals are eutherians, they look for evidence of a placenta.
C	Use molecular analysis to look for the protein keratin.
D	Examine the teeth
23) A fish that had been salt-cured subsequently develops a reddish color. You suspect that the fish has been contaminated by the extreme halophile, Halobacterium. Which of these features of cells removed from the surface of the fish, if confirmed, would support your suspicion? 1. The presence of the same photosynthetic pigments found in cyanobacteria 2. Cell walls that lack peptidoglycan 3. Cells that are isotonic to conditions on the surface of the fish 4. Its cells contain bacteriorhodopsin 5. The presence of very large numbers of ion pumps in its plasma membrane	
A	2 and 5
B	3 and 4
C	1, 4, and 5
D	2, 3, 4, and 5
24. 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)	
A	Turtle
B	Earthworm
C	Sea star
D	Fish
25) Which term accurately describes the behavior of Paramecium species that lack zoochlorellae in an aquarium with light coming from one side only?	
A	Positive chemotaxis

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B	Negative chemotaxis
C	Positive phototaxis
D	Negative phototaxis

26) The sporophytes of mosses depend on the gametophytes for water and nutrition. In seed plants, the reverse is true. From which seed plant sporophyte structure(s) do the immature (unfertilized) gametophytes directly gain water and nutrition?

A	Sporophylls
B	Embryos
C	Sporangia
D	Ovary

27) Which of these statements is true of the pine life cycle?

A	Cones are homologous to the capsules of moss plants.
B	The pine tree is a gametophyte.
C	Conifer pollen grains contain male gametophytes.
D	Double fertilization is a relatively common phenomenon.

28) Which of the following options represents the characteristics of a sponge

	Support	Nutrition	Digestion	Excretion
A	Internal	Autotrophic	External	Lateral pores
B	External	Filter-feeding	External	Specialized system
C	External	Heterotrophic	Internal	Diffusion
D	Internal	Filter-feeding	Internal	Osculum (excurrent pore)

29) Which of the following is a characteristic of nematodes?

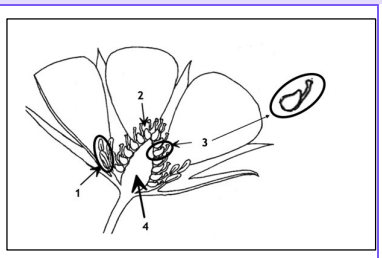
A	They have only longitudinal muscles
B	They have a true coelom
C	They have a gastrovascular cavity
D	Many species are diploblastic

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Mock Exam

1-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 some fruit.
3. Multiple fruit, which develops from an inflorescence with many dense florets, and the ovary walls are fused together into one fruit.

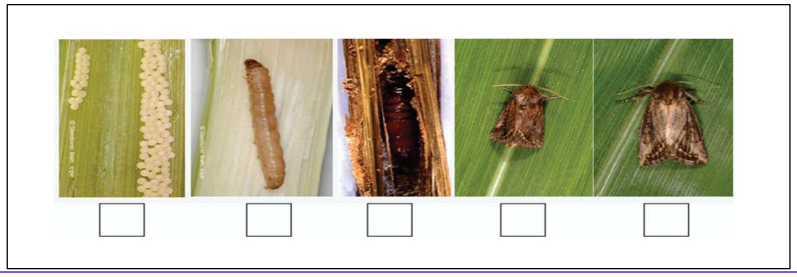


1. If the flower shown in the diagram is fertilized, which type of fruit will be developed?

(1: stamen, 2: carpel, 3: pistil, 4: receptacle)

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

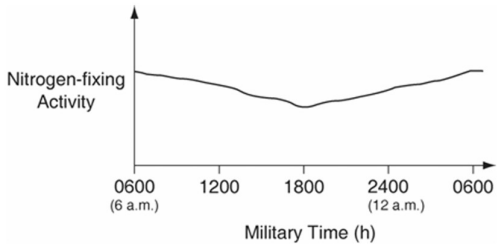
2. Identify the Corn borer stages of development below by inserting the following letters:



A	Larva
B	Pupa
C	Adult female
D	Egg

3. The data were collected from the heterocytes of a nitrogen-fixing cyanobacterium inhabiting equatorial ponds. Study the graph below and choose the most likely explanation for the shape of the curve.

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A	Enough O_2 enters heterocytes during hours of peak photosynthesis to have a somewhat-inhibitory effect on nitrogen fixation.
B	Light-dependent reaction rates must be highest between 1800 hours and 0600 hours.
C	Atmospheric N_2 levels increase at night because plants are no longer metabolizing this gas, so are not absorbing this gas through their stomata.
D	Heterocyte walls become less permeable to N_2 influx during darkness.
E	Enough O_2 enters heterocytes during hours of peak photosynthesis to have a somewhat-inhibitory effect on nitrogen fixation.

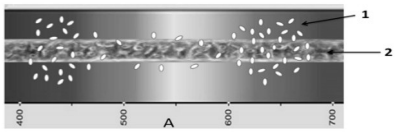
4. In 1881, a scientist named Engelmann mounted a filamentous green alga, Spirogyra, on a slide and placed some motile bacteria in a nutrient medium around the algal filament.

He illuminated the algal filament with a light spectrum (400–700 nm) obtained using a prism and viewed the slide under a microscope.

Diagram key:

1 – Bacteria 2 – Algal filament

A – Wavelength (nm)



1 – Bacteria 2- Algal filament A- Wavelength (nm)

Based on the above information, which of the following statements is correct?

A	The experiment was carried out to study respiration in algae.
B	The bacteria used in this experiment are aerobics in nature.
C	The bacteria are naturally attracted to red and blue light and not dependent on the algal filament.
D	The distribution of bacteria is dependent on the specific structures present in the algal filament.
E	The experiment was carried out to study respiration in algae.

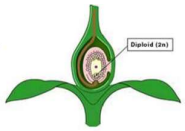
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5- Healthy individuals of Paramecium bursaria contain photosynthetic algal endosymbionts of the genus Chlorella. When within their hosts, the algae are referred to as zoochlorellae. In aquaria with light coming from only one side, P. bursaria gathers at the well-lit side, whereas other species of Paramecium gather at the opposite side. The zoochlorellae provides their hosts with glucose and oxygen, and P. bursaria provides its zoochlorellae with protection and motility. P. bursaria can lose its zoochlorellae: (1) if kept in darkness, the algae die, and (2) if prey items (mostly bacteria) are absent from its habitat, P. bursaria will digest its zoochlorellae. Which term most accurately describes the nutritional mode of healthy P. bursaria?

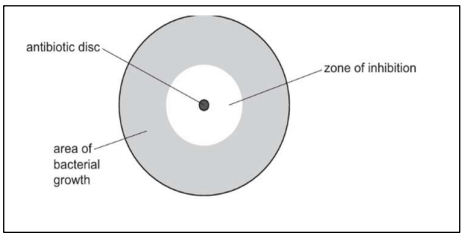
A	Photoautotroph
B	Photoheterotroph
C	Chemoheterotroph
D	Mixotroph

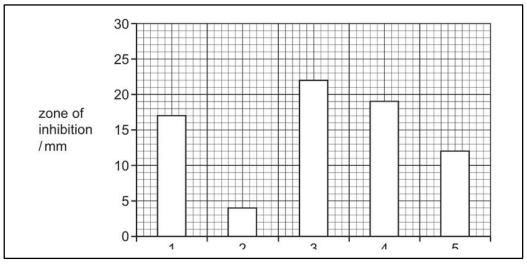
6. Sexual reproduction in plants and animals involves the union of two gametes to form a single cell called a zygote. Gametes include the egg and sperm cells. The zygote is formed after the sperm fertilizes the egg, resulting in a diploid (2n) chromosome number. The zygote develops into ... (Hint: The following figure indicates a fertilized egg.)

A	Embryo
B	Endosperm
C	Carpel
D	Ovule



7- When bacteria are grown in a Petri dish containing discs with antibiotics, there will be zones of inhibition of bacterial growth. The chart shows the size of the zones of inhibition when a species of bacteria was incubated on five different plates of agar, each containing a disc with a different antibiotic. Which conclusions can be made about the most and least effective antibiotics on this species of bacteria?





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	least effective antibiotic	most effective antibiotic
A	2	3
B	3	4
C	3	1
D	2	3

8- Which of the following is found only among annelids?

A	A hydrostatic skeleton
B	Segmentation
C	A clitellum
D	A closed circulatory system

9- Based on the data in the table below, identify the unknown animals and then select the correct statement:

Species	Crop	gizzard	Digestive glands	intestine	anus
1	-	-	+	+	+
2	+	-	-	+	+
3	+	+	+	+	+
4	-	-	+	+	-

A	1 Octopus 2 Hirudo medicinalis 3 Serpent starfish 4 Aporrectodea
B	1 Octopus 4 Aporrectodea 3 Serpent starfish 2 Hirudo medicinalis
C	1 Octopus 2 Hirudo medicinalis 3 Aporrectodea 4 Serpent starfish
D	1 Serpent starfish 2 Hirudo medicinalis. 3 Aporrectodea. 4 Octopus

10. It is known that certain types of fungi can facilitate seed germination and seedling growth in orchids. On which plant organ do these fungi occur, and what is their function for orchids? Choose the correct answer from the following:

A	(Fruit) to facilitate digestion of nutrients
B	(Leaf) to facilitate the formation of nutrients
C	(Stem) to facilitate the transport of water and nutrients
D	(Root) to facilitate water absorption

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Answer Keys for Exercises and the Mock Exam

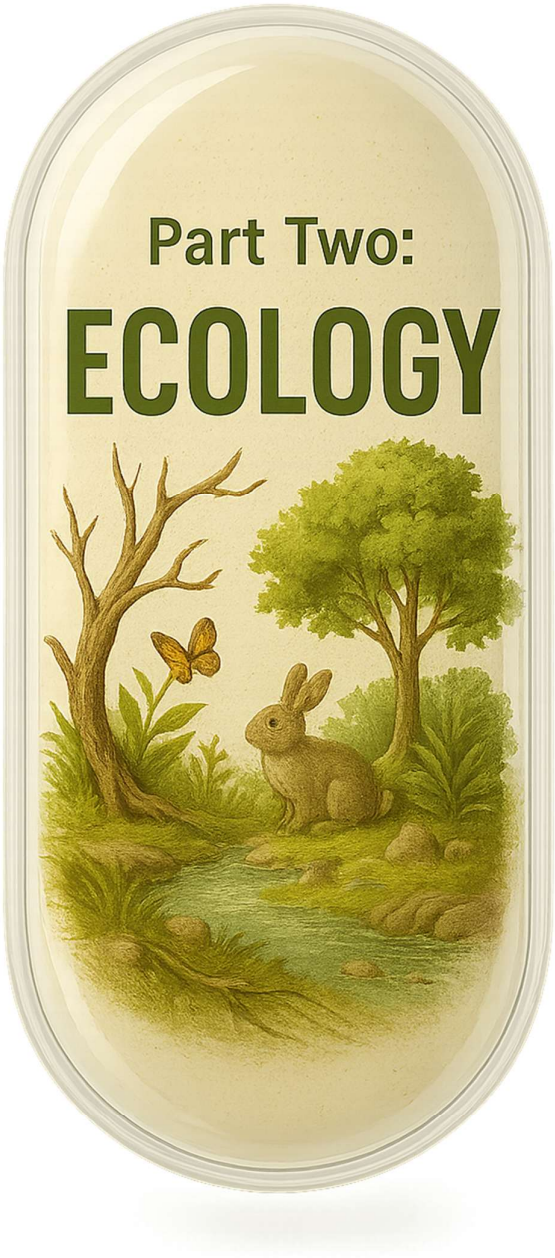
Exercises

1	2	٣	4	5	6	7	8	9	10	11	12
B	C	A	A	C	C	D	D	B	B	D	C
13	14	15	16	17	18	19	20	21	22	23	24
C	A	C	C	B	A	C	A	A	D	D	B
25	26	27	28	29							
D	C	C	D	A							

Mock Exam

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

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Introduction to Ecology

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

Modern ecology integrates concepts from physiology, behavior, evolution, and environmental science 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 examines interactions among species and the processes that maintain biodiversity. At the ecosystem level, it investigates energy flow, primary productivity, food webs, and biogeochemical cycles.

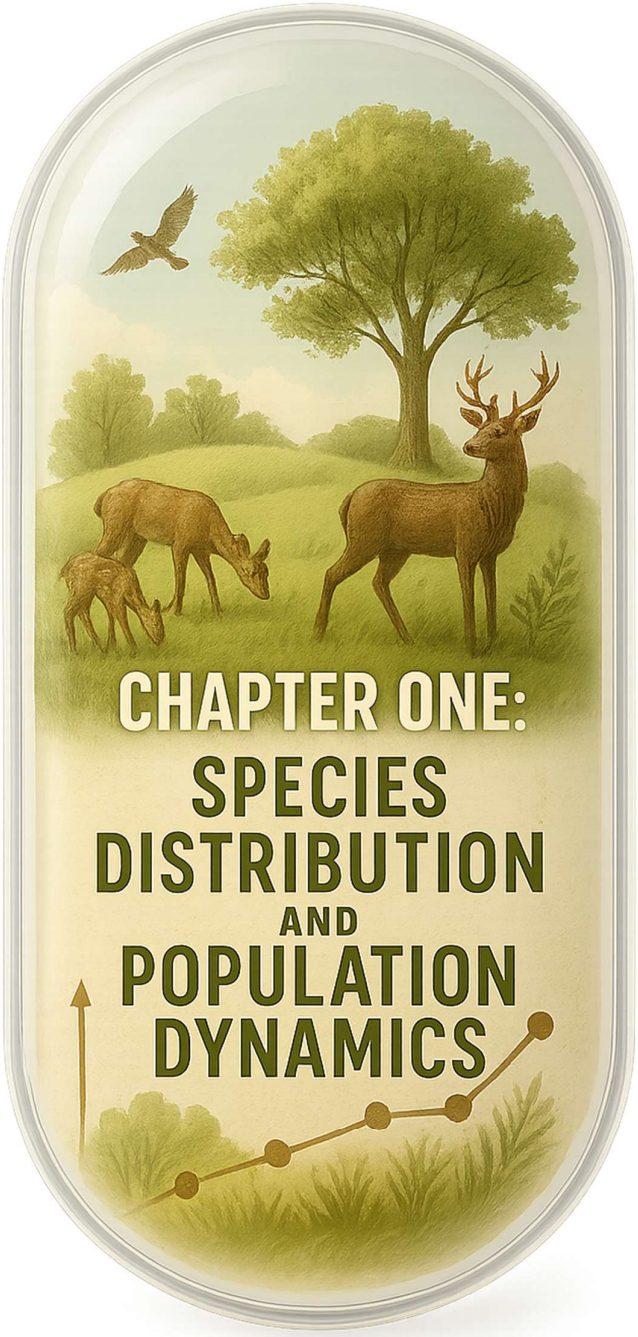
Ecology plays a central role in addressing global environmental challenges such as climate change, habitat fragmentation, pollution, invasive species, and biodiversity loss. By understanding ecological principles, scientists can develop sustainable strategies for natural resource management, design effective conservation programs, and predict how ecosystems will respond to environmental disturbances. Overall, ecology provides a framework for understanding the complex and dynamic relationships that link organisms to one another and to Earth's physical systems. Its insights form the foundation for maintaining ecosystem health, supporting human well-being, and ensuring the long-term sustainability of natural environments.

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Objectives

- ✓ Understand how Earth's climate varies according to latitude and seasons, and analyze the factors contributing to the rapid climate change observed today.
- ✓ Analyze the role of climate and environmental disturbances in shaping the distribution, structural characteristics, and functional properties of terrestrial biomes.
- ✓ Describe the diversity, structure, and ecological roles of aquatic biomes and explain why they are considered dynamic systems covering most of the planet's surface.
- ✓ Explain how the distribution of species is limited by interactions between organisms and the physical environment, and how this shapes ecological niches.
- ✓ Examine the interplay between environmental change and evolutionary processes, and its role in shaping populations and ecological communities over short and long timescales.
- ✓ Connect global climate patterns with biodiversity patterns and understand how environmental gradients influence species adaptation and distribution.
- ✓ Evaluate the ecological importance of natural and human-induced disturbances—such as fires, storms, and human activities—in shaping ecosystems and their functions.

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Interactions between organisms

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:

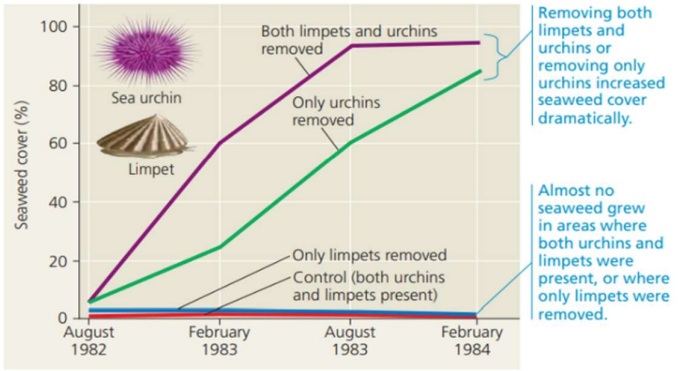
Negative interactions with predators (organisms that kill their prey) or herbivores (organisms that eat plants or algae) often limit a species' ability to survive and reproduce.

Abiotic Factors:

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

EXPERIMENT W. J. Fletcher, of the University of Sydney, Australia, reasoned that if sea urchins are a limiting biotic factor in a particular ecosystem, then more seaweeds should invade an area from which sea urchins have been removed. To isolate the effect of sea urchins from that of a seaweed-eating mollusc, the limpet, he removed only urchins, only limpets, or both from study areas adjacent to a control site.

RESULTS Fletcher observed a large difference in seaweed growth between areas with and without sea urchins.



CONCLUSION Removing both limpets and urchins resulted in the greatest increase in seaweed cover, indicating that both species have some influence on seaweed distribution. But since removing only urchins greatly increased seaweed growth while removing only limpets had little effect, Fletcher concluded that sea urchins have a much greater effect than limpets in limiting seaweed distribution.

Figure. 76. W. G. Fletcher's Experiment

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The effect of dynamic biological processes on mass density

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).
- 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

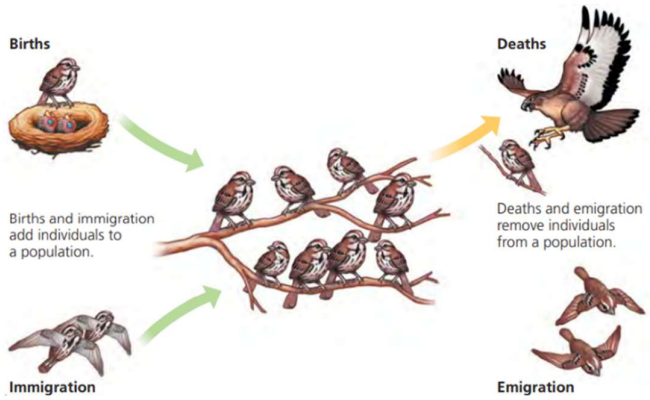


Figure. 77. The image illustrates the factors affecting population size

Patterns of Dispersion:

1) Clumped
2) Uniform
3) Random

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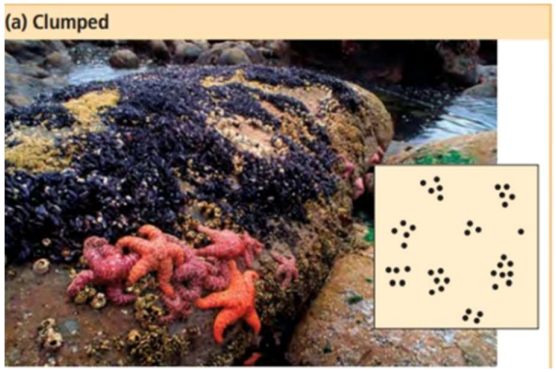


Figure. 78. Clumped Distribution

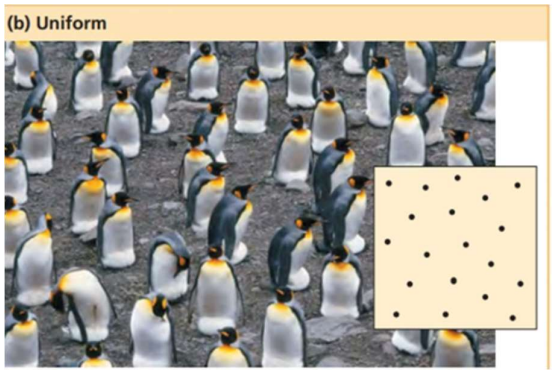


Figure. 79. Uniform Distribution

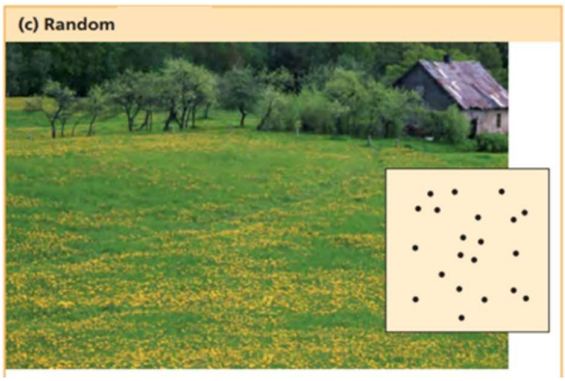


Figure. 80. Random Distribution

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Survivorship Curves:

Idealized survivorship curves: Types I, II, and III. The *y*-axis is logarithmic and the *x*-axis is on a relative scale so that species with widely varying life spans can be presented together on the same graph.

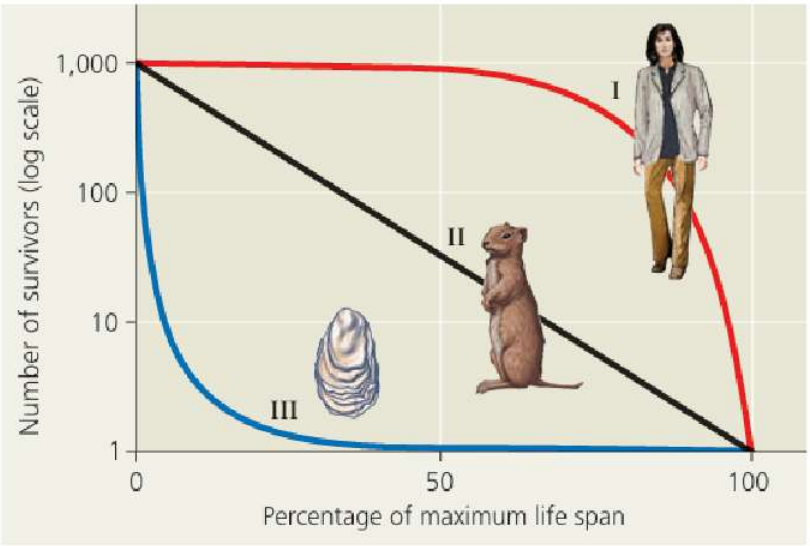


Figure. 81. The Ideal Growth Curve

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).

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.

Population growth predicted by the exponential model. This graph compares growth in a population with $r = 1.0$ (blue curve) to growth in a population with $r = 0.5$ (red curve).

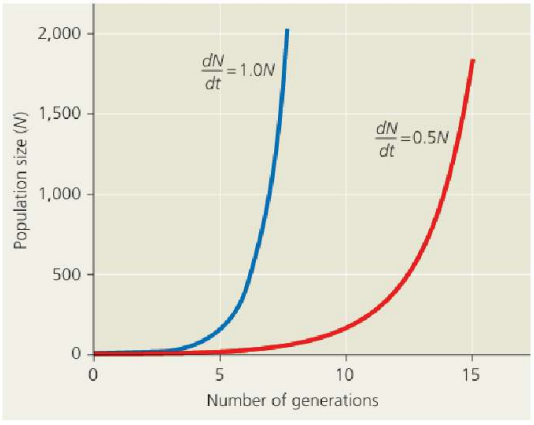


Figure. 82. Exponential Model

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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 predicted by the logistic model. The rate of population growth decreases as population size (N) approaches the carrying capacity (K) of the environment. The red line shows logistic growth in a population where $r = 1.0$ and $K = 1{,}500$ individuals. For comparison, the blue line illustrates a population continuing to grow exponentially with the same r.

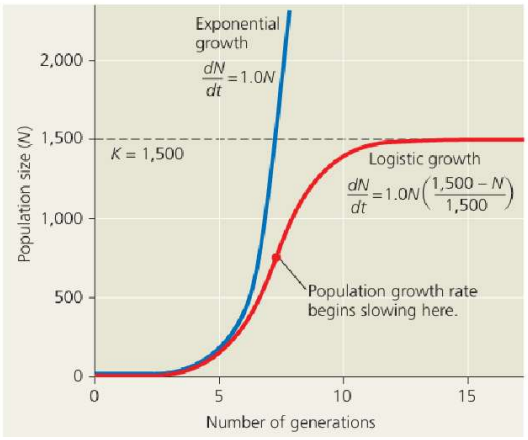


Figure 83. The Population Predicted by the Logistic Model

Factors Regulating 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 equilibrium for population density. This simple model considers only birth and death rates. (Immigration and emigration rates are assumed to be either zero or equal.) In this example, the birth rate changes with population density, while the death rate is constant. At the equilibrium density (Q), the birth and death rates are equal.

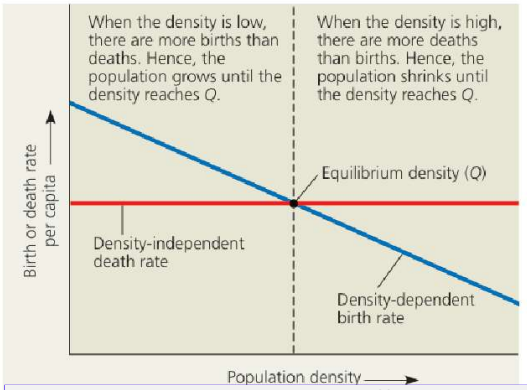


Figure 84. Determining Density Equilibrium

- A birth rate or death rate that does not change with population density is said to be density independent.

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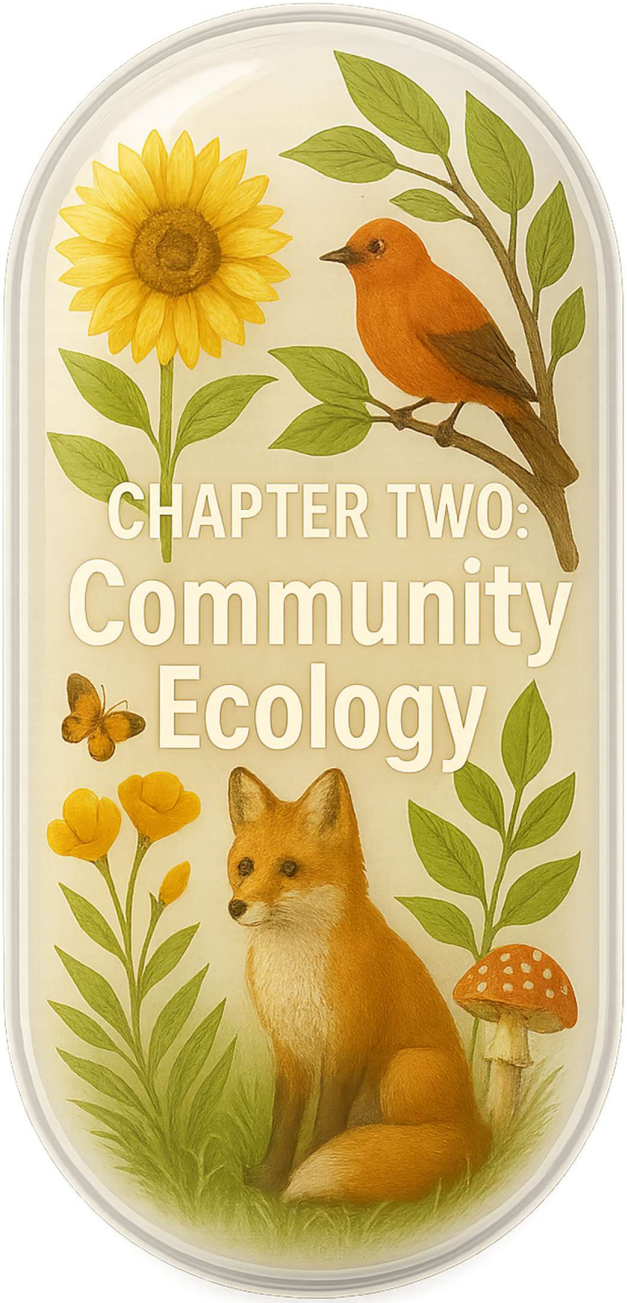
- In contrast, a death rate that rises with increasing population density is said to be density dependent, as is a birth rate that falls with increasing density

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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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.

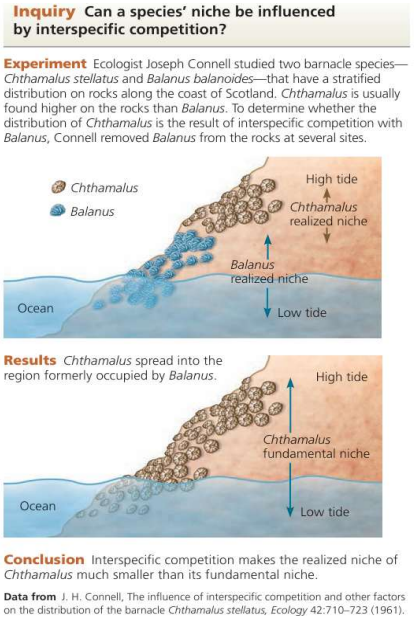
Competition:

- 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 occupy in a particular environment.

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- 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 into different beak sizes, with one adapted to eat larger seeds and the other to eat smaller seeds. Such character displacement plays an important role in reducing competition and promoting adaptation to different parts of the environment.



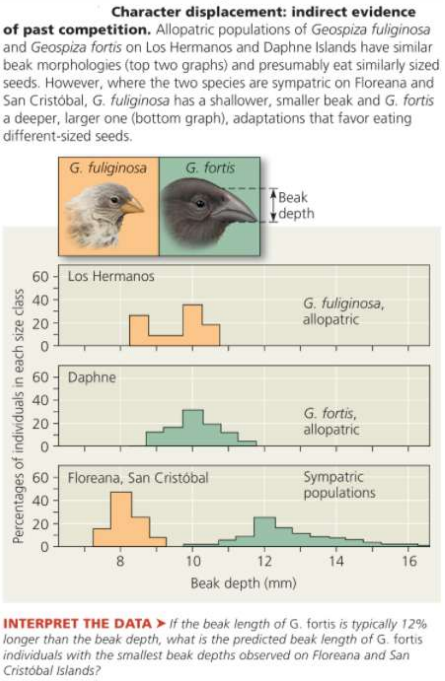


Figure 85. Character Displacement in Finches

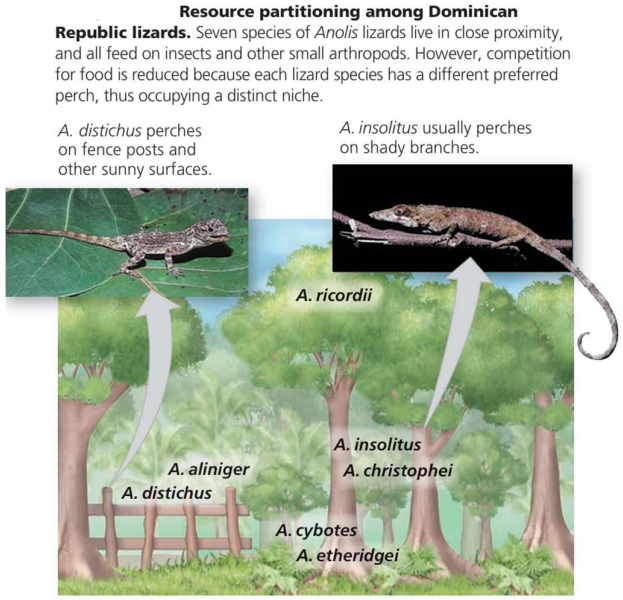


Figure 86. Resource Partitioning Among Dominican Republic Lizards

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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.

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 / –)

Diversity and Trophic Structure

Diversity and trophic structure characterize biological communities:
In addition to the relationships that arise among living organisms, communities are also characterized by diversity.

Species Diversity:

The diversity of species in a community refers to the variety of different living organisms that make up the community, and it has two main components:

- The first is species richness, which is the number of different species in the community.
- The second is relative abundance, which is the proportion each species represents of all individuals in the community.

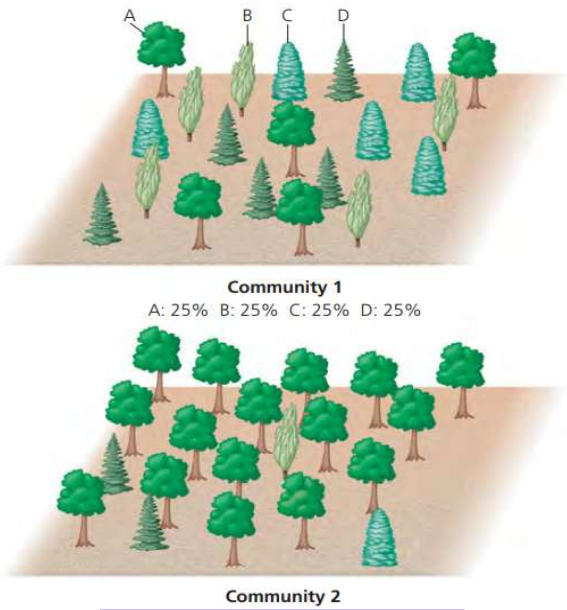


Figure 87. Types of Communities

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Imagine two small forest communities, each containing 100 individuals distributed among four tree species (A, B, C, and D) as follows:

- Species richness is the same for both communities because each contains four tree species, but their relative abundance is very different (see figure). You can easily notice all four tree species in Community 1, whereas in Community 2, if you don't look carefully, you might see only the abundant species A. Most observers would intuitively describe Community 1 as the more diverse of the two.
- Ecologists use many tools to quantitatively compare the diversity of different communities across time and space. They often calculate diversity indices based on species richness and relative abundance. One widely used index is the Shannon diversity index (H):

H = - (P_A \ln P_A + P_B \ln P_B + P_C \ln P_C + \ldots)

- where A, B, C, … are the species in the community, P is the relative abundance of each species, and ln is the natural logarithm. A higher H value indicates a more diverse community.

Let's use this equation to calculate the Shannon diversity index for the two communities in the figure HGSHFR:

- For Community 1:
  P = 0.25 for each species, so
  H = -4(0.25 \ln 0.25) = 1.39
- For Community 2:
  H = - [0.8 \ln 0.8 + 2(0.05 \ln 0.05) + 0.1 \ln 0.1] = 0.71

- These calculations confirm our intuitive description of Community 1 as the more diverse one.
- Determining the number and relative abundance of species in a community is easier said than done. Many sampling techniques can be used, but since most species in a community are relatively rare, obtaining a sample size large enough can be quite challenging.

Trophic Structure:

- The composition and dynamics of a community also depend on the feeding relationships among organisms — the trophic structure of the community.

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- 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.

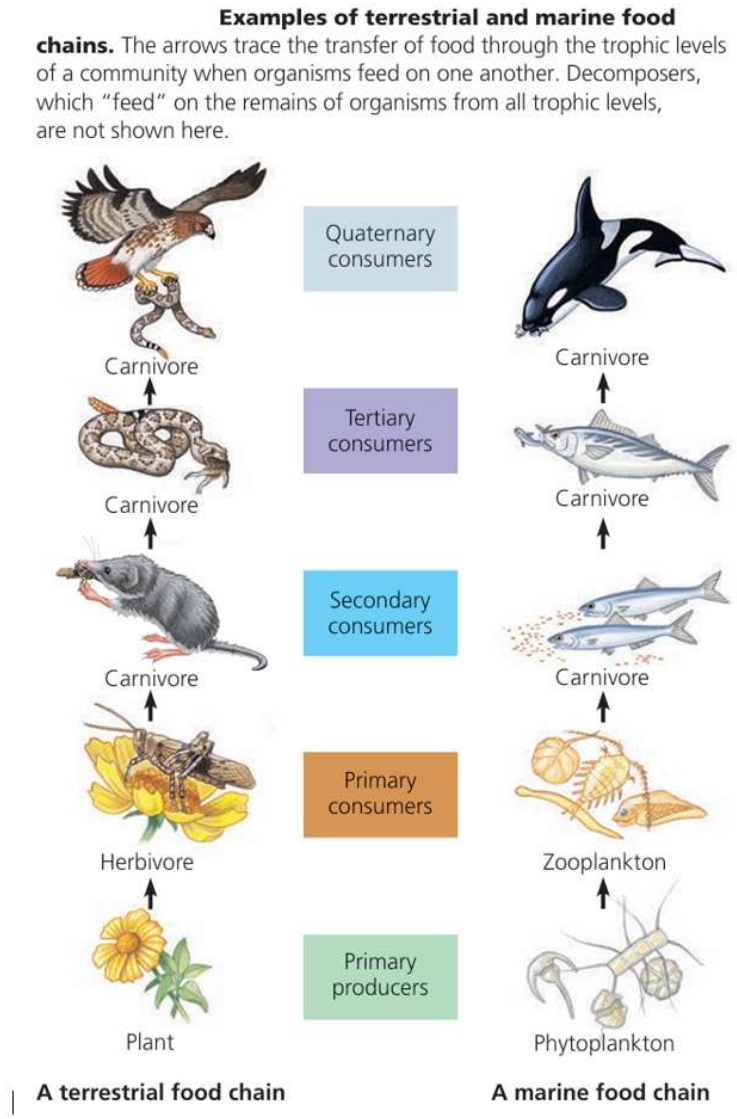


Figure 88. Examples of Terrestrial and Marine Food Chains

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Food Webs:

Scientists have realized that food chains are not isolated units, but are interconnected within food webs

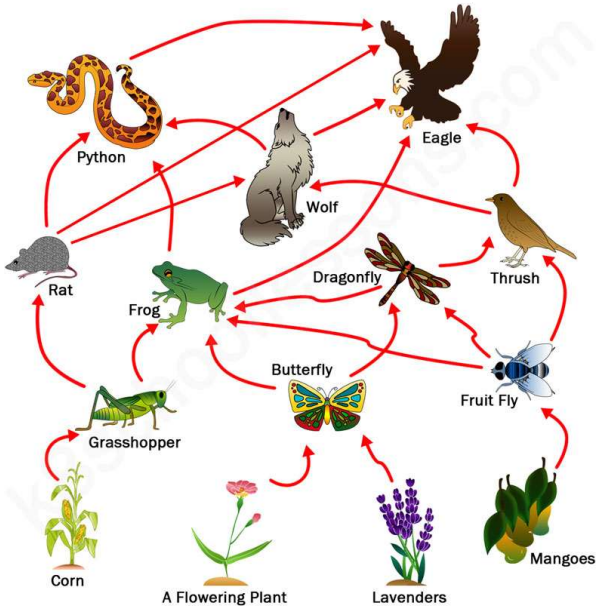


Figure 89. A Food Web

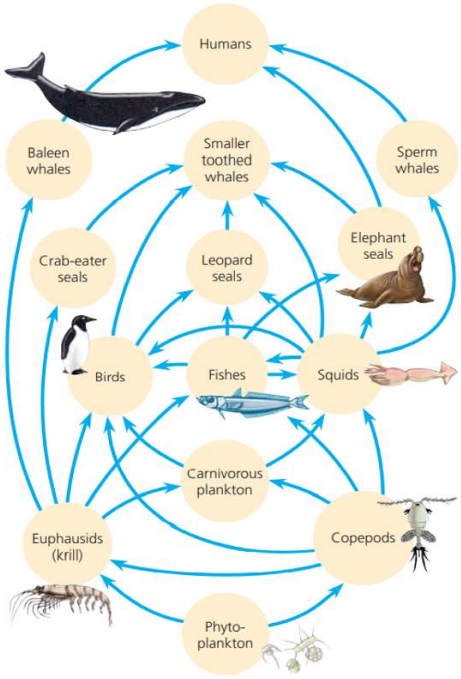


Figure 89. B Marine food web in the Antarctic: The arrows trace the transfer of food energy from producers (phytoplankton) through the various trophic levels. For simplicity, decomposers are omitted from this diagram.

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.

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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

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 can destroy 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.

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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Recovery following a large-scale disturbance.
The 1988 Yellowstone National Park fires burned large areas of forests dominated by lodgepole pines.



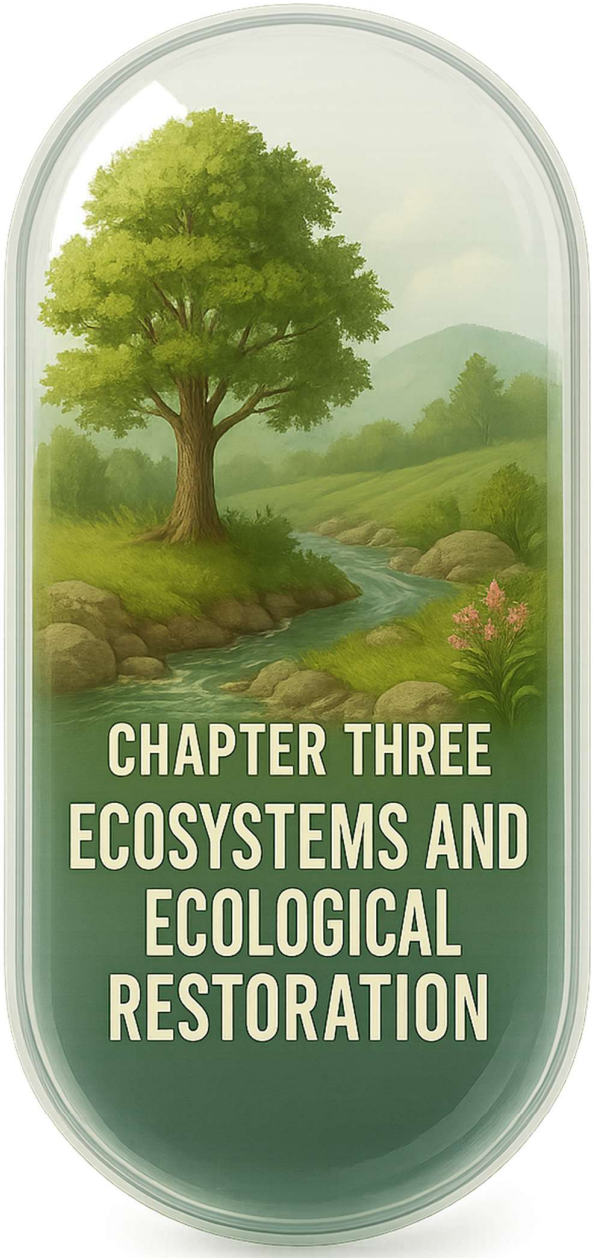
(a) Soon after fire. While all trees in the foreground of this photograph were killed by the fire, unburned trees can be seen in other locations.



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

Figure 90. Community Recovery One Year After Fire

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Ecosystems and Ecological Restoration

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.

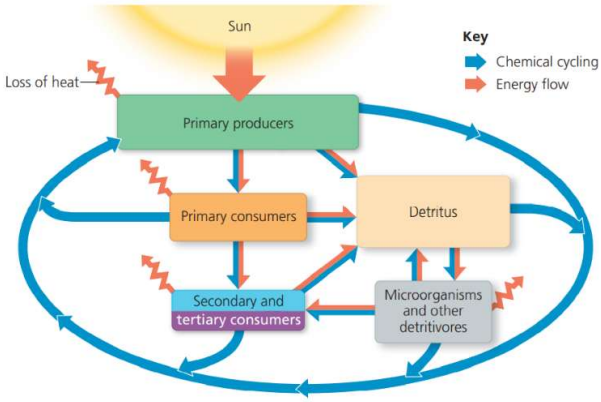


Figure 91. Energy Levels

- 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.

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.

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- We can measure the efficiency of animals as energy converters using the following equation:

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

- 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 loss 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.

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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.

An idealized pyramid of energy. This example assumes a trophic efficiency of 10% for each link in the food chain. Notice that primary producers convert only about 1% of the energy available to them to net primary production

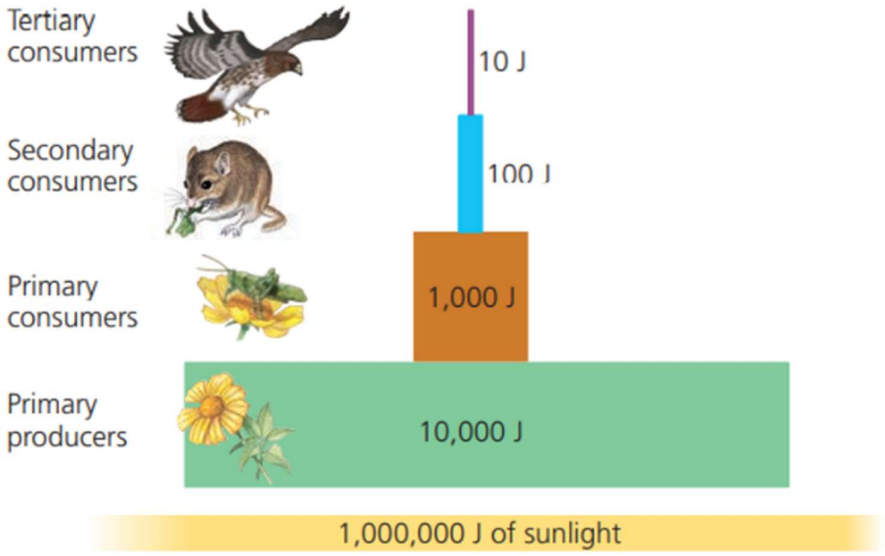


Figure 92. An Ideal Energy Pyramid

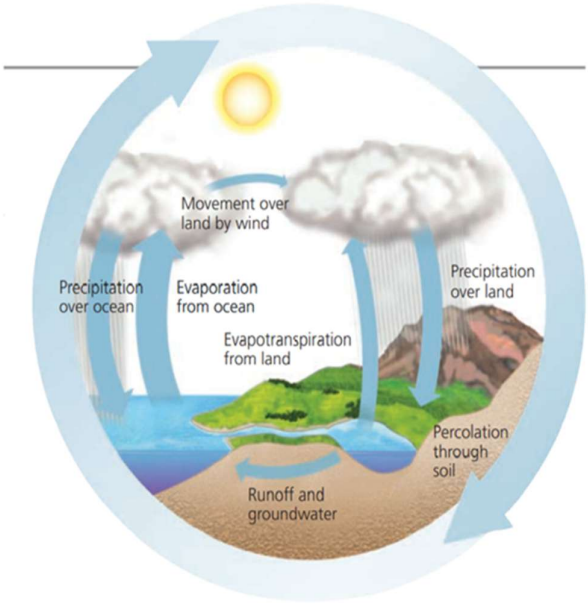
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Biological and Biogeochemical Processes

Biological and Geochemical Processes Cycle Nutrients and Water in Ecosystems

Biogeochemical Cycles:

Because nutrient cycles involve both biotic and abiotic components, they are called biogeochemical cycles.



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.

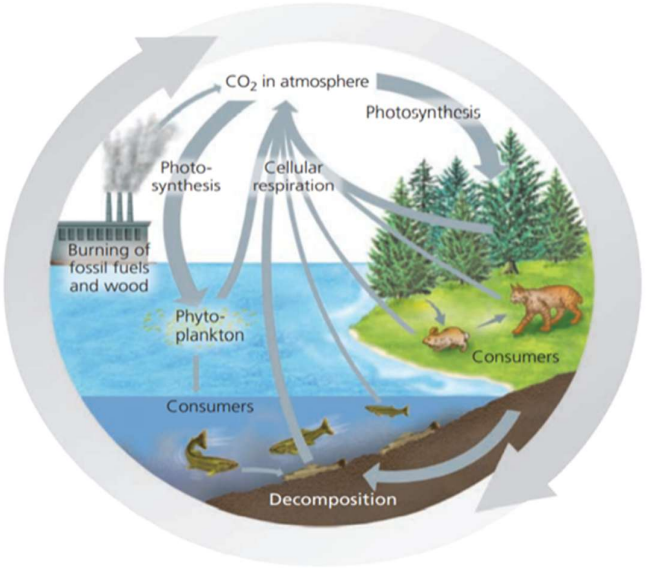
Forms available to life All organisms are capable of exchanging water directly with their environment. Liquid water is the primary physical phase in which water is used, though some organisms can harvest water vapor. Freezing of soil water can limit water availability to terrestrial plants.

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 93. The Water Cycle

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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 94. The Carbon 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

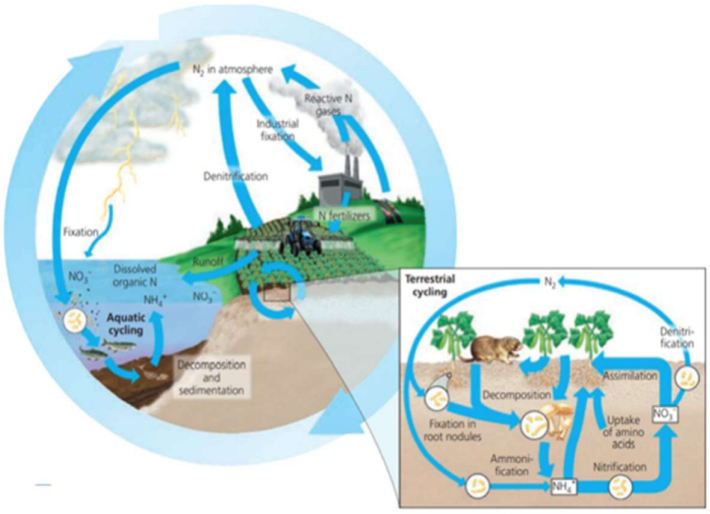


Figure 95. The Nitrogen Cycle

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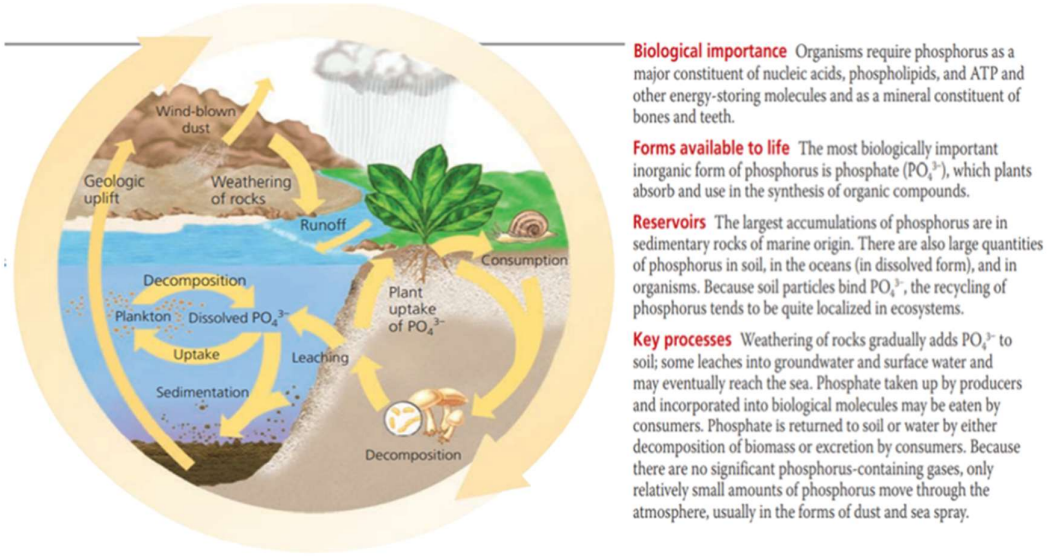


Figure 96. The Phosphorus Cycle

Restoration Ecologists Return Degraded Ecosystems to a More Natural State:

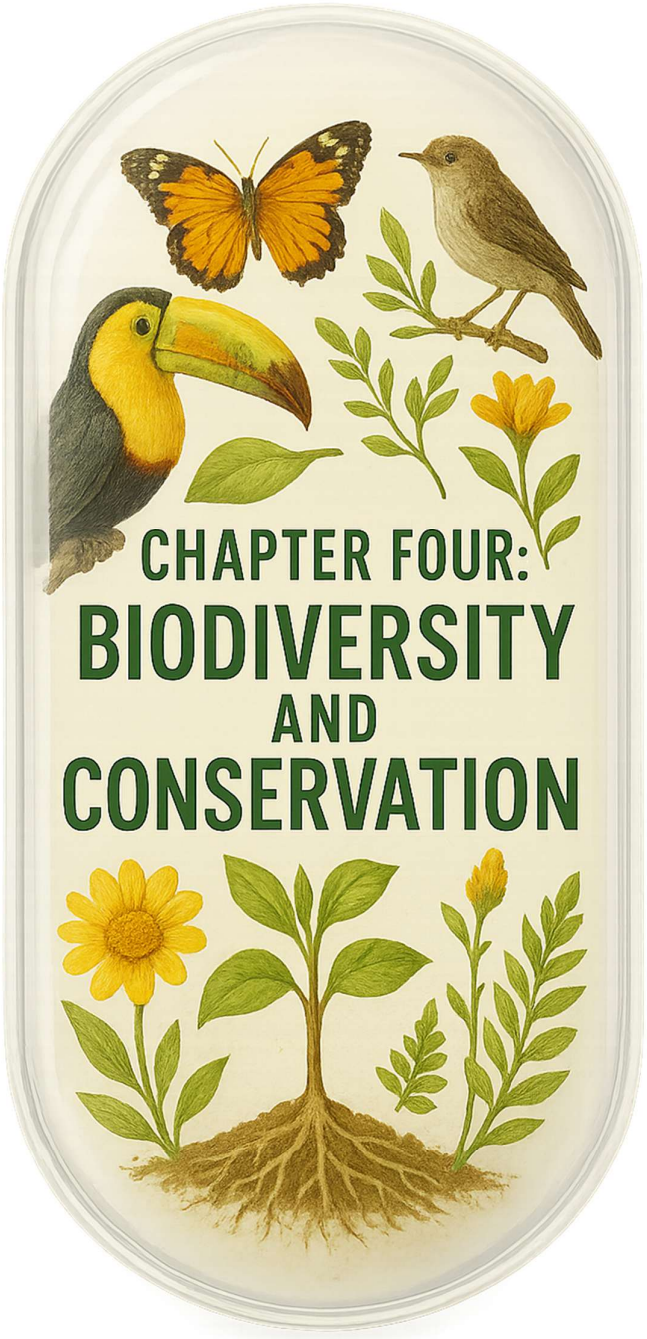
Scientists around the world often use two main strategies: bioremediation and biological augmentation.

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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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.

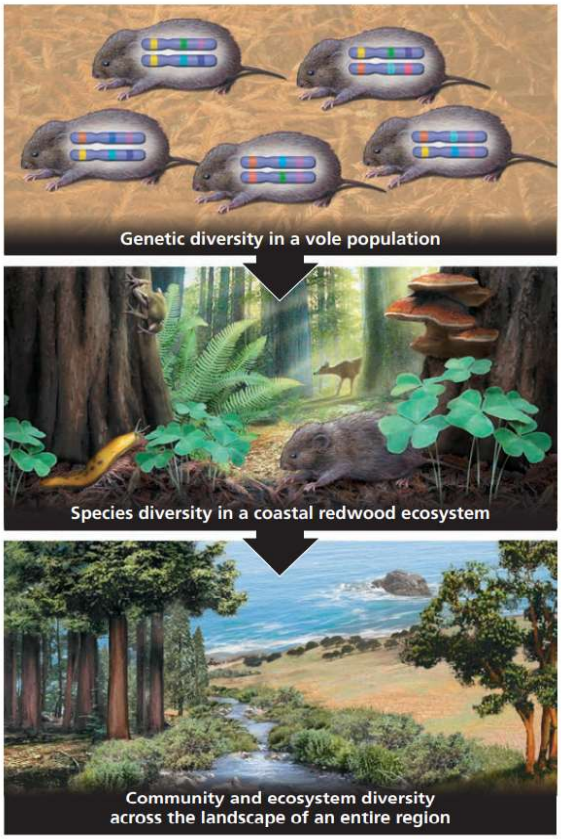


Figure 97. A sequence illustrating genetic, species, and ecosystem diversity.

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.

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Threats to Biodiversity:

- Habitat Loss
- Introduced Species
- Overharvesting
- Global Change

Landscape and Regional Conservation Help Sustain Biodiversity

Landscape Structure and Biodiversity:

- Fragmentation and Edges
- Corridors That Connect Habitat Fragments

Earth is Changing Rapidly as a Result of Human Actions

Nutrient Enrichment:

Human activity often removes nutrients from one part of the biosphere and adds them to another. Similarly, nutrients from farm soil may run off into streams and lakes, leading to nutrient depletion in one area and nutrient enrichment in another.

Toxins in The Environment:

- Some toxins are metabolized or excreted, while others accumulate in certain tissues—often in fatty tissues.
- One reason accumulated toxins are particularly harmful is that they become more concentrated at successive trophic levels of the food web. This phenomenon, known as biological magnification, occurs because the biomass at any given trophic level is produced from a much larger biomass at the level below. As a result, top-level carnivores tend to be the most severely affected by toxic compounds in the environment.

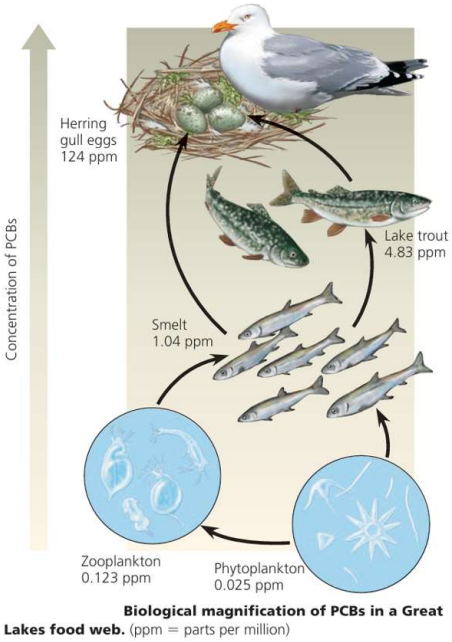


Figure 98.A Biological Magnification of Polychlorinated Biphenyls (PCBs)

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Greenhouse Gases and Climate Change:

The greenhouse effect. Carbon dioxide and other greenhouse gases in the atmosphere absorb heat emitted from Earth's surface and then radiate much of that heat back to Earth

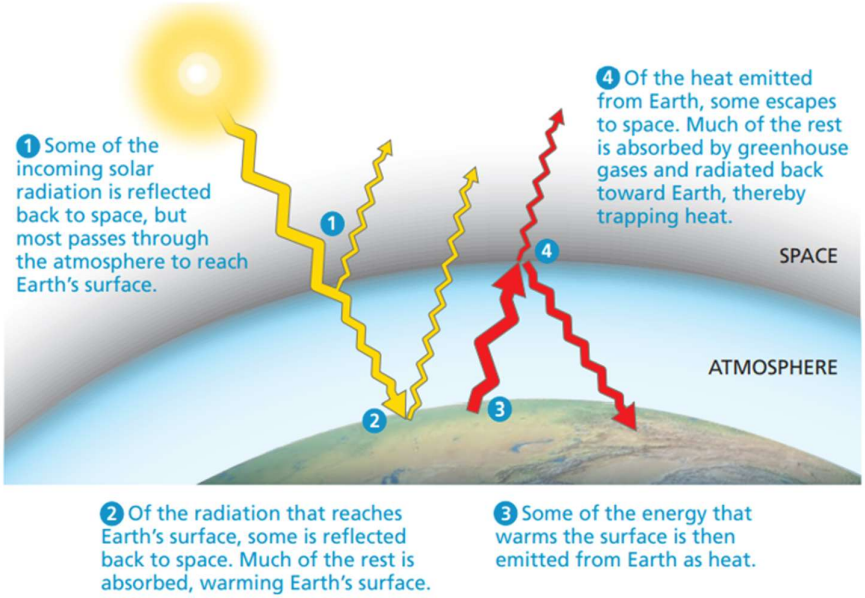
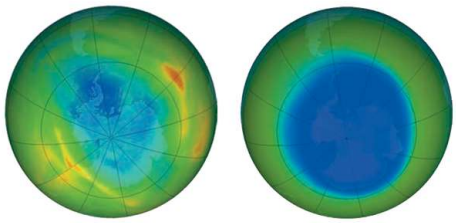


Figure 98.B The Effect of Global Warming)

Depletion of atmospheric ozone:

Erosion of Earth's ozone shield. The ozone hole over Antarctica is visible as the dark blue patch in these images based on atmospheric data.



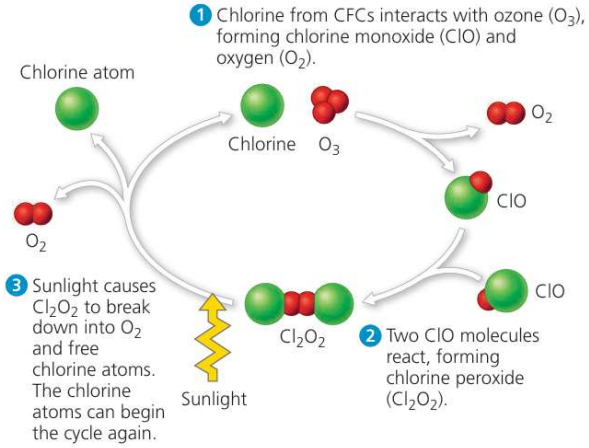


Figure 99. How Free Chlorine Is Destroyed in the Atmosphere

Sustainable development can improve human lives while conserving biodiversity:

With the increasing loss and fragmentation of habitats, changes in Earth's physical environment and climate, and growing human populations, we face difficult trade-offs in managing the world's resources. Ecologists use the concept of sustainability as a tool to help set long-term conservation priorities.

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Sustainable Development:

- We need to understand the interconnectedness of the biosphere if we are to protect species from extinction and improve the quality of human life.
- To this end, many nations, scientific organizations, and other groups have adopted the concept of sustainable development — economic development that meets the needs of people today without compromising the ability of future generations to meet their own needs.
    - **Substitution**: is the process of replacing non-renewable or harmful resources with more sustainable, renewable, or less damaging alternatives to reduce environmental impact and conserve natural resources.
    - **Recycling**: refers to reprocessing waste materials to produce new products.
    - **Reduce**: means consuming a smaller quantity of resources.
    - **Reuse**: is the practice of using an item multiple times for the same or a new purpose instead of discarding it after a single use. This helps reduce waste, conserve resources, and minimize environmental impact

Animal Behavior

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 its organ functions.

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 behavior?
- How the behavior occurs — this refers to the proximate causation of behavior. To analyze the proximate cause of 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 does this behavior occur this refers to the ultimate causation of behavior. To study ultimate causation, scientists aim to determine how 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.

Fixed Action Patterns

- The scientist Niko Tinbergen conducted an experiment in which he kept aquariums containing three-spined stickle
Male sticklebacks with red bellies attack other males that invade their territories.

Sign stimuli in a classic fixed action pattern.
A male stickleback fish attacks other male sticklebacks that invade its nesting territory. The red belly of the intruding male (left) acts as a sign stimulus that releases the aggressive behavior.



Figure 100. Male Stickleback Fish Attacking One Another

- 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

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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 red-colored areas (see figure).

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 101. Animal Migration

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 constitute 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.

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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

Learning (Acquired Behavior):

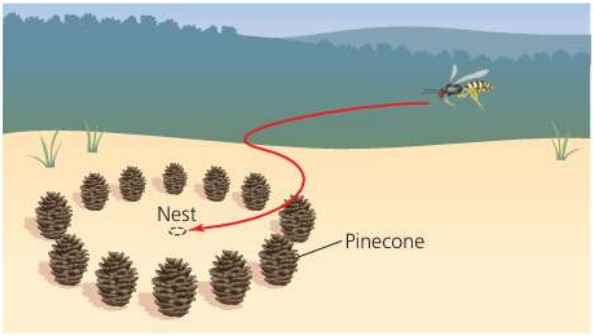
In some species, the ability of offspring to recognize and identify a parent is essential for survival. In young animals, this learning often takes the form of imprinting, which is the establishment of a long-lasting behavioral response to a specific individual or object. Imprinting can occur only during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



Spatial Learning and Cognitive Maps:

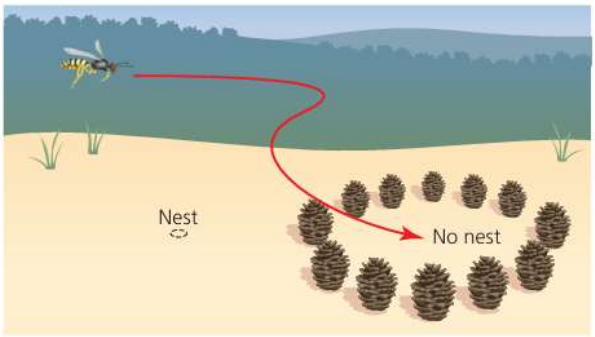
Inquiry **Does a digger wasp use landmarks to find her nest?**

Experiment A female digger wasp covers the entrance to her nest while foraging for food, but finds the correct wasp nest reliably upon her return 30 minutes or more later. Niko Tinbergen wanted to test the hypothesis that a wasp learns visual landmarks that mark her nest before she leaves on hunting trips. First, he marked one nest with a ring of pinecones while the wasp was in the burrow. After leaving the nest to forage, the wasp returned to the nest successfully.



Two days later, after the wasp had again left, Tinbergen shifted the ring of pinecones away from the nest. Then he waited to observe the wasp's behavior.

Results When the wasp returned, she flew to the center of the pinecone circle instead of to the nearby nest. Repeating the experiment with many wasps, Tinbergen obtained the same results.



Conclusion The experiment supported the hypothesis that digger wasps use visual landmarks to keep track of their nests.

Figure 102. The Digging Wasp Experiment

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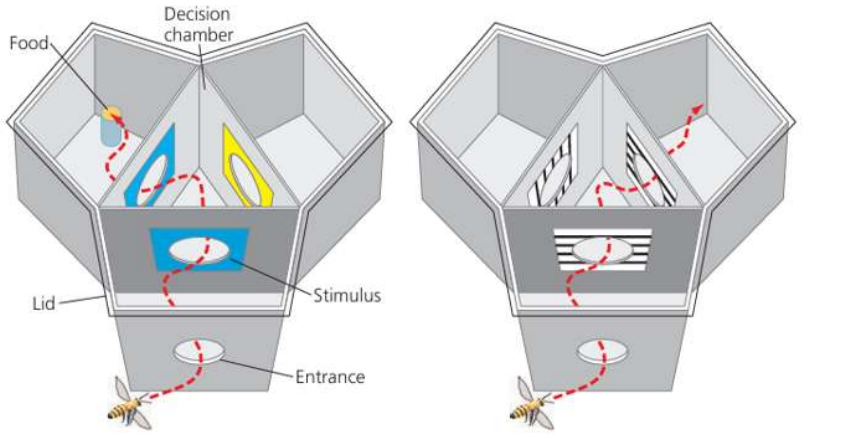
Associative Learning

- 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.

A maze test of abstract thinking by honeybees. These mazes are designed to test whether honeybees can distinguish "same" from "different."



1 Bees were trained in a color maze. As shown here, one group were rewarded for choosing the same color as the stimulus.

2 Bees were tested in a pattern maze. If previously rewarded for choosing the same color, bees most often chose lines oriented the same way as the stimulus.

Figure 103. The Honeybee Abstract Thinking Experiment

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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.



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.



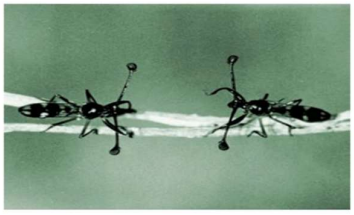
In polyandrous species, such as these red-necked phalaropes (Phalaropus lobatus), females (right) are generally more ornamented than males.

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.

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Mate Choice by Females:

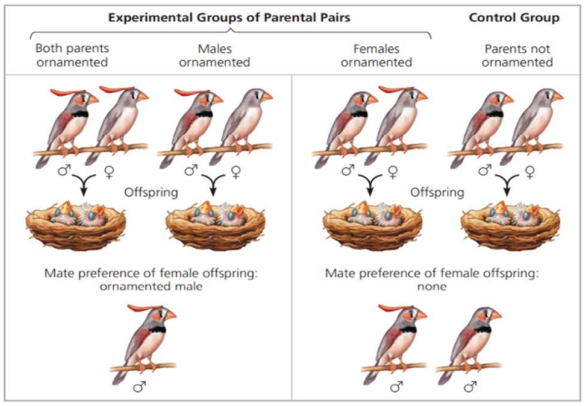


A face-off between male stalk-eyed flies competing for female attention.

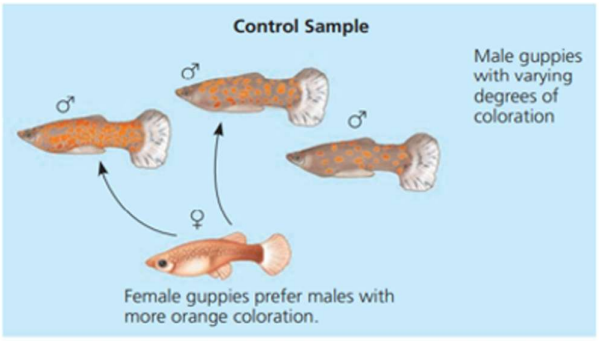


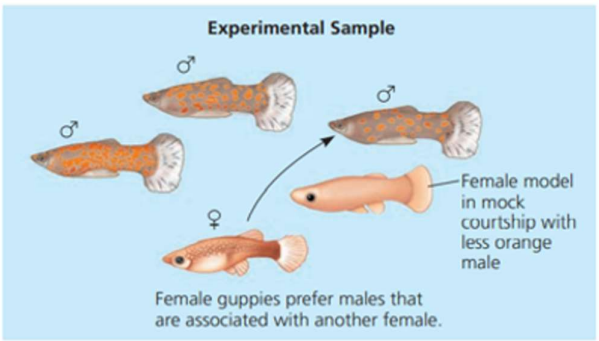
Appearance of zebra finches in nature. The male zebra finch (left) is more highly patterned and colorful than the female zebra finch.

Sexual selection influenced by imprinting. Experiments demonstrated that female zebra finch chicks that had imprinted on artificially ornamented fathers preferred ornamented males as adult mates. For all experimental groups, male offspring showed no preference for either ornamented or non-ornamented female mates.



Mate-Choice Copying:





Mate choice copying by female guppies (*Poecilia reticulata*).

In the absence of other females (control group), female guppies usually prefer males with more orange coloration. However, when a female model is placed near one of the males (experimental group), female guppies often copy the apparent mate choice of the model, even if that male is less colorful than others. Female guppies ignored the model's mate choice only when an alternative male had significantly more orange coloration.

Figure 104. Mate choice copying by female guppies

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Male Competition for Mates:



Agonistic interaction.

Male eastern grey kangaroos (*Macropus giganteus*) often "box" in contests that determine which male is most likely to mate with an available female.

Typically, one male snorts loudly and strikes the other with his forelimbs.

If the male under attack does not retreat, the fight may escalate into grappling, or the two males may balance on their tails while attempting to kick each other with the sharp toenails of their hind feet.

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.
- 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."

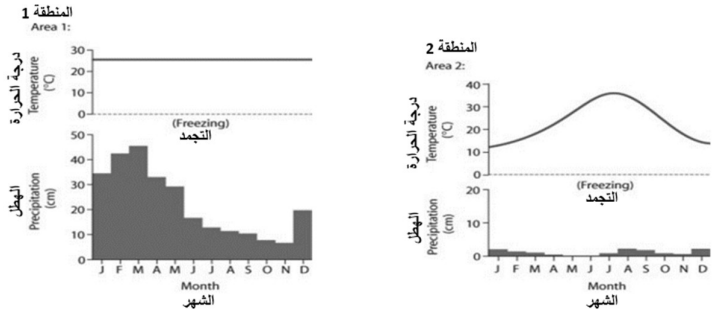
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- In the tit-for-tat strategy, an individual treats another in the same way it was treated during their previous interaction.
- Individuals following this strategy are always altruistic or cooperative in their first encounter with another and remain so if 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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Exercises

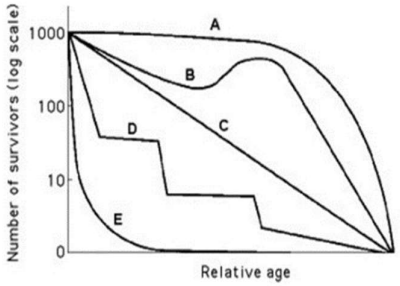
1- Based on the data presented in the figures, which of the following statements is correct?



I	Region 1 is considered desert-like due to its high average temperature.
II	Region 1 has a higher average precipitation than Region 2.
III	Region 2 is considered desert-like because of its low precipitation rate.
IV	Region 2 has greater annual variation in temperature.

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

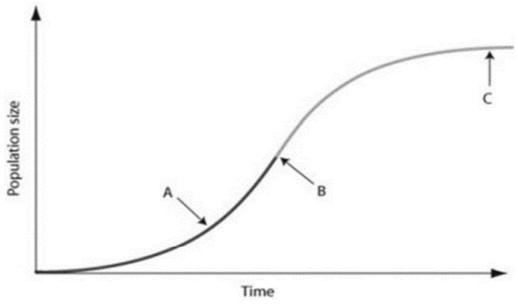
2- Which growth curve best describes the growth pattern in elephants?



A	B	C	D
A	B	C	E

3- In the figure, which of the arrows represents the carrying capacity?

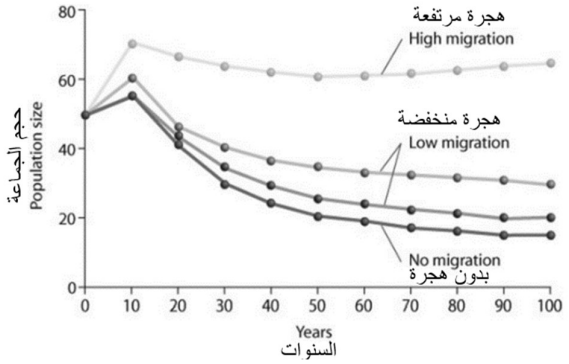
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A	B	C	D
A	B	C	Not shown on the diagram

4- Based on the figure, which factor contributes most significantly to stabilizing population size over time?

I. No immigration
II. Low immigration
III. High immigration



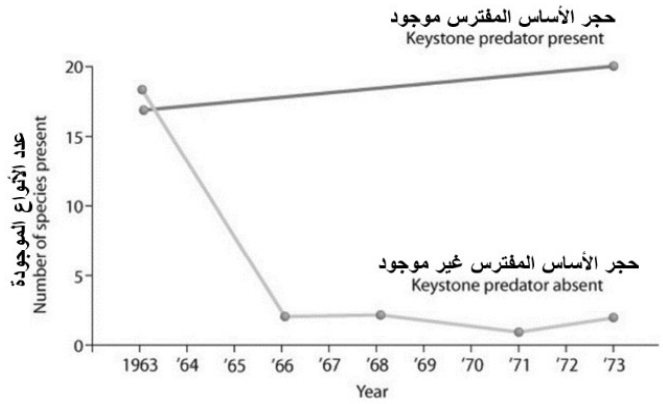
A	B	C	D
only I	only II	only III	only II & III

5- While studying two closely related species of predatory beetles—the two-spotted and the three-spotted beetles—you observe that each species searches for prey at dawn in areas where the other species is absent. However, in regions where their ranges overlap, the two-spotted beetle hunts at night while the three-spotted beetle hunts in the morning. When you bring them into the laboratory and isolate the two species, you find that the offspring of both species are naturally nocturnal. You have discovered a pattern of _____.

A	B	C	D
Mutualism	Character Displacement	Mimicry	Resource Partitioning

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6- What does the graph tell you about the effect of a keystone species on other species?



A	A keystone species has minimal interaction with other species in the environment.
B	Removing the keystone species from the community greatly reduces species richness.
C	Adding a keystone species to the community will make it more diverse.
D	Removing the keystone species from the community will eventually allow a new species to invade.

7- Dwarf mistletoe is a flowering plant that grows on certain forest trees. It obtains nutrients and water from the trees' vascular tissues. The trees receive no known benefits from the dwarf mistletoe, nor are they negatively affected by this interaction. Which of the following best describes the interaction between dwarf mistletoe and the trees?

A	B	C	D
Mutualism	Commensalism	Competition	Facilitation

8- If two closely related competitors are present and one species is experimentally removed from the community, the remaining species is expected to _____.

A	Shift its fundamental niche
B	Expand its niche
C	Become a target for specialized parasites
D	Become a target for specialized parasites

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9- The symbols +, –, and 0 are used to show the outcomes of interactions between individuals and groups of individuals. The symbol + indicates a positive interaction, – indicates a negative interaction, and 0 indicates interactions in which individuals are not affected. The first symbol refers to the first organism mentioned. What interaction exists between lions and African wild dogs if wild dogs are typically found to avoid areas with lions?

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

10- A stickleback fish will attack a model fish if the model has a red coloration. Which concept in animal behavior is demonstrated by this observation?

A	B	C	D
Sign stimulus	Perception	Imprinting	Classical associative learning

11- When a lizard displays a colored dewlap by extending and shaking the skin flap under its neck, this is an example of _____.



A	B	C	D
Innate Fixed Action Pattern	Countermovement	Signal	Instinctive Behavior

12- Several examples of types of animal behavior are listed. Choose the letter of the correct term (A–E) that matches each example in the following questions.

a) Operant Associative Learning

b) Classical Associative Learning

c) Innate (Instinctive) Behavior

d) Imprinting

e) Altruistic Behavior

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

a	b	c	d	e

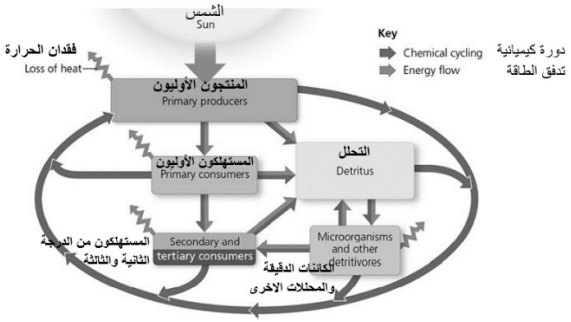
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An infant performs the sucking behavior perfectly when placed near the mother's nipple.				
a	b	c	d	e
A mother goat can recognize her offspring by scent.				
a	b	c	d	e
A cat rushes to its food dish when it hears the can opener.				
a	b	c	d	e

13- To recycle nutrients, an ecosystem must contain, at minimum, _____.

A	Producers
B	Producers and Decomposers
C	Producers, Primary Consumers, and Decomposers
D	Producers, Primary Consumers, Secondary Consumers, and Decomposers

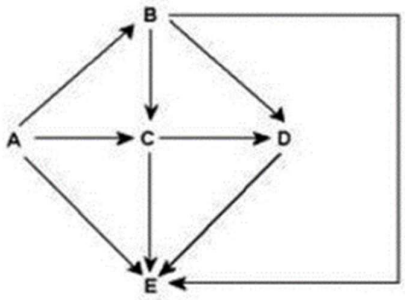
14- In the figure, what might the jagged arrow leaving microorganisms and other decomposers represent



A	Organic compounds broken down by bacteria
B	Energy consumed by bacteria
C	Energy loss from a worm during cellular respiration
D	Carbon dioxide and heat loss from decomposing materials because of solar radiation and rainfall

15- The food web of a certain terrestrial ecosystem (arrows represent energy flow and letters represent species). Which pair of species could be carnivores?

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A	B	C	D
A and D	B and C	C and D	C and E

16- Which of the following organisms is correctly paired with its trophic level?

A	Cyanobacteria - Primary consumer
B	Grasshopper - Secondary consumer
C	Phytoplankton - Primary producer
D	Fungus - Primary consumer

17- Which of the following can 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 an open pit mine
C	Dredging a riverbed to remove contaminated sediments
D	Adding fertilizer to nutrient-poor soil to enhance plant growth

18- What is the biological significance of genetic diversity within a population?

A	It is unlikely that genes for traits providing an advantage under local conditions will be present.
B	A more fit population can survive through competitive exclusion.
C	Genetic diversity reduces the likelihood of extinction.
D	Diseases and parasites do not spread among isolated populations.

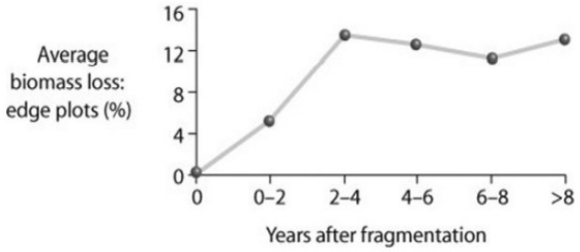
19- Which of the following criteria must be met for a species to be classified as invasive?

A	Native to the area, spreads rapidly, and replaces non-native species.
B	Introduced to a new area, spreads rapidly, and displaces native species.

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C	Introduced to a new area, spreads rapidly, and eliminates other invasive species.
D	Native to the area, spreads slowly, and replaces native species.

20- Based on the figure showing the effects of forest fragmentation, what can be said about edge effects?



A	Biomass decreases along the 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 has no effect on biomass.

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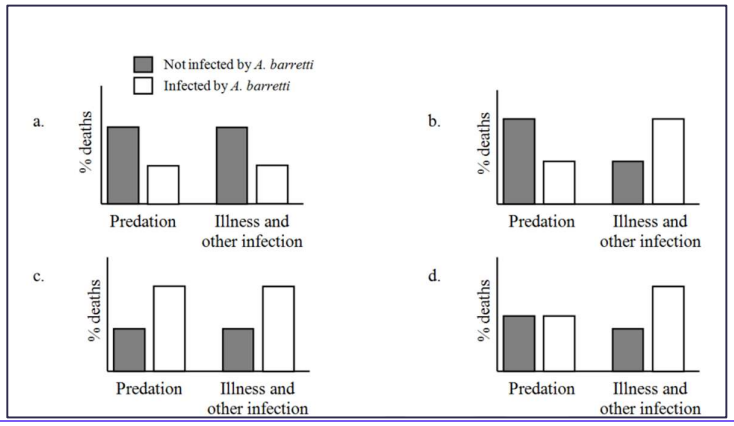
Mock Exam

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?



A	A
B	B
C	C
D	D

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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).

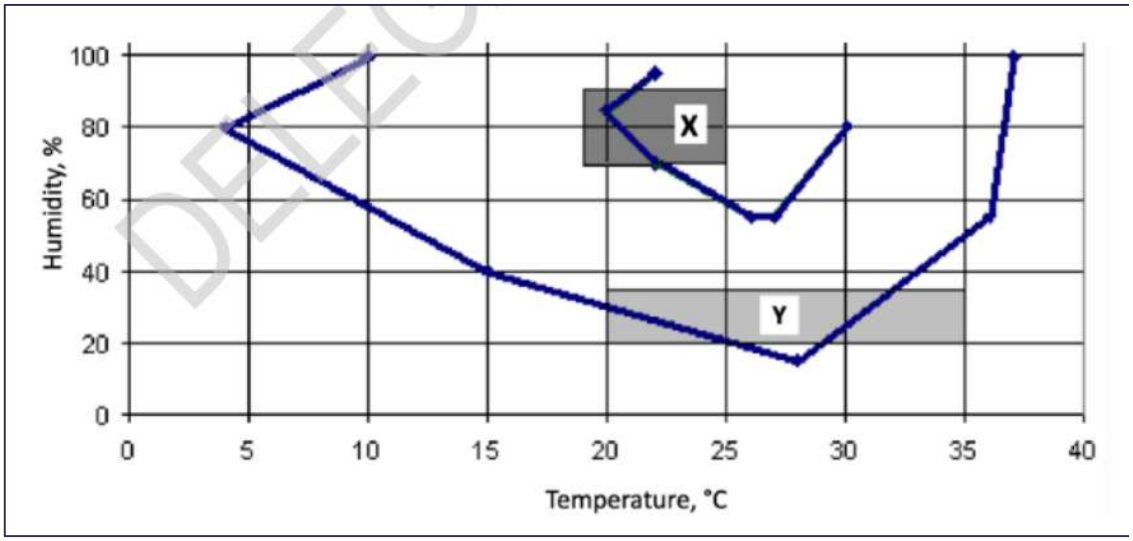
Analyze the risk of mass bursts of large numbers of codling moths based on these data in the coordinate space of the two-dimensional ecological niches formed in the zones marked with the letters X and Y (Figure 1). Table 1. 100% mortality of codling moth pupae is observed in the case of the following combinations of temperature and humidity.

Table 1. 100% mortality of codling moth pupae is observed in the case of the following combinations of temperature and humidity.

+37	+36	+28	+15	+4	+10	**Temperature, C**
100	55	15	40	80	100	**Humidity, %**

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, %**



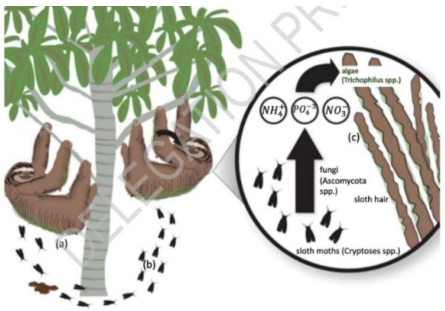
Using this information, which of the following options is correct?

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

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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.



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:

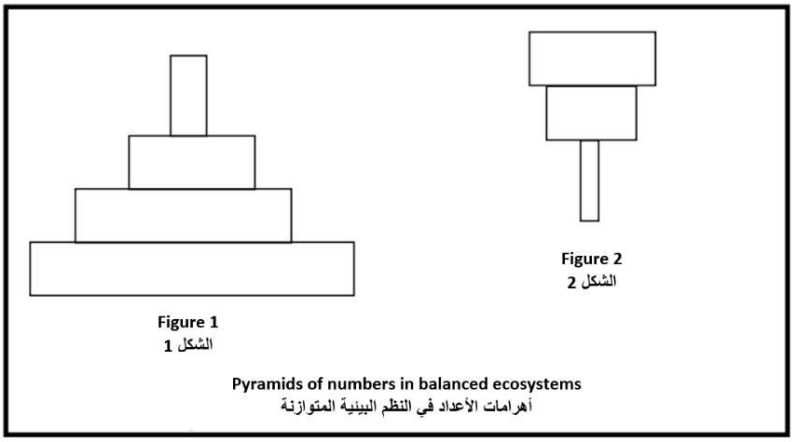
Trophic level	Name of Trophic level	Organisms found
Level 1	Producers	Phytoplankton
Level 2	Primary consumers	Zooplankton
Level 3	Secondary consumers	Small planktivorous fish

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

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	Figure 2

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A	grass → locust → snake → frog	grass → locust → frog
B	tree → ant → spider → lizard	tree → bird → parasites
C	grass → locust → frog → snake	phytoplankton → zooplankton → fishes
D	snake → frog → locust → grass	tree → ant → spider

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.

7- In ecosystems, rate of energy flow and nutrient cycling can determine ecosystem productivity and biodiversity. Which of the following organisms is 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

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1- proximate causation
2- ultimate causation

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
Species Y	Species Z	Species X	All have similar toxicity

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.

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Answer Keys for Exercises and the Mock Exam

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				

Mock Exam

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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