Courses

CHAPTER 1 I MODULE 3

ECOLOGY

Courses

MODULE 3

ECOLOGY

General Terms

Population: A group of individuals of one species living in one area who can interbreed and interact with each other. They are defined by their size, density, and dispersion.

Community: All organisms living in one area.

Ecosystem: Includes all the organisms in a given area as well as the abiotic (non-living) factors with which they interact.

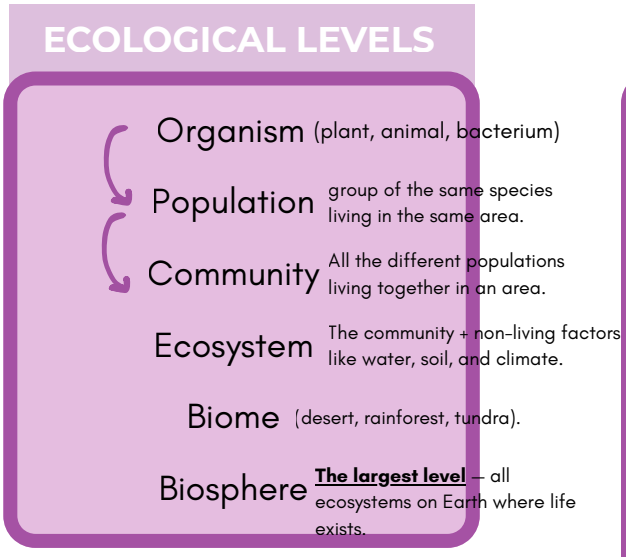
Abiotic factors: Nonliving components such as temperature, water, sunlight, wind, rocks, and soil.

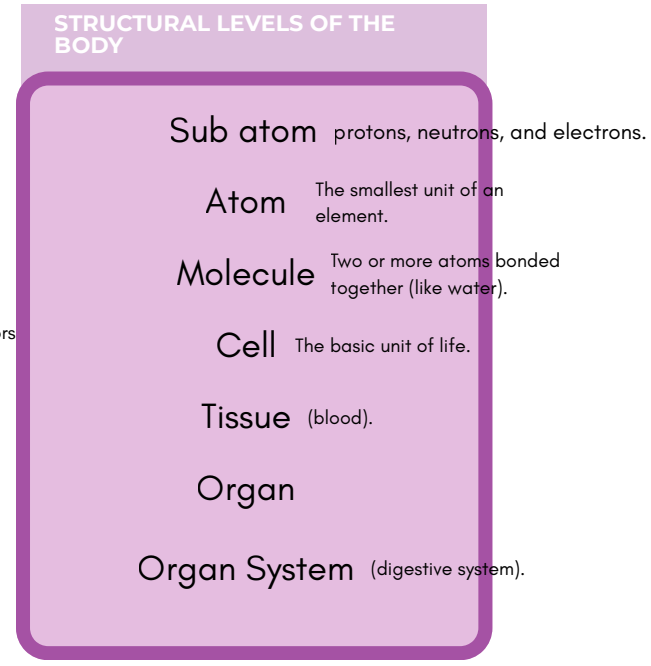
Biotic factors: All living organisms with which an organism might interact — birds, insects, predators, prey, parasites.

Biosphere: The global ecosystem — includes all life on Earth and its environment.

Biome: A very large region made up of many ecosystems, classified by climate and characteristic organisms.

Niche: What an organism eats and everything it needs to survive — its full ecological role in the ecosystem.





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Population Size: Number of individuals in a population.

→ Four variables limit the size of a population: **the number of births, the number of deaths, immigration, and emigration.**

Population Density: refers to the size of any population in relation to unit of space.

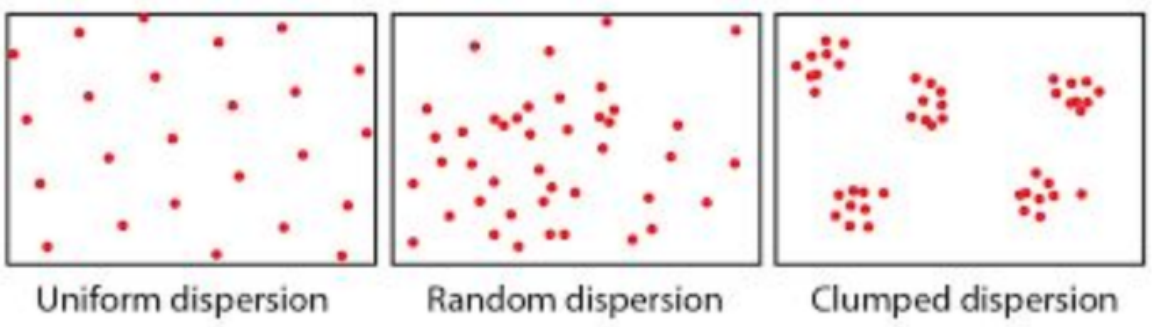
Population size ÷ Area OR Volume

Natality:
Natality refers to the rate of reproduction or birth per unit time.

Mortality:
Mortality refers to the number of deaths in population per unit time.

Population Dispersion : is the pattern of individuals in a population. It is three types: clumped, uniform, and random patterns.

Clumped	Uniform	Random
Individuals cluster together near resources or for protection. **Most common pattern in nature.**	Individuals are evenly spaced, often due to competition or territorial behavior.	Individuals distributed with no pattern. Occurs when resources are abundant and interactions are weak.
Ex: wolf packs, fish schools, trees around a water hole	*Ex: nesting seabirds spacing nests on a cliff, creosote bushes*	*Ex: dandelion seeds scattered randomly by wind*



The demographic transition is a long-term trend of declining birth and death rates, resulting in substantive change in the age distribution of a population.

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ECOLOGY

Population Growth

Exponential growth: No limiting factor is found .

Occurs when there is no limiting factor → the population grows faster and faster, producing a J-shaped curve.

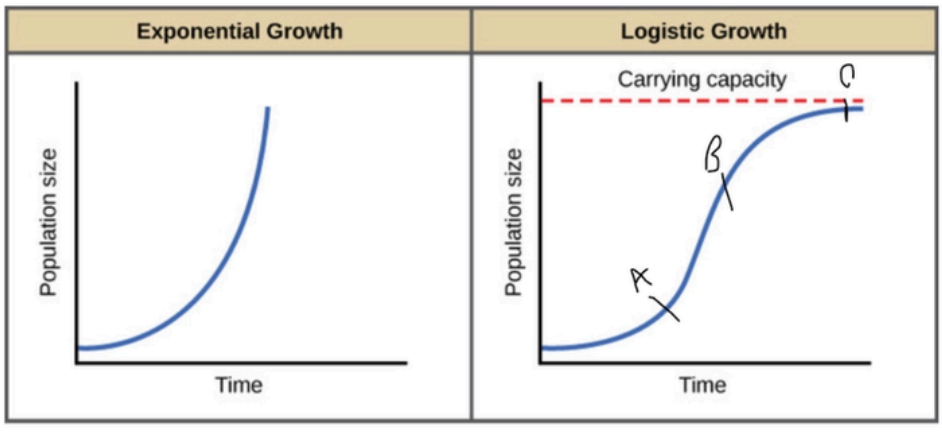
- Resources are unlimited. → Example: bacteria in a lab, early human population growth

Logistic [sigmoid] : Limiting factor are present

Growth slows as the population approaches the **environment's capacity.** Produces an S-shaped curve.

A. Exponential growth ,
B. Increasing with decreasing rate [due to limiting factor],
C. carrying capacity → max no of individuals the can be supported by an ecosystem

Phase	*What happens*
A — Exponential phase	Population grows rapidly — resources still plentiful
B — Slowing phase	Growth rate decreases — limiting factors intensify
C — **Carrying Capacity (K)**	Maximum number of individuals an ecosystem can **sustainably support** — population stabilizes here



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Population Growth

Limiting factors Factors that limit population growth.

Density-dependent factors

These are the factors that increase directly as the population density increases.
They include competition for food, Disease outbreak, Toxins [wastes], and predation

Density-independent factors

These are the factors whose occurrence is unrelated to the population density.
They include any natural disaster : earthquakes, storms, and fires and drought.

Density-dependent factors	Density-independent factors
These factors increase in effect as population **density increases**. They include: • Competition for food & space • Disease outbreaks (spread faster in dense populations) • Toxins and waste accumulation • Predation (more prey → more predators)	These factors affect the population **regardless of density** — natural disasters hit large and small populations equally. They include any **natural disaster**: • Earthquakes & volcanic eruptions • Storms and floods • Wildfires • Drought & extreme temperatures

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Species Interactions

Predation: It refers to one animal eating another animal, or animal eat plants. Prey-predator relationship , short term relationship

Adaptation of predator: fast, strong, canines, camouflage, front facing eye

Adaptation of prey: Fast, camouflage, lateral eyes, mimicry

- Alternative evolutionary relationship between prey & predator known as Coevolution relationship where evolution of one species depends on other species

Adaptations of the **Predator:**	Adaptations of the **Prey:**
Fast speed, strong muscles, canine teeth, camouflage, **front-facing eyes** (depth perception for judging distance to target)	Fast speed, camouflage, **lateral (side-facing) eyes** for wide field of view, mimicry, warning coloration (aposematism)

Difference between mimicry and camouflage: with mimicry, an organism resemble another organism or part of an organism [poisonous, or harmful part] while camouflage involves the resemblance of part of the environment.

Reproductive strategists

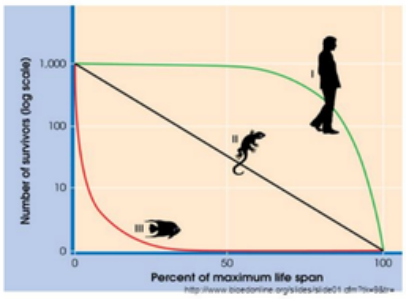
Survivorship Curves

Type I:
Common in K-selected species. Most individuals survive to adulthood, and death mainly occurs at old age.

Type III:
Common in r-selected species. Most individuals die at an early age, and only a small percentage survive long enough to reproduce.

Type II:
An intermediate pattern where the death rate remains relatively constant throughout life. Most organisms fall somewhere between the extremes.

	r **Unstable environment, density independent**	***K*** **Stable environment, density dependent interactions**
Organism size	Small	Large
Energy used to make each individual	Low	High
# Offspring produced	Many	Few
Timing of maturation	Early	Late (with much parental care)
Life expectancy	Short	Long
Lifetime reproductive events	One	More than one
Survivorship curve	Type III	Type I or II



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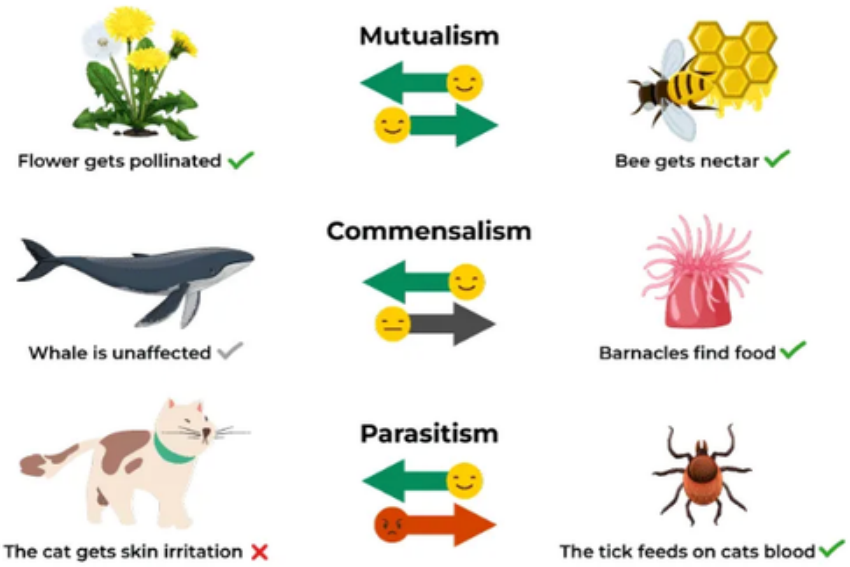


Species Interactions

Symbiosis:

→ Long term relationship

- Mutualism [+,+] → ex. E.coli, human
- Commensalism [+,0] → ex. remora fish, shark
- Parasitism [+,-] parasite, host → ex. Bacteria in your throat

Type	*Effect*	*Definition & Example*
Mutualism	[+, +]	Both species benefit from the relationship. *Ex: E. coli bacteria in human gut — bacteria get nutrients; humans get vitamin K. Bees and flowers.*
Commensalism	[+, 0]	One species benefits; the other is unaffected. *Ex: Remora fish attach to sharks — remora gets free food scraps and transport; shark is unaffected. Barnacles on whales.*
Parasitism	[+, –]	Parasite benefits; host is harmed. Parasite rarely kills host immediately — it needs the host alive. *Ex: Bacteria causing a throat infection. Ticks feeding on a dog's blood. Tapeworms in intestines.*

Competition

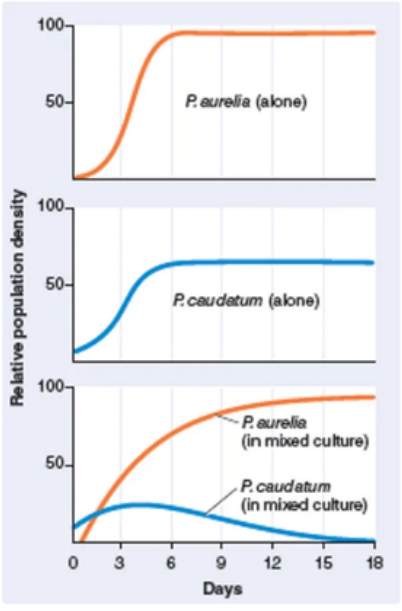
Two share same ecological niche

→ Competition is divided into **intraspecific** (within the same species) and **interspecific** (between

Competitive Exclusion : Two species cannot occupy the exact same ecological niche indefinitely

→ the more efficient competitor will outcompete and eliminate the other.

Experiment: Gause worked with Paramecium caudatum and Paramecium aurelia — when grown together, P. aurelia outcompeted P. caudatum, driving it to local extinction.



Competitive exclusion

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Energy transfer

Mode of nutrition:

Producers [Autotrophic]: Make their own food from non-living sources.

Photoautotrophs: derive energy from light & photosynthesis — plants, algae, phytoplankton, cyanobacteria

Chemoautotrophs: derive energy from oxidizing inorganic chemicals via chemosynthesis (no sunlight needed) — bacteria at hydrothermal vents using H2S

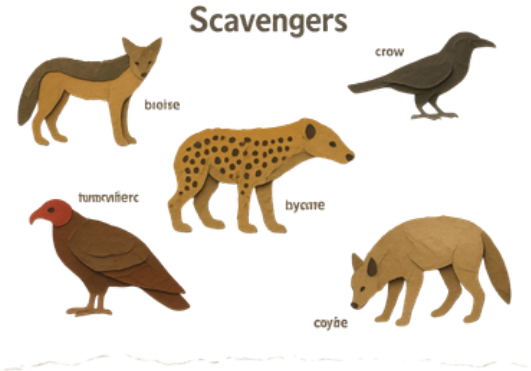
Consumers [Heterotrophic]: Cannot produce their own food — must eat other organisms for energy and nutrients.

Herbivores, carnivores, omnivores, scavengers

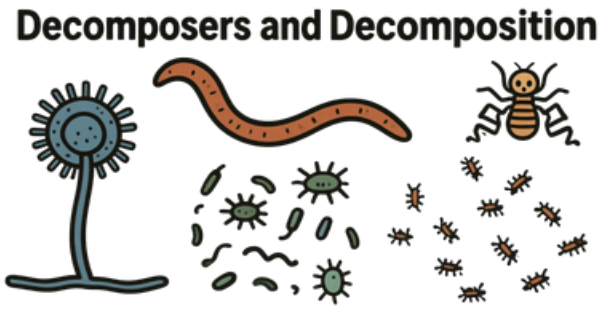
Decomposers are classified into 2 groups:

Detritivores : an animal which feeds on dead organic material and digest them within their body [Ex. insects, worms]

Saprotrophs : Excrete extracellular enzymes into dead organic matter , decompose them and absorb nutrients [Ex: bacteria, fungi]



DETRITIVORES



SAPROTROPHS

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ECOLOGY

Energy transfer

Food chain:

Series that shows which organisms feeds on which or how energy transfers through the ecosystem

→ Food chain can never have more than 4-5 trophic levels
→ As the trophic level increase, the Energy & Biomass decrease

- Any food chain starts with a producer (autotroph) — plant, tree, grass, diatom, phytoplankton
- Food chains can never have more than 4–5 trophic levels
- As trophic level increases, both Energy and Biomass decrease
- Decomposers convert the food chain into a food cycle
- A food web is an interconnected network of multiple food chains

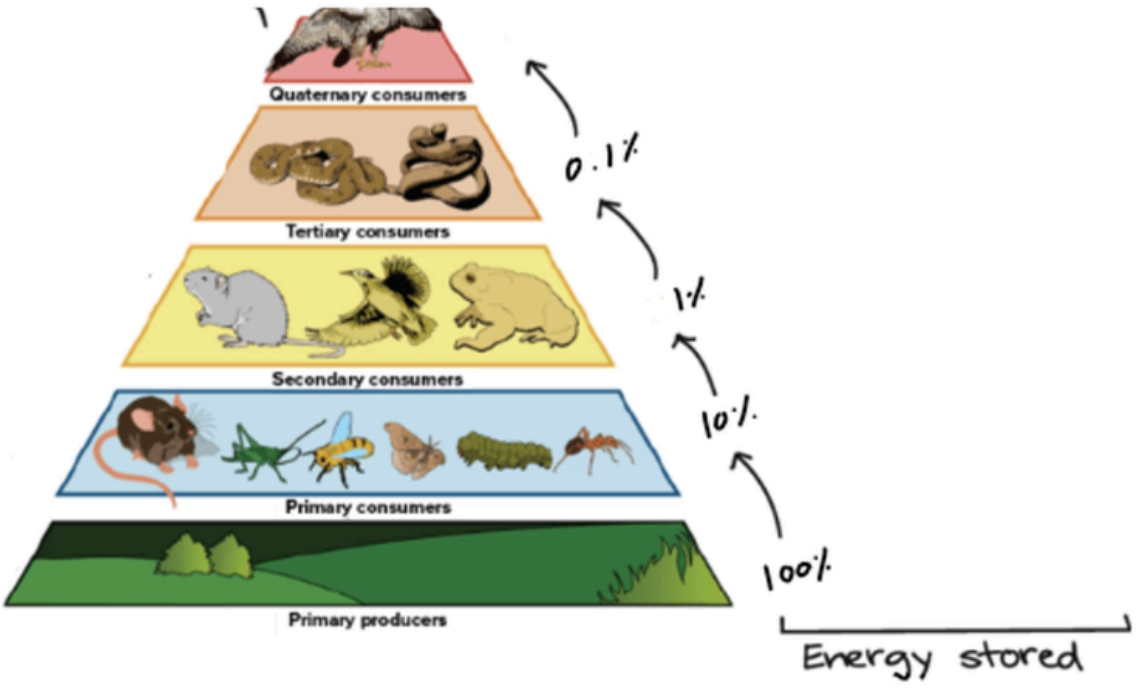
Energy Pyramid — The 10% Rule

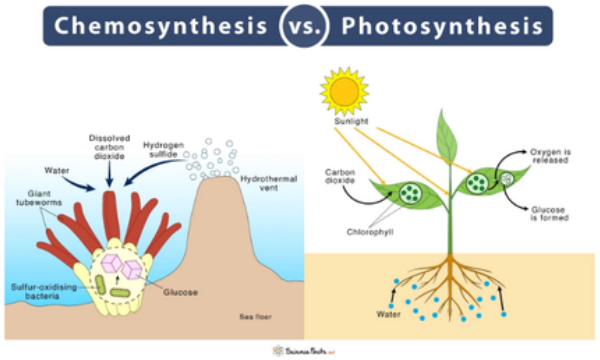
Energy moves: **Producers (100%)** → 1st Consumer (10%) → 2nd Consumer (1%) → 3rd Consumer (0.1%) → 4th Consumer (0.01%)

1st consumer → either herbivore /omnivore, Highest biomass
2nd consumer → [carnivore/omnivore], contains most pesticides

4th Consumer (Tertiary)	**0.01%**
3rd Consumer (Secondary)	**0.1%**
2nd Consumer — contains most pesticides	**1%**
1st Consumer (Herbivore) — highest biomass	**10%**
PRIMARY PRODUCERS (Autotrophs)	**100% — all energy stored**

Only 10% of energy is passed to the next trophic level — 90% is lost as heat through metabolism. The 2nd consumer (carnivore) accumulates the highest concentration of pesticides (biological magnification).





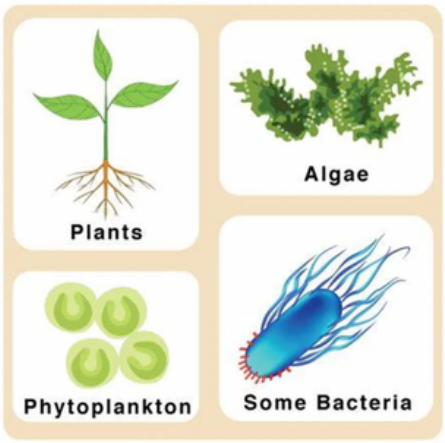
Autotroph

Autotrophs are classified into two:

Photoautotrophs: organisms that derive their energy from Light & photosynthesis

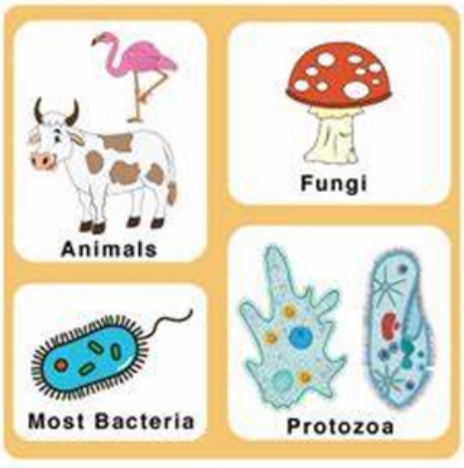
Chemoautotrophs: Organisms that derive their energy from oxidizing inorganic chemical compounds by chemosynthesis

Example:
Hydrothermal vents : places where sea water exits cracks in the sea floor , having been super heated and enriched with minerals and metals deep in the bedrock > release H2S



Heterotroph

an organism that eats other plants or animals for energy and nutrients.



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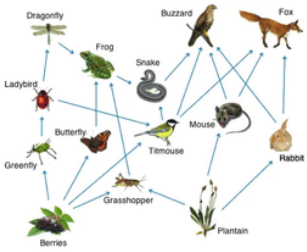
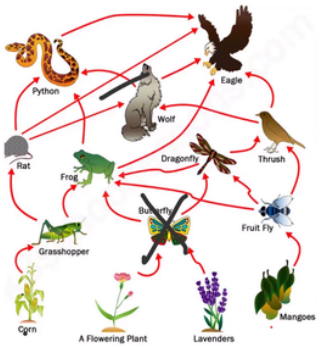
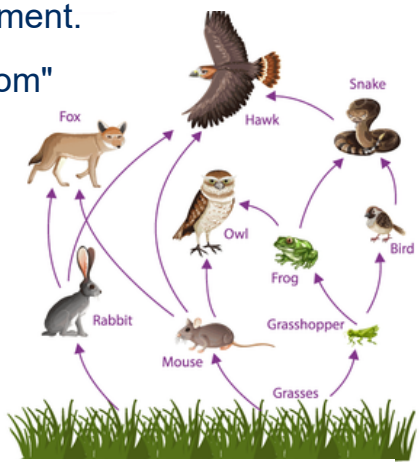




Food web

food web is not isolated it's a detailed interconnecting diagram that shows the overall **food relationships between organisms** in a particular environment.

→ The simplest explanation is that food webs are "who eats whom"

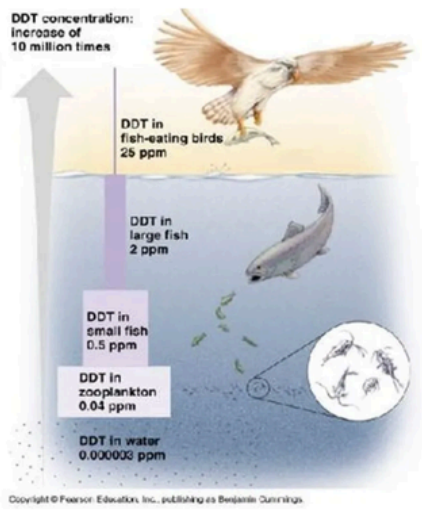


Biological magnification

the increase of concentration of a substance in the bodies of organisms in food chain until it reaches concentration that is very toxic
→ Ex. DDT, non biodegradable insecticide

Level	*Organism*	*DDT Concentration*
Water	—	0.000003 ppm
1st	Zooplankton	0.04 ppm
2nd	Small fish	0.5 ppm
3rd	Large fish	2 ppm
Top	**Fish-eating birds**	**25 ppm ■■ TOXIC!**

Biological magnification of DDT in a food chain



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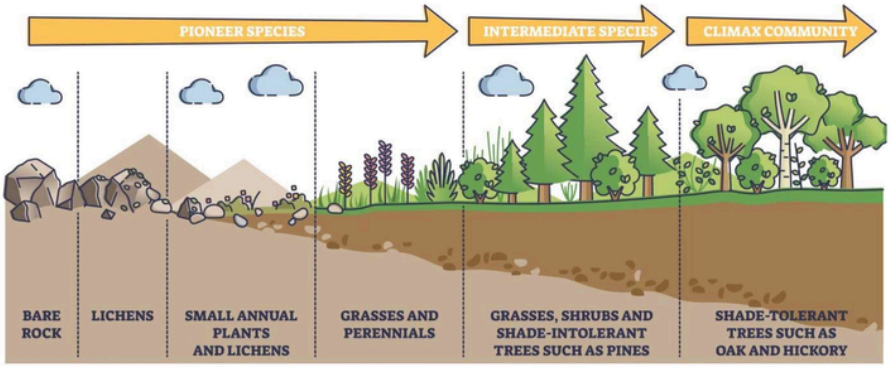

Ecological Succession

Total replacement of populations with others

the process by which the structure of a biological community evolves over time.

Types of succession:

the increase of concentration of a substance in the bodies of organisms in food chain until it reaches concentration that is very toxic
→ Ex. DDT, non biodegradable insecticide

Bare Rock	Lichens (Pioneer)	Mosses & Grasses	Shrubs & Bushes	Young Trees	Climax Community ■

■ Primary Succession	■ Secondary Succession
Occurs in areas **never previously inhabited** — starts from bare rock with no soil. • **No soil** present initially • **Pioneer organisms:** fast-growing, arrive as wind-blown spores • First pioneer: **Lichens** (algae/cyanobacteria + fungi) — grow on bare rock and break it down to form thin soil • Gradually replaced by mosses, grasses, shrubs, then trees *Ex: volcanic lava flows, newly exposed glacial rock*	Occurs in areas **previously inhabited but disturbed**. • **Soil IS present** — contains nutrients and seeds from previous community • Proceeds **faster** than primary succession • Pioneer organisms grow quickly since soil already exists *Ex: regrowth after a wildfire, abandoned farmland returning to forest, area after flooding*
→ Both types eventually reach a **Climax Community**: a stabilized community that no longer changes unless disturbed.	→ Secondary succession reaches the **Climax Community** more quickly due to existing soil.

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ECOLOGY

Natural Cycles — Biogeochemical Cycles

These cycles recycle chemical elements between living organisms and the environment. They are essential because Earth's resources are finite — matter cannot be created or destroyed, only cycled.

Water Cycle

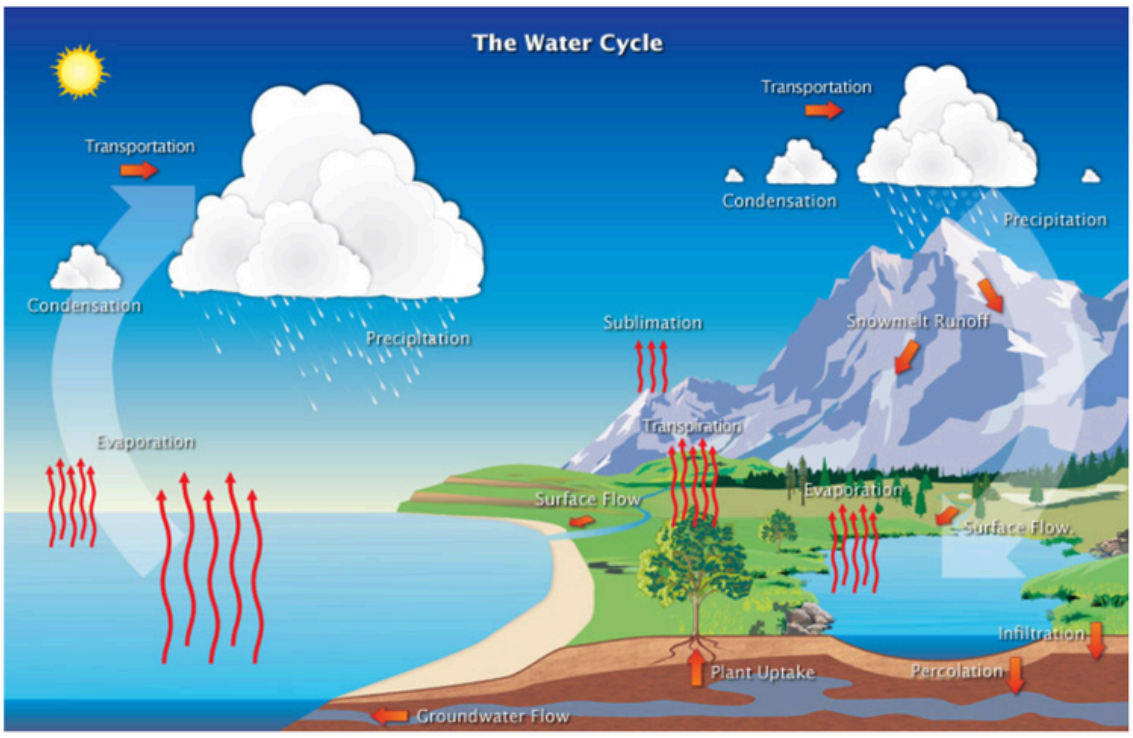
The sun is what makes the water cycle work.

Water enters the atmosphere via:

- **Evaporation** – The Sun heats water in oceans, lakes, rivers, and soil, turning liquid water into water vapor that rises into the air.
- **Transpiration** – Plants absorb water from the soil and release water vapor through tiny openings in their leaves. 🌿

Water returns to Earth via:

- **Precipitation** – Water vapor forms clouds and falls back to Earth as rain, snow, or hail.



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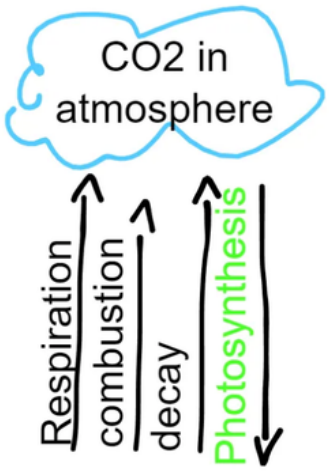
Natural Cycles — Biogeochemical Cycles

Carbon cycle :

CO2 enters the atmosphere via:

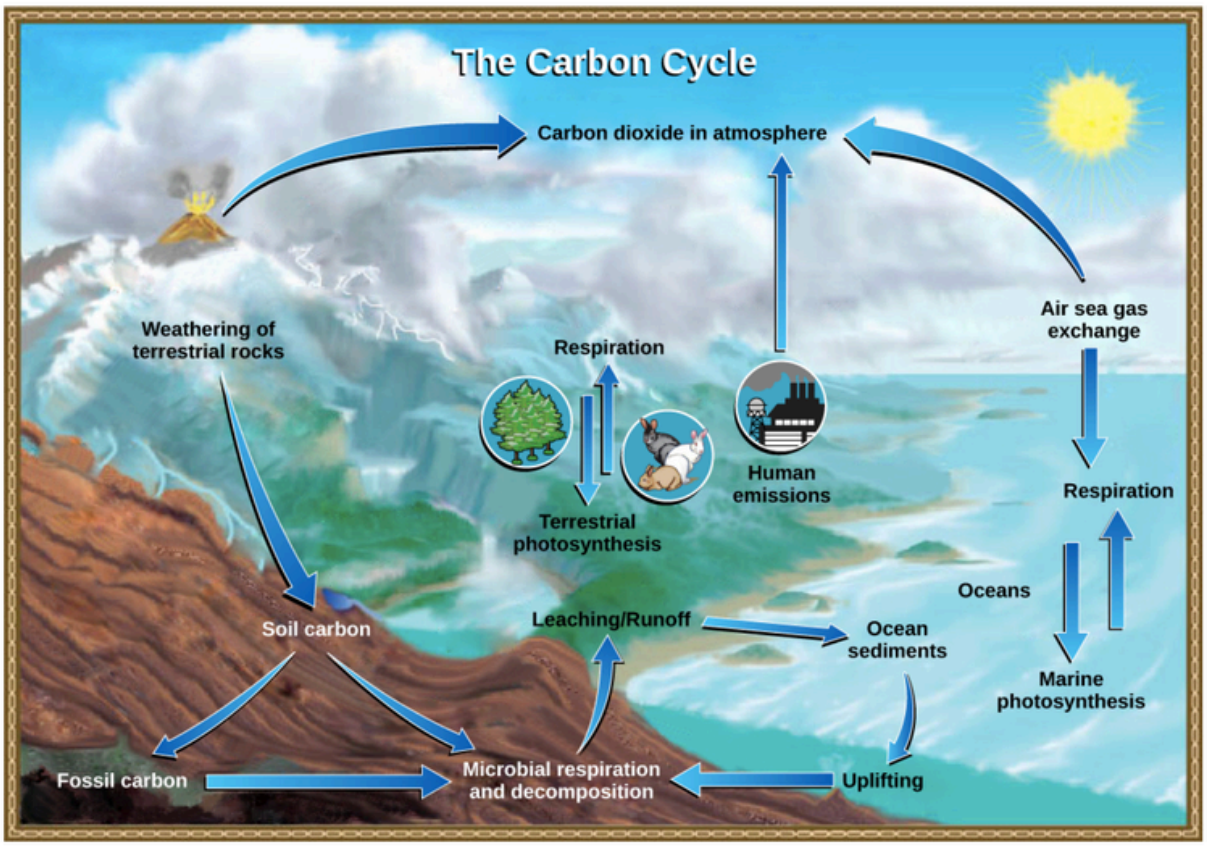
- **Respiration** — all organisms release CO2
- Combustion — burning fossil fuels and wood
- Decay — decomposers release CO2 breaking down organic matter



CO2 leaves the atmosphere via:

- **Photosynthesis** — plants absorb CO2 to make glucose

→ Burning fossil fuels adds excess CO2 that photosynthesis cannot absorb fast enough → **greenhouse effect & global warming.**



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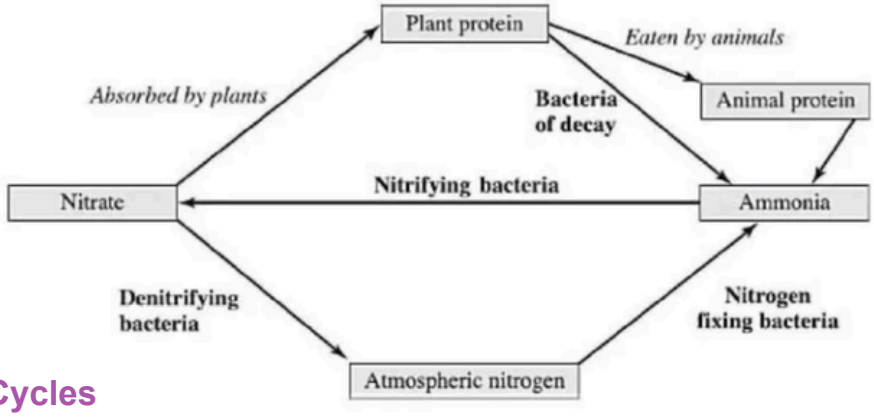
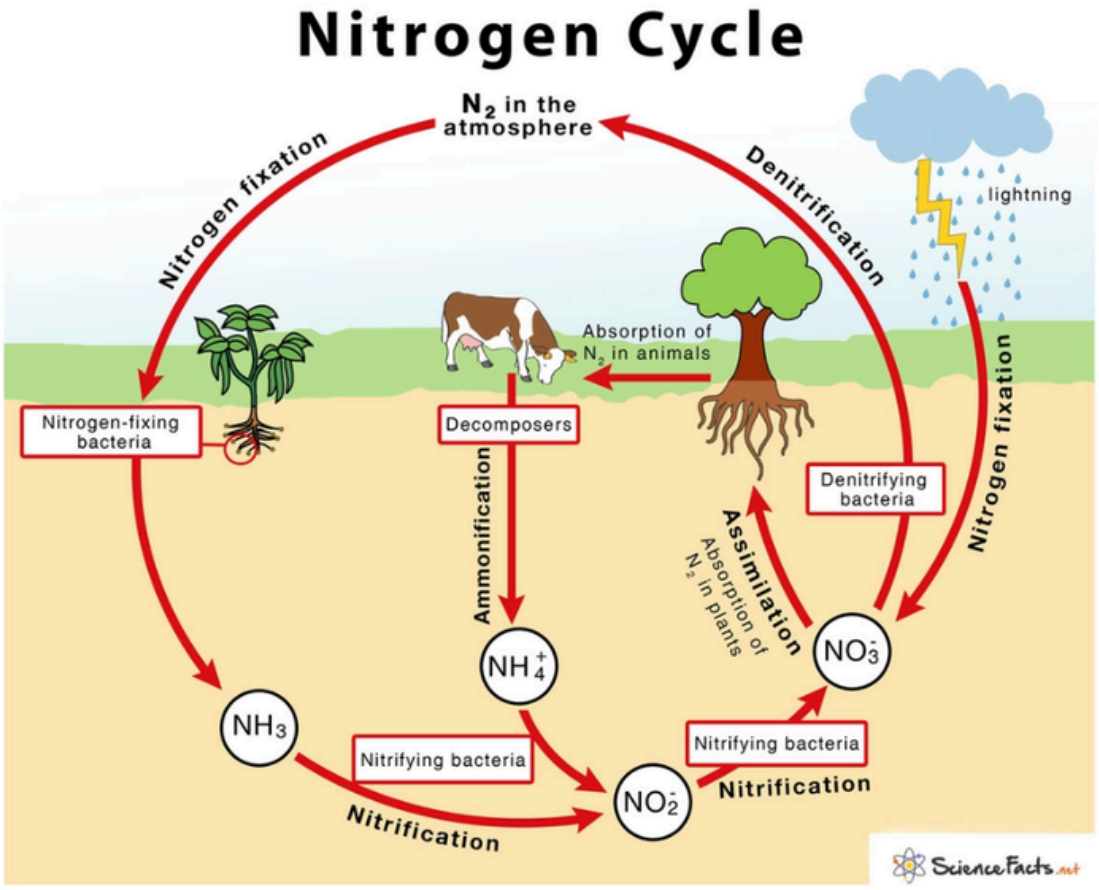


Natural Cycles — Biogeochemical Cycles

Nitrogen cycle:

Atmospheric N2 makes up 78% of air but is unusable directly by most organisms. Three bacterial stages:

Step 1: Nitrogen Fixation	$N_2 \rightarrow NH_4$ (ammonia) by **nitrogen-fixing bacteria** & decomposers. Makes nitrogen available to plants.
Step 2: Nitrification	$NH_4 \rightarrow NO_3$ (nitrate) by **nitrifying bacteria**. Plants absorb nitrate through roots.
Step 3: Denitrification	$NO_3 \rightarrow N_2$ (back to atmosphere) by **denitrifying bacteria**.



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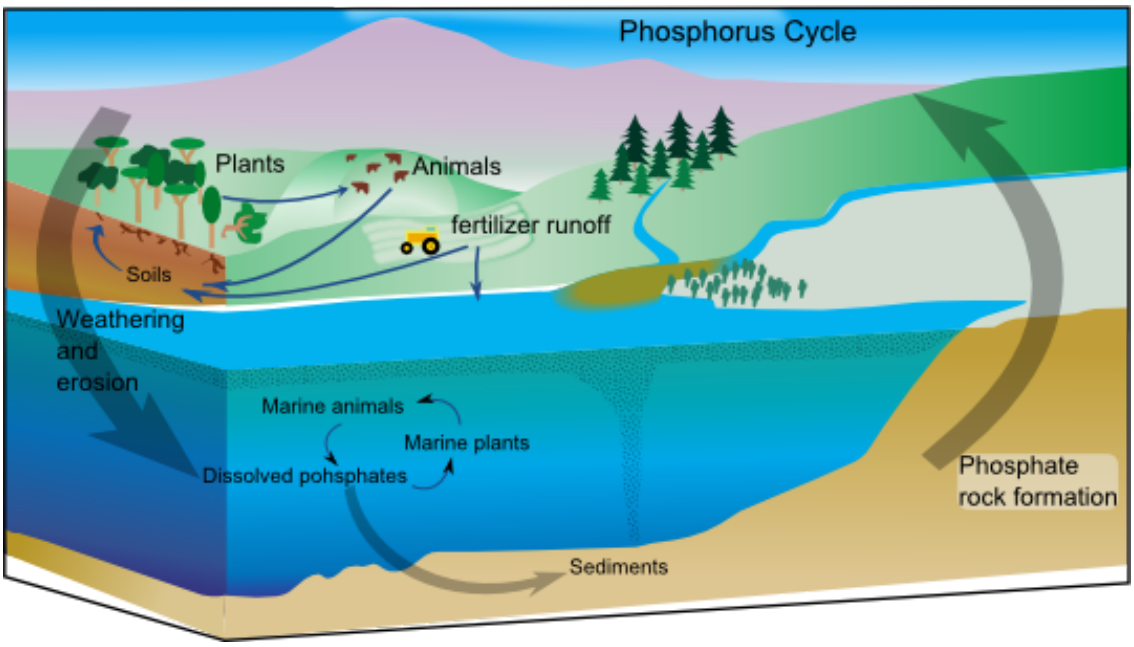
Natural Cycles — Biogeochemical Cycles

Phosphorus Cycle

Phosphorus is a component of nucleic acids (DNA, RNA) and cell membranes (phospholipids). Found as calcium phosphate in rocks and soils.

Exists only in solid form — no gas phase, unlike carbon or nitrogen.

1. Weathering	Rain and erosion break down phosphate-containing rocks → release phosphate ions into soil
2. Absorption by Plants	Plant roots absorb phosphate ions directly from soil
3. Absorption by Animals	Animals eat plants → phosphorus passes up the food chain
4. Return via Decomposition	Decomposers break down dead organisms → phosphorus returns to soil → cycle restarts



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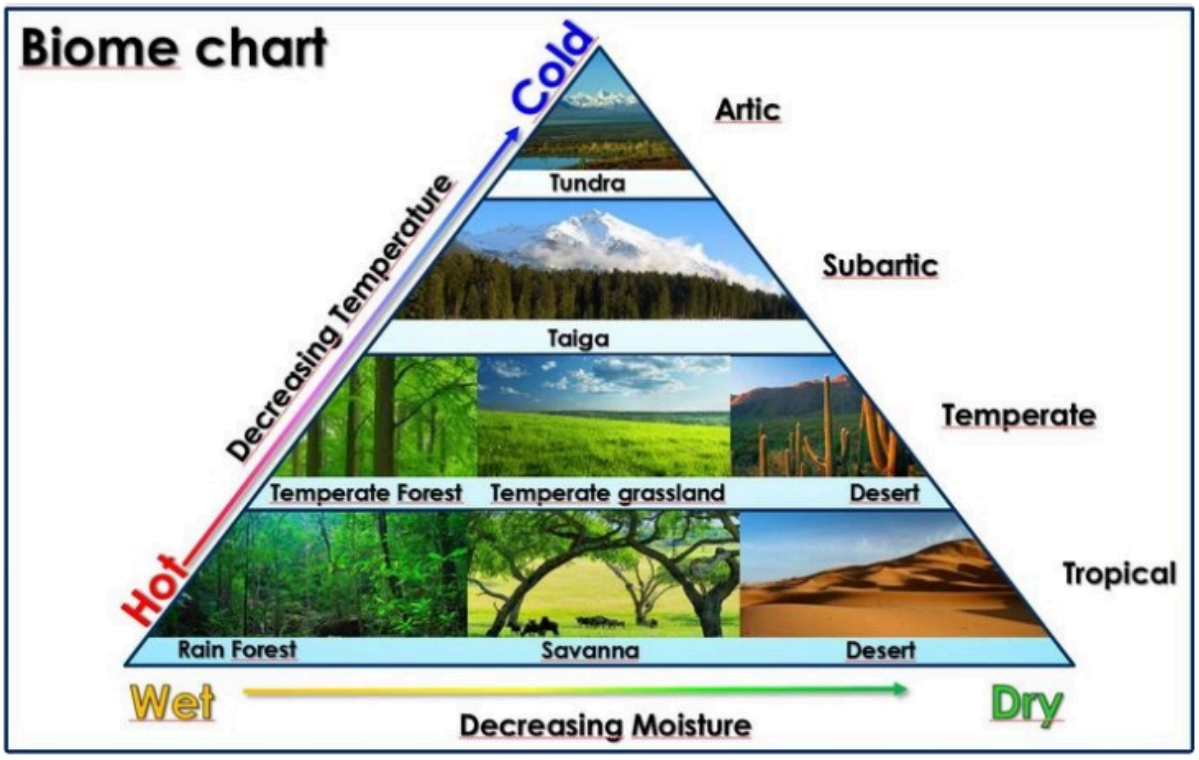
Biomes

Biomes are very large regions of Earth classified by climate (rainfall & temperature) and the organisms they contain.

• Each biome has characteristic flora (plants) and fauna (animals)
• Changes in altitude produce effects similar to changes in latitude — going up a mountain ≈ going toward the poles

→ **Order from equator to poles:** Tropical Rainforest → Desert → Grasslands → Shrubs → Temperate Deciduous Forest → Taiga → Tundra

■ Aquatic Biomes	■ Terrestrial Biomes
• Marine • Estuary • Fresh Water	• Tundra • Taiga • Temperate Deciduous Forest • Shrubland • Grassland • Desert • Tropical Rainforest



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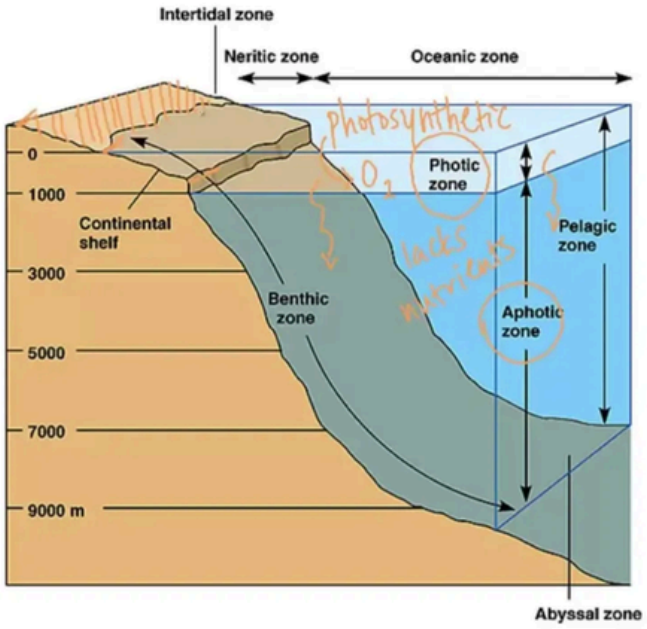


Biomes

Aquatic Biomes

1. Marine Biome

The largest biome — **covers 70% of Earth's surface.**
High salt concentration.
Most stable temperature (water **has high heat capacity**).
Provides most of Earth's food and oxygen thanks to algae and plankton.

Zone	
A) Intertidal	Where land and water meet. Alternates between dry (low tide) and submerged (high tide). Organisms must tolerate drying out.
B) Neritic	Shallow coastal waters. Coral reefs found here — supports enormous biodiversity.
C) Photic	Open ocean surface to depth of light penetration. Photosynthetic organisms (phytoplankton) live here.
D) Aphotic	Below the photic zone — no light. Producers are chemoautotrophs (Archaea, chemosynthetic bacteria using H_2S).
E) Abyssal	Deepest part of ocean. Extreme pressure, total darkness, very cold. No photosynthesis — dominated by decomposers.

Biomes

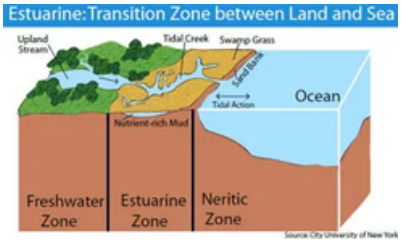
Aquatic Biomes

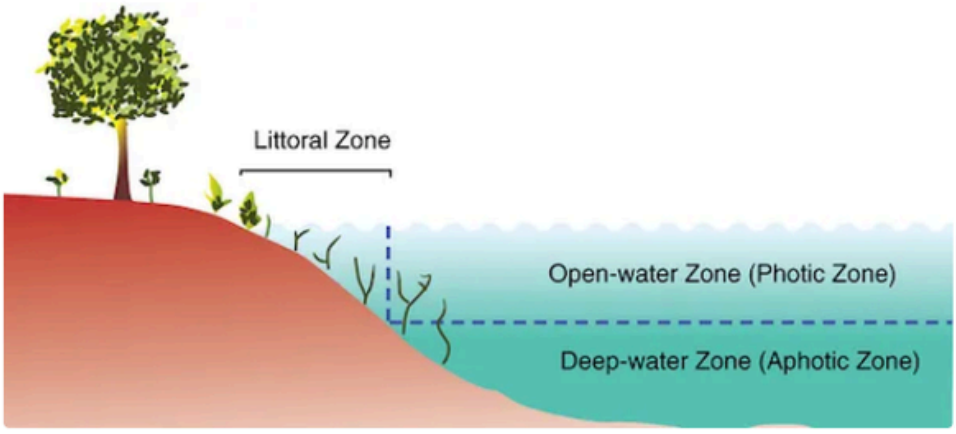
2. Fresh Water Biome

Includes: lakes, rivers, streams, ponds, wetlands.
Low salt concentration.

Zone	
Littoral Zone *(Photic)*	Near the shore of a lake. Many plants grow here supporting insects, snails, amphibians.
Limnetic Zone *(Photic)*	Open water as far as light penetrates. Many photosynthetic organisms (plankton) live here.
Profundal Zone *(Aphotic)*	Too deep — no light. Dominated by decomposers. No photosynthesis possible.

Estuary Zone: Zone where fresh water meets salt water. Characterized by high nutrients and high fish diversity. One of Earth's most productive ecosystems





Biomes

Terrestrial Biomes

Tundra [Permafrost]

Two types: Alpine tundra (mountain tops) & Arctic tundra (near poles).

- Characterized by very **low temperature.**
- Has **permafrost (permanently frozen topsoil).**
- Deep root growth is difficult because soil is frozen.
- Very few trees and animals → low species diversity.
- Very little rainfall (acts as a frozen desert).

Plants: grasses, mosses.
Animals: Arctic wolves, foxes, hares, reindeer, polar bears

Taiga (Boreal Forest):

largest terrestrial biome.

- It characterized by low temperature, and **snowy** rain.
- contains many **conifers** (evergreen trees) like
- cedar, pine, red wall.

Animals: moose, elk, porcupine, grizzly bear.

MODULE 3

ECOLOGY

Biomes

Terrestrial Biomes

Temperate Deciduous Forest

- Trees shed their leaves in winter and regrow in spring.
- Rich soil from leaf decomposition.

Animals: squirrels, raccoons, black bears.
Plants: birch, oak, maple.

Shrubland

- Dominated by shrubs (short, branched woody plants).
- Frequent fires are common — plants are adapted to fire.

Example: Mediterranean chaparral.

Courses

MODULE 3

ECOLOGY

Biomes

Terrestrial Biomes

Grasslands

- Low annual rainfall — inhospitable for forests.
- Supplies the largest amount of food for humans.

Two types

1. **Temperate Grasslands (Prairies):** fertile soil, converted to farmland — bison, wild horses
2. **Tropical Grasslands (Savanna):** support the largest herbivores — zebras, giraffes, elephants, rhinos

Desert

Extreme dryness and extreme temperature fluctuations (very high temp. at daytime, and heat lost rapidly at night). (very hot day, cold night).

Plants adapted to drought: store water, deep roots (e.g., cacti).

Animals: mostly nocturnal — active at night, hide or burrow during the day.

Biomes

Terrestrial Biomes

Tropical Rainforest

Only 4% of Earth but has the greatest species diversity.
Near equator.
Abundant rainfall, stable warm temperature, high humidity.
Tall canopy trees block sunlight — forest floor is dimly lit.
Poor soil (most nutrients stored in plants).
Rapidly decreasing due to deforestation.

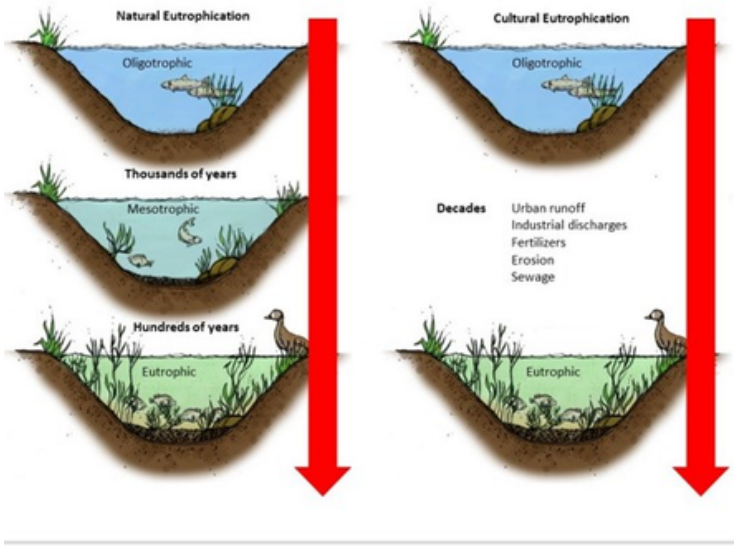
→ **Epiphytes:** plants growing on trees to access sunlight & nutrients high in the canopy.

Human Effects on the Biosphere

Eutrophication of Lakes

- **Runoff from sewage** and manure from pastures increases nutrient levels in lakes, especially nitrogen and phosphorus.
- These excess nutrients cause rapid growth **(blooms) of algae and aquatic** plants.
- Large populations of these photosynthetic organisms eventually die.
- Dead organic material accumulates on the lake bottom, gradually reducing the lake's depth.
- **Detritivores and decomposers** break down the dead organic matter and consume large amounts of oxygen.
- Oxygen levels in the lake decrease.
- **Low oxygen levels** make it difficult or impossible for some fish and aquatic organisms to survive.
- More fish die, which increases decomposition and further reduces oxygen levels.
- This cycle continues until the lake gradually fills with organic matter and sediment, eventually turning the aquatic ecosystem into a terrestrial ecosystem.

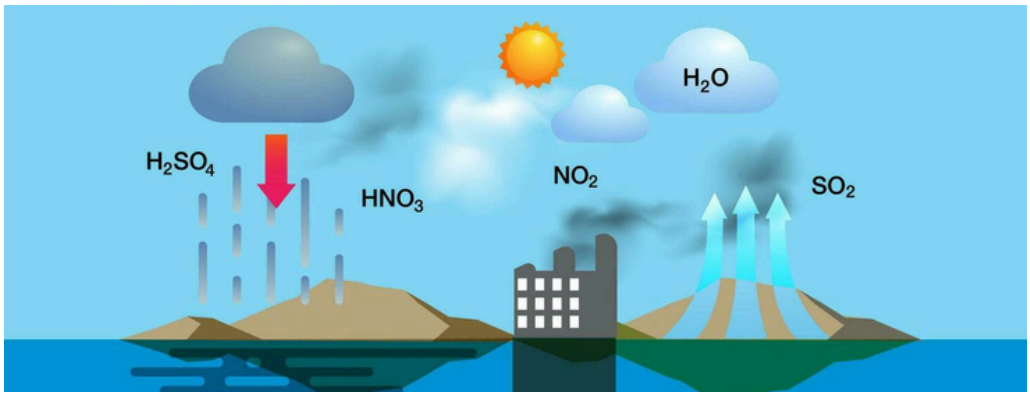
→ Leads to oxygen depletion, fish deaths, and eventually the lake disappears, turning into land



Human Effects on the Biosphere

Acid Rain

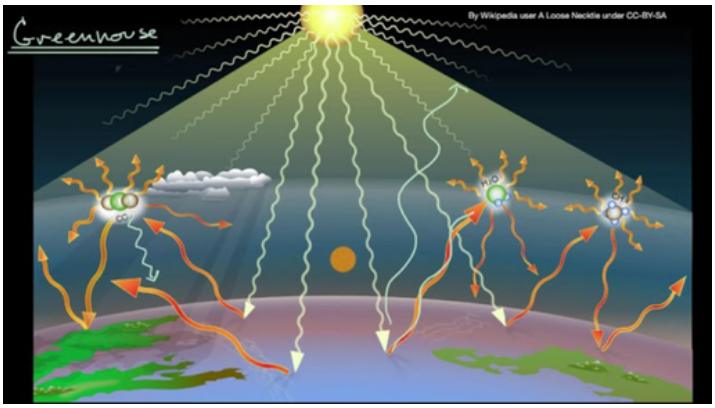
- Acid rain is caused by **air pollutants** released during the combustion of fossil fuels.
- **Nitrogen and sulfur** pollutants in the atmosphere react with water and oxygen to form nitric acid, nitrous acid, sulfurous acid, and sulfuric acid (from gases such as SO_2 and NO_2).
- As a result, the **pH of rainwater drops below 5.6.**
- Acid rain can cause death of organisms in lakes, with aquatic organisms being the most affected.
- It also damages ancient stone buildings and monuments by slowly dissolving the materials.



Human Effects on the Biosphere

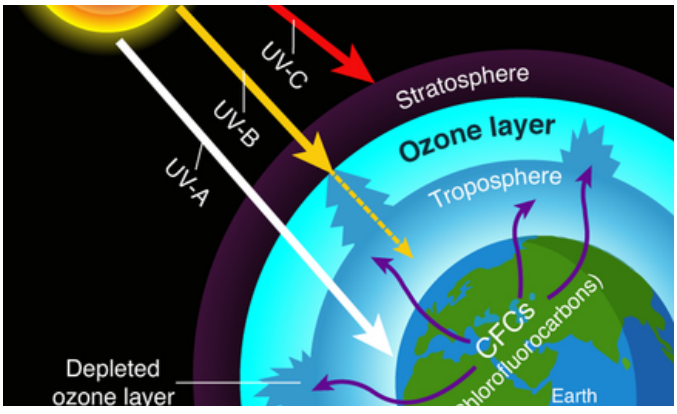
Global Warming

- **Burning fossil** fuels increases the concentration of carbon dioxide (CO_2), methane (CH_4), and water vapor in the atmosphere.
- These gases trap infrared radiation, preventing heat from escaping Earth.
- This process is known as the greenhouse effect.
- The increase in Earth's average temperature due to this effect is called global warming, which can have serious consequences for the planet.
- For example, polar ice caps may melt, causing sea levels to rise and potentially flooding major coastal cities.



Ozone Layer Depletion

- The accumulation of chlorofluorocarbons (CFCs) in the atmosphere, chemicals once widely used in refrigerants and aerosol sprays, damages the ozone layer (O_3).
- This damage creates holes in the ozone layer.
- As a result, more ultraviolet (UV) radiation reaches Earth's surface.
- Increased UV exposure is linked to a higher risk of skin cancer.



Human Effects on the Biosphere

Toxins

- Industrial toxins can enter the food chain and accumulate in organisms.
- Many cattle and poultry feeds contain antibiotics and hormones, which may negatively affect humans who consume these animals.

Some toxins act as:
Carcinogens – substances that cause cancer.
Teratogens – substances that cause birth defects.
→ These toxins often accumulate in fatty tissues of the body.

Biological Control and Pesticides

- Exposure to pesticides can increase the risk of cancer in humans.
- Pesticide use can also lead to the evolution of resistant pest strains through natural selection.
- Biological control is an alternative method used to manage pests.

Biological Control is an alternative method that manages pests without relying heavily on chemicals.

Examples of Biological Control

1. Crop rotation
- Farmers plant different crops each season.
- This breaks the life cycle of pests that depend on a specific crop.

2. Natural predators
- Introducing predators that eat pests (e.g., birds or beneficial insects).

→ Sometimes this can disturb the Ecological Balance.

3. Natural plant toxins
- Using chemicals naturally produced by plants instead of synthetic pesticides.

4. Insect birth control
- Male insects are exposed to Radiation.
- This makes them sterile, so they cannot reproduce, reducing pest populations.