

Species interaction (Biotic interaction)

Species interaction (in ecology) refers to the relationships between two or more different species living in the same ecosystem, where the presence or activities of one species affect the survival, growth, or reproduction of another.

These interactions can be **beneficial, harmful, or neutral**, and they play a crucial role in maintaining **ecosystem balance and biodiversity**. There are two types of interactions:

1. Interspecific Interactions

(Between different species)

A. Positive Interspecific Interactions

1. Mutualism (+ / +)

Definition: Both species benefit from the interaction.

Examples:

Bee ↔ flowering plant (pollination)

Lichen (algae + fungus)

Mycorrhiza (fungi ↔ plant roots)

Ants ↔ aphids

Gut bacteria ↔ huma

2. Protocooperation (+ / +)

Definition: Both species benefit, but the relationship is not obligatory.

Examples:

Crab ↔ sea anemone

Cattle egret ↔ grazing cattle

Hermit crab ↔ sea anemone

Crocodile ↔ plover bird

3. Commensalism (+ / 0)

Definition: One species benefits, the other is unaffected.

Examples:

Orchid on mango tree

Remora fish $\leftrightarrow$ shark

Barnacles on whale

Cattle egret feeding on insects flushed by cattle

Epiphytes on forest tree

4. Mimicry (+ / 0)

Definition: One species mimics another for protection or survival advantage.

Examples:

Viceroy butterfly mimicking monarch

Hoverfly mimicking wasp

Non-poisonous king snake mimicking coral snake

Stick insect resembling twigs

Leaf butterfly resembling dry leaves

5. Scavenging (+ / 0)

Definition: One species feeds on dead organisms without harming the original species.

Examples:

Vulture feeding on carcasses

Hyena feeding on dead animals

Jackal eating remains of prey

Crab feeding on dead fish

Ants feeding on dead insects

B. Negative Interspecific Interactions

6. Predation (+ / -)

Definition: One species kills and eats another.

Examples:

Lion $\rightarrow$ deer

Snake → frog

Hawk → mouse

Frog → insect

Spider → fly

7. Parasitism (+ / -)

Definition: Parasite benefits while host is harmed.

Examples:

Tapeworm in humans

Tick on dog

Leech on cattle

Lice on humans

Cuscuta (dodder) on host plant

8. Competition (- / -)

Definition: Both species suffer due to competition for limited resources.

Examples:

Weeds ↔ crop plants

Lion ↔ hyena for prey

Birds competing for nesting sites

Plants competing for sunlight

Fish species competing for food

9. Amensalism (- / 0)

Definition: One species is harmed, the other is unaffected.

Examples:

Penicillium fungus killing bacteria

Walnut tree releasing juglone inhibiting nearby plants

Tall trees shading small plants

Algae inhibiting other microorganisms

Antibiotic-producing microbes suppressing others

C. Neutral Interspecific Interaction

10. Neutralism (0 / 0)

Definition: Two species coexist without affecting each other.

Examples:

Frog and butterfly in a pond

Deer and owl in a forest

Earthworm and bird in soil ecosystem

Fish and tree near a river

Lizard and grasshopper in a field

2. Intraspecific Interactions

(Within the same species)

A. Positive Intraspecific Interactions

11. Cooperation (+ / +)

Definition: Individuals work together for mutual benefit.

Examples:

Ants building anthills

Wolves hunting in packs

Bees collecting nectar

Dolphins hunting fish in groups

Humans working in communities

12. Social Organization (+ / +)

Definition: Group living increases survival and efficiency.

Examples:

Herd of elephants

School of fish

Flock of birds

Colony of bats

Pride of lions

13. Parental Care (+ / +)

Definition: Parents protect and nourish their offspring.

Examples:

Birds feeding chicks

Kangaroo carrying joey

Humans caring for children

Crocodile guarding eggs

Fish guarding fry

B. Negative Intraspecific Interactions

14. Competition (– / –)

Definition: Individuals compete for food, space, or mates.

Examples:

Male deer fighting for females

Plants of same species competing for nutrients

Birds competing for nesting sites

Tigers competing for territory

Fish competing for food

15. Cannibalism (+ / –)

Definition: One individual eats another of the same species.

Examples:

Female praying mantis eating male

Spider cannibalism

Tadpoles eating smaller tadpoles

Fish eating their own young

Insects eating larvae of same species

16. Territoriality (– / –)

Definition: Individuals defend territory, harming rivals.

Examples:

Tigers marking territory

Birds defending nesting areas

Dogs fighting over space

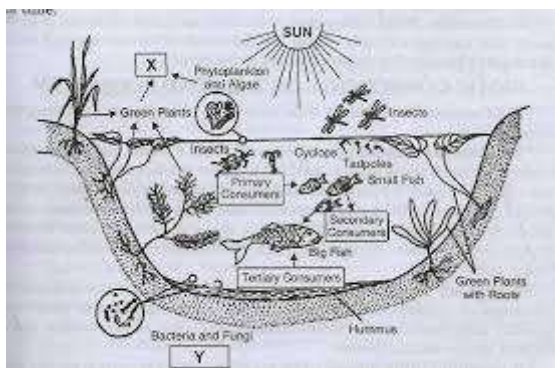
Structural and Functional Aspects of an Ecosystem with special reference to a Pond Ecosystem

Structural and Functional Aspects of Ecosystem

Pond Ecosystem

Introduction

An **ecosystem** is a functional unit of nature where **living organisms (biotic components)** interact with the **non-living environment (abiotic components)** through energy flow and nutrient cycling. A **pond ecosystem** is a small, self-sustaining **freshwater ecosystem**, making it an ideal model to study ecosystem structure and function.



I. Structural Aspects of Pond Ecosystem

The **structure** of an ecosystem refers to the **organization of its components**.

1. Abiotic Components

These are non-living physical and chemical factors:

Water

Sunlight

Temperature

Dissolved oxygen

Nutrients (nitrates, phosphates)

pH

Organic and inorganic matter

2. Biotic Components

Living organisms are grouped into:

(a) Producers (Autotrophs)

Green plants and algae

Examples: **Phytoplankton, Hydrilla, Vallisneria**

Function: Convert solar energy into chemical energy via photosynthesis

(b) Consumers (Heterotrophs)

Primary consumers: Zooplankton, insects, snails

Secondary consumers: Small fish, frogs

Tertiary consumers: Large fish, birds

(c) Decomposers

Bacteria and fungi

Break down dead organic matter and recycle nutrients

II. Zonation in Pond Ecosystem

Ponds show **distinct zones** based on depth and light availability.

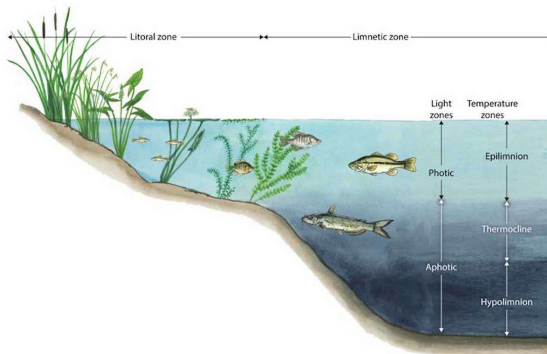
Zonation of Pond Ecosystem

1.Littoral zone: Near shore; rooted plants and insects

2.Limnetic zone: Open water; phytoplankton and fish

3.Profundal zone: Deep water; fewer organisms

4.Benthic zone: Bottom; decomposers and benthic fauna



III. Functional Aspects of Pond Ecosystem

Functional aspects include **energy flow, food chain, food web, ecological pyramids, and productivity.**

1. Food Chain in Pond Ecosystem

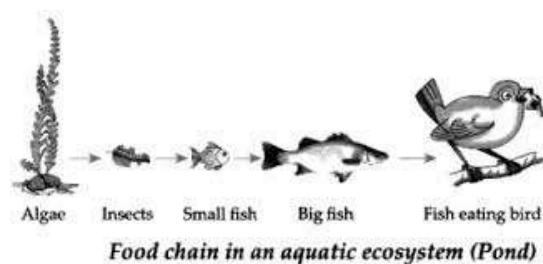
A **food chain** shows a **linear transfer of energy.**

Example:

Phytoplankton → Zooplankton → Small fish → Large fish → Bird

Energy flows **unidirectionally**

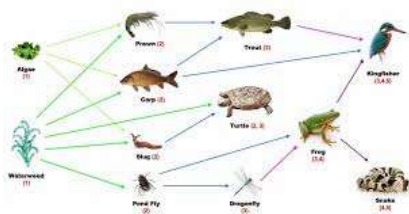
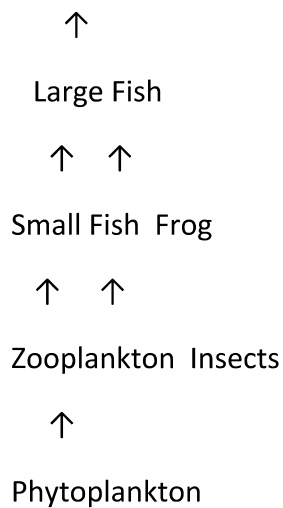
Only ~10% energy is transferred to the next trophic level (10% law)



2. Food Web

A **food web** is a network of interconnected food chains, providing ecosystem stability.

Bird



Importance of food web:

Alternative food sources

Maintains balance

Increases ecosystem stability

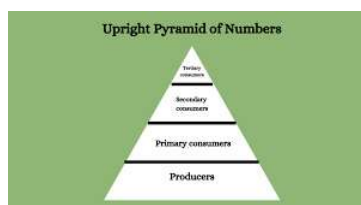
3. Ecological Pyramids

Ecological pyramids represent **trophic structure**.

(a) Pyramid of Numbers

Shows number of organisms

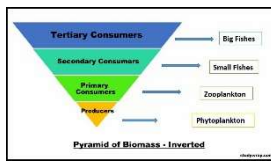
Upright in pond ecosystem



(b) Pyramid of Biomass

Shows total dry weight

Inverted in aquatic ecosystems (phytoplankton biomass < consumers)



Fish

Zooplankton

Phytoplankton

(c) Pyramid of Energy

Shows energy flow

Always upright

Tertiary Consumers

Secondary Consumers

Primary Consumers

Producers



4. Productivity in Pond Ecosystem

Productivity is the rate of biomass production.

Types:

(a) Primary Productivity

Produced by autotrophs

Gross Primary Productivity (GPP): Total photosynthesis

Net Primary Productivity (NPP):

$NPP = GPP - \text{Respiration}$

(b) Secondary Productivity

Biomass produced by consumers

Factors affecting productivity:

Light

Nutrient availability

Temperature

Water quality

IV. Role of Decomposers and Nutrient Cycling

Decomposers break down dead organisms

Release nutrients back into water

Maintain **biogeochemical cycles**

Conclusion

A pond ecosystem is a **complete, balanced, and self-regulated ecosystem**. Its **structural components** (biotic and abiotic) and **functional processes** (energy flow, food chains, food webs, pyramids, and productivity) together maintain ecological stability. Studying pond ecosystems helps understand larger ecosystems and environmental conservation.

Structural and Functional Aspects of a Forest Ecosystem

Introduction

A **forest ecosystem** is a large, complex **terrestrial ecosystem** dominated by trees and woody vegetation. It consists of **biotic (living)** and **abiotic (non-living)** components interacting through **energy flow, nutrient cycling, and ecological relationships**. Forest ecosystems play a vital role in **climate regulation, biodiversity conservation, carbon sequestration, and soil protection**.

I. Structural Aspects of Forest Ecosystem

The **structure** of a forest ecosystem refers to the **organization, composition, and spatial arrangement** of its components.

1. Abiotic Components

Abiotic components form the **physical and chemical environment** of the forest.

(a) Light

Primary source of energy

Intensity decreases from canopy to forest floor

Controls plant stratification and productivity

(b) Temperature

Moderated by tree cover

Influences metabolic activity of organisms

Forests have less temperature fluctuation

(c) Rainfall and Humidity

Forests receive moderate to high rainfall

High humidity supports diverse life forms

(d) Soil

Rich in organic matter (humus)

Supports root systems and microbial activity

Plays a key role in nutrient cycling

(e) Air and Wind

Influences transpiration and pollination

Disperses seeds and spores

2. Biotic Components

Biotic components are classified based on **mode of nutrition**.

(a) Producers (Autotrophs)

Definition: Green plants that prepare their own food through photosynthesis.

Examples:

Trees: Teak, Sal, Pine, Oak

Shrubs and grasses

Mosses and climbers

Role:

Form the base of the ecosystem

Convert solar energy into chemical energy

Provide food and shelter

(b) Consumers (Heterotrophs)**Primary Consumers (Herbivores)**

Feed directly on plants

Examples: Deer, elephant, rabbit, insects

Secondary Consumers

Feed on herbivores

Examples: Fox, snake, frog, birds

Tertiary Consumers (Top Carnivores)

Feed on secondary consumers

Examples: Tiger, lion, eagle, leopard

Role:

Maintain population balance

Transfer energy between trophic levels

(c) Decomposers

Examples: Bacteria, fungi, earthworms

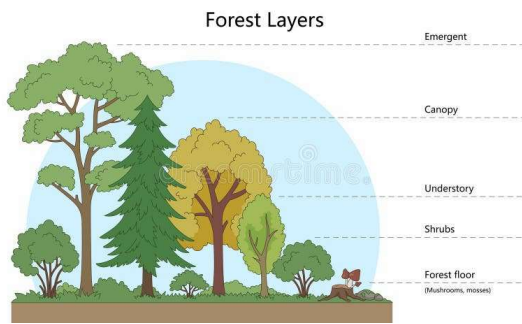
Role:

Decompose dead plants and animals

Convert organic matter into inorganic nutrients

Maintain soil fertility and nutrient cycling

II. Stratification in Forest Ecosystem



Forests show **vertical stratification** due to variation in light availability.

Emergent Layer

(Tallest trees)

Canopy Layer

(Dense tree crowns)

Understory

(Shrubs, young trees)

Forest Floor

(Herbs, litter, fungi)

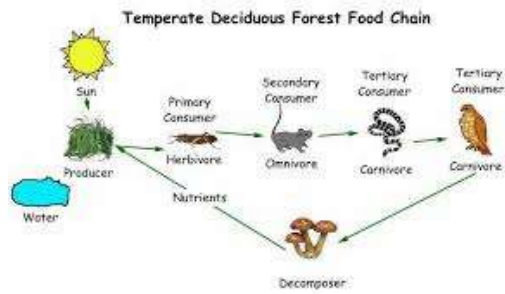
Layers Explained:

1. **Emergent Layer** – Tallest trees exposed to sunlight
2. **Canopy Layer** – Forms roof of forest, maximum photosynthesis
3. **Understory Layer** – Shrubs and young trees
4. **Forest Floor** – Leaf litter, decomposers, insects

III. Functional Aspects of Forest Ecosystem

Functional aspects include **energy flow, food chain, food web, ecological pyramids, and productivity.**

1. Food Chain in Forest Ecosystem



2.

A **food chain** represents a **linear pathway of energy transfer**.

Types of Food Chain

(a) Grazing Food Chain

Starts from producers and moves upward.

Example:

Green plants → Deer → Tiger

(b) Detritus Food Chain

Starts from dead organic matter.

Example:

Leaf litter → Fungi/Bacteria → Earthworm → Bird

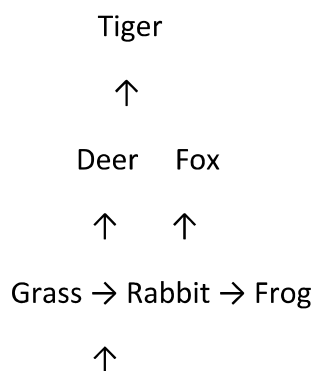
Importance:

Major pathway in forests

Helps recycle nutrient

2. Food Web in Forest Ecosystem

A **food web** is a network of interconnected food chains.



Insects



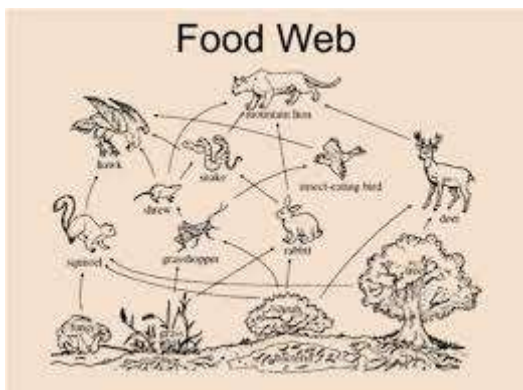
Plants



Dead organic matter



Bacteria and Fungi



Importance:

Provides alternate food pathways

Enhances ecosystem stability

Prevents collapse of ecosystem

3. Ecological Pyramids

(a) Pyramid of Numbers

Upright in forests

- Many producers, fewer top carnivores

(b) Pyramid of Biomass

- **Upright** in forest ecosystem
- Trees have maximum biomass

(c) Pyramid of Energy

- Always upright

- Shows gradual loss of energy

Tertiary Consumers

Secondary Consumers

Primary Consumers

Producers



4. Productivity in Forest Ecosystem

Productivity refers to the rate of biomass production.

(a) Primary Productivity

Produced by green plants.

- **Gross Primary Productivity (GPP):** Total photosynthesis
- **Net Primary Productivity (NPP):**

$$NPP = GPP - \text{Respiration}$$

NPP represents energy available to consumers.

(b) Secondary Productivity

- Biomass produced by consumers
- Depends on availability of NPP

Factors Affecting Forest Productivity

- Light availability
- Rainfall
- Soil nutrients
- Temperature

- Human activities (deforestation)

IV. Role of Decomposers and Nutrient Cycling

- Break down leaf litter and dead organisms
- Release nutrients like nitrogen and phosphorus
- Maintain **biogeochemical cycles**
- Prevent nutrient loss from ecosystem

Conclusion

The forest ecosystem is a **highly organized and self-sustaining ecosystem** with complex **structural components** and efficient **functional processes**. The interaction of producers, consumers, and decomposers through **food chains, food webs, ecological pyramids, and productivity** ensures ecological balance. Forest ecosystems are essential for maintaining biodiversity, climate stability, and environmental health.

Trophic level

A trophic level is the position or level an organism occupies in a food chain or food web, based on how it obtains its food and energy.

In simple terms, it shows who eats whom in an ecosystem and how energy flows from one organism to another.

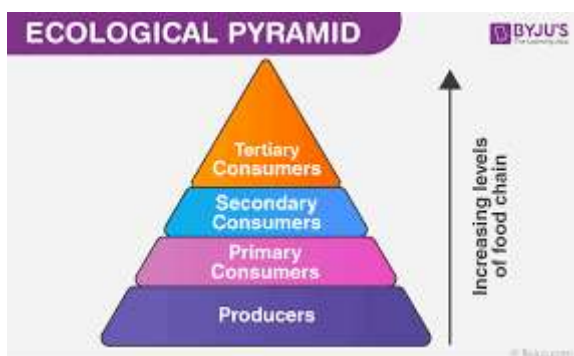
Examples of trophic levels:

Producers (plants) – first trophic level

Primary consumers (herbivores) – second trophic level

Secondary consumers (carnivores) – third trophic level

Tertiary consumers (top carnivores) – fourth trophic level



Trophic levels help explain energy transfer, food chains, food webs, and ecological balance.

Food Chain in Ecosystem

A **food chain** is a **linear sequence of organisms** in which each organism **feeds on the one below it** and is **eaten by the one above it**, representing the **flow of energy and nutrients** in an ecosystem. It starts with **producers** (autotrophs) and ends with **top carnivores**.

Types of Food Chain:

1. Grazing Food Chain (GFC):

- Starts from **living green plants** (producers)
- Energy is passed to **herbivores** (primary consumers) and then to **carnivores** (secondary and tertiary consumers)
- *Example:* Grass → Grasshopper → Frog → Snake → Eagle



2. Detritus Food Chain (DFC):

- Starts from **dead organic matter** such as leaves, dead plants, and animals
- Energy flows to **decomposers** (bacteria, fungi) and then to detritivores and consumers
- *Example:* Dead leaves → Earthworm → Frog → Snake

Importance of Food Chain:

- Shows how **energy flows** through an ecosystem
- Helps in understanding **feeding relationships**
- Forms the **basis of food webs**
- Maintains **ecological balance** by regulating populations

Simple Diagram:

Grass → Grasshopper → Frog → Snake → Eagle



Food Web

Definition

A **food web** is a **network of interconnected food chains** in an ecosystem. It shows **how energy and nutrients flow through different organisms**, and how multiple food chains are linked together. Unlike a food chain, a food web **demonstrates all possible feeding relationships** in an ecosystem, providing **stability and balance**.

Types of Food Web

1. Grazing Food Web

- Based on the **grazing food chain (living plants → herbivores → carnivores)**.
- Energy flows from **producers to primary consumers to secondary and tertiary consumers**.
- Example (Pond Ecosystem):**
Phytoplankton → Zooplankton → Small Fish → Large Fish → Bird

2. Detritus Food Web

- Based on the **detritus food chain (dead organic matter → decomposers → consumers)**.
- Energy flows through **dead organic material**, decomposers, and then detritivores.
- Example (Forest Ecosystem):**
Leaf litter → Fungi/Bacteria → Earthworm → Frog → Snake

3. Mixed Food Web

- Combines both **grazing and detritus food chains**.

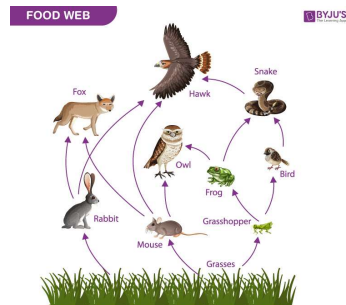
- Most natural ecosystems have **mixed food webs**, as energy comes from both **live plants and dead organic matter**.

- **Example:**

Grass → Rabbit → Fox → Eagle

+

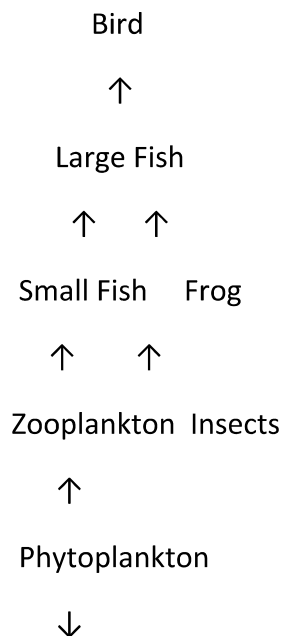
Dead Grass → Fungi → Earthworm → Frog → Snake



- **Importance of Food Web**

1. Shows all **feeding relationships** in an ecosystem.
2. Provides **alternate pathways for energy flow**, making ecosystems stable.
3. Explains **ecological balance** and predator-prey interactions.
4. Helps understand **effects of removal or addition of species** in an ecosystem.

Simple Pond Food Web Diagram



Dead organic matter



Bacteria and Fungi

Ecological Pyramid

Definition

An **ecological pyramid** is a **graphical representation of the trophic structure and function of an ecosystem**. It shows the **number, biomass, or energy content** of organisms at each trophic level. Ecological pyramids help to **understand energy flow, feeding relationships, and ecosystem productivity**.

Types of Ecological Pyramids

There are **three main types** of ecological pyramids:

1. Pyramid of Numbers

Definition:

Shows the **number of individual organisms at each trophic level**.

Features:

- Usually **upright**, as producers are most numerous.
- Sometimes **inverted**, especially in ecosystems like **trees supporting many herbivores**.

Example:

- Pond ecosystem:
Phytoplankton → Zooplankton → Small Fish → Large Fish

Diagram (upright example):

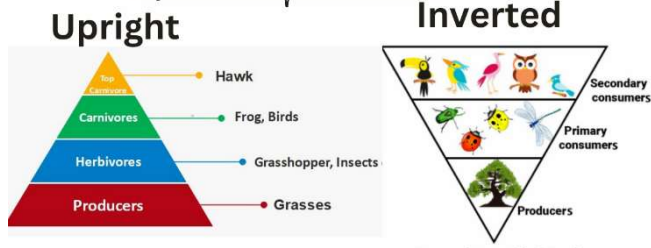
Large Fish

Small Fish

Zooplankton

Phytoplankton

Pyramid of numbers



2. Pyramid of Biomass

Definition:

Represents the **total biomass (dry weight)** of organisms at each trophic level.

Features:

- Usually **upright in terrestrial ecosystems** (trees have more biomass than herbivores).
- Often **inverted in aquatic ecosystems**, because phytoplankton have low biomass but high productivity.

Example (aquatic pond):

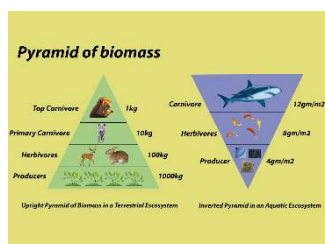
Fish

Zooplankton

Phytoplankton

Importance:

- Helps in understanding **energy stored as biomass**.
- Explains why **higher trophic levels are fewer in number**.



3. Pyramid of Energy

Definition:

Shows the **amount of energy stored or transferred** at each trophic level per unit area per unit time.

Features:

- **Always upright**, as energy decreases from one trophic level to the next.
- Represents **energy flow**, not the number or biomass of organisms.

Example:

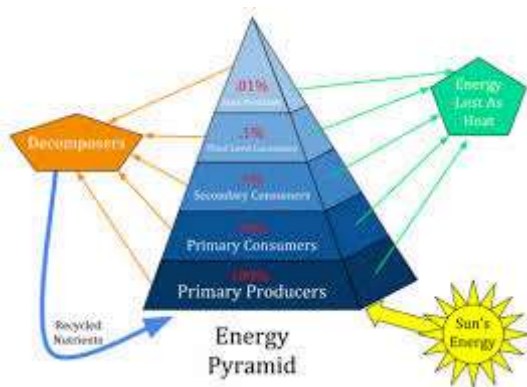
- Forest ecosystem:

Tertiary Consumers

Secondary Consumers

Primary Consumers

Producers



Importance:

- Shows **energy loss at each level** ($\approx 90\%$ lost as heat, only 10% transferred).
- Helps in understanding **ecosystem efficiency and productivity**.

Comparison of Three Ecological Pyramids

Feature	Pyramid of Numbers	Pyramid of Biomass	Pyramid of Energy
Represent s	Number of organisms	Total biomass	Energy content per unit area per time
Shape	Usually upright	Upright or inverted	Always upright
Example	Pond: phytoplankton → fish	Pond: phytoplankton < fish	Forest: trees → herbivores → carnivores

Shows Population distribution Standing crop Energy flow and efficiency

Importance of Ecological Pyramids

1. Visualizes **trophic structure of ecosystems**.
2. Helps in **studying energy flow** in ecosystems.
3. Explains **ecological efficiency and productivity**.
4. Useful in **comparing ecosystems**.
5. Helps in **conservation planning and management**.

Conclusion

Ecological pyramids are **fundamental tools in ecology**. They illustrate **trophic levels, energy flow, and biomass distribution**, helping scientists understand **ecosystem structure, stability, and productivity**. Among the three types, **pyramid of energy is the most reliable** because it never gets inverted and accurately shows energy transfer.

Productivity in Ecosystem

Definition

Productivity in an ecosystem is the **rate at which energy is captured by producers and converted into organic matter (biomass)** over a period of time. It indicates the **ability of an ecosystem to produce food and support life**.

Unit of Productivity:

- Energy per unit area per unit time (e.g., kcal/m²/year)
- Biomass per unit area per unit time (e.g., g/m²/year)

Types of Productivity

Ecosystem productivity is of **two main types**:

1. Primary Productivity

Definition:

Rate of production of **organic matter by autotrophs (producers)** through **photosynthesis**.

Subtypes:**(a) Gross Primary Productivity (GPP)**

- Total energy captured by producers
- Includes energy used for their own respiration

(b) Net Primary Productivity (NPP)

- Energy **available to consumers** after plant respiration is deducted

$$\begin{aligned} &[\\ &\text{NPP} = \text{GPP} - \text{Respiration (R)} \\ &] \end{aligned}$$

Examples:

- Pond ecosystem: Phytoplankton produce energy via photosynthesis
- Forest ecosystem: Trees and shrubs produce large biomass annually

Importance of NPP:

- Determines the **energy available for herbivores and higher trophic levels**
- Indicates **ecosystem health and fertility**

2. Secondary Productivity**Definition:**

Rate at which **consumers (herbivores and carnivores)** produce biomass by consuming primary producers or other consumers.

Examples:

- Insects feeding on plants produce secondary biomass
- Fish consuming zooplankton in a pond
- Deer feeding on grass in forests

Importance:

- Shows **energy transfer efficiency** between trophic levels
- Indicates **consumer growth and ecosystem productivity**

Factors Affecting Productivity

1. **Light intensity:** More sunlight → higher photosynthesis
2. **Temperature:** Influences metabolic rates
3. **Water availability:** Essential for photosynthesis
4. **Nutrient availability:** Nitrogen, phosphorus, and other minerals
5. **CO₂ concentration:** Required for photosynthesis
6. **Human activities:** Deforestation, pollution can reduce productivity

Examples of Ecosystem Productivity

Ecosystem	Primary Productivity	Secondary Productivity
Pond	Phytoplankton, aquatic plants	Fish, amphibians, insects
Forest	Trees, shrubs	Herbivores (deer), carnivores (tiger)
Grassland	Grasses	Rabbits, insects, foxes

Importance of Productivity in Ecosystem

1. Determines **energy flow through food chains and food webs**
2. Supports **biomass of consumers at higher trophic levels**
3. Indicates **ecosystem fertility and health**
4. Helps in **resource management and conservation**

Conclusion

Productivity is a **key functional aspect of ecosystems**, reflecting the **rate of energy capture and transfer**. **Primary productivity** sets the foundation for all higher trophic levels, while **secondary productivity** shows how efficiently energy moves through consumers. Healthy ecosystems have **high productivity**, ensuring biodiversity and ecological stability.

Biogeochemical Cycles

Introduction

The term **biogeochemical cycle** refers to the **cyclical movement of chemical elements and compounds between living (biotic) and non-living (abiotic) components of the ecosystem**.

These cycles ensure the **recycling of essential nutrients** such as carbon, nitrogen, phosphorus, oxygen, and water, which are vital for the survival of organisms.

Without these cycles, nutrients would be depleted, and ecosystems could not sustain life.

Key Points:

- Connects **atmosphere, hydrosphere, lithosphere, and biosphere**.
- Maintains **ecosystem stability and productivity**.
- Operates at **local, regional, and global scales**

Concept of Biogeochemical Cycle

- All elements required by organisms **continuously circulate through biotic and abiotic components**.
- They involve processes like:
 - **Assimilation:** Absorption of nutrients by organisms
 - **Decomposition:** Breakdown of organic matter to release nutrients
 - **Respiration and Combustion:** Release of carbon and energy
 - **Leaching and Sedimentation:** Movement and storage in soil and water

Significance:

1. Maintains **nutrient balance in ecosystems**
2. Prevents **nutrient depletion**
3. Supports **sustainable productivity of ecosystems**

Types of Biogeochemical Cycles

Biogeochemical cycles are classified into **two main types based on the reservoir of the element**:

1. Gaseous Cycles

- The **main reservoir of the element is in the atmosphere or hydrosphere**.
- Elements are **readily available** and circulate globally.
- **Examples:**
 - **Carbon Cycle:** Carbon moves between atmosphere, plants, animals, soil, and oceans.
 - **Nitrogen Cycle:** Nitrogen moves through atmosphere, soil, plants, and microbes.
 - **Oxygen Cycle:** Oxygen circulates between atmosphere, plants, and animals.
- **Importance:** Essential for **respiration, photosynthesis, and protein synthesis**.

2. Sedimentary Cycles

- The **main reservoir is in the soil or earth's crust**.
- Movement of elements is **slow and mostly local**.
- **Examples:**
 - **Phosphorus Cycle:** Phosphorus moves from rocks → soil → plants → animals → soil.
 - **Sulfur Cycle:** Sulfur moves from rocks and minerals → soil → plants → animals → atmosphere.
- **Importance:** Essential for **bone formation, nucleic acids, and enzymes**.

Key Features of Biogeochemical Cycles

1. Continuous and **self-regulating**
2. Connects **living organisms with environment**
3. Essential for **sustaining life on Earth**
4. Helps in **energy flow and nutrient recycle**

Carbon Cycle

Definition

The **carbon cycle** is the **biogeochemical cycle in which carbon continuously moves between the atmosphere, hydrosphere, lithosphere, and biosphere**. Carbon is a major element of **organic compounds**, essential for life, including **proteins, carbohydrates, and fats**.

Importance of Carbon Cycle

1. Maintains **carbon balance in nature**.
2. Provides **raw material for photosynthesis and organic molecules**.
3. Supports **energy flow in ecosystems**.
4. Regulates **global climate** via carbon dioxide levels.

Steps in the Carbon Cycle

1. Carbon Fixation

- **Definition:** Conversion of **inorganic carbon (CO₂)** into **organic compounds** by autotrophs.
- **Process:**
 - Performed mainly by **plants and phytoplankton** through **photosynthesis**.
 - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{Glucose} + \text{O}_2$
- **Example:**
 - Carbon dioxide from the atmosphere is fixed into glucose in leaves.

2. Carbon Assimilation

- **Definition:** Incorporation of carbon from **organic compounds into the bodies of consumers**.
- **Process:**
 - Herbivores eat plants → carbon is incorporated into their tissues.
 - Carnivores eat herbivores → carbon moves up the trophic levels.
- **Example:**
 - Rabbit eats grass → carbon from glucose becomes part of rabbit's body.

3. Sedimentation

- **Definition:** Deposition of **organic carbon in soil, water bodies, and rocks.**
- **Process:**
 - Dead plants, animals, and microorganisms settle in soil or water.
 - Over long periods, some carbon becomes **fossil fuels (coal, oil, natural gas).**
- **Example:**
 - Fallen leaves in forest floor → soil carbon
 - Dead marine organisms → limestone or fossil fuel

4. Release of Carbon Back to the Environment

- **Definition:** Carbon is **returned to the atmosphere** as **CO₂**.
- **Processes Involved:**
 1. **Respiration:** All organisms release CO₂ during energy production.
 - $\text{Glucose} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Energy}$
 2. **Decomposition:** Decomposers break down dead organisms → release CO₂
 3. **Combustion:** Burning of fossil fuels and biomass releases CO₂
 4. **Volcanic activity:** Carbon from rocks released as

Simplified Carbon Cycle Diagram

Atmosphere (CO₂)



Photosynthesis



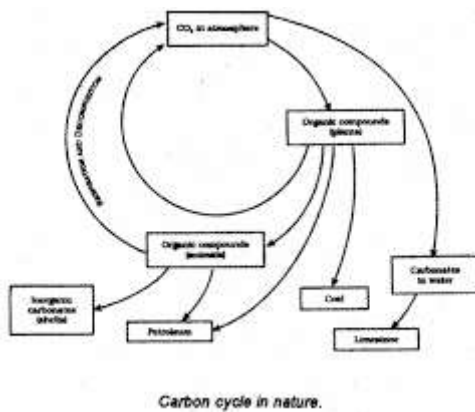
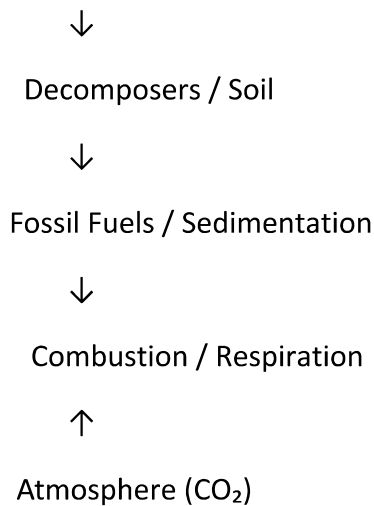
Plants (Glucose)



Herbivores / Carnivores



Dead Organisms / Litter



Key Points

- Carbon **cycles through living and non-living components**.
- Energy flow occurs through **trophic levels**, while carbon is **recycled**.
- Human activities like **deforestation and fossil fuel burning** increase atmospheric CO₂, affecting climate.

Conclusion

The **carbon cycle** is essential for **ecosystem stability, energy flow, and climate regulation**. Carbon moves through **fixation, assimilation, sedimentation, and release**, ensuring **continuous availability of this key element for life**.

Nitrogen Cycle

Definition

The nitrogen cycle is a biogeochemical cycle in which nitrogen moves between the atmosphere, soil, and living organisms. Nitrogen is an essential element for proteins, nucleic acids, and other biomolecules, but most organisms cannot use atmospheric nitrogen (N₂) directly.

Importance of Nitrogen Cycle

1. Supplies nitrogen for amino acids, proteins, and DNA.
 2. Maintains soil fertility and ecosystem productivity.
 3. Ensures balance between atmospheric and biologically available nitrogen.
- ### Steps in the Nitrogen Cycle

1. Nitrogen Fixation

Definition: Conversion of atmospheric nitrogen (N₂) into ammonia (NH₃) or related compounds usable by plants.

Types:

1. Biological Nitrogen Fixation:

Carried out by nitrogen-fixing bacteria (Rhizobium in legumes, Azotobacter in soil).

Reaction: $\text{N}_2 \rightarrow \text{NH}_3$

2. Industrial Nitrogen Fixation (Haber-Bosch process):

$\text{N}_2 + \text{H}_2 \rightarrow \text{NH}_3$ (using high temperature and pressure)

Produces fertilizers like ammonium nitrate.

2. Nitrogen Assimilation

Definition: Incorporation of fixed nitrogen into plant and animal tissues.

Process:

Plants absorb ammonium (NH₄⁺) or nitrate (NO₃⁻) from soil and synthesize amino acids, proteins, and nucleic acids.

Animals get nitrogen by eating plants or other animals. Example: Grass absorbs nitrates → rabbit eats grass → nitrogen incorporated into rabbit's body

3. Ammonification

Definition: Conversion of organic nitrogen from dead organisms and waste into ammonia (NH_3) by decomposers.

Process:

Proteins and nucleic acids $\rightarrow \text{NH}_3 \rightarrow \text{NH}_4^+$

Importance: Returns nitrogen to the soil for plant use.

4. Nitrification

Definition: Conversion of ammonium (NH_4^+) into nitrites (NO_2^-) and then nitrates (NO_3^-) by nitrifying bacteria.

Process:

1. $\text{NH}_4^+ \rightarrow \text{NO}_2^-$ (Nitrosomonas bacteria)

2. $\text{NO}_2^- \rightarrow \text{NO}_3^-$ (Nitrobacter bacteria)

Importance: Nitrates are readily absorbed by plants for growth.

5. Denitrification

Definition: Conversion of nitrates (NO_3^-) back into atmospheric nitrogen (N_2 or N_2O) by denitrifying bacteria in anaerobic conditions.

Process: $\text{NO}_3^- \rightarrow \text{N}_2$ or N_2O

Importance: Returns nitrogen to the atmosphere, completing the cycle.

6. Sedimentation (Storage)

Definition: Long-term storage of nitrogen in soil or rocks.

Process:

Organic matter buried in soil may become part of soil organic nitrogen or sediments.

Some nitrogen becomes part of fossil fuels or sedimentary deposits over millions of years.

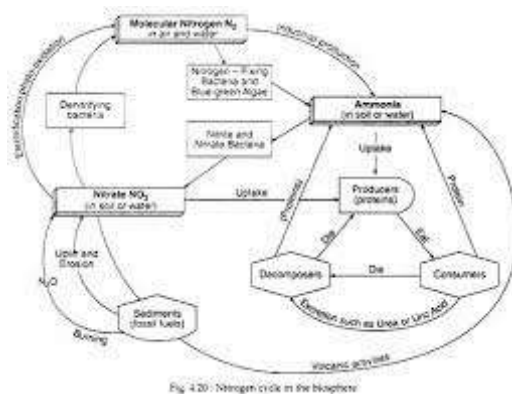
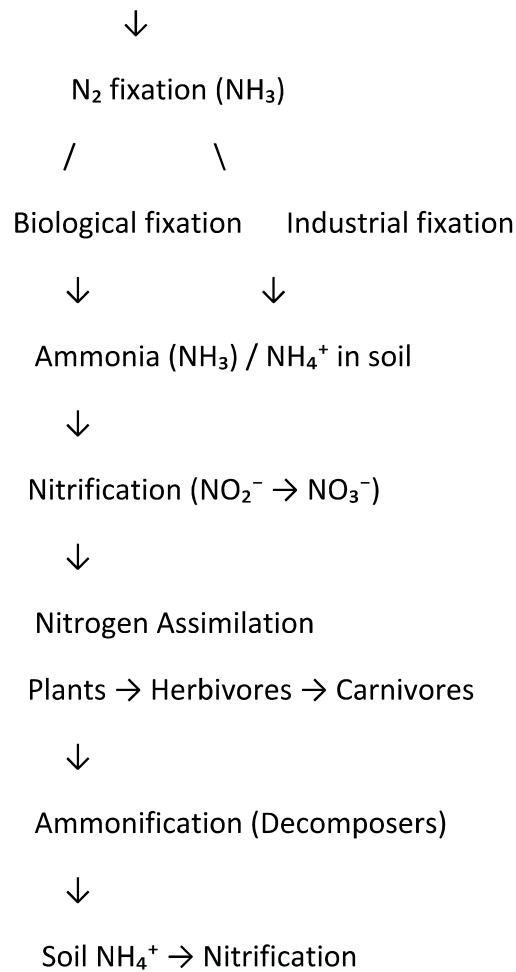
Importance: Acts as a slow-release reservoir of nitrogen.

Simplified Nitrogen Cycle Diagram

Atmosphere (N_2)

↑

Denitrification



Key Points

- Nitrogen cycles between atmosphere, soil, and organisms.
- Biological and industrial fixation make atmospheric nitrogen usable.
- Denitrification returns nitrogen to the atmosphere.
- Ensures continuous supply of nitrogen for life.

Conclusion

The nitrogen cycle is essential for synthesizing proteins, nucleic acids, and other vital biomolecules. It involves fixation, assimilation, ammonification, nitrification, denitrification, and sedimentation, ensuring nitrogen is recycled efficiently in ecosystems.

Plant Succession

Introduction

Plant succession is the **gradual and orderly change in the composition of plant communities over time** in a particular area. It results in the **development of a stable ecosystem** called a **climax community**.

- Succession occurs in **all types of ecosystems** – terrestrial, freshwater, and marine.
- It is a **natural process** driven by changes in environmental conditions and interactions among species.

Concept of Plant Succession

- Plant succession is the **process by which one plant community is replaced by another** over time.
- Each stage of succession is called a **seral stage (or seral community)**.
- The final, stable community is called the **climax community**, which remains relatively unchanged until disturbed.

Example:

- Bare land → Mosses → Grasses → Shrubs → Trees → Forest (climax)

Causes of Plant Succession

1. Abiotic Factors:

- **Soil formation and fertility:** Weathering of rocks provides minerals; humus improves fertility.
- **Water availability:** Determines which plants can survive.
- **Temperature and light:** Favor growth of certain species.

2. Biotic Factors:

- **Competition:** Plants compete for light, water, and nutrients.
- **Allelopathy:** Some plants release chemicals that inhibit growth of others.
- **Animal activity:** Grazing and seed dispersal affect plant establishment.

3. Disturbances:

- Fire, floods, or human activities can initiate succession in an area.

Types of Plant Succession

Plant succession is classified based on **starting point and environmental conditions**:

1. Primary Succession

- Occurs on **bare or newly formed land** where **no soil exists**.
- Examples: Bare rocks, sand dunes, lava flows.
- **Process:**
 - Pioneer species like **lichens and mosses** colonize → soil formation → grasses → shrubs → trees → climax forest.

2. Secondary Succession

- Occurs in areas where **soil already exists** but the previous community was disturbed or destroyed.
- Examples: Abandoned farmland, burned forest, areas cleared by flood.
- **Process:**
 - Rapid recolonization by herbs → shrubs → trees → climax community.

3. Autogenic Succession

- Caused by **changes produced by the community itself**.
- Example: Trees adding leaf litter → improves soil → favors growth of larger plants.

4. Allogenic Succession

- Caused by **external environmental factors**.
- Example: River deposits, landslides, or climate changes altering plant community.

Key Points

- Succession is **natural and directional**.
- Leads to a **stable climax community**.
- Involves **seral stages**, each building on the previous.
- **Biodiversity usually increases** during succession

Conclusion

Plant succession is a **continuous, gradual process** in which plant communities **change and mature over time**. It is influenced by both **abiotic and biotic factors**, and it results in the formation of a **climax community**, which represents a **stable and self-sustaining ecosystem**.

Process of Plant Succession

Plant succession is a **gradual and orderly replacement of one plant community by another**. The **process occurs in a series of stages**, each with specific ecological characteristics. According to **Clements' theory of succession**, there are **five main stage**.

1. Nudation

- **Definition:** The **first stage of succession**, where the area becomes **bare or exposed** due to some factor.
- **Cause:** Can be due to **climatic conditions, natural disasters, or human activities**.
- **Significance:** Prepares the site for colonization by pioneer species.
- **Example:** A bare rock surface after a lava flow or a sand dune.

2. Invasion (Migration or Colonization)

- **Definition:** Arrival and establishment of **pioneer species** in the bare area.
- **Characteristics:**
 - Pioneer species are hardy and can **tolerate extreme conditions**.
 - They begin to **modify the environment** by adding organic matter and forming soil.
 - **Examples:** Lichens, mosses, algae colonizing bare rocks or sand.

3. Competition (Struggle for Existence)

- **Definition:** Stage where different species **compete for limited resources** like light, water, nutrients, and space.
- **Outcome:**
 - Only the **best-adapted species survive**, while weaker species may be eliminated.
 - Leads to **natural selection** and better adaptation.
- **Example:** Grass and shrubs competing for sunlight in early successional stages.

4. Reaction (Modification of Environment)

- **Definition:** Stage where the **community itself changes the environment**, making it more suitable for other species.
- **Processes involved:**
 - Formation of soil from organic matter
 - Change in soil pH and moisture
 - Creation of shade by tall plants
- **Result:** Enables **new species to invade**, leading to further succession.
- **Example:** Mosses and lichens die and decompose → soil formation → grasses and shrubs grow.

5. Stabilization (Climax Stage)

- **Definition:** Final stage where the **ecosystem becomes stable and self-sustaining**.
- **Characteristics:**
 - Species composition remains **relatively constant**.
 - Community **resists invasion by new species**.
 - Represents the **climax community**, e.g., a mature forest.
- **Example:** Tropical rainforest, oak forest, or stable grassland

Simplified Flow of Succession

Nudation → Invasion → Competition → Reaction → Stability (Climax Community)

Key Points

1. Succession is a **continuous and directional process**.

2. Each stage is called a **seral stage**.
3. Pioneer species are **first colonizers** and modify the environment.
4. Climax community is **self-sustaining and stable**.
5. Human activities or disturbances can **restart succession** at any stage.

Conclusion

The **process of plant succession** involves **nudation, invasion, competition, reaction, and stability**, ensuring a **gradual transformation of ecosystems** into a **climax community**. This process is essential for **maintaining biodiversity, ecosystem balance, and soil fertility**.

Hydrosere

Definition

A **hydrosere** is a type of **plant succession that occurs in freshwater aquatic habitats**, such as **ponds, lakes, or swamps**, where the ecosystem gradually transforms from **open water to terrestrial forest**.

- It is a **hydic succession** (succession in water) and follows a **series of seral stages** leading to a **climax community**, usually a **forest**.
- The process is driven by **sedimentation, nutrient accumulation, and plant colonization**.

Process of Hydrosere

The hydrosere occurs in the following **successional stages (seral communities)**:

1. Phytoplankton Stage (Submerged Stage)

- **Pioneer colonizers:** Phytoplankton (microscopic algae) in open water.
- **Function:** Begin photosynthesis and produce oxygen, forming the **base of aquatic food chain**.

2. Submerged Hydrophyte Stage

- Plants grow **completely submerged** in water.
- **Examples:** Vallisneria, Hydrilla.
- These plants **trap sediments and add organic matter** to water.

3. Floating Hydrophyte Stage

- Plants **float on the surface** of water.

- **Examples:** Pistia, Eichhornia (water hyacinth), Lemna (duckweed).
- They **shade the water**, reduce light penetration, and **help in sediment accumulation**.

3. Reed-Swamp Stage (Emergent Plants)

- Plants with **roots in water, shoots above water** appear.
- **Examples:** Phragmites (reeds), Typha (cattails), Scirpus.
- These **accumulate more organic matter**, making water shallower.

4. Marsh-Meadow Stage

- Water becomes **shallow or marshy**, allowing **grasses and herbaceous plants** to grow.
- **Examples:** Carex, Juncus.
- Soil begins **dehydration**, preparing for terrestrial vegetation.

5. Woodland/Forest Stage (Climax Community)

- **Trees colonize**, and a **stable forest ecosystem** develops.
- **Examples:** Willows, Alders, Oaks (depending on region).
- Marks the **climax community** for the hydrosere

Diagram of Hydrosere Succession

Open Water (Phytoplankton)



Submerged Hydrophytes (Vallisneria)



Floating Hydrophytes (Eichhornia, Pistia)



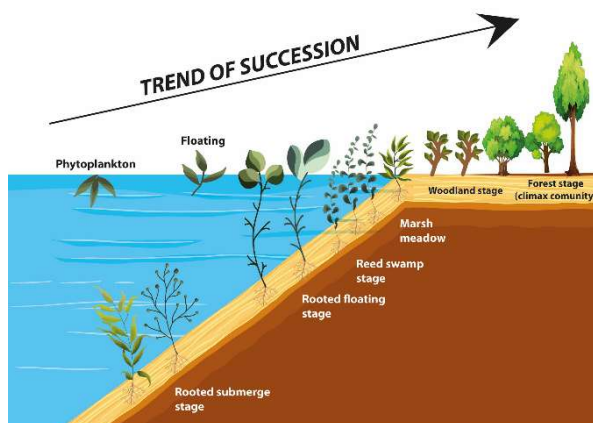
Reed-Swamp (Phragmites, Typha)



Marsh/Meadow (Carex, Juncus)



Forest Climax (Willow, Oak)



Key Points

1. Hydrosere occurs in **freshwater bodies** like ponds and lakes.
2. **Sedimentation** and **organic matter accumulation** gradually **convert water into land**.
3. Leads to a **stable climax community** (forest).
4. Demonstrates **primary succession** in aquatic habitats

Conclusion

Hydrosere is an excellent example of **aquatic succession**, showing how **ecosystems change over time from water to land** through **progressive seral stages**, ultimately forming a **stable terrestrial climax community**.

Xerosere

Definition

A **xerosere** is a type of **plant succession that occurs in extremely dry (xeric) habitats**, such as **deserts, sand dunes, or bare dry land**.

- It is a **terrestrial succession** that starts in **barren, arid areas** and ends in a **stable climax community**, usually a **desert scrub or forest** depending on local climate.
- The process demonstrates how **plants gradually modify harsh environments**, making them suitable for other species.
- **Process of Xerosere**

Xerosere occurs in **several seral stages**:

1. **Pioneer Stage (Colonization by Bare-ground Plants)**

- **Pioneer species** are hardy and drought-resistant.
- **Examples:** Lichens, mosses, algae.
- **Function:** These species **stabilize the soil** and begin **humus formation** by decomposing organic matter.

2. Grasses Stage (Herbaceous Plants)

- Soil becomes slightly **richer in organic matter**, allowing **grasses and small herbs** to grow.
- **Examples:** Cynodon, Eragrostis.
- These plants **bind the soil**, reduce erosion, and **increase water retention**.

3. Shrub Stage (Scrub Stage)

- Increased soil depth and nutrients allow **shrubs and small bushes** to grow.
- **Examples:** Acacia, Prosopis.
- These plants **provide shade**, reduce soil evaporation, and **support herbivores**.

4. Tree Stage (Arboreal Stage / Woodland Stage)

- With improved soil and microclimate, **trees start to establish**.
- **Examples:** Neem, Banyan, Teak (depending on region).
- Marks the **transition toward the climax community**.

5. Climax Community

- Final stable community depends on **local climate and soil**.
- In arid regions, may be **desert scrub or thorny forest**.
- Vegetation becomes **self-sustaining** and resists further change.

Diagram of Xerosere Succession

Bare Dry Land



Pioneer Stage (Lichens, Mosses)



Grass Stage (Herbaceous Plants)



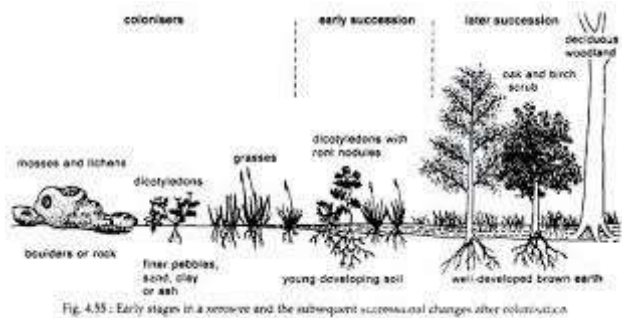
Shrub Stage (Acacia, Prosopis)



Tree Stage (Neem, Banyan)



Climax Community (Desert Scrub / Thorn Forest)



Key Points

1. Xerosere occurs in **dry, arid environments**.
2. **Pioneer species** prepare the habitat for other plants.
3. Leads to **progressive improvement of soil** and microclimate.
4. Final **climax community** is **stable and adapted to dry conditions**.

Conclusion

A **xerosere** is an excellent example of **primary succession in xeric habitats**, demonstrating how **life gradually colonizes barren land**. Through **pioneer colonization, soil formation, and progressive plant growth**, a **stable climax community** is eventually formed.

