# iii. Concept of ecosystem...

iii. Concept of ecosystem, structure, function and types of ecosystem, energy flow in an ecosystem: food chain, food web and ecological succession

# **Concept of Ecosystems**

## **Definition and Historical Context**

### 1. Ecosystem

- First defined by A.G. Tansley (1935) as the combined complex of **biotic (living)** communities and their **abiotic (non-living)** environment, interacting as a functional unit.
- Encompasses energy flow, nutrient cycling, and community dynamics within discrete spatial boundaries (though boundaries can be flexible).

## 2. Systems Perspective

- Approaches the study of ecology from a holistic viewpoint, where processes such as production, respiration, and decomposition link living organisms with geophysical processes (soil formation, hydrology, climate).
- Integrates multiple scales (microcosms to global biomes) and disciplines (soil science, physiology, climatology).

# **Fundamental Principles**

### 1. Functional Complexity

 Ecosystems are maintained via feedback loops (e.g., predator-prey population cycles), self-organization, and homeostatic tendencies (resilience to disturbances).

### 2. Material Cycling

• Closed loops of major elements (C, N, P, S) and micronutrients circulate between living organisms (bioaccumulation) and abiotic reservoirs (soil, water, atmosphere).

### 3. Emergent Properties

• Ecosystem-level phenomena (e.g., stability, diversity maintenance) arise from interactions among numerous species and environmental processes, not predictable by studying components in isolation.

# **Structure and Function of Ecosystems**

## **Structural Components**

### 1. Biotic Components

- **Producers (Autotrophs)**: Photosynthetic or chemosynthetic organisms (plants, algae, some bacteria) converting solar or chemical energy into organic matter.
- Consumers (Heterotrophs): Herbivores, carnivores, omnivores feeding on living organic matter.
- Decomposers (Detritivores, Saprophytes): Fungi, bacteria breaking down dead organic matter, releasing nutrients for reuse.

## 2. Abiotic Components

- Physical and chemical factors: Climate (temperature, precipitation), substrate (soil, water chemistry), topography, light availability.
- Nutrient regimes (N, P, K, micronutrients) essential for primary productivity.

# **Functional Processes**

## 1. Primary Production

- Rate at which autotrophs fix inorganic carbon (CO<sub>2</sub>) into organic forms (carbohydrates). Measured as **Gross Primary Productivity (GPP)**.
- **Net Primary Productivity (NPP)** = GPP Autotrophic Respiration. NPP represents biomass accumulation available to consumers.

## 2. Respiration and Decomposition

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- ∘ Organisms utilize organic matter for energy, releasing CO₂ back to the atmosphere.
- Decomposers transform complex organic molecules into simpler inorganic forms, completing nutrient cycles.

#### 3. Nutrient Cycling

- Biogeochemical cycles (C, N, P) facilitate ecosystem productivity.
- $\circ$  **Nitrogen Fixation** by symbiotic bacteria, **denitrification** by microbes returning  $N_2$  to the atmosphere, etc.

#### 4. Homeostasis and Feedback

- Negative feedback loops (e.g., plant growth balancing CO<sub>2</sub> uptake, herbivory limiting plant biomass) can stabilize ecosystems.
- Positive feedbacks may drive regime shifts (e.g., desertification if vegetation cover diminishes beyond a threshold).

# Types of Ecosystems

Ecosystems are often classified based on **dominant vegetation**, **climatic conditions**, or **physical environment**. Major categories span terrestrial (forest, grassland, desert) to aquatic (freshwater, marine), each with distinctive structural and functional traits.

# **Terrestrial Ecosystems**

#### 1. Forests

- Characterized by a closed canopy of trees, high biomass.
- Subtypes: tropical rainforests (high biodiversity, rapid decomposition), temperate deciduous forests (pronounced seasonal changes), boreal forests (conifer-dominated, cold, less decomposition).

### 2. Grasslands

- o Dominant grasses, few woody plants.
- Productivity is often linked to rainfall gradients (prairies, savannas, steppes). Support large herbivore populations, significant grazing pressure.

# 3. Deserts

- o Low precipitation, sparse vegetation, high temperature extremes (hot or cold deserts).
- Adaptations of flora and fauna revolve around water conservation and ephemeral growth cycles.

### 4. Tundra

- o Cold climate, permafrost-laden soils, short growing season.
- o Vegetation mostly lichens, mosses, low shrubs. Sensitive to climate warming.

# **Aquatic Ecosystems**

### 1. Freshwater

- Lentic (standing water: lakes, ponds) vs. lotic (flowing water: rivers, streams).
- o Stratification by temperature (thermocline) or oxygen affects species distributions, nutrient cycling.

### 2. Marine

- o Coastal (estuaries, mangroves, coral reefs) vs. open ocean (pelagic, benthic).
- Productivity often highest in **upwelling** zones or shallow continental shelves. Coral reefs host high biodiversity, sensitive to temperature and pH shifts.

# **Transitional Ecosystems**

### 1. Wetlands

- o Interface between terrestrial and aquatic realms, e.g., swamps, marshes, bogs.
- $\circ \ \ \text{Provide critical ecosystem services (water purification, flood control, high productivity)}.$

### 2. Mangroves and Salt Marshes

- o Coastal wetlands adapted to saline or brackish conditions.
- o Serve as nursery habitats, protect shorelines from erosion.

# 3. Urban Ecosystems

- o Human-dominated landscapes, interplay of built environment and remnant green spaces.
- Novel ecological processes influenced by pollution, invasive species, fragmented habitats.

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# **Energy Flow in an Ecosystem**

Energy in ecosystems is **unidirectional**—entering primarily via photosynthetic fixation of sunlight (or chemosynthesis in certain deep-sea vents) and moving through successive **trophic levels**. Understanding these flows is foundational to ecology.

# **Food Chain**

### 1. Linear Trophic Pathways

- Representation: Producers (plants/algae) → Primary Consumers (herbivores) → Secondary Consumers (carnivores) → Tertiary Consumers (top predators).
- o Simplified depiction; real ecosystems typically exhibit multiple, interconnected feeding links.
- Energy Transfer Efficiency: Often 5-20% of energy passes from one trophic level to the next (Lindeman's 10% law).

### 2. Grazing vs. Detritus Food Chains

- **Grazing**: Living plant biomass consumed by herbivores.
- Detritus: Decomposers breaking down dead organic material, contributing significantly to nutrient cycling.

## **Food Web**

### 1. Network of Interconnected Food Chains

- o More realistic representation of species feeding relationships.
- Demonstrates omnivory, predator switching, and trophic omnipresence (organisms feeding across multiple levels).
- Complexity can lend ecosystem **stability** (redundancy of energy pathways) or vulnerability if keystone species are lost.

## 2. Trophic Cascade Effects

- Changes at one level (e.g., apex predator removal) can ripple through the web (mesopredator release, herbivore overgrazing, plant community shifts).
- o Important for ecosystem management, rewilding strategies.

# **Ecological Succession**

## 1. **Definition**

• **Ecological succession** is the **gradual process of change** in species composition and community structure over time, often following disturbances or newly exposed substrates.

### 2. Primary Succession

- o Occurs on substrates lacking soil or previous life (e.g., lava flows, glacial retreat).
- Pioneer species (lichens, mosses) colonize, modify substrate, eventually allowing more complex plant communities to develop.
- Soil formation is a critical milestone.

### 3. Secondary Succession

- o Follows disturbances (fire, floods, deforestation) that do not completely remove soil or seed banks.
- Faster than primary succession; pioneer species are typically annuals or r-strategists, progressing to a more stable, climax community.

## 4. Climax Community?

- Classic concept that succession culminates in a stable, self-perpetuating community (e.g., mature forest).
- Modern ecology recognizes that dynamism, intermediate disturbance, and climate shifts often prevent strict equilibrium.

## 5. Successional Mechanisms

- Facilitation: early colonists modify habitat, enabling later arrivals.
- **Inhibition**: competition, allelopathy can hamper subsequent species.
- **Tolerance**: certain species can endure conditions at different successional stages, coexisting with new arrivals.

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# **Concluding Remarks**

The **concept of ecosystems** as integrated networks of **biotic** and **abiotic** components underpins much of ecological theory and conservation practice. By understanding **structure** (community composition, trophic organization) and **function** (productivity, nutrient cycling, energy flow), researchers and resource managers can better predict ecosystem responses to **disturbances** (climate change, land-use shifts) and design strategies to maintain **biodiversity** and **ecosystem services.Energy flow**—mapped via **food chains** and **food webs**—reveals how solar energy is converted into chemical energy by producers and subsequently partitioned among consumers and decomposers, while **ecological succession** describes how communities dynamically reorganize following disturbances. These classical topics remain central to advanced ecological inquiry, informing sustainable resource management, restoration ecology, and biodiversity conservation at local through global scales.

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