

### 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

- Organisms utilize organic matter for energy, releasing CO<sub>2</sub> 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.
  - **Nitrogen Fixation** by symbiotic bacteria, **denitrification** by microbes returning N<sub>2</sub> 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**
  - Dominant grasses, few woody plants.
  - Productivity is often linked to rainfall gradients (prairies, savannas, steppes). Support large herbivore populations, significant grazing pressure.
3. **Deserts**
  - 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**
  - Cold climate, permafrost-laden soils, short growing season.
  - 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).
  - Stratification by temperature (thermocline) or oxygen affects species distributions, nutrient cycling.
2. **Marine**
  - 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**
  - Interface between terrestrial and aquatic realms, e.g., swamps, marshes, bogs.
  - Provide critical ecosystem services (water purification, flood control, high productivity).
2. **Mangroves and Salt Marshes**
  - Coastal wetlands adapted to saline or brackish conditions.
  - Serve as nursery habitats, protect shorelines from erosion.
3. **Urban Ecosystems**
  - Human-dominated landscapes, interplay of built environment and remnant green spaces.
  - Novel ecological processes influenced by pollution, invasive species, fragmented habitats.

## 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).
- 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

- 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).
- 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

- 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

- 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.



## 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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