Environment and Habitat

Environment

- **Definition**:
    - The environment encompasses all living (biotic) and non-living (abiotic) elements that affect human life.
- **Components**:
    - **Biotic Elements**: Animals, plants, forests, fisheries, birds.
    - **Abiotic Elements**: Water, land, sunlight, rocks, air.

Habitat

- **Definition**:
    - A habitat is the specific physical environment where an organism lives, often referred to as the "address" of an organism.
- **Characteristics**:
    - Multiple organisms with similar needs may share the same habitat.
    - Examples of habitats include forests, lakes, coral reefs, and ice shelves.

Examples of Habitats

- **Coral Reef in the Phoenix Islands Protected Area**:

- Provides habitat for a diverse range of marine species, such as fish, crabs, and phytoplankton.

- **Ice Shelves of Antarctica**:
  - While few creatures inhabit the ice shelves themselves, the water beneath provides habitat for species adapted to extreme cold, such as penguins.
- **Alpine Habitat**:
  - Home to species like the ibex, which is adapted to high-altitude, cold conditions.

Ecosystem

Definition

- An ecosystem is a functional unit of nature where living organisms (producers, consumers, decomposers) interact with each other and with their physical environment.
- Every component in an ecosystem is interconnected, meaning a change in one factor can impact others. For example, a temperature change can affect plant growth, which in turn impacts animals dependent on those plants.

Origin

- The term "ecosystem" was coined by English botanist A.G. Tansley in 1935.

Components of an Ecosystem

Abiotic Components

Abiotic factors are non-living elements of an ecosystem that influence the living organisms within it. They include:

- **Physical Factors**:
  - **Water**: Essential for life; it helps in nutrient availability and is vital for plant growth and photosynthesis.
  - **Light**: Crucial for photosynthesis in plants; affects plant distribution and, consequently, the distribution of dependent species.
  - **Temperature**: Varies with seasons and locations; affects species survival and distribution. Some species are stenothermal (narrow temperature range), while others are eurythermal (wide temperature range).
  - **Humidity**: Influences transpiration in plants, plant distribution, and animal adaptations.
- **Chemical Factors**:
  - **Soil**: Contains essential nutrients and supports plant growth. Soil composition affects plant health and nutrient availability. Some plants, like pitcher plants, have adapted to nutrient-poor soils by becoming carnivorous.

- **Topographic Factors**:
  - **Altitude and Land Type**: Influences species distribution based on factors like temperature and precipitation. For example, species at high altitudes are adapted to colder climates.
- **Salinity**:
  - **Salinity Tolerance**: Organisms can be euryhaline (tolerate a wide range of salinities) or stenohaline (tolerate a narrow range of salinities).

Classification of Abiotic Factors

- **Climatic Factors**: Related to weather and climate conditions such as temperature, wind, humidity, and precipitation.
- **Edaphic Factors**: Related to soil characteristics, including soil type, moisture, and nutrient content.

Examples of Abiotic Factors

- **Water**: Vital for life and plant growth; interacts with soil nutrients.
- **Light**: Key for photosynthesis and influences the distribution of organisms.
- **Temperature**: Affects species distribution and survival.
- **Humidity**: Affects transpiration, plant and animal adaptations.

- **Soil**: Provides nutrients and supports plant life; some plants adapt to nutrient-poor conditions.
- **Topographic Factors**: Influence species distribution based on altitude and land type.
- **Salinity**: Determines the types of organisms that can thrive in different water bodies.

Effect of Abiotic Components on Terrestrial Primary Producers (Plants)

1. Light

- **High Light Intensity**:
  - Promotes root growth over shoot growth, resulting in a plant with higher transpiration rates, shorter stems, and smaller, thicker leaves.
  - Can cause plants to become compact and develop thicker, darker green leaves due to increased chlorophyll production.
- **Low Light Intensity**:
  - Slows down plant development, flowering, and fruiting.
  - Plants may become leggy with elongated stems and fewer leaves due to insufficient light for photosynthesis.
- **Critical Light Levels**:

  - When light intensity falls below a critical level, plants may stop growing and eventually die due to a buildup of CO_2 in the absence of photosynthesis.
- **Light Spectrum**:
  - **Red and Blue Light**: Effective in photosynthesis. Red light promotes cell elongation (etiolation), while blue light results in shorter, thicker plants with darker leaves.
  - **Ultraviolet (UV) Light**: Can lead to dwarfism in plants.

2. Frost

- **Impact on Moisture**:
  - Freezes moisture in the soil, limiting water availability to plant roots and causing increased transpiration.
  - Leads to dehydration as water in the plant's intercellular spaces freezes, increasing salt concentrations and damaging cells.
- **Disease**:
  - Can cause canker formation, which includes various plant diseases with symptoms resulting from fungal, bacterial, or viral infections.

3. Snow

- **Temperature Regulation**:

   - Acts as an insulating blanket, preventing further temperature drops and protecting plants from extreme cold and frost.
- **Physical Damage**:
   - Accumulation of snow on tree branches can lead to breakage or even uprooting of the trees.
- **Vegetative Development**:
   - Snow can shorten the vegetative development period of plants by covering and protecting them from harsher environmental conditions.

4. Temperature

- **High Temperatures**:
   - Can cause protoplasmic proteins in plants to coagulate, leading to cell damage and death.
   - Disrupts the balance between respiration and photosynthesis, causing a decline in overall plant health.
- **Desiccation**:
   - High temperatures lead to the desiccation of plant tissues and depletion of moisture, which further stresses the plants.

Biotic Components of an Ecosystem

1. Primary Producers (Autotrophs)

- **Definition**: Primary producers are organisms that produce their own food through photosynthesis or chemosynthesis. They form the base of the food chain.
- **Examples**:
  - **Terrestrial Ecosystems**: Herbaceous and woody plants (e.g., grasses, shrubs, trees).
  - **Aquatic Ecosystems**: Microscopic algae (e.g., phytoplankton).

- **Function**:
  - **Photosynthesis**: They convert sunlight into chemical energy stored in carbohydrates, which they use for growth and reproduction. This process also produces oxygen as a byproduct.
  - **Nutrient Supply**: They provide the primary source of energy for all other organisms in the ecosystem.

2. Consumers (Heterotrophs or Phagotrophs)

- **Definition**: Consumers cannot produce their own food and depend on organic substances derived from plants, animals, or both.

- **Classification**:
  - **Macro Consumers (Phagotrophs)**:
    - **Herbivores**: Primary consumers that feed directly on plants (e.g., cows, rabbits).
    - **Secondary Consumers**: Feed on primary consumers (e.g., wolves that eat rabbits).
    - **Tertiary Consumers**: Feed on secondary consumers (e.g., lions that eat wolves).
    - **Omnivores**: Consume both plants and animals (e.g., humans, bears).

  - **Micro Consumers (Saprotrophs or Decomposers)**:
    - **Saprotrophs**: Include bacteria and fungi that decompose dead organic matter, returning essential nutrients to the soil.
    - **Detritivores**: Includes earthworms and certain soil organisms that feed on detritus (dead organic matter) and assist in decomposition.
    - **Decomposition Process**:
      - **External Digestion**: Saprotrophs release enzymes outside their bodies to break down

complex organic substances into simpler forms, which they then absorb.

- **Role in Ecosystem**: They recycle nutrients, making them available for primary producers and maintaining ecosystem health.

Principles and Levels of Organization in Ecology

Ecology

- **Definition**: Ecology is the scientific study of the relationships between living organisms and their physical environment. It explores how organisms interact with each other and their surroundings, seeking to understand the vital connections between plants, animals, and their environments.
- **Etymology**: The term "ecology" comes from the Greek words "Oikos" (home or place to live) and "Logos" (study), meaning the study of the home or environment.

Levels of Organization in Ecology

1. **Individual**
   - **Definition**: An individual is a single living organism capable of independent function. This includes plants, animals, bacteria, fungi, etc.
   - **Characteristics**:

- **Respond to Stimuli**: Organisms react to environmental changes.
- **Reproduce**: They have the ability to produce offspring.
- **Grow and Adapt**: They undergo growth and adapt to their environment.
- **Equilibrium**: They maintain internal stability despite external changes.

- **Classification**: Organisms can be classified based on their cellular structure, such as unicellular (e.g., bacteria) or multicellular (e.g., plants and animals). Each species is a distinct unit capable of gene exchange through reproduction.

2. **Ecological Dominance Species**

- **Definition**: Species that exert significant control over other species within the same habitat due to factors such as abundance, size, productivity, or adaptability.
- **Characteristics**:
  - **Competitive Advantage**: Dominant species can outcompete others for resources.
  - **Adaptability**: They are highly adaptable to environmental changes.

- **Influence**: They have a significant impact on their habitat.
- **Proportion**: Their population size is dominant compared to others.
- **Mobility and Intelligence**: Especially true for humans, who can be highly influential due to their mobility and problem-solving abilities.

- **Example**: Caribou on the tundra, which play a crucial role in their ecosystem.

3. **Population**

- **Definition**: A population consists of individuals of the same species living together in a specific geographic area. They interact, interbreed, and compete for resources.
- **Characteristics**:
  - **Interbreeding**: Members of the same population can produce fertile offspring.
  - **Population Growth**: Growth can be influenced by birth rates, immigration, death rates, and emigration.
- **Dynamics**: The growth and decline of populations are influenced by various biotic and abiotic factors.

4. **Community**

- **Definition**: A community encompasses all the different populations of species living and interacting within a specific area.
- **Characteristics**:
  - **Interactions**: Organisms within a community interact with each other in various ways, including predation, competition, and mutualism.
  - **Ecological Amplitude**: The range of environmental conditions a species can tolerate.
  - **Biotic and Abiotic Factors**: The composition of a community is influenced by environmental conditions and the ecological amplitude of species.
- **Example**: A forest community includes trees, plants, animals, microorganisms, and their interactions with each other and the environment.

Interdependence in Ecological Communities

Competition

- **Definition**: Competition arises when organisms vie for the same limited resources.
  - **Interspecific Competition**: Competition between individuals of different species.

- **Intraspecific Competition**: Competition between individuals of the same species.

Stratification

- **Definition**: The formation of distinct layers within a community to reduce competition and conflict.
- **Purpose**: Allows different species to occupy different layers or zones, each adapted to specific conditions, minimizing overlap and competition.
  - **Example**: In a forest, stratification might include the canopy, understory, and forest floor, each supporting different plants and animals.

Dependence

- **Definition**: Some species rely entirely on the dominant species within their community for specific conditions necessary for their survival.
  - **Examples**:
    - **Bryophytes and Thallophytes**: Often depend on the shade and moisture provided by larger plants.
    - **Impact**: If the dominant species are removed, dependent species may not survive due to the loss of their required environmental conditions.

Ecosystem

- **Definition**: An ecosystem is a structural and functional unit of the biosphere comprising living organisms and their physical environment, interacting and exchanging materials.
- **Energy Flow**: Photosynthesis is the primary process that introduces energy into the ecosystem, which is then transferred through plant tissues and into other organisms.

Ecotone

- **Definition**: A transitional zone between two or more distinct communities, which may have a sharp or gradual boundary.
  - **Characteristics**:
    - **Ecotonal Community**: Includes species from the adjacent communities as well as unique species adapted to the transitional zone.
    - **Diversity**: Often, ecotones have greater species diversity and population densities compared to the adjacent communities, due to the overlap of different habitats.
  - **Human Impact**: Human activities, such as agriculture and urban development, create or alter ecotones by transforming natural landscapes.

- **Example**: A forest converted into a mixed-use area with grasslands and agricultural lands creates a human-induced ecotone where forest and open habitat species interact.

- **Buffer Zone**: Ecotones can act as protective barriers, absorbing pollutants and reducing environmental damage to neighboring ecosystems (e.g., wetlands filtering pollutants before they reach rivers).

Ecological Niche

- **Definition**: A niche is the unique functional role and position of a species in its habitat or ecosystem.
- **Interactions**: It describes how a species interacts within an ecosystem.
- **Factors**:
  - **Biotic Factors**: Food availability, predators.
  - **Abiotic Factors**: Temperature, landscape characteristics, soil nutrients, light, and other non-living factors.
- **Unique Roles**: Different species may share the same habitat but have different niches.
  - **Example**:

- **Dung Beetle**: Consumes dung in both larval and adult stages, stores dung balls in burrows, females lay eggs within these dung balls. The larvae have immediate access to food. The beetle aerates soil and releases beneficial nutrients back into the environment, performing a unique role.

- **Stability**: Greater niche diversity leads to more ecosystem stability due to multiple energy flow pathways and less fluctuation in species populations.
- **Analogy**:
  - **Habitat**: Address (where a species lives).
  - **Niche**: Profession (what a species does).

Habitat Preference and Usage

- **Habitat Preference**: The habitat most likely chosen by a species or best suited for it.
- **Habitat Usage**: How a species manipulates its surroundings to enhance survival and interacts with its habitat.

Competitive Exclusion Principle

- **Definition**: Two different species cannot occupy the same niche in the same geographic area for long.

  - **Outcome**: If two species occupy the same niche, they compete for resources, leading to one species outcompeting and replacing the other.
  - **Human Impact**: Introduction of new species into areas where niches are already occupied by native species, leading to invasive species.

Biome

- **Definition**: Terrestrial parts of the biosphere divided into large regions characterized by climate, vegetation, animal life, and general soil type.
- **Distinctiveness**: No two biomes are alike; climate determines their boundaries and the abundance of plants and animals.
  - **Key Climatic Factors**: Temperature and precipitation.
  - **Common Characteristics**: Plants and animals in a biome share characteristics due to similar climates and can be found across various continents.
  - **Example**: Taiga forests are found beyond the temperate regions in the northern hemisphere.
- **Difference from Habitats**: Any biome can comprise a variety of habitats.

Biosphere

- **Definition**: The biosphere is the biological component of the earth that supports life and includes the lithosphere (land), hydrosphere (water), and atmosphere (air).
- **Components**:
  - **Lithosphere**: Earth's solid outer layer.
  - **Hydrosphere**: All water bodies on Earth.
  - **Atmosphere**: The layer of gases surrounding the Earth.
- **Contents**:
  - All living organisms on Earth.
  - Dead organic matter produced by these organisms.
- **Limits**: Absent in extremes of the North and South poles, the highest mountains, and the deepest oceans due to hostile conditions.
- **System**:
  - **Matter**: Virtually a closed system with minimal inputs and outputs.
  - **Energy**: An open system with photosynthesis capturing solar energy at a rate of about 100 terawatts.
- **Evolution**:

  - Began with processes of **biopoiesis** (life created naturally from non-living matter) or **biogenesis** (life created from living matter).
  - At least some 3.5 billion years ago.

Key Points:

- **Biosphere Interactions**: The biosphere interacts with the lithosphere, hydrosphere, and atmosphere to support life.
- **Closed System**: Regarding matter, the biosphere is a closed system, meaning it has minimal matter exchange with the external environment.
- **Open System**: Regarding energy, the biosphere is an open system, receiving solar energy, which is essential for photosynthesis and sustaining life.
- **Historical Evolution**: The biosphere's evolution from simple organic compounds to complex life forms highlights the transition from non-living to living matter.

Principles of Ecology

Adaptation

- **Definition**: Adaptation is the biological mechanism by which organisms adjust to new environments or to changes in their current environment.

- **Purpose**: Enhances an organism's ability to survive and reproduce in its environment.
- **Example**: Animal camouflage to escape predators.

Morphological Adaptation

- **Desert Plants**:
  - Thick cuticle on leaves to minimize water loss through transpiration.
  - Stomata arranged in deep pits for reduced water loss.
  - Example: Opuntia has no leaves, only spines; photosynthesis is carried out by flattened stems, reducing transpiration.
- **Cold Climate Mammals**:
  - Shorter ears and limbs to minimize heat loss (Allen's Rule).
- **Hyperthermophiles**:
  - Organisms thriving in extremely hot environments, such as archaebacteria in hot springs and deep-sea hydrothermal vents (temperature from 60 °C).

Physiological Adaptation

- **High Altitude Adaptation**:

- Breathing rate increases to compensate for lower oxygen availability.
- Acclimatisation: The process of becoming accustomed to a new climate or new conditions.
- Body adjustments include increased red blood cell production and decreased binding capacity of hemoglobin to improve oxygen uptake.

Key Points

- Adaptations are crucial for the survival and reproductive success of organisms in varying environmental conditions.
- Morphological adaptations often involve physical changes that help organisms manage environmental stresses, such as extreme temperatures or water scarcity.
- Physiological adaptations involve internal body processes that enhance survival in specific environments, such as high altitudes with low oxygen levels.

Principles of Ecology

Behavioral Adaptation

- **Desert Lizards**:

- **Thermoregulation**: They bask in the sun to absorb heat when their body temperature drops and move into the shade when the ambient temperature increases.
- **Burrowing**: Some species burrow into the soil to escape above-ground heat.

Variation

- **Inducement**:
  - Variations are caused by changes in genetic makeup due to the addition or deletion of certain genes.
  - Factors: Mutations, change in climate, geographical barriers, etc.
- **Examples in Humans**:
  - Skin color, hair type (curly or straight), eye color, blood type among different ethnic groups.

Adaptive Radiation

- **Definition**:
  - Adaptive radiation is the process in which organisms diversify rapidly from an ancestral species into a multitude of new forms, especially when environmental changes create new challenges or niches.
- **Darwin's Finches**:

- Observed by Charles Darwin on the Galapagos Islands.
- Finches developed different beak types according to available food sources.
- Evolution from seed-eating to vegetarian and insectivorous finches.

Speciation

- **Definition**:
  - Speciation is the evolutionary process by which populations evolve to become distinct species.
- **History**:
  - Term coined by Orator F. Cook in 1906.
  - Charles Darwin described natural selection's role in speciation in his book "On the Origin of Species" (1859).
- **Modes of Speciation**:
  - **Allopatric Speciation**:
    - A population becomes separated by a geographic barrier.
    - Reproductive isolation develops, resulting in two separate species.
  - **Peripatric Speciation**:

- A small population becomes isolated on the periphery of the central population.
- Reduced gene flow leads to reproductive isolation.

- **Centrifugal Speciation**:
  - Population range expands and contracts, leaving an isolated fragment.
  - Central population evolves reproductive isolation.
- **Parapatric Speciation**:
  - Population subject to a selective gradient (cline).
  - Different selective conditions at each end of the gradient.
  - Reproductive isolation occurs upon the formation of a hybrid zone, which may be eliminated if disadvantageous.
- **Sympatric Speciation**:
  - Reproductive isolation evolves within a population without geographic barriers.
  - Often based on differences in food sources or other characteristics.

Key Points

- **Adaptation**: Essential for the survival and reproduction of organisms in varying environments.
- **Behavioral Adaptations**: Allow organisms to regulate their body temperature and escape harsh conditions.
- **Variation and Adaptive Radiation**: Lead to biodiversity and the evolution of new species through natural selection and environmental changes.
- **Speciation**: Results in the formation of distinct species through various geographic and reproductive isolation mechanisms.

Key Concepts in Ecology

Mutation

- **Definition**: Mutation is a change in genetic material resulting from an error in DNA replication, leading to the formation of new genes within a population.
- **Recombination**: In sexually reproducing populations, meiosis (cell division) and fertilization produce new gene combinations each generation.
  - Variation arises from these processes, ensuring members of the same species are not identical.
  - **Hugo de Vries' Theory**: Nature selects beneficial mutations and eliminates lethal ones. Accumulated

heritable changes over time result in new phenotypes and eventually new species (speciation).

Natural Selection

- **Definition**: A mechanism proposed by Darwin and Wallace where species adapt to their environment.
- **Process**: Natural selection selects among variations, favoring genes that enhance adaptation to the environment.
  - Offspring suited to their environment survive, reproduce, and pass on beneficial adaptations to their progeny.

Evolution

- **Definition**: The process that gives rise to new species, making organisms better suited to their environment.
- **Mechanisms**: Involves natural selection, adaptation, and variation.
  - **Historical Context**: Charles Darwin and Alfred Wallace proposed the theory of evolution in 1859, later extended through genetic discoveries (Neo-Darwinism).

Extinction

- **Causes**: Environmental changes or biological competition leading species to fail in adapting quickly enough.

- **Current Context**: The 6th Mass Extinction (Anthropogenic Extinction) is ongoing, driven by human activities.

Previous Mass Extinctions

1. **Ordovician-Silurian Extinction (443 million years ago)**:
   - Wiped out ~85% of species due to drastic temperature changes, glacier formation, and sea level fluctuations.
2. **Devonian Extinction (374 million years ago)**:
   - Eliminated three-quarters of marine invertebrates due to environmental changes like global warming, sea level rise and fall, and atmospheric composition changes.

3. **Permian Extinction (250 million years ago)**:
   - The most devastating, eradicating over 95% of species due to potential asteroid impacts or volcanic eruptions causing toxic oceans and atmospheric changes.
4. **Triassic Extinction (200 million years ago)**:
   - Eliminated ~80% of species, likely due to geological activity increasing CO2 levels, global temperatures, and ocean acidification.
5. **Cretaceous Extinction (66 million years ago)**:

- Killed 78% of species, including non-avian dinosaurs, likely due to an asteroid impact and ongoing volcanic activity.

The Sixth Mass Extinction

- **Human Impact**:
  - Environmental changes caused by human activities, including extreme weather, land use changes, deforestation, pollution, and biodiversity loss.
  - Over 70% of land surfaces transformed and significant freshwater resources used.
  - Agriculture contributes to soil degradation, deforestation, and pollution.
  - Large animals culled, invasive species introduced, and ecosystems disrupted by human activities.
- **Ecosystem Interdependence**:
  - The extinction of one species impacts others, risking ecosystem collapse.
  - The current extinction rate is 100-1,000 times higher than the pre-human background rate, indicating an ongoing sixth mass extinction.

Functions of an Ecosystem

Ecological Succession

- **Definition**: The process by which communities of plant and animal species in an area are replaced or changed over time.
- **Characteristics**:
  - Directional change in vegetation due to large-scale changes or destruction.
  - A progressive series of changes with one community replacing another until a stable, mature climax community develops.

Primary Succession

- **Definition**: Succession that occurs in an area where no community previously existed, such as newly exposed rock or sand surfaces, lava flows, and glacial tills.
- **Stages**:
  - **Pioneer Community (PC)**: The first organisms to colonize an area, often microbes, lichens, mosses, fungi, and bacteria.
  - **Habitat Alteration**: Pioneer species alter the habitat conditions by their growth and development.
  - **Seral Stages**: Intermediate stages leading to the climax community.

  - **Climax Community**: The stable, mature, complex, and long-lasting community that eventually develops.

Climax Community

- **Definition**: The final or stable community in a successional series (sere).
- **Characteristics**:
  - Self-perpetuating and in equilibrium with the physical habitat.
  - No net annual accumulation of organic matter.
  - Balanced annual production and energy use.

Characteristics of a Climax Community

- **Diversity**: Wide diversity of species.
- **Spatial Structure**: Well-drained spatial structure.
- **Complex Food Chains**: Involving various trophic levels and interactions.
- **Equilibrium**:
  - Balance between gross primary production and total respiration.
  - Balance between energy used from sunlight and energy released by decomposition.

- Balance between the uptake of nutrients from the soil and their return via litter fall.

- **Species Composition**: Maintains equilibrium as individuals in the climax stage are replaced by others of the same kind.

Key Processes in Ecosystems

- **Increased Productivity**: Gradual increase in the productivity of the ecosystem as succession progresses.
- **Nutrient Shift**: Shift of nutrients from reservoirs to living organisms.
- **Increased Diversity**: Increase in the diversity of organisms over time.
- **Complexity of Food Webs**: Gradual increase in the complexity of food webs through successional stages.

Secondary Succession

- **Definition**: The sequential development of biotic communities after the complete or partial destruction of an existing community.
- **Causes of Destruction**: Natural (e.g., wildfires, storms) or man-made (e.g., deforestation, agriculture).
- **Characteristics**:

- Faster than primary succession because it starts on well-developed soil or previously inhabited areas.
- Initiated by species like alders, birches, chir pine, and various grass species.

Stages of Secondary Succession

1. **Initial State**: A stable deciduous forest community.
2. **Disturbance**: An event (e.g., wildfire) destroys the forest.
3. **Aftermath**: The fire burns the forest to the ground, leaving empty but intact soil.
4. **Pioneer Stage**: Grasses and herbaceous plants grow back first.
5. **Intermediate Stage**: Small bushes and trees begin to colonize the area.
6. **Advanced Stage**: Fast-growing evergreen trees develop fully, with shade-tolerant trees growing in the understory.
7. **Climax Stage**: The short-lived, shade-intolerant evergreen trees die as larger deciduous trees overtop them, returning the ecosystem to a state similar to its original.

Succession in Plants

- **Xerarch Succession**: Occurs on land with low moisture content, such as bare rock. Over time, this habitat converts into a mesophytic habitat, requiring moderate water.

- **Hydrarch Succession**: Takes place in water bodies like ponds or lakes, eventually leading to medium water conditions (mesic).

Succession in Water

- **Primary Succession in Water**:
    - **Pioneer Species**: Small phytoplankton.
    - **Intermediate Stages**: Replaced by free-floating angiosperms, then rooted hydrophytes, sedges, grasses.
    - **Climax Community**: Eventually, trees develop, converting the water body into land over time.

Homeostasis

- **Definition**: The maintenance of stable equilibrium within an organism's internal environment despite varying external conditions.
- **Importance**: Successful homeostasis allows for the continuation of life, while failure leads to disaster or death.

Mechanisms to Achieve Homeostasis

Regulators (Endotherms)

- **Mechanism**: Maintain homeostasis through physiological means (e.g., constant body temperature, osmotic concentration) and sometimes behavioral means (e.g., seeking shade).

- **Examples**: Birds, mammals, and a few lower vertebrates and invertebrates capable of thermoregulation and osmoregulation.
- **Characteristics**:
  - **Internal Heat Generation**: Regulate body temperature internally (warm-blooded).
  - **Wide Distribution**: Found in diverse environments.
  - **Active Creatures**: Generally more active.
  - **Fixed Osmotic Concentration**: Body fluids maintain a constant osmotic concentration.
  - **Energy Consumption**: Significant energy is used to maintain constancy.

Conformers (Ectotherms)

- **Mechanism**: Depend on external environmental changes and cannot regulate their own internal temperature.
- **Examples**: Amphibians, reptiles, insects (cold-blooded).
- **Characteristics**:
  - **External Temperature Dependence**: Body temperature changes with the environment (cold-blooded).
  - **Narrow Distribution**: Limited to specific environments.
  - **Less Active**: Generally less active.

- **Variable Osmotic Concentration**: Body fluids' osmotic concentration fluctuates with the external medium.
- **Energy Efficiency**: Less energy is used to maintain constancy.

Comparison of Regulators and Conformers

- **Homeostasis**:
  - Regulators: High level.
  - Conformers: Lower level.
- **Internal Heat Regulation**:
  - Regulators: Generate internal heat (warm-blooded).
  - Conformers: Body temperature varies with surroundings (cold-blooded).
- **Distribution**:
  - Regulators: Wide.
  - Conformers: Narrow.
- **Activity Levels**:
  - Regulators: Active.
  - Conformers: Less active.
- **Osmotic Concentration**:
  - Regulators: Fixed.

  - Conformers: Fluctuates.

- **Energy Use**:
  - Regulators: High.
  - Conformers: Low.

Coping Mechanisms for Stressful Environments

Migration

- **Definition**: Temporary movement to a more hospitable area to escape stressful conditions, with a return when the stress period is over.

Suspension

1. **Hibernation**:
   - **Definition**: A state of low metabolic rate, reduced heartbeat, slow breathing, and low body temperature.
   - **Preparation**: Animals build up body fat during late summer and autumn for energy during winter hibernation.
2. **Aestivation**:
   - **Definition**: A state to avoid summer-related heat and desiccation.
   - **Examples**: Snails, fish.
3. **Diapause**:

- **Definition**: A stage of suspended development seen in many zooplankton species in lakes and ponds.

4. **Brumation**:
    - **Definition**: A state of sluggishness, inactivity, or torpor exhibited by reptiles (e.g., snakes, lizards) during winter or extended periods of low temperature.

Trophic Levels

- **Definition**: Trophic levels represent the different positions that organisms occupy in a food chain, illustrating the flow of energy within an ecosystem.
- **Levels**:
    - **Autotrophs (Producers)**: Green plants and algae (TL 1).
    - **Heterotrophs**:
        - **Herbivores (Primary Consumers)**: TL 2.
        - **Carnivores (Secondary Consumers)**: TL 3.
        - **Carnivores (Tertiary Consumers)**: TL 4.
        - **Top Carnivores (Quaternary Consumers)**: TL 5.
- **Energy Flow**:
    - Energy flows in a unidirectional manner, decreasing from the first trophic level to the next.

- Typically, there are no more than four to five trophic levels due to the diminishing energy.

- **Species Flexibility**:
  - An organism may occupy more than one trophic level simultaneously, representing functional levels rather than species-specific roles. For example, a sparrow is a primary consumer when eating seeds and a secondary consumer when eating insects.

Producers (Autotrophs)

- **Role**: Plants and algae produce their own food through photosynthesis, serving as the primary producers.
- **Energy Source**: They utilize energy from the sun, with about 50% of sunlight radiation being photosynthetically active, supporting photosynthesis within the 400-700 nm wavelength range. However, only 2-10% of this energy is captured by plants.
- **Exception**: In deep-sea hydrothermal ecosystems, primary producers use chemosynthesis instead of photosynthesis to manufacture food.

Consumers (Heterotrophs)

- **Role**: These species cannot manufacture their own food and must consume other organisms.

- **Types**:
  - **Herbivores**: Animals that eat primary producers.
  - **Carnivores**: Animals that eat other animals.
  - **Omnivores**: Animals that eat both plants and other animals.

Decomposers

- **Role**: Decomposers break down complex organic matter into inorganic substances like carbon dioxide, water, and nutrients through decomposition.
- **Materials**: Decomposition involves detritus, which includes dead plant remains, animal remains, and fecal matter.

Process of Decomposition

1. **Fragmentation**: Detritivores (e.g., earthworms) break down detritus into smaller particles.
2. **Leaching**: Water-soluble inorganic nutrients are carried into the soil and precipitate as unavailable salts.
3. **Catabolism**: Bacterial and fungal enzymes degrade detritus into simpler inorganic substances.
4. **Humification and Mineralization**:

- **Humification**: Formation of humus, a dark, amorphous, and resistant substance that decomposes slowly and serves as a nutrient reservoir.
- **Mineralization**: Microbes further degrade humus, releasing inorganic nutrients.

- **Conditions**: Decomposition is an oxygen-requiring process influenced by the chemical composition of detritus and climatic factors:
  - **Rate**: Decomposition is slower if detritus is rich in lignin and chitin, but faster if rich in nitrogen and water-soluble substances like sugars.
  - **Climate**: Warm and moist environments favor decomposition, while low temperatures slow it down.

Food Chain

- **Definition**: A food chain represents the transfer of food energy from green plants (producers) through a series of organisms, each of which eats the previous one and is eaten by the next.
- **Example**: Grasses → Grasshopper → Frog → Snake → Hawk/Eagle.

Types of Food Chains

1. **Grazing Food Chain**:

  - Consumers eat plants or plant parts as their food.
  - Example: Grass is eaten by a caterpillar, which is eaten by a lizard, which is then eaten by a snake.
  - **Aquatic Example**: Phytoplankton eaten by zooplankton, which are eaten by fish, and then by pelicans.
  - Called grazing because it starts with grasses.

2. **Detritus Food Chain**:
  - Starts from organic matter of dead and decaying animals and plants, consumed by detritivores or decomposers.
  - In terrestrial ecosystems, a larger fraction of energy flows through the detritus food chain than through the grazing food chain.
  - In aquatic ecosystems, the grazing food chain is the major conduit for energy flow.
  - Detritus food chains may be connected to grazing food chains at some levels, where some organisms of the detritus food chain are prey to grazing food chain animals, and some omnivores (like cockroaches, crows) consume both.

Food Web

- **Definition**: A food web consists of multiple interlinked food chains, representing all the possible paths of energy flow in an ecosystem.
- **Origin**: The concept was introduced by Charles Elton in his 1927 book, "Animal Ecology".
- **Function**: Provides more than one alternative for food, increasing the chances of survival. If any organism in a food chain is removed, consumers can shift to another organism within the food web.
- **Limitation**: Decomposers (detritivores) are often not included in food webs.

Species Interaction

- **Types of Biotic Interactions**:
  - **Negative Interactions**:
    - **Amensalism (-, 0)**: One species is harmed while the other is unaffected. Example: Large tree vs. small plant (large tree blocks light to small plant).
    - **Predation (+, -)**: One species benefits while the other is harmed. Example: Tick vs. host.
    - **Competition (-, -)**: Both species are harmed as they compete for the same resource in short supply.

- **Positive Associations**:
  - **Commensalism (+, 0)**: One species benefits while the other is unaffected. Example: Suckerfish vs. shark, epiphytic plants on trees, barnacles on whales, plover birds cleaning crocodiles' teeth.
  - **Mutualism (+, +)**: Both species benefit. Example: Coral and zooxanthellae, lichens (fungi and algae), hermit crab and sea anemone.

Mutualism vs. Symbiosis

- **Mutualism**: A functional association where both species benefit. It can be:
  - **Obligatory**: Species are completely dependent on each other.
  - **Facultative**: One species can survive without the other.
- **Symbiosis**: A close and prolonged association between two different species, where both are entirely dependent on each other.
  - **Neutral Interactions**:
    - **Neutralism (0, 0)**: True neutralism, where neither species affects the other, is extremely unlikely.

Ecological Pyramids

Ecological pyramids graphically represent the structure and energy flow of an ecosystem by depicting the relationship between different trophic levels. They are categorized into three types:

1. **Pyramid of Numbers**
2. **Pyramid of Biomass**
3. **Pyramid of Energy or Productivity**

1. Pyramid of Numbers

- **Definition**: Represents the total number of individual organisms at each trophic level.
- **Characteristics**:
  - **Upright Pyramid**: Shows a decreasing number of individuals from lower to higher trophic levels. For example, in a grassland or pond ecosystem, there are many producers (plants) and fewer herbivores and carnivores.
  - **Inverted Pyramid**: Shows an increasing number of individuals from lower to higher trophic levels. This occurs in parasitic food chains where one producer supports numerous parasites, which in turn support even more hyper-parasites. Example: Tree ecosystems, where one large tree supports many insects and other organisms.

2. Pyramid of Biomass

- **Definition**: Represents the total biomass (living organic matter) present at each trophic level in an ecosystem. It can be expressed in terms of dry weight or energy content (calories per unit area).
- **Characteristics**:
  - **Upright Pyramid**: Common in terrestrial ecosystems where a large biomass of primary producers supports a smaller biomass of primary consumers, secondary consumers, and so on. Example: Forest ecosystems, where the base has a large biomass of plants and the top levels have significantly less biomass.
  - **Inverted Pyramid**: Seen in aquatic ecosystems where the biomass of primary producers (e.g., phytoplankton) is much smaller compared to the biomass of consumers. This occurs because phytoplankton have a high turnover rate (rapid growth and reproduction), supporting a larger biomass of higher trophic levels. Example: Marine ecosystems, where small phytoplankton support larger fish and marine animals.

3. Pyramid of Energy or Productivity

- **Definition**: Shows the flow of energy through different trophic levels and is always upright. It represents the amount of energy available at each trophic level over time.

- **Characteristics**:
  - Energy decreases as you move up the trophic levels due to energy loss (typically about 90% of energy is lost at each level through metabolic processes, heat, and waste).

Phytoplankton

- **Definition**: Microalgae or autotrophic plankton that float in the surface waters of aquatic ecosystems. They can be either chemosynthetic or photosynthetic.
- **Characteristics**:
  - **Photosynthetic Phytoplankton**: Found in the upper layers of water bodies where sunlight is available. Examples include diatoms and dinoflagellates.
  - **Chemosynthetic Phytoplankton**: Found in deep, dark sections of water bodies, where sunlight does not reach. They derive energy from chemical reactions rather than sunlight.
- **Importance**: Phytoplankton form the base of aquatic food chains, contributing significantly to primary production and oxygen production in aquatic environments.

Secondary Productivity

Secondary Productivity refers to the rate at which new organic matter is formed by consumers in an ecosystem. This includes herbivores, carnivores, and omnivores that convert primary producers (plants) into biomass through consumption.

Key Points:

- **Dependence**: Secondary productivity is influenced by:
    - The type of primary producers present (e.g., plants, algae).
    - Environmental factors such as temperature, humidity, and nutrient availability.
    - The efficiency with which consumers convert consumed food into new biomass.

Primary Production in the World's Ecosystems

Primary Production is the creation of organic compounds by primary producers (plants, algae, and some bacteria) through processes like photosynthesis.

Most Productive Ecosystems:

- **Net Primary Production (NPP) per Unit Area**: Estuaries, swamps and marshes, tropical rainforests, and temperate rainforests are highly productive in terms of NPP per unit area.
- **Total NPP**: When accounting for the total area, open oceans, tropical rainforests, savannas, and tropical seasonal forests become the most productive ecosystems due to their vast coverage.

Pyramid of Energy

Pyramid of Energy represents the amount of energy available at each trophic level and the loss of energy during transfers between levels.

Key Characteristics:

- **Always Upright**: Energy pyramids are always upright because energy decreases as it moves up trophic levels.
- **Energy Transfer**: Approximately 90% of energy is lost between trophic levels due to metabolic processes, heat production, and incomplete digestion.

Lindman's 10% Law

Lindman's 10% Law (1942) states that, on average, only about 10% of the energy from organic matter at one trophic level is transferred to the next higher trophic level.

Implications:

- **Energy Loss**: The remaining 90% is lost due to:
  - Respiration (energy used for metabolic processes).
  - Heat loss.
  - Incomplete digestion and assimilation.
- **Biological Magnification**: This concept helps explain how toxins can become more concentrated at higher trophic levels as they accumulate through the food chain

Pollutants and Trophic Levels

Pollutants that are persistent and non-degradable can accumulate and magnify through different trophic levels in an ecosystem. These pollutants remain in the environment for a long time, leading to potential long-term ecological and health impacts.

Key Concepts

Non-Degradable Pollutants

- **Definition**: Pollutants that do not break down easily in the environment and remain in the same trophic level for extended periods.

- **Examples**: Chlorinated hydrocarbons (organochlorides) like DDT (dichlorodiphenyltrichloroethane), endosulfan, chloroform, and carbon tetrachloride.

Processes of Movement

1. **Bioaccumulation**
   - **Definition**: The gradual accumulation of pollutants or chemicals in an organism over time. This occurs when an organism absorbs a substance at a faster rate than it can eliminate it.
   - **Example**: DDT accumulating in fish or other organisms at the beginning of the food chain.

2. **Biomagnification**
   - **Definition**: The progressive increase in concentration of a pollutant at each trophic level as it moves up the food chain. This occurs because each trophic level accumulates the pollutant from all the organisms it has consumed.
   - **Requirements**: The pollutant must have a long biological half-life, be fat-soluble, and not readily excreted.
   - **Example**: DDT concentration increasing from plankton to fish, then to larger predators like birds or mammals.
3. **Bioconcentration**
   - **Definition**: The accumulation of a chemical in an organism solely from the surrounding water.
   - **Process**: Occurs when the concentration of a pollutant in the organism is higher than in the surrounding environment, due to uptake from water.

Properties of Bioaccumulants and Biomagnificants

- **Movement Up the Food Chain**: Bioaccumulants tend to move up the food chain, concentrating more at higher trophic levels.
- **Non-Biodegradable**: These substances have long lifespans and do not degrade easily, leading to persistent environmental presence.

- **Fat Solubility**: They are typically fat-soluble, meaning they are stored in fatty tissues and not easily excreted, which can lead to transfer through food and mother's milk.
- **Health Impacts**: Can lead to various health issues, such as:
  - **Minamata Disease**: Caused by mercury, leading to neurological damage, blindness, hearing loss, and muscle weakness.
  - **Cancer**: Plastics, such as polyethylene and polyvinyl chloride, are linked to increased cancer rates.

Plastic Pollution

- **Health Risks**: Plastics, especially polyethylene and PVC, are associated with various health issues, including cancer.
- **Alternatives**: Efforts are being made to replace harmful plastics with safer alternatives such as high-density polyethylene (HDPE) and polyethylene terephthalate (PET). However, PET has limitations, including poor resistance to high temperatures, leading to a focus on developing bioplastics