ENVIRONMENTAL ECOLOGY

पर्यावरण पारिस्थितिकी

Class Notes (English)

- Basic Concepts of Environmental Ecology
- Biodiversity
- Wildlife Conservation
- Forest Resources and Conservation
- Atmospheric Pollution
- Protection of Aquatic Systems
- Other Issues Related to Pollution
- India: Environmental Policy, Legislation, Institutions, Schemes etc.
- Global Treaties, Institutions, Processes, etc.
- Others

KHAN GLOBAL STUDIES
Most Trusted Learning Platform

ENVIRONMENTAL ECOLOGY

1. Introduction To Ecology

- Ecology is the **study of organisms and how they interact** with the environment around them.
- The term was coined by the **German zoologist, Ernst Haeckel, in 1866** to describe the economies of living forms.
- It comes from the Greek word **'Oikos'** meaning **home** or place to live in and **'logos'** meaning **study.**

1.1. Types of Ecology

Global Ecology

- It is the **study of the Earth's ecosystems** among the land, oceans, and atmosphere.

Landscape Ecology

- It deals with **spatial distribution, patterns, and behaviors** across large geographical areas.
- Landscape ecologists might study the impact of development on a particular species of native grass in a specific area.

Population Ecology

- It studies the **rise and fall in the number of a species.**
- Population ecologists may compare the population of a species near a new food source to a population that lacks access to that food source.

Microbial Ecology

- It looks at the **smallest fundamental levels of life,** that is, the **cellular level.**
- Involves mainly the first two life kingdoms: Kingdom Monera and Kingdom Protista.
- Connections are made between microbes and their relationships with each other and their environments.

Behavioral Ecology

- It studies the different ways organisms **evolve and adapt to changes** in their habitat.
- Behavioral ecologists often study **mating patterns,** or what characteristics male and female animals prefer when seeking to reproduce.

Community Ecology

- It focuses on how **interactions between living things alter community structure.**
- Community ecologists study interspecific interactions, like predator-prey and competition.

Ecosystem Ecology

- It is the study of **interactions between living (biotic) and non-living (abiotic)** elements within an ecosystem framework.
- It includes understanding how things like climate and soil composition affect the behaviours and interactions of populations from different species.

Deep Ecology

- A new area of study which proposes that human beings function as a part of the environment, not in opposition to it.
- It is more **related to philosophy and political science** than other branches of ecology.

1.2. Autecology and Synecology

Autecology	Synecology
Study of an individual organism or individual species or a population in relation to their environment.	**Study of groups of organisms or many species** or communities in relation to their environment.
Also called population ecology.	Also called community ecology.
Comparatively **simple** experimental and inductive.	**Complex**, philosophical and deductive.
Example: Study of Zebra population in relation to its environment	**Example:** Study of the entire grassland ecosystem.

2. Levels of ecological organisations

Individual

- Organism that has the **ability to act or function independently.**
- Single, may be any type of living organism like plant, bacterium, fungi, etc.

Population

- Total of all living organisms of the **same species living and interacting in a particular area and are** capable of interbreeding.
- The main limiting factors for the growth of a population are abiotic and biotic components.

Community

- Different types of population **interacting at a particular geological area** form a community.
- **Two Types:** Major community and Minor community

Major Community

- A large community that functions as a **self-regulating, self-sustaining, and independent unit.**
- Major communities are relatively independent of other communities and include several minor communities.
- **Example:** a pond ecosystem.

Minor Community

- A more compact community that is **not individually self-sustaining and relies on interactions** with other communities.
- **Example:** a collection of organisms living in a piece of deadwood.

Ecosystem

- **A naturally occurring assemblage of organisms** living together with their environment and functioning as a loose unit.
- It is a relatively **self-contained, dynamic system** composed of a natural community along with its physical environment.

Biome

- The world's **major communities,** classified according to the **predominant vegetation** and characterized by **adaptations** of organisms to that particular environment.

Biosphere

- It is made up of the parts of Earth where life exists—**all ecosystems.**
- A highly interacting zone comprising atmosphere, hydrosphere and lithosphere.

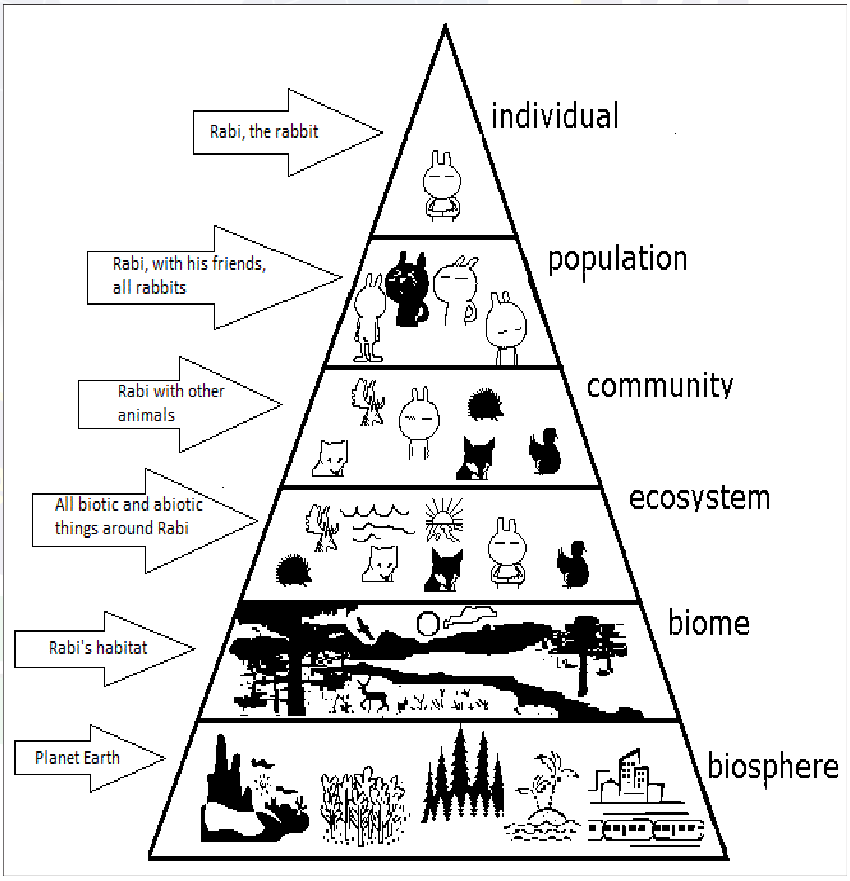

Figure.1. Levels of Organisations in Ecology

3. Processes at different levels of ecological organisations

3.1. Population

3.1.1. Population Density

- It is the **concentration of individuals within a species** in a specific geographic locale.
- It can be used to describe the location, growth, and migration of many organisms.

3.1.2. Population Distribution

- Population distribution describes **how the individuals are distributed,** or spread throughout their habitat.

Patterns of Population Distribution

Uniform

- Organisms are **evenly spaced** over the area they occupy.
- This is typical of species in which individuals compete for a scarce environmental resource, such as water in a desert.

Random

- Organisms have an **unpredictable distribution.**
- This is typical of species in which individuals do not interact strongly.

Clumped

- Organisms are **clustered together in groups** and this may reflect a patchy distribution of resources.
- This is the **most common pattern** of population distribution.

3.1.3. Factors Affecting Population Growth

- **Natality:** Refers to the number of **births** during a given period in the population that are added to the initial density.
- **Mortality:** Number of **deaths** in the population during a given period.
- **Immigration:** Number of individuals of the same species that have **come into the habitat from elsewhere** during the time period under consideration.
- **Emigration:** Number of individuals of the population who **left the habitat** and gone elsewhere during the time period under consideration.

3.1.4. Survivorship Curve

There are three general types of survivorship curves.

- **Type I:** Characterized by **high survival in early and middle life,** followed a **rapid decline in** survivorship in **later life.**
- **Type II:** Intermediate between Type I and III, where roughly **constant mortality rate** is experienced regardless of age.
- **Type III: Greatest mortality** is experienced **early on in life,** with relatively low rates of death for those surviving this bottleneck. Characteristics of species that produce a large number of offspring.

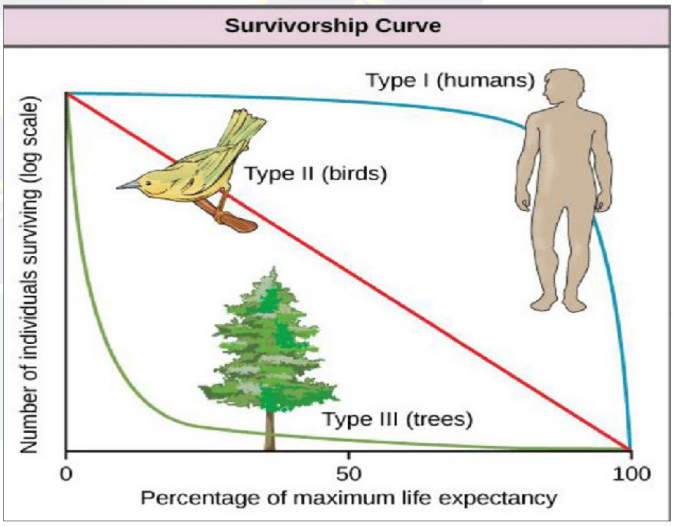

Figure.2. Survivorship curve

3.1.5. Growth Pattern

Exponential Growth (r-Adapted Growth)

- Under ideal conditions, populations of most species can grow at exponential rates.
- There is **no competition to place limits** on a geometric rate of growth.
- The population starts out growing slowly. As population size increases, the growth rate also increases,

resulting in an exponential **(J-shaped) curve.**

- Can be seen in populations that are very small or in regions that are newly colonized by a species.
- If a population of size N and birth rate be represented as b, death rate as d, then the rate of change of N can be given by the equation:

  $dN/dt = rN$, where r = intrinsic rate of natural increase

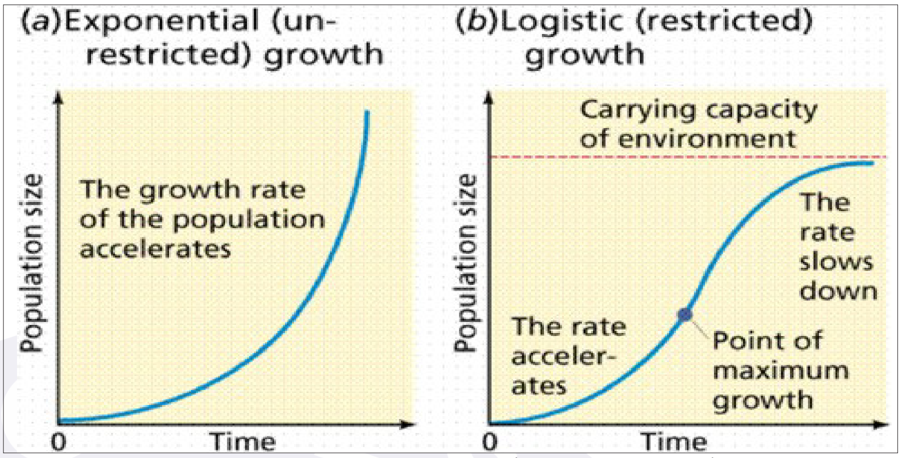

Figure.3. Growth pattern Logistical

Growth (K-Adapted Growth)

- Occur when population numbers begin to approach **a finite carrying capacity.**
- Carrying capacity (K) defines the **limit of the resources beyond which they cannot support** any number of organisms.
- A population growing in a habitat with limited resources **shows initially a lag phase,** followed by phases of acceleration and deceleration **and finally an asymptote.**
- This is known as **Verhulst-Pearl Logistic Growth** and is represented using theequation:

  $dN/dt = rN((K-N)/K)$

3.1.6. Population Stabilization

- The inherent tendency of the population is to increase in number.
- But this increase in number is not infinite since the **carrying capacity** of the environment **always imposes a restriction** upon it.
- Population is regulated by two factors: Density independent factors and Density dependent factors.

Density Independent Factors

- The **extrinsic factors** are density independent factors. They are not connected with population density. **Example:** food, space, shelter, weather, etc.

Density Dependent Factors

- They are **intrinsic factors** and arise within the population.
- They are connected with the population and include competition, predation, emigration, reproductivity, diseases, etc.

3.2. Community

3.2.1. Characteristics of a Community

3.2.1.1. Species Diversity

- Species diversity is a **product of richness and evenness;** it is species richness weighted by species evenness.
- **Species richness** is the **number of species** in a community and the **distribution of individuals among the species** is called **species evenness.**
- Whittaker (1965) described three types of diversity:
  - ✓ **α-index diversity** (diversity within one community,
  - ✓ **β-index diversity** (diversity between communities), and
  - ✓ **γ-index diversity** (diversity in the ranges of communities).

Diversity Indices

- A diversity index is a **mathematical measure of species diversity** in a community.
- It is **a measure of the number of species in an area** and the relative abundance of individuals among those species.

- Species diversity is calculated by various methods such as:
  - Simpson's index
  - Shannon Leaver index
  - Odum's species per thousand individuals
  - Kothe's deficit index

3.2.1.2. Dominance

- A community has many species, of which **one or few species play a dominant role** in the community by virtue of their number, size and activities.
- Species structure in most communities is either abundant or rare.

3.2.1.3. Ecological Niche

- Ecological niche is defined as the **role or function of species it plays in its ecosystem.**
- In the ecological complex, different plants and animals of different species differ in their function and their combined interactions with other species in its environment.
- It can also be defined as the small habitat of single species within a large habitat in which it survives.

3.2.1.4. Ecotone and Edge-effect

- **An area or zone of transition** between two or more diverse communities is known as an ecotone. Changes in the physical environment create ecotones.
- **Example:** Between forest and grassland or between a soft-bottom and a hard-bottom marine substrate.
- The ecotonal community commonly contains many of the organisms of each of the overlapping communities in addition to organisms characteristic of and often restricted to ecotones.
- The tendency for **increased variety and density of species at community junctions** is known as the **edge effect.**
- The edge effect is thus, along the boundary line, an area displaying a greater than usual diversity of species.
- **Species that use edges** for the purpose of **reproduction or survival** are frequently termed as **edge species.**

3.2.1.5. Keystone Species

- A keystone species is a species that has a disproportionate effect on its environment relative to its abundance.
- An ecosystem may experience a dramatic shift if a keystone species is removed, even though that species was a small part of the ecosystem by measures of biomass or productivity.
- Their very presence contributes to a diversity of life and their extinction would consequently lead to the extinction of other forms of life.
- **Example:** Birds called Blue Jays (Cyanocitta cristata), disperse seeds that give rise to oak forests. Without Blue Jays, oak forests are not naturally replenished and without the forests, all other species in the ecosystem cannot survive.

3.2.1.6. Interspecific Interactions in a Community

- Populations of two species may interact in basic ways that correspond to **combinations of neutral, positive, and negative** (0, +, and -) as follows: 00, - -, + +, + 0, - 0, and + -.
- Three of these combinations (+ +, - -, and + -) are commonly subdivided, resulting in nine important interactions and relationships.
  - **Neutralism,** in which neither population is affected by association with the other;
  - **Competition, direct interference type,** in which both populations actively inhibit each other;
  - **Competition, resource use type,** in which each population adversely affects theother indirectly in the struggle for resources in short supply;
  - **Amensalism,** in which one population is inhibited and the other not affected;
  - **Commensalism,** in which one population is benefited, but the other is not affected;

- **Parasitism;** and Predation, in which one population adversely affects the other by direct attack but nevertheless depends on the other;
- **Protocooperation,** in which both populations benefit by the association but their relations are not obligatory; and
- **Mutualism,** in which the growth and survival of both populations is benefited, and neither can survive under natural conditions without the other.

Analysis of two-species population interactions

Type of interaction	*Species 1*	*Species 2*	*General nature of interaction*
Neutralism	0	0	Neither population affects the other
Competition, direct interference type	–	–	Direct inhibition of each species by the other
Competition, resource use type	–	–	Indirect inhibition when common resource is in short supply
Amensalism	–	0	Population 1 inhibited, 2 not affected
Commensalism	+	0	Population 1, the *commensal,* benefits, while 2, the *host,* is not affected
Parasitism	+	–	Population 1, the *parasite,* generally smaller than 2, the *host*
Predation (including herbivory)	+	–	Population 1, the *predator,* generally larger than 2, the *prey*
Protocooperation	+	+	Interaction favorable to both but not obligatory
Mutualism	+	+	Interaction favorable to both and obligatory

Note: 0 indicates no significant interaction; + indicates growth, survival, or other population attribute benefited (positive term added to growth equation); – indicates population growth or other attribute inhibited (negative term added to growth equation).

Figure.4. Interspecific Interactions in a Community

Symbiosis

- An interaction characterized by **two or more species living purposefully** in direct contact with each other.
- **Example:** Symbiosis in lichens (combination of a fungal partner (mycobiont) and an algal partner (phycobiont).
- Three major types: mutualism, commensalism and parasitism.

Mutualism

- Mutualism can be **either obligate or facultative.**
- Species involved in **obligate mutualism cannot survive** without the relationship. **Example:** leafcutter ants and certain fungi have an obligate mutualistic relationship.
- **Facultative mutualistic species can survive individually** when separated but often not as well. **Example:** relationship between mycorrhizal fungi and plant roots.

Commensalism

- Commensalism can be **difficult to identify** because the individual that gets benefit may have **indirect effects** on the other individual that are **not readily noticeable** or detectable.
- **Example:** Epiphytes widely found in tropical rainforests grow on the branches of trees in order to access light, but the presence of them does not affect the trees.

Parasitism

- Parasitism is a good example of how species interactions are integrated.
- Parasites typically do not kill their hosts, but can significantly **weaken them.**
- Example: trematode that parasitizes certain aquatic snails.

3.2.1.7. Energy flow in a Community

- Through the series of steps of eating and being eaten, energy flows from one trophic level to another.
- Green plants or other photosynthesizing organisms use light energy from the Sun to manufacture carbohydrates for their own needs.
- This stored energy is transferred to the second trophic level, which comprises grazing herbivores, decomposers, and detritus feeders.
  - **Detritivore** is a **heterotrophic organism,** which obtains its nutrition by **feeding on detritus,** i.e., decomposing plant and animal parts. **Example:** beetles, butterflies, earthworms, millipedes, woodlice, etc.
- Most of the energy assimilated at the second trophic level is again lost as heat in respiration, as energy used for movement, and energy is lost as waste.
- Organisms in each trophic level pass much less energy than they receive as biomass.
- The decomposers break down the bodies of the animals and plants when they die, releasing and utilizing much of the energy stored within them.
- In general, the more steps between producer and final consumer, the less energy remains available.

- Eventually, all **energy flowing** through the trophic levels is **dissipated as heat.** The process whereby energy loses its capacity to do useful work is called **entropy.**

3.2.1.8. Ecological Succession

- Ecological succession is the **process** by which the structure of a **biological community evolves over time.**
- This can be caused by a number of factors, including changes in climate, the arrival of new species, or the removal of a dominant species.
- Two different types of succession—primary and secondary.

Primary Succession

- **Occurs in essentially lifeless areas—**regions in which the soil is incapable of sustaining life as a result of such factors as lava flows, newly formed sand dunes, or rocks left from a retreating glacier.

Secondary Succession

- Occurs in areas where a **community that previously existed has been removed;** it is typified by smaller-scale disturbances that do not eliminate all life and nutrients from the environment.

Seral Stages and Climax Community

- The **sequential progression of species** during succession is known as **sere or seral stages.**
- At every seral stage certain species are present which can exploit the particular conditions of the community.
- **One seral stage is replaced by another seral stage** till a climax community (stable community) is established.
- These changes allow other species that are better suited to this modified habitat to succeed the old species.

Changes Occurring during Community Succession

Habitat conditions	Changes from Hydrism or Xerism to Mesism
Soil	Maturation of soil and development of soil profile.
Mineral cycles	Open in the beginning. Closed later on.
Nutrients exchange amongst organisms, detritus and soil	Poor initially. Later becomes important.
Biochemical diversity	Low to high.
Community	Simple short lived to complex long lived.
Species composition	Changes rapidly in the beginning, more gradually later and then becomes almost stable.
Species diversity	Increases in the beginning declines later on.
Number of autotrophs	Increases in the beginning but declines later on to become stable.
Number of heterotrophs	Increases to become stable
Total biomass	Increases
Food chains	Become complex and form food webs
Net primary productivity	Increases to stable level in the meadow stage, shows linear progress again and later becomes stable.

Plant Succession

- Plant succession is an orderly **process of community change in a unit area.**
- The community passes through several developmental stages in a definite sequence from simple to complex.

Types of Succession

Based on origin

- **Primary succession:** Formation of an ecosystem from bare rock, sand or clear glacial pool **where previous life does not exist.**
- **Secondary succession:** Formation of a new ecosystem after the disturbance of an existing ecosystem.
  - The succession progressing on such an area is also termed as **subsere.** The **climax is reached very quickly** in the secondary succession.
  - Causes of destruction of the previous community: landslides, earthquakes,volcanic eruption, fire, or cut down by farmers for cultivation.

Based upon factors responsible for environment changes

- **Autogenic succession: Organisms themselves bring change** in the environment during succession.
- **Allogenic succession: External environmental factors cause change** in the environment during succession. **Example:** application of nitrogenous fertilizers, which increases the growth of vegetation.

Based on habitat

- **Hydrosere:** when the succession starts in **aquatic environments** such as ponds, lakes, swamps, etc.
- **Xerosere:** the successional stages occur in the **desert area or in dry habitats.**
  - **Lithosere:** succession occurs in the rocky area; and
  - **Psammosere:** succession occurs in the sand.
- **Halosere:** succession starting on saline soil or water.
- **Oxylosere:** Succession on acidic soil

Hydrosere: 7 stages

- **Phytoplankton stage**
  - Aquatic plants (phytoplankton) and animals (zooplankton) add large amounts of organic matter and nutrients in water due to their various life activities.
  - After their death, they settle at the bottom of the pond to form a layer of muck.
- **Submerged Stage**
  - The developing layer on the bottom creates a substrate for rooted submerged hydrophytes such as Hydrilla, Elodea, etc.
  - These plants reproduce an increasing number and add organic matter after their death.
- **Floating Stage**
  - Broad-leafed plants of floating type **grow and provide shade,** and due to the absence of light, algal growth is reduced and ultimately eliminated.
  - These broad leaves intercept more soil particles from the air, evaporate more water. Ultimately, water height is reduced, and the **pond becomes shallower.**
- **Reed Swamp Stage**
  - Vegetations are finally anchored in the bottom muck by spreading their fibrous roots and rhizomes.
  - Shoots of the plants are partly entirely exposed to the air, and they intercept more soil particles, and the water body silt up.
- **Marsh Meadow Stage**
  - The remnant land of the open pond dries up in summer and freezes in winter.
  - **Drainage improves,** the soil lies above the water, and organic matter exposed tothe air decomposes rapidly. The meadow starts to grow there.
- **Woodland Stage**
  - This stage is characterized by the **plants that can tolerate water-logged soil** around their roots.
  - By this time, a mass accumulation of humus and mineralization of soil favors the new tree species.

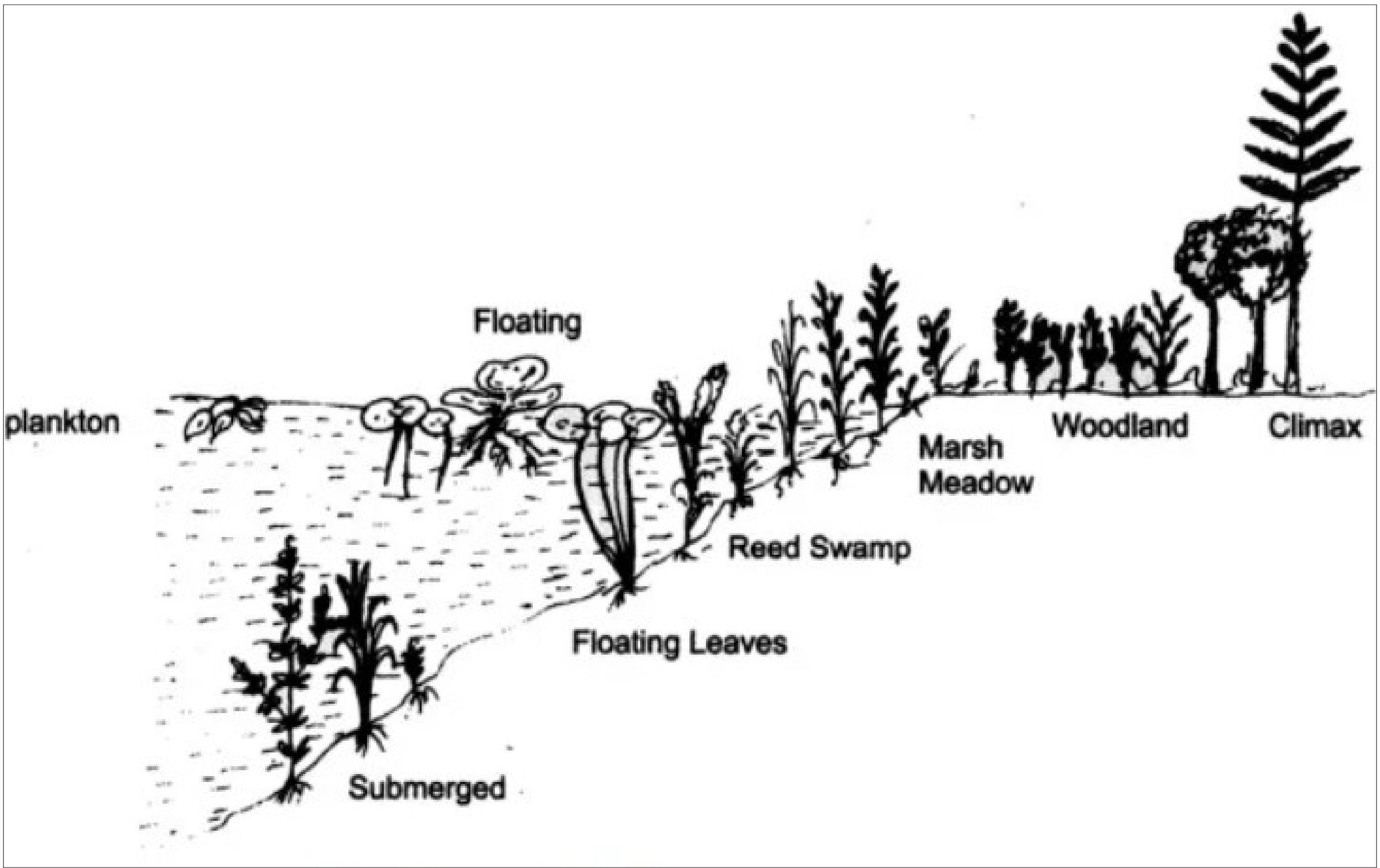

Figure.5. Stages in Hydrosere

- **Climax**
  - ✔ Vegetation gets the ultimate shape in this stage. The vegetation may be of any type, depending upon prevailing environmental conditions.

Xerosere: 6 Stages

- **Crustose-lichen stage**
  - ✔ These are able to withstand extreme desiccation due to excessive dryness.
  - ✔ During the rainy season they absorb large quantities of water and flourish rapidly.
  - ✔ Crustose lichens **produce some acids** which bring about **weathering of rocks.**
  - ✔ The organic matter of algae becomes mixed with the small particles of rocks to form the very thin layer of soil on the rocks.
- **Foliose-lichens Stage**
  - ✔ As soon as little soil is formed, higher forms of lichens (foliose-lichens) appear.
  - ✔ They overlap the crustose-lichens and cause their gradual death and decay.
  - ✔ **More and more humus accumulates** and gradually a thin layer of soil is formed.
  - ✔ Associated with the lichens a few mites and then spiders make their appearance in cracks and crevices of the rock.
- **Mosses Stage**
  - ✔ The development of a **thin humus-rich soil layer** on the rock surface favors the growth of some **xerophytic mosses.**
  - ✔ These mosses grow, compete with the lichens and add more organic matter to the soil after death and decay.
  - ✔ The accumulated thick layer of soil retains a greater amount of water.
  - ✔ It provides suitable habitat for the invasion of herbs, grasses, and ferns.

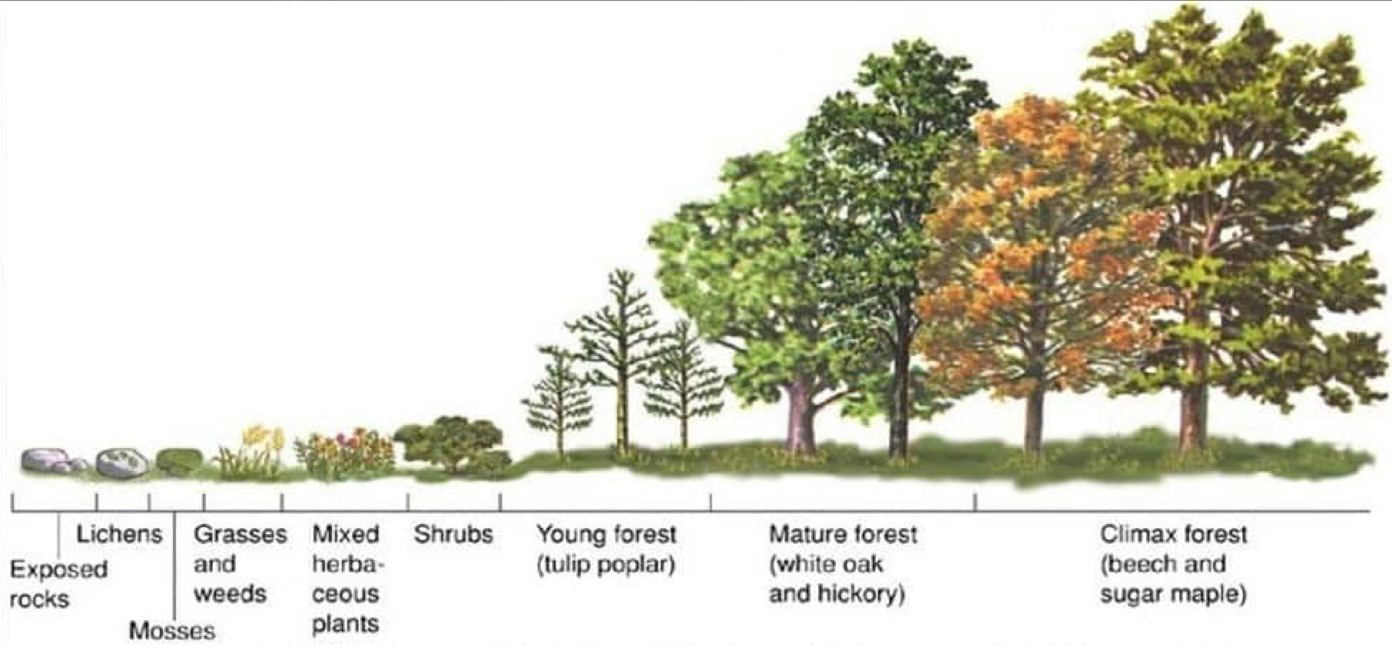

Figure.6. Stages in Xerosere

- **Herb Stage**
  - The weathering of rocks by physical, chemical, and biological means provides more soil and nutrients.
  - Various bacteria and fungi decompose the accumulated organic matter.
  - Certain larger herbs and grasses enter the community.
- **Shrub Stage**
  - On the soil, thus prepared by lichens, mosses, and herbs, shrubs find favorable conditions for their growth.
  - They **over-sheds the herbaceous vegetation** and produce more organic matter.
- **Climax Stage/Vegetation**
  - With the establishment of shrubs, more and more soil is formed and the **environment becomes increasingly humid.** This favours the growth of woody trees.
  - In the beginning, trees show stunted growth and are sparsely placed. Then a climax forest community is established.

3.3. Ecosystem

3.3.1. Components of the Ecosystem

Biotic Components

- **Living components** or factors that affect an ecosystem or other organisms living in that ecosystem.
- Divided into three categories: Autotrophs, Heterotrophs and Saprotrophs.

Autotrophs

- Derived from the two Greek words **'auto', meaning self,** and **'trophe', meaning nutrition.**
- An autotroph is an organism that can make its own food.
- They **synthesize organic nutrients from inorganic materials,** using energy from sunlight or a chemical source to drive the process.
- **Photolithoautotrophs:** Plants, algae, cyanobacteria and some eubacteria that **derive energy from light.**
- **Chemolithoautotrophs:** Bacteria that **utilize the oxidation of inorganic compounds** such as hydrogen sulfide or ferrous iron as an energy source.

Heterotrophs

- A heterotroph (Greek **heteron = (an) other** and **trophe = nutrition)** is an organism that **requires organic substrates** to get its carbon for growth and development.
- All animals are heterotrophic, as well as fungi and many bacteria.
- Heterotrophs are unable to synthesize organic, carbon based compounds independently from the inorganic environment's sources.

Decomposers

- Decomposers are organisms (often fungi or bacteria) that **break down organic materials to gain nutrients and energy.**
- When an organism dies, it leaves behind nutrients that are locked tightly together.
- A scavenger may eat the carcass, but its feces still contains a considerable amount of unused energy and nutrients.
- Decomposers such as fungi will later induce further breakdown. This last step releases raw nutrients in a form usable to plants, which quickly incorporate the chemicals into their own cells.
- This process greatly increases the nutrient-load of an ecosystem, in turn allowing for greater biodiversity.

Abiotic Components

- Abiotic components are **non living chemical and physical factors** in the environment.
- Important Abiotic Components are 7 in number: Light, temperature, water, atmospheric gases, wind, soil (edaphic) and physiographic (nature of land surface) factors.

Light

- Light energy (sunlight) is the primary source of energy in nearly all ecosystems.
- It is the energy that is used by green plants during the process of photosynthesis.
- Plants which grow well in bright sunlight are called **heliophytes** and plants which grow well in shady conditions are known as **sciophytes.**
- Factors such as quality of light, intensity of light and the length of the light period (day length) play an important part in an ecosystem.

Terms Related to Light

Phototropism

- Directional growth of plants in response to light where the direction of the stimulus determines the direction of movement.

Phototaxis

- Movement of the whole organism in response to a unilateral light source, where the stimulus determines the direction of movement.

Photokinesis

- Variation in intensity of locomotory activity of animals which is dependent on the intensity of light stimulation, and not the direction.

Photonasty

- Movement of parts of a plant in response to a light source, but the direction of the stimulus does not determine the direction of the movement of the plant.

Temperature

- The distribution of plants and animals is greatly influenced by extremes in temperature for instance the warm season.
- The **occurrence or non-occurrence of frost** is a particularly important determinant of plant distribution since many plants cannot prevent their tissues from freezing or survive the freezing and thawing processes.

Water

- Plant and animal habitats vary from entirely aquatic environments to very dry deserts.
- Plants can be classified into 3 groups according to their water requirements:
  - ✔ **Hydrophytes:** plants which grow in water, e.g. water-lilies and rushes.
  - ✔ **Mesophytes:** plants with average water requirements, e.g. roses, sweet peas.
  - ✔ **Xerophytes:** plants which grow in dry environments where they often experience a shortage of water, e.g. cacti and often succulents.

Atmospheric Gases

- The most important gases used by plants and animals are oxygen, carbon dioxide and nitrogen.

Wind

- Winds or air currents arise on a world-wide scale as a result of a complex interaction between **expanding and rising hot air** and the various effects of the rotation of the earth.
- Hot air rises mostly because of convection at the equator and at mid-latitudes.
- The earth's rotation results in a centrifugal force at mid- latitudes. This force is known as the **Coriolis force** and tends to deflect winds.
- Winds carry water vapour which may condense and fall in the form of rain, snow or hail.
- Wind plays a role in **pollination and seed dispersal** of some plants, as well as the dispersal of some animals, such as insects.

Soil (edaphic factors)

- These factors include soil texture, soil air, soil temperature, soil water, soil solution and pH, together with soil organisms and decaying matter.

Physiographic factors

- These factors are those associated with the physical nature of the area, such as altitude, slope of land and the position of the area in relation to the sun or rain-bearing winds.

3.3.2. Types of the Ecosystem

Aquatic Ecosystem

- All such ecosystems that are primarily **located on or inside water bodies.**
- Sub-divided into: Freshwater Ecosystem and Marine Ecosystem.

Terrestrial Ecosystem

- All such ecosystems which are mainly l**ocated on land.**
- Sub-divided into: Forest, grassland, mountain and desert ecosystem.

3.3.3. Functions of Ecosystem

It means exchange of matter and energy between abiotic and biotic components.

Producer Level

- The fundamental source of energy in almost all ecosystems is energy from the sun.
- The energy of sunlight is used by the ecosystem's autotrophic organisms.
- Autotrophs use the energy stored within the simple carbohydrates to **produce the more complex organic compounds.**
- The autotrophic segment of the ecosystem is commonly referred to as the producer level.
- Organic matter generated by autotrophs directly or indirectly **sustains heterotrophic organisms.**

Trophic Levels and Food Chain

- Together, the autotrophs and heterotrophs form various trophic (feeding) levels in the ecosystem:
  - the **producer level,** composed of those organisms that make their own food;
  - the **primary-consumer level,** composed of those organisms that feed on producers;
  - the **secondary-consumer level,** composed of those organisms that feed on primary consumers; and so on.
- The movement of organic matter and energy from the producer level through various consumer levels makes up a **food chain.**
- For example, a typical **food chain in a grassland** might be grass (producer) → mouse (primary consumer) → snake (secondary consumer) → hawk (tertiary consumer).
- In the marine food chain, **single-celled organisms** called phytoplankton (including diatoms, Cyanobacteria, etc) are the **primary producers.**
  - Crustaceans are herbivorous animals which feed on diatoms and herrings are carnivorous animals which feed on Crustaceans.
- In many cases the food chains of the ecosystem **overlap and interconnect, forming a food web.**
- The **final link** in all food chains is made up of **decomposers,** ie. those heterotrophs that break down dead organisms and organic wastes.
- A food chain in which the primary consumer feeds on living plants is called a **grazing pathway;** and that in which the primary consumer feeds on dead plant matter is known as a detritus pathway.
- Both pathways are important in accounting for the energy budget of the ecosystem.

Law of 10%

- As energy moves through the ecosystem, much of it is **lost at each trophic level.**
- For example, only about 10 percent of the energy stored in grass is incorporated into the body of a mouse that eats the grass.
- The remaining 90 percent is stored in compounds that cannot be broken down by the mouse or is lost as heat during the mouse's metabolic processes.
- Energy losses of similar magnitude occur at every level of the food chain.
- Only a few food chains extend beyond five members, because the **energy available at higher trophic levels is too small** to support further consumers.

Flow of Energy

- The flow of energy through the ecosystem drives the movement of nutrients within the ecosystem.
- Unlike energy, which is continuously lost from the ecosystem, **nutrients are cycled through the ecosystem,** oscillating between the biotic and abiotic components in what are called **biogeochemical cycles.**
- Decomposers play a key role in many of these cycles, returning nutrients to the soil, water, or air, where they can again be used by the biotic constituents of the ecosystem.

Ecological Pyramid

- An ecological pyramid (or trophic pyramid) is a concept related to ecosystem energetics.
- It is a graphical representation designed to show the biomass or productivity at each trophic level in a given ecosystem.
- Biomass pyramids show the abundance or biomass of organisms at each trophic level, while productivity or energy pyramids show the production or turnover in biomass.

3.3.4. Bioaccumulation in Food Chain

- Bioaccumulation occurs when **toxins build up - or accumulate** - in a food chain.
- The **animals at the top** of the food chain are **affected most severely.**

Process of Bioaccumulation

- **Small amounts** of toxic substances - often pesticides or pollution from human activity - are **absorbed by plants.**
- These plants are **eaten by primary consumers** in low concentrations.
- The toxin **cannot be excreted** so when the primary consumers are eaten by secondary consumers all the toxin is **absorbed by the secondary consumers.**
- This repeats as secondary consumers are eaten by higher level consumers.
- At each trophic level of the food chain, the toxins **remain in the tissues** of the animals - so the concentration of toxin becomes most concentrated in the body tissues of the animals at the top of the food chain.

3.3.5. Ecological Pyramids

- Ecological pyramids were developed by Charles Elton (1927) and are, therefore, also called **Eltonian pyramids.**
- In a pyramid the various steps of a food chain are represented sequence wise
- An ecological pyramid **can be upright, inverted or spindle shaped.**
- There are three types of ecological pyramids: Pyramid of Numbers, Pyramid of Biomass and Pyramid of Energy.

Pyramid of Numbers

- It is a graphic representation of the **number of individuals per unit area of various trophic levels** stepwise with producers at the base and carnivores at the top.
- In most cases, the pyramid of numbers is **upright** with members of successive higher trophic levels being less than the previous one.
- The maximum number of individuals occurs at the producer level.
- The producers support comparatively fewer numbers of herbivores, the latter fewer number of primary carnivores and so on. Top carnivores are very few in number.
- In a grassland, a larger number of grass plants or herbs support a fewer number of grasshoppers that support a still smaller number of frogs, the latter still smaller number of snakes and the snakes very few peacocks or falcons.
- A similar case is found in a pond ecosystem where a large number of phytoplankton support a comparatively smaller number of zooplanktons the latter fewer number of small-sized fIshes, the small-sized fishes become food of still fewer larger-sized fishes or water birds.
- The number of pyramids in a **higher trophic level is generally smaller** than that of the lower trophic level because the organisms of the higher trophic level are dependent for their food and energy on the organisms of the lower trophic level.

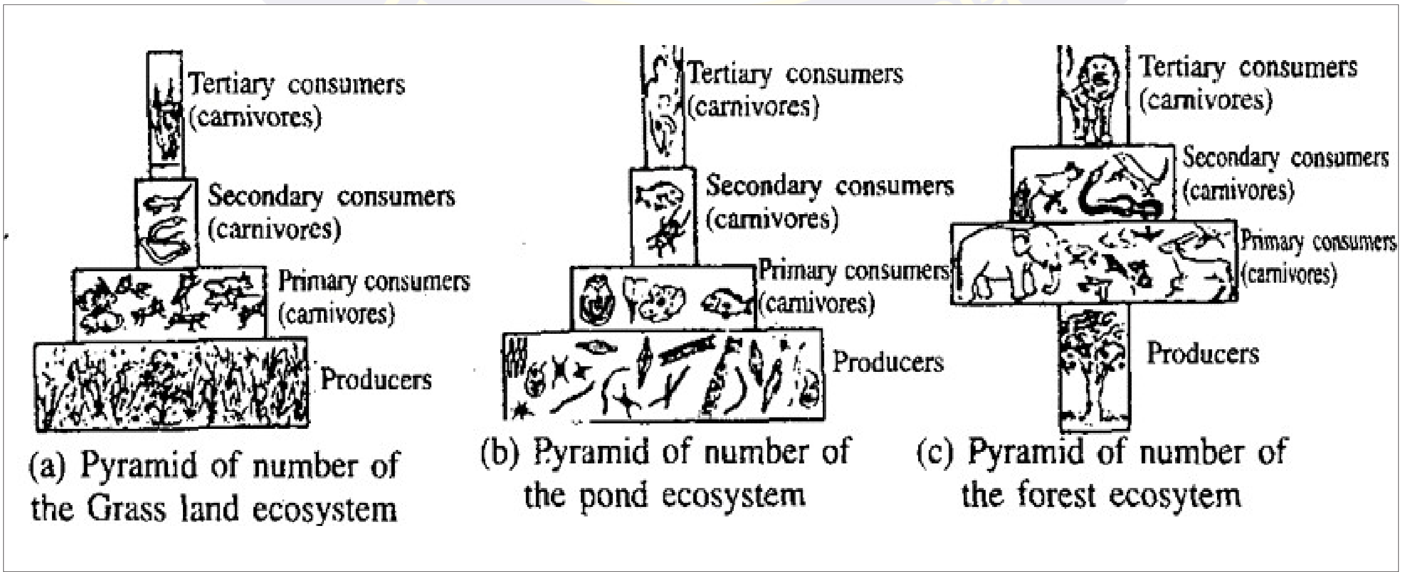

Figure.7. Pyramid of numbers

Pyramid of Biomass

- It is a graphic representation of **biomass present sequence-wise per/unit area** of different trophic levels with producers at the base and top carnivores kept at the tip.
- It is more accurate than the pyramid of numbers because the pyramid of numbers does not take into consideration the size of the individual.
- Maximum biomass occurs in producers. There is a progressive reduction of biomass found in herbivores, primary carnivores, secondary carnivores, etc.
- It is found that about 10-20% of the biomass is transferred from lower trophic level to higher level.
- The rest is consumed in providing energy for giving heat, overcoming entropy and performing various body activities.
- Pyramid of biomass is **upright for terrestrial habitats.**
- **Inverted or spindle-shaped** pyramids are obtained **in aquatic habitats** where the biomass of a trophic level depends upon reproductive potential and longevity of its members.
- Thus the biomass of phytoplankton may be smaller than that of zooplankton and that of the latter less than of primary carnivores.
- However, if total biomass produced per unit time is calculated, the pyramid of biomass shall always be upright.

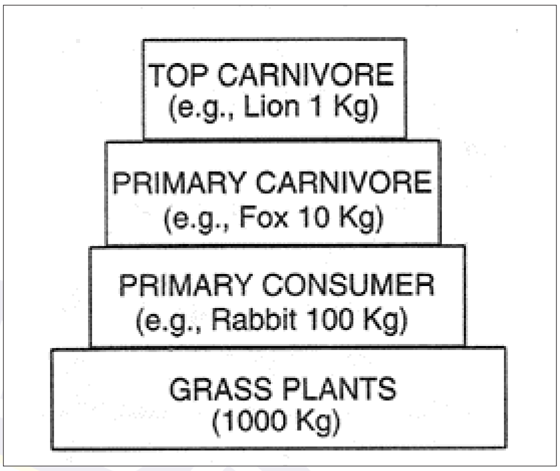

Figure.8. Upright pyramid of biomass for terrestrial habitats

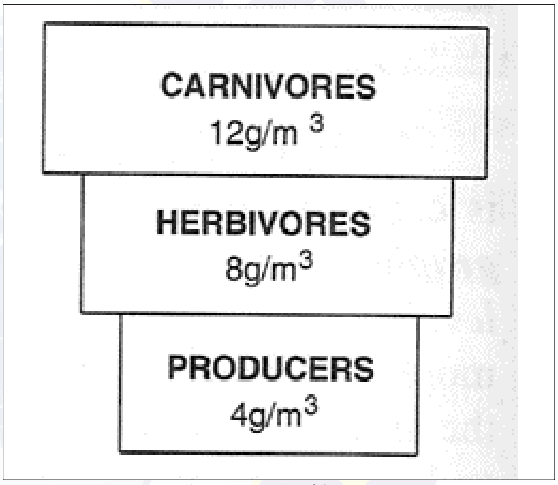

Figure.9. Inverted pyramid of biomass in an aquatic system Pyramid of Energy

Pyramid of Energy

- It is a graphical representation of the **amount of energy trapped per unit time and area** in different trophic levels of a food chain.
- The energy content is **expressed as Kcal/m2/year or KJ/m2/year.** Maximum energy content is present in producers.
- They obtain the energy from solar radiation. The energy is converted in chemical form and stored inside organic matter manufactured by the producers.
- As the energy passes into higher trophic level along with food, its amount decreases because of its **dissipation as heat** and used in overcoming entropy as well as for performing various body activities.

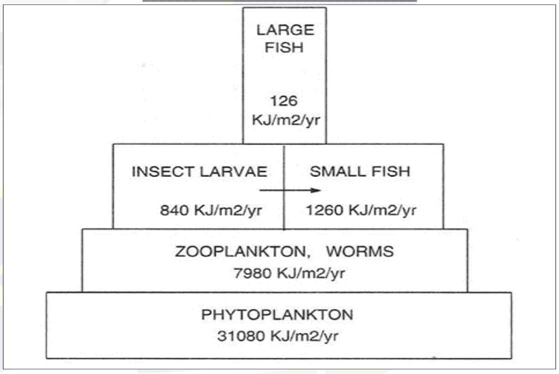

Figure.10. Pyramid of energy in a fish pond

3.3.6. Ecosystem Productivity

- Productivity within an ecosystem can be defined as the percentage of energy entering the ecosystem incorporated into biomass in a particular trophic level.
- Biomass is the total mass, in a **unit area at the time of measurement, of living or previously living organisms** within a trophic level.
- The productivity of the primary producers is especially important in any ecosystem because these organisms bring energy to other living organisms.
- The rate at which photosynthetic primary producers incorporate energy from the sun is called **gross primary productivity.**

- **Net primary productivity** is the energy that remains in the primary producers after accounting for the organisms' respiration and heat loss.
- The net productivity is then available to the primary consumers at the next trophic level.

Measuring Ocean Productivity

- Ocean productivity largely refers to the production of organic matter by phytoplankton.
- The total productivity of a region or system is the gross primary productivity. Some of this organic material is used to sustain phytoplankton.
- The amount leftover is known as the net productivity, which is the **amount of organic material available to support the heterotrophs** of the ocean.
- Net primary production is the gross primary production minus energy used for growth and development of the plant.
- Primary productivity is calculated by measuring the uptake of CO2, or the output of oxygen.
- Production rates are expressed as grams of organic carbon per unit area per unit time.

Factors Affecting Ocean Productivity

Nutrient Availability

- Phytoplankton require relatively uniform amounts of Nitrogen and Phosphorus.
- The dissolved N:P ratio in the deep ocean is close to the **16:1 ratio** of planktonbiomass.
- Iron is found in biomass in trace amounts, but it is used for essential purposes inorganisms.
- Scarcity often affects productivity in oceans, especially in regions of upwelling.
  - ✔ **Regions of upwelling are the most productive** waters in the world.
- Although they occupy less than 2% of the oceans, they support high biodiversity and provide 20% of the world's fish harvest.

Light

- Sunlight is the energy source for phytoplankton. However, very little sunlight penetrates below a depth of 80m.
- Photosynthesis is restricted to the upper, light-penetrated part of the ocean - known as the **photic zone.**
- Also, sunlight causes surface water to be much warmer than underlying water.
- Warm water has a lower density than colder water, so it stays above it, **creating a thermocline.**
- The two layers experience limited mixing, restricting primary production to the warmer surface waters.

Seasonality

- In some temperate and subpolar regions, productivity reaches a maximum during the spring as the phytoplankton transition from light to nutrient limitation.

3.4. Biomes

Factors affecting distribution of biomes

- Temperature and sunlight (angle of the sun and how the sun's rays hit the earth affect heating of the planet)
- Water and precipitation (ranges from dry to wet areas)
- Wind patterns (affects temperature and water loss)
- Rocks and soil (pH, mineral content, salinity, etc.)

Description of important biomes

Biomes	Physical Characteristics	Plants	Animals
1. Tundra	2 seasons, dry, frozen deserts. Winter: Extreme cold and snow. Summer: flooding caused by snow melt. Permafrost layer (permanently Frozen, about 3m below ground). Location: far North and far south – towards the polar ice caps. Average temperature: 10 degrees celsius Rainfall: 25 cm/yr, Snow: 10 – 20 cm/yr	No trees, dominated by mosses and Lichens and grasses, some small shrubs	Insect blooms, large hooved mammals (caribou, musk ox), bears, Wolves, small rodents (lemmings), Migrants during the breeding Season
2. Taiga/Bore al Forest	Long winter, short fall and spring, 2-3 months of summer, Wetter seasons, heavy rain and snow. Location: coniferous forest, far northern and far Southern latitudes.	Trees 5 – 10 m high, Boreal forest, conifers – pine, spruce, bog plants (ferns and mosses)	Diverse array of migrants from the tropics with few resident species (moose, bear, lynx, fox, voles), large insect blooms
3. Temperate Deciduous Forest	4 seasons, Rainfall: 80-140 cm/yr	Complex levels of vegetation deciduous trees, loose leaves in fall	Diverse array of migrants from the tropics and resident species
4. Savanna	Dry, rainfall: 90 – 150 cm/yr, Location: tropical to subtropical, 3 seasons	Grasses, forbs, trees short and (2m tall), Clumped together (10 m tall)	Large ungulates, large predators
5. Temperate Grassland	Temperate and some subartic grassland (extreme northern prairies – steppes and some extreme southern grasslands – Pampas of Argentina) Rainfall: 25-70 cm/yr	Grasses	Large ungulates
6. Chaparral	Mild wet winter followed by hot, dry, summer Many plant species rely on wildfires to renew soil. Location: near coastlines (California, Chile) Mediterranean type of climate	Short trees and shrubs	Diversity of mammals, birds, Insects, etc. That like dry Habitats
7. Desert	Very dry, rainfall: less than 25 cm/yr Location: primarily equatorial but some reach Into temperate regions	Cactus, Sagebrush, Creosote and shrubs	Small rodents, reptiles
8. Tropical rainforest	Very wet - heavy rainfall, soil - poor in nutrients, Temperature constant throughout the year Wet and dry seasons, Location: equatorial, 23.5 degree N latitude, 23.5 degree S latitude	Large trees- broad-leaved evergreens, Epiphytes, not much forest Floor vegetation (little sunlight).Canopy 30 - 40 m above ground	Highest diversity of animals
Aquatic Biome	**Freshwater and marine**		
1. Marine Pelagic Zone	Deep ocean, dependent on upwellings	Algae	Various birds, large mammals, fish
2. Marine Benthic	Ocean floor, no light	None	Detritus feeders, predatory fish
3. Marine Estuaries	Where rivers flow into the ocean, mix of saltwater and freshwater, marshes rich in plants and animals	Aquatic vegetation, marsh plants	Rich variety
4. Marine Intertidal zone	Shoreline to shallow waters	Algae	Marine worms, clams, oysters, crustaceans
5. Coral, reefs	Tropical oceans	Algae	Coral, fish

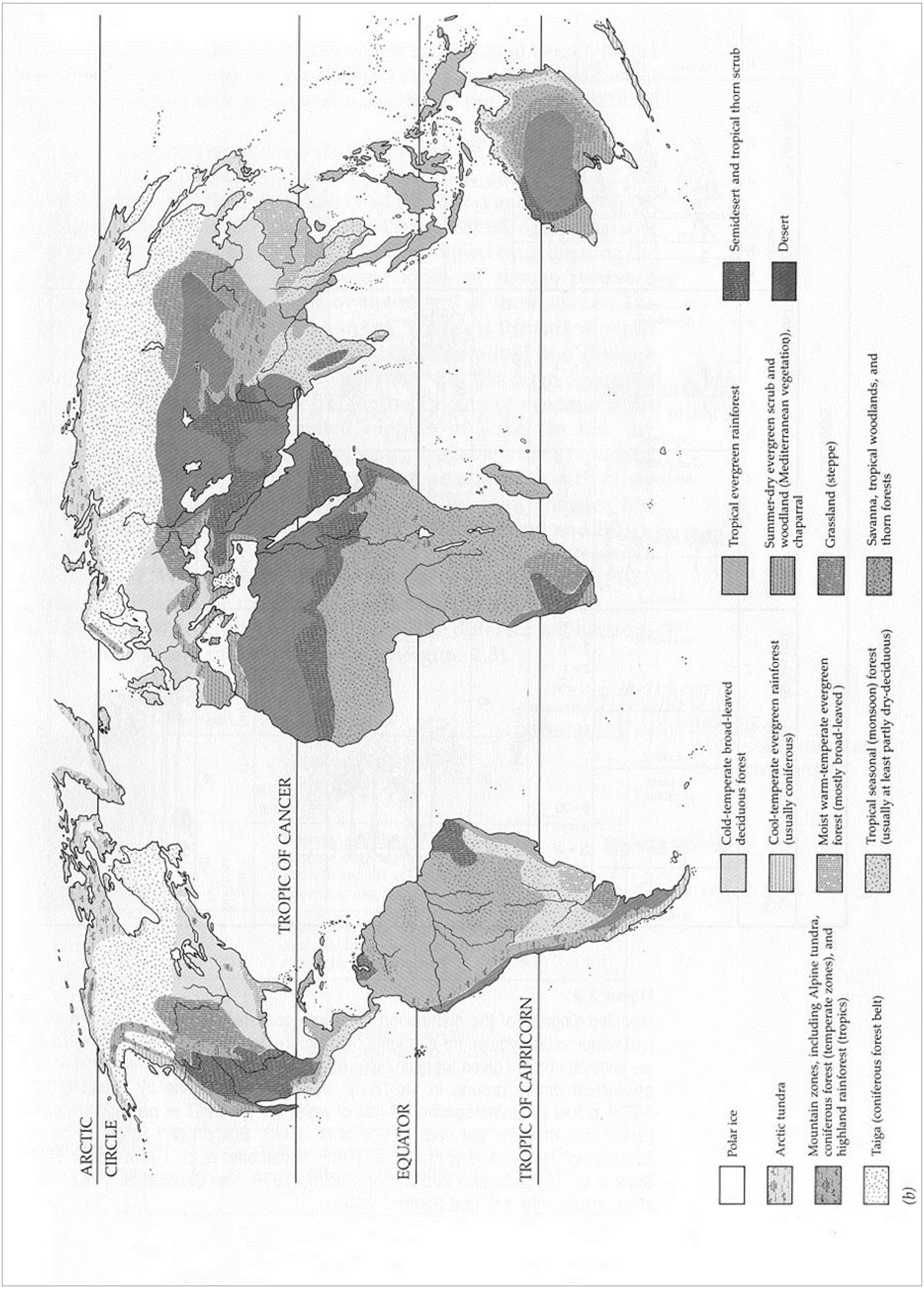

Figure.11. Biomes of the world

3.5. Biosphere

- The biosphere is made up of the parts of Earth where life exists.
- Components of biosphere:
  - ✔ **Lithosphere** (solid surface layer)
  - ✔ **Atmosphere** (layer of air that stretches above the lithosphere)
  - ✔ **Hydrosphere** (water—on the surface, in the ground, and in the air)
- Since life exists on the ground, in the air, and in the water, the biosphere overlaps all these spheres. It has existed for about 3.5 billion years.
- The biosphere's earliest life-forms, called prokaryotes, survived without oxygen.
- Some prokaryotes developed a unique chemical process. They were able to use sunlight to make simple sugars and oxygen out of water and carbon dioxide, a process called photosynthesis.
- These photosynthetic organisms were so plentiful that they changed the biosphere.
- The addition of oxygen to the biosphere allowed more complex life-forms to evolve.
- Animals, which consume plants (and other animals) evolved. Bacteria and other organisms evolved to decompose, or break down, dead animals and plants.
- The biosphere benefits from this food web. The remains of dead plants and animals release nutrients into the soil and ocean. These nutrients are reabsorbed by growing plants.
- This exchange of food and energy makes the biosphere a self-supporting and self-regulating system.

3.6. Biogeochemical Cycles

- A biogeochemical cycle is a **circuit or pathway by which a chemical element or molecule moves** through both biotic ("bio-") and abiotic ("geo-") compartments of an ecosystem.
- All the chemicals, nutrients, or elements—such as carbon, nitrogen, sulfur , phosphorus—used in ecosystems by living organisms operate on a closed system, which means that these chemicals are recycled.

3.6.1. Carbon Cycle

- A biogeochemical cycle by which **carbon is exchanged** between the biosphere, geosphere, hydrosphere and atmosphere of the Earth.
- Major reservoirs of carbon in the cycle are: atmosphere, terrestrial biosphere, oceans and sediments.

In the Atmosphere

- Carbon exists in the Earth's atmosphere **primarily as the gas** carbon dioxide (CO2).
- Although it is a very small part of the atmosphere overall (approximately 0.037% on a molar basis and rising), it plays an important role in supporting life.
- Other gases containing carbon in the atmosphere are methane and chlorofluorocarbons.

Carbon is taken from the atmosphere in several ways

- When plants perform photosynthesis to convert carbon dioxide into carbohydrates, releasing oxygen in the process.
- At the surface of the oceans towards the poles, seawater becomes cooler and CO2 is more soluble. This is coupled with the ocean's t**hermohaline circulation** which transports dense surface water into the ocean's interior.
- In upper ocean areas of high productivity, organisms form tissue containing reduced carbon, and some also form carbonate shells, tests, or other hard body parts.
- These are, respectively, oxidized (soft-tissue pump) and redissolved (carbonate pump) at lower average levels of the ocean than those at which they formed, resulting in a **downward flow of carbon.**

Carbon can be released back into the atmosphere in many different ways

- Through the **respiration** performed by plants and animals.
- Through the **decay** of animal and plant matter.
- Through **combustion** of organic material which oxidizes the carbon it contains, producing carbon dioxide (as well as other things, like smoke).
- **Production of cement:** lime, is produced by heating limestone, which produces a substantial amount of carbon dioxide.
- At the surface of the oceans where the water becomes warmer, dissolved carbon dioxide is released back into the atmosphere
- **Volcanic eruptions and metamorphism** release gases into the atmosphere. These gases include water vapor, carbon dioxide and sulfur dioxide.

In the Biosphere

- Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts (e.g., fruits).
- **Most carbon leaves the biosphere through respiration.** When oxygen is present, aerobic respiration occurs, which releases carbon dioxide into the surrounding air or water, following the reaction:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

- Otherwise, anaerobic respiration occurs and releases methane into the surrounding environment, which eventually makes its way into the atmosphere or hydrosphere.
- Burning of biomass can also transfer substantial amounts of carbon to the atmosphere
- Carbon may also be circulated within the biosphere when dead organic matter becomes incorporated in the geosphere.

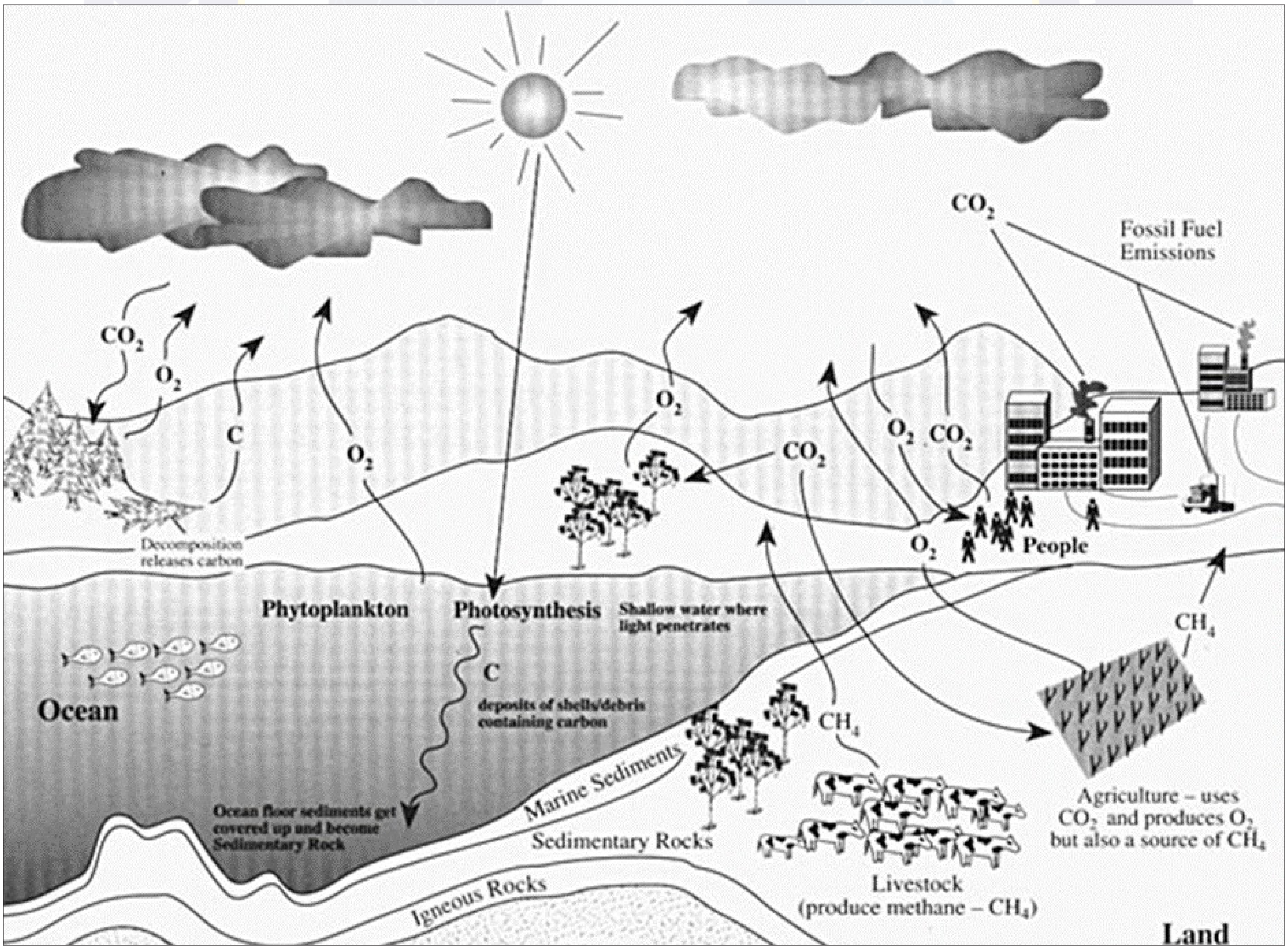

Figure.12. Carbon Cycle

In the Ocean

- The sea contains carbon mostly in the form of **bicarbonate ions.**
- **Inorganic carbon,** that is carbon compounds with no carbon-carbon or carbon-hydrogen bonds, is important in its reactions within water.
- This **carbon exchange** becomes important in controlling pH in the ocean and can also vary as a source or sink for carbon.
- Carbon is readily exchanged between the atmosphere and ocean. In regions of oceanic upwelling, carbon is released in the atmosphere.
- Conversely, regions of downwelling, transfer carbon (CO_2) from the atmosphere to the ocean.
- When CO_2 enters the ocean, carbonic acid is formed:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

Human Impact

- Felling of forests, coal-burning power plants, automobile exhausts, factory smokestacks,and other waste vents of the human environment contribute billions of tons of carbon dioxide into the earth's atmosphere. This alters the Carbon Cycle drastically.
- The atmospheric concentration of CO_2 has **reached around 417ppm – a 50% increase** over the 1750-1800 average. Pre-industrial levels were about 278ppm.
- This imbalance in the Carbon cycle is responsible for phenomena like greenhouse effect, global warming and climate change.

3.6.2. Nitrogen Cycle

- The nitrogen cycle is the biogeochemical cycle that **describes the transformations of nitrogen** and nitrogen-containing compounds in nature.

Parts of the Cycle

- Earth's atmosphere is about 79% nitrogen, making it the largest pool of nitrogen.
- However, N_2 is unavailable for use by most organisms because there is a triple bond between the two nitrogen atoms, making the molecule almost inert.
- In order for nitrogen to be used for growth it must be **"fixed" (combined) in the form of ammonium (NH_4) or nitrate (NO_3) ions.**
- Six processes participate in the cycling of nitrogen through the biosphere: nitrogen fixation, decay, nitrification, denitrification, anammox and, leaching and weathering of rocks.

Nitrogen Fixation

- Nitrogen fixation is the process by which **nitrogen is taken from its relatively inert molecular form** (N_2) in the atmosphere and converted into nitrogen compounds useful for other chemical processes (such as, notably, ammonia, nitrate and nitrogen dioxide).

Three processes of nitrogen fixation in the biosphere:

Atmospheric fixation by Lightning

- Lightning **breaks nitrogen molecules** and enables their atoms to combine with oxygen in the air forming nitrogen oxides.
- These dissolve in rain, forming nitrates, which are carried to the earth.
- Atmospheric nitrogen fixation probably contributes some 5% of the total nitrogen fixed.

Biological Fixation

- Nitrogen fixation is **performed biologically by a number of different prokaryotes,** including bacteria, and actinobacteria.
- Biological nitrogen fixation requires a complex set of enzymes and a huge expenditure of ATP (Adenosine triphosphate).

- The most fundamental enzyme required for nitrogen fixation is **Nitrogenase,** which is present only in the **diazotrophic (nitrogen fixing) bacteria.**
- Important diazotrophs are:
  1. Cyanobacteria: Anabaena, Nostoc, Gloeotheca, Calothrix
  2. Others: Azotobacter, Azomonas, Agrobacterium,
- Symbiotic Nitrogen Fixers: Non Leguminous Host
  1. Frankia: Wide range of tree species
  2. Acetobacter: Sugar cane
  3. Nostoc: the Hornwort Anthoceros
  4. Anabaena: the Fern Azolla
- Symbiotic Nitrogen Fixers: Leguminous or some closely related Host
  - ✔ By 5 genera of closely related diazotrophs: Rhizobium, Azorhizobium, Bradyrhizobium, Photo Rhizobium, Sinorhizobium.
- Plants that contribute to nitrogen fixation include the **legume family – Fabaceae** – with taxa such as clover, chickpea, soybeans, alfalfa, lupins, peanuts, and rooibos.

Industrial fixation by Haber and Bosch Process

- Under great pressure, at a temperature of 600°C, and with the **use of a catalyst,** atmospheric nitrogen and hydrogen can be combined to form ammonia (NH3).
- Ammonia can be used directly as fertilizer, but most of it is **further processed to urea and ammonium nitrate** (NH4NO3).
- Industrial nitrogen fixation probably contributes some 20% of the total nitrogen fixed.

Decay

- Decay (also called **Ammonification or Mineralization**) is carried out by a number of microbes and some fungi.
- The proteins made by plants enter and pass through food webs just as carbohydrates do.
- At each trophic level, their **metabolism produces organic nitrogen compounds** that return to the environment, chiefly in excretions and also as a part of the dead remains of the organism.
- The final beneficiaries of these materials are microorganisms of decay. They break down the molecules in excretions and dead organisms into ammonia.

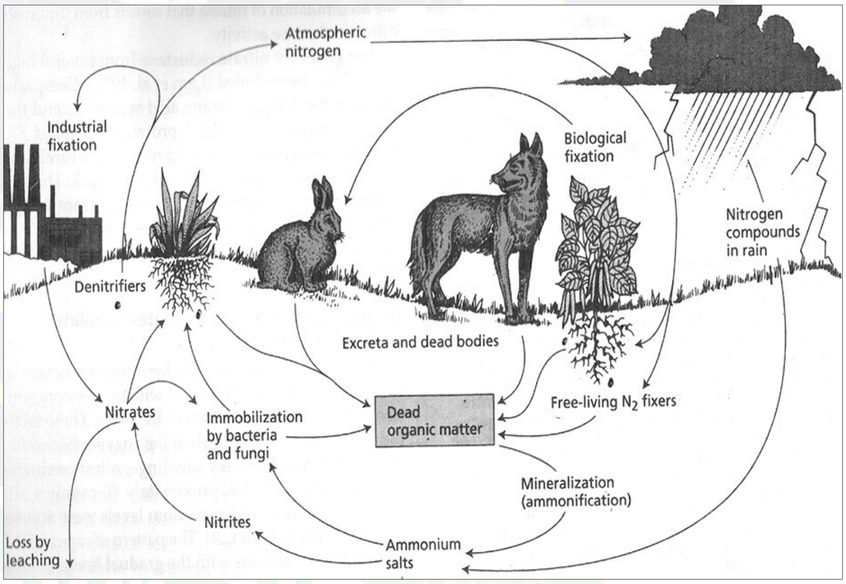

Figure.13. Nitrogen Cycle

Nitrification

- Ammonia can be taken up directly by plants — usually through their roots. However, most of the ammonia produced by decay is converted into nitrates.
- **This is accomplished in two steps:**
  - ✔ Bacteria of the genus Nitrosomonas and Nitrococcus oxidize NH3 to nitrites (NO2−).
  - ✔ Bacteria of the genus Nitrobacter oxidize the nitrites to nitrates (NO3−).
- These two groups or autotrophic bacteria are called **nitrifying bacteria.**

Denitrification

- Denitrification **reduces nitrates to nitrogen gas,** thus replenishing the atmosphere.
- Once again, bacteria are the agents, for example Thiobacillus denitrificans, Bacillus denitrificans

Anammox

- In this biological process, **nitrite and ammonium are converted directly into dinitrogen gas.**
- This process makes up a major proportion of dinitrogen conversion in the oceans. The overall catabolic reaction is:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O.$$

Leaching and Weathering of Rocks

- A small amount of Nitrate is leached down to ground water deposits causing pollution. The situation is aggravated by **indiscriminate use of nitrogen fertilizers.**
- Excess nitrate in drinking water reacts with hemoglobin and forms nonfunctional methaemoglobin that impairs oxygen transport. This is called **Methemoglobinemia or Blue-baby syndrome.**
- The **weathering of rocks** releases fixed nitrogen ions into the soil but the process is so slow that it has a **negligible effect** on the availability of fixed nitrogen.

Human Impact on the Cycle

- Humans have contributed significantly to the nitrogen cycle by **artificial nitrogen fertilization and planting of nitrogen fixing crops.**
- In addition, humans have significantly contributed to the transfer of nitrogen trace gases from Earth to the atmosphere.
- N_2O has risen in the atmosphere as a result of agricultural fertilization, biomass burning, cattle and feedlots, and other industrial sources.
- **N_2O breaks down in the stratosphere** and acts as a catalyst in the destruction of atmospheric ozone.
- **NH_3** in the atmosphere **has tripled** as the result of human activities. It is a reactant in the atmosphere, where it acts as an aerosol and **decreases air quality.**
- **NO actively alters atmospheric chemistry,** and is a precursor of tropospheric (lower atmosphere) ozone production, which contributes to smog, acid rain, and increases nitrogen inputs to ecosystems.

Algal bloom

- An algal bloom is a **rapid increase in the density of algae** in an aquatic system.
- Algae can multiply quickly in waterways with an overabundance of nitrogen and phosphorus, particularly when the water is warm and the weather is calm.
- Algal blooms **can create dead zones** beneath them. They prevent light from penetrating the water's surface.
- They also prevent oxygen from being absorbed by organisms beneath them.

3.6.3. Phosphorus Cycle

- It is the biogeochemical cycle that describes the **transformation and translocation of phosphorus** in soil, water, and living and dead organic material.
- Phosphorus is a major constituent of biological membranes and nucleic acids.
- It is a key player in fundamental biochemical reactions involving **genetic material (DNA, RNA) and energy transfer (ATP).**
- Many animals also need large quantities of this element to make **shells, bones and teeth.**
- The **natural reservoir of phosphorus is rock,** which contains phosphorus in the form of phosphates.

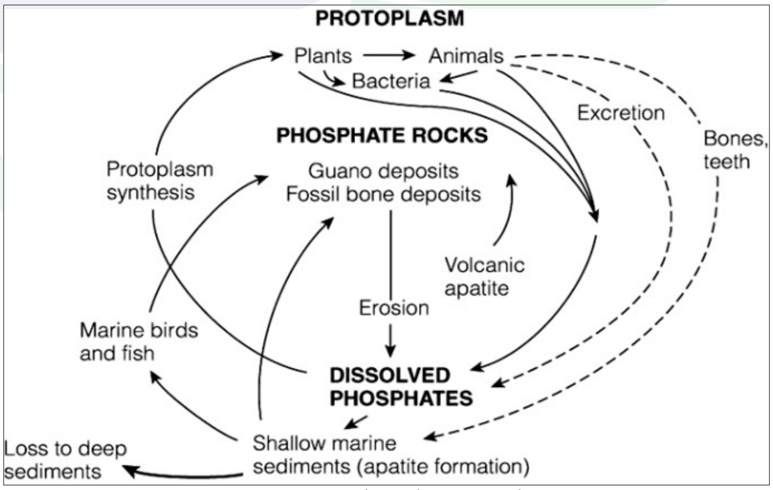

Figure.14. Phosphorus cycle

- When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants.
- Herbivores and other animals obtain this element from plants.
- Unlike the carbon cycle, there is no respiratory release of phosphorus into the atmosphere.

Four Major Components

- **Tectonic uplift** and exposure of phosphorus-bearing rocks to the forces of weathering.
- **Physical erosion and chemical weathering** of rocks producing soils and providing dissolved and particulate phosphorus to rivers.
- **Riverine transport** of phosphorus to lakes and the ocean.
- **Sedimentation** of phosphorus associated with organic and mineral matter and burial in sediments.

Steps Involved in Phosphorus Cycle

Weathering

- The natural reservoir of phosphorus is **rock,** which contains phosphorus **in the form of phosphates.**
- When it rains, phosphates are removed from the rocks (via weathering) and are distributed throughout both soils and water.
- **Different microorganisms** like Actinomycetes, Pseudomonas, Bacillus, Aspergillus, Penicillium, etc. are **involved in the solubilization of phosphorus** in the soil.
- Natural processes like volcanic activity and asteroid activity also aid in the release of phosphorus into the soil.

Absorption by Plants

- Plants absorb phosphate salts that have been dissolved in water.
- They can either take up phosphorus **directly from the soil,** or can be made available to plants **by different symbiotic microorganisms.**
- The **aquatic plants** in oceans also absorb phosphorus **from the lower layers of aquatic sediments.**

Movement of Phosphorus in the Food Chain

- The phosphates then move from plants to animals when herbivores eat plants and carnivores eat plants or herbivores.
- The phosphorus transferred to the consumers is **used for the formation of biomolecules** like the nucleotides and connective tissues like bones.

Return of Phosphorus to the Ecosystem

- The phosphates absorbed by animal tissue eventually return to the soil through the excretion, as well as from the final decomposition of plants and animals after death.
- In this step, the organic forms of phosphorus are **converted into their inorganic forms by the process of mineralization.**
- The phosphorus in the soil is also transported to the ocean during rainfall or by the running off of soil to the water bodies.
- The phosphorus in the ocean **undergoes deposition, forming layers of sediments.**
- The sediment formation leads to the formation of rocks and the cycle continues.

Human Impacts on the Phosphorus Cycle

- Humans can alter the phosphorus cycle in many ways, including in the **cutting of tropical rainforests** and through the **use of agricultural fertilizers.**
- As the forest is cut or burned, nutrients originally stored in plants and rocks are quickly washed away by heavy rains, causing the land to become unproductive.
- **Agricultural runoff** provides much of the phosphate found in waterways.
- Crops often cannot absorb all of the fertilizer in the soils, causing excess fertilizer runoff and increasing phosphate levels in rivers and other bodies of water.

3.6.4. Sulphur Cycle

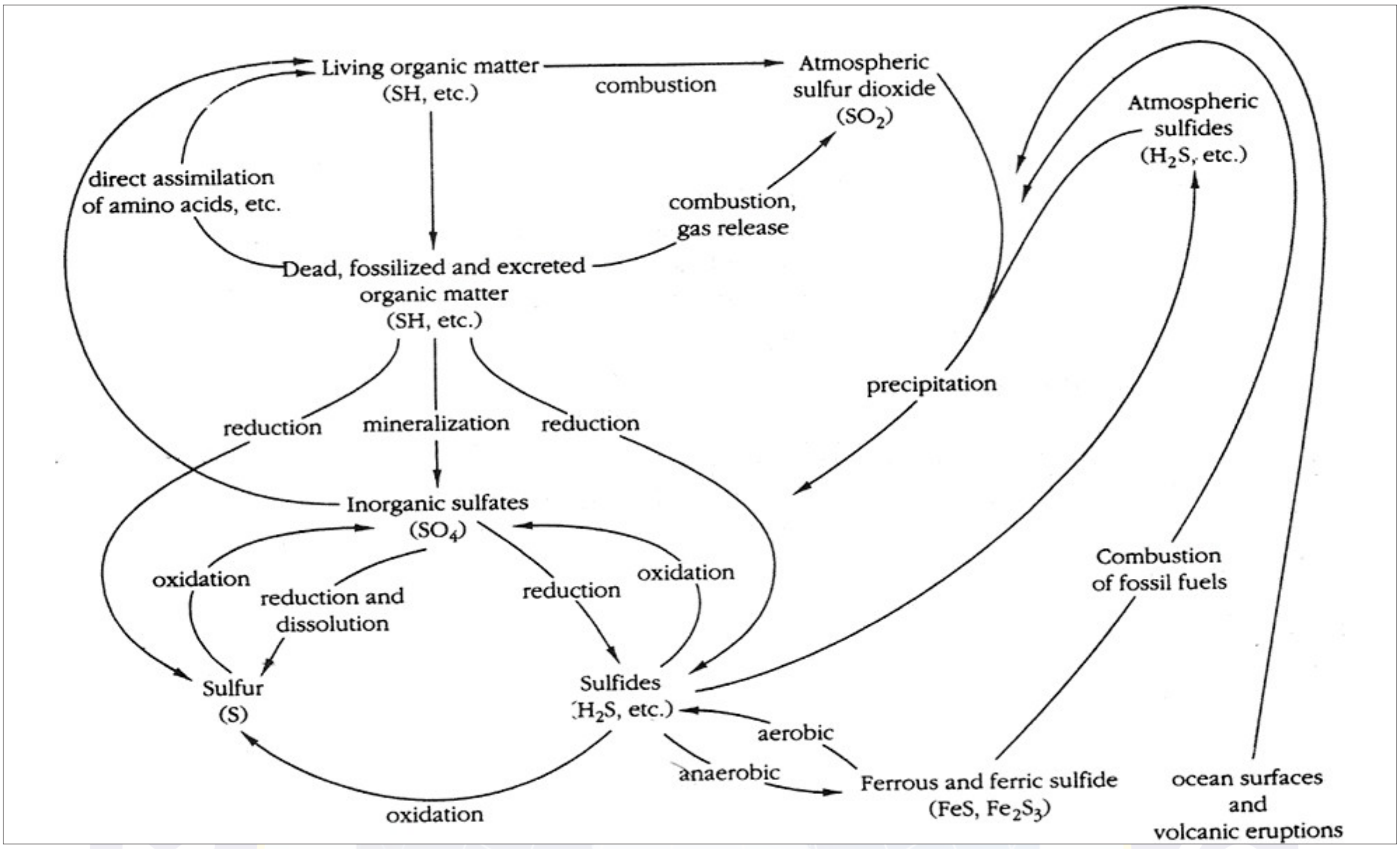

Figure.15. Sulphur Cycle

- It describes the **movement of sulfur** through the atmosphere, mineral forms, and through living things.
- Most of the earth's sulphur is tied up **in rocks and salts** or buried deep in the ocean in **oceanic sediments.**

Steps Involved in Sulphur Cycle

Weathering

- Sulfur is released from geologic sources through the weathering of rocks. Once sulfur is exposed to the air, it **combines with oxygen, and becomes sulfate (SO4).**

Sulphur Assimilation

- **Plants and microbes assimilate sulfate** and convert it into organic forms.
- As animals consume plants, the sulfur is moved through the food chain and released when organisms die and decompose.
- **Some bacteria – for** example Proteus, Campylobacter, Pseudomonas and Salmonella – have the ability to reduce sulfur.
- These bacteria get their energy by reducing elemental sulfur to hydrogen sulfide. This process is known as **dissimilatory sulfate reduction.**

In the Atmosphere

- Sulphur enters the atmosphere through both natural and human sources.
- Natural sources include volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms.
- Sulphur enters the atmosphere through human activity mainly as a consequence of **industrial processes** where sulphur dioxide (SO2) and hydrogen sulphide (H2S) gases are emitted on a wide scale.
- When sulphur dioxide enters the atmosphere it reacts with oxygen to **produce sulphur trioxide gas** (SO3), or with other chemicals in the atmosphere, to produce sulphur salts.
- Sulphur dioxide may also react with water to produce sulphuric acid (H2SO4).
  - ✔ Sulphuric acid may also be produced from dimethyl sulphide, which is emitted to the atmosphere by plankton species.
- All these particles will settle back onto earth, or react with rain and **fall back onto earth as acid deposition.**