BOT 141: Basic Principles of Botany - ECOLOGY

•Before delving into the subject matter of Ecology, it will be important for us to understand what the word Ecology means.

• The word "ecology" has its origin from two Greek words:

-*oikos* which means a house, home, dwelling place or habitat of an organism and

-*logos* meaning a branch of study.

• Literally therefore, it is the study of living organisms with their environments (house, home, habitat etc.)

- The environment of organisms includes both physical, biological and non-biological environments which these organisms interact with.
- Therefore, in a broader sense, ecology is the science that studies the interactions between living organisms and their environment.
- It involves their mode of life, habits, effects upon each other and their habitats as well as the effects of the environment upon the organisms.
- In summary, ecology is the science that deals with the living organisms as they are found in their natural habitats (i.e. homes).

SCOPE OF ECOLOGY

- Basically, ecology is a biological science since it is concerned with the interrelationship of organisms with their environment (including the non-living environment).
- Ecology as study is not restricted to biology alone wanders into other subject areas gathering bits and bits of information to expand its own base.
- For instance, the spatial distribution of organisms on the earth demands a good knowledge of geography, demography, mathematics and statistics.
- The study of soil organisms and their relationships with the soil requires a good knowledge of pedology (soil science).

- In the vein, the study of man as an organisms brings into the fold of ecology several other fields such as anthropology, sociology, economics etc.
- Today, at global level, man is concerned with the maintenance and sustainability of his environment and therefore a good knowledge of environmental law becomes important.
- Also, the relationships between developing foetus and the mother as in most animals requires a good knowledge of medicine, veterinary medicine, nursing and health management.
- What about Theology? Our relationship with the unseen God.

- From the above, we could see that ecology as a subject is an interdisciplinary synthetic science. It is difficult to set limit to its scope except that (for convenience) it remains a biological science dealing with living organisms.

SUB-DIVISIONS OF ECOLOGY

- Ecology can be sub-divided into many but varying ways.
- However, the traditional sub-division of ecology are plant and animal ecologies. These two sub-divisions can not be justified due to their interdependences.
- Another approach divides ecology as autecology (i.e. ecology of single individual or population) and synecology (i.e. ecology of more than one but different species of organisms or communities).
- This approach has been modify to reflect different levels of community organisation.
- Thus, we talk of population and community ecologies and indeed ecosystem ecology.

ECOLOGICAL CONCEPTS

- At this point, it with be important for us to understand some important ecological terms or concepts:

- Population: This refers to a group of organisms of the same species, living together in a particular area and can interbreed among themselves.
- Community: This is a natural assemblage of several species population in a given area.
- Sample: This refers to part of a whole/entity taken to represent the whole/entity.
- Ecosystem: Is a complex interacting systems of communities with their physical environments.

ECOSYSTEM

- As stated earlier, it is a complex interacting systems of communities with their physical environments.
- It consists of the biotic and abiotic components.
- This concept is central to the study of ecology and indeed many scholars refer to ecology as the study ecosystem.
- Functions of the ecosystem include among others (a) to allow energy flow and cycling/recycling of minerals and

  (b) stabilizing the system in order to ensure continuity of life.

Components of the Ecosystem

Biotic component: This refers to the living organisms in the ecosystem.

Abiotic component: refers to the physical (or non-living) environment in the ecosystem.

Biotic Component

Living organisms are grouped as either (a) Autotrophs or (b) Heterotrophs.

Autotrophs

- These refer to organisms that produce their own for as well as for other organisms.
- They are better referred to as Producers.
- They include all photosynthetic green plants (with chlorophylls) and chemosynthetic bacteria and algae.

Heterotrophs STOPPED 2/10/15

- These organisms depend directly or indirectly upon the autotrophs for their food.
- They can be further subdivide into Phagotrophs and Osmotrophs

Phagotrophs

- These include all organisms that ingest and digest their food inside their bodies.
- Generally, they are referred to as Consumers.
- They include the:

  - Herbivores (plant eating organisms)

  - Carnivores (animal/flesh eating organisms) and

  - Omnivores (organisms that eat all kinds of food).

Osmotrophs

- These include all organisms that secrete digestive enzymes exo-cellularly to break down food into simpler forms and then absorb the digested food.

- They are mostly parasitic and saprophytic bacteria and fungi.
- These organisms are generally called Decomposers because of their role in the decomposition of dead organic matter.
- However, it is important to note here that parasites and some consumers (insects and worms) are not decomposers, but they help in the decomposition and break down of dead organisms into smaller bits.
- Based on the above, heterotrophs are better sub-grouped as ***Biophages*** (i.e. feeding on living organisms) and ***Saprophages*** (i.e. feeding on dead matter)

Abiotic Component

- The physical environment and its several interacting variables make up the abiotic component of the ecosystem.
- It includes:

  -Lithosphere

  -Hydrosphere

  -Atmosphere and

  -Radiant Solar energy.

  The position and movement of the earth as well as the gravitational force are additional components of the environment.

Energy Flow

- Energy is required for proper functioning of the ecosystem and all organisms need energy to survive
- At any given time in an ecosystem, energy flow is unidirectional.
- The solar energy is the chief source of energy in the ecosystem as the energy used for all life processes are obtained from it.
- This energy is fixed by green plants by converting the light to chemical energy via photosynthesis and make it available to other organisms as food.

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

- Since heterotrophs can not fix this energy from the sun, they use the plants as their energy source.
- Thus, series of feeding relationships will be established – this feeding relationship is called the food chain.
- The energy fixed in each feeding step/stage is lost in to other steps as heat which cannot be re-utilized.
- The first step in the production of food by plants is called ***Gross production*** or ***Gross photosynthesis***.
- Out of the energy fixed in this production, some are lost during respiration by plants. The remaining amount is used in building up of tissues and organs by plants and the balance is called ***Net production*** or ***Net photosynthesis***.
- During digestion of food by animals, complex organic molecules are broken down to simpler ones and new compounds re-synthesized.

- As a result, a good percentage of energy is again lost as heat while a little fraction is stored in the animal tissues.
- Consequently, energy transfer along the food chain follows an average of 10% rule, i.e. about 10% energy is fixed in successive higher trophic levels.
- Example, if a plant fixes 1000 kcal of energy, the herbivore will store only 100 kcal in its body (others will be lost as heat in faeces, respiration etc). Similarly, carnivore feeding on herbivore will only make available 10 kcal energy to the next trophic level and in that order.
- This explains in part, at least, the reasons for the limited number of links in food chain.

Food Chain and Food Web

- As noted earlier, energy flow is a sequence of steps from one organism to another in terms of energy fixed and stored in a food chain.
- A **food chain** is a chain that shows how each living thing gets its food. Some animals eat plants and some animals eat other animals.
- Every organism needs to obtain energy in order to live. For example, plants get energy from the sun, some animals eat plants, and some animals eat other animals.
- A food chain is the sequence of who eats whom in a biological community (an ecosystem) to obtain nutrition.
- A food chain starts with the primary energy source, usually the sun.

Plant → Man

This the simplest food chain.

- Another food chain is as shown below:

Grass → Ant → Toad → Snake → Hawk → Man

Trophic level	1st	2nd	3rd	4th	5th	6th

The arrow shows the direction of energy flow in the food chain

From the above examples, we will observe that food chain is unidirectional.

- Each organism in the food chain occupies a position. The position of any organism in the chain represents its trophic level.
- **Primary producers** are the base of every food chain – these are called **autotrophs**.

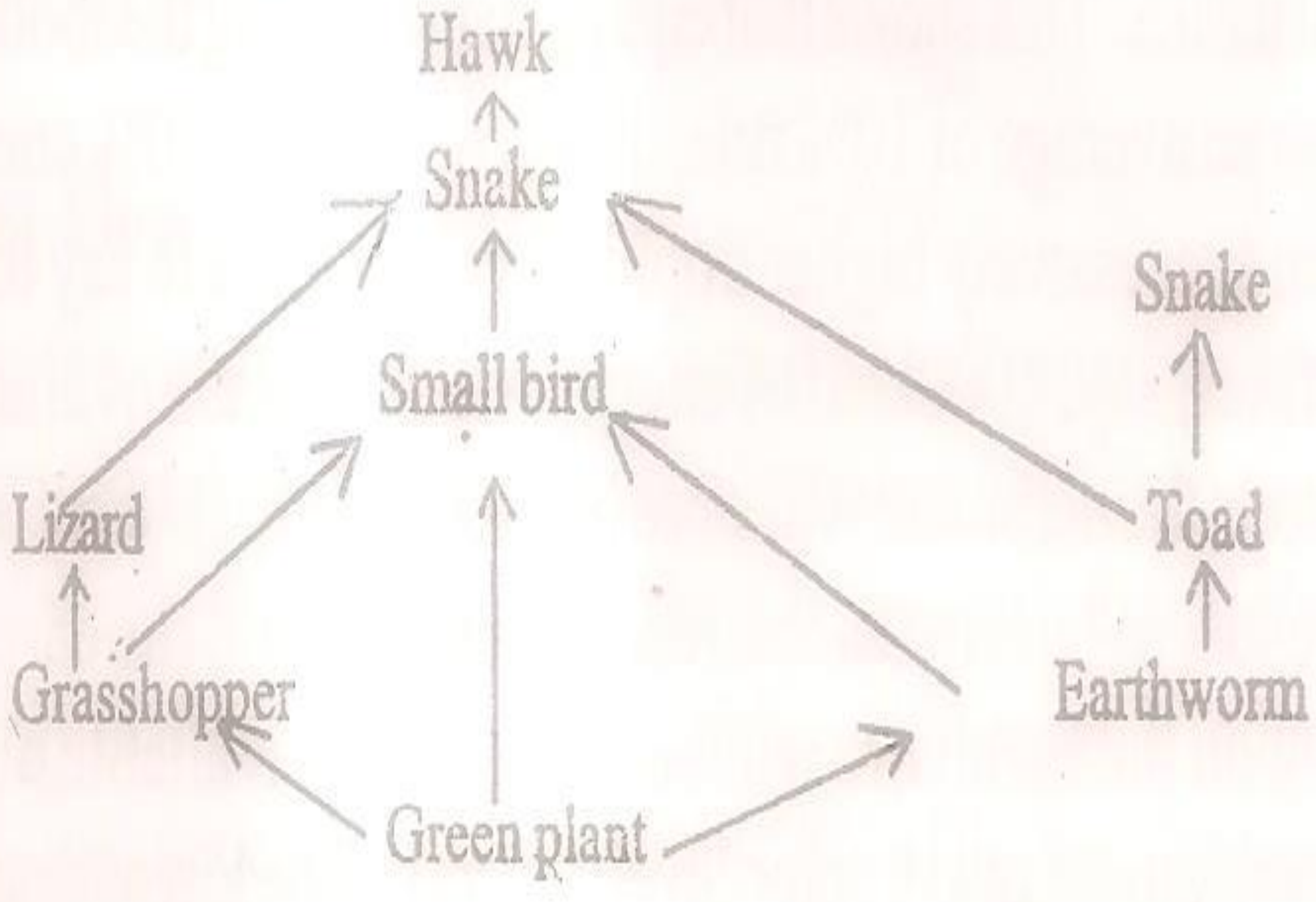
Food Web

- In food web, organisms' position in the food chain can vary as their diet varies.

  -For example, when a bear eats berries, the bear is functioning as a primary consumer.

  -When it eats a plant-eating rodent, it functions as a secondary consumer.

  -When it eats salmon, it functions as a tertiary consumer (this is because salmon is a secondary consumer, since salmon eat herring that eat zooplankton that eat phytoplankton, that make their own energy from sunlight).
- In any food web, energy is lost each time one organism eats another. Because of this, there have to be many more plants than there are plant-eaters. There are more autotrophs than heterotrophs, and more plant-eaters than meat-eaters.



Schematic drawing of a food web

- A **food web** (or **food cycle**) represents feeding connections in an ecological community and hence is also referred to as a consumer-resource system.
- Thus, the same organism may operate in an ecosystem at more than one trophic level, i.e. deriving its food from more than one source.
- Consequently, we have several food chains interlocked together and linking each other to form a network of food chain known as Food web.

Biogeochemical Cycle

- This refers to the movement of chemical elements in the biosphere in a characteristic pathway from the environment to organisms and back to the environment
- The term "biogeochemical" indicates that biological, geological and chemical factors are all involved.
- The circulation of chemical nutrients like carbon, oxygen, nitrogen, phosphorus, calcium, and water etc. through the biological and physical world are known as biogeochemical cycles.
- The most important biogeochemical cycles affecting ecosystem health are water, carbon, nitrogen, and phosphorus cycles.
- Along with energy, water and several other chemical elements cycle through ecosystems and influence the rates at which organisms grow and reproduce.

- The growth and life processes of organisms require about 40 elements which are cycled and recycled in the biosphere in one form or the other.
- About 10 major nutrients and six trace nutrients are essential to all animals and plants, while others play important roles for selected species.
- The most important biogeochemical cycles affecting ecosystem health are the water, carbon, nitrogen, and phosphorus cycles.

Water Cycle

- The **water cycle**, also known as **hydrologic cycle** or the **H_2O cycle**, describes the continuous movement of water on, above and below the surface of the earth.
- The mass of water on earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables.
- The water moves from one reservoir to another, such as river to ocean, or ocean to atmosphere, by the physical processes of evaporation, condensation, precipitation , infiltration, runoff, and subsurface flow.
- In so doing, the water goes through different phases: liquid, solid (ice), and gas (vapor).

- The water cycle involves the exchange of energy, which leads to temperature changes.
- For instance, when water evaporates, it takes up energy from its surroundings and cools the environment.
- When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.
- The evaporative phase of the cycle purifies water which then replenishes the land with freshwater.
- The flow of liquid water and ice transports minerals across the globe reshapes the geological features of the Earth, through processes as erosion and sedimentation.
- The water cycle is also essential for the maintenance of most life and the earth’s ecosystems.

Description of Water Cycle

- The main driver for the water cycle is the sun which heats up water in oceans and seas.
- Consequent upon this, water evaporates as water vapour into the air while ice, rain and snow can sublime directly into water vapour.
- Rising air currents take the vapour up into the atmosphere where cooler temperatures cause it to condense into clouds.
- Air currents move water vapour around the globe, cloud particles collide, grow, and fall out of the upper atmospheric layers as precipitation.
- Some precipitation falls as snow or hail, sleet, and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years.

- Most water falls back into the oceans or onto land as rain, where the water flows over the ground as surface runoff.
- A portion of runoff enters rivers, with stream moving water towards the oceans.
- Runoff and water emerging from the ground (groundwater) may be stored as freshwater in lakes.
- Not all runoff flows into rivers, much of it soaks into the ground as infiltration.
- Some water infiltrates deep into the ground and replenishes aquifers, which can store freshwater for long periods of time.

- Some infiltrated water stay close to the land surface and can seep back into surface-water bodies (ocean) as groundwater discharge.
- Some groundwater finds openings in the land surface and comes out as freshwater springs.
- In river valleys and flood-plains there is often continuous water exchange between surface water and ground water.
- Over time, the water returns to the ocean, to continue the water cycle.

Effects Water Cycle on biogeochemical cycling

- While the water cycle is itself a biogeochemical cycle, flow of water over and beneath the earth is a key component of the cycling of other biogeochemical.
- Runoff is responsible for the transport of eroded sediments.
- The salinity of the oceans is derived from erosion and transport of dissolved salts from the land.
- The cultural eutrophication of lakes is primarily due to phosphorus, applied to agricultural fields as fertilizers, and then transported overland and down rivers.
- Both runoff and groundwater flow play significant roles in transporting nitrogen from the land to water bodies.
- Runoff also plays a part in the carbon cycle, again through the transport of eroded rock and soil.

Carbon cycle

- The **carbon cycle** is the biogeochemical cycle by which carbon is exchanged within the biosphere , pedosphere, geosphere, hydrosphere, and atmosphere of the Earth.
- Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events that are capable of making and sustaining life on earth.
- It describes the movement of carbon as it is recycled and reused throughout the biosphere.
- The *global carbon budget* is the balance of the exchanges (incomes and losses) of carbon between the carbon reservoirs or between one specific loop (e.g., atmosphere ↔ biosphere) of the carbon cycle.

- An examination of the carbon budget of a pool or reservoir can provide information about whether the pool or reservoir is functioning as a source or sink for carbon dioxide.
- **Relevance for the global climate**

Carbon-based molecules are crucial for life on earth, because it is the main component of biological compounds.

- Carbon is also a major component of many minerals.
- Carbon also exists in various forms in the atmosphere.
- Carbon dioxide (CO_2) is partly responsible for the greenhouse effect and is the most important human-contributed Green House gas.

- In the past, human activities have seriously altered the global carbon cycle, most significantly in the atmosphere in the area of fossil burning.
- Although carbon dioxide levels have changed naturally over the years, human emissions of carbon dioxide into the atmosphere exceed natural fluctuations.
- Changes in the amount of atmospheric CO_2 are considerably altering weather patterns and indirectly influencing oceanic chemistry.
- Records from ice cores have shown that, although global temperatures can change without changes in atmospheric CO_2 levels, CO_2 levels cannot change significantly without affecting global temperatures.
- Current carbon dioxide levels in the atmosphere are rising faster than ever recorded, making it critical to the understanding of how the carbon cycle works and what its effects are on the global climate.

Main components of Carbon Cycle

Atmospheric Carbon Cycle

- Carbon in the earth's atmosphere exists in two main forms: carbon dioxide and methane.
- Both gases absorb and retain heat in the atmosphere and are partially responsible for the greenhouse effect.
- Methane produces a large greenhouse effect per volume as compared to carbon dioxide, but it exists in much lower concentrations and is short-lived than carbon dioxide, making carbon dioxide the more important greenhouse gas.
- Carbon dioxide leaves the atmosphere through photosynthesis, thus entering the terrestrial and oceanic biospheres.

- Carbon dioxide dissolves directly from the atmosphere into water bodies (oceans, lakes, etc.), as well as in precipitation as raindrops fall through the atmosphere.
- When dissolved in water, carbon dioxide reacts with water molecules to form carbonic acid, which contributes to ocean acidity.
- It can then be absorbed by rocks through weathering.
- It also can acidify other surfaces it touches or be washed into the ocean.
- Human activity over the years has significantly increased the amount of carbon in the atmosphere, mainly in the form of carbon dioxide, thus modifying the ecosystems' ability to extract carbon dioxide from the atmosphere thereby emitting it directly e.g. by burning fossil fuels and manufacturing concrete.

Terrestrial biological carbon cycle

- The terrestrial biosphere includes the organic carbon in all land-living organisms, including dead and alive as well as carbon stored in soils.
- About 500 gigatons of carbon are stored above ground in plants and other living organisms, while soil holds approximately 1,500 gigatons of carbon.
- Most carbon in the terrestrial biosphere is organic carbon, while about a third of soil carbon is stored in inorganic forms, such as calcium carbonate.
- Organic carbon is a major component of all organisms living on earth.
- Autotrophs extract it from the air in the form of carbon dioxide, converting it into organic carbon, while heterotrophs receive carbon by consuming other organisms.

- Carbon leaves the terrestrial biosphere in several ways and on different time scales.
- The combustion or respiration of organic carbon releases it rapidly into the atmosphere.
- It can also be exported into the oceans through rivers or remain in soils in the form of inert carbon.
- Carbon stored in soil can remain there for up to thousands of years before being washed into rivers by erosion or released into the atmosphere through soil respiration.
- Between 1989 and 2008 soil respiration increased by about 0.1% per year.
- In 2008, the global total of CO_2 released from the soil reached roughly 98 billion tonnes, about 10 times more than human contribution into the atmosphere each year.
- There are a few plausible explanations for this trend, but the most likely explanation is that increasing temperatures have increased rates of decomposition of soil organic matter, which has increased the flow of CO_2.

Oceanic carbon cycle

- Oceans contain the greatest quantity of actively cycled carbon in this world and are second to the lithosphere in the amount of carbon they store.
- The oceans' surface layer holds large amounts of dissolved organic carbon that is exchanged rapidly with the atmosphere.
- Carbon enters the ocean mainly through the dissolution of atmospheric carbon dioxide, which is converted into carbonate.
- It can also enter the oceans through rivers as dissolved organic carbon.
- It is converted by organisms into organic carbon through photosynthesis and can either be exchanged throughout the food chain or precipitated into the deeper ocean layers as dead soft tissue or in animal shells as calcium carbonate.
- It circulates in this layer for long periods of time before being deposited as sediment or returned to the surface waters through circulation.

- Oceanic absorption of CO_2 is one of the most important forms of carbon removal limiting the rise in carbon dioxide caused by humans in the atmosphere.
- However, this process is limited by a number of factors.

  -the rate of CO_2 dissolution in the ocean is dependent on the weathering of rocks and this process takes place slower than current rates of human greenhouse gas emissions and thus decrease CO_2 uptake.
- CO_2 absorption also makes water more acidic, which affects ocean bio-systems.

Nitrogen cycle

- The **nitrogen cycle** is a cycle in which nitrogen is converted into its various chemical forms.
- This transformation can be carried out through biological and physical processes.
- Important processes in the nitrogen cycle include fixation, ammonification, nitrification, and denitrification.
- The atmosphere contains 78% nitrogen, making it the largest pool of nitrogen.
- However, atmospheric nitrogen has limited biological use, leading to scarcity of usable nitrogen in many ecosystems.
- The nitrogen cycle is of particular interest to ecologists because nitrogen availability can affect the rate of key ecosystem processes, including primary production and decomposition.
- Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle.

Ecological functions of Nitrogen cycle

- Nitrogen is necessary for all known forms of life.
- It is a component of all amino acids and proteins, and is present in the bases that make up nucleic acids such as RNA and DNA.
- In plants, nitrogen is found in chlorophyll molecules, which are essential for photosynthesis and growth.
- Nitrogen gas (N_2) is the largest constituent of the Earth's atmosphere, but this form is relatively nonreactive and unusable by plants.
- Chemical processing or natural fixation (through bacterial conversion) are necessary to convert gaseous nitrogen into compounds such as nitrate or ammonia which can be used by plants.
- The abundance or scarcity of this "fixed" nitrogen (also known as reactive nitrogen) frequently limits plant growth in both managed and wild environments.
- The nitrogen cycle, like the carbon cycle, is an important part of every ecosystem.

The processes of the nitrogen cycle

- Nitrogen is present in the environment in a wide variety of chemical forms including organic nitrogen, ammonium (NH_4^+), nitrite (NO_2), nitrate (NO_3^-), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2).
- Organic nitrogen may be in the form found in living organism, humus or the intermediate products of organic matter decomposition.
- The processes of the nitrogen cycle transform nitrogen from one form to another.
- Many of these processes are carried out by microbes, either in their effort to harvest energy or to accumulate nitrogen in a form needed for their growth.

Nitrogen fixation

- Atmospheric nitrogen must be processed or "fixed" to be used by plants.
- Some fixation occurs in lightning strikes, but most fixation is done by free-living bacteria (*Azotobacter*) or symbiotic bacteria (diazotrophs).
- These bacteria have the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia, which is converted by the bacteria into other organic compounds.
- Most biological nitrogen fixation occurs by the activity of nitrogenase enzyme, found in a wide variety of bacteria and some *Archaea*.
- Symbiotic nitrogen-fixing bacteria such as *Rhizobium* usually live in the root nodules of legumes (such as peas, alfalfa, and locust trees).

- Here they form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates.
- Because of this relationship, legumes will often increase the nitrogen content of nitrogen-poor soils.
- Today, about 30% of the total fixed nitrogen is produced industrially using the Haber-Bosch process, which uses high temperatures and pressures to convert nitrogen gas and hydrogen into ammonia.

Nitrogen Assimilation

- Plants through their roots absorb nitrogen from the soil either as nitrate ions or ammonium ions.
- If nitrate is absorbed, it is first reduced to nitrite ions and then ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll.
- Most nitrogen obtained by terrestrial animals can be traced back to the eating of plants at some stage of the food chain.
- In plants that have a symbiotic relationship with *Rhizobia*, some nitrogen is assimilated in the form of ammonium ions directly from the nodules.

- While many animals, fungi, and other heterotrophic organisms obtain nitrogen by ingestion of amino acids, nucleotides and other small organic molecules, other heterotrophs (including many bacteria) are able to utilize inorganic compounds, such as ammonium as sole N sources.

Ammonification

- When a plant or animal dies or an animal expels waste, the initial form of nitrogen is organic.
- Bacteria or fungi convert the organic nitrogen within the remains back into ammonium (NH_4^+), a process called ammonification or mineralization.

Nitrification

- The conversion of ammonia to nitrate is performed primarily by soil-living bacteria and other nitrifying bacteria.
- In the primary stage of nitrification, the oxidation of ammonium (NH_4^+) is performed by bacteria such as the *Nitrosomonas* species, which converts ammonia to nitrites (NO_2^-).
- Other bacterial species such as *Nitrobacter*, are responsible for the oxidation of the nitrites into nitrates (NO_3^-).
- It is important for the ammonia to be converted to nitrates because accumulated nitrites are toxic to plant life.

Denitrification

- Denitrification is the reduction of nitrates back to the inert nitrogen gas (N_2), completing the nitrogen cycle.
- This process is performed by bacterial species such as *Pseudomonas* and *Clostridium* in anaerobic conditions.
- They use the nitrate as an electron acceptor in the place of oxygen during respiration.
- These facultatively anaerobic bacteria can also live in aerobic conditions.
- Denitrification happens in anaerobic conditions e.g. waterlogged soils.
- The denitrifying bacteria use nitrates in the soil to carry out respiration and consequently produce nitrogen gas, which is inert and unavailable to plants.

Marine nitrogen cycle

- The nitrogen cycle is an important process in the ocean as well.
- While the overall cycle is similar, there are different players and modes of transfer for nitrogen in the ocean.
- Nitrogen enters the water through precipitation, runoff, or as N_2 from the atmosphere.
- Nitrogen cannot be utilized by phytoplankton as N_2 so it must undergo nitrogen fixation which is performed predominately by cyanobacteria.
- Phytoplankton need nitrogen in biologically available forms for the initial synthesis of organic matter.
- Ammonia and urea are released into the water by excretion from plankton.

- Bacteria are able to convert ammonia to nitrite and nitrate but they are inhibited by light so this must occur below the euphotic zone.
- Ammonification or Mineralization is performed by bacteria to convert the ammonia to ammonium.
- Nitrification can then occur to convert the ammonium to nitrite and nitrate.
- Nitrate can be returned to the euphotic zone by phytoplankton to continue the cycle.
- N_2 can be returned to the atmosphere through denitrification.

Human influences on the nitrogen cycle

- Extensive cultivation of legumes (soybean, alfalfa, and clover), growing use of chemical fertilizers, and pollution emitted by vehicles and industrial plants, human beings have doubled the annual transfer of nitrogen into biologically available forms.
- In addition, humans have significantly contributed to the transfer of nitrogen trace gases from Earth to the atmosphere and from the land to aquatic systems.
- Human alterations of global nitrogen cycle are most intense in developed countries and in Asia, where vehicle emissions and industrial agriculture are prevalent.

- Nitrous oxide (N_2O) has risen in the atmosphere as a result of agricultural fertilization, biomass burning, cattle feedlots, and industrial sources.
- N_2O has deleterious effects in the stratosphere, acts as a catalyst in the destruction of atmospheric ozone.
- Nitrous oxide is also a greenhouse gas and is currently the third largest contributor to global warming, after carbon dioxide and methane.
- While methane is not as abundant in the atmosphere as carbon dioxide, it is nearly 300 times more potent in its ability to warm the planet than carbon dioxide.

- Ammonia (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, decreasing air quality and clinging to water droplets, eventually resulting in nitric acid (HNO_3) that produces acid rain.
- Atmospheric ammonia and nitric acid also damage respiratory systems.

Oxygen cycle

- The **oxygen cycle** is the biogeochemical cycle that describes the movement of oxygen within its three main reservoirs: the atmosphere (air), the total content of biological matter within the biosphere, and lithosphere (Earth's crust).
- Failures in the oxygen cycle within the hydrophere can result in the development of hypoxic zones.
- The main driving factor of the oxygen cycle is photosynthesis, which is responsible for the modern Earth's atmosphere and life on earth.
- The main source of atmospheric free oxygen is photosynthesis, which produces sugars and free oxygen from carbon dioxide and water.

- An additional source of atmospheric free oxygen comes from photolysis, whereby high energy ultraviolet radiation breaks down atmospheric water and nitrous oxide into component atoms.
- The free H and N atoms escape into space leaving O_2 in the atmosphere.
- The main way free oxygen is lost from the atmosphere is via respiration and decay, mechanisms in which animal life and bacteria consume oxygen and release carbon dioxide.
- The presence of atmospheric oxygen has led to the formation of ozone (O_3) and the ozone layer within the stratosphere.
- The ozone layer is extremely important to modern life as it absorbs harmful ultraviolet radiation.

Phosphorus cycle

- The **phosphorus cycle** is the biogeochemical cycle that describes the movement of phosphorous through the lithosphere, hydrosphere, and biosphere.
- Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movement of phosphorus, because phosphorus and phosphorus-based compounds are usually solids.
- Consequently, phosphorus gradually becomes less available to plants because it is slowly lost in runoff.
- Low concentration of P in soils reduces plant growth, and slows soil microbial growth and activities.

- Soil microorganisms act as both sinks and sources of available P in the biogeochemical cycle.
- On the other hand, humans have caused major changes to the global P cycle through shipping of P minerals, and use of P fertilizer, and also the shipping of food from farms to cities, where it is lost as effluent.

Ecological functions of Phosphorous

- Phosphorus is an essential nutrient for plants and animals.
- It is a limiting nutrient for aquatic organisms.
- Phosphorus forms parts of important life-sustaining molecules that are very common in the biosphere.

- Phosphorus does not enter the atmosphere as soil minerals but rather as phosphorus fertilizers .
- Phosphates from fertilizers, sewage and detergents can cause pollution in lakes and streams.
- Over enrichment of phosphate in both fresh and marine waters can lead to massive algae blooms which die and decay, leading to eutrophication of fresh waters.
- Phosphorus normally occurs in nature as part of a phosphate ion $(PO_4)^{3-}$, consisting of P atom and 4 oxygen atoms, the most abundant form is orthophosphate.

- On land most phosphorus is found in rocks and minerals.
- Weathering of rocks and minerals release phosphorus in a soluble form where it is taken up by plants, and transformed into organic compounds.
- The plants may then be consumed by herbivores and the phosphorus is either incorporated into their tissues or excreted.
- After death, the animal or plant decays, and phosphorus is returned to the soil where a large part of the phosphorus is transformed into insoluble compounds.
- Runoff may carry a small part of the phosphorus back to the ocean.
- Generally with time the soils become deficient in phosphorus leading to ecosystem retrogression.

Biological functions of Phosphorous

- The primary biological importance of phosphates is as a component of nucleotides, which serve as energy storage within cells (ATP) or when linked together, form the nucleic acids DNA and RNA.
- The double helix of DNA is only possible because of the phosphate ester bridge that binds the helix.
- As bio-molecule, phosphorus is also found in bone and the enamel of mammalian teeth, whose strength is derived from calcium phosphate.
- It is also found in the exoskeleton of insects, and phospholipids of biological membranes.
- It also functions as buffering agent in maintaining acid base homeostasis in the human body.

Phosphorous and Human influences

- Nutrients are important to the growth and survival of living organisms, and hence, are essential for development and maintenance of healthy ecosystems.
- Humans have greatly influenced the phosphorus cycle via mining, converting it to fertilizer, and by shipping fertilizer and related products around the globe.
- Transporting phosphorus in food from farms to cities has made a major change in the global Phosphorus cycle.
- However, excessive amounts of nutrients, particularly phosphorus and nitrogen, are detrimental to aquatic ecosystems.
- Waters are enriched in phosphorus from farms run off, and from effluent that is inadequately treated before it is discharged to waters.

Sulfur cycle

- **Sulfur cycle** is the collection of processes by which sulfur moves to and fro as minerals and living systems.
- Such cycles are important because they affect many minerals.
- Sulfur cycles are also important for life because it is an essential element, being a constituent of many proteins and cofactors.

Sulfur and Human Impacts

- Human activities have a major effect on the global sulfur cycle.
- The burning of coal, natural gas, and other fossil fuels has greatly increased the amount of S in the atmosphere and ocean and depleted the sedimentary rock sink.

- Without human impact sulfur would stay tied up in rocks for years until released through erosion and weathering processes.
- Human activities greatly increase the flux of sulfur in the atmosphere, some of which is transported globally.
- The result of human impact on these processes is to increase the pool of oxidized sulfur (SO_4) on global cycle, at the expense of the storage of reduced sulfur in the Earth's crust.
- Therefore, human activities do not cause a major change in the global pools of S, but do produce massive changes in the annual flux of S through the atmosphere.

- When SO_2 is emitted as an air pollutant, it forms sulfuric acid through reactions with water in the atmosphere.
- Once the acid is completely dissociated in water the pH can drop to 4.3 or lowered causing damage to both man-made and natural systems.

Interactions between species

- Populations occurring together in an area interact with each other in many but different ways. These interactions are generally called biotic interactions
- These biological interactions refer to feeding (nutrition), energy based relationships occurring among living components within a given community
- **Intra specific** interactions refer to interactions among individuals of the same species
- **Inter specific** interactions refer to interactions among individuals of two or more different species

Types of interactions

- **Competition**: An interaction where one organism performs less well in the presence of the presence of another organism than if alone.
- **Mutualism**: Refers to interactions where each participating organism performs better in the presence of the other organism. Symbiosis is a form of mutualism
- **Predation**: Is a relationship where one organism (predator) feeds upon another organism (prey), which is usually smaller in size

Types of interactions

- **Parasitism**: In this case, one organism (parasite) lives upon or in the body of the other organism (host) taking food and nutrients from the host's living tissues in a detrimental manner
- **Commensalism**: This is an interaction between two organisms in which one benefits, while the other remains unaffected by the other's presence
- **Ammensalism**: This refers to an interaction between two organisms wherein one organism is harmed by the presence of the other while the associated organism is unaffected. It is the opposite of commensalism

NICHE

- A niche combines the most suitable habitat with the functional relationships/roles of an organism in the community
- A niche may thus be described as the sum total of biotic and abiotic factors to which a given species is uniquely adapted to in an ecosystem
- No two species can occupy exactly the same niche, though their niches may overlap, in which case competition for a specific resource may occur

NICHE Cont’d

In summary, it is the sum total of an organism’s:

- Actual dwelling place in the habitat
- Functional role in the ecosystem (producer, consumer or decomposer)
- Requirement for abiotic resources,
- Tolerance ranges for each abiotic condition in the ecosystem

SUCCESSION

- Biotic communities are continually changing. These changes may be cyclic or non-cyclic
- Succession refers to a series of unidirectional, cumulative, often permanent changes that takes place in a community bringing it to a stable, complex state called **climax**
- Two major types: Primary and Secondary
- Individual successions called seres (Prisere and subsere); developmental stages called seral stages
- Succession in water and on drylands referred to as Hydrarch and Xerarch respectively

BIOMES

- These are large, natural terrestrial ecosystems mainly identified by predominant types of vegetation
- Type of vegetation in a biome is largely determined by climatic factors, particularly rainfall and temperature
- Regions across the world with similar climates have similar biomes

Types of Biomes

- Tropical rain forests
- Dense forests with very many and different evergreen tree species, epiphytes and climbers
- High annual rainfall (2000-2500mm) and average temperature of 27^{0}C throughout the year
- Savanna (tropical grasslands)
- Scattered, drought tolerant trees
- Extensive areas of grasslands, mostly perennial in nature
- Generally poor, infertile soils
- Warm/Cool dry season alternating with hot, rainy season

Types of Biomes Cont'd

- Mangrove swamps
  - Forests with small, evergreen broad leaved tree species
  - Hot and wet climate throughout the year [very high annual rainfall (2500mm and above) and average temperature of 26^0C throughout the year]
  - Water logged soil conditions
- Desert/Semi-desert
  - Very sparse vegetation, mainly annuals and some succulent perennials with deep root systems
  - Extremely high and low temperatures with very little rainfall (less than 250mm annually)
  - Animal diversity also very low in this environment

Types of Biomes Cont'd

- Montane (mountain) Vegetation

- Evergreen forests; less luxuriant species compared to rain forests
- Mostly cool climate throughout the year with average to high annual rainfall

- Tundra

- Mostly treeless, marshy vegetation comprising dwarf shrubs, grasses, sedges, lichens and moss species
- Very cold climate (average of 10^0C) with water permanently frozen in the subsoil [permafrost]
- Vegetation adapted to a very short growing season