UNIT – II

Ecosystem – concept, structure, types and functions- energy flow and bio-geo chemical cycle- Nitrogen cycle, Phosphorus cycle and Water cycle. Ecosystem diversity – Hydric system – hydrophytic adaptations, Xeric systems – xerophytic adaptations and halophytic adaptations.

Ecosystems: Concept, Structure and Functions of Ecosystems

Concept of an Ecosystem

Living organisms cannot live isolated from their non-living environment be•cause the latter provides materials and energy for the survival of the former i.e. there is interaction between a biotic community and its environment to produce a stable system; a natural self-sufficient unit which is known as an ecosystem.

An ecosystem is, therefore, defined as a natural functional ecological unit com•prising of living organisms (biotic community) and their non-living (abiotic or physio chemical) environment that interact to form a stable self-supporting sys•tem. A pond, lake, desert, grassland, meadow, forest etc. are common examples of ecosystems.

Structure and Function of an

Ecosystem Each ecosystem has two

main components

(1) Abiotic

(2) Biotic

(1) Abiotic Components

The non living factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behaviour and inter- relationship of organisms.

Abiotic components are mainly of two types:

(a) Climatic Factors

Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors

Which include soil, pH, topography minerals etc

The functions of important factors in abiotic components are given below

Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic mat•ter, and living organisms. Soils provide nutrients, water, a home, and a struc•tural growing medium for organisms. The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling.

The atmosphere provides organisms found within ecosystems with carbon di•oxide for photosynthesis and oxygen for respiration. The processes of evapora•tion, transpiration and precipitation cycle water between the atmosphere and the Earth’s surface.

Solar radiation is used in ecosystems to heat the atmosphere and to evapo•rate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis.

Photosynthesis provides the energy for plant growth and me•tabolism, and the organic food for other forms of life.

Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.

Water is the medium by which mineral nutrients enter and are trans-located in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical reactions. Plants and animals receive their water from the Earth's surface and soil. The original source of this water is precipita•tion from the atmosphere.

(2) Biotic Components

The living organisms including plants, animals and micro-organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components.

On the basis of their role in the ecosystem the biotic components can be classi•fied into three main groups:

(A) Producers

(B) Consumers

(C) Decomposers or Reducers.

(A) Producers

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photo•synthesis. As the green plants manufacture their own food they are known as Autotrophs (i.e. auto = self, trophos = feeder)

The chemical energy stored by the producers is utilised partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers

The animals lack chlorophyll and are unable to synthesise their own food. There•fore, they depend on the producers for their food. They are known as heterotrophs (i.e. heteros = other, trophos = feeder)

The consumers are of four types, namely:

(a) Primary Consumers or First Order Consumers or Herbivores

These are the animals which feed on plants or the producers. They are called her•bivores. Examples are rabbit, deer, goat, cattle etc.

(b) Secondary Consumers or Second Order Consumers or Primary Carnivores

The animals which feed on the herbivores are called the pri•mary carnivores. Examples are cats, foxes, snakes etc.

(c) Tertiary Consumers or Third Order Consumers:

These are the large carnivores which feed on the secondary consumers. Example are Wolves.

(d) Quaternary Consumers or Fourth Order Consumers or Omnivores

These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

(C) Decomposers or Reducers

Bacteria and fungi belong to this category. They breakdown the dead organic materials of producers (plants) and consumers (animals) for their food and re•lease to the environment the simple inorganic and organic substances produced as by-products of their metabolisms.

These simple substances are reused by the producers resulting in a cyclic ex•change of materials between the biotic community and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder)

Schematic Representation of the Structure of an Ecosystem Relationship within an Ecosystem

Energy Flow in Ecosystem

The chemical energy of food is the main source of energy required by all living organisms. This energy is transmitted to different trophic levels along the food chain. This energy flow is based on two different laws of thermodynamics

First law of thermodynamics, that states that energy can neither be created nor destroyed, it can only change from one form to another.

Second law of thermodynamics, that states that as energy is transferred more and more of it is wasted.

Energy Flow in Ecosystem

The energy flow in the ecosystem is one of the major factors that support the survival of such a great number of organisms. For almost all organisms on earth, the primary source of energy is solar energy. It is amusing to find that we receive less than 50 per cent of the sun's effective radiation on earth. When we say effective radiation, we mean the radiation, which can be used by plants to carry out photosynthesis.

Most of the sun's radiation that falls on the earth is usually reflected back into space by the earth's atmosphere. This effective radiation is termed as the Photosynthetically Active Radiation (PAR).

Overall, we receive about 40 to 50 percent of the energy having Photosynthetically Active Radiation and only around 2-10 percent of it is used by plants for the process of photosynthesis. Thus, this percent of PAR supports the entire world as plants are the producers in the ecosystem and all the other organisms are either directly or indirectly dependent on them for their survival.

The energy flow takes place via the food chain and food web. During the process of energy flow in the ecosystem, plants being the producers absorb sunlight with the help of the chloroplasts and a part of it is transformed into chemical energy in the process of photosynthesis.

This energy is stored in various organic products in the plants and passed on to the primary consumers in the food chain when the herbivores consume (primary consumers) the plants as food. Then conversion of chemical energy stored in plant products into kinetic energy occurs, degradation of energy will occur through its conversion into heat.

Then followed by the secondary consumers. When these herbivores are ingested by carnivores of the first order (secondary consumers) further degradation will occur. Finally, when tertiary consumers consume the carnivores, energy will again be degraded. Thus, the energy flow is unidirectional in nature.

Moreover, in a food chain, the energy flow follows the 10 percent law. According to this law, only 10 percent of energy is transferred from one trophic level to the other; rest is lost into the atmosphere. This is clearly explained in the following figure and is represented as an energy pyramid.

Trophic level

The producers and consumers in the ecosystem can be arranged into different feeding groups and are known as trophic level or the feeding level.

The producers (plants) represent the first trophic level.

Herbivores (primary consumers) present the second trophic

level.

Primary carnivores (secondary consumers) represent the third

trophic level Top carnivores (tertiary consumers) represent the last

level.

Food Chain

There are basically three different types of food chains in the ecosystem, namely –

Grazing food chain (GFC) – This is the normal food chain that we observe in which plants are the producers and the energy flows from the producers to the herbivores (primary consumers), then to carnivores (secondary consumers) and so on.

Saprophytic or Detritus food chain (DFC) – In this type of food chain, the dead organic matter occupies the lowermost level of the food chain, followed by the decomposers and so on.

Parasitic food chain (PFC) – In this type of food chain, large organisms either the producer or the consumer is exploited and therefore the food passes to the smaller organism.

In nature, we mostly observe food web as there are many organisms which are omnivores. As a result, they occupy multiple trophic levels.

The energy flow is the amount of energy that moves along the food chain. This energy flow is also known as calorific flow. The energy flow in the ecosystem is important to maintain an ecological balance. The producers synthesise food by the process of photosynthesis. A part of the energy is stored within the plants. The remaining energy is utilised by the plants in their growth and development. This stored energy is transferred to the primary consumers when they feed on the producers. This energy is further passed on to the secondary consumers when they feed on the primary consumers, and so on. The 10 percent law of energy flow states that when the energy is passed on from one trophic level to another, only 10 percent of the energy is passed on to the next trophic level.

Biogeochemical cycle

In ecology and Earth science, a biogeochemical cycle or substance turnover or cycling of substances is a pathway by which a chemical substance moves through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth. There are biogeochemical cycles for the chemical elements calcium, carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, selenium, iron and sulfur; molecular cycles for water and silica; macroscopic cycles such as the rock cycle; as well as human-induced cycles for synthetic compounds such as polychlorinated biphenyl (PCB). In some cycles there are reservoirs where a substance remains for a long period of time.

Systems

Ecological systems (ecosystems) have many biogeochemical cycles operating as a part of the system, for example, the water cycle, the carbon cycle, the nitrogen cycle, etc. All chemical elements occurring in organisms are part of biogeochemical cycles. In addition to being a part of living organisms, these chemical elements also cycle through abiotic factors of ecosystems such as water (hydrosphere), land (lithosphere), and/or the air (atmosphere).

The living factors of the planet can be referred to collectively as the biosphere. All the nutrients— such as carbon, nitrogen, oxygen, phosphorus, and sulfur—used in ecosystems by living organisms are a part of a closed system; therefore, these chemicals are recycled instead of being lost and replenished constantly such as in an open system.

The flow of energy in an ecosystem is an open system; the sun constantly gives the planet energy in the form of light while it is eventually used and lost in the form of heat throughout the trophic levels of a food web. Carbon is used to make carbohydrates, fats, and proteins, the major sources of food energy. These compounds are oxidized to release carbon dioxide, which can be captured by plants to make organic compounds. The chemical reaction is powered by the light energy of the sun.

Sunlight is required to combine carbon with hydrogen and oxygen into an energy source, but ecosystems in the deep sea, where no sunlight can penetrate, obtain energy from sulfur. Hydrogen sulfide near hydrothermal vents can be utilized by organisms such as the giant tube worm. In the sulfur cycle, sulfur can be forever recycled as a source of energy. Energy can be released through the oxidation and reduction of sulfur compounds (e.g., oxidizing elemental sulfur to sulfite and then to sulfate).

Although the Earth constantly receives energy from the sun, its chemical composition is essentially fixed, as the additional matter is only occasionally added by meteorites. Because this chemical composition is not replenished like energy, all processes that depend on these chemicals must be recycled. These cycles include both the living biosphere and the nonliving lithosphere, atmosphere, and hydrosphere.

Reservoirs

The chemicals are sometimes held for long periods of time in one place. This place is called a reservoir, which, for example, includes such things as coal deposits that are storing carbon for a long period of time. When chemicals are held for only short periods of time, they are being held in exchange pools. Examples of exchange pools include plants and animals.

Plants and animals utilize carbon to produce carbohydrates, fats, and proteins, which can then be used to build their internal structures or to obtain energy. Plants and animals temporarily use carbon in their systems and then release it back into the air or surrounding medium. Generally, reservoirs are abiotic factors whereas exchange pools are biotic factors. Carbon is held for a relatively short time in plants and animals in comparison to coal deposits. The amount of time that a chemical is held in one place is called its residence time.

Important cycles

The most well-known and important biogeochemical cycles are shown below

Nitrogen Cycle

"Nitrogen Cycle is a biogeochemical process which transforms the inert nitrogen present in the atmosphere to a more usable form for living organisms."

Furthermore, nitrogen is a key nutrient element for plants. However, the abundant nitrogen in the atmosphere cannot be used directly by plants or animals. Read on to explore how the Nitrogen cycle makes usable nitrogen available to plants and other living organisms.

Nitrogen Cycle is a biogeochemical process through which nitrogen is converted into many forms, consecutively passing from the atmosphere to the soil to organism and back into the atmosphere.

It involves several processes such as nitrogen fixation, nitrification, denitrification, decay and putrefaction. The nitrogen gas exists in both organic and inorganic forms. Organic nitrogen exists in living organisms, and they get passed through the food chain by the consumption of other living organisms.

Inorganic forms of nitrogen are found in abundance in the atmosphere. This nitrogen is made available to plants by symbiotic bacteria which can convert the inert nitrogen into a usable form – such as nitrites and nitrates.

Nitrogen undergoes various types of transformation to maintain a balance in the ecosystem. Furthermore, this process extends to various biomes, with the marine nitrogen cycle being one of the most complicated biogeochemical cycles.

Stages of Nitrogen Cycle

Process of Nitrogen Cycle consists of the following steps – Nitrogen fixation, Nitrification, Assimilation, Ammonification and Denitrification. These processes take place in several stages and are explained below:

Nitrogen fixation

It is the initial step of the nitrogen cycle. Here, Atmospheric nitrogen (N_2) which is primarily available in an inert form, is converted into the usable form -ammonia (NH_3).

During the process of Nitrogen fixation, the inert form of nitrogen gas is deposited into soils from the atmosphere and surface waters, mainly through precipitation. Later, the nitrogen undergoes a set of changes, in which two nitrogen atoms get separated and combine with hydrogen to form ammonia (NH_4^+).

The entire process of Nitrogen fixation is completed by symbiotic bacteria which are known as Diazotrophs. Azotobacter and Rhizobium also have a major role in this process. These bacteria consist of a nitrogenase enzyme which has the capability to combine gaseous nitrogen with hydrogen to form ammonia.

Nitrogen fixation can occur either by the atmospheric fixation- which involves lightening or industrial fixation by manufacturing ammonia under high temperature and pressure condition. This can also be fixed through man-made processes, primarily industrial processes that create ammonia and
nitrogen-rich fertilisers.

Types of Nitrogen

Fixation

Atmospheric fixation: A natural phenomenon where the energy of lightning breaks the nitrogen into nitrogen oxides and is then used by plants.

Industrial nitrogen fixation: Is a man-made alternative that aids in nitrogen fixation by the use of ammonia. Ammonia is produced by the direct combination of nitrogen and hydrogen and later, it is converted into various fertilisers such as urea.

Biological nitrogen fixation: We already know that nitrogen is not usable directly from the air for plants and animals. Bacteria like Rhizobium and blue-green algae transform the unusable form of nitrogen into other compounds that are more readily usable. These nitrogen compounds get fixed in the soil by these microbes.

Nitrification

In this process, the ammonia is converted into nitrate by the presence of bacteria in the soil. Nitrites are formed by the oxidation of Ammonia with the help of Nitrosomonas bacterium species. Later, the produced nitrites are converted into nitrates by Nitrobacter. This conversion is very important as ammonia gas is toxic for plants.

The reaction involved in the process of Nitrification is as follows:

$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$

$2NO_2^- + O_2 \rightarrow 2NO_3^-$

Assimilation

Primary producers – plants take in the nitrogen compounds from the soil with the help of their roots, which are available in the form of ammonia, nitrite ions, nitrate ions or ammonium ions and are used in the formation of the plant and animal proteins. This way, it enters the food web when the primary consumers eat the plants.

Ammonification

When plants or animals die, the nitrogen present in the organic matter is released back into the soil. The decomposers, namely bacteria or fungi present in the soil, convert the organic matter back into ammonium. This process of decomposition produces ammonia, which is further used for other biological processes.

Denitrification

Denitrification is the process in which the nitrogen compounds makes its way back into the atmosphere by converting nitrate (NO_3^-) into gaseous nitrogen (N). This process of the nitrogen cycle is the final stage and occurs in the absence of oxygen. Denitrification is carried out by the denitrifying bacterial species- Clostridium and Pseudomonas, which will process nitrate to gain oxygen and gives out free nitrogen gas as a byproduct.

Nitrogen Cycle in Marine Ecosystem

The process of the nitrogen cycle occurs in the same manner in the marine ecosystem as in the terrestrial ecosystem. The only difference is that it is carried out by marine bacteria.

The nitrogen-containing compounds that fall into the ocean as sediments get compressed over long periods and form sedimentary rock. Due to the geological uplift, these sedimentary rocks move to land. Initially, it was not known that these nitrogen-containing sedimentary rocks are an essential source of nitrogen. But, recent researches have proved that the nitrogen from these rocks is released into the plants due to the weathering of rocks.

Importance of Nitrogen Cycle

Helps plants to synthesise chlorophyll from the nitrogen compounds.

Helps in converting inert nitrogen gas into a usable form for the plants through the biochemical process.

In the process of ammonification, the bacteria help in decomposing the animal and plant matter, which indirectly helps to clean up the environment.

Nitrates and nitrites are released into the soil, which helps in enriching the soil with necessary nutrients required for cultivation.

Nitrogen is an integral component of the cell and it forms many crucial compounds and important biomolecules.

Nitrogen is also cycled by human activities such as combustion of fuels and the use of nitrogen fertilisers. These processes, increase the levels of nitrogen-containing compounds in the atmosphere. The fertilisers containing nitrogen are washed away in lakes and rivers and results in eutrophication

Nitrogen is abundant in the atmosphere, but it is unusable to plants or animals unless it is converted into nitrogen compounds.

Nitrogen-fixing bacteria play a crucial role in fixing the atmospheric nitrogen into nitrogen compounds that can be used by the plants.

The plants absorb the usable nitrogen compounds from the soil through their roots. Then, these nitrogen compounds are used for the production of proteins and other compounds in the cell.

Animals assimilate nitrogen by consuming these plants or other animals that contain nitrogen.

Humans consume proteins from these plants and animals and then, the nitrogen assimilates into our system. During the final stages of the nitrogen cycle, bacteria and fungi help decompose organic matter, where the nitrogenous compounds get dissolved into the soil which is again used by the plants. Some bacteria then convert these nitrogenous compounds in the soil and turn it into nitrogen gas. Eventually, it goes back to the atmosphere. These sets of processes repeat continuously and thus maintain the percentage of nitrogen in the atmosphere

Phosphorus cycle

The phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus 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 at the typical ranges of temperature and pressure found on Earth. The production of phosphine gas occurs in only specialized, local conditions. Therefore, the phosphorus cycle should be viewed from whole Earth system and then specifically focused on the cycle in terrestrial and aquatic systems.

On the land, phosphorus gradually becomes less available to plants over thousands of years, since it is slowly lost in runoff. Low concentration of phosphorus in soils reduces plant growth, and slows soil microbial growth - as shown in studies of soil microbial biomass. Soil microorganisms act as both sinks and sources of available phosphorus in the biogeochemical cycle. Locally, transformations of phosphorus are chemical, biological and microbiological: the major long-term transfers in the global cycle, however, are driven by tectonic movements in geologic time.

Humans have caused major changes to the global phosphorus cycle through shipping of phosphorus minerals, and use of phosphorus fertilizer, and also the shipping of food from farms to cities, where it is lost as effluent.

Ecological function

Phosphorus is an essential nutrient for plants and animals. Phosphorus is a limiting nutrient for aquatic organisms. Phosphorus forms parts of important life-sustaining molecules that are very common in the biosphere. Phosphorus does enter the atmosphere in very small amounts when the dust is dissolved in rainwater and seaspray but remains mostly on land and in rock and soil minerals. Eighty percent of the mined phosphorus is used to make fertilizers. Phosphates from fertilizers, sewage and detergents can cause pollution in lakes and streams. Over-enrichment of phosphate in both fresh and inshore marine waters can lead to massive algae blooms which, when they die and decay leads to eutrophication of freshwaters only. An example of this is the Canadian Experimental Lakes Area. These freshwater algal blooms should not be confused with those in saltwater environments. Recent research suggests that the predominant pollutant responsible for algal blooms in saltwater estuaries and coastal marine habitats is nitrogen.

Phosphorus occurs most abundantly in nature as part of the orthophosphate ion (PO4)3−, consisting of a P atom and 4 oxygen atoms. On land most phosphorus is found in rocks and minerals.
Phosphorus-rich deposits have generally formed in the ocean or from guano, and over time, geologic processes bring ocean sediments to land. Weathering of rocks and minerals release phosphorus in a soluble form where it is taken up by plants, and it is 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 (thousands of years) soils become deficient in phosphorus leading to ecosystem retrogression.

Major pools in aquatic systems

There are four major pools of phosphorus in freshwater ecosystems: dissolved inorganic phosphorus (DIP), dissolved organic phosphorus (DOP), particulate organic phosphorus (POP), and particulate
inorganic phosphorus (PIP). Dissolved material is defined as substances that pass through a 0.45μm

filter. DIP consists mainly of orthophosphate (PO_4^{3-}) and polyphosphate, while DOP consists of DNA and phosphoproteins. Particulate matter are the substances that get caught on a 0.45µm filter and do not pass through. POP consists of both living and dead organisms, while PIP mainly consists of hydroxyapatite, $Ca_5(PO_4)_3OH$.

Biological function

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 our DNA is only possible because of the phosphate ester bridge that binds the helix. Besides making biomolecules, phosphorus is also found in bone and the enamel of mammalian teeth, whose strength is derived from calcium phosphate in the form of hydroxyapatite. It is also found in the exoskeleton of insects, and phospholipids (found in all biological membranes). It also functions as a buffering agent in maintaining acid base homeostasis in the human body.

Phosphorus cycling

Phosphates move quickly through plants and animals; however, the processes that move them through the soil or ocean are very slow, making the phosphorus cycle overall one of the slowest biogeochemical cycles.

The global phosphorus cycle includes four major processes: (i) tectonic uplift and exposure of phosphorus-bearing rocks such as apatite to surface weathering; (ii) physical erosion, and chemical and biological weathering of phosphorus-bearing rocks to provide dissolved and particulate phosphorus to soilslakes and rivers; (iii) riverine and subsurface transportation of phosphorus to various lakes and run-off to the ocean; (iv) sedimentation of particulate phosphorus (e.g., phosphorus associated with organic matter and oxide/carbonate minerals) and eventually burial in marine sediments (this process can also occur in lakes and rivers).

In terrestrial systems, bioavailable P (‘reactive P’) mainly comes from weathering of phosphorus-containing rocks. The most abundant primary phosphorus-mineral in the crust is apatite, which can be dissolved by natural acids generated by soil microbes and fungi, or by other chemical weathering reactions and physical erosion. The dissolved phosphorus is bioavailable to terrestrial organisms and plants and is returned to the soil after their decay. Phosphorus retention by soil minerals (e.g., adsorption onto iron and aluminum oxyhydroxides in acidic soils and precipitation onto calcite in neutral-to-calcareous soils) is usually viewed as the most important processes in controlling terrestrial P-bioavailability in the mineral soil. This process can lead to the low level of dissolved phosphorus concentrations in soil solution. Various physiological strategies are used by plants and microorganisms for obtaining phosphorus from this low level of phosphorus concentration.

Soil phosphorus is usually transported to rivers and lakes and can then either be buried in lake sediments or transported to the ocean via river runoff. Atmospheric phosphorus deposition is another important marine phosphorus source to the ocean. In surface seawater, dissolved inorganic phosphorus, mainly orthophosphate (PO_4^{3-}), is assimilated by phytoplankton and transformed into organic phosphorus compounds. Phytoplankton cell lysis releases cellular dissolved inorganic and organic phosphorus to the surrounding environment. Some of the organic phosphorus compounds can be hydrolyzed by enzymes synthesized by bacteria and phytoplankton and subsequently assimilated. The vast majority of phosphorus is remineralized within the water column, and approximately 1% of associated phosphorus carried to the deep sea by the falling particles is removed from the ocean reservoir by burial in sediments. A series of diagenetic processes act to enrich sediment pore water phosphorus concentrations, resulting in an appreciable benthic return flux of phosphorus to overlying bottom waters. These processes include (i) microbial respiration of organic matter in sediments, (ii) microbial reduction and dissolution of iron and manganese (oxyhydr)oxides with subsequent release of associated phosphorus, which connects the phosphorus cycle to the iron cycle, and (iii) abiotic reduction of iron (oxyhydr)oxides by hydrogen sulfide and liberation of iron-associated phosphorus. Additionally, (i) phosphate associated with calcium carbonate and (ii) transformation of iron oxide-bound phosphorus to vivianite play critical roles in phosphorus burial in marine sediments.These processes are similar to phosphorus cycling in lakes and rivers.

Although orthophosphate (PO43-), the dominant inorganic P species in nature, is oxidation state (P5+), certain microorganisms can use phosphonate and phosphite (P3+ oxidation state) as a P source by oxidizing it to orthophosphate.[20] Recently, rapid production and release of reduced phosphorus compounds has provided new clues about the role of reduced P as a missing link in oceanic phosphorus.

Phosphatic minerals

The availability of phosphorus in an ecosystem is restricted by the rate of release of this element during weathering. The release of phosphorus from apatite dissolution is a key control on ecosystem productivity. The primary mineral with significant phosphorus content, apatite [Ca5(PO4)3OH] undergoes carbonation.

Little of this released phosphorus is taken up by biota (organic form), whereas a larger proportion reacts with other soil minerals. This leads to precipitation into unavailable forms in the later stage of weathering and soil development. Available phosphorus is found in a biogeochemical cycle in the upper soil profile, while phosphorus found at lower depths is primarily involved in geochemical reactions with secondary minerals. Plant growth depends on the rapid root uptake of phosphorus released from dead organic matter in the biochemical cycle. Phosphorus is limited in supply for plant growth. Phosphates move quickly through plants and animals; however, the processes that move them through the soil or ocean are very slow, making the phosphorus cycle overall one of the slowest biogeochemical cycles.

Low-molecular-weight (LMW) organic acids are found in soils. They originate from the activities of various microorganisms in soils or may be exuded from the roots of living plants. Several of those organic acids are capable of forming stable organo-metal complexes with various metal ions found in soil solutions. As a result, these processes may lead to the release of inorganic phosphorus associated with aluminum, iron, and calcium in soil minerals. The production and release of oxalic acid by mycorrhizal fungi explain their importance in maintaining and supplying phosphorus to plants.

The availability of organic phosphorus to support microbial, plant and animal growth depends on the rate of their degradation to generate free phosphate. There are various enzymes such as phosphatases, nucleases and phytase involved for the degradation. Some of the abiotic pathways in the environment studied are hydrolytic reactions and photolytic reactions. Enzymatic hydrolysis of organic phosphorus is an essential step in the biogeochemical phosphorus cycle, including the phosphorus nutrition of plants and microorganisms and the transfer of organic phosphorus from soil to bodies of water. Many organisms rely on the soil derived phosphorus for their phosphorus nutrition.

Phosphorus and Eutrophication

A simplified illustration of the nitrogen and phosphorus cycles in a wetland (modified from Kadlec and Knight (1996), “Treatment Wetlands”; images from IAN, University of Maryland).

Eutrophication is an enrichment of water by nutrient that lead to structural changes to the aquatic ecosystem such as algae bloom, deoxygenation, reduction of fish species. The primary source that contributes to the eutrophication is considered as nitrogen and phosphorus. When these two elements exceed the capacity of the water body, eutrophication occurs. Phosphorus that enters lakes will accumulate in the sediments and the biosphere, it also can be recycled from the sediments and the water system. Drainage water from agricultural land also carries phosphorus and nitrogen. Since a large amount of phosphorus is in the soil contents, so the overuse of fertilizers and over- enrichment with nutrients will lead to increasing the amount of phosphorus concentration in agricultural runoff. When eroded soil enters the lake, both phosphorus and the nitrogen in the soil contribute to eutrophication, and erosion caused by deforestation which also results from uncontrolled planning and urbanization.

Wetland

Wetlands are frequently applied to solve the issue of eutrophication. Nitrate is transformed in wetlands to free nitrogen and discharged to the air. Phosphorus is adsorbed by wetland soils which are taken up by the plants. Therefore, wetlands could help to reduce the concentration of nitrogen and phosphorus to remit and solve the eutrophication. However, wetland soils can only hold a limited amount of phosphorus. To remove phosphorus continually, it is necessary to add more new soils within the wetland from remnant plant stems, leaves, root debris, and undecomposable parts of dead algae, bacteria, fungi, and invertebrates

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 by mining phosphorus, converting it to fertilizer, and by shipping fertilizer and 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.The input of P in agricultural runoff can accelerate the eutrophication of P- sensitive surface waters. Natural eutrophication is a process by which lakes gradually age and become more productive and may take thousands of years to progress. Cultural or anthropogenic eutrophication, however, is water pollution caused by excessive plant nutrients; this results in excessive growth in the algal population; when this algae dies its putrefaction depletes the water of oxygen. Such eutrophication may also give rise to toxic algal bloom. Both these effects cause animal and plant death rates to increase as the plants take in poisonous water while the animals drink the poisoned water. Surface and subsurface runoff and erosion from high-phosphorus soils may be major contributing factors to this fresh water eutrophication. The processes controlling soil Phosphorus release to surface runoff and to subsurface flow are a complex interaction between the type of phosphorus input, soil type and management, and transport processes depending on hydrological conditions.

Repeated application of liquid hog manure in excess to crop needs can have detrimental effects on soil phosphorus status. Also, application of biosolids may increase available phosphorus in soil.In poorly drained soils or in areas where snowmelt can cause periodic waterlogging, reducing conditions can be attained in 7–10 days. This causes a sharp increase in phosphorus concentration in solution and phosphorus can be leached. In addition, reduction of the soil causes a shift in phosphorus from resilient to more labile forms. This could eventually increase the potential for phosphorus loss. This is of particular concern for the environmentally sound management of such areas, where disposal of agricultural wastes has already become a problem. It is suggested that the water regime of soils that are to be used for organic wastes disposal is taken into account in the preparation of waste management regulations.

Water cycle

As the Earth's surface water evaporates, wind moves water in the air from the sea to the land, increasing the amount of freshwater on land.

Water vapor is converted to clouds that bring fresh water to land in the form of rain snow and sleet

Precipitation falls on the ground, but what happens to that water depends greatly on the geography of the land at any particular place.

The water cycle, also known as the hydrologic cycle or the hydrological 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 from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, surface runoff, and subsurface flow. In doing so, the water goes through different forms: liquid, solid (ice) and vapour.

The water cycle involves the exchange of energy, which leads to temperature changes. 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. It is also involved in reshaping the geological features of the Earth, through processes including erosion and sedimentation. The water cycle is also essential for the maintenance of most life and ecosystems on the planet.

The sun, which drives the water cycle, heats water in oceans and seas. Water evaporates as water vapor into the air. Some ice and snow sublimates directly into water vapor. Evapotranspiration is water transpired from plants and evaporated from the soil. The water molecule H2O has smaller molecular mass than the major components of the atmosphere, nitrogen and oxygen, N2 and O2, hence is less dense. Due to the significant difference in density, buoyancy drives humid air higher. As altitude increases, air pressure decreases and the temperature drops (see Gas laws). The lower temperature causes water vapor to condense into tiny liquid water droplets which are heavier than the air, and fall unless supported by an updraft. A huge concentration of these droplets over a large space up in the atmosphere become visible as cloud. Some condensation is near ground level, and called fog.

Atmospheric circulation moves water vapor 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 in valleys in the landscape, with streamflow 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 infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge. Some groundwater finds openings in the land surface and comes out as freshwater springs. In river valleys and floodplains, there is often continuous water exchange between surface water and ground water in the hyporheic zone. Over time, the water returns to the ocean, to continue the water cycle. Many different processes lead to movements and phase changes in water

Condensed water vapour that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, graupel, and sleet. Approximately 505,000 km3 (121,000 cu mi) of water falls as precipitation each year, 398,000 km3 (95,000 cu mi) of it over the oceans. better source needed] The rain on land contains 107,000 km3 (26,000 cu mi) of water per year and a snowing only 1,000 km3 (240 cu mi).[4] 78% of global precipitation occurs over the ocean.

Canopy interception

The precipitation that is intercepted by plant foliage eventually evaporates back to the atmosphere rather than falling to the ground.

Snowmelt

The runoff produced by melting

snow. Runoff

The variety of ways by which water moves across the land. This includes both surface runoff and channel runoff. As it flows, the water may seep into the ground, evaporate into the air, become stored in lakes or reservoirs, or be extracted for agricultural or other human uses.

Infiltration

The flow of water from the ground surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater. A recent global study using water stable isotopes, however, shows that not all soil moisture is equally available for groundwater recharge or for plant transpiration.

Subsurface flow

The flow of water underground, in the vadose zone and aquifers. Subsurface water may return to the surface (e.g. as a spring or by being pumped) or eventually seep into the oceans. Water returns to the land surface at lower elevation than where it infiltrated, under the force of gravity or gravity induced pressures. Groundwater tends to move slowly and is replenished slowly, so it can remain in aquifers for thousands of years.

Evaporation

The transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere. The source of energy for evaporation is primarily solar radiation. Evaporation often implicitly includes transpiration from plants, though together they are specifically referred to as evapotranspiration. Total annual evapotranspiration amounts to approximately 505,000 km3 (121,000 cu mi) of water, 434,000 km3 (104,000 cu mi) of which evaporates from the oceans. 86% of global evaporation occurs over the ocean.

Sublimation

The state change directly from solid water (snow or ice) to water vapor by passing the

liquid state. Deposition

This refers to changing of water vapor directly to ice.

The movement of water through the atmosphere. Without advection, water that evaporated over the oceans could not precipitate over land.

Condensation

The transformation of water vapor to liquid water droplets in the air, creating clouds

and fog. Transpiration

The release of water vapor from plants and soil into

the air. Percolation

Water flows vertically through the soil and rocks under the influence of

gravity. Plate tectonics

Water enters the mantle via subduction of oceanic crust. Water returns to the surface via

volcanism. The water cycle involves many of these processes.

The residence time of a reservoir within the hydrologic cycle is the average time a water molecule will spend in that reservoir . It is a measure of the average age of the water in that reservoir.

Groundwater can spend over 10,000 years beneath Earth's surface before leaving. Particularly old groundwater is called fossil water. Water stored in the soil remains there very briefly, because it is spread thinly across the Earth, and is readily lost by evaporation, transpiration, stream flow, or groundwater recharge. After evaporating, the residence time in the atmosphere is about 9 days before condensing and falling to the Earth as precipitation.

The major ice sheets – Antarctica and Greenland – store ice for very long periods. Ice from Antarctica has been reliably dated to 800,000 years before present, though the average residence time is shorter.

In hydrology, residence times can be estimated in two ways. The more common method relies on the principle of conservation of mass and assumes the amount of water in a given reservoir is roughly constant. With this method, residence times are estimated by dividing the volume of the reservoir by the rate by which water either enters or exits the reservoir. Conceptually, this is equivalent to timing how long it would take the reservoir to become filled from empty if no water were to leave (or how long it would take the reservoir to empty from full if no water were to enter).

An alternative method to estimate residence times, which is gaining in popularity for dating groundwater, is the use of isotopic techniques. This is done in the subfield of isotope hydrology.

Time-mean precipitation and evaporation as a function of latitude as simulated by an aqua-planet version of an atmospheric GCM (GFDL's AM2.1) with a homogeneous "slab-ocean" lower boundary (saturated surface with small heat capacity), forced by annual mean insolation.

Global map of annual mean evaporation minus precipitation by latitude-longitude

The water cycle describes the processes that drive the movement of water throughout the hydrosphere. However, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,500,000 mi3 (1,386,000,000 km3) of the world's water supply, about 321,000,000 mi3 (1,338,000,000 km3) is stored in oceans, or about 97%. It is also estimated that the oceans supply about 90% of the evaporated water that goes into the water cycle.

During colder climatic periods, more ice caps and glaciers form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age, glaciers covered almost one-third of Earth's land mass with the result being that the oceans were about 122 m (400 ft) lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 5.5 m (18 ft) higher than they are now. About three million years ago the oceans could have been up to 50 m (165 ft) higher.

The scientific consensus expressed in the 2007 Intergovernmental Panel on Climate Change (IPCC) Summary for Policymakers is for the water cycle to continue to intensify throughout the 21st century, though this does not mean that precipitation will increase in all regions. In subtropical land areas – places that are already relatively dry – precipitation is projected to decrease during the 21st century, increasing the probability of drought. The drying is projected to be strongest near the poleward margins of the subtropics (for example, the Mediterranean Basin, South Africa, southern Australia, and the Southwestern United States). Annual precipitation amounts are expected to increase in near-equatorial regions that tend to be wet in the present climate, and also at high latitudes. These large-scale patterns are present in nearly all of the climate model simulations conducted at several international research centers as part of the 4th Assessment of the IPCC. There is now ample evidence that increased hydrologic variability and change in climate has and will continue to have a profound impact on the water sector through the hydrologic cycle, water availability, water demand, and water allocation at the global, regional, basin, and local levels.[16] Research published in 2012 in Science based on surface ocean salinity over the period 1950 to 2000 confirm this projection of an intensified global water cycle with salty areas becoming more saline and fresher areas becoming more fresh over the period:

Fundamental thermodynamics and climate models suggest that dry regions will become drier and wet regions will become wetter in response to warming. Efforts to detect this long-term response in sparse surface observations of rainfall and evaporation remain ambiguous. We show that ocean salinity patterns express an identifiable fingerprint of an intensifying water cycle. Our 50-year observed global surface salinity changes, combined with changes from global climate models, present robust evidence of an intensified global water cycle at a rate of 8 ± 5% per degree of surface warming. This rate is double the response projected by current-generation climate models and suggests that a substantial (16 to 24%) intensification of the global water cycle will occur in a future 2° to 3° warmer world. An instrument carried by the SAC-D satellite Aquarius, launched in June, 2011, measured global sea surface salinity.

Glacial retreat is also an example of a changing water cycle, where the supply of water to glaciers from precipitation cannot keep up with the loss of water from melting and sublimation. Glacial retreat since 1850 has been extensive.

Human activities that alter the water cycle include:

agricultur

e industry

alteration of the chemical composition of the

atmosphere construction of dams

deforestation and afforestation

removal of groundwater from

wells water abstraction from

rivers

urbanization - to counteract its impact, water-sensitive urban design can be

practiced Effects on climate

The water cycle is powered from solar energy. 86% of the global evaporation occurs from the oceans, reducing their temperature by evaporative cooling. Without the cooling, the effect of evaporation on the greenhouse effect would lead to a much higher surface temperature of 67 °C (153 °F), and a warmer planet.[citation needed]

Aquifer drawdown or overdrafting and the pumping of fossil water increases the total amount of water in the hydrosphere, and has been postulated to be a contributor to sea-level rise.

Effects 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 biogeochemicals. Runoff is responsible for almost all of the transport of eroded sediment and phosphorus from land to waterbodies. The salinity of the oceans is derived from erosion and transport of dissolved salts from the land. Cultural eutrophication of lakes is primarily due to phosphorus, applied in excess to agricultural fields in fertilizers, and then transported overland and down rivers. Both runoff and groundwater flow play significant roles in transporting nitrogen from the land to waterbodies. The dead zone at the outlet of the Mississippi River is a consequence of nitrates from fertilizer being carried off agricultural fields and funnelled down the river system to the Gulf of Mexico. Runoff also plays a part in the carbon cycle, again through the transport of eroded rock and soil

Adaptations in Hydrophyte

Adaptations in hydrophyte are of three kinds, ecological, physiological and anatomical. For the survival in an aquatic habitat, hydrophytes modify its structures like leaves, stem, roots and the physiology of the cells to adapt themselves according to the different aquatic habitats like freshwater, marine water, lakes, ponds etc.

The adaptations in hydrophyte depend upon the conditions like temperature, osmotic concentration, toxicity, flow, dissolved oxygen, nutrients etc. of water. All these factors may influence plant growth and reproduction in the hydrophytes.

Adaptation in hydrophytes is a common phenomenon which is necessary for all the aquatic plants to thrive according to the surrounding. As the different plants live in different habitats, they need certain modifications so as to adapt themselves to the changing environment. Similarly, hydrophytes also undergo few changes in its morphology, physiology and anatomy to survive in the different aquatic habitat.

Types of Adaptations in

Hydrophytes Ecological

Adaptations

Roots

In hydrophytes, the major absorbing part, i.e. roots are the less significant structure. Its overall growth is either poorly developed, reduced or absent. The accessory components of root-like root cap and root hairs are generally lacking in floating hydrophytes. In the plant species like Lemna, Ecchorhnia etc. root pocket is present instead of root cap whose function is to maintain the water balance.

Wolffia and Utricularia are the plants where the roots are absent, but Hydrilla comprises poorly developed roots. The emergent forms contain well-developed roots.

Stems

In submerged forms comprise an elongated, narrow, cushioned and flexible stem. The stems are wide, small, stoloniferous, narrow, cushioned with extensive parenchyma, floats horizontally in the free-floating hydrophytes, as in Azolla. In rooted floating hydrophytes, a stem functions as a rhizome or runner.

Leaves

Free-floating hydrophytes consist of leaves that are elongated, slender, flattened, and the upper surface is coated with a waxy cuticle. Submerged hydrophytes contain leaves that are slender, translucent, elongated, fibrillar, straight and finely dissected. In amphibious plants, the leaves are of two kinds (submerged and aerial leaves). The submerged leaves show resistant against potential damage by the water current and absorb dissolved carbon dioxide.

The leaves of emergent hydrophytes resemble with the leaves of terrestrial plants. Aerial leaves are bulbous, lobed in structure and showing features similar to the mesophytic characters by having a wax coating on the upper leaf surface. This waxy coating prevents the leaves of hydrophytes against wilting, physical damage, chemical injuries, blockage of stomata etc. The partly submerged plant possesses different patterns of leaves or shows heterophylly, like in Ranunculus aquatilis.

Physiological Adaptations

Shoot system: Stems and leaves can participate in the process of photosynthesis, where the oxygen and carbon dioxide liberated as a result of photosynthesis and respiration, respectively is retained in the air cavities. The hydrophyte plants can make the use of gases like oxygen and carbon dioxide present in the air cavities for future cell activities. Petioles in floating hydrophytes have a huge tendency of regeneration that reasonably controlled by the auxins.

Protective layer: Mucilage canals are composed of mucilage cells, which secreting a lubricating agent, i.e. mucilage to protect the plant body against friction, desiccation, decay etc. by covering the entire plant body.

Food storage: In some hydrophytes like a water lily, the food reserves inside a structure refer as the rhizome.

Osmotic concentration: Hydrophytes possess a low osmotic concentration of the cell sap than the surrounding water.

Transpiration: It is absent in submerged plants while floating, and emergent hydrophytes go through high rate of water loss or transpiration.

Reproduction: The vegetative reproduction commonly occurs in hydrophytes by the propagation of the vegetative structures like runners, stolons, root-tubers etc.

Pollination and dispersal: Both pollination and dispersal of fruits occur by the agency of water. The dispersed seeds and fruits generally remain on the water surface, as they are light in weight.

Other properties: Processes like an exchange of water, nutrients and gases occur by the entire plant surface. Mucilage functions as a lubricating agent by surrounding the submerged parts of hydrophyte and protects it from epiphytes. An aerial part of hydrophyte bears "Hydathodes" that removes the additional water entering into the plant body via endosmosis.

Anatomical

Adaptations

Epidermis

It is present as a thin or a single layer comprising parenchymatous cells that are non-protective in function. The epidermis of the leaves include chloroplasts that participate in the process of photosynthesis.

Mucilage encircles the epidermis of the submerged parts and protects the plant against decay. The hypodermis is either absent or poorly developed. The cuticle is lacking in the submerged parts of hydrophytes but can be present as a thin layer on the aerial parts.

Stomata

The submerged parts lack stomata, but the upper surface of floating leaves carry stomata that refers as "Epistomatous leaves". Potamogeton is a hydrophyte consisting of non-functional stomata. The emergent hydrophytes consist of scattered stomata on all aerial parts of hydrophyte plant.

Aerenchyma

It can define as the air cavities found between the differentiated mesophylls, which allows the convenient diffusion of the gases. The diffused gases travel through the internal gas spaces of young leaves, then forced down to the root by the aerenchyma of the stem as a result of water pressure.

Older leaves do not support the pressure gradient, so the gases from the roots expel out through the leaves.

Cortex

Hydrophytes possess a highly-developed, thin-walled, parenchymatous cortex that helps the plant against mechanical stresses and permits efficient gaseous exchange. The large air cavities occupy its major portion. Hydrophytes comprise starch granules as the primary reserve food material that accumulate inside the cortex and pith.

Mechanical tissue

Hydrophytic plants possess mechanical tissue (sclerenchyma and collenchyma) that completely lacks or develops poorly in floating and submerged parts, but present in aerial or terrestrial parts.
Cystoliths or sclereids of variable shapes are present in the tissues of leaves and other

plant cells. Vascular tissue

Submerged hydrophytes comprise of poorly-developed xylem and tracheids. In contrast, the amphibious plants contain well-developed xylem, which assembles towards the central region. Secondary growth in stems and roots does not occur in hydrophytes. In hydrophytes, the presence of endodermis and pericycle are distinct.

Mesophyll cells

Hydrophytic plants possess undifferentiated mesophyll cells in the submerged leaves and differentiated mesophylls (palisade and spongy mesophylls) with the well-developed air cavities in both floating and emergent hydrophytic leaves.

Conclusion

Therefore, we can conclude that all the living creatures undergo specific changes according to the environmental conditions of the surrounding where they have to live in, whether it is aquatic or terrestrial. Hence, the hydrophytic plants also go through a few modifications in their morphology and physiology to sustain life in an aquatic environment.

Mesophytes

Mesophytes represent the group of plants that can neither grow in the complete aquatic habitat nor the scarcity of water or dry conditions. These are the land plants that show features similar to both hydrophytes and xerophytes. These grow under favourable conditions, where the concentration of water and temperature are not too much high and not too much low.

Both the vascular and mechanical tissue are highly developed and differentiated in mesophytic plants. Mesophyte plants require stable atmospheric conditions or temperate zone, where the conditions are not too dry and wet.

Mesophytes define as the community of terrestrial plants which can neither adjust in too wet nor in water-scarce conditions. It requires a moderate amount of hot and humid climatic conditions and develops in soil that provides an average dry-wet environment for the plant growth. Mesophytes constitute the largest ecological community of land plants. It includes two significant communities depending upon the ecological conditions, namely community of grasses and herbs and the community of woody plants.

Mesophytes are the group of plant species that involves two major

communities. The community of grasses and herbs

It includes perennial grasses and herbs, which further classifies into the Arctic and alpine mat grasslands and mat herbage, Meadow and Pasture on cultivated land.

The Arctic and alpine mat grasslands and mat herbage is a particular group of mesophytes that are ubiquitous in Polar Regions and mountain tops. It comprises of small-sized soft shrubs. The mat grasslands include members of the Gramineae family, and the examples of mat herbage include dicot herbs like Ranunculus, Saxifraga, Delphinium, Potentilla etc. Arctic and Alpine mat grassland and mat herbage

Meadow is the intermediate link between the mesophytes and hydrophytes that require moisture content of 60-83%. It includes the members belonging to the Compositae, Papilionate etc.

Pasture on cultivated land has a shorter period of vegetation, where the population or density of the plants is disturbed by grazing. It involves dicot herbs, grasses and mosses.

The community of woody plants

It includes bushlands and forests. The community of woody plants further classify into mesophytic bushlands, deciduous forests and evergreen forests. In mesophytic bushlands, the temperature is not too much favourable for the forest plants, but too much feasible for the mat herbage vegetation, which includes plants like Arabis, Salix, and Lathyrus etc.

Mesophytic bushlands

Deciduous forests are distributed in the temperate, cold or tropical regions where the annual rainfall is upto 80-150 cm. These are characterized by the periodic defoliation of leaves after every 5-8 months of foliation. It includes Betula birch forest, Quercus oak forest etc.

Evergreen forests are distributed in tropical and sub-tropical regions. These are common in the cold temperate zone of Southern Hemisphere. Sub-tropical evergreen forest is found in the areas with heavy rainfall, and the plants reach a length of 30 metres like the montane forest, pine forest etc.
Tropical evergreen forest is found in low lying regions with an annual rainfall of 180 cm or more, and the plants are of 40-50 metres in height like palm forest etc.

Roots

Mesophytes contain a highly developed and branched root. Unlike hydrophytes, the roots comprise a root cap that protects the root tip from degeneration and promotes geotropic movement. These can develop perennating organs like corms, rhizomes and bulbs to store food and water.

The roots of monocot mesophytes comprise a cluster of the fibrous root system for the absorption of water, while the roots of dicot mesophytes comprise a well-developed tap root system. The root hairs are present abundantly for the uptake of water and minerals from the soil.

Stems

Mesophyte plants contain a wide, linear, branched, and hard stem that can be herbaceous or woody. These are generally aerial and profusely branched. The stem comprises an extensive network of mechanical and conductive tissues that mediates water and minerals conduction all inside the plant body.

Leaves

Mesophytes consist of large, broad, narrow leaves with varying shapes and sizes. The dicotyledonous leaves of mesophytes include a large number of stomata on the lower leaf surface and few or none on the upper leaf surface. The stomata in monocotyledonous leaves generally contain the uniform distribution of stomata on both the sides of a leaf. It performs a significant role in the evaporation of excess water.

Cuticle

A protective waxy cuticle surrounds the aerial parts of the plant body and prevents excessive transpiration. Besides that, it also protects the internal tissues against physical, chemical, ecological or mechanical stresses.

Water supply

It requires a more or less continuous water supply, but undergoes hardship in extreme conditions, as they lose water rapidly. Generally, mesophytes suffer water and temperature stresses.

Mesophyte plants that are growing in the rainy climate possess on especial organ “Hydathodes” that opens without the guard cells. The excessive water exudes out of hydathodes in the form of droplets by a process refers to as “Guttation”.

Adaptations

Leaves: These are comparatively thin and large, which increases the surface area for the absorption of light energy or increases the rate of photosynthesis.

Cuticle: As the leaves are larger, there will be excessive water loss. So to combat this condition, a waxy cuticle encircles the epidermis.

Mesophylls: It develops extensively and differentiates to aid gaseous exchange between the plants and surrounding.

Vascular bundles: It is well developed consisting of both xylem and phloem connective tissue. Xylem helps in the transportation of the absorbed water from the roots to leaves. Phloem helps in the conduction of organic minerals all around the plant. The vascular bundles allow the plants to keep water balance, by enabling the conduction of water and minerals from the leaves to all other parts of the mesophytic plants.

Roots: The root system in mesophytes are the well-developed structures that generally grows deep inside the soil that in turn provide anchorage to the plant. It also allows for efficient water and mineral absorption from the surrounding soil. Besides this, it also comprises of accessory structures like root hairs and root cap.

Stomata: These are generally present in the lower leaf surface to slow down the excessive evaporation. The stomata tend to open all the time unless the plant is experiencing extreme water loss.

Conclusion

Therefore, we can conclude that the mesophytes are the group of plant system that grows under an intermediate range of temperature and moisture and acts as a connecting link between the hydrophytes and xerophytes.

Xerophyte

A xerophyte (from Greek ξηρός xeros dry, φυτόν phuton plant) is a species of plant that has adaptations to survive in an environment with little liquid water, such as a desert or an ice- or snow- covered region in the Alps or the Arctic. Popular examples of xerophytes are cacti, pineapple and some Gymnosperm plants.

The structural features (morphology) and fundamental chemical processes (physiology) of xerophytes are variously adapted to conserve water, also common to store large quantities of water, during dry periods. Other species are able to survive long periods of extreme dryness or desiccation of their tissues, during which their metabolic activity may effectively shut down. Plants with such morphological and physiological adaptations are xeromorphic. Xerophytes such as cacti are capable of withstanding extended periods of dry conditions as they have deep-spreading roots and capacity to store water. The leaves are waxy and thorny that prevents loss of water and moisture. Even their fleshy stems can store water.

The structural adaptations of these two resurrection plants are very similar. They can be found on the grounds of Bulgaria and Greece.

Plants absorb water from the soil, which then evaporates from their shoots and leaves; this process is known as transpiration. In dry environments, a typical mesophytic plant would evaporate water faster than the rate of water uptake from the soil, leading to wilting and even death.

Xerophytic plants exhibit a diversity of specialized adaptations to survive in such water-limiting conditions. They may use water from their own storage, allocate water specifically to sites of new tissue growth, or lose less water to the atmosphere and so channel a greater proportion of water from the soil to photosynthesis and growth. Different plant species possess different qualities and mechanisms to manage water supply, enabling them to survive.

Cacti and other succulents are commonly found in deserts, where there is little rainfall. Other xerophytes, such as certain bromeliads, can survive through both extremely wet and extremely dry periods and can be found in seasonally-moist habitats such as tropical forests, exploiting niches where water supplies are too intermittent for mesophytic plants to survive. Likewise, chaparral plants are adapted to Mediterranean climates, which have wet winters and dry summers.

Plants that live under arctic conditions also have a need for xerophytic adaptations, since water is unavailable for uptake when the ground is frozen, such as the European resurrection plants Haberlea rhodopensis and Ramonda serbica.

In an environment with very high salinity such as mangrove swamps and semi-deserts, water uptake by plants is a challenge due to the high salt ion levels. Besides that, such environments may cause an excess of ions to accumulate in the cells, which is very damaging. Halophytes and xerophytes evolved to survive in such environments. Some xerophytes may also be considered halophytes, however, halophytes are not necessarily xerophytes. The succulent xerophyte Zygophyllum xanthoxylum, for example, has specialised protein transporters in their cells which allow storage of excess ions in their vacuole to maintain normal cytosolic pH and ionic composition.

There are many factors which affect water availability, which is the major limiting factor of seed germination, seedling survival, and plant growth. These factors include infrequent raining, intense sunlight and very warm weather leading to faster water evaporation. An extreme environmental pH and high salt content of water also disrupt plants' water uptake.

Cistus albidus is a xerophyte which grows in European countries such as France, and Italy and North African countries like Morocco.

Succulent plants store water in their stems or leaves. These include plants from the family Cactaceae, which have round stems and can store a lot of water. The leaves are often vestigial, as in the case of cacti, wherein the leaves are reduced to spines, or they do not have leaves at all. These include the C4 perennial woody plant, Haloxylon ammodendron which is a native of northwest China.

Non-succulent perennials successfully endure long and continuous shortage of water in the soil. These are hence called 'true xerophytes' or euxerophytes. Water deficiency usually reaches 60–70% of their fresh weight, as a result of which the growth process of the whole plant is hindered during cell elongation. The plants which survive drought are, understandably, small and weak.

Ephemerals are the 'drought escaping' kind, and not true xerophytes. They do not really endure drought, only escape it. With the onset of rainfall, the plant seeds germinate, quickly grow to maturity, flower, and set seed, i.e., the entire life cycle is completed before the soil dries out again. Most of these plants are small, roundish, dense shrubs represented by species of Papilionaceae, some inconspicuous Compositae, a few Zygophyllaceae and some grasses. Water is stored in the bulbs of some plants, or at below ground level. They may be dormant during drought conditions and are, therefore, known as drought evaders.

Shrubs which grow in arid and semi-arid regions are also xeromorphic. For example, Caragana korshinskii, Artemisia sphaerocephala, and Hedysarum scoparium are shrubs potent in the semi-arid regions of the northwest China desert. These psammophile shrubs are not only edible to grazing animals in the area, they also play a vital role in the stabilisation of desert sand dunes.

Bushes, also called semi-shrubs often occur in sandy desert region, mostly in deep sandy soils at the edges of the dunes. One example is the Reaumuria soongorica, a perennial resurrection semi-shrub. Compared to other dominant arid xerophytes, an adult R. soongorica, bush has a strong resistance to water scarcity, hence, it is considered a super-xerophytes.

Importance of water conservation

If the water potential (or strictly, water vapour potential) inside a leaf is higher than outside, the water vapour will diffuse out of the leaf down this gradient. This loss of water vapour from the leaves is called transpiration, and the water vapour diffuses through the open stomata.
Transpiration is natural and inevitable for plants; a significant amount of water is lost through this process. However, it is vital that plants living in dry conditions are adapted so as to decrease the size

of the open stomata, lower the rate of transpiration, and consequently reduce water loss to the environment. Without sufficient water, plant cells lose turgor. This is known as plasmolysis. If the plant loses too much water, it will pass its permanent wilting point, and die.

In brief, the rate of transpiration is governed by the number of stomata, stomatal aperture i.e. the size of the stoma opening, leaf area (allowing for more stomata), temperature differential, the relative humidity, the presence of wind or air movement, the light intensity, and the presence of a waxy cuticle. It is important to note, that whilst it is vital to keep stomata closed, they have to be opened for gaseous exchange in respiration and photosynthesis.

Xerophytic plants may have similar shapes, forms, and structures and look very similar, even if the plants are not very closely related, through a process called convergent evolution. For example, some species of cacti, which evolved only in the Americas, may appear similar to euphorbias, which are distributed worldwide. An unrelated species of caudiciforms plants with swollen bases that are used to store water, may also display some similarities.

Under conditions of water scarcity, the seeds of different xerophytic plants behave differently, which means that they have different rates of germination since water availability is a major limiting factor. These dissimilarities are due to natural selection and eco-adaptation as the seeds and plants of each species evolve to suit their surrounding.

Reduction of surface area

Xerophytic plants can have less overall surface area than other plants, so reducing the area that is exposed to the air and reducing water loss by transpiration and evaporation. They can also have smaller leaves or fewer branches than other plants. An example of leaf surface reduction are the spines of a cactus, while the effects of compaction and reduction of branching can be seen in the barrel cacti. Other xerophytes may have their leaves compacted at the base, as in a basal rosette, which may be smaller than the plant's flower. This adaptation is exhibited by some Agave and Eriogonum species, which can be found growing near Death Valley.

Some xerophytes have tiny hairs on their surfaces to provide a wind break and reduce air flow, thereby reducing the rate of evaporation. When a plant surface is covered with tiny hairs, it is called tomentose. Stomata are located in these hairs or in pits to reduce their exposure to wind. This enables them to maintain a humid environment around them.

In a still, windless environment, the areas under the leaves or spines where transpiration takes place form a small localised environment that is more saturated with water vapour than normal. If this concentration of water vapour is maintained, the external water vapour potential gradient near the stomata is reduced, thus, reducing transpiration. In a windier situation, this localisation is blown away and so the external water vapour gradient remains low, which makes the loss of water vapour from plant stomata easier. Spines and hairs trap a layer of moisture and slows air movement over tissues.

The succulent leaves of Dudleya brittonii are visibly coated with a 'powdery' white which is the epicuticular wax.

The color of a plant, or of the waxes or hairs on its surface, may serve to reflect sunlight and reduce transpiration. An example is the white chalky epicuticular wax coating of Dudleya brittonii, which has the highest ultraviolet light (UV) reflectivity of any known naturally-occurring biological substance.

Cuticles

Many xerophytic species have thick cuticles. Just like human skin, a plant's cuticles are the first line of defense for its aerial parts. As mentioned above, the cuticle contains wax for protection against biotic and abiotic factors. The ultrastructure of the cuticles varies in different species. Some examples are Antizoma miersiana, Hermannia disermifolia and Galenia africana which are xerophytes from the same region in Namaqualand, but have different cuticle ultrastructures.

A. miersiana has thick cuticle as expected to be found on xerophytes, but H. disermifolia and G. africana have thin cuticles. Since resources are scarce in arid regions, there is selection for plants having thin and efficient cuticles to limit the nutritional and energy costs for the cuticle construction.

In periods of severe water stress and stomata closure, the cuticle's low water permeability is considered as one of the most vital factor in ensuring the survival of the plant. The rate of transpiration of the cuticles of xerophytes is 25 times lower than that of stomatal transpiration. To give an idea of how low this is, the rate of transpiration of the cuticles of mesophytes is only 2 to 5 times lower than stomatal transpiration.

Physiological adaptations

There are many changes that happen on the molecular level when a plant experiences stress. When in heat shock, for example, their protein molecule structures become unstable, unfold, or reconfigure to become less efficient. Membrane stability will decrease in plastids, which is why photosynthesis is the first process to be affected by heat stress.[11] Despite the many stresses, xerophytes have the ability to survive and thrive in drought conditions due to their physiological and biochemical specialties.

Dudleya pulverulenta is called 'chalk lettuce' for its obvious structures. This xerophyte has fleshy succulent leaves and is coated with chalky wax.

Water storage

Some plants can store water in their root structures, trunk structures, stems, and leaves. Water storage in swollen parts of the plant is known as succulence. A swollen trunk or root at the ground level of a plant is called a caudex and plants with swollen bases are called caudiciforms.

Production of protective molecules

Plants may secrete resins and waxes (epicuticular wax) on their surfaces, which reduce transpiration. Examples are the heavily-scented and flammable resins (volatile organic compounds) of some chaparral plants, such as Malosma laurina, or the chalky wax of Dudleya pulverulenta.

In regions continuously exposed to sunlight, UV rays can cause biochemical damage to plants, and eventually lead to DNA mutations and damages in the long run. When one of the main molecules involved in photosynthesis, photosystem II (PSII) is damaged by UV rays, it induces responses in the plant, leading to the synthesis of protectant molecules such as flavonoids and more wax. Flavonoids are UV-absorbing and act like sunscreen for the plant.

Heat shock proteins (HSPs) are a major class of proteins in plants and animals which are synthesised in cells as a response to heat stress. They help prevent protein unfolding and help re-fold denatured proteins. As temperature increases, the HSP protein expression also increases.

Evaporative cooling

Evaporative cooling via transpiration can delay the effects of heat stress on the plant. However, transpiration is very expensive if there is water scarcity, so generally this is not a good strategy for the plants to employ.

Stomata closure

Most plants have the ability to close their stomata at the start of water stress, at least partially, to restrict rates of transpiration. They use signals or hormones sent up from the roots and through the transpiration stream. Since roots are the parts responsible for water searching and uptake, they can detect the condition of dry soil. The signals sent are an early warning system - before the water stress gets too severe, the plant will go into water-economy mode.

As compared to other plants, xerophytes have an inverted stomatal rhythm. During the day and especially during mid-day when the sun is at its peak, most stomata of xerophytes are close. Not only do more stomata open at night in the presence of mist or dew, the size of stomatal opening or aperture is larger at night compared to during the day. This phenomenon was observed in xeromorphic species of Cactaceae, Crassulaceae, and Liliaceae.

As the epidermis of the plant is covered with water barriers such as lignin and waxy cuticles, the night opening of the stomata is the main channel for water movement for xerophytes in arid conditions. Even when water is not scarce, the xerophytes A. Americana and pineapple plant are found to utilise water more efficiently than mesophytes.

Phospholipid saturation

The plasma membrane of cells are made up of lipid molecules called phospholipids. These lipids become more fluid when temperature increases. Saturated lipids are more rigid than unsaturated ones i.e. unsaturated lipids becomes fluid more easily than saturated lipids. Plant cells undergo biochemical changes to change their plasma membrane composition to have more saturated lipids to sustain membrane integrity for longer in hot weather.

If the membrane integrity is compromised, there will be no effective barrier between the internal cell environment and the outside. Not only does this mean the plant cells are susceptible to disease- causing bacteria and mechanical attacks by herbivores, the cell could not perform its normal processes to continue living - the cells and thus the whole plant will die.

Delayed germination and growth

The surrounding humidity and moisture right before and during seed germination play an important role in the germination regulation in arid conditions. An evolutionary strategy employed by desert xerophytes is to reduce the rate of seed germination. By slowing the shoot growth, less water is consumed for growth and transpiration. Thus, the seed and plant can utilise the water available from short-lived rainfall for a much longer time compared to mesophytic plants.

During dry times, resurrection plants look dead, but are actually alive. Some xerophytic plants may stop growing and go dormant, or change the allocation of the products of photosynthesis from growing new leaves to the roots. These plants evolved to be able to coordinately switch off their photosynthetic mechanism without destroying the molecules involved in photosynthesis. When water is available again, these plants would "resurrect from the dead" and resume photosynthesis, even after they had lost more than 80% of their water content. A study has found that the sugar levels in resurrection plants increase when subjected to desiccation. This may be associated with how they survive without sugar production via photosynthesis for a relatively long duration.Some examples of resurrection plants include the Anastatica hierochuntica plant or more commonly known as the Rose of Jericho, as well as one of the most robust plant species in East Africa, Craterostigma pumilum. Seeds may be modified to require an excessive amount of water before germinating, so as to ensure a sufficient water supply for the seedling's survival. An example of this is the California poppy, whose seeds lie dormant during drought and then germinate, grow, flower, and form seeds within four weeks of rainfall.

Leaf wilting and abscission

If the water supply is not enough despite the employment of other water-saving strategies, the leaves will start to collapse and wilt due to water evaporation still exceeding water supply. Leaf loss (abscission) will be activated in more severe stress conditions. Drought deciduous plants may drop their leaves in times of dryness.

The wilting of leaves is a reversible process, however, abscission is irreversible. Shedding leaves is not favourable to plants because when water is available again, they would have to spend resources to produces new leaves which are needed for photosynthesis.

The leaf litter on the ground around a plant can provide an evaporative barrier to prevent water loss.[citation needed] A plant’s root mass itself may also hold organic material that retains water, as in the case of the arrowweed (Pluchea sericea).

Uses

Agave americana is a versatile xerophyte. All parts of the plant can be used either for aesthetics, for consumption, or in traditional medicine.

Land degradation is a major threat to many countries such as China and Uzbekistan. The major impacts include the loss of soil productivity and stability, as well as the loss of biodiversity due to reduced vegetation consumed by animals. In arid regions where water is scarce and temperatures are high, mesophytes will not be able to survive, due to the many stresses. Xerophytic plants are used widely to prevent desertification and for fixation of sand dunes. In fact, in northwest China, the seeds of three shrub species namely Caragana korshinskii, Artemisia sphaerocephala, and Hedysarum scoparium are dispersed across the region. These shrubs have the additional property of being palatable to grazing animals such as sheep and camels. H. scoparium is under protection in China due to it being a major endangered species. Haloxylon ammodendron and Zygophyllum xanthoxylum are also plants that form fixed dunes.

A more well-known xerophyte is the succulent plant Agave americana. It is cultivated as an ornamental plant popular across the globe. Agave nectar is garnered from the plant and is consumed as a substitute for sugar or honey. In Mexico, the plant's sap is usually fermented to produce an alcoholic beverage.

Many xerophytic plants produce colourful vibrant flowers and are used for decoration and ornamental purposes in gardens and in homes. Although they have adaptations to live in stressful weather and conditions, these plants thrive when well-watered and in tropical temperatures. Phlox sibirica is rarely seen in cultivation and does not flourish in areas without long exposure to sunlight.