

BLOCK 1 ECOLOGY AND ECOLOGICAL FACTORS

The study of Ecology has become essential in the modern era. This is because man has caused changes in the various abiotic components such as air, water and land. These changes have threatened or affected the survival of the other organisms. Realizing the significance/importance of the changes caused by man in the environmental factors, there is a need to have abundant knowledge about the basic concept of ecology, its various components and relationship between various components.

The block contains four units that provide information about basic concept of ecology, various ecological factors and various adaptations found in plants growing in water and land habitat. The first unit explains in brief the term ecology and provides an introduction about basic concepts such as population, community, ecosystem, and biosphere. Some of the historical perspectives have also been included to make you aware about the important contribution of various scientists and workers in the area.

The second and third units describe in detail the important abiotic components such as water, soil, light and temperature. Their composition and properties have been listed in detail. These ecological factors affect the survival, growth and development of various living components including plants and animals. Physical factors light soil and water are necessary for the survival of plants while temperature and light regulate their growth, development and distribution in various areas on the earth.

The unit four provides information about various adaptations that support the survival of vegetation in the dry areas or water bodies. The plants growing in dry land and water habitats show adaptations. The vegetation growing in these areas possess some characteristic features which are commonly not found in other plants. The adaptations have been seen in the form of morphological or anatomical changes.

Objectives

After studying this block, you should be able to:

- define and explain the terms environment and ecology,
- describe various physical factors in the environment such as soil, water, light and temperature,
- describe in detail various properties of these physical factors, and
- describe adaptations in plants growing in water and dry habitats.

Unit 1

INTRODUCTION TO PLANT ECOLOGY

Structure

1.1	Introduction	1.6	Basic terms of Ecology
	Expected Learning Outcomes		Environment
1.2	What is Ecology?		Biosphere
1.3	History of Ecology		Ecosystem
1.4	Subdivisions of Ecology		Population
1.5	Relationship of Ecology with other Disciplines of Biology		Community
		1.7	Summary
		1.8	Terminal Question
		1.9	Answers

1.1 INTRODUCTION

Organisms do not live in isolation. All organisms are linked to their surroundings. The survival of an organism thus depends upon its surroundings. These surroundings of an organism constitute its (are called as - delete) environment. Any change in the surroundings/environment affects the growth and survival of living organisms to a significant extent. Nutrients and energy get distributed among various living components present in a particular environment. Ecology is the study of the relationship of organisms i.e. plants, animals, microorganisms with their surroundings (environment). Ecological studies deal with the relationships of organisms with their environment. The present unit provides information about basic concepts in ecology.

Expected Learning Outcomes

After the study of this Unit, you should be able to

- ❖ define various terms used in ecology (environment, population, community, ecosystem and ecosphere),

- ❖ describe subdivisions of ecology,
- ❖ outline differences between natural and man-made environment,
- ❖ describe components of the ecosystem,
- ❖ enlist characteristics of the community,
- ❖ enumerate knowledge about recent developments in the field of ecology, and
- ❖ discuss the interrelationships between ecology and other disciplines of biology.

1.2 WHAT IS ECOLOGY?

Hanns Reiter (1868) gave the concept of ecology. The term 'ecology' is derived from two words '*oikos*' meaning home and '*logos*' meaning study. The term was (given by -delete) coined in 1869 by the German biologist Ernst Haeckel. Literally it means 'study of home'. According to him ecology is a branch of science which deals with the study of interrelationship between living organisms and their surroundings (environment). Scientifically 'ecology' has been defined as 'study of inter-relationships of organisms with their surroundings. Various other definitions have been given by (other – delete) different scientists. Woodbury (1954) defined ecology as "science that investigates organisms in relation to their environment". E.P. Odum (1969) defined ecology as "the study of structure and function of nature".

1.3 HISTORY OF ECOLOGY

Ever since man occupied this planet, s/he has been very closely linked to her/his surroundings. Thus, early man obtained all the basic needs – food, clothing and shelter – from the surroundings. The Greek scholar, Theophrastus (370-250 BC) was the first person to introduce a scientific/ecological approach to the world. He described the relationship between organisms and the environment in scientific terms. (History records mention that organisms survive in natural conditions since ancient times – delete). In the 18th century, European naturalist, French Gorges Buffon (1707-1788) introduced the concept of ecology by describing the relationship of animals to their environment in his book on Natural History. Plant geographers such as Carl Ludwig Willdenow (1765-1812) pointed the role of environment/surroundings in the development of vegetation. A Swedish naturalist, Carl Linnaeus (1707-1778) laid the grounds of modern ecology around 250 years ago. He studied all kinds of organisms – plants, animals, etc. – as well as the types of minerals and soils. (developed a system of naming plants and animals called as Binomial Nomenclature. According to this system, name of each living organism consists of two parts - genera and species – delete). The German explorer, Alexander von Humboldt (1769-1859) studied relationship of vegetation and environment during his travels to various parts of the world. He compiled his findings in his book '*Voyage aux regions equinoxialis*'. He described vegetation zones based on

latitude and altitude. He correlated vegetation with environmental characteristics and coined the term 'plant association'. Charles Darwin (1809-1882) gave the theory of 'Natural Selection' in his book '**Origin of Species**'. He compared the similarities and dissimilarities between species found in different regions. He attributed differences in the species to geological barriers. The theory was based on the concept of competition between species. Herbert Spencer (1820-1903) was considered as the founder of social ecology gave the concept of 'survival of the fittest'. Most of the studies carried out in the 19th century focused on animal behavior. (The contributions of – delete) Some renowned ecologists (that – delete) who have contributed (a lot – delete) to the development of ecological studies have been listed below.

Ecologists and their contribution to modern ecology.

Ecologists	Year	Contribution to field of ecology
A. Lavoisier and de Saussure	(1734-1794)	Described the nitrogen cycle. He defined various compartments of biosphere namely atmosphere, hydrosphere, and lithosphere.
Thomas Robert Malthus	(1766-1834)	Gave the concept of 'population'
I. Geoffroy Saint-Hilaire	(1805–1861)	Gave the term 'ethology' years before term the term 'ecology' was coined.
Kerner	(1831-1898)	Gave account of vegetation and succession in book 'Plant Life of Danube Basin'.
Ernest Haeckel	(1834-1919)	Coined/ used (Invented- delete) the term 'ecology' for the first time in science.
A. Schimper	(1856-1901)	Explained the regional flora in book 'Plant Geography'.
Alfred Russel Wallace	(1858)	Proposed "geography" of animal species. He grouped living organisms into communities.
Karl Möbius	(1877)	Coined the term 'biocoenosis' meaning living community.
J. Warming	(1841-1924)	Integrated morphology, physiology, taxonomy and biogeography into one branch of science. He wrote first text on plant ecology, ' Plantensamfund '. Described various types of vegetation. He introduced the terms 'hydrophytes, xerophytes,

		halophytes and mesophytes’.
Eugenius Warming	(1841-1924)	Emphasized role of abiotic factors and introduced term ‘adaptation’ to explain behavior of species under set of environmental conditions. He is the founder of Ecological Plant geography.
Vladimir Vernadsky	(1869-1939)	Gave the concept of ‘biosphere’
H. C. Cowles	(1869-1939)	Published books on vegetation dynamics and ecological succession.
Arthur G. Tansley	(1871-1955)	He combined living organisms and their physical environment into one system. He gave the term ‘ecosystem’ (1936). He is the founder of British Ecological Society.
Fredric E. Clements	(1874-1945)	Published book on the phytogeography of North America (1905). He considered ecology as ‘the science of community’. He stated that development of plant community is a complex process growing through different stages.
V.E. Shelford	(1877-1968)	Defined ecology as ‘science of communities’. He gave the terms ‘food web’ and ‘biome’. He showed interrelationship between plant and animals.
Charles E. Elton	(1900-1991)	Father of animal ecology. Coined the terms ‘food chain’ and ‘food cycle’ in book named ‘Animal Ecology’.
R. Hesse	(1927)	Wrote a book ‘Ecological Animal Geography’
G. Evelyn Hutchinson	(1903-1991)	He is called as “Father of Modern Ecology”. He gave the concept of limnology, entomology, mathematical theory of population dynamics. He introduced the concept of ‘niche’.
Vladimir I. Vernadsky	(1920)	Detailed the idea of the biosphere and described ‘biogeochemical cycles’.
Christien Raunkier	(1934)	Gave the concept of life form in

		plants.
William Wheeler and Charles Carpenter	(1956)	Gave the concept of 'Behavioral ecology'.
Macfadyen	(1957)	Emphasized the role of relationships between living organisms and environment.
J. Braun Balnquet	(1958)	Studied lake ecology. He trained two Indian ecologists R. Misra and G. S. Puri
Eugene P. Odum	(1913-2002)	Defined ecology as the science of ecosystems. Contributed to modern ecology through books 'Fundamentals of Ecology', 'Ecology and Basic Ecology'.
Howard T. Odum	(1924-2002)	Cofounder of 'Ecosystem ecology and thermodynamics'.
R. A. Lindeman	(1942)	Gave the concept of 'ecological energetics'. He traced energy relationships within organisms present in a lake community. Gave the ecological models and concept of ecosystem ecology.
F.H. Borman, J.S. Olson	(1976)	Worked on cycling of nutrients and water
R.G. Weigert	(1976)	Studied 'Ecological Energetics'
Harper	(1977)	Gave a book on 'Unified Study of Animals and Plants'
Began and Mortimer	(1981)	Gave an update on 'Population Ecology'
B. Bolin and R.B. Cook	(1983)	Edited a volume on 'The Major Biogeochemical Cycles and their interactions'.

In the Indian scenario, ancient/classical epics and holy books such as Ramayana, Mahabharata, Vedas, Samhitas, Brahmanas, and Araanyakas-Upnishads provide a mention of basic ecological concepts. The Charak-Samhita and Susruta-Samhita ancient Indian texts on medicine, and surgery mentioned the role of plants in treating human ailments. These records showed that people during ancient times had good understanding of plant and animal ecology. The basic concepts of ecology in India began with the study of

forest vegetation by forest officers. The first comprehensive account was given by Professor Dudgeon from University of Allahabad. He discussed the role of environment in succession of communities. Extensive synecological studies were carried out on grassland and forest communities in India. Professor R. Mishra (1944, 1945) studied ecology of aquatic plants and has been referred as 'father of Indian ecology'. He gave methods of soil analysis and established 'Society for Tropical Ecology' in 1958 and 'School of Ecology' at Banaras Hindu University in 1960.

As the studies advanced, the ecological concepts were linked to other disciplines of biology and science. With passage of time, ecological researches became more applied to human welfare. The studies on the effect of changes in the environmental conditions such as pollution on various types of vegetation and other components of environment were initiated. Agencies such as MAB (Man and Biosphere programme of UNESCO) and IUCN (International Union for Conservation of Nature and Natural Resources, Switzerland) that focused their work on biological basis of productivity and human welfare were formed.

SAQ 1

Discuss in brief the contributions of various scientists in the development of modern ecology.

1.4 SUDIVSIONS OF ECOLOGY

Ecology is divided into two types namely animal and plant ecology. The division was based on the category of organisms studied. In modern system, ecology has been divided into two types: autecology and synecology. The division has been made on the basis of study of individual organism or a group of organism.

Autecology is the study of individual species in relation to their environment. It includes the study of geographical distribution, taxonomic position, morphological characters, reproduction, life cycle and behavior of species with reference to ecological factors or environment.

Synecology is the study of a population or community in relation to their environment. It comprises of community and ecosystem ecology. The composition and behavior of communities and their relationship to the environment are studied.

It has also been broadly classified into two types depending upon the study of habitat.

- **Aquatic Ecology** – This includes study of living organisms present in fresh water, estuarine and marine habitat.

- **Terrestrial Ecology**- This includes study of living organisms present in forest, grassland, cropland and desert habitats.

Other subdivisions of ecology have been made on the basis of the aspect of ecology studied (Fig 1.1). These mainly include

Organism ecology – It is based on relationship of living organisms (animal and plants) to biotic and abiotic factors in their environment.

Behavioral ecology – It is study of behavior of living organisms in relation to changing environmental conditions.

Population ecology – It is the study of structure and dynamics (size, density, dispersion, demographics) of population in relation to environment. Variations in growth and regulation of a population (**this word – demonology - is inappropriate here. Its dictionary meaning is the “study of demons” or “black magic”. The word demography could be used. It is defined as “the statistical characteristics of human populations)** are considered.

Community ecology – It deals with structure and organization of a biological community with respect to environmental interactions. Factors such as structure, biodiversity, distribution, abundance of species and interactions such as predation, herbivory, competition, parasitism and mutualism are studied.

Ecosystem ecology – It is the study of living organisms (animals, plants and microorganisms) along with the non-living components of their environment (water, air and soil). The aspects such as nutrient and energy flows are considered.

Taxonomic ecology – It is study of different taxonomic groups of living organisms in relation to their environment. It includes microbial ecology, mammalian ecology, insect ecology, human ecology.

Physiological ecology/Eco-physiology – It is the study of changes in the physiological procedures/functions such as nutrition and metabolism in living organisms in response to environmental factors. Various adaptations in organisms under different ecological conditions are studied.

Chemical ecology – It is study of adaptation of animals or insects with respect to production of chemical substances.

Palaeoecology – It is the study of organisms and their environment in the geological past. Cytoecology- It deals with the study of cytological details of the species in relation to environmental conditions.

Production ecology / ecological energetics – It is the study of energy conversion and flow through different organisms in relation to space and time.

Ethology – It is the study of animal behavior in different environments.

System ecology – It is analysis of structure and function of an ecosystem using applied mathematics or statistics.

Habitat Ecology – It is the study of living organisms in different habitats.

Besides these some other branches of ecology such as conservation ecology, production ecology, space ecology, radiation ecology has also been recognized.

In an ecological system, various levels of biological organization (hierarchy) are noted. These range from individual organisms to the biosphere. Various units included in hierarchy include organisms, populations, communities, ecosystems and the biome. Hierarchy is the system of grouping organisms at different levels (Fig 1. 2). The levels of organization connected with ecological grouping are called ecological hierarchy.

- i) **An individual** (organism) is the basic and distinct unit of ecological hierarchy. Individuals carry out all life processes and exchanges materials with the surroundings.
- ii) **A population** is a group of individuals of the same species living together in a common area at a particular time.
- iii) **A community** is the assembly of populations of different organisms in a particular environment.
- iv) **The ecosystem** is the association of living and non-living components present in a particular environment of an area.
- v) **A Biome** is the group of terrestrial ecosystems present at the regional or sub continental level.
- vi) **The Biosphere** is the part of the earth where life is present. It comprises of atmosphere (air), lithosphere (land) and hydrosphere (water).

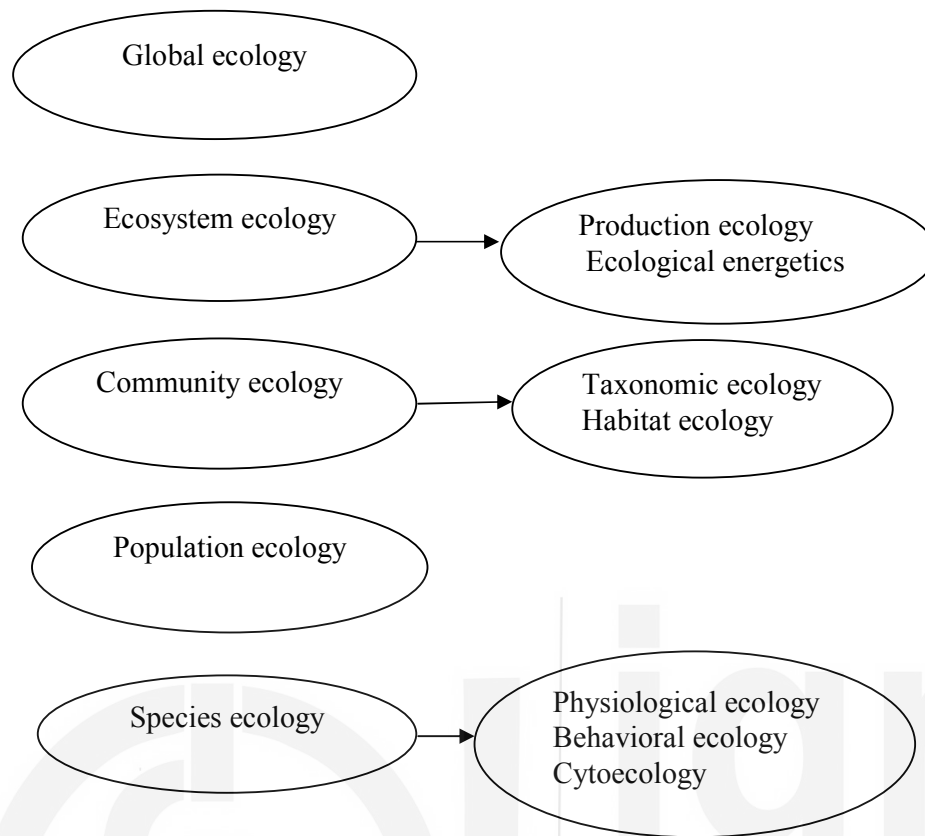


Fig. 1.1: Study of ecology at various levels.

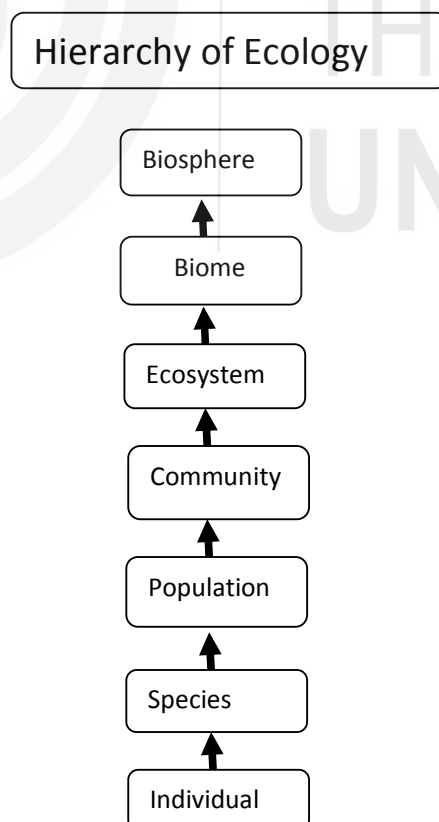


Fig. 1.2: Various levels of hierarchy known in ecology.

SAQ 2

List the major differences between

- a. Synecology and autoecology
- b. Aquatic and terrestrial ecology
- c. Community and ecosystem ecology

1.5 RELATIONSHIP OF ECOLOGY WITH OTHER DISCIPLINES OF BIOLOGY

Ecology is an integrated science. The interactions taking place within an ecological system is complex and involves various kinds of physical, chemical and biological processes. The dependence of ecology on other branches of science makes it an interdisciplinary science. All the living organisms i.e. plants, animals and microorganisms form an important component of ecological study. The survival, distribution and abundance of these organisms are influenced by changes in physical factors such as temperature, light, rainfall and altitude. Branches of science such as geology, hydrology and metrology influence the survival and distribution of biotic communities to a greater extent. The branches of biology such as zoology, botany, microbiology were integrated into ecology so that structural and biochemical processes involved in the adaptation of organisms to changing environmental conditions can be studied. Interactions between living organisms is studied using various aspects such as morphology, physiology, genetics, taxonomy, molecular biology, developmental biology, ornithology, bacteriology and entomology (Fig 1.3). The relationship of ecology with other divisions of sciences can also be represented by model of cake (Fig 1.4) in which various layers represent basic divisions of biology, taxonomy, genetics, molecular biology. The thicker slices represent higher divisions of biology such as botany, zoology, microbiology while thinner slices represent divisions such as phycology, ornithology dealing with specific organisms. Each organism is studied considering various aspects such as morphology, genetics, evolution, physiology, developmental biology, molecular biology etc.

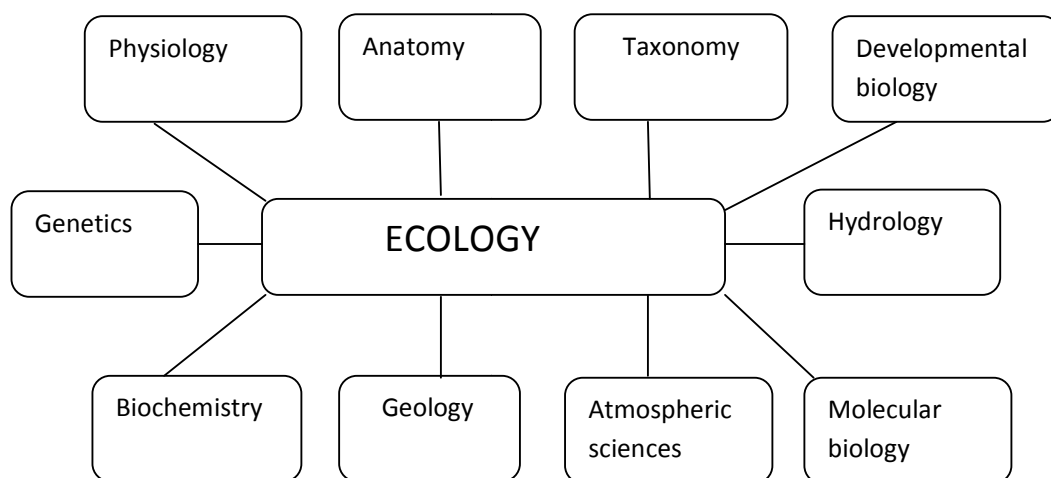


Fig. 1.3: Interrelationship of ecology with other disciplines of science and biology.

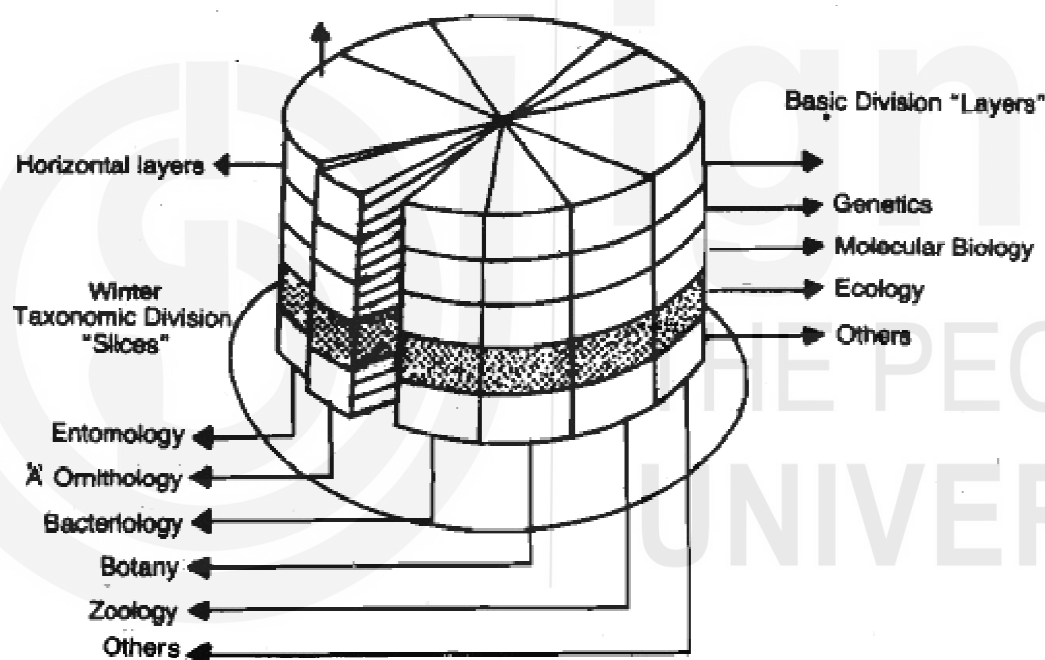
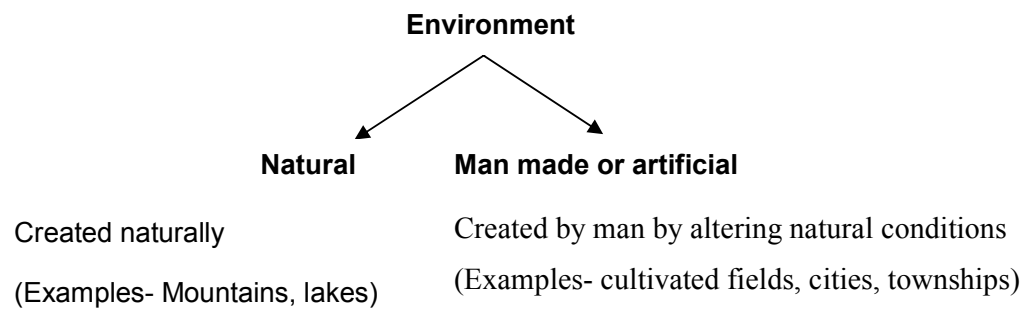


Fig. 1.4: The layered biological cake showing relationship of ecology with other disciplines of biology.

1.6 BASICS OF ECOLOGY

1.6.1 Environment

Each living organism depends on its surroundings for survival and sustenance. Environment provides food, energy, water, oxygen, shelter and other necessities to living organisms. The total of all of the surroundings – air, water, land, vegetation that influence the existence of living beings is referred to as environment. Environment is broadly classified into two types natural and manmade.



Components of environment

Environment consist of two components

- Living or biotic
- Non-living or abiotic

Biotic components- All the living components are referred as biotic components. These include plants, animals and microorganisms.

Abiotic components – All non-living factors are called as abiotic components. These include water, air, soil/land, and physical factors such as light and temperature.

External and internal environment

Organisms possess an internal environment which is enclosed by outer body surface. The body surface acts an exchange barrier between external and internal environment. In single celled organisms, exchange of materials is carried out directly with the external environment (Fig 1.5). Internal environment is relatively more stable as compared to the external environment.

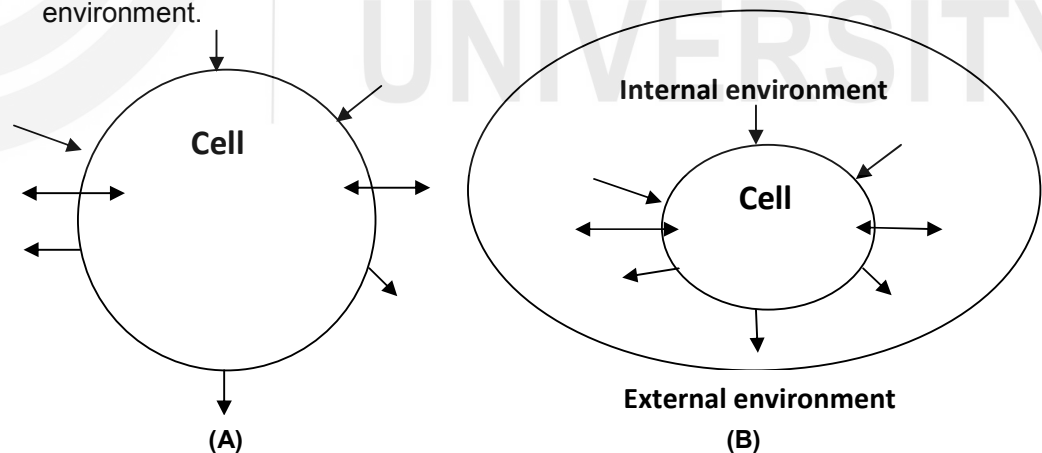


Fig. 1.5: External and internal environment in (A) Unicellular (B) Multicellular organism.

SAQ 3

Describe the various components of environment.

1.6.2 Biosphere

The part/zone/layer of earth where life exists is referred as biosphere (ecosphere). The global ecological system is composed of all living beings and elements of lithosphere (rock), hydrosphere (water), and atmosphere (air). It is a closed self-regulating system. It is regarded as the sum of all ecosystems (Fig 1. 6). The biosphere is supposed to have evolved from the process of biogenesis (life created from living matter) around 3.5 billion years ago. The biosphere extends from 11,000 meters below sea level to 15,000 meters above it. The concept of term biosphere was given by English geologist Eduard Suess (1831-1914) and Russian physicist Vladimir I. Vernadsky (1863-1945).

Hydrosphere (water) – Water constitutes around 70% of the earth's surface. It includes water resources such as oceans, seas, rivers, lakes, streams, ponds, glaciers, polar ice caps and ground water. About 97% water is present in oceans and seas, 2% in ice caps and the remaining 1 % as fresh water.

Lithosphere (Land) - It is the solid component or the hard surface (crust) of earth. It consists of three layers: crust, mantle and core. The uppermost part consists of weathered rocks, minerals and organic matter and is known as soil. The mantle and core form the inner layer of lithosphere.

Atmosphere (air) – It consists of a complex mixture of gases, water vapor and particulate matter. This layer sustains life on earth by providing gases such as oxygen and carbon dioxide essential for photosynthesis and respiration in living organisms. Atmosphere is divided into different zones such as troposphere, stratosphere, mesosphere, thermosphere, magnetosphere depending upon temperature gradients.

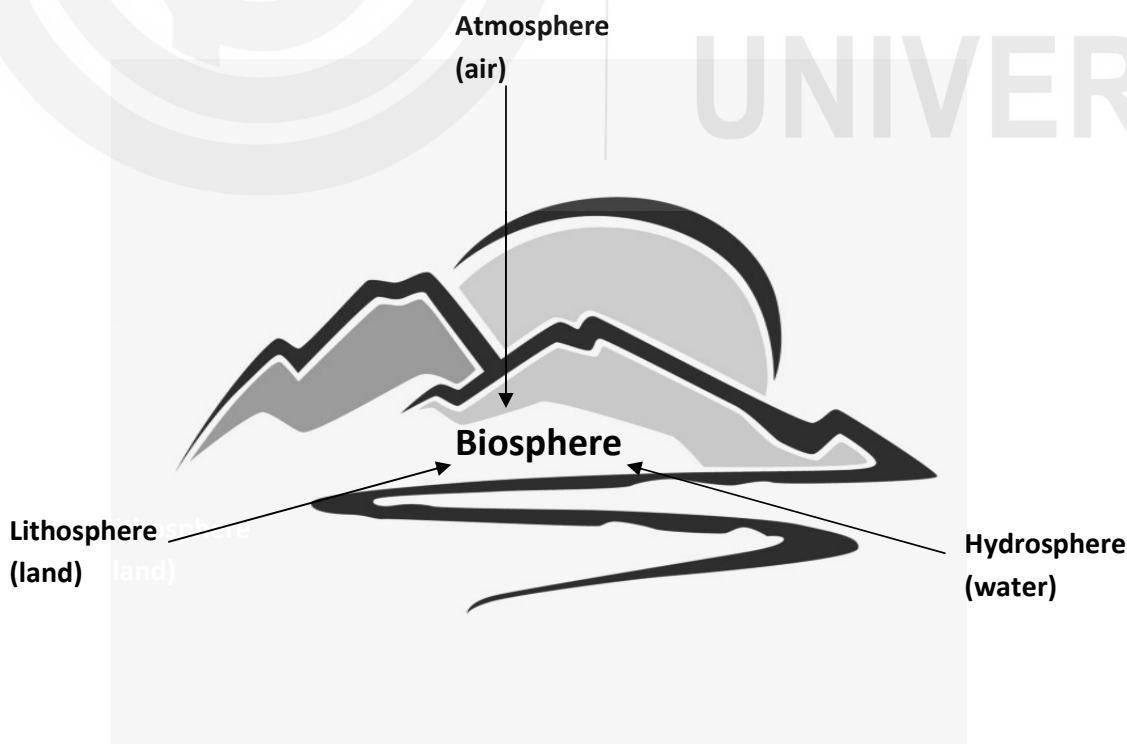


Fig. 1.6: Deniction of the biosphere.

1.6.3 Ecosystem

An ecosystem is an ecological unit composed of living and non-living things. The living or biotic components interact with non-living or abiotic components of the environment and maintain the equilibrium in the environment. Arthur Tansley (1935) proposed the term 'ecosystem' and defined it as interaction of all living and non-living components of the environment.

Components of the ecosystem

a. Abiotic Components

These include the non-living or physico-chemical factors. They support the biotic components. They restrict the growth, number and diversity of the population of a species and hence called as limiting factors. These components vary from one ecosystem to another. These factors are classified broadly under three categories:

Climatic factors – These include physical factors such as light, temperature, wind, humidity.

Edaphic factors – These include soil, its structure and properties. Parameters such as soil type, soil profile, organic matter, minerals, soil and soil organisms are included in it.

Physical factors – These include water, air.

Materials- It includes inorganic components such as carbon, sulphur, nitrogen, phosphorus etc. All these elements circulate in different components of ecosystem via biogeochemical cycles. The organic components of an ecosystem are proteins, carbohydrates, lipids and amino acids. These are synthesized by biota (flora and fauna) of an ecosystem.

b. Biotic components

Biotic components are the living components of the ecosystem (Fig 1. 7). These include plants, animals, and micro-organisms. They act as autotrophs, heterotrophs and saprotrophs. They have a direct or indirect influence on other organisms present in an ecosystem.

Producers (autotrophs) -They are autotrophic in nature i.e. convert energy procured from sun into food. They include photosynthetic organisms. They are called as producers, transducers or convertors. In terrestrial ecosystems, producers are green plants. In the aquatic ecosystems, the floating plants (referred as phytoplankton) and rooted plants (called macrophytes) are the main producers. Freshwater and marine ecosystems consist of algae as the dominant producers. The photosynthetic plants bear chlorophyll and synthesize a high-energy complex organic compound (or food) from the inorganic raw materials utilizing sunlight through a process called photosynthesis.

Consumers - They are heterotrophic organisms. They eat food produced by autotrophs. Herbivores take their food directly from the producers i.e. they eat plants, hence also referred as primary consumers. Carnivores feed on

animals, hence referred as secondary consumers. Tertiary or quaternary consumers include organisms that feed on secondary carnivores. Omnivores mainly include humans that feed on both plants and animals.

Decomposers -They include microorganisms such as bacteria and fungi. They are also referred as saprotrophs or reducers. Scavengers, detritivores and decomposers feed on dead decaying matter and produce organic constituents. The breakdown of nonliving organic matter into inorganic matter occurs via digestive enzymes secreted by microorganisms. In the process of conversion, recycling of the essential nutrients takes place. The remaining substances are added as minerals in substratum through the process of mineralization.

In an ecosystem, various components interact with each other. Biotic components depend on abiotic components for their survival. Abiotic components such as soil get enriched by organic matter added after decay and decomposition carried out by microbes or saprotrophs.

At functional level of an ecosystem, primary producers (plants) harvest energy from the sun through the process called photosynthesis. This energy is transferred from plants to other organisms i.e. **consumers which** include both herbivores and carnivores (Fig 1. 8). Later on energy gets transferred to fungi and bacteria via death/decay and decomposition process. There is a continuous flow of nutrients and energy in an ecosystem. The organic constituents produced after decomposition can again be used by producers.

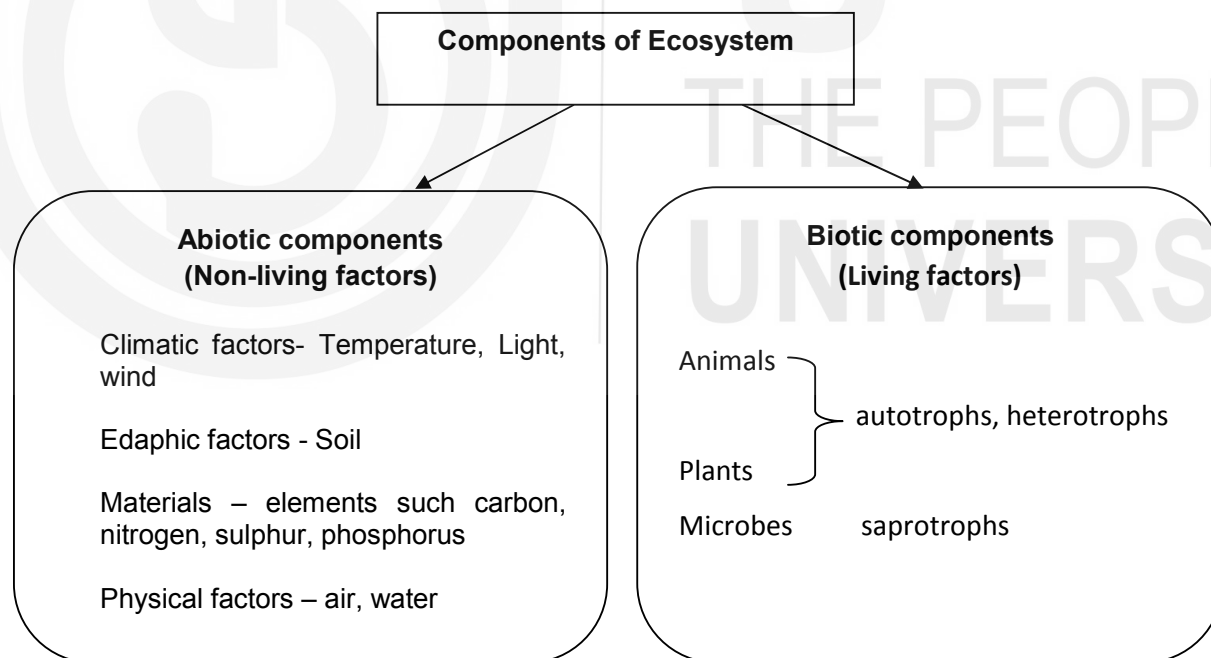


Fig. 1.7: Components of an ecosystem.

Types of ecosystem

Ecosystems are broadly classified as :

- **Natural** – these ecosystems develop naturally without interference of human beings. Example forests, lakes, deserts.

- Artificial or manmade – these ecosystems are developed by humans after modification of natural ecosystems. Example forests were transformed in crop fields, smart cities, gardens and dams (Fig 1.9).

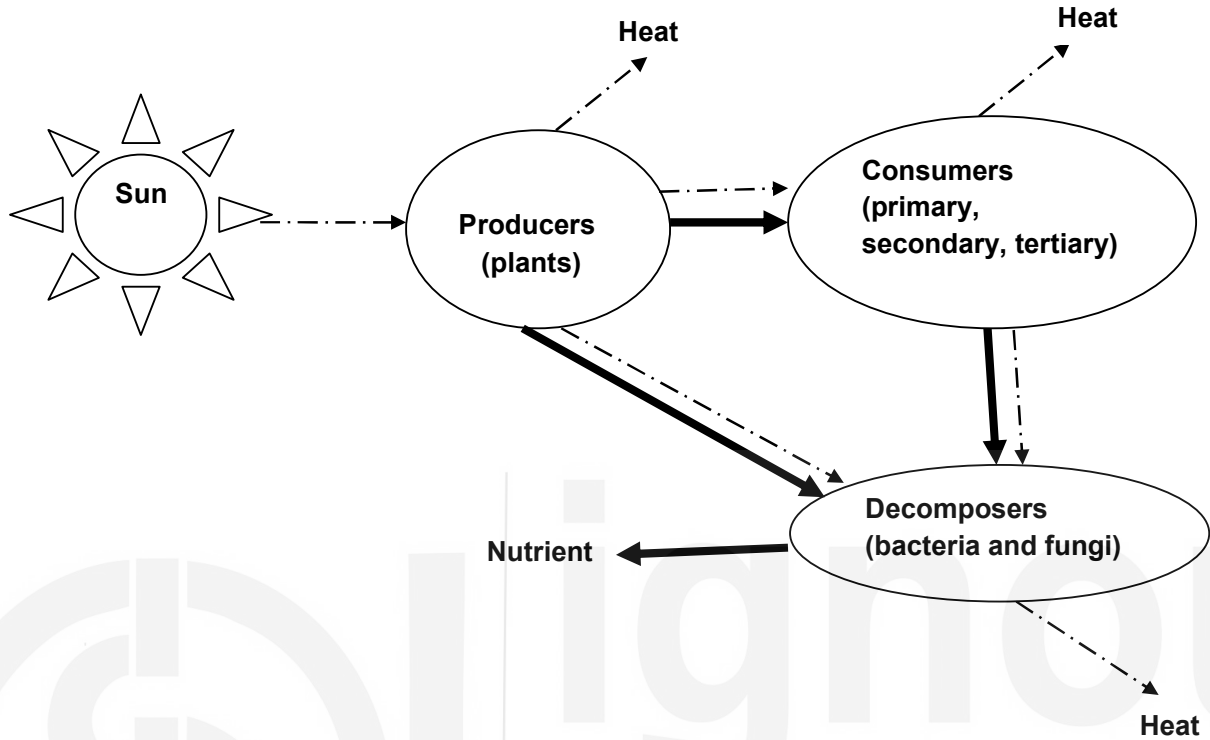


Fig. 1.8: Energy and nutrient flow through various biotic components of an ecosystem.

Ecosystems have also been classified into two types depending upon the size.

- Micro-Ecosystems- small ecosystem. Example -drop of water.
- Macro-Ecosystem- big ecosystem. Example- Caribbean Sea, mountain range of Andes.

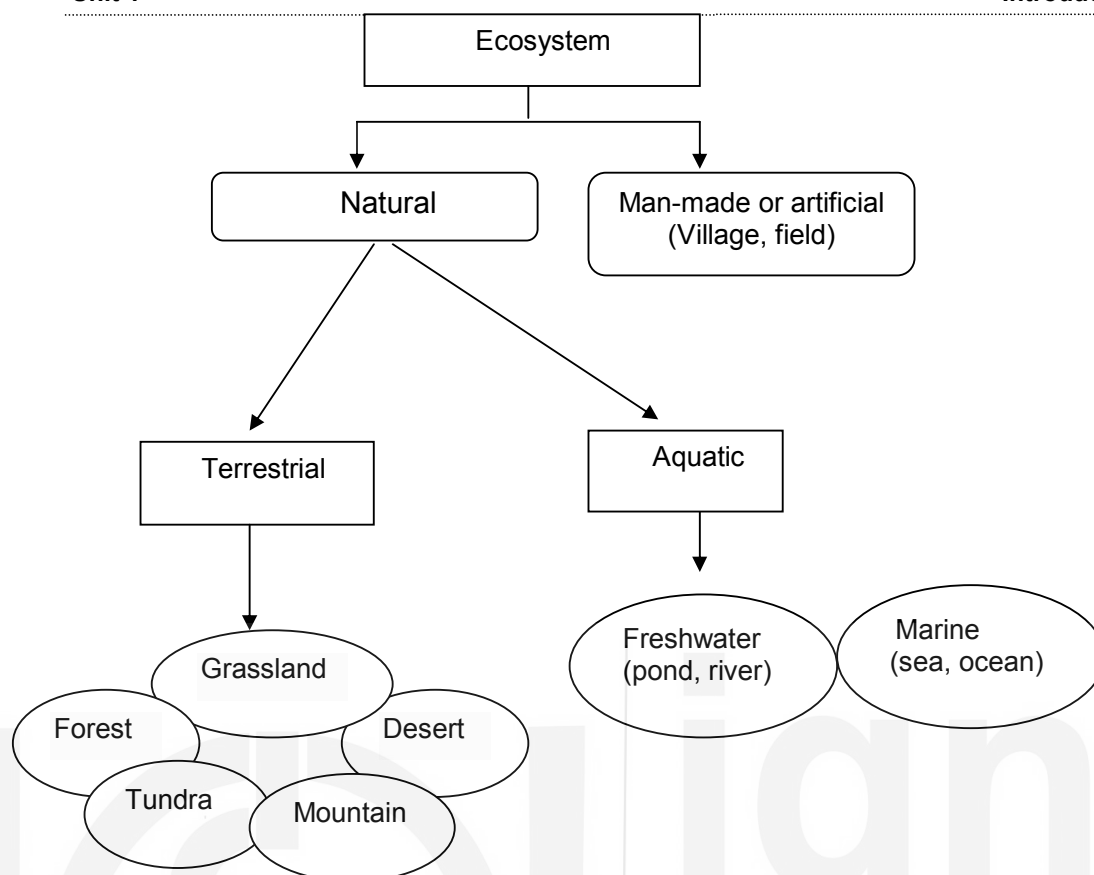


Fig. 1.9: Various types of ecosystems.

SAQ 4

Explain how heat energy trapped by plants is used by other organisms.

SAQ 5

Answer in one word:

- 1) The process of breakdown of complex organic matter
 - 2) The organisms which are dependent upon producers for their food
 - 3) Heat energy from the sun is trapped by
-

1.6.4 Population

A population is group of individuals of the same species present within a specific area at a particular time. It can also be defined as group of similar individuals of the same species capable of interbreeding among themselves. Growth, survival and movement/spread of population are regulated by various factors. Changes in the physical factors significantly alter the size of the population and affect the interactions between various populations.

Populations of the same species that can interbreed are referred as meta-populations.

The characteristics of population are represented by many attributes. These mainly include

1. Numerical attributes
2. Structural attributes

Numerical attributes

This includes parameters such as natality (birth rate), mortality (death rate), and density. These are given in figures.

Density- It is the number of individuals of a population present per unit area.

Natality (birth rate) – It is rate at which numbers of individuals are added to a population (by birth) over the specified time.

Mortality – Rate at which the individuals are lost from a population by death.

Dispersal- Rate at which individuals (of a population) move/migrate from an area.

Distribution- It is the total area of occurrence of a population.

Abundance- It is the number of individuals within a particular population.

Structural attributes

This includes parameters such as age, distribution, dispersion.

Population growth

Within any population, individuals are born and individuals die. If there are more individuals being born than dying, the population grows in size, while if more individuals are dying than being born, the population shrinks. Movement of individuals also affects the size of the population. Individuals enter or leave a population. This is referred as immigration and emigration.

The population size changes with time. The growth rate of population is calculated (given – delete) by the equation

$$dN/dt = rN$$

where 'r' is the intrinsic rate of natural increase in population. It is the difference between birth and death rate of the population.

N is the size of the population

The change in the size of the population is noted at time t.

The changes in population are explained by the exponential growth model. When resources are unlimited, populations exhibit exponential growth, resulting in a J-shaped curve. This means that size of population goes on increasing and after some time becomes constant. Maximum size of population that environment can sustain/support at a particular time is known

as carrying capacity. The growth rate of population slows down when it reaches the carrying capacity. When resources are limited, populations exhibit logistic growth. In logistic growth, population growth decreases as the resources get used (limited) and it levels off at carrying capacity resulting in an S-shaped curve (Fig 1.10).

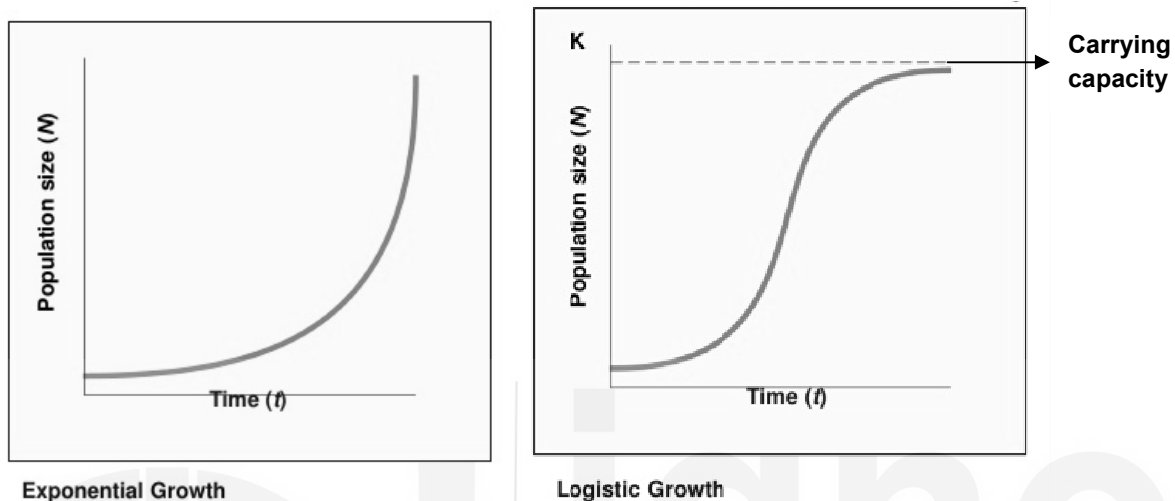


Fig. 1.10: J and S shaped population growth curve.

Other properties studied for population include measurement of dimensions such as population density, abundance or size. In a population, factors such as gender, age, developmental stage and size are considered as important. The rate of change of population growth and distribution of individuals is referred as study of dynamics. Biological and non-biological (environmental) factors influence population size. Biological factors include various types of interactions within the species. Environmental variables (non-biological factors) such as temperature, precipitation, disturbance, pollution, salinity, and pH also play an important role in regulating population size.

1.6.5 Community

(Community represents the population of species living and interacting in an area at a particular time. – delete) When several populations share a common habitat, resources and interact among themselves, they develop into a community (biocoenosis). Community is, **therefore**, an assemblage of populations of two or more species occupying the same geographical area at a particular time. All the organisms, microorganisms, plants and animals share a common habitat and interact among themselves. The organisms of a community usually exhibit feeding (trophic) relationships among themselves. Ecological communities can differ in terms of the types and numbers of species they contain. This is because environmental conditions influence the composition of a community to a great extent. For example- In Arctic zone communities, **very** few species are present while in some tropical rainforests, **a large (huge – delete) number** of species are present in a community.

Each community exhibits a number of characteristics such as diversity, density, dominance, composition and stratification. The transitional zone between two or more communities is called “ecotone”.

Community ecology or synecology includes the study of the interactions between species in communities on spatial and temporal scales. The parameters such as distribution, structure, abundance, demography and interactions between populations are considered. The properties such as species richness, productivity and succession are studied.

Structure of Community

In a community, the number of species and size of population varies. The community can be small having a single species or large comprising of several species. The structure of a community is the result of many interacting factors, both abiotic (non-living) and biotic (living organism-related). Community structure is influenced by many factors, including abiotic factors, species interactions, level of disturbance, and chance events. Environmental factors determine the characteristic of the community and pattern of organization of members in the community.

The organization of a biological community with respect to ecological interactions is referred to as community structure. A community's structure can be described by its **species richness and species diversity**. **Species richness** is the number of different species present in a community. Communities with the highest species richness are found in areas near the equator because of warm temperatures, plenty of rainfall and less seasonal variations. Communities with the lowest species richness lie near the poles because of cold, dry climate. Other factor that affects species-richness is the latitude. Species richness is generally highest in tropical latitudes but decreases significantly as we move towards the poles.

Dominance- In each community, few species are present in greater numbers. These are called dominant species. They modify the habitat and greatly influence the growth of other species present in the community to a great extent.

Diversity- It is the number of species (richness) and their occurrence or abundance (evenness). The greater is number of species and their distribution, more is the species diversity. Species diversity is measured in terms of number of different species in the community (species richness) and their relative abundances (species evenness). Larger numbers of species and more abundance of species lead to higher species diversity. Example - A forest community with 2020 different kinds of trees has greater species diversity than a forest community with only 55 kinds of trees.

Diversity is also related to the stability of the community. Communities with high species diversity are more stable. This is because many alternate pathways are available to enable the individuals to obtain energy and nutrients. In an area with high species diversity, if one of the species disappears, its function can be taken over by the other relatively close species.

Dependence- In a community there are some species which depend upon the dominant species for their survival. Example lower plants such as **bryophytes/thallophytes** are dependent on the shade and moisture conditions provided by dominant species.

In a community, processes such as **energy flow** and **matter cycling** take place. Energy flows via feeding relationships. The food energy gets transferred through different biotic components in a chain like manner referred to as the food chain. Food chains collectively form a food web. Solar energy absorbed by producers is converted to food and transferred to consumers. Functioning of an organism in an ecosystem is referred as '**ecological niche**'.

The community dynamics change with time. This dynamic nature is reflected in the succession of organisms in a habitat. A series of changes results in the development of a relatively stable community, which maintains its structure in a particular area. Such a stable and mature community is called a climax community. The communities at various stages of succession are called seral communities. The community changes are gradual. The communities reach equilibrium and maintain a dynamic balance with the environmental changes in course of time. The process of change in communities and their environment at a place in the course of time is called "ecological succession".

Foundation and keystone species

Some species have strong impact on community structure and play a vital role in maintaining the balance of the community. These species include foundation and keystone species. A **foundation species** plays a unique, essential role in a community as it supports the other organisms. Kelps (brown algae) are foundation species that form the basis of the kelp forests in the sea at the coast of California. They create environments for survival of other organisms that make the forest community. The corals of a coral reef are another foundation species. The exoskeletons of living and dead coral make up most of the reef structure, which protects other species from waves and ocean currents.

A **species** that has a vast effect on community structure relative to their biomass or abundance is referred as a **keystone** species. A sharp reduction in diversity or collapse structure commonly occurs when this species is removed from the community. Keystone species belongs to higher trophic levels (top predators) and tends to modify their environment. The intertidal starfish *Pisaster ochraceus* (sea star), found in the northwestern United States, is an ideal example of a keystone species. If these are removed from the intertidal zone, populations of their prey (mussels) increase altering the species composition of the community greatly and reducing species diversity sharply. The mussel population expands and almost replaces the other species. When the sea stars are present, many species of barnacles and algae were found in the lower part of the intertidal zone. The loss of diversity occurred because mussels population increased removing the other species. The sea stars keep a check at the mussels population.

Interactions in a community

Living organisms show different types of interactions which can be harmful or beneficial to the organisms. These interactions are essential for the survival, growth, reproduction and continuance of the species. Species interact in different ways in a community. Interactions can be intraspecific i.e. between same species or inter-specific i.e. between different species. Intraspecific interactions include colonization, aggregation, while neutralism, competition and prey-predator relationships are interspecific. The other types of interactions reported in a community include competition, predation, parasitism, mutualism, commensalism, etc.

Competition

Species present within a community compete with each other for resources. This is considered to be an important limiting factor of growth of population. The competition can be of two types

Interspecific – If competition occurs between the individuals of different species.

Intraspecific – If competition occurs between the individuals of same species.

Predation

It is the killing of an individual of another species for food. The predator species (an animal that kills and eats other animals) kills or harms the prey species (animals killed and eaten by other animals). Some predators kill their prey before eating them, while some other act as parasites and feed on prey when alive. Example - Feeding of herbivores on plants (grazing cow). Predation affects the population size of predators and prey.

Mutualism

It is a type of interaction in which both the species get benefitted. Example of such association is symbiosis. Symbiosis is a close, prolonged association between two or more different organisms of different species that benefit each other. Examples- *Rhizobium* bacteria growing in root nodules of legumes, insects pollinating the flowers of angiosperms.

Commensalism

A type of relationship among organisms in which one organism benefits while the other organism is neither benefitted nor harmed. The organism that benefitted is called the commensal while the other organism that is neither benefitted nor harmed is called the host. Example, in epiphytes, trees support plants such as orchids which get benefitted but trees are not harmed. Opposite of commensalism is amensalism, an interspecific relationship in which a product of one organism has a negative effect on another organism.

Parasitism

Parasitism is an interaction in which one species lives **on/inside** the body of the other species (**serving as a** host) and depends upon it for its food requirements. The organism which is dependent is called as parasite.

Example- *Cuscuta* absorbs nutrients from the host plants through specialized structures called haustoria.

SAQ 6

Define the terms

- Biosphere
- Environment
- Population
- Species
- Carrying capacity

SAQ 7

Give differences between

- 1) Foundation and keystone species
- 2) Commensalism and amensalism
- 3) Prey and predator

SAQ 8

Answer in one word

- 1) J shaped graph for population growth represents.
- 2) S shaped graph for population growth represents.
- 3) The movement of population from one region to another.
- 4) High species diversity leads to.
- 5) Competition occurs between the individuals of different species.
- 6) The process of change in communities at one place in the course of time.

Classification of Communities

Depending on the conditions of their existence, plant communities have been divided into different groups.

Hydrophytic – plant communities living in water (aquatic habitats).

Mesophytic – plant communities living in moist soil habitat.

Xerophytic – plant communities living in dry or arid habitat.

Heliophytic – communities growing on conditions of abundant light.

Sciophytic – communities growing in shade.

Depending upon the location/habitat of their growth, they have also been designated as desert communities, mountain communities and estuarine communities.

1.7 SUMMARY

- Ecology is the study of relationships of living organisms and their environment.
- Ecology is interconnected with other disciplines of biology.
- Ecology has two main subdivisions- autoecology- study of individuals or populations of a single species with respect to their environment and synecology- study of interacting populations of different species.
- Environment or surroundings are composed of various living (biotic) and non-living (abiotic) factors that influences the organisms' growth and survival.
- The part of earth where life exists is referred as biosphere (ecosphere). It is composed of all living beings and elements of lithosphere, hydrosphere, and atmosphere.
- Population is the group of individuals of same species capable of interbreeding. The rate of population growth is characterized by attributes such as natality (birth rate), mortality (death rate), density, abundance and dispersal. Depending upon the availability of resources, population growth can be exponential or logistic.
- Ecosystem- is the interaction of non-living (abiotic) and living (biotic) components with the environment. It can be natural or manmade.
- Community is the assemblage of several populations of different species present in a particular area. Community attributes consist of dominance, diversity, interactions and trophic structure.

References and text books

Begon, M., J. L. Harper and C. R. Townsend, 1990. Ecology - Individuals, Populations and Communities, Blackwell Scientific Publ., London, UK, 2nd edition.

Silvertown, J. 1982. Introduction to Plant Population Ecology. Longman, London, UK.

1.8 TERMINAL QUESTIONS

1. Answer in short
 - a) Three components of biosphere
 - b) Major attributes of population

- c) Biotic and abiotic components of ecosystem
 - d) Various types of interactions in organisms of a community
2. List the major differences between
 - a) Producers and consumers
 - b) Natural and man-made environment
 - c) intraspecific and interspecific interactions
 - d) J and S shaped population curve
 3. Outline the major divisions of ecology.
 4. List in detail the abiotic components of the ecosystem.
 5. Microbes form an important biotic component of ecosystem. Explain.
 6. What do you understand by the term relative abundance?

1.9 ANSWERS

Self Assessment Questions

1. Many British and American ecologists have contributed a lot to evolution of modern day ecological concepts. Eugen Warming emphasized the role of abiotic factors (drought, fire, salt, cold) in the life of living organisms and introduced term 'adaptation' to explain species behavior under set of environmental conditions. H. C. Cowles (1869-1939) and F.E. Clements (1874-1945) published books on vegetation dynamics. Clements contributed lot to plant ecology and considered ecology as the science of community. He published series on phytogeography of North America. Sir Arthur Tansley (1914) is considered as the founder of British Ecological Society. He coined the term 'ecosystem', the interactive system established between the biocoenosis (the group of living organisms), and the environment in which they live. P. Odum (1971), Institute of Ecology, University of Georgia defined ecology as 'the study of structure and function of nature/environment or science of ecosystems. He contributed tremendously to modern ecology through books 'Fundamentals of Ecology', and 'Ecology and Basic Ecology'. R. Lindman made notable contributions to ecological energetics, productivity and ecological models associated with them.

2. a)

Autecology	Synecology
Study of individual species in relation to their environment	Study of a population or community in relation to their environment
Parameters such as geographical distribution, taxonomic position,	Parameters such as composition, behavior of communities in

morphological characters, reproduction, life cycle and behavior of species with reference to ecological factors or environment are studied.	relation to environment are studied.
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b.

Aquatic Ecology	Terrestrial Ecology
Study of ecology of aquatic systems	Study of ecology of terrestrial systems
Includes fresh water ecology, estuarine ecology and marine ecology	Includes forest ecology, grassland ecology, cropland ecology and desert ecology

c.

Community Ecology	Ecosystem Ecology
It deals with structure and organization of a biological community with respect to environmental interactions.	It is the study of living organisms i.e. animals, plants and microbes along with the abiotic components of their environment (water, air and soil).
Factors such as structure, biodiversity, distribution and abundance of species are studied.	The aspects such as nutrient and energy flows are studied.
Various types of interactions such as predation, herbivory, competition and parasitism and mutualism are considered.	Food chain, food web, ecological pyramids and trophic levels are considered.

3. **Environment consist of two components**-Living or biotic and non-living or abiotic.

Biotic components- All the living components are referred as biotic components. They Include plants, animals and microorganisms

Abiotic components – All non-living factors are called as abiotic components. These include water, air, soil/land, and physical factors such as light and temperature.

4. In an ecosystem, plants harvest energy from the sun through the process called photosynthesis. Hence are referred as primary producers. Other living organisms (consumers- both herbivores and carnivores) feed on plants and energy gets transferred to them. These organisms are called consumers. Energy gets transferred to fungi and bacteria via death/decay and decomposition process. Hence in an ecosystem, a continuous flow of nutrients and energy occurs.

5.

- 1) The organisms which are dependent upon producers for their food- consumers (herbivores, carnivores).
- 2) Heat energy from the sun is trapped by –producers (green plants).

6.

- Biosphere - The part/zone/layer of earth where life exists is referred as biosphere (ecosphere). It is the global ecological system composed of all living beings and elements of lithosphere, hydrosphere, and atmosphere.
- Population - A population is group of all of the individuals of the same species present within a specific area. It can also be defined as collection of individuals of the same species present together in a particular space and time.
- Species - Species is the group of similar individuals capable of interbreeding among themselves.
- Environment - The total of all of the surroundings – air, water, land , vegetation that influence the existence of living beings is referred to as environment.
- Carrying capacity -Maximum population size that the environment can sustain at a particular time is called carrying capacity.

7. a). Prey and predator

Foundation species	Keystone species
A species that plays an essential role in a community as it supports the other organisms.	A species that has a vast effect on community structure relative to their biomass or abundance.
Example- Kelp (brown algae) is a foundation species that creates environments that allow the survival of organisms that make up forest community.	Example- The intertidal sea star <i>Pisaster ochraceus</i> , found in the northwestern United States.
Species can be of any trophic level and does not seem to influence environmental conditions.	Species belongs to higher trophic levels (top predators), and tends to modify the environment.

b).

Commensalism	Amensalism
A type of interaction in which one organism benefits while the other organism is neither benefited nor harmed.	A type of interaction in which product of one organism has a negative effect on another organism.

The organism that is benefited is called the commensal while the other organism that is neither benefited nor harmed is called the host.	A larger or stronger organism excludes a smaller or weaker because of deprivation of food. The chemical secretion from organisms damage or kill the other organism.
Example, an epiphytic orchid attached to the tree for support benefits the orchid but neither harms nor benefits the tree.	Example- secretion penicillin from <i>Penicillium</i> kills bacteria. Juglone secreted by <i>Juglans nigra</i> destroys many herbaceous plants within its root zone.

c).

Prey	Predator
Animals that are killed and eaten by other animals.	An animal that kills the prey
Organism is harmed/killed in the process.	Organism gets benefitted

8.

- a) J shaped graph for population growth represents-exponential growth.
- b) S shaped graph for population growth represents-logistic growth.
- c) The movement of population from one region to another-migration
- d) High number of species - species richness or diversity.
- e) Competition occurs between the individuals of different species-intraspecific competition.
- f) The process of change in communities at one place in the course of time- succession.

Terminal questions

1.

- a) Three components of biosphere – mainly three components. These are hydrosphere, lithosphere and atmosphere

Hydrosphere (water) – It is the layer of water present on earth and includes water resources such as oceans, seas, rivers, lakes, streams, ponds, glaciers, polar ice caps and ground water.

Lithosphere (Land) - It is the solid component or the hard surface (crust) of earth. It consists of three layers: crust, mantle and core. The uppermost part consists of weathered rocks, minerals and organic matter and is known as soil.

Atmosphere (air) - It is layer of gases surrounding the earth and consists of a complex mixture of gases, water vapor and particulate matter.

b) Major attributes of population-

Population is represented by many attributes. These mainly include

Numerical attributes- These include parameters such as natality (birth rate), mortality (death rate), density (number of individuals of a population per unit area). These are given in figures.

Structural attributes – This include parameters such as age, distribution (area covered by a population), dispersion (Rate at which individuals move from a population) and abundance (number of individuals within a population).

c) Biotic and abiotic components of ecosystem

Biotic – Living components of ecosystem. Includes plants (producers), animals (consumers), microbes (decomposers)

Abiotic – Non-living components of ecosystem. Include soil, physical factors such as temperature, light.

d) Various types of interactions in organisms of a community

Intraspecific – Interactions occurring within the population of same species

Interspecific - Interactions occurring within different species.

Some positive and negative interactions such as parasitism, mutualism and symbiosis have also been reported among species.

2 a.

Producers	Consumers
They are also called as autotrophs, transducers or convertors.	They are also called as heterotrophs.
They convert energy obtained from sun into food. They include photosynthetic organisms.	They are heterotrophic organisms that eat food produced by autotrophs.
In terrestrial ecosystems, producers are green plants. In the aquatic ecosystems, the floating plants called phytoplankton and rooted plants called macrophytes are the producers. Algae are the	Herbivores (primary consumers) eat plants, while carnivores (secondary or macroconsumers) eat animals. Quaternary consumers or tertiary carnivores include organisms that feed on secondary carnivores. Omnivores

dominant producers in freshwater and marine ecosystems.	include humans that feed on both plants and animals.
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b.

Natural ecosystems	Man made or artificial ecosystems
Created naturally	Created by man by altering natural conditions
Examples- Mountains, lakes	Examples- cultivated fields, cities, townships

c.

Interspecific	Intraspecific
If competition occurs between the individuals of different species.	If competition occurs between the individuals of same species.

d.

J shaped curve	S-shaped curve
When resources are unlimited, populations exhibit exponential growth	When resources are limited, populations exhibit logistic growth.
Size of population goes on increasing and after some time becomes constant.	Population growth decreases as the resources are limited.
Exponential growth	Logistic growth

3. Ecology

Ecology has been divided into two types

Autecology is the study of individual species in relation to their environment. The geographical distribution, taxonomic position, morphological characters, reproduction, life cycle and behavior of species are studied in reference to the environment.

Synecology is the study of a population or community in relation to their environment. The composition and behavior of plant communities and their relationship to the environment are studied.

Apart from these ecological studies have also been divided into many other types such as organism, population, community and habitat ecology depending upon the component of ecology studied.

4. These include the non-living or physico-chemical factors. They support the biotic components. They restrict growth, number, and diversity of population of a species, hence are called as limiting factors. These factors mainly include

Climatic factors – Include physical factors such as light, temperature, wind, humidity.

Edaphic factors- Include soil and its structure. Chemical and physical properties like the soil type, soil profile, organic matter, minerals, soil water, and soil organisms are included in it.

Physical factors – Includes water, air.

Materials – Includes inorganic components such as carbon, sulphur, nitrogen, phosphorus etc. All these elements get cycled (biogeochemical cycles) via different components of ecosystem. The organic components of an ecosystem are proteins, carbohydrates, lipids and amino acids. These are synthesized by biota (flora and fauna) of an ecosystem.

5. Microbes represent the major group of organisms involved in decomposition of organic matter. They include bacteria and fungi. They are referred as decomposers/saprotrophs or reducers. Decomposers break down organic matter into inorganic matter via secretion of digestive enzymes. In an ecosystem they play an important role because they recycle nutrients from decaying organic material. They help in the process of mineralization which builds up organic matter (an essential component of soil).
6. In a community many species are present in abundance while some are rarely present. The species present in large number can be counted and represent abundance. The relative proportion of different species in a community is referred as relative abundance.

ECOLOGICAL FACTORS: SOIL AND WATER

Structure

2.1	Introduction	2.3	Water
	Expected Learning Outcomes		States of Water
2.2	Soil		Precipitation Types
	What is Soil?		Global Distribution of Water
	Origin and Formation of Soil		Properties of Water
	Composition of Soil		Water Cycle
	Soil Profile	2.4	Summary
	Soil Biota and Fertility	2.5	Terminal Questions
		2.6	Answers

2.1 INTRODUCTION

In the previous Unit, an introduction regarding the various abiotic factors that occur in environment has been given. Abiotic factors form an important component of an ecosystem and affect the survival of an individual, population or community to a greater extent. The present unit provides you detailed information about the two major abiotic factors i.e. soil and water.

Expected Learning Outcomes

After the study of this unit you should be able to:

- ❖ describe the process of soil formation,
- ❖ describe the composition of soil,
- ❖ enlist the properties of soil,
- ❖ describe the structure of soil horizon,
- ❖ enumerate different forms of water and their sources,

- ❖ enlist the properties of water, and
- ❖ discuss the importance of hydrological cycle.

2.2 SOIL

Soil forms the outer layer of the earth's crust. The word soil is derived from the word '*solum*' meaning earthy material that supports plant growth. Soil acts as a substrate that provides mechanical support to plants and as a reservoir of water and nutrients for plants. It is composed of inorganic and organic materials. Inorganic components include mineral elements derived from parent rock material. Organic matter comprises of organic wastes, dead remains of plants, animals and their decomposition products. Large number of algae and microorganisms such as bacteria, viruses and fungi form an important component of soil.

2.2.1 What is Soil?

Soil is a natural resource formed by weathering (breakdown) of rocks. It has been defined as the matrix (sand-silt-clay) containing living biomass and dead organic matter with some concentration of air and water. It is a rich source of organic and inorganic materials that support plant life and microscopic communities. Inorganic material includes mineral elements derived from weathering and fragmentation of parent rock material. Organic components include organic wastes, dead remains of plants and animals and their decomposition products.

2.2.2 Origin and Formation of Soil

Various models have been proposed to explain the formation of soil. The process of soil formation (soil genesis) was proposed by Hans Jenny (1941) and Roy W. Simonson (1959). According to these authors, soil formation consists of (includes – delete) two steps: 1) accumulation of parent material and 2) differentiation into different horizons. Organic matter is added to soils after decay and decomposition of remains of plant and animal. The rate of soil formation is regulated by environmental factors.

Soil Formation

The process of soil formation begins with the changes in the parent material (rocks), accumulation of raw material followed by buildup of organic materials at the surface. Various physical, chemical, biological, and anthropogenic processes are involved in the alteration of the parent material to form soil. Two main steps involved in soil formation include

1. **Weathering of rocks** - The breakdown of rocks is called weathering. It can be physical or chemical. Physical weathering occurs by mechanical forces. Changes in temperature cause contraction or expansion of rocks leading to formation of cracks and fissures in rocks. This breaks rocks into smaller pieces. Low temperatures freeze the water present in the rock crevices causing expansion and this force breaks the rocks into

small pieces. Besides these, hail, rainfall, wind also help in breaking of rocks into smaller particles due to friction.

Chemical weathering is brought about by action of water or activities of organisms present in soil. Water brings chemical changes in rocks due to dissolution. Oxidation-reduction reactions and organic acids produced by microbes assist in the breakdown of rocks and add organic matter to soil.

2. **Mineralization and humification** – The small pieces of rocks or particles produced by weathering of rocks get converted into a homogenous matrix via the process of mineralization. Plants and animals play an important role in this process. The roots of the plants invade the soil particles further breaking the particles into fine material. The microbes associated with the roots of plants secrete organic acids and humic acids that further assist in breakdown of rock material to fine soil particles. Microorganisms such as bacteria, fungi and actinomycetes assist in the decomposition process. In the process, organic compounds get converted into inorganic nutrients. The breakdown of organic compounds leads to formation of simple products such as carbon dioxide, water and minerals. The process is called mineralization. Incompletely decomposed organic material left after mineralization forms the humus which is a dark, homogeneous, amorphous, colloidal substance. Humus gives loose texture to the soil which provides aeration and helps in retaining water and nutrients.

The process of soil formation depends upon several factors such as the parent material (rock), climate, topography (relief) (Fig 2.1).

Factors affecting soil formation include

The development of soil profile is influenced by several factors. These mainly include changes in the parent material, climate change, topography, organisms. All these factors change the characteristics of soil and give it a distinctive profile.

Parent Material – The parent material plays an important role in deciding the characteristic of the soil. The chemical composition of the parent material determines the properties of the soil. Color, texture, structure, mineral composition and permeability of soil depend upon the parent material. A soil developed from coarse grained parent material is resistant to weathering and is coarse in texture. The soil formed from limestone possesses high level of soluble bases and is fertile in nature. The soil formed from the parent material which is low in soluble ions is acidic. This is because water moving through the soil removes the bases and substitutes them with hydrogen ions. Soils developed from sandstone are low in soluble bases.

Climate – Climate influences soil development and soil chemistry. Climatic factors regulate the rate of chemical reactions occurring during soil formation. Precipitation also affects development of horizons as the translocation of dissolved ions through the soil gets affected. Soils of hot, dry desert regions are generally devoid of organic material because less vegetation and few microbial species are available for decomposition. The lack of precipitation

inhibits chemical weathering leading to coarse textured soil in arid regions. In contrast, high rate of annual precipitation flushes out organic material from the soil. The cold temperatures restrict the microbial activity hence affecting the buildup of organic matter in the tundra region. In the warm and wet tropics, rapid rate of bacterial activity promotes decomposition leading to buildup of high organic matter. The rate of biological processes gets enhanced in presence of rising temperature. The rate of reaction gets doubled for each 10°C rise in temperature. Enzyme-catalyzed reactions are sensitive to high temperatures and attain a maximum between 30 and 35°C. The velocity of water determines the rate of soil erosion and deposition of organic material. The rate of percolation of water i.e. the movement of water from one part of the soil to another is also affected by climate. The rate of absorption of the solar radiation is regulated by soil properties such as color. Dark soils absorb more radiation.

Topography (elevation) – It is a factor that poses a significant impact on soil formation because it determines runoff of water. Slope angle and length affects runoff generated when rain falls to the surface. Water erosion is more effective on steeper, un-vegetated slopes. Water moving across the surface drives away the parent material thus impeding soil development. The amount of water and its rate of flow increases down the slope direction.

Biological Factors – The biological components of the soil include vegetation, microorganisms and associated fauna. These organisms influence the soil composition to a greater extent. Soil forming fauna mainly includes microorganisms such as bacteria, fungi, actinomycetes, earthworms, small arthropods and burrowing animals (rabbits, moles). Biological processes carried out by organisms present in the soil or associated with roots of the plants help in build of organic matter in soil. Pioneer species such as grasses and algae lead to build up organic matter on the surface of the parent material. The soils that possess less number of microbes (desert soils) are also not well formed and lack organic matter.

Time – All pedogenic (soil forming) processes occur over time. Young soils show only minimal profile development i.e. possess only horizon A while the mature soils possess all the horizons.

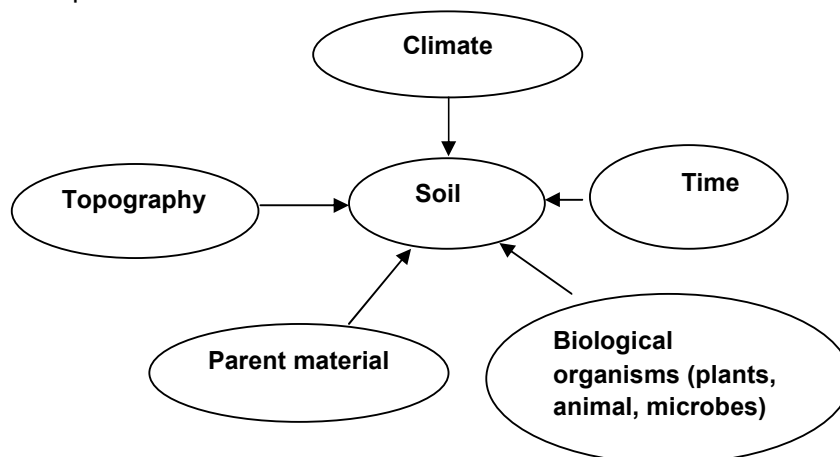


Fig. 2.1: Diagrammatic representations of the processes affecting soil formation.

2.2.3 Composition of soil

Soils are mainly composed of four elements namely minerals, organic matter, air and water. Most of the top soils contain about 45% minerals, 25% water, 25% air, and 5% organic matter. These percentages can vary tremendously depending upon the type of soil (Fig 2.2).

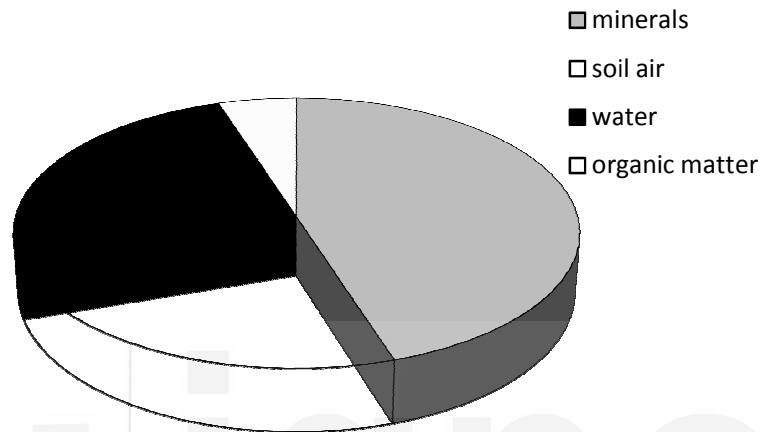


Fig. 2.2: Composition of an ideal soil.

Minerals – They are formed by breaking of parent rock material and addition of dissolved substances. These mainly include elements such as carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, aluminium, silica and various alkaline earth metals

Soil Organic Matter (SOM) – Organic matter consists of dead plants, animal, microbes and fungi or their parts, as well as waste products in various stages of decomposition. It is formed as a result of decay and decomposition of organic compounds. The elemental composition of SOM includes carbon, oxygen, hydrogen, nitrogen, phosphorus, and sulfur. Organic matter forms a minor portion of the soil but has a very strong impact on the properties and function of soil. Organic matter is able to absorb and hold large quantities of water. It also helps in binding water to the soil and holding the soil aggregates together. Organic matter has high cation exchange capacity (CEC). The negative charge on the organic matter of soil attracts the cations necessary for plant growth and reproduction. The soil having organic matter content of 20 to 35% (on a dry weight basis) is considered as organic soil.

Air and Water – Air and water occupy pore spaces between the solid soil particles. The amount of air present in the soil depends upon the amount of water. If more water is present than pore space can hold, it is said to be saturated. If soil is saturated by water, little air is available. In anaerobic conditions, air spaces are filled with water, oxygen and other gases are unable to diffuse from the outside atmosphere. Air helps in the process of oxidation and converts organic material into useful elements. The amount of water held in soil depends upon its texture and structure. In sandy soils, water drains

quickly, while in clay water is held between the soil particles. In areas of low evaporation rate, water moves downward and dissolves the soluble minerals together with soluble humus material and the process is called leaching or eluviation.

Water present in the soil is of different types

Gravitational/ground water – The water that moves into the soil under the influence of gravity after rain or irrigation is the gravitational water.

Capillary water – The amount of water retained in the soil against the pull of gravity. The water is enclosed in between the spaces between soil particles as thin film. This is the most important source of water utilized by plants from the soil.

Hygroscopic water- The amount of water in air dried soil. The water is present in relatively small amount.

The moisture holding capacity of the soil is governed by its properties such as particle size, porosity and texture. Maximum amount of moisture the soil can hold is called maximum retentive capacity. In this condition, air present in the soil pores gets replaced by water after heavy rainfall or irrigation. If water supply is stopped, water from larger pores (macropores) drains out and pores gets filled with air, while water remains retained in smaller pores (micropores). The water left in soil after draining out of gravitational water is called field capacity. It is defined as soil with water content of -0.33 bar suction pressure (0.0033MPa). It is generally expressed as the percentage of the weight or volume of soil occupied by water when saturated at a standard temperature. It varies with soil texture i.e. proportion of sand, silt and clay.

At certain point, moisture decreases to a level that is not available for plants, soil is supposed to have reached a wilting point. It is defined as the amount of water at -15 bar suction pressure or -1.5 MPa.

Structure of soil

It refers to the arrangement or grouping of soil particles. This can occur as a continuum single granule (large) or many aggregates (small). Soil particles are of different sizes. Gravel consists of small, loose, rock particles larger than 2 mm. These are the largest particles in the soil. Then there are sand particles (are the largest – delete) ranging in size from 0.05 to 2.00 mm. There are also silt (consists of – delete) particles ranging from 0.002 to 0.05 mm and clay contains particles less than 0.002mm. Sand and silt are the “inactive” or ‘inert’ part of the soil matrix. They do not retain soil water or nutrients. Clay is the “active” portion of the soil matrix. Large amount of surface area per unit mass of clay and surface charge attracts ions and water. The negatively charged clay particles attract positive ions cations and release them to the soil water. Cations such as potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+} and Fe^{3+}), and zinc (Zn^{2+}) are essential plant nutrients held by the soil particles. They play an important role in plant growth and development.

Soil texture

This property of soil is based on the soil particles. A soil texture includes the percentage of sand, silt and clay. Soil texture varies according to percentages of these three (Table 1). The proportion of sand, silt, and clay always adds up to 100 percent for all mineral soils. Texture depends upon the parent material and soil forming process. A strongly developed structure possesses heavy texture. Depending upon the percentage of sand, silt and clay, soil texture has been divided into different classes organized into a “textural triangle”. A soil containing 15% clay, 20% silt and 65% sand is sandy loam and a soil containing equal amounts of sand, silt and clay is clay loam (Fig 2.3). Till now 12 soil textures have been reported.

Soil texture is important in determining the nutrient holding, water holding, water movement and movement of soil air. Texture influences the permeability which generally decreases with decreasing particle size.

Table 2.1: Particle size of different soil components.

Particle name	Size range
sand	2 mm-0.05 mm
silt	0.05 mm-0.002 mm
clay	<0.002 mm

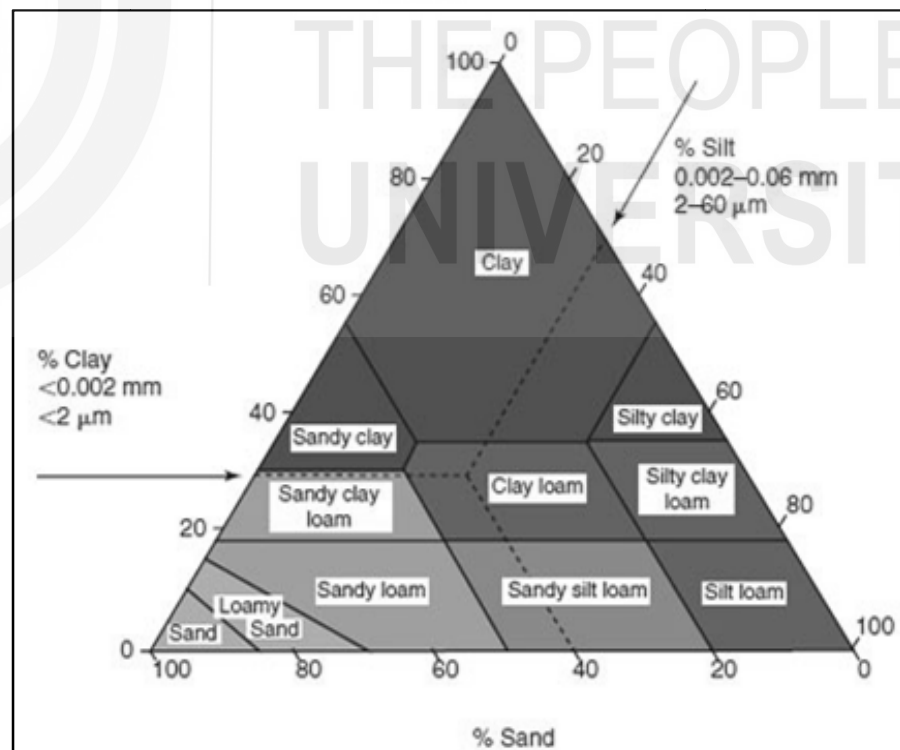


Fig. 2.3: Soil texture triangle.

Soils have been categorized as fine, coarse depending upon its composition and size of the particles and (Table 2.2).

SOIL TYPE	PARTICLE SIZE PLATY /COLUMNAR/ BLOCKY /GRANULAR/ PRISMATIC
very fine (thin)	<1 mm/ <10 mm/ <5 mm/ <1 mm
fine (thin)	1 – 2 mm/ 10 – 20 mm/ 5 –10 mm/ 1 – 2 mm
medium	2 – 5 mm/ 20 – 50 mm/ 10 – 20 mm/ 2 – 5 mm
coarse (thick)	5 –10 mm/ 50 –100 mm/ 20 –50 mm/ 5 –10 mm
very coarse (thick)	>10 mm />100 mm/ >50 mm />10 mm

Soil particles get grouped to form aggregates with pore spaces in between. Soils have also been divided into different grades and classes.

Class- It describes the average size of individual aggregates. Classes are of different types such as very fine (thin), medium, coarse (thick) and very coarse (very thick).

Grade- It represents the degree of aggregation. It is based on the properties of cohesion and adhesion between soil particles or aggregates. The soils have been graded in the range of 0 to 3.

1. No aggregation i.e. no definite orderly arrangement of particles (structure less)
2. Poor aggregation between particles. Soil is referred as disturbed (aggregates are broken)
3. Well formed distinct aggregates. A mixture of full aggregates, broken aggregates and some non-aggregated material.
4. Strong durable aggregates. Very large aggregates and little/no non-aggregated material.

Different types of structural forms have been noted in soils (Table 3). These include plate like, prismatic, columnar, block like, spherical and granular. Variations in size are based on soil aggregates (ped). Ped is considered as the unit of soil structure. Soils have peds of different shapes. A well developed granular structure facilitates aeration and water movement. Water movement and drainage are poor in soils having blocky, prismatic, columnar and platy structures.

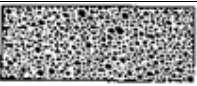
Plate like (platy) – they occur in any part of soil profile or are inherited from soil material.

Prism like (prismatic, columnar) – they occur in subsoil particularly in arid and semi arid region

Block like (blocky) (cubelike, subangular) – present in subsoil particularly in humid regions

Spheroidal (granular, crumb) – characteristic of soils subject to change

Table 2.3: Structure of soil particles.

Type	Structure	Presence in soil horizon	Picture
Granular	roughly spherical, 1-10 mm in diameter	A horizon	
Platy	flat peds lie horizontally in the soil	A, B and C horizon	
Blocky	Cube-shaped with flat surfaces. Edges and corners can be angular or sub angular. Size range from 5-50 mm	B horizon	
Prismatic	Larger, vertically elongated blocks. Size ranges from 10-100mm	-	
Columnar	Prisms like with bounded flat or slightly rounded vertical faces.	-	
Massive	Compact, coherent separated into peds. Show slow permeability, and poor aeration	-	
Single grain	Very sandy soils, every grain acts independently, not organized into peds. Permeability is rapid, but fertility and water holding capacity are low.	-	

2.2.4 Soil profile

A soil profile is a physical and chemical description of the layers (horizons) that make up the soil, from the surface to the depth (Fig 2.4). The layers of the soil are formed and are well differentiated from the original parent material. Horizons are labeled according to characteristic properties. Different layers of soil are formed with time, climatic changes, activities of living organisms and relief. The system was developed by the US Department of Agriculture

(USDA). These layers are referred to as O, A, E, B, C and R depending on their position and nature. A typical profile of a mature soil includes the following horizons:

Table 2.4: Description of different layers in soil horizon.

Layers of soil horizon	Description
O (organic)	Top layer dominated by organic material. It includes layer of litter and humus. This horizon is not present in cultivated soils, manicured lawns, and severely eroded soils.
A	The mineral soil horizon present at the surface or below an O horizon is referred as topsoil. It contains a mixture of organic and mineral components. It has more organic carbon. This layer supports plants and microbial growth. This layer is formed when organic matter gets transformed into humic materials by soil biota. The humic materials coat the soil particles, coloring them brown and black. The formation of this horizon takes long time as decades. This horizon increases in thickness and SOM content.
E (elluvial)	Horizon characterized by eluviation i.e. removal of materials such as silicate clay, iron, aluminum, or organic matter. It is commonly not found. Usually pale colored and low in organic matter. The texture is similar to horizon A.
B	Horizon is dominated by loss of most of the original rock material and shows illuviation i.e. concentration of the silicate clay, iron, aluminum, or humus from higher horizons. These materials get added by leaching from overlying horizons. This zone is formed when dissolved and suspended materials are carried downward to greater depths with percolating rainwater. It has various sub horizons which are denoted as B _{t1} , B _{t2} , B _{tg} .
C	It is the layer of soil excluding hard bedrock. It lacks characteristics of O, A, E or B horizons.
R	The underlying hard bedrock

SAQ 1

How the soil structure influences its function?

SAQ 2

What makes up the organic matter component of soil?

SAQ 3

Name some factors affecting soil structure?

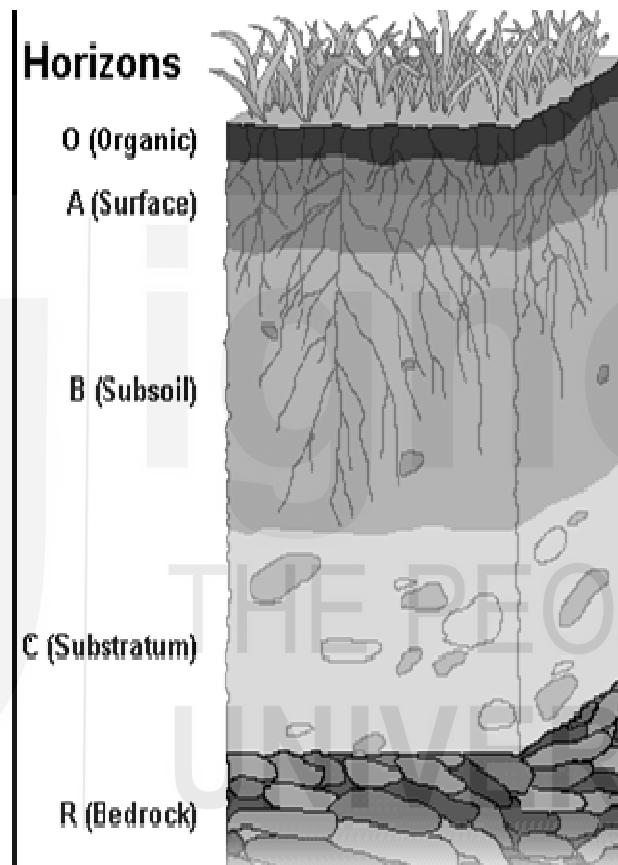


Fig. 2.4: Various horizons in the soil profile.

2.2.5 Properties of soil

Properties of soil whether physical or chemical influence nutrient and water retention required for sustaining fertility and maintaining productive potential required for development of plants.

Physical Properties

Light and heavy soils

The presence of sand, silt or clay imparts a particular texture to soil. Presence of high silt particularly clay gives it a fine texture but show slow water and air movement. These soils become hard because of high water holding capacity. Such soils are called heavy soils. In contrast, coarse, sandy and gravel soils are called light soils because they cannot retain water for longer period.

Soil pores

Pores are the spaces between soil particles or aggregates. They are important because they allow air and water to move through the soil. They are of different types

- i. Interstitial: small spaces between soil particles or aggregates
- ii. Tubular: bigger tube like spaces made by plant roots or soil animals

Pores are generally broken up into two size classes depending upon the size.

- i. Macropores: bigger pores that allow free movement of air and water
- ii. Micropores: small pores that help in movement of air and water by capillary action.

Soil Color

Color is the most useful property for identification of soil (Table 2.5). It is determined by the amount of organic matter and iron. Colors of soil matrix and mottles indicate water and drainage conditions in the soil. These colors may occur as the dominant color (the matrix) or in patches (mottles). The color of the soil can be quickly determined by comparison of the sample with a standard set of color chips mounted in a note-book called **Munsell Color Chart (Figure 2.5)**. Soil color is described by the parameters called hue, value and chroma. Hue describes (where in – delete) the color spectrum where the color of soil exists (colors yellow, red, blue, green, and gray). Chroma indicates the strength of the color.

Table 2.5: Soil color and their respective properties.

Soil color	Properties
rich brown color	well aerated soils with pore space dominated by oxygen
grey or blue-grey colors	poorly drained soils wet soils developed under anaerobic conditions
Brownish black or dark brown colors	high organic content like horizon A soil
Red and yellow soil	presence of iron oxides and indicates good drainage and aeration
Yellow color	presence of hydrated iron oxides and hydroxide
black	indicates manganese oxides

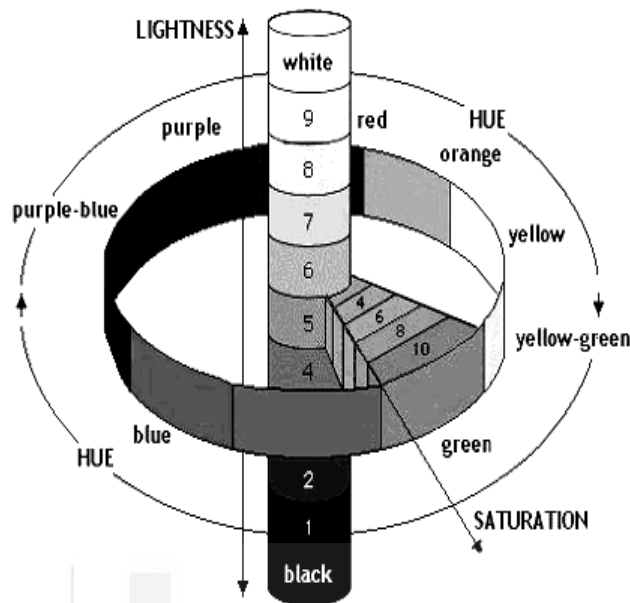


Fig. 2.5: Measurement of soil color.

Temperature

Soil temperature influences its properties. Fluctuations in temperature help the physical breaking of rock and mineral grains. Lower temperature affects accumulation of organic matter because of low biological activity. Increase in temperature support chemical weathering.

Drainage

Soil drainage indicates status of soil when it is saturated (water in excess of field capacity). Excess free water in the root zone can kill plants or pose difficulty in their establishment. The U.S. Department of Agriculture recognizes seven classes of drainage ranging from “excessively drained,” where the water moves out of the soil rapidly, to “very poorly drained,” where water moves out of the soil very slowly. Drainage is affected by soil texture. The coarser soils tend to drain more rapidly. The shallow soils tend to drain more rapidly. This property also depends upon rate of precipitation. The areas with greater rainfall may drain slowly. Topography also influences drainage as ground level soils drain slowly.

Soil Consistence

Soil particle form aggregates. The aggregates arrange into discrete structural units called “peds”. Between the peds are present pores which play an important role in movement of air and water. Soil consistence is the property of breaking down of peds. It depends on the soil moisture content. The resistance of a soil to deformation or rupture is determined by the cohesive and adhesive properties of the soil. Coarse textured soils possess large pore spaces that lead to high infiltration, percolation and drainage, while fine textured soil contains small pores and high amount of surface water

Bulk density

Bulk density is the weight of a given volume of oven-dried soil divided by the volume i.e. mass of soil per unit volume of soil. It is expressed as weight per volume and generally represented as grams per cubic centimeters (g/cc). The formula for its calculation is

$$D_b = M_s/V_t$$

Where D_b = bulk density

M_s = mass of solids

V_t = total volume

Soil bulk density values range from 0.5 to 3.0 but most values are between 0.8 and 1.8. It reflects the amount of pore space in the soil and is an indicator of soil health. It is inversely proportional to pore space.

Pore space = $1 - \text{bulk density/particle density}$

For example, at a bulk density of 1.60 g/cc, pore space equals 0.40 or 40%. At a bulk density of 1.06 g/cc, pore space equals 0.60 or 60%.

Soil texture, organic content and compaction affect the property of bulk density. High bulk density indicates compacted soils. The plant growth is restricted in these soils. The practices such as cover cropping, addition of crop residues increase organic matter thereby reducing bulk density. Example- A soil with 100% mineral soil material and bulk density of 1.33 g/cc, while another soil with 95% mineral soil material and 5% organic soil material has bulk density of 1.26 g/cc. The difference in bulk density relates to a difference in mineral soil material and organic soil material. The average particle density of mineral soil material is 2.65 g/cc, while that of organic soil material is 1.25 g/cc. Lower the pore space or higher the bulk density of the soil, the higher the suitability of the soil for aquaculture.

Soil permeability

The rate at which water moves down through the soil is referred as permeability. It is usually measured in inches per hour. Pore size, texture, structure, organic content and compaction determine the permeability of a soil. Rate or coefficient of permeability is determined by measuring rate of flow of water through a column of soil. The permeability differs for various layers of soil horizon. The property depends upon the pores between soil particles. Soils with high clay content possess low permeability, while sandy soils have a higher permeability. A sandy loam has a permeability of 2.0 to 6.0 inches per hour, while sandy clay loam has a permeability of 0.2 to 0.6 inches per hour. In an impermeable soil, water is lost through seepage and infiltration is low. Infiltration is the rate at which water enters the soil. Applying water at rates greater than what soil can take results in ponding. The increase in runoff leads to soil erosion and loss of fertility.

Organic matter improves soil structure, improving permeability and infiltration. Fine-textured soils (clayey) contain more total pore space than coarse-

textured soils (sandy). Water moves more slowly through a fine-textured soil leading to lower permeability and infiltration. Calcium improves soil structure by encouraging aggregation and increasing pore size. This increases permeability and infiltration. Microorganisms (e.g., bacteria and fungi) and macroorganisms (e.g., insects and earthworms) present in the soil increase permeability and infiltration by encouraging the formation of soil aggregates and creating macropores in the soil.

Infiltration is influenced by factors such as dryness and slope. Dry soils repel water. This is true for soils rich in organic content. Slope may cause water to run off.

Odor

Odor is the indicator of wetness. In waterlogged soils, bacteria use oxygen for respiration releasing hydrogen sulfide gas that smells like “rotten eggs”. Sulfur smell is prevalent in soils around marshes or overwatered potted plants.

Water holding capacity

The amount of water the soil can hold against the flow of gravity is also called as field capacity. The maximum amount of water that the soil can hold is called water holding capacity. It is the difference between the amount of water in the soil at field capacity and the amount of water in the soil at wilting point. It is also referred to as Available Water Capacity (AWC) or Plant Available Water (PAW). It is measured in inches/foot or inches/inch. The soil moisture content after soil cannot support agronomic plant growth is referred as wilting point. Soil texture plays an important role in this property. Sandy soils possess low water holding capacity, while clayey soils tend to have a higher water holding capacity. Very high clay content reduces water holding capacity because the tiny pores between the particles hold water tightly.

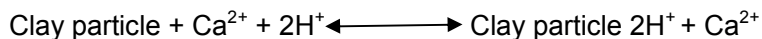
Chemical Properties

Cation Exchange Capacity (CEC)

Soil can hold some amount of cations which are present in an exchangeable form. The total number of charged sites present on soil particles within a given volume of soil is known as ion exchange capacity. Total number of negatively charged sites present on the clay particles and humus is called cation exchange capacity (CEC). It depends upon the number of exchange sites on clay particles and net charge of soil particles or magnitude of the negative charge per unit weight of soil. This property increases in soils with high clay and organic matter content. Clay and organic matter particles are negatively charged (anions). They attract cations (positively charged particles) to their surfaces. The bonds between the clay mineral surface and the cations are relatively weak, hence cations get exchanged for other cations dissolved in the solution. When the adsorbed cations get replaced by other cations, the process is called “cation exchange”. The greater the clay and organic matter content, the greater the CEC. It is determined in terms of milliequivalents (m.e.) per milligrams of soil. If soil has a CEC value of 1 m.e., this means that it is capable of holding milligram of hydrogen or equivalent for every 100g of soil. Elements like calcium have two charges equivalent to two hydrogen ions.

The amount of calcium required to displace 1 milligram of hydrogen is 40/2 i.e. 20 milligrams. CEC depends upon the quantity of exchangeable hydrogen ions and other bases present in the soil.

Cation exchange is an important property of soils for retaining nutrients and increasing their availability to plants. Cations present in soils mainly include nutrients such as potassium, calcium, and magnesium. The loosely held nutrients can then be taken up by plant roots or by other soil organisms. This property helps soil to filter environmental contaminants from wastewater.



Soil pH

The acidic or basic nature of the soil depends upon the relative concentration of H ions (acidity) or OH ions present in it. Acidity is due to the presence of excess of H ions, while alkalinity is due to the excess of OH ions. The pH scale ranges from 0 to 14. Values below 7.0 are acidic and above 7.0 are alkaline. A pH value of 7 is considered neutral, where H⁺ and OH⁻ are equal, both at a concentration of 10⁻⁷ moles/liter. Indication of the acidity or alkalinity of the soil is also known as “soil reaction”. pH of soil affects solubility of ion which in turn affects microbial and plant growth. A pH range of 6.0 to 6.8 is ideal for most crops because it provides optimum solubility of the most important plant nutrients.

In acid soils, hydrogen and aluminum are the dominant exchangeable cations. Factors that affect soil pH include parent material, vegetation, and climate.

SAQ 4

Which of the soil property helps in the exchange of nutrients in plants?

Types of soil

The soils have been differentiated into different types depending upon the basis of their origin and relationship with the parent rock.

Residual soils – These soils are formed at the same site where the weathering of the parent material takes place i.e. formed under *in situ* conditions from underlying rocks. In India, these soils are of two types- reddish soils which are poor in calcium, magnesium, phosphorus and nitrogen but rich in iron (oxides), and black soil which is rich in clay and possess high quantities of potash, calcium, magnesium and iron.

Transported soils – These soils are formed from weathered material which is transported and deposited away from the site of origin. These soils are of different types depending upon the type of agent involved in its transport

- **Colluvial**- These soils are formed from material transported by pull of gravity or under conditions of landslide. It is very coarse and consists of large fragments of rock.

- Alluvial – The soil is formed under conditions of running water such as flood plains, river terraces and delta. The soil particles are rounded and smooth. The particle size varies depending upon the speed of transporting water.
- Glacial – These soils are formed by the grinding action of ice and snow. Heavy snow masses and glaciers push the surface material. Sharp edged rocks get grounded into smooth particles by abrasive action.
- Aeolian – The soils formed by transportation through wind. These include dunes and loess. They occur along the side of water bodies. The water currents erode the land and lead to deposition of soil particles.

Classification of soils

Soil scientists have come up with systems for classifying soils. Soil taxonomy experts from Russia, FAO and Canada have classified the soils on the basis of genesis i.e. development. Soils have been classified into twelve categories or orders (Table 2.6)

Table 2.6: Classification of soils.

Name	Features	Areas where found
Alfisols	enriched in aluminum- and iron-bearing minerals, low in humus content	formed in areas with low rainfall mainly temperate forests
Andisols	permeable, erosion-resistant, and high in mineral nutrients	formed in areas of volcanic ash
Aridisols	dry, have low organic and humus content	formed in deserts
Entisols (young soils)	lack nutrients	formed in areas of floodplains and mountains
Gelisols	with permafrost	formed in areas of very cold climates
Histosols	possess 12 to 18% organic carbon	formed in wetlands
Inceptisols	possess <u>clay</u> minerals, metal oxides, <u>humus</u>	fairly young soils found in river deltas, upland forests and tundra <u>environments</u>
Mollisols	brown soil rich in humus, rich in nutrients (calcium, magnesium, potassium, sodium)	formed in grasslands

Oxisols	very low fertility, possess <u>clay</u> minerals and metal oxides	old soils formed in the tropics
Spodosols	ashy gray, acidic sandy soils with low fertility	formed in temperate coniferous forests
Ultisols	reddish, clay-rich, acidic soils with low nutrient content	formed in humid temperate and tropical regions
Vertisols	dark-coloured soils with moderate <u>humus</u> content, saline and rich in calcium	Found in Mississippi delta regions and plains of California

In India six types of soils are found. These include

Alluvial soil – Soil which is deposited near rivers, seas and glaciers is called as alluvial soil. It is found in Indo-Ganga Brahmaputra Plains, Coastal Plains and the broad river valleys of South India.

Red soil – Soil that develops under very low rainfall condition on granite and rocks is referred as red soil. The presence of oxides of iron gives them red color. Found mainly in almost whole of Tamil Nadu, South-eastern Karnataka, North-eastern and South-eastern Madhya Pradesh, Jharkhand the major parts of Orissa, and the Hills and Plateaus of North-east India.

Black soil – It is very clayey thick in texture. It possesses high water holding capacity and is very fertile. This type of soil is best for cultivation of cotton. Found in plateaus of Maharashtra, Gujarat, Madhya Pradesh mainly Malwa.

Mountain soil – It is formed by deposition of organic matter provided by forests. It is rich in humus and heterogeneous in nature. It is sandy and porous. Found on the hill slopes covered with forests particularly the Himalayan region.

Laterite soil – It is a kind of clayey soil formed under high temperature and high rainfall. Found mainly in South Maharashtra, the Western Ghats in Kerala and Karnataka, at places on the Eastern Ghats, in some parts of Assam, Tamil Nadu, Karnataka

Desert soil – The soil has sand (90 to 95 percent) and clay (5 to 10 percent). In some regions this soil has the high percentage of soluble salts, but lacks in organic matter. Found mostly in the arid and semi-arid regions, receiving less than 50 cm of annual rainfall.

2.2.6 Soil Biota and Fertility

Soil biota i.e. living organisms present in soil play an important role in soil formation and development (Table 2.7). Soil organisms alter soil physical, chemical and biological properties of the soil in different ways. The biotic communities influence the spatial heterogeneity of resource. Biological

functions of soil biota help in improving soil health, function, quality, fertility and provide a sustainable alternate for soil management.

Soil formation and improvement of soil structure is the major function performed by soil biota. Bacteria present abundantly in soil secrete mucilaginous and organic substances which cover cells and their colonies. These substances help in cementing the soil grains to form larger aggregates. Fungi present in the soil also help in binding the soil particles together.

Larger soil organisms such as rodents, insects and worms help in mechanical mixing and weathering of soil. The roots of plants widen the fissures in rocks helping in their breakdown to form small fine particles. Invertebrates play a role in stabilizing soil structure. Earthworms help in mixing of soil but make it more fertile by increasing aeration and drainage. They bring down the lower soil to the surface and mix soil by digging burrows. Burrowing activities bring subsoil to the surface. It also helps in the creating passage for gaseous exchange i.e. diffusion of oxygen and release of carbon dioxide.

Decay and nutrient cycling is another major function performed by organisms present in the soil. These organisms act as chief agents of decay in organic matter. Decomposition and mineralization help in the release of inorganic nutrients that are absorbed by the plant roots. Organisms include bacteria, actinomycetes and fungi. These organisms bring out hydrolysis and oxidation of organic compounds through various enzymatic reactions. Soil fauna such as millipedes, centipedes, earthworms, mites, ants, beetles and snails consume plant products (litter) and leave the decomposed product in soil. The complex organic compounds are broken down into simpler compounds. Example - proteins are broken down into amino acids, ammonium compounds, nitrates and nitrites. Worms utilize un-decomposed remains of plants and animals as food. In the process they convert it into useful organic matter.

Nitrogen fixation is another important function performed by microbes present in the soil.

Microorganisms such as *Azotobacter*, *Clostridium*, *Rhizobium* help in fixation of atmospheric nitrogen by converting the atmospheric nitrogen to organic nitrogen. The fixed nitrogen is utilized by other organisms. The amount of nitrogen fixation has a direct effect on soil fertility.

Heterotrophic soil organisms including bacteria and fungi produce growth promoting substances such as 3-indole acetic acid (and other – delete). These substances support the growth of plants.

Table 2.7: Common populations of some soil microorganisms.

Organism	Count (Number)/g of soil
Bacteria	$10^8 - 10^9$
Actinomycetes	$10^7 - 10^8$
Fungi	$10^5 - 10^6$
Algae	$10^4 - 10^5$

Protozoa	$10^4 - 10^5$
Nematoda	$10 - 10^2$

In the Table, the numerals indicate the power to which the figure (10) is multiplied is NOT clearly seen. Please correct this Table for easy reading

SAQ 5

Microbes are very important for soil build up. Explain.

SAQ 6

Answer in short

- Soil formation involves two steps.
- humus
- zones of soil horizon
- soil permeability

2.3 WATER

Water is a tasteless, odorless and colorless liquid with the chemical formula H_2O . Henry Cavendish (1781) showed that water is composed of oxygen and hydrogen. Joseph Louis Gay-Lussac and Alexander von Humboldt (1805) showed that water is composed of two parts hydrogen and one part oxygen. The first sample of pure heavy water was isolated by Gilbert Newton Lewis in 1933. In a water molecule, two hydrogen atoms are covalently bonded to a single oxygen atom. The oxygen atom is electronegative and possesses two lone pairs of electrons. The angle between the hydrogen atom and oxygen is 109.47° (Fig 2.6). The lone pairs of electrons on the oxygen atom (and – delete) are located in the direction opposite to that of hydrogen atoms.

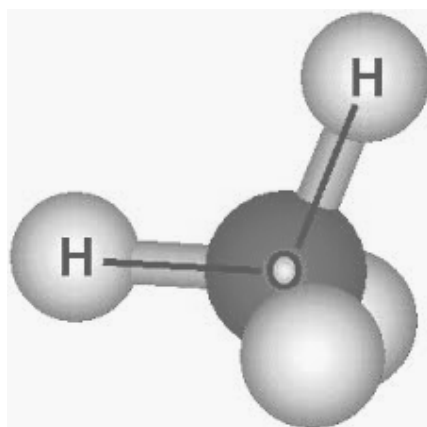


Fig. 2.6: Structure of water molecule.

2.3.1 States of Water in the Environment

Water occurs in three phases- solid, liquid, gas. The liquid is the most common phase. It remains as a liquid because of oxygen which is electronegative in nature. The solid phase of water is known as ice. The gaseous phase of water is known as water vapor (steam). The fourth state is supercritical fluid and is not very common. At a specific critical temperature and pressure (647 K and 22.064 MPa), the liquid and gas phases merge to one homogeneous fluid phase. Supercritical water is the hot water occurring naturally in deep hydrothermal vents.

2.3.2 Types of Precipitation

Interchange of water (occurs – delete) between earth's surface and atmosphere occurs via precipitation. It is the form of water which comes down on earth from the sky or atmosphere. It forms an important part of hydrologic cycle. It is essential for sustaining life on earth. Precipitation plays a key role in renewing our natural water resources. Precipitation is of different types (Fig 2.7).

Rain

In this type of precipitation, water falls down in the form of drops from the clouds in the sky. The water droplets are 0.5 mm or larger. Rain is important component of water cycle and replenishes major portion of freshwater on earth. When the droplets are smaller in size i.e. less than half a millimeter it is referred as drizzle. The rate of rainfall varies across various regions of globe. Rainfall has been categorized into three types

Light- when water drops fall at the rate of 0.01 to 0.1 inches per hour

Moderate – when water drops fall at the rate of 0.1 to .3 inches per hour

Heavy- water drops fall at the rate of more than 0.3 inches per hour.

Snow

In this type of precipitation, solid form of water i.e. snowflakes fall down on earth. Snow is formed when the atmospheric temperatures are above freezing. Snow has fluffy, white and soft structure. It is of different shapes such as flat plates and thin needles. The type of snow formation depends upon the humidity and temperature conditions. The process of snow precipitation is called snowfall.

Hail

It is a form of precipitation in which big balls and irregular lumps of ice (hailstones) fall on earth as a result of thunderstorms. It is a kind of solid precipitation. Hailstones are formed from super-cooled droplets of water and measure from 0.2 inches (5 millimeters) to 6 inches (15 centimeters) in diameter. Hailstones are noted in winter or cold weather.

Dew

It is a type of precipitation in which water droplets are formed on the objects near the ground through condensation of moisture. During clear nights, the

exposed surfaces are cooled by radiation (heat – delete) and the atmospheric moisture condenses resulting in the formation of water droplets.

Sleet (Ice Pellets)

It is a type of precipitation composed of small and semitransparent balls of ice. The formation of sleet takes place in freezing atmospheric conditions. Snow falls, comes in contact with warm air, melts into rain. Rain droplets fall into a freezing layer of air and convert raindrops into ice pellets. This form of precipitation is experienced during thunderstorms.

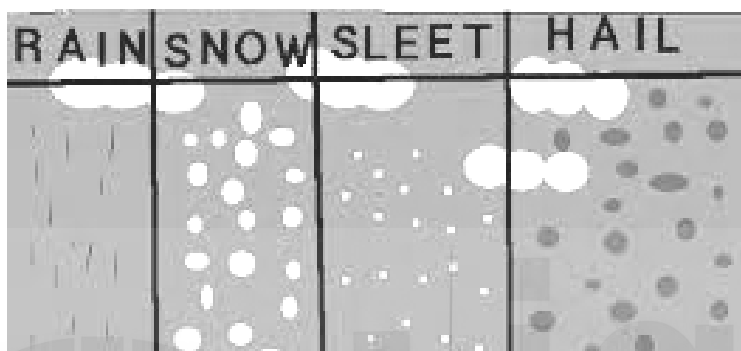


Fig. 2.7: Different types of precipitation.

2.3.3 Global Distribution of Water

Water is distributed across various regions of earth. Oceans cover roughly 70% of the area of the earth, they reflect blue light, and hence the earth appears blue from space. Therefore earth is also referred as blue planet. The total volume of water on Earth is estimated at 1.386 billion km³ (333 million cubic miles). Out of the total water available, only 3% of water is freshwater and remaining 97% is saline (Fig 2.8). Most (97%) of the water present on earth is saline. Average salinity is 35‰ (or 3.5%). This is equivalent to 34 grams of salts dissolved in 1 kg of seawater or 35,000 mg of salt ions dissolved per liter of seawater. Water with a salinity level between 0.35‰ and 1‰ is referred as marginal water. The ratio of salt water to fresh water on Earth is around 40 to 1.

Of the total freshwater, about 69% exists in the form of ice, snow, 30% as groundwater and less than 1% (about 0.3%) as liquid. This means that only one percent of the water is available for use by humans and rest (99%) is underground. Of the total liquid surface fresh water, 87% is contained in lakes, 11% in swamps, and 2% in rivers. Approximately 680,000 km² of freshwater is present in the form of glaciers and permanent snow/ice cover. These include water resource present as ice sheets in the Antarctic, Arctic and Greenland. This water is not accessible. Melting glaciers provide a natural source of river water and groundwater.

Fresh water is defined as water with a salinity less than 1 percent that of the oceans i.e. below around 0.35‰ (is called as freshwater. – delete). Rivers and lakes provide an excellent source of freshwater for human use. Surface waters include the lakes (as well as ponds), reservoirs, rivers and streams and wetlands. The flow of water into these water bodies comes from rainfall, runoff,

melting snow, ice and base-flow from groundwater systems. Surface waters account for small volume (0.3 percent) of the Earth's total freshwater resources. Lakes store the largest volume of fresh surface waters (90,000 km³). This accounts for forty times more water than the water found in rivers or streams. Lakes (They – delete) are estimated to cover a total area of about 2.7 million km². This represents around 2% of the land's surface (excluding polar regions). Mostly lakes are small but world's 145 largest lakes are estimated to contain over 95% of all lake freshwater. Lake Baikal (Russia) is the world's largest, deepest lake which contains 27 % of the freshwater contained in lakes. Lake waters provide many services such as fishing, recreation, transport and water supply for the world's population. The total volume of water stored in rivers and streams is estimated at about 2,120 km³. A large area of sub-surface, porous rock that holds water is an aquifer. Aquifers are commonly drilled and have wells installed in them to provide water for agriculture and personal use.

Wetlands are water-saturated environments and are commonly characterized as swamps, bogs, marshes, mires and lagoons. Wetlands cover an area about four times greater than the world's lakes. They contain only 10% of the water found in lakes and other surface waters. They cover total of about 6% of the Earth's land surface. Water is used mainly for irrigation (68%), public supply (21%), and industry (11%).

Water existing in the voids of the geological stratum below the surface of the earth is called groundwater. It is found enclosed in pores and fissures of rocks. Out of the total 13, 84,12,0000 cubic km of water existing on earth, about 8,00,0042 cubic km is groundwater. Groundwater comprises 95%, surface water 3.5% and soil moisture 1.5%. Out of all the fresh water on the earth, only 0.36% is readily available to use. Around 61,234 cubic km of water exists in the form of soil moisture. Groundwater and soil moisture together constitute the sub-surface water. Groundwater is 0.58% of the total water resources available in nature. It is located up to a depth of 4 km below the earth's surface. Most of the groundwater originates as meteoric water from precipitation in the form of rain or snow. Rain or snow melt infiltrates the ground and moves downward to form groundwater. Groundwater is stored in different layers of earth by infiltration through pores and fissures of permeable rocks. **It is present** in small spaces (**pore space**), between mineral grains and subsurface of rock or sediments. The main source of groundwater is rainfall. It infiltrates through seepage slowly into the earth and collects there. It is also called 'plutonic water'. Other sources of groundwater include seepage from surface water (lakes, rivers, reservoirs, and swamps), irrigation, and underground wastewater treatment systems (septic tanks). Morris et al. (2003) reported that groundwater systems provide 25 to 40% of the world's drinking water. Groundwater is an important part of the water cycle because surface and atmospheric water goes underground through rainfall, rivers and lakes.

Groundwater mainly comes from three sources.

(i) Meteoric Water

This is the main source of groundwater. This water is received in the form of rain and snow, hence it is called 'meteoric' or 'shooting star water'. Water infiltrates down through rock joints, pores, fissures of rocks and is stored in the form of groundwater. Groundwater can directly be derived from atmospheric moisture via condensation of water vapor from circulating air present in pore spaces. This is also known as 'condensational water'. It is the basic source of water in arid and semi-arid areas. The difference in the temperature between land and air during summers cause a difference of pressure between the water vapor in the atmosphere and the soil. This results in penetration of water vapor into soil. Seepage of water from lakes, rivers, oceans and also man-made channels adds to groundwater. This occurs mainly in the humid regions.

(ii) Connate Water

Water contained in pores and cavities of sedimentary rocks under seas and lakes is called connate water. It is also called 'sediment water'. It is the second important source of groundwater. This water is entrapped in the interstices of sedimentary and volcanic rocks at the time of deposition. This water is highly mineralized and salty.

(iii) Magmatic Water

Water that gets converted to vapors after condensation (of – delete) as a result of volcanic action at the time of entering hot rocks is called magmatic water. Hot magma enters rocks due to volcanic action after which its vapor drops are condensed and converted into water. This is called magmatic water. Springs, wells, and geysers are sources of such water. It is generated in the interior of the earth but consequently travels to the upper layers of the earth's surface.

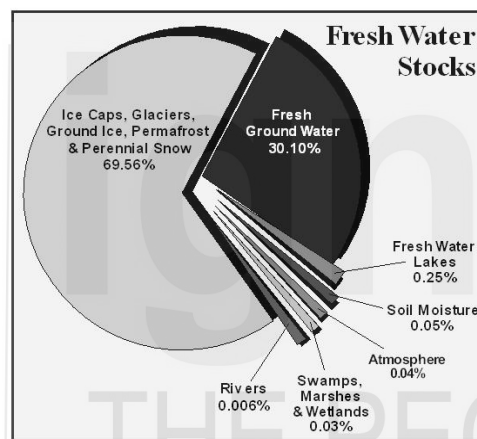
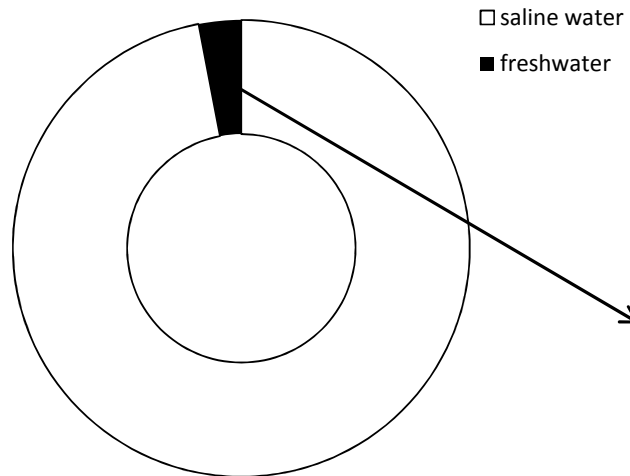


Fig 2.8: Global distribution of water.

SAQ 7

What is the proportion of fresh and saline water on earth?

SAQ 8

List the major sources of surface and ground water.

2.3.4 Properties of Water

A molecule of water consists of two atoms of hydrogen (H) joined to one oxygen (O) atom via covalent bonds. The two atoms i.e. H and O are bound to each other asymmetrically with two H atoms at the end and atom of O in the centre. Water is a polar solvent. A single molecule of water possesses two lone pairs of electrons on oxygen atom and two hydrogen atoms. Oxygen attracts electrons much more strongly than hydrogen, resulting in a net positive charge on the hydrogen atoms, and a net negative charge on the oxygen atom. The difference in electro negativity leads to dipole moment, making the oxygen partially negative and each hydrogen partially positive. These atomic charges give water molecule a net dipole moment (Fig 2.9).

Electrical attraction between water molecules due to dipole moment pulls the water molecules closer together, making it difficult to separate thereby raising the boiling point. The charge differences make the water molecules to attract each other (the relatively positive areas being attracted to the relatively negative areas) and other polar molecules. This attraction contributes to hydrogen bonding.

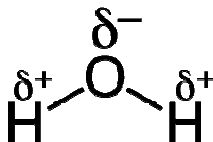
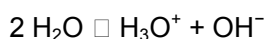


Fig. 2.9: Charges on the atoms in a water molecule.

Water dissociates or ionizes into a hydronium ion and hydroxide ion.



Hydrogen bonding is responsible for many physical properties of water.

Water is a solvent that dissolves many substances in comparison to any other liquid. It acts as a fluid that dissolves and transports molecules of nutrients and metabolites, helps in regulation of temperature and maintenance of the chemical equilibrium within the living cells.

Physical properties of water

1. **High boiling and melting point**

It possesses a high melting and boiling point. Strong bonding between oxygen and hydrogen atom occurs due to electron-negativity of oxygen and hence more energy is required to break the hydrogen bonds between water molecules.

2. **Specific heat**

Water molecules are linked to each other by hydrogen bonds. The bonding between water molecules (water – delete) leads to high specific heat. If water is to be heated, more energy is required to break hydrogen bonds between molecules. About 4.18 joules of energy is required to heat one gram of water by 1°C. The energy used for heating water by 1°C is called specific heat. Hence the specific heat of water is 4.1814 J (joule).

3. **Miscibility**

Water acts as a good solvent because of high polarity. Salts or substances mix well and dissolve in water. The substances that dissolve in water are called as hydrophilic (water-loving) substances, while those that do not mix well with water are known as hydrophobic (water-fearing) substances. Water is miscible with many liquids. It is capable of forming a single homogeneous layer of liquid. Water being a relatively polar compound tends to be miscible with liquids of high polarity such as ethanol and acetone.

When an ionic or polar compound enters water, it is surrounded by water molecules (hydration). The partially negative dipole ends of the water are attracted to positively charged components of the solute. Ionic and polar substances such as acids, alcohols, and salts are relatively soluble in water. Non-polar substances such as fats and oils do not dissolve in water. Non-polar molecules stay together in water because water molecules hydrogen bond to each other and form van der Waals interactions with non-polar molecules.

4. ***Enthalpy (latent heat)***

It is the amount of energy (is – delete) required to melt ice from -160°C up to its melting point or to heat the same amount of water by about 80°C . The specific enthalpy of fusion of water is 333.55 KJ/kg at 0°C .

5. ***Density***

The density of water is about 1 gram per cubic centimeter. The density varies with temperature. The density rises with increase in temperature followed by a decrease. Water molecules come close to each other at low temperature and hence density increases. Water is most dense at 4°C . At low temperatures, movement of water molecules ceases. The bonds between molecules become relatively fragile. Air molecules get trapped between moieties of water. This makes the ice lighter than water.

6. ***Vapor pressure***

The vapor pressure is the pressure at which water vapor (gaseous form of water) is in thermodynamic equilibrium with its condensed state. The temperature and pressure at which solid, liquid, and gaseous form of water coexist in equilibrium is called the triple point of water. This point is given in units of temperature i.e. kelvin, degree Celsius and Fahrenheit.

7. ***Electrical conductivity***

In pure form, water cannot conduct electricity and acts as an insulator. If water has a salt or solute dissolved in it, then it can conduct electricity.

8. ***Cohesion and adhesion***

Water molecules stay close to each other because of hydrogen bonds between water molecules. This property is called cohesion. Water also has high adhesion properties because of its polar nature. Water forms a thin film on extremely clean/smooth surfaces such as glass. This is because of stronger molecular forces between glass and water molecules (adhesive forces). The property of cohesion is responsible for the viscosity of water. It is the property of a material that measures the force necessary to separate the molecules and allow the object to pass through the liquid. In biological cells and organelles, water is in contact with membrane and protein surfaces which are hydrophilic.

9. Surface tension

Water has a high surface tension in comparison to other liquids. The cohesive forces between water molecules lead to high surface tension. Surface tension tends to straighten the surface causing a rise/pull up in water.

10. Capillary action

Water exhibits capillary action. This is a property where water rises into a narrow tube against the force of gravity. This occurs due to interplay of the forces of adhesion and surface tension. In this manner, water is carried through xylem up stem of plants. The strong intermolecular attractions (cohesion) hold the water column together and adhesive properties maintain the water attachment to the xylem and prevent rupture caused by transpiration pull.

Chemical properties**1. Geochemistry**

Water leads to weathering of rocks. The physical and chemical processes convert solid rocks and minerals into soil and sediment. Water (ice ??) can form clathrate compounds, known as clathrate hydrates, with a variety of small molecules that can be embedded in its spacious crystal lattice. For example, “in chemistry, water of crystallization or water of hydration are water molecules that are present inside crystals”.

2. Acidity

Pure water has the concentration of hydroxide ions (OH^-) equal to that of the hydronium (H_3O^+) or hydrogen (H^+) ions, which gives pH of 7 at 298 K. Water possess a capacity to absorb carbon dioxide from the atmosphere or water to form carbonic acid. This dissociates further to form hydrogen ion and bicarbonate ion. The dissociation of bicarbonate ion produces hydrogen ion. The abundance of hydrogen ions gives the measure of acidity. More is the number of hydrogen ions, more acidic is the solution.

3. Acid-base reactions

Water is amphoteric. It has the ability to act as either an acid or a base in chemical reactions. According to the Bronsted-Lowry definition, an acid is a proton (H^+) donor and a base is a proton acceptor. When reacting with a stronger acid, water acts as a base. Similarly when reacting with a stronger base, it acts as an acid. Oxygen present in the water molecule possesses two lone pairs of electrons, hence it acts as a Lewis base or electron pair donor. It forms hydrogen bonds between the donors and hydrogen atoms of water.

4. **Redox reactions**

Water contains hydrogen which has an oxidation state of 1 and oxygen which has an oxidation state of 2. It oxidizes chemicals such as hydrides, alkali metals, and some alkaline earth metals. It can be oxidized to emit oxygen gas.

5. **Electrolysis**

Water can be split into its constituent elements, hydrogen and oxygen, by passing an electric current through it. This process is called electrolysis.

SAQ 9

Water acts as a good solvent. How?

2.3.5 Water Cycle

The mechanism by which water moves (from – delete) through different components of environment (i.e. air, water and land) is called the water cycle. Solar energy and gravity drive the movement of water through different components of water cycle. The water present in the water bodies/reservoirs such as oceans, atmosphere, glaciers, groundwater, lakes and rivers gets heated up and escape into the atmosphere as vapor (gaseous form of water). This process is known as evaporation. Hence evaporation is an important component of the hydrological cycle (Fig 2.10). Water also returns to atmosphere via transpiration i.e. loss of water by plants. The changes in temperature condense vapors to form clouds. The water comes down on earth as precipitation which can be of different types such as rain, dew, snow or hail. The rainfall pattern is mainly related to wind circulation. Global precipitation pattern is also affected by ocean currents, mountains and continents. More precipitation falls near the equator, whereas less precipitation tends to fall near north and south latitudes. The processes of evaporation and transpiration (evapo-transpiration) regulate the water found in soil (i.e. soil moisture content). The water on land can either return to the oceans or other water bodies by surface runoff, rivers, glaciers, and subsurface groundwater flow. The water present in river, lakes, and aquifers is referred as 'blue water'. Water used by plants and subsequently released into the air is called as "green water".

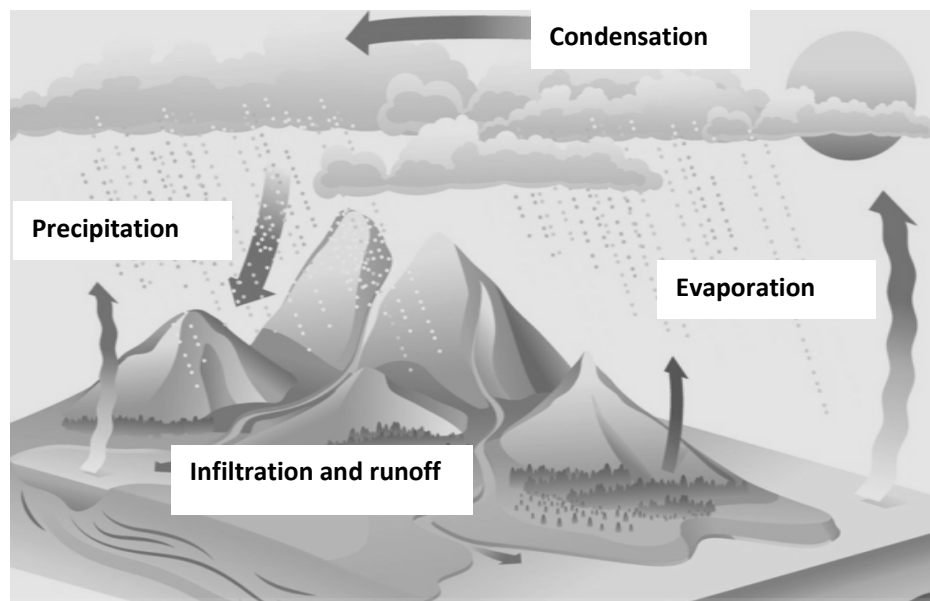


Fig. 2.10: Water cycle.

SAQ 10

Circulation of water on earth occurs in a cyclic way. Explain.

2.4 SUMMARY

- Soil is one of the important constituents of the environment. It is a complex system consisting of mineral matter derived from rocks, organic matter obtained from death and decay of plants and animals, air and water.
- Soil formation involves processes such as weathering and humification.
- Based on sites of origin, soil has been classified as residual and transported. Residual soils develop at site where parent rock material is present, transported soils develop when the parent rock material is carried to distant places. Depending upon the agent involved in their transport, soils are classified into different groups. colluvial (by gravity), glacial (by ice and snow), aeolian (by wind)
- Soil is made up of particles of various sizes, shapes mixed in different proportions. Based on the size of soil particles, they have been classified into different types such as clay, silt, sand, coarse and gravel.
- The proportion of clay, silt and sand particles decide the texture of the soil. The soil structure comprises of soil particles arranged in aggregates. Soil with high proportion of sand and gravel is called as light soil while that having high proportion of clay and silt is referred as heavy soil.

- Permeability and aeration are important soil properties that influence the availability of water and gases. Poor aerated soils affect root growth because of limited availability of nutrients and water.
- Cation exchange capacity (CEC) is an important soil property that helps in making the nutrients such as Ca, Mg, K, Na, Cu, Mn, Zn available to plants and organisms present in the soil. It is the total number of exchange sites on the soil colloids including humus and clay particles.
- Fauna and microorganisms present in the soil play a major role in making it fertile. Decomposition processes, production of growth substances, secretion of organic acids help in binding soil particles, formation of aggregates, aeration and build up of organic matter. They also help in nutrient cycling via nitrogen fixation.
- Water, as a solvent, is critically essential for the existence of living beings.
- It is a universal solvent that facilitates chemical reactions within the living organisms.
- Water is classified into two types: namely fresh water and saline (marine) water depending upon salt content present in it. Each form of water contains varying amounts of dissolved salt (K, Na, Mg) content.
- High dipole moment and strong hydrogen bonding in water molecule contributes to properties such as high boiling point, miscibility, specific heat, surface tension.
- Water is distributed in various components of environment via water cycle. Cycling of water depends upon the processes such as evaporation, condensation and precipitation.

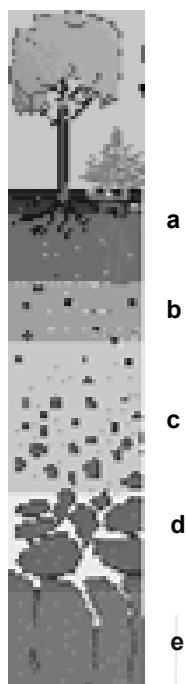
Suggested readings

Brady, N.C. 1990. The Nature and Properties of Soils. Macmillan Publishing Company, NY.

David E. Cloelman, D.A. Crossley, Jr. Paul F. Hendrix (2004) Fundamentals of Soil Ecology. Second edition, Elsevier Academic Press, USA.

2.5 TERMINAL QUESTIONS

1. Label the different layer of soil profile in the given figure.



2. What causes soil aggregates to form?
3. Differentiate between
 - a. Heavy and light soil
 - b. O and A horizon of soil
 - c. soil structure and texture
 - d. bulk density and permeability
 - e. alluvial and laterite soil
4. What is cation exchange capacity of soil? Discuss its importance.
5. Enlist the major roles of soil biota.
6. Lakes do not freeze when temperature drops below 0°C. Why?
7. What attributes make water a good solvent?
8. Explain the role of solar energy in water cycle.
9. Water acts as an excellent solvent for living beings. How?

2.6 ANSWERS

Self Assessment Questions

1. In soil, the composition and texture play an important role in deciding its function. Texture and organic matter content of soil determines its nutrient and water holding capacity, movement of air, water and permeability. These properties also depend upon the particle size. Example sand and silt particles are usually inert, more porous, granular

which facilitates aeration and water movement. They show high permeability. In contrast, clayey soils possess low permeability. Besides this the formation of soil aggregates also depends upon the soil structure and influences its functioning to a greater extent. The presence of organic content affects the ability to absorb/hold large quantities of water and holding the soil aggregates together.

2. The dead plants, animal, their remains and microbial waste products build up the organic matter after decay and decomposition. The organic compounds get converted into simpler forms. The elemental composition of organic matter includes carbon, oxygen, hydrogen, nitrogen, phosphorus, and sulfur. It plays an important role in absorption of water and also helps in holding the soil aggregates together. The negative charge on the organic matter of soil attracts, hold, and release cations necessary for plant growth.
3. The formation of soil depends upon various factors. These mainly include
 - Parent Material- This is the material from which the soil has developed. Various properties of soil such as color, texture, structure, mineral composition and permeability depends upon the parent material.
 - Climate- Climatic factors such as temperature influence the rate of chemical reactions occurring during soil formation. The biological processes show an enhancement at high temperature. This is because enzyme-catalyzed reactions are sensitive to high temperatures and attain a maximum between 30 and 35°C.
 - Biological Factors- The biological components of the soil include vegetation, microorganisms and associated fauna. Organisms such as microbes, earthworms, arthropods and burrowing animals influence the soil composition to a greater extent. These organisms add organic content to soil and help in soil aggregation. Growth of pioneer species such as grasses and alga also lead to build up organic matter in soil.
4. Cation exchange capacity (CEC) i.e. the capacity of soil particles to exchange cations. Clay and organic matter particles are predominantly negatively charged (anions). They attract cations (positively charged particles) to their surfaces. The bonds between the clay mineral surface and the cations are relatively weak, hence cations get exchanged for other cations dissolved in the solution. Nutrients free from cation exchange move into the soil solution from where, there are picked up by plant roots easily. The loosely held nutrients can then be taken up by plant roots or by other soil organisms. CEC is high in soils rich in clay and high organic content. Cations mainly include plant nutrients such as potassium (K), calcium (Ca), and magnesium (Mg). Hence this property plays an important role in retaining and supplying plant nutrients.

5. Living organisms present in soil play an important role in soil formation and development. They alter soil physical, chemical and biological properties in different ways.
- Decomposers such as bacteria, fungi and actinomycetes carry out decay and decomposition of organic matter. This leads to builds up of inorganic nutrients which be absorbed by plants.
 - The growth promoting substances released by heterotrophic organisms such as bacteria help in growth and establishment of soil organisms around roots of plants.
 - Bacteria such as *Azotobacter*, *Clostridium* help in capturing the atmospheric nitrogen and converting it into nitrogenous compounds such as nitrates which can be used by plants. Biological fixation of nitrogen by these microbes affects soil fertility.
 - Bacteria and blue green algae secrete mucilaginous substances which cover their cells and colonies. These substances act as effective materials for cementing the soil grains into larger aggregates.
6. 1) Soil formation involves two steps.
- Two processes involved in soil formation include
- Weathering of rocks - The breakdown of rocks into smaller particles by the action of physical (mechanical) or chemical forces. Changes in temperature lead to contraction or expansion of rocks leading to development of cracks and fissures in rocks which break rocks in smaller pieces. Low temperatures cause expansion due to freezing of water present in the rock crevices, breaking the rocks into small pieces. Hail, rainfall and wind also help in breaking of rocks due to friction. Activities of organisms present in soil also assist in weathering of rocks.
 - Mineralization and humification- The rock particles get converted into a homogenous matrix. The roots of the plants invade the soil particles further breaking the particles into fine material. Organic acids and humic acids produced by microbes assist in the breakdown of rocks to fine soil particles and add organic matter to soil. Microorganisms such as bacteria, fungi and actinomycetes assist in the decomposition process which converts the organic compounds into inorganic nutrients. The process of conversion of organic compounds into simpler products such as carbon dioxide, water and minerals is called as mineralization. Incompletely decomposed organic material left after mineralization forms the humus which is a dark, homogeneous, amorphous, colloidal substance. Humus gives loose texture to the soil for proper aeration and possess greater property for retaining water and nutrients.
- 2) Humus

Incompletely decomposed organic material left after mineralization forms the humus. It is a dark, homogeneous, amorphous, colloidal substance. Humus gives loose texture to the soil for proper aeration and possess greater property for retaining water and nutrients.

3) Permeability

The rate at which water moves down through the soil is referred as permeability. Pore size, texture, structure determines the permeability of a soil. The permeability differs for various layers of soil horizon. Soils with high clay content possess low permeability. The property is also dependent upon the pores between soil particles. This is because pores allow for the movement of air and water through the soil. A sandy loam has a permeability of 2.0 to 6.0 inches per hour, while sandy clay loam has a permeability of 0.2 to 0.6 inches per hour. Organic matter improves soil structure, improving permeability and infiltration. Fine-textured soils (soils with high clay content) contain more total pore space, hence water moves more slowly leading to lower permeability and infiltration.

7. Of the total water available on earth, only 3% is freshwater and remaining 97% is saline. This means that most of the water presents on the earth is saline in nature. Fresh water is defined as water with a salinity less than 1 percent that of the oceans i.e. below around 0.35‰ is called as freshwater. Rivers, lakes provide an excellent source of freshwater for human use. Out of the total freshwater (3%), about 69% exists in the form of ice, snow, 30% as groundwater and less than 1% (about 0.3%) as liquid. Most of the surface fresh water is contained in lakes (87%), swamps (11%) and rivers (2%). Only one percent of the water is available for use by humans, and rest i.e. 99% is underground. Water with an average salinity of 35‰ (or 3.5%) is called as saline water.
8. Majority of the freshwater on earth is present in the form of surface water in lakes, ponds, reservoirs, rivers, streams and wetlands. The flow into these surface water bodies comes from rainfall, runoff from melting snow and ice. Surface waters account for small volume (0.3 percent) of the Earth's total freshwater resources. Lakes store the largest volume of fresh surface water i.e. about 95%. They are estimated to cover a total area of about 2.7 million km². This represents around 2% of the land's surface (excluding polar regions). The total volume of water stored in rivers and streams is estimated at about 2,120 km³. Some amount of water is also present in aquifers.

Water existing in the voids of the geological stratum below the surface of the earth is called groundwater. It is found enclosed in pores and fissures of rocks. Groundwater comprises 95%, surface water 3.5% and soil moisture 1.5%. It is available in three forms

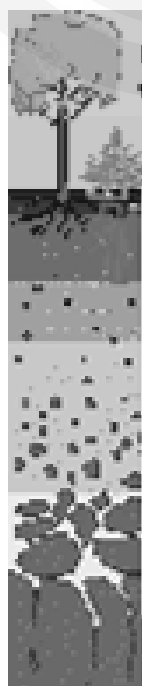
'Meteoric Water' is the main source of groundwater and is received in the form of rain and snow. This water infiltrates from the surface through fissures, pores and joints of rocks till it is stored on non-permeable rocks in the form of groundwater

Second: 'Connate Water', which exists in pores and cavities of sedimentary rocks of seas and lakes. It is also called sedimentary water.

'Magmatic Water' which converts into water after condensation of vapor as a result of volcanic action at the time of entering hot rocks.

9. The mechanism by which water moves from through different components of environment i.e. air, water and land is called water cycle. Solar energy and gravity drives the motion of water in the water cycle. The water present in the water bodies/reservoirs such as oceans, atmosphere, glaciers, groundwater, lakes, rivers gets heated up and escapes into the atmosphere as vapor (gaseous form of water). This process is known as evaporation. Hence evaporation is an important component of the hydrological cycle (Figure 2.9). Water also returns to atmosphere via transpiration i.e. loss of water by plants. The changes in temperature condense vapors to form clouds. The water comes down on earth as precipitation which can be of different types such as rain, dew, snow or hail. The rainfall pattern is mainly related to wind circulation. Global precipitation pattern is also affected by ocean currents, mountains and continents. More precipitation falls near the equator, whereas less precipitation tends to fall near north and south latitude. The processes of evaporation and transpiration (evapotranspiration) regulate the water found in soil (i.e. soil moisture content). The water on land can either return to the oceans or other water bodies by surface runoff, rivers, glaciers, and subsurface groundwater flow.

Terminal Questions



a – O (organic) horizon. it is the top layer dominated by organic material

b – A horizon The mineral soil horizon present below an O horizon is referred as topsoil.

c – E (elluvial) horizon – characterized by eluviation i.e. removal of materials such as silicate clay, iron, aluminum, or organic matter

d – b horizon – the zone is dominated by loss of most or all of the original rock structure and shows illuviation

e – C horizon – It is the layer of soil excluding hard bedrock.

2. Biological factors help bind soil particles together

- Bacterial exudates
- Root activity and exudates (sugars that act as glue)
- Fungal hyphae
- Macrofauna (especially earthworm) activity and waste

Soils high in sand and silt do not form aggregates well. Some types of clay soils form stable aggregates. Climatic factors such as temperature, precipitation affect soil aggregate formation. Action of freezing and thawing increases the likelihood of particles sticking together.

3.

a. Heavy and light soil

Soil with high proportion of sand and gravel is called as light soil while that having high proportion of clay and silt is referred as heavy soil.

b. O and A horizon of soil

Top layer dominated by organic material is designated as O. It includes layer of litter and humus. This horizon is not present in cultivated soils, manicured lawns, and severely eroded soils.

The mineral soil horizon present below horizon O is zone A. It is referred as topsoil. It contains a mixture of organic and mineral components. This layer supports plants and microbial growth. It is formed when organic matter gets transformed by soil biota into humic materials. The humic materials coat the soil particles, coloring them brown and black. The formation of a recognizable horizon A takes long as decades.

c. soil structure and texture

This property of soil is based on the size of the particles. A soil texture is the percentage of sand, silt and clay. Soil texture varies according to percentages of sand, silt, and clay. Soil texture is important in determining the nutrient holding, water holding, water movement and movement of soil air.

It is the arrangement of soil particles in aggregates and pore spaces around them. It is defined in terms of grade, class and type of aggregates. Class- It describes the average size of individual aggregates. Classes have been divided into types such as very fine (thin), medium, coarse (thick) and very coarse (very thick).

d. bulk density and permeability

Bulk density is the weight of a given volume of oven-dried soil divided by the volume i.e. mass of soil per unit volume of soil. It is expressed as weight per volume and generally represented as grams per cubic centimeters (g/cc). High bulk density indicates compacted soils that restrict root growth. It reflects the amount of pore space in the soil and is an indicator of soil health.

The rate at which water moves down through the soil is referred as permeability. It is usually measured in inches per hour. Pore size, texture, structure determines the permeability of a soil. Rate or coefficient of permeability is determined by measuring rate of flow of water through a column of soil. The permeability differs for various layers of soil horizon. Permeability and infiltration is affected by texture of soil, organic content and compaction. Soils that are high in clay content possess low permeability, while sandy soils have a higher permeability.

e. alluvial and laterite soil

Alluvial soil – soil which is deposited near rivers, seas and glaciers is called as alluvial soil. Indo-Ganga Brahmaputra Plains, Coastal Plains and the broad river valleys of South India.

Laterite soil- is a kind of clayey rock or soil formed under high temperature and high rainfall. Found mainly in South Maharashtra, the Western Ghats in Kerala and Karnataka, at places on the Eastern Ghats, in some parts of Assam, Tamil Nadu, Karnataka

4. It is the amount of cations present in exchangeable form in a soil sample. It depends upon the net charge of soil particles. Clay and organic matter particles are predominantly negatively charged (anions). They attract cations (positively charged particles) to their surfaces. The bonds between the clay mineral particles and cations are relatively weak, hence cations get exchanged for other cations dissolved in the solution. This process is called “cation exchange”. The greater the clay and organic content of soil, greater is the CEC. By this process the nutrients ions like potassium, calcium, and magnesium held up by soil particles are taken up by plant roots. This property also helps in removing contaminants from soil.
5. Living organisms present in soil play an important role in soil formation and development. They alter soil physical, chemical and biological properties in different ways. Living organisms present in soil play an important role in soil formation and development. They alter soil physical, chemical and biological properties in different ways.
 - i) Decomposers such as bacteria, fungi and actinomycetes carry out decay and decomposition of organic matter. This leads to builds up of inorganic nutrients which be absorbed by plants.
 - ii) Larger soil organisms help in mechanical mixing and weathering of soil. Rodents, insects and worms turnover great amounts of soil exposing the soil to various physical and chemical agents of weathering. These organisms not only help in mixing of soil but also make it fertile by increasing aeration and drainage.
 - iii) The growth promoting substances released by heterotrophic organisms such as bacteria help in growth and establishment of soil organisms around roots of plants.

- iv) Bacteria such as *Azotobacter*, *Clostridium* help in capturing the atmospheric nitrogen and converting it into nitrogenous compounds such as nitrates which can be used by plants. Biological fixation of nitrogen by these microbes affects soil fertility.
- v) Bacteria and blue green algae secrete mucilaginous substances which cover their cells and colonies. These substances act as effective materials for cementing the soil grains into larger aggregates.

The functional services provided by them include

- development of soil structure and soil aggregation.
 - release of inorganic nutrients via decomposition and mineralization
 - build up of organic content via decomposition and mineralization
 - mechanical mixing, weathering of soil and aeration.
 - facilitate gaseous exchange i.e. diffusion of oxygen and release of carbon dioxide
6. Water has a high density at 4°C. At low temperature water expands. It becomes lighter both above and below this temperature. This unique property prevents its freezing.
 7. Properties such as high polarity, capacity for hydrogen bonding, capacity to dissolve ions, miscibility make it an ideal solvent.
 8. In water cycle, solar energy is the driving force that leads to heating up of water from water bodies leading to evaporation. The water vapors then move into atmosphere, condense to form clouds and then cooled to precipitate as rain or snow. The water returns to ground via precipitation or run off. The whole cycle of water flow from land to atmosphere is driven by energy obtained from sun.
 9. Water molecules are closely bound to each other by hydrogen bonding. They stick to the surface because of the adhesive property. Water acts as a good solvent which contains dissolved and suspended molecules distributed evenly throughout the medium. Hence it acts a good transport medium in living organisms.

Plant and microbial polysaccharide act as gum and serve as binding material. Organic compounds and biological agents such as roots and fungal hyphae play an important role in --- structure of soil. Organic matter consists of living or dead biomass (roots, leaves of plants and microbes). Physical processes such as deformation and compaction by plant roots and soil fauna, freezing-thawing, wetting-drying have significant effect on soil structure. Plant roots and humus plays a role in formation of aggregates. Bacteria, fungi and their metabolic products play role in promoting granulation in soil.

Organic matter and mineral composition have profound effect on cation absorption capacity. Interchange of cations in solution with that on surface is important for soil fertility. The capacity of soils to adsorb ions (CEC) is due to exchange sites on organic matter and soil particles.

Unit 3

ECOLOGICAL FACTORS: LIGHT AND TEMPERATURE

Structure

3.1	Introduction	3.3	Temperature
	Expected Learning Outcomes		Latitudinal and Altitudinal Variations
3.2	Light		Global Temperature Distribution (Isotherms)
	Electromagnetic Spectrum		Shelford's Law of Tolerance
	Solar Energy Input	3.4	Summary
	Periodic Variation (Seasonal and Diurnal)	3.5	Terminal Questions
	Light and Distribution (Optimal and Limiting Factors)	3.6	Answers

3.1 INTRODUCTION

Abiotic factors such as light, temperature, wind, water, air, and soil play an important role in sustaining living organisms in an ecosystem. In the previous Unit, abiotic components namely soil and water have been introduced to you. The present Unit discusses the role of two other important abiotic components, light and temperature. These two factors play an important role in establishment, survival and development of biotic communities. The study of this Unit will provide you information about solar radiation reaching earth, its electromagnetic spectrum and effect of variations in light on growth and distribution of biotic communities. The amount of light energy reaching the earth regulates the surface temperature thus influencing the growth, development and distribution of various biotic communities. All living organisms get adapted to a particular temperature in which they survive and reproduce. They also tolerate fluctuations in temperature by developing certain specialized structural and physiological features called as adaptations.

Expected Learning Outcomes

After reading this unit, you will be able to :

- ❖ describe various components of light and its electromagnetic spectrum,
- ❖ outline the properties of solar radiation and its effects on living organisms,
- ❖ describe the impact of light variations on development of biotic communities,
- ❖ effect of light on growth and distribution of living organisms,
- ❖ explain the effect of changes in light at various latitudes and altitudes, and
- ❖ variation in the distribution of biotic communities under the influence of temperature.

3.2 LIGHT

Sun is the ultimate source of energy for living beings present in the biosphere. The electromagnetic radiations from the sun supply energy and warm up the earth. Light regulates the various essential activities in living organisms including plants and animals. The radiation coming from sun provides a favorable global temperature for the survival of living beings. Light plays an important role in essential processes such as photosynthesis in plants. It is a process by which plants convert the light energy from sun into usable chemical energy. Variations in availability of light affect the distribution of biotic communities to a greater extent.

3.2.1 The Electromagnetic Spectrum

The radiation emitted from sun travels through space and reaches earth. Electromagnetic spectrum of sun consists of (different – delete) rays of different wavelengths ranging from gamma rays, X rays, ultra violet, visible, infrared, and radiowaves. Ultraviolet (UV), gamma and x-rays have shortest wavelengths, while microwaves and radio waves have longer wavelengths. Electromagnetic radiation has a dual nature i.e. both particle and wave. Solar radiation is a form of energy. It is present in the form of packets of energy called photons. The photons of each wavelength have different quanta of energy. The amount of energy depends upon wavelength or frequency. It is expressed as

$$E = h \nu$$

E – energy of wave (joule/sec)

h – Planck's proportionality constant. Value is 1.6×10^{-34} cal/sec

ν – frequency of wave (hertz cycles/sec)

Frequency is inversely proportional to wavelength and expressed as

$$\nu = c/\lambda$$

c – Velocity of light (3×10^8 m/sec)

λ – Wavelength (cm/m)

The part of light which is seen by our eyes is the visible spectrum. The visible light covers the wavelength with range of 0.4 to 0.7 μm . We perceive colors from the visible portion of the spectrum. Blue, green, and red are the primary colors of the visible spectrum. Each color of the visible spectrum has a particular wavelength (Fig 3.1). The longest wavelength in visible spectrum is red and shortest is violet. The radiations ranging from 300 to 900 nm affect the photobiological processes in living organisms.

Infrared (IR) region of spectrum covers the wavelength ranging from approximately 0.7 μm to 100 μm . The infrared region can be divided into two categories based on their properties - the reflected IR, and the emitted or thermal IR. The reflected IR region is used for remote sensing. It is similar to radiation in the visible portion. The reflected IR covers wavelengths within the range of 0.7 μm to 3.0 μm . The thermal IR region represents the part of the radiation emitted from the Earth surface in the form of heat. The thermal IR covers wavelengths in the range of 3.0 μm to 100 μm .

Table 3.1: Wavelength range of various colors in the visible spectrum.

Color	Wavelength (μm)
Violet	0.4 - 0.446 μm
Blue	0.446 - 0.500 μm
Green	0.500 - 0.578 μm
Yellow	0.578 - 0.592 μm
Orange	0.592 - 0.620 μm
Red	0.620 - 0.7 μm

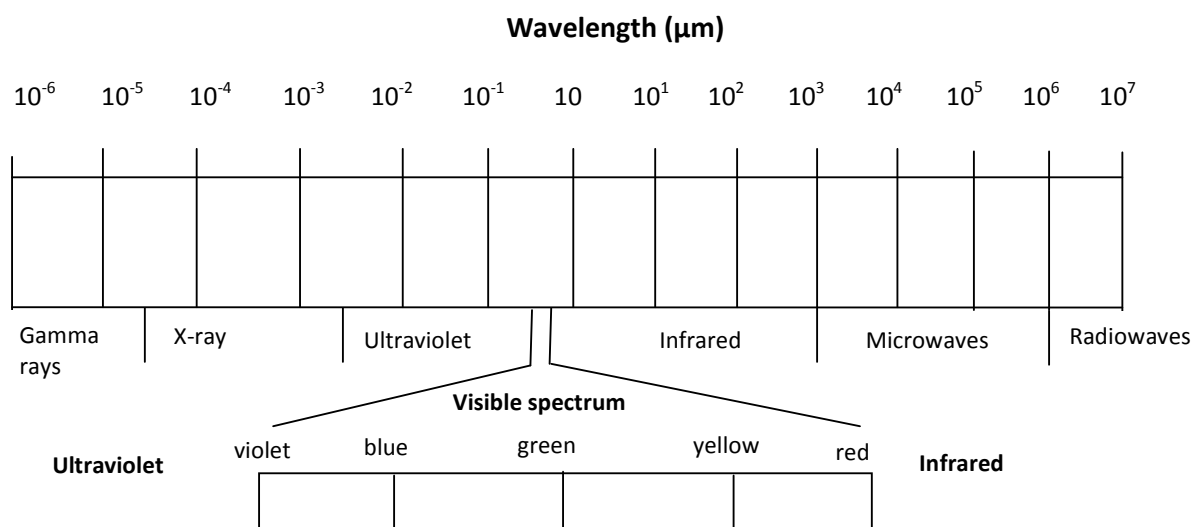


Fig. 3.1: Electromagnetic spectrum.

SAQ 1

Calculate the energy for quantum of radiation of wavelength 500 nm in joules and ergs.

SAQ 2

Answer in one word

- Solar energy is present in the form of packets of energy.
 - The part of light which is seen by our eyes.
 - Wavelength of visible part of spectrum.
 - The longest wavelength in visible spectrum.
 - The shortest wavelength in visible spectrum.
-

3.2.2 Solar Energy Input

The incoming solar radiation is known as insolation. It is received in the form of short waves which are of electromagnetic nature. These short-wave or ultraviolet rays are absorbed partly by the atmosphere. On reaching the earth surface they get reflected back and get converted into long-wave radiation. Earth's surface receives this radiant energy at the rate of two calories per square centimeter per minute. The solar radiation (energy) reaches the earth surface. Approximately 5.6×10^{27} cal/min of energy is radiated by sun, of which around half of 1 billionth is intercepted by earth. The amount of incoming solar radiation absorbed by atmosphere has a constant value and is referred as solar constant. It is the rate at which solar radiation falls on the surface of earth when earth is at mean distance from sun. The rays are perpendicular to the solar beam. On an average the value of solar constant is $2 \text{ cal/cm}^2/\text{min}$.

The radiation has been categorized as short wave or long wave. Visible light and ultraviolet radiation are commonly called short wave radiation, while infrared radiation is referred to as long wave radiation. The short wave radiation is the radiation which comes from sun and strikes the earth surface. The Sun radiates energy mainly in the form of visible light with small amounts of ultraviolet and infrared radiation. Hence, solar radiation is considered shortwave radiation. Some of the short wave radiation that reaches earth surface gets reflected back. This is referred as albedo. It differs for different surfaces.

Albedo = reflected radiation/incident radiation $\times 100$

A surface covered by ice or snow have high albedo (0.8-0.9 i.e. 80-90% of the incoming radiation gets reflected back). In contrast, a forest has a low albedo because around 0.05 i.e. 5% of the radiation gets reflected back. The global average albedo is around 0.30 (i.e. 30% reflectance).

Some of the energy absorbed by the earth's surface is emitted back into space as long wave radiation. The amount of energy emitted depends upon the temperature of the surface. Hotter is the surface, more is the energy emitted. Long wave radiation emitted by the earth's surface is absorbed by water vapor and carbon dioxide in the atmosphere. The absorbed radiation keeps the surface temperature warm as the gases present in the atmosphere do not allow radiation to reflect back. The process is called greenhouse effect. The difference between incoming short wave (solar) radiation and outgoing long wave (terrestrial) radiation i.e. net radiation determines the surface temperature. If the amount of incoming shortwave radiation is more than the amount of outgoing long wave radiation, surface temperature increases. Inversely, surface temperature decreases if amount of long wave radiation is more than the incoming short wave radiation. The amount of incoming short wave radiation intercepted (received) by earth and amount of long wave radiation emitted by earth surface balances and the average surface temperature of earth remains approximately 15°C. The amount of radiation absorbed is continuously reradiated from earth as heat in the form of infra red radiation and released in space. The amount of radiation which is transmitted back regulates the surface temperature of earth. The spectral distribution of radiation gets altered in the region of clouds, water and vegetation. Ultraviolet radiation gets absorbed by ozone layer present in the atmosphere, while visible light gets absorbed in the atmosphere.

Heat Budget

The earth receives a certain amount of insolation (terrestrial radiation) and reflects back some amount into space. This process of absorption and reflection maintains a constant temperature and heat budget on earth. We assume that total heat received by earth is around 100 units. Roughly, 35 units are reflected back into space before reaching the earth's surface, 27 units are reflected by clouds, 2 units by ice/snow and 6 units by the atmospheric layer itself. The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth's surface. Out of the 51 units radiated reaching the earth in the form of terrestrial radiation, 17 units are reflected back to the space directly and the remaining 34 units are absorbed by the atmosphere. The total of 48 units of radiation absorbed by the atmosphere (14 units from insolation + 34 units from terrestrial radiation) is released back into space. Thus, the total radiation returning from the earth and the atmosphere respectively is $17+48=65$ units which balances the total of 65 units received from the sun. This is termed as heat budget or heat balance of the earth.

Solar radiation travelling through the atmosphere gets scattered, dispersed or absorbed. In terms of percentage, about 30% of the radiation gets reflected by clouds, scattered and lost in space. Around 19% is absorbed by gases such as oxygen, ozone and water, ice crystals and suspended particles (Fig 3.2). The remaining 51% reaching the earth surface is either absorbed or reflected

by earth surface. The absorbed radiation gets converted into heat energy and causes warming. Thus in total 70% (19% by atmosphere and 51% by earth) of the radiation is involved in the functioning of the biosphere.

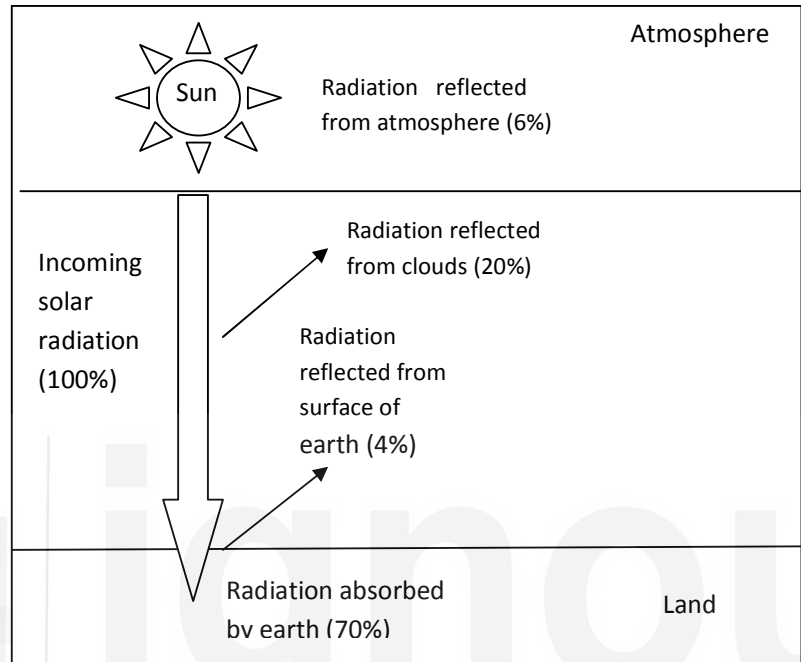


Fig. 3.2: Percentage of incoming radiation from Sun that is reflected and absorbed by the surface of the earth, atmosphere and clouds.

SAQ 3

Explain in brief the heat budget of earth.

Factors Affecting Distribution of Insolation

The amount of radiation absorbed or reflected depends upon several factors including angle of incidence of radiation, topography of the region and color of the land surface (and – delete). Smooth, rough, water and ice covered surfaces reflect different proportions of radiation. Rough surfaces have low albedo than smooth surfaces. Light colored surfaces reflect more radiation than dark surfaces. Some factors that regulate the amount of insolation reaching the earth's surface per unit have been listed below.

1. The Angle of Incidence or the Inclination of the Sun's Rays:

The angle of incidence or the angle which the sun's rays make with the earth's surface determines the amount of solar radiation received by earth. Reflectivity depends upon the angle of incident radiation. A smaller angle means that some amount of radiation will be received and will serve a larger area on the earth. The intensity will be less concentrated. The surfaces that are less perpendicular to the sun rays reflect more radiation than surfaces which are at right angles with the incoming radiation. A larger angle means the sun's rays will be nearly vertical over the place and the amount will serve a smaller area.

As a result, the radiation received will be more concentrated and the intensity will be greater. At 45° latitude, the amount of radiation received is only 75%. The amount of radiation received at equator is more. Arctic/Antarctic regions and poles receive only 40-50% of the radiation respectively.

2. Duration of Sunshine

The amount of solar radiation received by earth depends on duration of time for which the sun shines over a particular place. At the equator, duration of sunshine is 12 hours throughout the year, hence the amount of radiation received is more compared to the other places on the earth. At winter solstice i.e. 22 December, the southern hemisphere receives more sunshine because of summer there, while at summer solstice i.e. 21 June, the northern hemisphere receives more sunshine as it is summer time there. Solstice is the time when sun reaches its highest position in the sky as seen from the North or South Pole.

3. Transparency of Atmosphere

The amount of cloud cover and its thickness, dust and water vapor also determine the rate of absorption, reflection and transmission of solar radiation. **When** the wavelength of the radiation is more than the radius of the obstructing particle (such as a gas), then scattering of radiation takes place. In contrast if the wavelength is less than the obstructing particle (such as a dust particle), then reflection takes place. Absorption of solar radiation takes place if the obstructing particles happen to be water vapor, ozone molecules, carbon dioxide molecules or clouds.

4. Land-Sea Differential

The temperature of the air resting over a landmass differs markedly from that resting over a water body present at the same latitude. Reflection of radiation is more by land than by sea. Average penetration of insolation is more in water (up to 20 m) than in land (up to 1 m) only. The specific heat of water is 2.5 times higher than landmass, therefore water takes longer to get heated up and cool down. This is the reason why land cools more rapidly than water. Moreover, water currents, tides and drifts exist only in oceans which carry the heat to lower layers. This delays the process of heating and cooling. Snow covered areas reflect up to 70-90% of insolation.

5. Prevailing Winds

The oceanic winds have the moderating influence on the sea and coastal areas. These areas have cool summers and mild winters. The effect is pronounced only on the windward or the outer side. The leeward side or the interior side do not get the moderating effect of the sea, and hence experience extremes of temperature.

6. Slope

The direction and angle of slope control the amount of solar radiation received. Slopes more exposed to the sun receive more solar radiation. This type of response has been noted in the Himalayan region.

7. Ocean currents

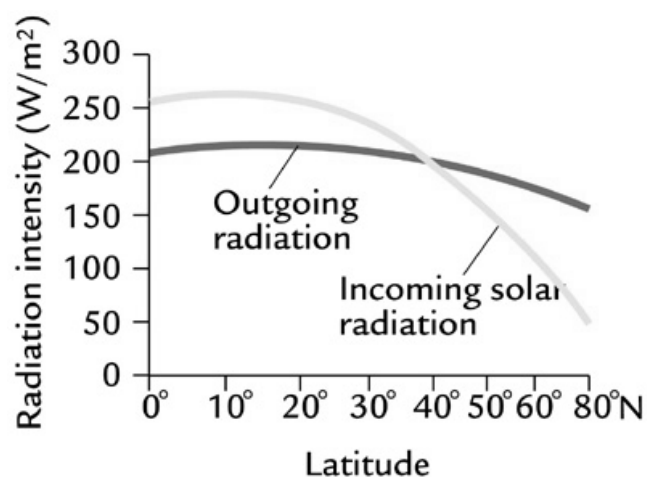
Ocean currents influence the temperature of adjacent land areas considerably. Warm currents raise the temperatures of the coastal areas, whereas cold currents lower them. At higher latitudes, the eastern coasts have lower temperatures due to the influence of cold currents. Westerly winds produce the moderating effects on land surfaces. The influence of the ocean currents is most pronounced in the tropics.

8. Altitude

The amount of insulation received varies from latitude to latitude. Altitude has a direct effect on surface temperatures. Lower layers of the atmosphere are compressed under atmospheric pressure. Earth being closer to sun's surface becomes warmer. At higher altitudes the temperature gradually decreases and the air becomes cooler. These variations are noted in different seasons and different locations on earth. For example the two cities in Ecuador namely Quito and Guayaquil, though close to each other have mean annual temperatures of 13.3°C and 25.5°C respectively. The difference occurs due to altitude. Guayaquil is 12 meters above sea level, while Quito is higher in the Andes Mountains at 2,800 meters.

9. Latitude

There is variation in the distribution of radiation according to change in latitudes. Decrease in radiation from equator towards the poles is noted on a global scale. Radiation strikes lower latitudes directly. At latitudes below 40° , more solar radiation is received by earth and less is lost. At higher latitudes, the incident radiation of low intensity falls obliquely on the surface, travels through the atmosphere and spreads through a greater area. The radiation also penetrates deeper into the atmosphere. More heat is lost than received. The vertical beam falling on or near the equator is more intense (Fig 3.3, 3.4). This is the main reason for decline in mean annual temperature from equator towards the poles. The atmosphere and oceans act as giant thermal engines that transfer heat from the tropics towards the poles. Winds and ocean currents help in the transportation of heat energy from lower to higher latitudes. Thus, transfer of heat energy from the lower latitudes to the higher latitudes maintains an overall balance over the earth's surface.



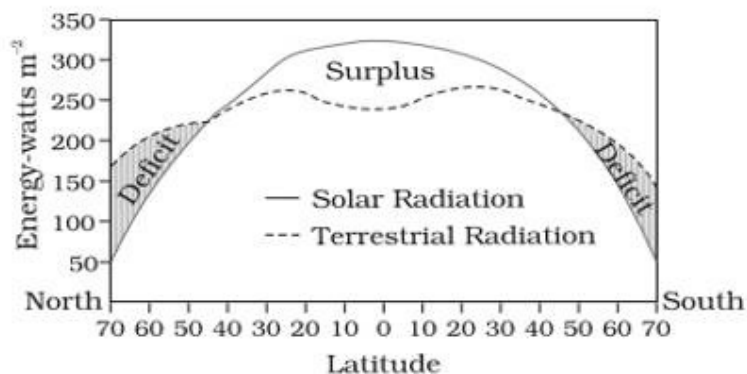


Fig. 3.3: Radiation as regulated by changes in latitude.

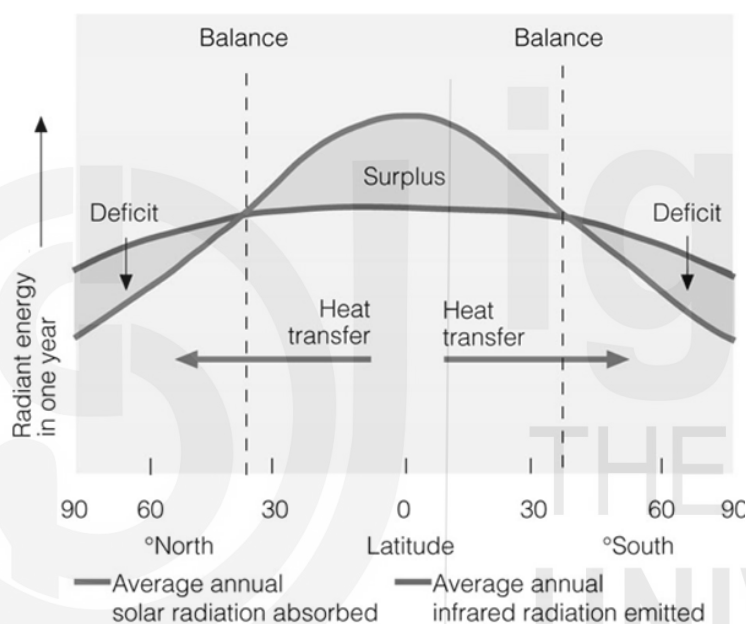


Fig. 3.4: Heat transfer and heat balance across the latitudes.

3.2.3 Periodic Variation (Seasonal and Diurnal)

The rotation of earth leads to variation in the amount of radiation reaching the earth. The seasonal changes are seen due to movement of earth around the sun. Earth travels around sun in an elliptical plane. Earth rotates about an axis tilted to an angle of 23.5° that passes through North and South poles giving brightness of day followed by darkness at night (diurnal cycle). The sun rays do not fall vertically on all parts of the earth due to inclination at an angle of 23° . During its rotation it moves between 23.5° N and 23.5° S latitudes. At the vernal equinox i.e. March 21 and autumnal equinox i.e. September 22, the sun is directly overhead at the equator. At this point of time, equator region receives highest amount of shortwave radiation. Every place on earth receives 12 hours of each day and night.

In summer, solar rays fall directly on Tropic of Cancer (23.5° N) in Northern hemisphere leading to highest input of solar radiation and longer days. At the same time. Southern hemisphere experiences winter. In winter. solar rays fall

directly on Tropic of Capricorn (23.5°S) in Southern hemisphere leading to highest input of solar radiation and longer days leading to less input of solar radiation and hence shorter days (Fig 3.5).

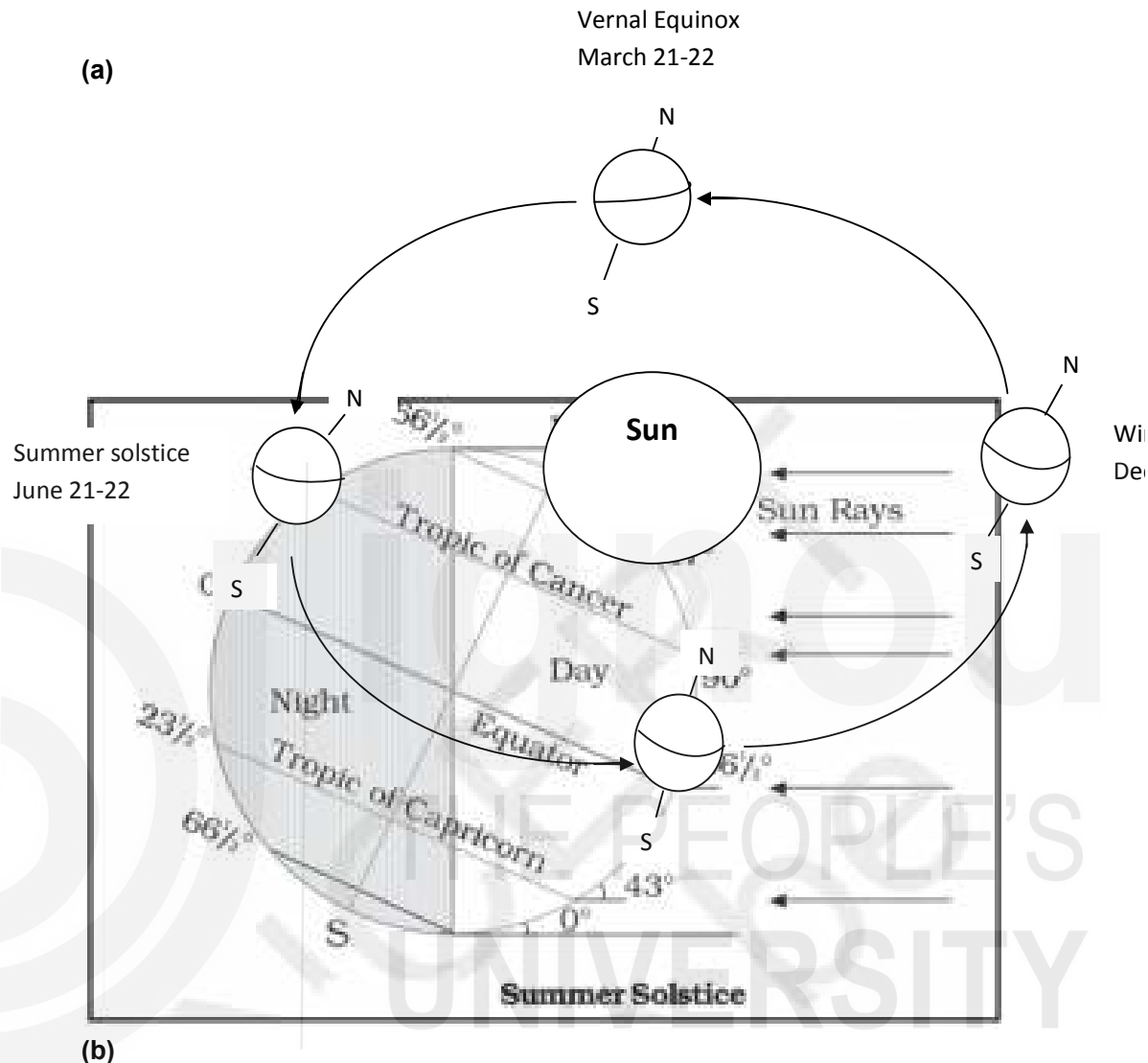


Fig. 3.5: Solstice across (a) various times of year and b) various latitudes.

SAQ 4

The amount of solar radiation reaching earth changes over period of time. Explain.

3.2.4 Light and Distribution

The variation in light affects the global distribution of living organisms. Intensity i.e. amount of light per unit area over a particular time, quality i.e. wavelength composition and duration or the photoperiod play a crucial role in origin and development of plant and animal species.

Light influences distribution of terrestrial species. The composition of plant species vary according to availability of light. This is because light plays a critical role in development of plants. Plants absorb radiation particularly the red and blue regions of the spectrum.

Variation in light in the terrestrial ecosystems results due to changes in the interception of light by vegetation. In forests, canopy of trees receive maximum radiation. Herbs and shrubs receive the light filtered after use by tree canopy. Hence in a forest light is efficiently utilized, though it is only 1% of the incident solar radiation.

Plants also show preferences for utilization of light. Some plants prefer growing in bright light while others grow in shady areas. The plants have been classified as sciophytes (shade loving) and heliophytes (light loving). Some heliophytes that can grow in shade are termed as facultative sciophytes. Similarly sciophytes that can grow in bright light are termed as facultative heliophytes.

Plants harness light energy for photosynthesis. The intensity of light at which energy is harnessed via photosynthesis is sufficient to meet the energy requirement of respiration is called as light compensation point. Under shade conditions, plants do not have much energy to carry on photosynthesis. The canopy of the tree functions above the compensation point. In aquatic systems, vertical stratification of light intensity occurs with increasing depth. The spectral quality of light changes, due to differences in light penetration, in water. Generally less than 1% of the sunlight can penetrate up to a depth of 30 m in water. The light penetration also gets reduced when suspended materials such as silt, clay, planktons are present in water. Clear and pure water absorb light at a rapid rate and cause profound changes in its spectral distribution. Red and blue wavelengths are mostly filtered out and greenish light penetrates at a greater depth. Light compensation point reaches at a certain depth called compensation depth. The zones above and below this depth are referred as photic and aphotic zones. A lake is usually divided into three zones depending upon the intensity of light received. The littoral zone includes areas where light penetrates. In this zone aquatic plants grow. The profundal zone includes deep areas where light penetrates and is used for photosynthesis by plants. This area lies below the compensation depth. The limnetic zone lies above the profundal zone. It extends outward from the littoral zone. Plantktons are predominantly present in this area (Fig 3.6).

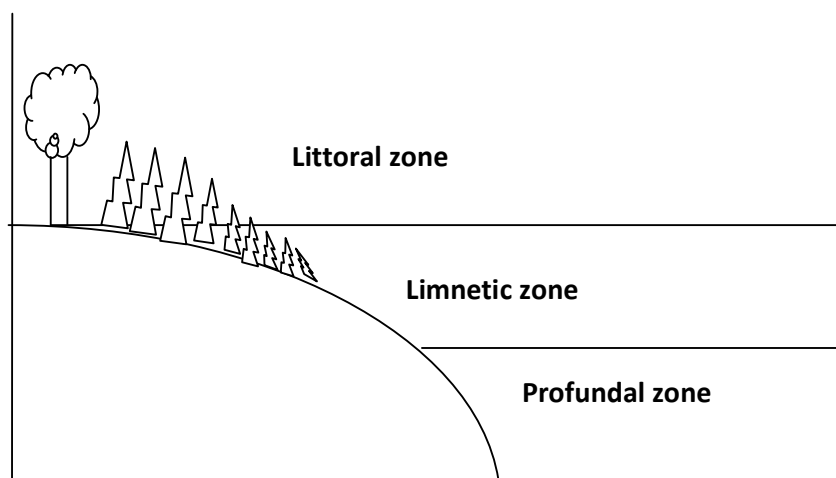


Fig. 3.6: Zones in a freshwater lake.

Plants

Various activities of living organisms are regulated by light. Breeding, migration in animals and flowering, seed germination in plants are controlled by length of the day i.e. period of light and darkness. This behavioral phenomenon is called photoperiodism. Some plants such as radish, potatoes, spinach require light for more than 12 hours per day to induce flowering. These are called as long day plants. In contrast plants such as tobacco, dahlia requires light of less than 12h for blooming. These are called as short day plants. The orientation and movement of plants and animals is affected by light. In plants the phenomenon is called as phototropism.

Photoperiodism plays an important role in life of organisms and also affects their distribution to a significant extent. These responses are diurnal, lunar or annual. Biological rhythms are controlled by light. Reproduction and migration in birds are annual photoperiodic responses. Photoperiodic responses are also noted in animals. Light is necessary for the activation of gonads (sex organs) which carry the essential reproductive processes in many animals. Example- In salmon, light accelerates the development of larvae. In contrast in other animals like *Mytilus* the development is retarded in presence of light. The direction of movement of insects is also regulated by light. Birds use sunlight as a means for orientation and migration. Protective coloration/mimicry is affected by light. Productivity of aquatic organisms is also influenced by light. Photosynthesis gets affected by light and brings changes in populations of plankton, nekton, cephalopods and decapods.

SAQ 5

How are short day plants different from long day plants?

3.3 TEMPERATURE

Temperature is another important abiotic factor crucial for existence of living organisms. It regulates various essential activities such as growth and reproduction. Temperature shows variation from region to region depending upon the topography, latitude and longitude. Temperature varies according to geography of the region. Temperature gradients depend upon the presence of barriers such as mountain ranges and ocean currents.

3.3.1 Latitudinal and Altitudinal Variations

Variations in temperature on earth occur from changes in incoming solar radiation and distribution of land and water masses. Physical factors such as movement of wind, water, direction of slopes of hills and mountains also bring alteration in temperature. The length of day varies with latitudes. The rate of incoming solar radiation varies from region to region. On an average every point on earth gets the same hours of sunlight i.e. 12 hrs/day but the rate of heat received varies. This depends upon the amount of radiant energy delivered unit area/hr and angle of incident light. The vertical beam of radiation is more intense than the oblique beam. The amount of incident radiant energy/unit area increases along the latitudes. At lower altitudes, the rate of warming by absorption of solar radiation is greater than rate of cooling of outgoing infra red radiations. The reverse is true for higher latitudes i.e. rate of cooling is more than rate of absorption. At 28°N and 33°S rate of cooling and warming are equal. The poles receive only 40% of radiant energy of that received by equator. The places located at the same latitude show differences in temperature. This happens because of movement of hot, cold air currents and water masses present in the region. Example cities of Calcutta and Nagpur are located at the same latitude but temperature in Calcutta is regulated by sea present in the proximity. Land and water absorb heat differently and this produces contrast in temperature within the same latitude. The temperature at these places shows diurnal and seasonal variations. Three distinct heat zones have been distinguished in each hemisphere based on the temperature variation. These include hot Torrid zone found near the equator, Moderate or temperate zone located in the middle and Cold zone located at the poles. Each temperature zone comprises of a particular vegetation and animal species.

Altitudinal variations

Temperature decreases with increasing altitude. This is mainly due to changes in the convection in the troposphere (the lowermost layer of the atmosphere). The air present on the earth surface gets heated up by solar radiation. Convection currents transport air from lower to higher region and vice versa. When air from sea level rises to upper atmosphere it expands and increases in volume. During expansion of gases, the molecules push aside the neighboring molecules, losing their kinetic energy leading to decrease in temperature. Condition of temperature in which no change of heat takes place between system and surrounding is termed as adiabatic change.

Various regions of the earth surface possess temperature ranges with an annual mean temperature. Continental land masses have broad temperature ranges. The southern hemisphere has less temperature variation than northern hemisphere. This is because southern hemisphere has more masses of water.

3.2.2 Global Temperature Distribution

Temperature differs from one part of the world to the other. The amount of insolation received determines the temperature of the earth. Thus **latitude, altitude, distance from sea, surface features and landscape** are some important factors that affect the distribution of temperature.

Insolation is highest at **the** equator, hence temperature is high near the equator. Altitude is the second major control of temperature of a place. The temperature depends upon albedo of the surface. *It* is the measure of diffusive reflection of solar radiation out of the total solar radiation received by a body,

Another major factor affecting the distribution of the temperature on earth is existence of land and oceans. There is more land in Northern Hemisphere and more water in the Southern hemisphere. *(hence there is – delete) There is therefore a difference between the specific heat of land and water. Thus,* continents get heated faster and *(get cooled – delete) also cool* faster in comparison to the oceans. **The loss of heat from the continents is fast as compared to oceans.** **The** highest and lowest temperatures are observed in the interiors of the continents due to difference in the specific heat. The moderating effect on temperature of the land due to proximity of the seas is called **Maritime influence**. The increasing effect on temperature of the land at interior of the continents is called **Continental Influence**.

Temperature variation occurs both horizontally and vertically.

- A) Horizontal Distribution of Temperature
- B) Vertical Distribution of Temperature

Distribution of temperature across the latitudes over the surface of the earth is called its horizontal distribution. The global distribution of temperature can be represented with the help of isotherms. Isotherms basically represent horizontal distribution of temperature. These are the imaginary lines joining places having equal temperatures. They *run parallel to the latitudes*. The spacing of isotherms indicates the latitudinal thermal gradient i.e. steepness or slow gradual nature of temperature change. Close spacing indicates a rapid change in the temperature and wide spacing means slow change. Same amount of insolation is received by all the points located on the same latitude, hence the isotherms show close correspondence. Temperatures above the oceans and land masses vary even at the same latitude because of differential heating of land and water.

The difference between the mean temperature of a place and the mean temperature of its parallel (latitude) is called the temperature anomaly or thermal anomaly. The temperature variation along latitude varies on account of altitude, land-water contrasts, prevailing winds and ocean currents. The

largest anomalies occur in the northern hemisphere and the smallest in the southern hemisphere. The anomaly is said to be negative when the temperature at a place is less than the expected temperature of the latitude. Conversely, the anomaly is positive when the temperature at a place is more than the expected temperature of the latitude. For the year as a whole, the anomalies are negative over the continents from about 40° latitude towards the poles and positive towards the equator. Over the oceans, the anomalies are positive pole-ward from about 40° latitude and negative towards the equator.

The highest temperatures occur over tropics and sub-tropics. These areas receive the highest amount of insolation. The temperature gradient is closely spaced over middle and higher latitudes. Isotherms are irregular over the northern hemisphere due to an enhanced land-sea contrast. Because of more land over water, the northern hemisphere is warmer. The belt of high temperature widens over the continents. Mountains also affect the horizontal distribution of temperature. Isothermal maps for January and July indicate changing patterns of global temperature with reference to the apparent movement of the sun, distribution of land and water, ocean currents and prevailing winds. Due to the difference between the specific heat between water and land, the temperature over the landmass is high in summer and low in winter in comparison to sea at any latitude. The vertical distribution of temperature on earth is also unequal.

Horizontal distribution of temperature

It is influenced by several factors. These include winds, nature of the soil, slope, topography, relief features, etc.

Latitude

The angle of incidence of sun's rays goes on decreasing from the equator towards the poles. Higher the angle of incidence, higher is the temperature. Similarly, lower the angle of incidence, lower is the temperature. This is why the temperature is higher near the tropical regions and lower towards the poles.

Altitude

The temperature in the troposphere goes on decreasing with increase in height. Temperature decreases at an average rate of nearly 6°C degree per 1000 m altitude. This is known as normal lapse rate.

Land and sea contrast

There is a great contrast between land and water surfaces because of differences in the rate of heating of land surfaces. Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly. Because of this, temperature is relatively higher on land during day time and it is higher in water during the night. The places situated near the sea come under the moderating influence of the sea and land breezes which moderates the temperature. There are also seasonal variations in the temperature of land and sea. During summer, the air above land has a higher

temperature than the oceans. But the air above oceans gets higher temperature than landmass in winter.

A snow-covered land (polar areas) warms very slowly because of a large amount of reflection of solar energy. A vegetation covered land does not get heated excessively because great amount of insolation is used in evaporating water from the plants. The presence of warm ocean currents (Gulf Stream and North Atlantic Drift) makes the Northern Atlantic Ocean warmer. Isotherms bend towards the poles. The temperature decreases sharply and the isotherms bend towards the equator in land areas. The effect of the oceans is well pronounced in the southern hemisphere (due to few landmasses). In the northern hemisphere, land masses are cooler than the oceans. As the air gets warmer over the oceans than the landmasses in the northern hemisphere, isotherms bend towards the north (poles) when they cross the oceans and to the south (equator) over the continents. Here, the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere. During summer in the northern hemisphere, isotherms bend towards the equator while crossing oceans, towards the poles while crossing landmasses. Isotherms are wide spaced over oceans while they are closely spaced over landmasses

Ocean Currents

Warm currents make the coasts warmer, while cold currents reduce the temperature of the coasts. The North-Western European Coasts do not freeze in winter due to the effect of North Atlantic Drift (a warm current), while (the – delete) Quebec on the coast of Canada is frozen due to the Cold Labrador Current flowing along it. Quebec is situated in lower latitudes than the North-West European Coast.

Air Currents

Air mass also affects the temperature. The places which come under the influence of warm air mass experience high temperature, while the places that come under the influence of cold air mass experience low temperature.

Vegetation Cover

Soil devoid of vegetation cover receives more heat. Vegetation cover absorbs much of sun's heat and prevents radiation reflect back in the atmosphere. Hence the temperature variations in densely forested areas are lower than those in desert areas.

Vertical Distribution of Temperature

Temperature in the troposphere decreases with increase in the altitude. Lapse rate is uniform at a given level at all latitudes within the troposphere. In the lower stratosphere, the lapse rate remains constant for some height, while higher temperatures exist over the poles because this layer is closer to earth at the poles.

Long winter night, clear sky, dry air and absence of winds leads to quick radiation of heat from the earth's surface, as well as from the lower layers of the atmosphere. This results in the cooling of the air near the earth's surface.

The upper layers which lose their heat not so quickly are comparatively warm. During winters the mountain slopes cool very rapidly due to the quick radiation of heat. The air resting above them becomes cold and its density increases. Hence, it moves down the slopes and settles down in the valleys. This air pushes the warmer air of valleys upwards and leads to the phenomenon of inversion of temperature. High slopes remain comparatively warmer. Movement of heavy and dense cold air towards the valley slopes is termed as air drainage.

The earth can **generally be** divided into three broad temperature zones viz. Torrid zone, Temperate zone and Frigid zone (Fig 3.7).

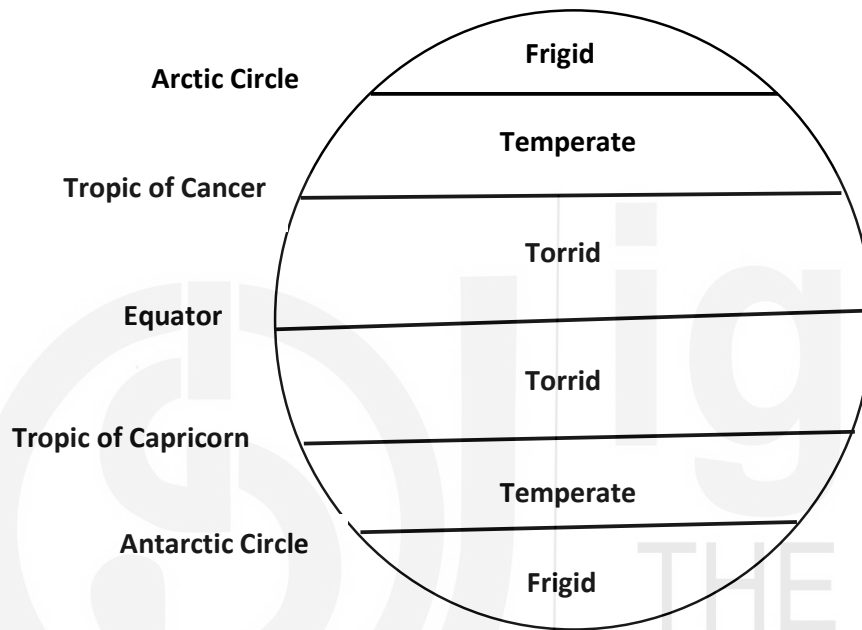


Fig. 3.7: Various temperature zones of the earth.

Torrid Zone

Torrid Zone is the tropical region. **It exists on both sides of the Equator. It extends to the Tropic of Cancer in the north and the Tropic of Capricorn in the south.** The temperature remains high. This is because sun is directly overhead during some time of the year. In the Northern Hemisphere, the overhead sun moves north from the equator until it reaches 23.5 °North (Tropic of Cancer) for the June solstice. This zone forms the hottest region of the world. This zone includes most of Africa, southern Asia, Indonesia, New Guinea, northern Australia, southern Mexico, Central America and northern South America.

Temperate Zones

Temperate zones are the mid latitudinal areas. The temperature is moderate. There are two temperate areas viz. North and South. The **sun is never directly overhead. The** climate ranges from warm to cool. The region experiences four seasons **namely spring, summer, autumn and winter.** The North Temperate zone includes Great Britain, Europe, northern Asia, North

America, northern Mexico, while South Temperate zone includes southern Australia, New Zealand, southern South America and South Africa.

Frigid Zones

The frigid zones or the polar regions, experience the midnight sun and the polar night for part of the year. The day is one year long, with six months of day and six months of night. These regions are the coldest regions of the earth. They are covered with ice and snow.

Adiabatic Heating and Cooling

Adiabatic change refers to the change in temperature with pressure. On descent through atmosphere, the lower layers of the air are compressed under atmospheric pressure. As a result, they are dry and warm. The air expands as pressure decreases. This expansion reduces the temperature and releases the latent heat of condensation in the process. When air rises upwards and cools the region it is known as adiabatic cooling. This happens as a result of the expansion of air when lifted upwards. When the air descends, it gets warmed and this is called adiabatic warming.

Distribution of temperature over the period of time or seasons

During January, it is winter in the northern hemisphere and summer in the southern hemisphere. Isotherms over the northern continents show that landmasses are overcooled and polar cold winds are able to penetrate southwards. In contrast, isotherms over the northern oceans show a poleward shift indicating that oceans are warmer and are able to carry high temperatures polewards. Isotherms bend towards south while moving from sea to land. The western margins of continents are warmer than their eastern counterparts. Westerly winds carry high temperature into the landmasses. Lowest temperatures are recorded over northern Siberia and Greenland. The high temperature belt runs in the southern hemisphere around 30°S latitude. The temperature gradient is close to the eastern margins of continents. For instance, along the east coast of Asia and North America, the temperature changes at the rate of 1.5°C per degree latitude, while along the western margins it changes at the rate of 0.5°C per degree latitude. Isotherms exhibit a more regular behavior in the southern hemisphere (Fig 3.8)

During July, isothermal behavior is the opposite of what it is in January. It is summer in the northern hemisphere and winter in the southern hemisphere. Over the northern continents, a poleward bend of the isotherms indicates that the landmasses are overheated and the hot tropical winds are able to go far into the northern interiors. Isotherms over the northern oceans show shift towards equator indicating that the oceans are cooler and are able to carry the moderating effect into tropical interiors. The lowest temperatures are experienced over Greenland. The highest temperature belt runs through northern Africa, west Asia, north-west India and arid southeastern USA. The temperature gradient is irregular and follows a zigzag path over the northern hemisphere. The gradient becomes regular over the southern hemisphere but shows a slight bend towards the equator at the edges of continents. Thermal equator now lies to the north of the geographical equator (Fig. 3.9).

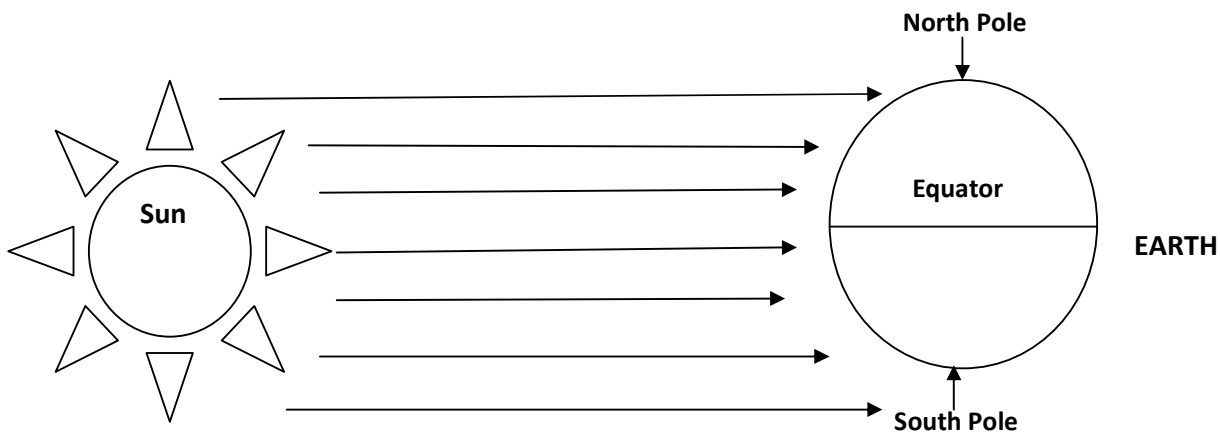
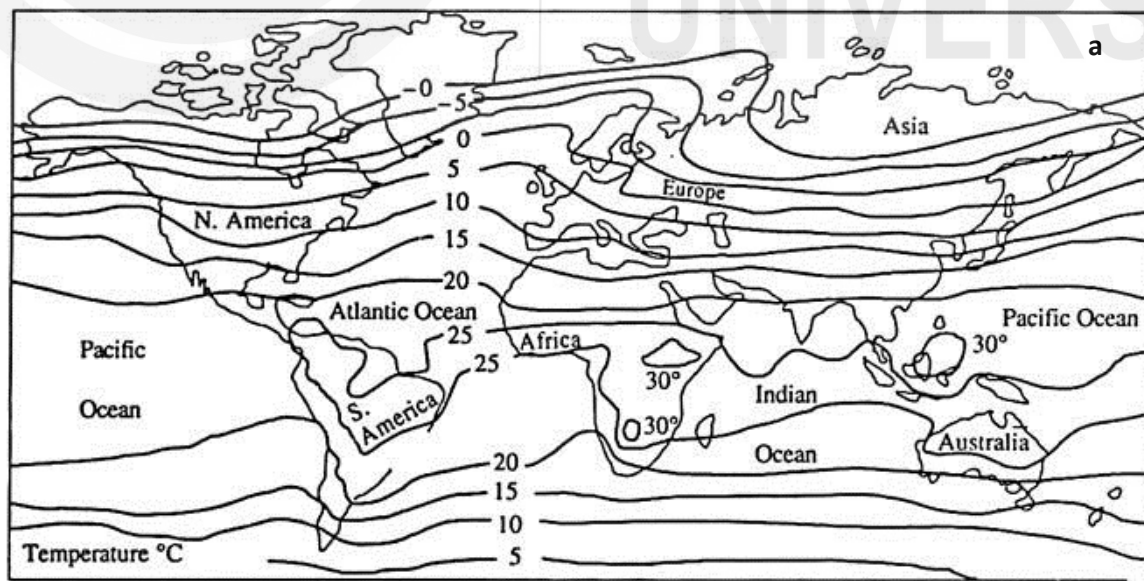


Fig.3.8: Distribution of sun's heat rays across the earth.

Mean thermal equator

Thermal equator is a global isotherm having the highest mean annual temperature at each longitude around the globe. The *highest temperatures are recorded in the Tropics* but the *highest mean annual temperatures are recorded at equator*. The thermal equator shifts towards north and south with shift in the position of vertical rays of the sun. The mean annual temperature shifts (*towards – delete*) northwards during the summer solstice to a much greater extent than towards south at the time of winter solstice (Fig 3.9). During winter season, the angle of incidence of the sun's rays is low in tropics. The average annual temperature of the tropical regions is therefore lower than the observed near the equator.

Earth due to its rotation reaches perihelion (the minimum distance from the Sun in its orbit) in early January and is at aphelion (maximum distance) in early July.



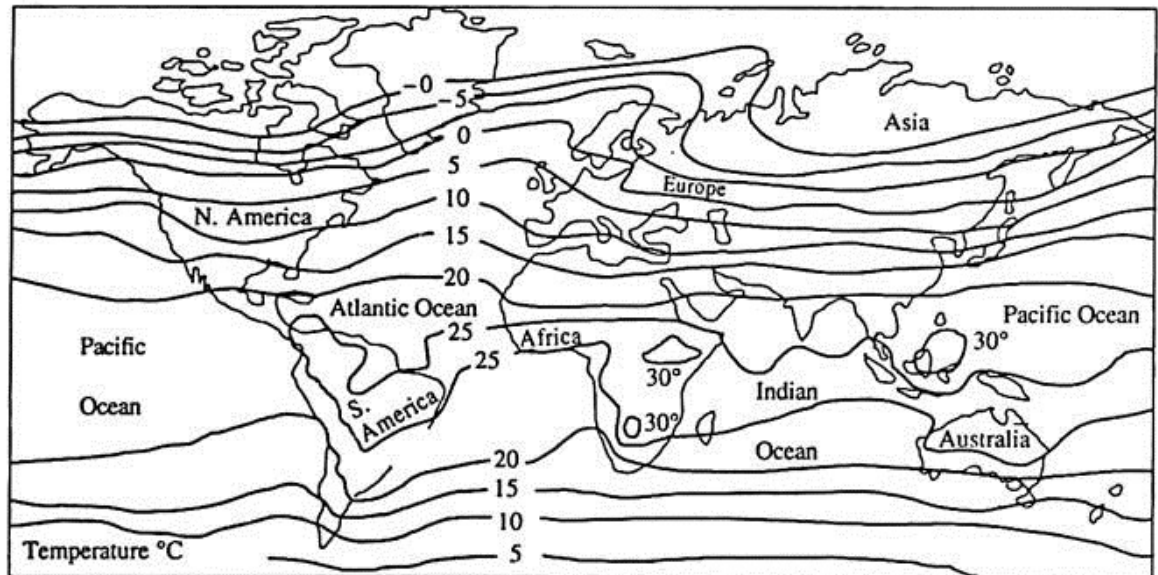


Fig. 3.9: Isotherms showing horizontal distribution of temperature during (a) January (b) July.

Temperature inversion

The temperature in the lower layers of air increases with elevation. This happens commonly along a slope (surface – delete). The surface radiates heat back to space rapidly and cools down at a faster rate than the upper layers. As a result the lower cold layers get condensed and become heavy. The surface underneath makes them move towards the bottom where the cold layer settles down as a zone of low temperature while the upper layers are relatively warmer. This condition, opposite to normal vertical distribution of temperature, is known as temperature inversion. This phenomenon is specially observed in the inter-montane valleys. The phenomenon in which temperature increases with increasing altitude temporarily and locally under certain conditions is known as inversion of temperature.

In the mountain areas, temperature of the air **increases with increasing altitude**. There is no obstruction in the receipt of insolation in the day. Air is thin and hence there is great loss of insolation in the night. During night, radiation from the upper exposed slopes of the mountains causes the surface and air over it to cool rapidly. The cooler air is denser and gets drained by the valley slopes and displaces the warmer air toward up. There is an inversion of the temperature. A high temperature range is noted in the interior areas of continents than at seas. This is because the sea heats and cools slowly but the land heats and cools rapidly.

Temperature is **low in clouded areas** because the clouds obstruct the receipt and loss of insolation. In desert areas, insolation is received without obstruction in the day and lost without obstruction in the night. Ice or snow absorbs less and reflects the insolation more. Hence, the daily temperature range is low in snow bound areas. The prevailing winds also have a greater effect on the annual temperature range. The variation in the annual temperature range in west and east European countries is due to land and sea winds. Winds from the land blow in Arabian countries (and therefore – delete)

increase the annual range of temperature. Winds from the oceans and seas blow into Western Europe and reduce the annual temperature range. Warm and cool winds also disturb the temperature range. Temperature inversion takes place only under certain specific conditions. These include

1. Long nights, so that the outgoing radiation is greater than the incoming radiation.
2. Clear skies, which allow unobstructed escape of radiation.
3. Calm and stable air, so that there is no vertical mixing at lower levels.

Equator

The duration of the day or night is the same in equatorial countries. The sun's rays are vertical all through the year. There is no difference between the summer and winter seasons.

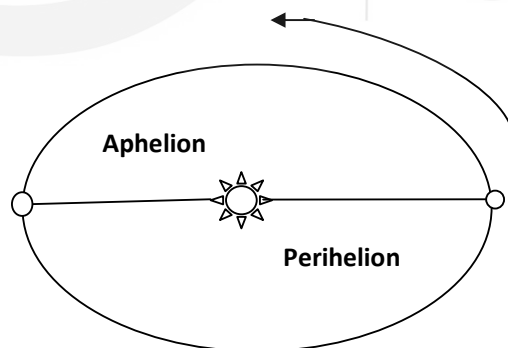
Poles

The duration of the day and the inclination of the sun rays go on increasing towards the poles. This causes a difference between the temperatures of the two seasons. Hence, towards the poles, the annual temperature range goes on increasing.

Oceans

The equalizing effect of sea water makes the winter less cold and the summer less hot. This reduces the annual range of temperature near the seas. The ocean currents near the coasts also affected the temperature range. The shift of ocean currents changes the weather and seasons. They also increase the annual temperature range on coasts.

The countries situated far into the interior of the continent have a high annual range of temperature. Due to the warm Gulf Stream, the winter of Western Europe is less cold.



Distribution of living organisms

Changes in temperature influence the geographical distribution of living organisms. Every organism requires a particular temperature for its survival and growth. The temperature requirement varies for each species. The lower minimum, upper lethal (harmful) and optimum temperature are called as cardinal temperatures. These vary for each species. Temperature is one of

the most important ecological factors with profound effect on essential activities of living organisms. It regulates many physiological processes such as metabolism, growth and reproduction. An optimum temperature is required for all the essential metabolic events in living organisms. This is because temperature primarily affects the stability and activities of enzymes involved in various biochemical reactions occurring in cells. Some organisms have narrow limit of tolerance to high/low temperatures (stenothermal) while others have a wide range of tolerance capacity (eurythermal). The characteristics of biotic communities are determined by temperature. Different types of biomes develop throughout the globe in response to changing climatic conditions (temperature variations). The temperature varies with latitude and longitude, therefore, vegetation and fauna (animal species) all differ from region to region.

Environments such as fresh water, marine water and land are subjected to fluctuations in temperature (Fig 3.10). Temperature fluctuations are less common in aquatic environment as compared to terrestrial environments. Changes in temperature lead to formation of strata. The uppermost layer is called epilimnion. Here the temperature can rise up to 37°C during summer. The stagnant water at the bottom is called hypolimnion. Its temperature is about 5°C. Between two layers is the zone of thermocline or metalimnion. It is characterized by rapid fluctuations in temperature.

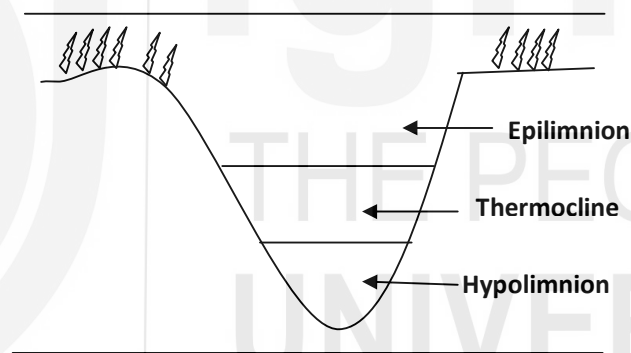


Fig. 3.10: Different zones in a water body (such as lake).

SAQ 6

Changes in temperature lead to formation of strata in water bodies. Explain.

Plants

Both extremely low and high temperatures have adverse effects on plant growth. Low temperature leads to formation of ice crystals in the intercellular spaces causing severe injuries to tissues. Extremely high temperature cause adverse effects on a number of vital physiological processes like respiration, transpiration, protein metabolism etc. These effects cause stunting and finally death of plants. This is called as heat injury.

Plants differ considerably in temperature tolerance. There is little metabolic activity at temperature below 0°C or higher than 40°C. Arctic and alpine plants

carry on photosynthesis at temperature below freezing point. Most of the seed plants become inactive or get killed after 55°C. Few species of blue-green algae can grow in hot springs between 55-70°C. Certain species of yeast can tolerate temperature of 114°C in dormant conditions. Bacteria can tolerate temperatures between 120-130°C. Few fungi species can withstand temperature up to 89°C. Hence temperature is one of the factors that limit the geographical distribution of plants. Based on the temperature requirement, plants have been classified into different categories.

Megatherms – The plants that live in high temperature throughout the year. These plants are found in equatorial and tropical rain- forests.

Mesotherm – The plants that live at high temperature of summer, alternating with low temperature of winter. They are found in deciduous forest of tropical and subtropical regions.

Microtherm – The plants that live in extremely low temperature. These include plants of temperate and high altitudes (up to 12000 feet of tropical and subtropical region). These regions are dominated by mixed coniferous forest.

Hekiskotherm – It includes plants of Arctic and Alpine regions (above 16000 feet in tropics and 12000 feet in temperate). Alpine vegetation prevails in such locality.

Temperature and moisture determine distribution of vegetation. Different belts of vegetation occur between the equator and the poles. Vegetation is primarily determined by heat. Plants which grow in a hot climate cannot grow in a cold climate and vice versa. The same crops cannot be cultivated in all regions of the world. Different crops are cultivated in different regions of the world. This is due to difference in their temperature requirement for growth. The mechanism by which temperature influences the distribution of species and vegetation has been studied by modeling population growth. Impact of temperature on various stages in the life cycle of plants has been established. An analysis suggests that heat during the growing season (measured as day degrees) controls the distribution of vegetation (Fig 3.11). For perennial vegetation both the heat during the growing season and absolute minimum temperature are critical. The northern latitudinal and upper altitudinal limits of lowland and southern vegetation are directly controlled by climate. In contrast, the southern and lower altitudinal limits of upland and northern vegetation are controlled by temperature-sensitive competition with southern or lowland species. Many of the temperature-sensitive processes of plant growth and development, such as the non-linearity of extension growth and variations in the threshold temperatures of processes, may increase the realized heat sum at a particular geographical location.

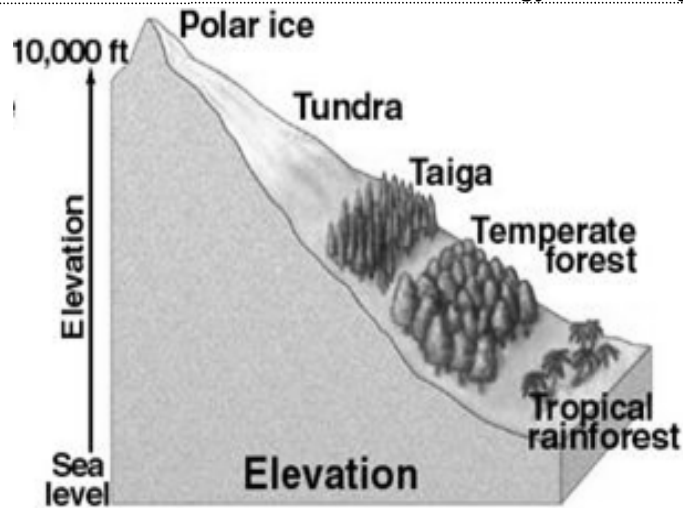


Fig. 3.11: Type of vegetation present at various altitudes.

SAQ 7

What are mega and mesotherms?

Plant processes

Temperature affects the rate of many physiological processes in plants. These include transpiration, photosynthesis, respiration and seed germination.

Transpiration – Rise in temperature increases transpiration rate. High temperature influences the saturation deficit of the atmosphere. It decreases the humidity of air. Thus more water is transpired. High rate of transpiration is linked to high rate of water absorption from soil.

Photosynthesis – Photosynthesis is one of the physiological processes regulated by temperature. The optimum temperature for photosynthesis for most of the plants is 25 to 35°C. Photosynthesis stops at 40°C in temperate plants and at 50°C in tropical plants. In some desert plants photosynthesis continues even at 80°C, while algae require lower temperature range for photosynthesis.

Respiration – The rate of respiration increases with the rise of temperature. It is maximum at optimum temperature but decreases at high temperature.

Germination of seed – Temperature also affects the germination of seeds. Every seed needs an optimal temperature for growing.

Spreading of diseases – Temperature and humidity affects the spreading of plant diseases. Low temperature along with high humidity favors the attack of pests and spread of fungal infections.

Animals

Animals also respond to changes in temperature. An optimum temperature is required to carry out essential metabolic activities in animals. Based on temperature requirements animals have been classified as

Poikilothermic or ectothermic: Also known as cold blooded animals. In these animals, the body temperature changes with the environment. These include invertebrates, fish and amphibians. They cannot regulate body temperature by physiological means.

Homothermic or endothermic: (animals- delete) Also known as warm blooded animals. Their body temperature does not depend upon the environmental temperature. These include birds and mammals. They regulate body temperature by producing heat.

Heterothermic: Animals which possess limited capacity of temperature regulation. They respond to extreme of temperatures by hibernating or aestivating. These mainly include marsupials.

Temperature affects the cellular, physiological, and behavioral processes in animals. Some of the functions regulated by temperature include

Cellular lethality: Very high and low temperature alter the cellular function. Low temperatures (get – delete) damage cellular proteins due to freezing while high temperatures coagulate proteins.

Metabolism: Functioning of enzymes require an optimum temperature. Slight increase in temperature increases the rate of metabolism due to enhancement in enzyme activity, but extremely high temperature inhibit enzyme functioning decreasing the metabolic rate.

Reproduction: Processes such as gametogenesis occur at specific temperature. The temperature requirement varies for each species. Breeding season varies for each species according to temperature. Fecundity (reproductive potential) of the species is also affected by temperature.

Growth and development: Growth is influenced by temperature. The length of oysters increases (1 to 10 mm) when temperature increases (from 10 to 20°C). Development of poikilotherms is regulated by temperature. High temperatures enhance the development process in these animals.

Morphology: The size of the animals is affected by temperature. Colder regions harbor larger species. This is because low temperature helps animals to conserve more metabolic heat. Small sized animals are found in hot desert areas. The change in the body form due to seasonal variations in temperature is referred as cyclomorphosis.

Behavior: Temperature directly affects the patterns of behavior in animals. Cold blooded animals tend to show orientation towards warmer regions. The process is called thermotaxis. Reptiles such as snakes detect the presence of mammals and birds through their body heat.

Besides all these processes, distribution of animals is regulated by variations in temperature. Changes in temperature affect stages of life cycle, reproduction, development and ultimately the survival of animals. Disease spreads, predation or parasitism indirectly influence survival of organism.

Organisms overcome the extreme/unfavorable temperature conditions by developing certain characters/features referred as adaptations. Animals

produce heat resistant cysts, eggs, pupae spores that can tolerate extremes of temperature (very high and low). Hibernation and aestivation are the well noted thermal adaptations in animals like amphibians, reptiles, birds and some mammals. In plants unfavorable/stress conditions can be overcome by forming dried spores and seeds.

SAQ 8

List the difference between Poikilothermic and Homothermic animals.

3.3.3 Shelford's Law of Tolerance

Any factor when present in less or more amount affects survival of the population. All the living organisms have an ecological minimum and maximum for tolerance to a factor. The concept was given by V.E. Shelford in 1913. According to (which – delete) this concept, the abundance or distribution of an organism is controlled by several factors (climatic, topographic, environmental and biological) and each of these factors have maximum or minimum limits that an organism can tolerate. Every organism thus, has an ecological minimum and maximum for every factor and the range between two limits is known as limit or zone of tolerance (Fig 3.12). The range of minimum and maximum limits signifies the tolerance capacity of an organism. For example, soil nutrients are important for the growth and development of plants. Uptake of any of the nutrients in excess limits the uptake of the other nutrient, restricting the growth of the plant.

Organisms show variation in tolerance to factors. They may have a more range of tolerance for one factor and less for another factor. Wide range of tolerance to factors indicates that organisms are most widely distributed and are more diverse in the community. Every environmental factor has two zones:

(a) Zone of tolerance (b) Zone of intolerance

(a) Zone of tolerance

This zone is favorable for the growth and development of organism. Zone of tolerance can be sub-divided into the following:

- (i) **Optimum zones:** It is the most favourable zone for growth and development of an organism.
- (ii) **Critical minimum zone:** It is the lowest minimum limit below which growth and development of the organism ceases.
- (iii) **Critical maximum zone:** It is the highest maximum limit above which growth and development of the organism ceases.

(b) Zone of intolerance

Tolerance with respect to various factors differs from species to species. Organisms that have a wide range of tolerance for all factors have a better chance of survival and hence, are widely distributed.

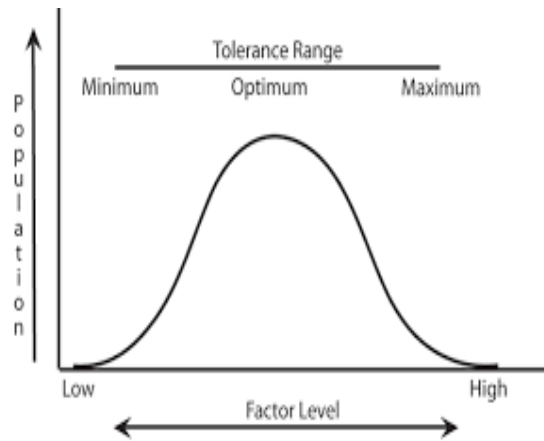


Fig. 3.12: Diagrammatic representation of the tolerance range.

3.4 SUMMARY

- Temperature decreases from the equator to the poles. This is because higher rates of insolation are received at the equator than at the poles.
- Regions in the same latitudinal position receive approximately the same amount of insolation and hence experience the same temperature changes throughout a year
- The portion of the southern hemisphere is largely dominated by oceans and has very few land masses → it therefore constitutes a fairly smooth surface which does not disrupt regular change of temperature with latitude. The isotherms in the northern hemisphere demonstrate intense north-south polarizations/deflections. This is because the northern hemisphere has a comparatively 'rough' surface filled with many large land masses
- Shifts in the isotherms: more drastic shift over land masses compared to over the oceans. Land heats up more rapidly in the summer and cools rapidly in the winter. Isotherms over land masses register higher than expected temperatures in summer and lower than expected temperatures in winter. Oceans respond more slowly to temperature changes. They heat up more slowly in summer and cool slowly in winter. The isotherms above oceans register lower than expected temperatures in the summer and higher than expected temperatures in winter. Since oceans heat up and cool down less drastically than land, the shifts in the isotherms are less polarizing.
- Furthermore, warm currents help to draw isotherms for higher than expected temperatures further poleward whilst cold currents help draw isotherms for lower temperatures towards equator
- In summer, land heats up more rapidly though it receives the same amount of insolation as the oceans in the same latitude

Suggested readings

Woodward FI (1988) Temperature and the distribution of plant species. Symp. Soc. Exp. Biol. 42, 59-75.

3.5 TERMINAL QUESTIONS

1. Describe in brief the components of earth's electromagnetic spectrum
2. Equatorial regions receive more solar radiation as compared to polar regions. Why?
3. What you mean by adiabatic heating and cooling?
4. Vegetation shows gradation with change in latitude and latitude. Explain.
5. Explain the concept of isotherms.
6. Earth is divided into different heat zones. Explain.
7. Define
 - insolation
 - albedo
 - phototropism
 - solstice
8. Differentiate between
 - longwave and shortwave radiation
 - sciophytes and heliophytes
 - littoral and profundal zone of lake
9. Explain the phenomenon of temperature inversion
10. State the shelford laws of tolerance.
11. The tolerance of an organism is regulated or governed by certain factors. Explain

3.6 ANSWERS

Self Assessment Questions

1. $500\text{nm} = 0.00005\text{cm} = 5 \times 10^{-5} \text{ cm}$
 $v = \frac{C}{\lambda} = \frac{3 \times 10^8}{5 \times 10^{-5}}$
 $E = h v = 6.6 \times 10^{-34} \times \frac{3 \times 10^8}{5 \times 10^{-5}} = 3.96 \times 10^{-19} \text{ joules}$

Divide this by 4.18 to get 0.947×10^{-19} calories

2.

- Solar energy is present in the form of packets of energy - photon
- The part of light which is seen by our eyes- visible spectrum
- wavelength of visible part of spectrum – 0.4-0.7 μm
- The longest wavelength in visible spectrum –red
- The shortest wavelength in visible spectrum - violet.

3. The earth receives a certain amount of insolation (terrestrial radiation) and reflects back some amount into space. This process of absorption and reflection maintains a constant temperature and heat budget on earth. We assume that total heat received by earth is around 100 units. Roughly, 35 units are reflected back into space before reaching the earth's surface, 27 units are reflected by clouds, 2 units by ice/snow and 6 units by the atmospheric layer itself. The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth's surface. Out of the 51 units radiated reaching the earth in the form of terrestrial radiation, 17 units are reflected back to the space directly and the remaining 34 units are absorbed by the atmosphere. The total of 48 units of radiation absorbed by the atmosphere (14 units from insolation + 34 units from terrestrial radiation) is released back into space. Thus, the total radiation returning from the earth and the atmosphere respectively is $17+48=65$ units which balances the total of 65 units received from the sun. This is termed as heat budget or heat balance of the earth.

Solar radiation travelling through the atmosphere gets scattered, dispersed or absorbed. In terms of percentage, about 30% of the radiation gets reflected by clouds, scattered and lost in space. Around 19% is absorbed by gases such as oxygen, ozone and water, ice crystals and suspended particles. The remaining 51% reaching the earth surface is either absorbed or reflected by earth surface. The absorbed radiation gets converted into heat energy and causes warming. Thus in total 70% (19% by atmosphere and 51% by earth) of the radiation is involved in the functioning of the biosphere.

4. The rotation of earth leads to variation in the amount of radiation reaching the earth. The seasonal changes are seen due to movement of earth around the sun. Earth travels around sun in an elliptical plane. Earth rotates about an axis tilted to an angle of 23.5° that passes through North and South poles giving brightness of day followed by darkness at night (diurnal cycle). The sun rays do not fall vertically on all parts of the earth due to inclination at an angle of 23° . During its rotation it moves between 23.5° N and 23.5° S latitudes. At the vernal equinox i.e. March 21 and autumnal equinox i.e. September 22, the sun is directly overhead at the equator. At this point of time, equator region receives

highest amount of shortwave radiation. Every place on earth receives 12 hours of each day and night.

In summer, solar rays fall directly on Tropic of Cancer (23.5°N) in Northern hemisphere leading to highest input of solar radiation and longer days. At the same time, Southern hemisphere experiences winter. In winter, solar rays fall directly on Tropic of Capricorn (23.5°S) in Northern hemisphere leading to highest input of solar radiation and longer days leading to less input of solar radiation and hence shorter days.

5. A plant's classification as a long-day or a short-day species is determined by photoperiodism, a term for the amount of daylight or darkness needed for plants to grow or, bloom.

Short-Day Plants

The plants that flower when exposed to long periods of darkness and short periods of light i.e. less than critical minimum. They require less than 12 hours of daylight to flower. They are also called long night plants. They normally flower in the early spring or autumn. Examples - *Kalanchoe* spp., *Salvia* spp., *Allium cepa*, *Glycine max*, *Fragaria ananassa*.

Long-Day Plants

The plants that require light period more than the critical maximum to flower are called long day plants. The plants need about eight hours of darkness to induce flowering. GA induces flowering in most of the long day plants. They normally flower in the spring or early summer. They are also called short night plants. Examples *Lactuca sativa*, *Spinacia oleracea*, *Petunia hybrid*, *Solanum tuberosum*.

6. Temperature leads to formation of strata. The uppermost layer is called epilimnion. Here the temperature can rise up to 37°C during summer. The stagnant water at the bottom is called hypolimnion. Its temperature is about 50°C. Between two layers is the zone of thermocline or metalimnion. It is characterized by rapid fluctuations in temperature.
7. **Megatherms** – The plants that live in high temperature throughout the year. These plants are found in equatorial and tropical rain- forests.

Mesotherm – The plants that live at high temperature of summer, alternating with low temperature of winter. They are found in deciduous forest of tropical and subtropical regions.

8. **Poikilothermic or ectothermic** – Also known as cold blooded animals. In these animals body temperature changes with the environment. These include invertebrates, fish and amphibians. They cannot regulate body temperature by physiological means.

Homothermic or endothermic animals – also known as warm blooded animals. Their body temperature does not depend upon the environmental temperature. These include birds and mammals. They regulate body temperature by producing heat.

Terminal questions

1. Electromagnetic spectrum of sun consists of different rays of different wavelengths ranging from gamma rays, X rays, ultra violet, visible, infrared, radiowaves. Ultraviolet (UV), gamma and x-rays have shortest wavelengths, while microwaves and radio waves have longer wavelengths. Electromagnetic radiation has a dual nature i.e. both particle and wave. The part of light which is seen by our eyes is the visible spectrum. The visible light covers the wavelength with range of 0.4 to 0.7 μm . Blue, green, and red are the primary colors of the visible spectrum. The longest wavelength in visible spectrum is red and shortest is violet. Infrared (IR) region of spectrum covers the wavelength range from approximately 0.7 μm to 100 μm .
2. Radiation gets variably distributed across various latitudes. A distinct gradation of decrease in radiation from equator towards the poles is noted. Radiation strikes lower latitudes directly and receive less solar radiation. At regions of high latitudes, the incident radiation of low intensity falls obliquely on the surface and penetrates deep into the atmosphere. More heat is lost than received. Near the equator vertical beam of radiation is seen which is more intense. This is the main reason why the equator receives more radiation and shows high temperature.
3. Adiabatic change refers to the change in temperature with pressure. On descent through atmosphere, the lower layers are compressed under atmospheric pressure. As a result, they are dry and warm. On ascent, the air expands as pressure decreases. This expansion reduces the temperature and releases the latent heat of condensation in the process. When a parcel of air rises upwards and cools this is known as adiabatic cooling. This adiabatic cooling is the result of the expansion of air as it is lifted upwards. When the air descends, it gets warmed and this is called adiabatic warming.
4. Variations in the latitude and altitude lead to changes in the temperature, humidity, heat and illumination that then affect the plant species composition and community structure. Altitude and latitude are directly connected to temperature and so have direct impact on vegetation. With the change in altitude and latitude there is a change in the sunlight distribution patterns which indirectly affects the viability and germination of the seeds. Plants thriving in areas with low light intensity will survive more in high altitude region and vice versa and hence more widely distributed. Connected to latitude we call tropical flora, temperate flora, tundras etc. Connected to altitude we call montane vegetation, alpine vegetation etc. Altitude, influence vegetation to such an extent that it can create temperate vegetation in tropical regions at higher altitudes, even close to Equator. Generally, at high altitude the plants show a stunted growth which is due to the effect of wind (Anemomorphosis).
5. Distribution of temperature across the latitudes over the surface of the earth is shown with the help imaginary lines joining places having equal

temperatures, reduced to sea level to eliminate the effects of altitude called isotherms. Isotherms represent horizontal distribution of temperature. Isotherms are the lines that join the places with the identical temperatures. They *run parallel to the latitudes*. Isotherms are generally tend east-west following the parallels and show sudden bends in areas of land- water contrasts. The spacing of isotherms indicates the latitudinal thermal gradient i.e. steepness or slow gradual nature of temperature change. Close spacing indicates a rapid change in the temperature and wide spacing means slow change.

6. Earth is divided into various heat zones. These include

Torrid Zone

Torrid Zone is the tropical region. The temperature remains high. This is because sun is directly overhead during some time of the year. This zone includes most of Africa, southern Asia, Indonesia, New Guinea, northern Australia, southern Mexico, Central America and northern South America.

Temperate Zones

Temperate zones are the mid latitudinal areas. The temperature is moderate. There are two temperate areas viz. North and South. The **sun is never directly overhead** and the climate ranges from warm to cool. The region experiences four seasons **namely Spring, Summer, Autumn and Winter**. The North Temperate Zone includes Great Britain, Europe, northern Asia, North America, northern Mexico, while South Temperate Zone includes southern Australia, New Zealand, southern South America and South Africa.

Frigid Zones

The frigid zones or polar regions, experience the midnight sun and the polar night for part of the year. The day is one year long, with six months of daylight and six months of night. These regions are the coldest regions of the earth. They are covered with ice and snow.

- 7.

- The incoming solar radiation is known as insolation.
- Some of the shortwave radiation that reaches earth surface gets reflected back. This is referred as albedo.
- The orientation and movement of plants and animals is affected by light. In plants the phenomenon is called as phototropism.
- Solstice is the time when sun reaches its highest position in the sky as seen from the North or South Pole.

8.

- Some plants prefer growing in bright or diffused light while others grow --- in shady areas. The plants have been classified as sciophytes (shade loving) and heliophytes (light loving).
- The littoral zone includes all those areas where light penetrates. In this zone aquatic plants grow. The profundal zone includes deep areas where light penetrates and is used for photosynthesis by plants. This area lies below the compensation depth.
- Visible light and ultraviolet radiation are commonly called shortwave radiation, while infrared radiation is referred to as longwave radiation. Shortwave radiation (visible light) contains a lot of energy while longwave radiation (infrared light) contains less energy. shortwave radiation has a shorter wavelength .

9. The temperature in the lower layers of air increases instead of decreasing with elevation. The surface radiates heat back to space rapidly and cools down at a faster rate than the upper layers. The lower layers get condensed and become heavy. The sloping surface underneath makes them move towards the bottom where the cold layer settles down as a zone of low temperature while the upper layers are relatively warmer. This condition, opposite to normal vertical distribution of temperature, is known as Temperature Inversion. Vertical temperature gets inverted during temperature inversion. The phenomenon in which temperature increases with increasing altitude temporarily and locally under certain conditions is known as inversion of temperature.

In the mountain areas, temperature of the air **increases with increasing altitude**. During night, radiation from the upper exposed slopes of the mountains causes the surface and air over it to cool rapidly. This cooler air is denser and gets drained by the valley slopes and displaces the warmer air toward up. There is an inversion of the temperature. There is a higher temperature range in than interior areas of continents than at seas because the sea heats and cools slowly but the land heats and cools rapidly.

The prevailing winds also have a greater effect on the annual temperature range. The variation in the annual temperature range in west and east European countries is due to land and sea winds. Winds from the oceans and seas blow into Western Europe and reduce the annual temperature range. Winds from the land blow in Arabian countries and therefore increase the annual range of temperature. Warm and cool winds disturb the temperature range. Temperature is **low in clouded areas** because the clouds obstruct the receipt and loss of insolation. In desert areas, no obstruction is present in the way of solar insolation.

10. Abundance or distribution of an organism is controlled by several factors (climatic, topographic, environmental and biological) and each of these factors have maximum or minimum limits that an organism can tolerate.

Any factor when present in less or more amount affects survival of the population. All the living organisms have an ecological minimum and maximum for tolerance to a factor. The range of minimum and maximum limits signifies the tolerance capacity of an organism. For example, soil nutrients are important for the growth and development of plants. Uptake of any of the nutrients in excess limits the uptake of the other nutrient, restricting the growth of the plant.



ADAPTATIONS OF HYDROPHYTES AND XEROPHYTES

Structure

4.1	Introduction		
	Expected Learning Outcomes	4.3	Xerophytes
4.2	Hydrophytes		Ephemeral Annuals
	Free-floating Plants		Succulents
	Rooted Plants with Floating Leaves	4.4	Summary
	Submerged Floating Plants	4.5	Terminal Questions
	Rooted Submerged Plants	4.6	Answers

4.1 INTRODUCTION

Plants grow in different habitats such as water and land. They possess certain characteristics that help (in – delete) them to survive in these habitats. These features are referred as adaptations. These include various structural, morphological and anatomical changes in the plants. The modifications in the morphology, anatomy and structure help the plant species to adapt to a particular environment. The present Unit describes the characteristic features of plants growing in water (hydrophytes) and dry/arid land habitats (xerophytes).

Expected Learning Outcomes

After the study of this Unit you will be able to:

- ❖ understand the term hydrophytes and xerophytes,
- ❖ list the various features of hydrophytes and xerophytes,
- ❖ describe different types of hydrophytes,

- ❖ describe different types of xerophytes, and
- ❖ discuss ecological significance of both **kinds of** species.

4.2 HYDROPHYTES

Hydrophytes are plants that live in water. They are adapted to living in aquatic environments. They are found in areas such as ponds, rivers and streams, lakes, wetlands and other aquatic environments. They develop certain features (adaptations) to ensure their survival in aquatic environment. Hydrophytes either float on the surface of water, **or** remain fully submerged or half submerged in water. Some aquatic plants grow in soil which is permanently saturated with water. These plants are referred as emergent species. Hydrophytes depend on water for their growth and support.

Classification of Hydrophytes

In the last 100 years, several botanists and ecologists have made attempts to classify hydrophytes. The main emphasis has been on the manner in which these aquatic plants survive in the environment. Thus, we come across numerous ways at looking at the hydrophytes. Some of these efforts at classifying hydrophytes are enumerated here.

Arber (1920) categorized aquatic angiosperms into two groups - rooted and non-rooted. The further categorization of these plants was done on the basis of foliage and inflorescence.

Danserau (1945) categorized aquatic forms into two types -helophyta and hydrophyta. The hydrophyta was further subdivided into 1) natantia which includes plants not fixed to the substratum, 2) radicantia which includes plants fixed to the substratum and 3) adnata which comprises of plants fixed on rocks or other plants. Radicantia was further divided into emersa i.e. partially emerged plants and subemersa i.e. floating plants. Emersa was further divided into Foliacea i.e. plants with well developed leaves, Junciformia i.e. plants with reduced leaf development and Nymphoidea i.e. plants with floating leaves. Subemersa was further divided into three classes Vittata i.e. plants having long stem and soft leaves, Rosulata i.e. plants having reduced leaves and Annua i.e. therophytic annuals. – **This paragraph needs to be checked carefully by the contributing author and then included in the final printing.**

On the basis of attachment of the plants to the soil, Luther (1949) classified hydrophytes into different types. Haptophytes i.e. plants which are attached to the substrate. Example- algae, lichens, bryophytes and angiosperms. Rhizophytes i.e. plants in which **the** basal parts penetrate the soil or the substrate in which they grow. Planophytes i.e. freely floating plants with submerged or surface-floating photosynthetic organs. These include planktophytes and pleustophytes (larger floating algae, liverworts ferns and some angiosperms). Rhizophytes possess a short stem and a rosette of stiff leaves, with or without stolons. Some rhizophytes also possess **a** long stem, submerged leaves and aerial or submerged reproductive organs as referred as elodeids.

Penfound (1952) categorized hydrophytes into three aquatic forms — emergent, floating and submerged. The British ecologists, Tansley (1949), Spence (1964) and Sculthorpe (1967) classified vascular hydrophytes based on this recognition.

Free-floating plants

Plants float on the surface of water. The roots are not attached to the soil surface but float on the surface of water. The roots are absent or poorly developed (fragile). These plants possess rosettes of aerial, floating leaves. The anatomy of leaf and stem shows the presence of reduced assimilatory tissues (thallus – delete). The plants can be rhizomatous or of the cormous type. The reproductive organs are aerial and floating. Example – *Salvinia*, *Eichhornia crassipes*, *Pistia*, *Trapa*, *Lemna*, *Wolffia* (Fig 4.1). *Lemna* possess one strand of root, while *Wolffia* is rootless. Some species such as *Nymphaea* possess floating leaves attached on long flexible petioles while other species such as *Nymphoides* show stoloniferous trailing stems with floating leaves present on short petioles.

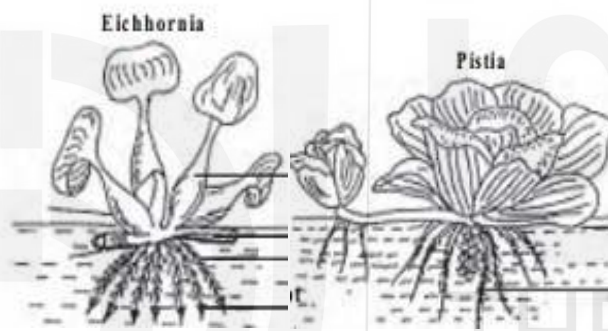


Fig. 4.1: *Eichhornia* and *Pistia*, two free-floating water plants.

Floating submerged plants

The foliage (or the leaves) of these plants are submerged in water. The plants are heterophyllous i.e. submerged leaves are present along with floating leaves. Leaves are filiform i.e. ribbon-shaped or finely divided. These plants are found at depth of about 12 m. The reproductive organs are either aerial floating or submerged (Fig 4.2). They are of different types:

- (i) **Caulescent-** The plants do not possess rhizome. The roots arise from nodes of leafy stems. Example - *Elodea*, *Hydrilla*, *Najas*, *Potamogeton*.
- (ii) **Stoloniferous-** The leaves are rosette type arising from a condensed, tuberous stock called rhizome. Example- *Isoetes*, *Sagittaria*, *Vallisneria*.
- (iii) **Thalloid-** The plant body is reduced to a cylindrical or flattened, creeping or floating, polymorphic thallus having erect or trailing secondary branches. Example- *Hydrobryum*, *Podostemon*.

Submerged species rise to the surface to flower and sink to the bottom of the substratum to perennate. Example- *Lemna trisulca*, *Utricularia*.

Rooted submerged plants

Plants in this group are completely submerged and anchored to the substratum. The plants possess long internodes, no palisade parenchyma, presence of chloroplasts in the epidermal cells, etc. Examples - *Vallisneria*, *Hydrilla*, *Potamogeton*, *Najas*, *Ceratophyllum*, *Myriophyllum*.

In *Vallisneria*, unisexual staminate flowers break off from the inflorescence and float on the surface of water. The scape of the pistillate flower elongates and reaches the surface of water where it gets pollinated by pollens of the staminate flower. After fertilization the scape shortens and young plant completes its development under water.

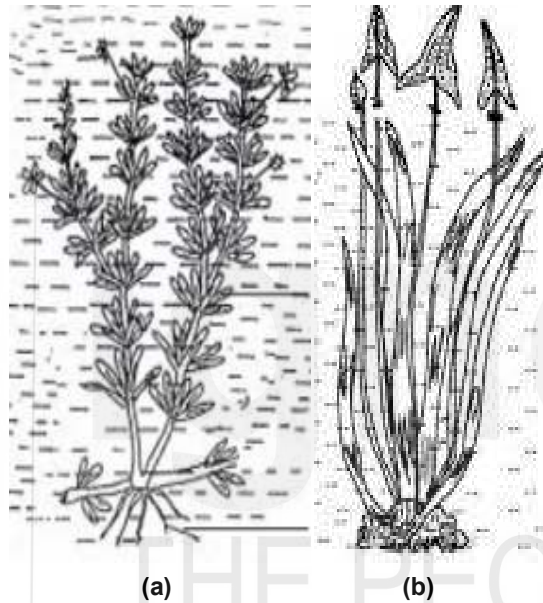


Fig. 4.2: (a) *Hydrilla* a rooted submerged plant and (b) *Sagittaria*, a submerged floating plant.

Emergent plants

The plants grow in shallow water with their underground parts in water or water saturated soil. The shoots grow well above the surface of water (Fig 4.3). They are also known as marsh plants or helophytes. They commonly occur as rhizomatous or cormous perennials. Some of the species are heterophyllous. The submerged and/or floating leaves precede the mature aerial leaves. They produce aerial reproductive organs. Example- *Typha*, *Phragmites*, *Scirpus*, *Sagittaria*. The leaf surface is reduced. In marshy hydrophytes such as *Rhizophora*, *Ceriops*, special roots grow erect and project above the poorly aerated muddy soil. These structures called pneumatophores. Example - *Rhizophora*, *Avicennia*.

Some varieties of rice grow with its roots partly submerged in water (wet paddy cultivation) i.e. under oxygen-poor conditions. The roots possess large air channels. The oxygen concentration is low in the soil.

Roots of vascular hydrophytes live and grow normally in low oxygen conditions. Certain hydrophytes grow in still water or wet soil. Their roots possess the ability to respire anaerobically.

Heterophylly is one of the characteristic features of hydrophytes. Heterophylly means the presence of two or more distinct types of **leaves** in a single individual. The leaf types may differ markedly in shape and in anatomical organization or they may differ in habit and anatomy. In extreme case of heterophylly, the leaf types differ in all the above three aspects and a full-grown plant may bear submerged, floating and aerial leaves at the same time. The change from one leaf type to the other may be quite abrupt or it may be more gradual with transitional forms. Transition forms of leaves are found ranging from finely dissected to the fully aerial entire types. Only the veins of the aerial lamina are developed, the remaining development of lamina (the inter-venous mesophyll tissue) is totally arrested. Example- In the plant, *Sagittaria sagittifolia*, the first formed 'juvenile' leaves are dissected or ribbon-shaped submerged type and the later formed ones are the floating or aerial type (usually associated with the reproductive phase). Heterophylly can occur because of various causes such as age, genotype, nutrient status and change in environmental factors such as photoperiod, temperature and moisture conditions.



Fig. 4.3: (a) *Typha* and (b) *Phragmites*, the emergent plant species.

Reproduction

The dispersal of seeds and fruits occurs in water. Water currents carry the **spores** ? [should it be seeds/fruits?] of hydrophytes, seedlings of mangroves and entire floating plants such as *Lemna*, *Salvinia*, etc. In submerged species, flowers are raised in the air above the surface of water for pollination. Most of the hydrophytes flower much less than land plants. *Elodea canadensis* and *Acorns calamus* propagate only by vegetative reproduction and do not produce flowers at all. The propagation of most aquatic plants occurs by vegetative means such as fragmentation. This has been noted in *Elodea*. Fragmentation of the plant body, followed by regeneration from any small part, bearing a vegetative bud, is a common occurrence in free-floating plants and submerged hydrophytes having long delicate stems. The propagation also occurs by runners as noted in *Eichhornia* and production of thalli as noted in

Lemna. Colonization by means of rhizomes, stolons, runners, etc. is also widespread amongst hydrophytes. These organs store food and serves as hibernacula that enables survival of plants under unfavorable environmental conditions.

When flowers are present, fertilization takes place at or above the surface of water.

Hydrophytes also exhibit phenomenon known as **pseudo-vivipary**. The hydrophytes of the family Alismaceae show pseudo-vivipary. The vegetative propagules replace some or all of the sexual flowers in the inflorescence. Submerged hydrophytes bear plantlets in place of flowers all along the axis of their inflorescence. Some species of *Sagittaria* and *Potamogeton* form small tubers on the ends of stolons or lateral branches, while in some species such as *Hydrocharis*, *Myriophyllum* and *Utricularia*, the inflorescence develops specialized dwarf-shoots known as turions at the apex.

Production of gemmiparous buds from foliar tissues has also been reported in some species of hydrophytes. The buds arise at **specific meristematic regions** in the leaf-lamina. A single leaf bears several such buds, each capable of developing into a plantlet (or bulbil) which may either drop off or become independent when the leaf decays.

Adaptations in aquatic plants

Hydrophytes (plants – delete) live either completely or partly submerged in water with some leaves or flowers out of the water. Some of the general characteristics of the hydrophytes include

1. In free-floating plants, leaves are flat and contain air spaces that give the plant **buoyancy** allowing the leaves to float on the surface of water. The leaves absorb sunlight to carry out photosynthesis. The leaves possess a thin layer of epidermis as they do not need to conserve water to maintain water balance within the plant.
2. Roots are poorly formed or absent. Roots if present are thin, poorly developed and short. This has been noted in submerged hydrophytes. Example- *Nymphaea*, *Nelumbo* possess thin and poorly developed roots present embedded in the mud. In floating species with rosette leaves, roots (adventitious) are shorter and less branched. Example - *Salvinia*, *Eichhornia*, *Pistia* etc. The roots of these species develop chloroplastids in their epidermal and cortical cells which trap light and contribute in photosynthetic activity.
3. Root hairs are absent. In some hydrophytes root hairs are present. Roots are undeveloped. This is because they are not required to absorb large amounts of water.
4. Stem is long slender and flexible in submerged plants Example -*Hydrilla*, *Potamogeton*. Stem is slender or thick, short and spongy in free floating forms. Example - *Eichhornia*. Stem is a well-developed rhizome in rooted plants with free floating leaves. Example- *Nymphaea*, *Nelumbo*, *Pontederia*, The tough and woody-rhizomes have been found in

Cyperus, *Scirpus*, *Typha* etc. The stem has little or no lignin tissues. This is because the strengthening tissues are not required. The hollow stem helps the plant have buoyancy and provide space for storage of gases such as carbon dioxide and oxygen. The plants have undeveloped xylem tissues because there is no requirement for water transport within the tissue. In these plants, water can directly enter (into – delete) the leaves and stem via osmosis and therefore transport of the water is not required.

The gases diffuse from the leaves into aerenchyma of the stem. The gaseous exchange allows the plant to float and survive in the aquatic environments. Gaseous exchange is also important for meeting the oxygen requirement of cells during respiration. The gases diffuse through the stem and are important for sustaining carbon dioxide within the plant.

5. Leaves of hydrophytes differ depending on their submergence in water. In submerged forms, leaves are thin, long and ribbon like or finely dissected. Example- *Vallisneria*, *Potamogeton*. In partly submerged plants, leaves are wide/broad, floating on the surface of water. This increases surface area for absorption of sunlight required for photosynthesis and evaporation.
6. In some hydrophytes leaf petiole or the base forms a bladder-like swelling. Example- *Trapa*, *Pistia*, *Hydrocharis* etc. These flat surfaces help in floating of plant and mainly consist of spongy parenchyma. In *Eichhornia*, the whole petiole may be swollen into a bulbous spongy float. In submerged species, the petioles or the leaf-bases remain slender and elongated. The bifurcations in the leaf increase the surface area for the absorption of nutrients, exchange of gases such as carbon dioxide. The linear and the finely divided forms of leaves in the submerged parts offer less resistance to water currents. Dissected leaves have a higher surface area/volume ratio. Mechanical tissues, (such as angular collenchyma) found along the margins of finely divided or ribbon-shaped leaves of some species such as *Eichhornia*, help in resisting tearing stress.
7. Leaf and stem cells of hydrophytes possess intercellular air spaces called lacunae or aerenchyma (Fig 4.4). These are small air pockets present in the cell and assist in the exchange of gases such as oxygen and carbon dioxide. Air spaces help in maintaining buoyancy in the cell. The plants retrieve gases via diffusion and dissolution in water. Exchange of gases takes place through diffusion.
8. Vascular system (xylem or phloem tissues) of stem and roots is not well developed. This is because that the plants are constantly surrounded by water. They can absorb the water through their leaves and stems by osmosis and hence do not require xylem and phloem for the transport of water.
9. Cuticle and stomata are absent particularly in the submerged species. Thick waxy cuticle if present around/on the stomata facilitates

transpiration and protects stomata. Stomata are mostly absent or if present are non-functional. Stomata are found mostly on the upper side of the leaf in submerged species. The stomata remain open because there is no need to conserve water as the water is abundantly available.

10. Vascular tissue is reduced and stele consists of few vascular elements/bundles towards the periphery.
11. The secondary growth is completely absent. This is an important feature for increasing thickness of stems and roots.
12. A significant proportion of biomass is represented by the underground parts, e.g., rhizome, roots, bases of the aerial shoots in vascular hydrophytes. Example in *Typha* sp. more than 50% of the biomass can be accounted by the roots.
13. Closely packed hairs present at the hydrophobic tips protect the leaf surface from getting wet. The strength of floating leaves results from their leathery texture. The mucilage accumulation on the aerial organs protects them from getting too wet. Mucilage also prevents rapid diffusion of water through the cell wall. This benefits the plants where stomata are confined to the upper surface of leaf lamina.
14. Heterophylly is the phenomenon noted in hydrophytes. The different forms of leaves are produced on the same plant. Example- *Sagittaria sagittifolia*, *Limnophila heterophylla*. In submerged species entire, rounded or slightly lobed floating aerial leaves are found along with linear, ribbon-shaped or finely dissected submerged leaves.

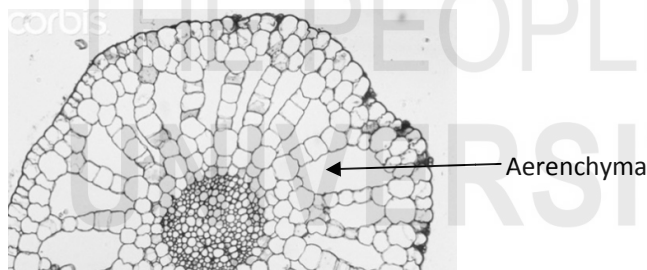


Fig. 4.4: T.S. of *Hydrilla* stem showing presence of aerenchyma.

SAQ 1

Define hydrophytes. Give some examples

SAQ 2

Describe the major anatomical changes noted in hydrophytes.

SAQ 3

Hydrophytes produce leaves of different types in the same plant. Explain.

SAQ 4

Give an account of ecological importance of hydrophytes.

4.3 XEROPHYTE

The plants adapted to live in dry habitats are termed as xerophytes. They possess means to prevent water loss or to store the available water. They are defined as plants that grow on substrate that usually (become – delete) possess gravitational ground water at a depth of 20-25 cm. They are basically of two types - ephemerals and succulents. Succulents are the plants that store water. Example- Cactus, Agave. They possess thick, fleshy stems or leaves.

The adaptations in xerophytes can be morphological (structural) or physiological or both. The adaption in xerophytes include

- waxy leaf coatings
- ability to drop leaves during dry periods
- ability to fold leaves to reduce sunlight absorption and
- development of a dense, hairy leaf covering.

The adaptations help the xerophytes to escape drought or to endure recurrent drought. During drought, dehydration of plants cells and tissues takes place. A considerable increase in the temperature causes overheating leading to dehydration.

Heat-resistant plants respond to high temperatures. Stimulation in protein synthesis and high respiration rates have been noticed in these plants. These are the results of high levels of nucleic acids, [especially RNA (complexed with protein could it be “with complex proteins” Please check!)]. The hardened plants maintain all their essential processes at a high level during drought. Leaves of hardened plants are usually rich in starch and all tissues are high in organic high-energy bond phosphates (ADP and ATP). Hardened plants have a greater absorbing surface in the root system. Thus the absorption of mineral elements is more intense in hardened plants. Roots are more resistant to high temperatures because of presence of high levels of starch. Small leaves (xeromorphism) in these plants occur because of rapid increase in nucleoproteins, enhanced protein synthesis, cell division and differentiation of cells.

Protective adaptive reactions against high temperatures mainly involve increase in respiration, and increased synthesis of organic acids, which bind to released ammonia and increase (in – delete) the hydrophilic viscosity of the protoplasm. Reproductive organs are sensitive to dry conditions and injures to reproductive organs such as gynoecea leads to a reduction in fruit production. Pollination and fertilization are also affected in water deficit conditions. The cell shows changes in colloidal-chemical properties such decrease in elasticity and protoplasmic viscosity.

Morphological characteristics of xerophytes

Plants appear dwarf, thick or stunted (*Aloe*, *Agave*) or prostrate (*Euphorbia prostrata*).

1. The root system is well developed, extensive, penetrating very deep. Root hairs and root caps are very well developed.
2. The leaves are reduced in area to check transpiration (*Casuarina*). The leaves may be modified into phyllodes (*Acacia melanoxylon*) or they become succulent (*Aloe*, *Agave*, *Yucca*).
3. The leaves show various features like gray or light green coloration, rolling, wilting, leaf fall, leathery glandular outgrowth, leaf spines, and a coating of wax or presence of hairs, etc.
4. The stems are usually stunted, hard, rigid and covered with thick bark.
5. The stems may be modified into phylloclades (*Opuntia*, *Euphorbia*) or cladodes (*Ruscus*, *Asparagus*).
6. The stem may show coating of hairs or wax, or spines etc.
7. In plants where the leaves are absent or caducous, the stem performs the function of photosynthesis (*Capparis aphylla*).
8. The lamina of the leaf may be very much segmented (*Acacia*, *Prosopis*) or long, narrow and needle-like (*Pinus*).

Types of Xerophytes

Three types of xerophytes have been known on the basis of differences in their morphology, physiology and taxonomy.

1. Ephemeral Annuals

The ephemerals are prominently found in semi-arid regions. They complete their entire life cycle within a few weeks. With the onset of rains, seeds of plants germinate, quickly grow to maturity, set flowers and set seeds. This means that they completed their entire life cycle in a short span of time before the soil dries out again. The morphological adaptations in ephemerals include small size and large shoots in comparison to root. Such plants have been termed 'drought escaping' and considered as false xerophytes as they do not really endure drought (they cannot survive low water conditions for long period of time without permanent injury to the cells) or rather escape it. Most of these plants are small rounded, dense shrubs represented and belonging to the families Papilionaceae (*Astragalus sp.*, etc.), Compositae (e.g., *Artemisia*), Zygophyllaceae, Boraginaceae and Gramineae (some grasses).

2. Succulents

Succulents also contribute a large percentage of vegetation to the flora of the most semi-arid regions. They are frequently found in locally dry habitats such as sandy soils, sea beaches, etc., of more humid climate. The succulents are a distinct group of plants, not only in structure but also in metabolism and water-economy as well (the accumulation of organic acids, pentosans and

mucilage by succulents is well-known). Their structural modification enables the plant to accumulate (specify the product/s) in the proliferated tissue, depending upon the extensibility of individual cells, and also large reserves of water during brief rainy seasons. Succulence is due to the proliferation of parenchymatous cells accompanied by an enlargement of vacuoles of mature cells and a considerable reduction in the size of intercellular spaces. The cells of the water-storage tissues are rich in glue-like mucilage. This holds water very efficiently. Water is lost through transpiration. A few stomata are seen in the epidermis of the fleshy stems. The stomata open only at night. The succulents shrivel during the periods of drought as they become depleted of water and swell up again with the advent of rain. The features such as relatively thick cuticle and closing of stomata during day are important factors permitting conservation of water (Fig 4.5). The succulents such as cactus can survive rainless months and replenish their water supply again during the following rain. These plants belong to the families Euphorbiaceae, Crassulaceae, Liliaceae, Amaryllidaceae, Portulacaceae, etc. Example of stem succulents is cactus and the leaf succulents include *Agave*, *Aloe*, *Sedum*.

Cacti are unique among all types of desert plants in having shallow, but vast spreading roots, enabling them to absorb superficial water quickly. The rootlets wither away when supply of water in the surface soil is exhausted and reappear within a very short time when there is (again – delete) a supply of water in the soil.

Plants decrease the water loss by evolving a metabolic change. The stomata open during night, absorb CO₂ (dark fixation) which is stored in the cells in the form of dicarboxylic acids (e.g., malic acid). During the day, they keep their stomata closed thereby preventing loss of water. The dicarboxylic acids get transformed into sugars at night (Crassulacean acid metabolism).

They avoid drought by means of conserving water. The tissues of succulents do not have any intrinsic resistance to the harmful effects of drought. The survival of plant depends on xeromorphic characters such as reduction of leaves to spines, ridges or protuberances, so that water can be conserved. The thick and waxy epidermis helps in retention of water.

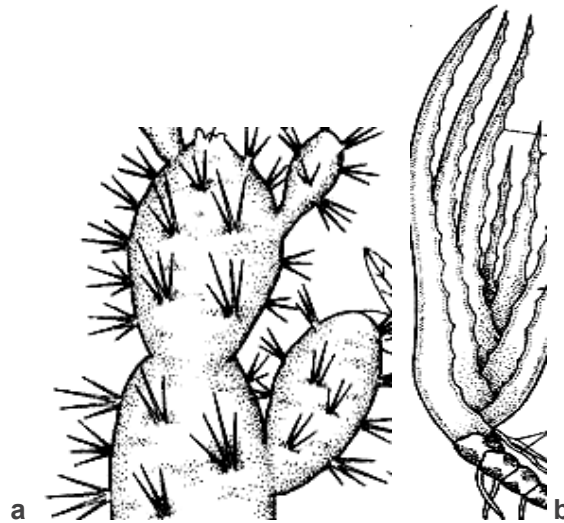


Fig. 4.5: (a) *Opuntia* (b) *Aloe*, the succulent xerophytic plant species.

Example – *Opuntia dillenii* (Nagphani) is a succulent xerophyte. The function of photosynthesis has been taken over by the stem in the absence of leaves. The stem is flattened and green referred as pycnoclad. It is thick and fleshy due to the storage of water. The pycnoclades have thick cuticle and sunken stomata. Mucilage helps in retaining water. The axillary branches are modified into spines present in the areoles. They reduce transpiration.

Euphorbia royleana (Danda thor) is a succulent plant with caduceous leaves. The stem is angular, green and bears spines in pairs. It performs the function of photosynthesis throughout the year. The stem stores water.

Aloe barbadensis (Ghikanwar) – is a succulent shrub. The stem is reduced, thick and fleshy, leaves store water. The margin and apex of the leaf are spiny to reduce transpiration. The leaves are thick and arranged in whorls. The leaf surface is shining and bears a thick cuticle. The stomata are present on the lower surface. Leaf bears tuft of trichomes or hairs. Mucilaginous latex present in the plant helps in retaining water.

Asparagus is a cultivated succulent xerophyte. The leaves are modified into scales. The latter are spiny and bear a whorl of axillary branches. The branches are modified into cladodes. Each cladode is a leaflike, needle-shaped and fleshy structure. The roots are adventitious which store food and water to form root-tubers in fascicles.

3. Non-Succulent Perennials

Members of this category are the true xerophytes (euxerophytes)—the drought-enduring plants. They successfully endure long and continuous dearth of water in the soil. Soil-drought conditions are usually accompanied by dry atmospheric conditions such as high temperature, low humidity and often high wind velocity, all of which favor high transpiration rates. In euxerophytes, water deficiency usually reaches 60-70% of their mean fresh weight. It affects growth process such as cell elongation.

Example -Acacia nilotica (Kikar or Babool) is a non-succulent, drought enduring tree. It possesses an extensive taproot system. The stem is thick, erect and covered over by brown corky bark in its older parts. The leaves are compound, stipulate, and bipinnate, the pinnules are small and oval. The stipules are modified into spines to reduce transpiration and prevent grazing (from – delete) by animals.

Solanum xanthocarpum is a wild herb with yellow prickles all over the surface, commonly found in dry areas and wastes land. The spines reduce transpiration and also provide protection against grazing animals. Other examples are *Argemone mexicana* (Prickly poppy, Jangli post), *Nerium odorum* (Kanaer), *Zizyphus nummularian* (Jangli beri). The leaves are small, leathery with the hairy or bloomy coating. The stipules are modified into spines. The branches are slender but stiff. These species grow in arid areas or waste lands.

SAQ 5

Describe some important structural features of xerophytes.

SAQ 6

Differentiate between ephemeral and succulent plants.

Adaptive features in xerophytes

The morphological and physiological characteristics enable plants to withstand drought.

The major features include:

(1) Dehydration

Desert plants can withstand considerable dehydration as high as 50% of their dry weight. These plants can tolerate protoplasmic desiccation to a much larger extent by changing the colloidal chemical state of the protoplasm. The gelatinous coating on the cell walls of the blue-green algae helps in maintaining hydration in cells.

(2) Rapid Elongation of Tap Root

In arid and semi-arid regions the surface soil (which is no deeper than a few cms) dries out. The plants possess long tap root system that penetrates deep into the soil. This prevents drying of the soil from the surface downwards by the extensive root system which helps the soil in retaining water.

(3) Absorptive Capacity

The production of extensive root system in proportion to shoot system not only increases the total absorptive capacity of the plant but reduces the exposure of the plant to the atmosphere. Many desert plants have adventitious roots which are deep and are capable of absorbing even the little amount of available water present in the moist subsoil.

(4) High Osmotic Pressure of the Cells

High osmotic pressure of the cells is a characteristic feature of the xerophytes. It indicates high solute content of the soil. The cells possess a very high water-potential (100-150 atmosphere). The cell walls exhibit little or no elasticity. Rigid and inelastic cell-wall structure prevents cellular collapse under water-stress conditions and influences the water-holding capacity of the cell. This feature enables plants to adapt themselves to drought conditions and provide resistance to water loss through transpiration. This also helps in the development of negative water-potential and helps in uptake of water from dry soils.

(5) Ability to Reduce Transpiration Rates

Leaves are modified to spines to reduce loss of water through transpiration. Anatomical features, e.g., dead hairs and sunken stomata, help to reduce transpiration rates in xerophytes. The stomata close during the day. The leaf-shedding provides a means of enduring transpiration for branches devoid of leaves. Many xerophytes retain their leaves throughout the season. In these species, the epidermis is multilayered, heavily cutinized and waxy to provide greater resistance to desiccation under extreme dry conditions. The closure of stomata is coupled with cutinization of the epidermal cells. Plants of this type are referred as sclerophylls (hard leaved). The thick cuticle prevents the breakage and consequent damage to the leaves caused by high wind generally prevalent in desert areas. Heavily cutinized leaf surface reflects much of the sun's rays, thereby reducing transpiration through reduced heat absorption.

A greater density of epidermal hairs on one or both surfaces of the leaves is a prominent feature of xerophytes. The stomatal surface is protected by a dense coating of hairs. Living hairs probably increase the rate of cuticular transpiration by increasing the surface of the leaf but reduce the transpiration by reflection of large proportion of incident light. Dead hairs perhaps reduce the rate of stomatal transpiration under conditions of intense sunlight or strong wind. Hairs act as a mechanical barrier to keep the air currents away (above – delete) from the stomatal surface.

Sunken stomata i.e. presence of stomata in cavities below the level of epidermal surface are found commonly in xerophytes. They help in reducing water loss via transpiration. The spongy tissue is not present but compactly packed palisade cells are present beneath both upper and lower epidermis. They contribute largely towards reduction in transpiration rates.

Under drought conditions many xerophytes possess the capacity to change their form or position so that the amount of light received per unit area generally becomes less. In this way, the aerial transpiring surface is protected from direct contact with air. The leaflets of many desert legumes fold upwards in such a manner that only approximately half the leaf-surface is exposed to air. Some desert grass leaves roll or fold lengthwise along the longitudinal furrows in their upper surface. These are caused due to turgor movements caused by loss in turgidity of the rows of enlarged colorless cells, often termed bulliform cells (motor cells). This phenomenon has been observed in species

of family Ericaceae. In certain erect and shrubby xerophytic plants, the leaf blades are permanently oriented in a vertical position.

The light green color of most desert plants is thought to reflect light rays to prevent more light being absorbed and converted into heat, raising the temperature of the leaf thus promoting rapid transpiration. Green tissues function efficiently only when they are turgid and their photosynthetic efficiency falls off rapidly if they are water-deficient. In extreme water-deficient conditions of the habitat on the other hand photosynthetic efficiency is greatly decreased. The epidermal cells of many xerophytic leaves are in a collapsed state in extreme water scarcity conditions of soil and air but the cells straighten up whenever there is an increase in the moisture content—this bellow-like action of the epidermal cells seems to be typical of many desert plants.

Xerophytes have more intense assimilation rate than other plants for their palisade cells and chloroplasts are better developed and also can only function part-time because of the restriction of their activity during periods of water-deficit.

(6) Reduction in Size of Leaf Blades

The leaf blades, pinnae and pinnules of compound leaves of desert plants are (in – delete) smaller in size and more compact. The desert flora is mostly microphyllous. The leaf blades contain a denser network of veins. Presence of microphyllous leaves reduce the amount of transpiration due to this decrease of the aggregate area of the total transpiring surface. Often in microphyllous plants, the small size of the individual leaf units is compensated by greater numbers.

The water diffusion through the mesophyll is very slow (diffusion is cell by cell). The cells located near the veins can obtain sufficient water supply during the water crisis. More stomata are found towards the midrib than the margins of the leaves. The tip of leaf blade is the part devoid of water supply. The breaking up of leaf blades or reducing the size of individual leaf reduces degeneration of leaf tissues caused due to drought. Microphyllly - the smaller leaf blade leads to less heating of leaf surface when exposed to strong intensity of light.

Desert plants often lack green leaves altogether. In plants such as *Ephedra*, the reduction in the size of the leaf blades is such that only vestigial part is visible. In certain species, leaf blades are lost entirely, the photosynthetic function is taken over by the expanded petioles (phyllodes) or stems or both.

(7) Change in the Size and Shape of the Cells

The cells of xerophytic plants are small in size with small vacuoles. Cells having a larger proportion of protoplasm and consequently smaller vacuole are least disturbed by loss of water and are also protected against injury. When desiccated small cells decrease their volume to nearly half and the reduction in size may be as high as 5-10 times. Cells of hibernating or storage organs and reproductive structures, e.g., spores, zygotes and seeds generally lack vacuoles which help them to survive through drought conditions.

Buds are resistant to drought. Their cells are completely devoid of vacuoles.

The plants develop elongated cells that possess narrow cell cavity. Vegetative organs of ferns and certain angiosperms can remain in a dry state and can again revive in water supply without any apparent injury to their cells. The protoplast of these cells protected against injury by the extraordinarily firm nature of the cell vacuoles which resist desiccation.

(8) **Metabolism**

The cell metabolism changes in conditions of desiccation. The thickened cell walls, formation of protective coverings might be due to accelerated conversion of polysaccharides into their anhydrous forms, example-cellulose. Desiccation may also promote development of suberised cork cells. Thickness of bark is greatest in desert plants compared to plants grown in moist conditions. In xerophytes conducting vessels are well developed and the heavily thickened vessels are more numerous, larger in diameter and longer.

As with cutin, lignification of the vessels occurs in xerophytes. Annual growth rings are more pronounced in xerophytes as compared to mesophytes. Lignified bast fibres and sclerenchyma are also noted in xerophytes. The palisade cells are partly lignified, and accumulation of gums and tannins frequently occur in the lignified fibres or cutinized cells forming the hypodermis.

4.4 SUMMARY

- Plants growing in water are referred as hydrophytes while those growing on dry land habitats are called xerophytes.
- Hydrophytes occur as floating, submerged or emergent forms.
- Leaves of hydrophytes are flat, thin containing air spaces that give the plant **buoyancy** allowing them to float on the surface of water.
- In hydrophytes, roots are poorly developed while the stem is thin and slender.
- In hydrophytes, gaseous exchange occurs via aerenchyma present in the leaves and stem of the plant.
- Hydrophytes exhibit heterophylly, i.e. **show** presence of two or more distinct types of leaves **on** a single plant. The leaves differ markedly in shape and anatomical organization.
- Adaptations such as waxy coating over leaves, ability to drop leaves during dry periods, folding of leaves to reduce sunlight absorption, reduction of leaf size and development of spines help xerophytes to escape and adapt drought/dry conditions. Presence of dense, hairy leaf covering helps them in tolerating extreme heat and dry conditions.
- The development of deep and extensive root system helps in the absorption of water to the maximum.

- The reduction in leaf area prevents transpiration. In other species, leaves become succulent and store water. The stem is modified into phyllodes which performs photosynthetic functions.

Suggested readings

Judd, Walter S., Christopher Campbell, Elizabeth A. Kellogg, Michael J. Donoghue, and Peter Stevens. *Plant Systematics: A Phylogenetic Approach*. 2nd ed. with CD-ROM. Sunderland, MD: Sinauer, 2002.

A.A. Oyedele and J.F.N. Abowei The Classification, Distribution, Control and Economic Importance of Aquatic Plants International Journal of Fisheries and Aquatic Sciences 1(2): 118-128, 2012 ISSN: 2049-8411 E-ISSN: 2049-842X

4.5 TERMINAL QUESTIONS

1. List the primary differences between hydrophytes and xerophytes.
2. Describe three types of hydrophytes with examples.
3. Hydrophytes do not possess well developed root system. Comment
4. Hydrophytes do not possess well developed root system. Comment
5. How the reproduction in hydrophytes takes place?
6. Xerophytes show physiological changes to overcome drought conditions. Explain.
7. Give the major anatomical features of significance found in xerophytes.

4.6 ANSWERS

Self assessment questions

1. Plants which are found in water bodies or aquatic habitats are called hydrophytes. They can be growing on the surface of water (floating) or submerged in water. Example *Hydrilla*, *Eicchornia*, *Pistia*.
2.
 - The anatomy of leaf and stem shows the presence of reduced assimilatory thallus. These flat surfaces help in floating of plant and mainly consist of spongy parenchyma.
 - The roots of these species develop chloroplasts in their epidermal and cortical cells which trap light and contribute in photosynthetic activity.
 - Leaf and stem cells of hydrophytes possess intercellular air spaces, called lacunae or aerenchyma. These small air pockets present in aerenchyma assist in the exchange of gases such as oxygen and carbon dioxide. Air spaces help in maintaining buoyancy in the cell.

- Vascular system (xylem or phloem tissues) of stem and roots is not well developed. This is because that the plants are constantly surrounded by water. They can absorb the water through their leaves and stems via osmosis, hence do not require conducting tissue such as xylem and phloem for the transport of water.
 - Cuticle and stomata are absent particularly in the submerged species. Exchange of gases takes place through diffusion.
3. Heterophylly is one of the characteristic features of hydrophytes. It is the phenomenon in which different forms of leaves are produced in the same plant. Example- *Sagittaria sagittifolia*, *Limnophila heterophylla*. The leaf types may differ markedly in shape and anatomical organization. Transition forms of leaves are found ranging from finely dissected to the fully aerial entire types. Only the veins of the aerial lamina are developed, the remaining development of lamina (the inter-venous mesophyll tissue) is totally arrested. In *Sagittaria sagittifolia*, the first formed 'juvenile' leaves are invariably of the dissected or ribbon-shaped submerged type and the later formed ones on the other hand, are the floating or aerial type (usually associated with the reproductive phase). In submerged species entire, rounded or slightly lobed floating aerial leaves are found along with linear, ribbon-shaped or finely dissected submerged leaves. Heterophylly can be attributed to both internal causes such as age, genotype and nutrient status of the plant as well as influence of environmental factors namely photoperiod, temperature and moisture conditions.
4. Aquatic plant species form an important part of communities present in freshwater, shallow-water lakes, ponds and other aquatic bodies.

- They provide food for many types of herbivorous animals. Water lilies growing in commercial fish ponds are eaten as a food by certain herbivorous fish. Some of the hydrophyte species are eaten by humans. These include species such as wild rice (*Zizania*), water caltrop (*Trapa natans*), chinese water chestnut (*Eleocharis dulcis*), Indian Lotus (*Nelumbo nucifera*), water spinach (*Ipomoea aquatica*), watercress (*Rorippa nasturtium-aquaticum*), watermimosa (*Neptunia oleracea*), water mimosa (*Neptunia natans*), taro (*Colocasia esculenta*), bullrush (*Cyperus*), cattail, (*Typha*), water-pepper (*Polygonum hydropiper*), wasabi (*Wasabia japonica*), totora (*Scirpus californicus*).

Some aquatic plants used for animal nutrition include water hyacinth (*Eichhornia*), duckweed species such as *Lemna*, *Spirodela* and *Wolffia*, *Trichanthera gigantea*. Other aquatic species include algae and all seaweed and kelp, *Utricularia* (bladderworts) and water lettuce.

- They provide habitat for birds and many species of insects and mammals.

- Species of water lilies provide a beautiful aesthetic to aquatic habitats. The sacred lotuses (*Nelumbo nucifera*, *N. nelumbo*) are especially important in this regard in a number of cultures of countries like India, China, Japan, in architectural motifs and decorations, and as symbolism in literature.

5.

- Production of extensive root system. This increases the total absorptive capacity of the plant. Deep roots absorb even the smallest quantity of water available (even from the moist subsoil).
- Leaves are modified to spines to reduce loss water through transpiration. Anatomical features, e.g. dead hairs, sunken stomata help to reduce transpiration rates in xerophytes. The stomata close during the day.
- Many xerophytes which retain their leaves throughout the season, epidermis (sometimes multiple or more than one layer of epidermis is observed) is heavily cutinized and waxy to provide greater resistance to desiccation under extreme dry conditions. Plants of this type are sometimes referred to as sclerophylls (hard leaved). This thick cuticle may also be advantageous in preventing the breakage and consequent damage to the leaves caused by bending of the blades by high wind generally prevalent in a desert. Heavily cutinized leaf surface reflects much of the sun's rays, thereby reducing transpiration through reduced heat absorption.
- Presence of hairs on the leaf margins of one or both surfaces of the leaves is another prominent feature of xerophytes. Hairs act as a mechanical barrier to keep the air currents away above the stomatal surface. Living hairs probably increase the rate of cuticular transpiration by increasing the transpiring surface of the leaf but reduce the transpiration by reflection of large proportion of incident light. Dead hairs perhaps reduce the rate of stomatal transpiration particularly under conditions of intense sunlight or strong wind.
- Xerophytes possess the capacity to change their form or position so that the amount of light received per unit area generally becomes less. The leaflets of many desert legumes fold upwards in such a manner that only approximately half the leaf-surface is exposed to air. This helps in reducing the transpiration.
- The light green colour of most desert plants is thought to reflect light rays to prevent more light being absorbed and converted into heat, raising the temperature of the leaf thus promoting rapid transpiration. In extreme water-deficient conditions of the habitat on the other hand photosynthetic efficiency is greatly decreased.
- The leaf blades, pinnae and pinnules of compound leaves of desert plants are in smaller in size and more compact, i.e., the desert flora is mostly microphyllous. resence of microphyllous

leaves reduce the amount of transpiration due to this decrease of the aggregate area of the total transpiring surface. Microphylls - the smaller leaf blade leads to less heating of leaf surface when exposed to strong intensity of light.

6.

Ephemeral plants	Succulent plants
These plants complete their entire life cycle within a few weeks. Seeds germinate, quickly grow to maturity, flower and set seed, i.e., the entire life cycle is completed before the onset of drought conditions.	Leaves possess proliferated parenchymatous cells and show fewer amounts of intercellular spaces. The cells possess the capacity to store large amount of water.
Possess large shoots in comparison to roots. Most plants are small roundish, dense shrubs.	Stomata are open only during night and closed during day are important factors permitting conservation of water.
Called as 'drought escaping' or false xerophytes as they escape drought conditions.	They can survive periods of drought and replenish their water supply again during the following rain.
Represented by members of family Papilionaceae, Compositae, Zygophyllaceae, Boraginaceae and some grasses.	Include members of family Euphorbiaceae, Crassulaceae, Liliaceae, Amaryllidaceae, Portulacaceae, etc.
Example <i>Astragalus</i> , <i>Artemesia</i>	Example - <i>Agave</i> , <i>Aloe</i> , <i>Sedum</i> .

Terminal Questions

1.

Hydrophytes	Xerophytes
Plants live in water or aquatic habitat	Plants live in dry conditions.
Plants have a poor root system	Plants possess a well developed root system
Leaves are spongy	Leaves are reduced
Show heterophylly	Do not show heterophylly
Categorized into three types free-floating, submerged and emergent types	Categorized as ephemerals, succulents and non-succulents

Stem is thin, fragile and lacks vasculature	Stem is well developed and possess vasculature
Stomata are less or absent	Well developed stomata are present

2. Hydrophytes are mainly classified into three types

Free-floating plants

Plants float on the surface of water but are not attached/rooted in the soil. These plants possess rosettes of aerial, floating leaves. The plants can be rhizomatous or cormous type. The roots are absent or poorly developed (fragile). The reproductive organs are floating, aerial.

Example – *Salvinia*, *Eichhornia crassipes*, *Pistia*, *Trapa*, *Lemna*, *Wolffia*.

Submerged floating plants

Foliage of these plants is entirely submerged in water. Plants are anchored to the substratum and possess rhizomes and slender stems with long internodes. The plants are heterophyllous i.e. submerged leaves precede or accompany the floating leaves. Leaves are filiform or ribbon-shaped or even finely divided. The reproductive organs are either aerial floating or submerged. Submerged species rise to the surface to flower and sink to the bottom of the substratum to perennate. Example *Elodea*, *Hydrilla*, *Najas*, *Potamogeton*, *Sagittaria*, *Vallisneria*.

Emergent plants

The plants grow with their underground parts in water or water-saturated soil. The shoots grow well above the surface of water. They are also known as marsh plants or helophytes. Occur as rhizomatous or cormous perennials. Some of the species are heterophyllous. The submerged and/or floating leaves precede the mature aerial leaves. They produce aerial reproductive organs, e.g., *Typha*, *Phragmites*, *Scirpus*, *Sagittaria* etc.

3. Vascular system (xylem or phloem tissues) of stem and roots is not well developed in hydrophytes. This is because that the plants are surrounded by water and do not require conducting elements such as xylem and phloem for the transport of water. They can absorb the water by osmosis via leaves and stems.
4. Water currents carry the spores of hydrophytes, seedlings of mangroves and entire floating plants to long distances. Example *Lemna*, *Salvinia*.

When flowers are present fertilization takes place at or above the surface of water. In submerged species, flowers need to be raised into the air above the surface of water for pollination.

Some species such as *Elodea canadensis* and *Acorns calamus* propagate only by vegetative reproduction and do not produce flowers at all. The propagation occurs by fragmentation in species such as *Elodea* and by runners as seen in *Eichhornia*. Species such as *Lemna* produce

thalli. In fragmentation, a small part, bearing a vegetative bud appears on the plant body which later separates and grows into a new plant. Colonization by means of rhizomes, stolons, runners, etc., is also widespread amongst hydrophytes. Several submerged hydrophytes bear plantlets in place of flowers all along the axis of their inflorescence.

Hydrophytes also exhibit phenomenon known as pseudovivipary. The vegetative propagules replace some or all of the normal sexual flowers in the inflorescence. Example -inflorescence of *Myriophyllum verticillatum*, a turion was formed at the apex. Some species of *Sagittaria* and *Potamogeton* form small tubers on the ends of stolons or lateral branches, whilst some species of *Hydrocharis*, *Myriophyllum* and *Utricularia* develop specialized dwarf-shoots known as turions. The hydrophytes of the family Alismaceae show pseudo-vivipary.

Production of gemmiparous buds from foliar tissues has also been reported in some species of hydrophytes. These buds arise at specific sites of meristematic cell-aggregates in the leaf-lamina. A single leaf may bear several such buds, each capable of developing into a plantlet (or bulbil) which may either drop off or become independent when the leaf decays.

5. Desert plants can withstand considerable dehydration as high as 50% of their dry weight. This is because they can tolerate protoplasmic desiccation to a much larger extent by changing the colloidal chemical state of the protoplasm. The gelatinous coating on the cell walls of the blue-green algae helps in maintaining hydration in cells. The characteristics of the cells of xerophytes plants are that cells are small in size with small vacuoles. The size of the desiccated small cells decrease to nearly half. Cells having a larger proportion of protoplasm and consequently smaller vacuole are least disturbed by loss of water and are also protected against injury. Cells of hibernating or storage organs and reproductive structures, e.g., spores, zygotes and seeds generally lack vacuoles which help them to survive through drought conditions.

The shape of the cell also assists in tolerating drought conditions. The spherical and cubical cells of plants not adapted to desiccation, hence plants develop elongated cells. Certain xerophytic mosses have cells which are much elongated with narrow cell cavity.

6.
 - i) Leaves are modified to spines to reduce loss water through transpiration. The leaf blades, pinnae and pinnules of compound leaves of desert plants are in smaller in size and more compact, i.e., the desert flora is mostly microphyllous. The leaf blades contain a denser network of veins. Presence of microphyllous leaves reduce the amount of transpiration due to this decrease of the aggregate area of the total transpiring surface. Often in microphyllous plants, the small size of the individual leaf units is

- compensated by greater numbers. Microphylls - the smaller leaf blade leads to less heating of leaf surface when exposed to strong intensity of light.
- ii) The leaf-shedding of xerophytes provides a means of enduring transpiration for the branches, devoid of leaves, lose very little water. Many xerophytes which retain their leaves throughout the season, epidermis (sometimes multiple or more than one layer of epidermis is observed) is heavily cutinized and waxy to provide greater resistance to desiccation under extreme dry conditions. Plants of this type are sometimes referred to as sclerophylls (hard leaved). This thick cuticle may also be advantageous in preventing the breakage and consequent damage to the leaves caused by bending of the blades by high wind generally prevalent in a desert. Heavily cutinized leaf surface reflects much of the sun's rays, thereby reducing transpiration through reduced heat absorption.
 - iii) Xerophytes possess the capacity to change their form or position so that the amount of light received per unit area generally becomes less. The aerial transpiring surface is protected from direct contact with air. The leaflets of many desert legumes fold upwards in such a manner that only approximately half the leaf-surface is exposed to air. Some desert grass leaves roll or fold lengthwise along the longitudinal furrows in their upper surface. These are caused due to turgor movements caused by loss in turgidity of the rows of enlarged colorless cells, often termed bulliform cells (motor cells). This phenomenon has been observed in species of family Ericaceae. In certain erect and shrubby xerophytic plants, the leaf blades are permanently oriented in a vertical position.
 - iv) The light green color of most desert plants is thought to reflect light rays to prevent more light being absorbed and converted into heat, raising the temperature of the leaf thus promoting rapid transpiration. Green tissues function efficiently only when they are turgid and their photosynthetic efficiency falls off rapidly if they are water-deficient. In extreme water-deficient conditions of the habitat on the other hand photosynthetic efficiency is greatly decreased. The epidermal cells of many xerophytic leaves are in a collapsed state in extreme water scarcity conditions of soil and air but the cells straighten up whenever there is an increase in the moisture content—this bellow-like action of the epidermal cells seems to be typical of many desert plants. Desert plants often lack green leaf altogether. In certain plants such as *Ephedra*, the reduction in the size of the leaf blades has progressed so far that the leaves in *Ephedra* are probably vestigial. In such species, where leaf blades have been lost entirely, the photosynthetic function is taken over by the expanded petioles (phylloides) or stems or both.
 - v) The stomata close during the day. The closure of stomata is coupled with highly efficient cutinization of the epidermal cells.

- vi) A greater density of epidermal hairs is a prominent feature of one or both surfaces of the leaves of many xerophytes.

7.

Anatomical features such as sunken stomata i.e. presence of stomata in cavities below the level of epidermal surface help to reduce transpiration rates in xerophytes.

Presence of compactly packed palisade cells beneath both upper and lower epidermis reduces transpiration rate.

Presence of dense coating of hairs around the stomata surface and permanent revolute margins of the blade. Dead hairs reduce the rate of stomatal transpiration particularly under conditions of intense sunlight or strong wind. Hairs act as a mechanical barrier to keep the air currents away above the stomatal surface. Peltate hairs shade the upper leaf surface in some xerophytes.

Stomata are located towards the midrib of the leaves.

The reducing the size of individual leaf units by discarding much of the intervening mesophyll reduces the likelihood of severe drought.