Syllabus

ECOLOGY, EVOLUTION AND ANIMAL BEHAVIOUR
SC–109

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Chapter 1 : Ecosystem : Components and Major Ecosystems

Chapter 2 : Ecosystem : Dynamics and Energy Flow.

Chapter 3 : Ecological adaptations in animals.

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UNIT

1

ECOSYSTEM : COMPONENTS AND MAJOR ECOSYSTEMS

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :
- Different abiotic and biotic components that constitute the ecosystem.
- Terrestrial ecosystems and aquatic ecosystems.
- Macrophytes, phytoplanktons and macroconsumers.
- Herbivores, carnivore order-1 and carnivore order-2.

• 1.1. INTRODUCTION

The term ecosystem was first introduced by Tansley in 1935. He defined ecosystem as "the system resulting from the integration of all the living and non-living factors of the environment. He recognized that an ecosystem includes not only organisms but also physical factors of the environment. More recently, the term ecosystem has been defined by P. Odum (1971) as "the basic functional unit of organisms and their environment, interacting with each other and within their own components. An ecosystem may be as small as a puddle or as large as the entire earth, the biosphere.

• 1.2. STRUCTURE OF ECOSYSTEM

The structure of an ecosystem is basically a description of different abiotic and biotic components that constitute the ecosystem :

(A) Abiotic Components

The term abiotic refers to all kinds of non-living elements of the ecosystem which are essential to the dynamics and stability of the ecosystem. These are of the following kinds :

Table 1. Different components of an ecosystem

Main Components	Parts of Main Components
(1) Abiotic components	(a) Inorganic substances (b) Organic substances (c) Climatic factors

(2) Biotic components	(a) Autotrophic components (producers) (b) Heterotrophic components (consumers) (i) Macroconsumers (ii) Microconsumers

(1) Inorganic substances : Some inorganic elements are vital for the synthesis of organic compounds and play an important role in the dynamicity of the ecosystem. These are S, C, H, N, P, O elements. They keep on circulating in the ecosystem in the form of biogeochemical cycles. In these cycles, they are first utilized by the producers, then passed on to the consumers and from consumers, they are released back in the environment. The amount of these inorganic substances, present at any given time in an ecosystem is designated as the standing state or standing quality.

(2) Organic substances : Important organic substances include amino acids proteins, lipids, carbohydrates and highly organized molecules like DNA, RNA and A.T.P. molecules. These organic components are basic structural and functional components of all living organisms of the ecosystem. They circulate in the ecosystem along different chains and come back to the environment in the form of organic detritus.

(3) Climatic factors : They are also called physical factors of the ecosystem. Rainfall, temperature, wind, water, soil, light, moisture, pH etc. constitute these physical factors. They play an important role in the dynamicity and stability of the ecosystem. They are interconnected with each other and form a complex system.

(B) Biotic Components

Biotic components refer to the living organisms of the ecosystem and constitute its trophic structure. Biotic components are distinguished on the basis of their nutritional relationships, which are discussed below :

(1) Autotrophic components : Autotrophic (auto-self; trough-nourishing) components of ecosystem are commonly called producers or energy transducers. They convert solar energy into chmical energy in the form of complex organic substances (carbohydrates, lipids, proteins etc.) with the help of some inorganic substances (H_2O, CO_2 etc.). Autotrophics fall into following two groups :

(i) Photoautotrophs which contain green photosynthetic pigment chlorophyll to transduct the solar or light energy of sun, *e.g.*, trees, grasses, algae, other tiny phyloplanktons and photosynthetic bacteria.

(ii) Chemoautotrophs which use energy generated in oxidation-reduction process, but their significance in the ecosystem as producers is minimal *e.g.*, sulphur bacteria.

(2) Heterotrophic components : Heterotrophic (Hetero-other; tropic-nourishing) organisms are called consumers as they depend for their food on the producers (autotrophs). The activities of utilization, rearrangement and decomposition of complex organic materials predominates in this component of the ecosystem. The consumers are of following two main types :

(a) Macroconsumers : These are also called phagotrophs (phago- to eat) and include mainly animals which ingest other organisms or chunks of organic matter. Depending on their food habits, consumers may either be herbivores or carnivores.

(b) Microconsumers : These are also called decomposers, reducers, saprotrophs, osmotrophs and scavengers. Microconsumers include microorganisms such as bacteria, actinomycetes and fungi. They breakdown complex organic compounds of dead or living protoplasm, absorb some of the products and release inorganic nutrients in the environment, making them available again to autotrophs or producers.

The disintegrating dead organic matter is also known as organic detritus. By the action of detritivores (= decomposers), the disintegrating detritus result into particulate organic matter (POM) and dissolved organic matter (DOM) whcih play important role in the maintenance of the edaphic environment.

• 1.3. KINDS OF ECOSYSTEM

An ecosystem may be as small as a single log, a puddle or as large as an ocean the whole earth or biosphere. The vast ecosystem — the biosphere as a whole is, however, dificult to handle and thus for the sake of convenience we divide it into units of smaller ecosystem. An ecosystem can be natural or artificial, temporary or permanent and large or tiny. Thus, various constituent ecosystems of the biosphere fall into the following categories :

(1) Natural Ecosystems

These types of ecosystem operate by themselves without any major interference by man. Based upon the particular kind of habitat, these are further classified as :

(a) Terrestrial ecosystem such as forests, grasslands, deserts, a single log etc.

(b) Aquatic ecosystems which may be further distinguished as follows :

(i) Fresh water ecosystems : These may be lotic (running water as spring, brook, stream or river) or lentic (standing water as lake, pond, pool, puddle, ditch, swamp etc.).

(1) Marine ecosystems : These include salt water bodies which may be deep bodies as an ocean or shallow ones as a sea or estuary.

(2) Artificial ecosystems : These are also called man made or man engineered ecosystems. These are maintained artificially by man where, by addition of energy and planned manipulations, natural balance is disturbed regularly, *e.g.*, rice-fields; orchards, gardens villages, cities, dams, aquarium and manned spaceship.

Major Ecosystems : There are various types of ecosystem operating as self sufficient interacting systems of the biosphere.

(1) Pond Ecosystem : A pond as a whole serves as a good example of a lentic aquatic and fresh water ecosystem (Fig. 1). In fact, it represents a self-sufficient and self-regulating system. It has the following components :

(I) Abiotic components : In the pond ecosystem, the abiotic substances include all kinds of constituents. Climatic factors are heat, light, pH, temperature, slope of the pond, depth of the pond etc. Organic compounds in the pond ecosystem include water, CO_2, O_2, Ca, N_2, PO_4, amino acids, humic acids etc. Inorganic salts occur in the form of phosphates, nitrates and chlorides of sodium, potassium and calcium. Some proportion of nutrients exist in solution state but most of them are present as stored in particulate matter as well as in living organisms.

(II) Biotic components : These include all the living organisms of the pond ecosystem which are interconnected with each other. They are classified into the following types :

(a) Producers : They are autotrophic green plants and photosynthetic bacteria. The producers fix radiant energy of the sun with the help of carbondioxide and water with the help of minerals derived from water and mud. They manufacture complex organic substances as carbohydrates, proteins and lipids. Producers of a pond are of following types :

(i) Macrophytes : These include mainly the rooted large-sized plants which comprise three types of hydrophytes : partly or completely submerged, floating and emergent aquatic plants. The common plant species are *Trapa, Typha, Elcocharis, Sagittaria, Nymphaea, Potamogeton, Chara, Hydrilla, Vollisneria, Utricularia, Marsilea, Nelumbo*, etc. Besides these plants, some free floating forms also occur in the pond ecosystem *e.g., Azolla, Salveinia, Wolffia, Eichhornia, Spirodella, Demna* etc.

(ii) Phytoplanktons : These are microscopic (minute), floating or suspended lower plants (algae) that are distributed throughout the water, but mainly in the pholic zone. Most of them are filamentous algae such as *Spirogyra, Ulothrix, Zygnema, Cladophora* and *Oedogonium*. There also occur some chlorococcales (*e.g., Chlorella*), closterium cosmarium, *Endorina, Pandorina, Pediastrum, Scendesums, Volvox, Diatonms, Anabaena, Gloeotrichia, Microcystis, Oscillatoria, Chlamydomonas, Spirulina* etc. and some flagellates.

(b) Macroconsumers : They are phagotrophic heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Macroconsumers are of following three types :

(i) Herbivores (primary consumers) : These animals feed directly on living plants (producers) or plant remains. They may be large or minute in size and are of the following types :

Benthos : These are bottom dwelling forms such as fish, insect larvae, beetles, mites, molluscs and crustaceans etc.

Zooplanktons : They feed chiefly on phytoplanktons and are mostly the rotifers as Brachionus, Asplanchna, Lecane etc. Although, some protozoans as Euglena, Coleps, Dileptus etc. and crustaceans such as Cyclops, Stendypris etc. are also present in the pond.

Besides these small sized herbivores, some mammals such as cow, buffalo etc., also visit the pond casually and feed on marginal rooted macrophytes. Some birds also regularly visit the pond to feed on some hydrophytes.

(ii) Carnivore order-1 (secondary consumers) : These carnivores feed on the herbivores and include chiefly insects, fishes and amphibians (frog). They feed upon zooplanktons.

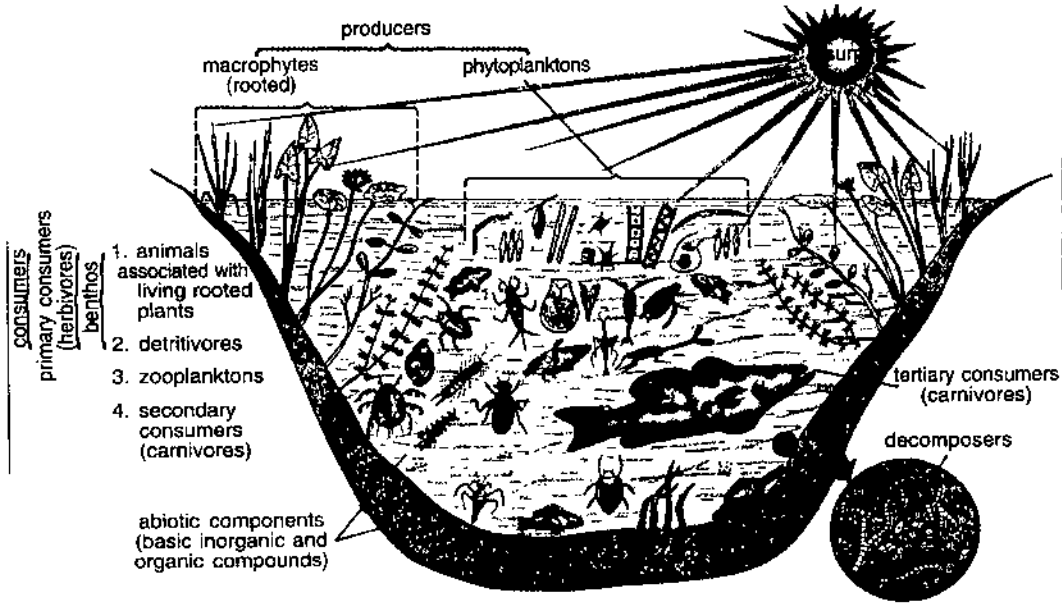


Fig. 1. A pond ecosystem showing its basic structural units – the abiotic (inorganic and organic compounds) and biotic (producers, and consumers – herbivores, carnivores and decomposers) components

(iii) Carnivore order-2 (tertiary consumers) : These are some large fish as game fish that feed on the smaller fish and thus become the tertiary consumers.

(c) Decomposers (microconsumers) : These animals feed upon decomposed organic matter. They bring about the decomposition of dead organic matter of both producers and consumers. In pond, they include fungi (Aspirgillus, Cephalosporium, Cladosporium, Rhizopus, Penicillium, Alternaria, Fusarium), bacteria and actinomycetes.

(2) Ocean (Marine) Ecosystem

Oceans cover almost 70% part of the earth's surface. Each ocean indeed represents a very large and stable ecosystem. Their general structure is discussed below :

Biotic Components : They can be discussed as :

(i) Producers : The producers or autotrophs of the ocean are responsible for trapping the radiant energy of sun with the help of their pigments. They are mainly phytoplanktons (diatoms, dinoflagellates and some microscopic algae). Sea-weeds also are important producers of the ocean ecosystem.

(ii) Consumers : They are divided as follows :

Primary consumers : These comprise of mainly crustaceans, molluscs, and fishes which feed upon producers directly.

Secondary consumers : They are carnivorous fishes which feed upon primary consumers, (Herbivores).

Tertiary consumers : They are the top carnivorous consumers that feed on the secondary consumers.

(iii) Decomposers : These are microconsumers (bacteria and fungi) that decompose the dead organic matter and feed upon it.

Abiotic Components of Ocean Ecosystem : In ocean ecosystem temperature, salinity and depth, H_2O, CO_2, O_2 and the salt contents constitute the abiotic components. In comparison with small fresh water ecosystem, the marine ecosystem is divided into different zones which differ in both biotic and abiotic components.

(3) Grassland Ecosystem

This is a terrestrial ecosystem and the the various components of grassland ecosystem are as follows :

Abiotic Components : These are the nutrients present in soil and the aerial environment. Thus the elements like C, H, O, N, P, S etc. are supplied by CO_2, H_2O, nitrates, phosphates and sulphates and comprise of abiotic components.

Biotic Components : These may be categorised as :

Producers : They are mainly grasses (*Dichanthium, Cynodon, Desmodium, Digitaria, Diactyloctenium* etc.), herbs and shrubs which bound the sunlight into chemical energy.

Consumers : These occur in the following sequence :

(i) Primary consumers : These are mainly grazing animals like cattles, deers, sheep, rabbits, horses etc. and some insects like hesptocorisa, Dysdercus, Coccinella, some termites and millipedes etc., that feed on the leaves of grasses.

(ii) Secondary consumers : They are the animals which feed upon herbivores and include fox, jackals, frogs, snakes, birds etc.

(iii) Decomposers : In this ecosystem, fungi (Mucor, Aspergillus, Penicillium, Cladosporium, Rhizopus, Fusarium etc.), bacteria and actinomycetes decompose the dead organic matter and release minerals back to the soil.

(4) Forest Ecosystem

The different components of a forest ecosystem are as follows :

Abiotic Components : Apart from other usual inorganic and organic substances, the humans (accumulated organic matter) and stratification of light, temperature are also found in forest ecosystem.

Biotic Components : They are as follows :

Producers : These are mainly trees that show much species diversity and greater degree of stratification especially in tropical moist deciduous forests. In tropical moist deciduous forest, these are mainly Tactona grandis, Butea frondosa, Shorea robusta and Lagerstroemia parviflora. In temperate coniferous forests, the producer trees are species of Abies, Picea, Pinus, Cedrus, Juniperus, Rhododendron etc. In temperate deciduous forests, the dominant trees are species of Quercus, Acer, Betula, Thuja, Picea etc.

Consumers :

(i) Primary consumers : They are ants, flies, beetles, leafhoppers, bugs and spiders which live on trees and feed upon large grazing animals like elephants, nilgai, deer, moles, squirrels, shrews, flying foxes, fruits bats, mongooses etc.

(ii) Secondary consumers : They are carnivores like snakes, birds, lizards, foxes etc. feeding on the herbivores.

(iii) Tertiary consumers : They are top carnivores like Lion, Tiger etc. that eat carnivores of secondary consumers level.

Decomposers : These are a wide variety of microorganisms including fungi (species of Aspergillus, Coprinus, Polyporus, Ganoderma, Fusarium, Alternaria, Trichoderma etc.), bacteria and actinomycetes.

(5) Desert Ecosystem

Desert ecosystems are characterized with high temperature and scarcity of water. The species composition of such ecosystem is much more varied and typical due to these factors.

Producers : These are mainly shrubs, especially bushes, some grasses and a few trees.

Consumers : The most common animals are reptiles and insects, able to live under xeric conditions. In addition to them, there are also found some nocturnal rodents and birds. The ship of desert camels feed on tender shoots of the plants.

Decomposers : *These are vry few, as due to poor vegetation* the amount of dead organic matter is comparatively less. They are some fungi and bacteria, most of which are thermophilic.

(6) Cropland Ecosystem

The ecosystems, described so far, are natural in the sense that they all operate as self-regulating systems without much direct interference and manipulations by man. However, in nature we also find another kind of ecosystem, where man is very much involved in their operation. An example of such ecosystem is cropland ecosystem. They are artificial or man engineered in order to obtain more food, cloth, timber, medicines, and other useful products, man becomes responsible for the replacement of natural systems.

Abiotic Components : Man changes the composition of abiotic components of cropland ecosystem by manipulation in the physico-chemical environment. It includes addition of fertilizers to soil, chemicals for disease control, water for irrigation and soil texture etc. under most suitable conditions of *growth and yield.*

Biotic Components : They are also modified according to the interest and need of man.

Producers : They comprise mainly of single or two species of plants which man wants to grow in the cropland ecosystem. We have ecosystems of dominant crop species like wheat, maize, jowar, paddy, sugarcane, vegetables etc.

Consumers :

(i) Primary consumers : These are smaller animals including chiefly the insects and larger animals like rats, rabbits, birds etc.

(ii) Secondary consumers : They are carnivores like frogs and some birds that feed upon the insects.

(iii) Tertiary consumers : These are carnivores such as snakes and hawks whcih feed on the secondary consumers, frogs, and smaller birds.

Decomposers : These are microbes present in soil as well as air and comprise of bacteria, fungi and actinomycetes

• SUMMARY

The term ecosystem was first introduced by Tansley in 1935. According to P. Odum "the basic functional unit of organisms and their environment, interacting with each other and within their own components. An ecosystem may be as small as a puddle or as large as the entire earth, the biosphere. Structurally, ecosystem consists of biotic and abiotic components. Abiotic components are inorganic substances, organic substances and climatic factors. Biotic components refer to all the living organisms. Both the components play an imortant role in dynamicity and stability of the ecosystem. For the sake of convenience, biosphere is divided into two kinds of major ecosystems, natural and artificial. Natural systems consist of terrestrial and aquatic major ecosystems.

Key words : Ecosystem, components, abiotic, biotic, climatic, dynamicity, biosphere.

• STUDENT ACTIVITY

1. Make a chart to show pictures of different kinds of ecosystems.

• TEST YOURSELF

Long Answer Questions

1. Describe the structure of an ecosystem by taking an example of pond ecosystem.
2. Describe various components of an ecosystem.
3. Give an account of major ecosystems.

Short Answer Questions

4. Describe different kinds of ecosystems.
5. Describe biotic components of bond ecosystems.
6. Draw a picture of bond ecosystem.
7. Describe grassland ecosystem.

Objective Questions

(1) Lentic aquatic ecosystem is :
(a) river (b) ocean (c) pond (d) stream

(2) Lotic aquatic ecosystem is :
(a) pond (b) river (c) ditch (d) ocean

(3) Biotic factors is :
(a) light (b) carbon cycle
(c) producer (d) moisture

(4) Climatic factor is :
(a) temperature (b) producer
(c) consumers (d) decomposer

(5) Decomposer is :
(a) macroconsumer (b) microconsumer
(c) producer (d) none of these

Ans. 1. (c) **2.** (b) **3.** (c) **4.** (a) **5.** (b)

UNIT

2

ECOSYSTEM : DYNAMICS AND ENERGY

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Primary succession and secondary succession.
- Autotrophic succession and heterotrophic succession.
- Different stages of succession on the basis of dominant plant types or species.
- Protozoans, creeping animals, animal life in floating, reed-swamp and sedge-meadow stages respectively.
- Energy at autotrophic level, first trophic level and cornivores trophic levels.

• 2.1. INTRODUCTION

Ecosystem is a complex system which consists of abiotic and biotic components. The community structure (living organisms) and physical environment of an ecosystem are never stable, but dynamic, changing, more or less, regularly over time and space. Environment is always changing over a period of time due to (i) variation in climatic and physiographic factors (ii) the activities of the species of the community themselves. These influences and interaction of the communities and physical environment bring about marked changes in the environment and the dominance of the existing community. The communities sooner or later are replaced by other communities best suited to prevailing environmental conditions at the same place in any ecosystem. The overall process is called dynamicity of the ecosystem and can be discussed in detail under the heading of ecological succession.

Odum (1971) preferred the term `ecosystem development, rather than the 'ecological succession' for this dynamic process and defined it as follows :

(1) This process takes place in a direction and in an order, therefore predictable.

(2) It results from modification of the physical environment by the community, that is succession is community controlled even though the physical environment determines the pattern, the rate of change and often sets limits as to how far development can go.

(3) it culiminates in a stabilized ecosystem.

• 2.2. CAUSES OF ECOSYSTEM DEVELOPMENT (SUCCESSION)

Ecosystem development is a complex dynamic process and there are several causes for this as discussed below :

Initial or Initiating Causes : The climatic factors such as erosion and deposits, wind, fire etc. are the initiating cuases of succession. The various activities of organisms also contribute to initiate the ecological development. The initial causes produce the base areas on destroy the existing populations in an area.

Ecesis or Continuing Causes : These are the processes as migration ecesis, aggregation, competition reaction etc. which cause successive waves of population as a result of changes, chiefly in the edaphic features of the area.

Stabilizing Causes : This is climate that established any one of the species of the community into the ecosystem.

• 2.3. TRENDS OF SUCCESSION

An ecological succession proceeds along the following four lines :

(1) A continuous change in the kinds of plants and animals.

(2) A tending increase in the diversity of species.

(3) An increase in the organic matter and biomass supported by the available energy flow.

(4) Decrease in net community production or annual yield.

Basic Types of Succession

(1) Primary succession : It starts from the primitive substratum, where there was no previously any sort of living matter. The first group of organisms establishing there are known as the pioneers primary community or primary colonisers.

(2) Secondary succession : It starts from previously built up substrata with already existing living matter. The action of any external force, as a sudden change in climatic factors, biotic intervention, fire etc. causes the existing community to disappear. Thus area becomes devoid of living matter but its substratum is built up, instead of primitive.

(3) Autotrophic succession : It is characterised by early and continued dominance of autotrophic organisms like green plants. It begins in a predominantly inorganic environment and the energy flow is maintained indefinitely. There is gradual increase in the organic matter content supported by energy flow.

(4) Heterotrophic succession : It is characterised by early dominance of heterotrophs, such as bacteria, actinomycetes, fungi and animals. It begins in a predominantly organic envionment and there is a progressive decline in the energy content.

General Process of Succession : In a primary autotrophic succession, the following steps would occur in a sequence.

(1) Nudation : This is the primitive stage of an ecosystem in which the substratum happens to be a bare area without any form of life. The area may develop due to several causes such as landslide, erosion, deposition or other catastrophic agencies. Man is also responsible for nudation due to his developmental activities.

(2) Invasion : This is the successful establishment of a species in a bare area. The species actually reaches this new site from any other area. It involves the following steps :

(i) Migration(dispersal) : In this process, seeds, spores or other propagules of the species reach the bare area through air, water, birds, and other animals.

(ii) Ecesis (Establishment) : After migration, the process of successful establishment of the species as a result of adjustment with the prevailing environmental conditions is known as ecesis. In plants, after migration seeds or propagules germinate, seedlings grow into adults and start to reproduce. Only a few of them are capable of doing this under primitive harsh conditions and thus most of them become dead. Thus, as a result of ecesis, the individuals of species become established in the area.

(3) Aggregation : After establishment the individuals of the species increase their population by reproduction with a course of time. They come to each other and this process is called aggreagation.

(4) Competition and coaction : In an aggregation, the individuals of the species compete with each other for space and mutation. This is called competition. In this close association, individuals of a species affect each other's life in various ways and this is called coaction. The species, if unable to compete with other species, if present would be discarded. To withstand competition, reproductive capacity, wide ecological amplitude etc. are of much help to the species.

(5) Reaction : This is the most important stage in succession. Environmental conditions change or modify by the influence of established living organism which is called reaction. As a result of reactions, changes take place in soil, water, light conditions, temperature etc. of the environment. Due to all these, the environment is modified, becoming unsuitable for the existing community which sooner or later is replaced by another community (seral community). The whole sequence of communities that replaces one another in the given area is called `sere', and various communities constituting the sere, as seral communities, seral stages or developmental stages.

(6) Stabilization (Climax) : Finally, there occurs a stage in the process, when the final terminal community becomes more or lss stabilised for a longer period of time and maintains itself in equilibrium with the climate of the area. This final community is not replaced and is known as climax community and the stage as climax stage.

Sometimes due to changes in local conditions as soil characteristics or microclimate the process of succession becomes deflected in different directions from that presumed under climatic conditions of the area. Thus the climax communities are likely to be different from the presumed climatic climax community. This type of succession is called deflected succession.

• 2.4. SUCCESSION IN A POND

In a pond, primary autotrophic succession takes place through the general steps of succession in a sequence. Successive changes take place in plants as well as animal life. But as the changes are more obvious in plants than animals, it looks as it is a succession of plants only. Changes in plants are so obvious that we designate the different stages of succession on the basis of dominant plant types or species, which are as follows (Fig. 1).

(1) Phytoplankton stage : They are the pioneer communities such as blue-green algae, green algae, diotoms and bacteria etc. They are the primitive organisms which start development of the pond ecosystem.

(2) Rooted submerged stage : After some time, the dead matter of phytoplanktons and silt brought from the surrounding land by rain water and by wave action of pond water, become mixed and form a soft mud at the bottom of the pond. This new surface (bottom) becomes suitable for the growth of rooted submerged hydrophytes like Myriophyllum, Elodea, Hydrilla Potamogeton, Vallisneria, Utricularia etc. These plants bring about further build up of the substratum as a result of their death and decay. The water level also decreases making the pond shallower. This modified habitat provides the surface for growth of other types of plant community.

(3) Rooted floating stage : The new community of plants is rooted hydrophytes with their large leaves floating on the water surface. They colonise the habitat with their rhizomes. These are species of Nelumbo, Nymphaea, Limnanthemum, Apomogelon, Trapa, Monochoria etc. Some free floating species as Azolla, Lemna, Wolffia, Pistia, Spirodella, Salvinia etc. also become associated with the rooted plants due to availability of salts and other minerals in abundance. The water level further decreases with more build up substratum make floating species sooner or later disappear from the area.

(4) Reed-swamp stage : This sage is also known as amphibious stage as the plants are rooted in the pond but most part of their shoots remains exposed to air. Species of scirpus, Typha, Sagittaria and phragmites etc. are the main plants of this stage. The water level is by now very much reduced and finally becomes unsuitable for the growth of these smphibians species.

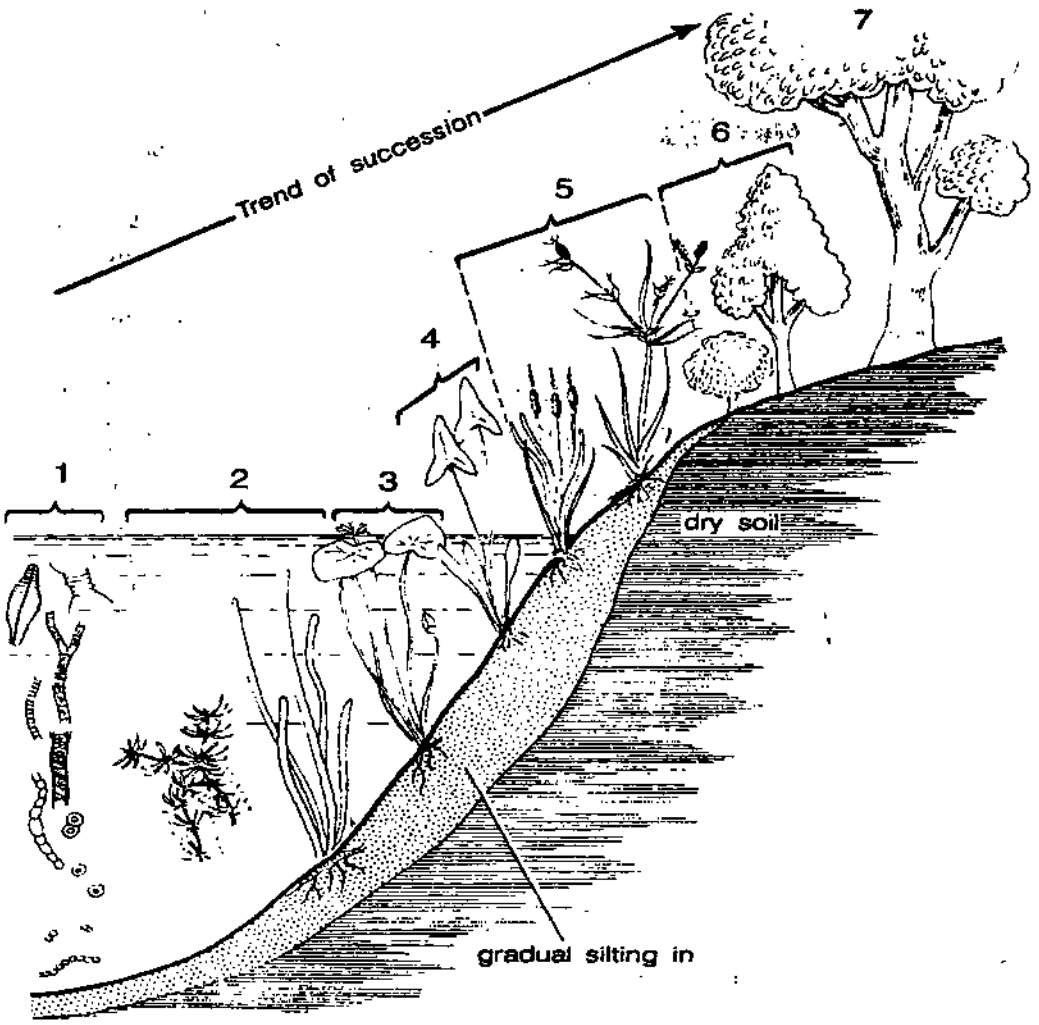


Fig 1. Diagram showing different plant communities appearing at different stages of a hydrosere originating in a pond. Note the gradual decrease in water level and successive development of the soil in area to give finally a terrestrial habitat for forest climax community. (1) phytoplankton stage (pioneer community); (2) rooted submerged stage; (3) rooted floating stage; (4) reed swamp stage; (5) sedge-meadow stage; (6) woodland stage; (7) forest stage (climax community)

(5) Sedge-meadow stage : Due to successive decrease in water level and further changes in the substratum, species of some cyperaceae and Gramineae such as Carex, Tuncus, Cyperus, and Eleocharis colonise the area. Their rhizomes spread into the mud : Due to high rate of transpiration the mud becomes soft land. By loosing water. the nutrients like NH_3 and sulphides etc. get oxidised to nitrates and sulphates. Thus the pond ecosystem gradually changes into terrestrial ecosystem.

(6) Woodland stage : After the death of marshy vegetation, the area is now invaded by the species of terrestrial plants like shrubs (Salix, Cornus) and trees (Populus, Alnus). By this time, there is much accumulation of humus with rich flora of microorganisms. Thus mineralisation of the soil favours the arrival of new tree species in the area.

(7) Forest stage : This is the climax community. Now the species of various trees start to invade the built up area. The growth of various species depnds upon the climatic conditions like light, temperature and rainfall. Thus in the hydrosere (Pond), stage 1 is the pioneer community, stage 7 is the climax community, and stage 2 to 6 are the seral communities (seral stages).

Changes in Communiy of Animals during Succession : With the ageing of a pond and the development of marshes, the animal life also undergoes changes. These are as follows :

(1) Protozoans : Various protozoans like paramecium, Amoeba, Euglena etc. are the pioneer species found in pond ecosystem. If planktonic growth is rich then fishes like blue gill fish, sun fish, large mouth bass etc. start to appear in the pond.

(2) Creeping animals : Over the submerged vegetation, the creeping animals like Asellas, Gammarus, Daphnia, Cypris, Cyclops, and some insects like dragon flies, maylflies etc. inhabit the pond.

(3) Animal life in floating stage : In this stage, various hydra species like gill breathing snails, frogs, salamanders, diving beetles and other insects are found to inhabit the pond.

(4) Animal life in reed-swamp stage : In this stage, animals of the floating stage start to be replaced by lung breathing snails like Lymnea, Physa and Gyraulus. Among insects water scorpion, giant water bug scavenger beetles etc. are present at this stage. The bottom of the pond is now inhabitated by some annelids, mud pickrel and bull heads. Red winged black birds, king fisher, great blue heron, swamp sparrow, ducks, musk rats, beaver's etc. become common in the area.

(5) Animal life in sedge-meadow stage : The animals like snails as Anodonta, Psidium etc. become common at this stage.

Finally, at the woodland stage, under terrestrial conditions most of the terrestrial forms of animal life appear in the area.

• 2.5. ENERGY FLOW IN ECOSYSTEM

To understand energy flow in ecosystem, first we will explain the following characteristic features of ecological energetics :

(i) Quantity of solar energy reaching an ecosystem per unit of area per unit of time.

(ii) Efficiency of the producers in absorption and conversion of solar energy.

(iii) The use of this converted chemical form of energy by the consumers of different trophic levels.

(iv) The total input of food energy and its efficiency of assimilation.

(v) The loss of energy through respiration heat, excretion etc.

(vi) The gross net production.

The flow of energy in any ecosystem follows the following principles :

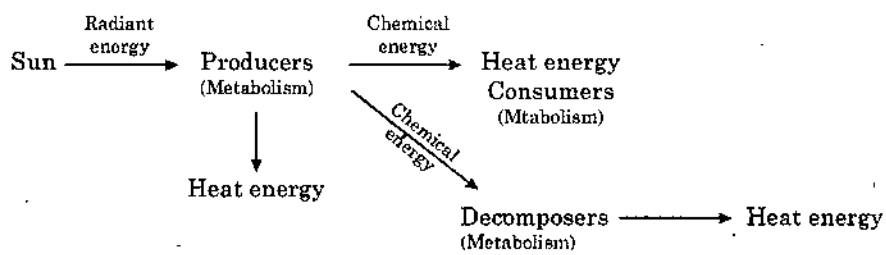


Fig. 2. Energy flow from Sun to all heterotrophic organisms through autotrophs.

(I) It is always unidirectional, *i.e.*, from autotrophs to heterotrophs.

(II) It follows always the rules of thermodyamics. The first law of thermodynamics states "Energy is conserved and can be transformed from one form to another". Autotrophs convert or transform the solar energy into chemical energy (food). The second law of thermodynamics states that no process (work) will occur without energy loss in the form of heat, no system is 100% efficient.

We will discuss the energy capture, energy use, energy loss, at each trophic level and transfer (flow) of energy from one trophic level to another under the following headings.

(1) Energy at autotrophic level : In any ecosystem, the autotrophs utilize only 0.1% of the total solar radiation coming to earth surface in production of food through the process of photosynthesis. From this bound energy (potential energy), they consume 21% of the energy in metabolic reactions like growth, development, maintenance and reproduction.

(2) Energy at first trophic level : At this level, consumers are herbivores which directly feed upon autotrophs. Only 17% of the net primary production (NPP) of the autotrophic level is available for consumption for herbivores. 3.4% of NPP is available for decomposers and the remaining 79.5% is not utilized at all but becomes part of the accumulating sediments. It is obvious, then that much more energy is available for herbivores than is consumed. It may also be noted that various pathways of loss are equivalent to and account for total energy capture of the autotrophs, *i.e.*, gross production (GP). The energy used by decomposers, herbivores and not utilized energy are equivalent to net production.

(3) Energy at carnivores trophic level : Only 28.6 percent of net production of herbivorous level is consumed by carnivores. This is more efficient utilization of resources than occurring at autotroph → herbivore transfer level. At the carnivore level

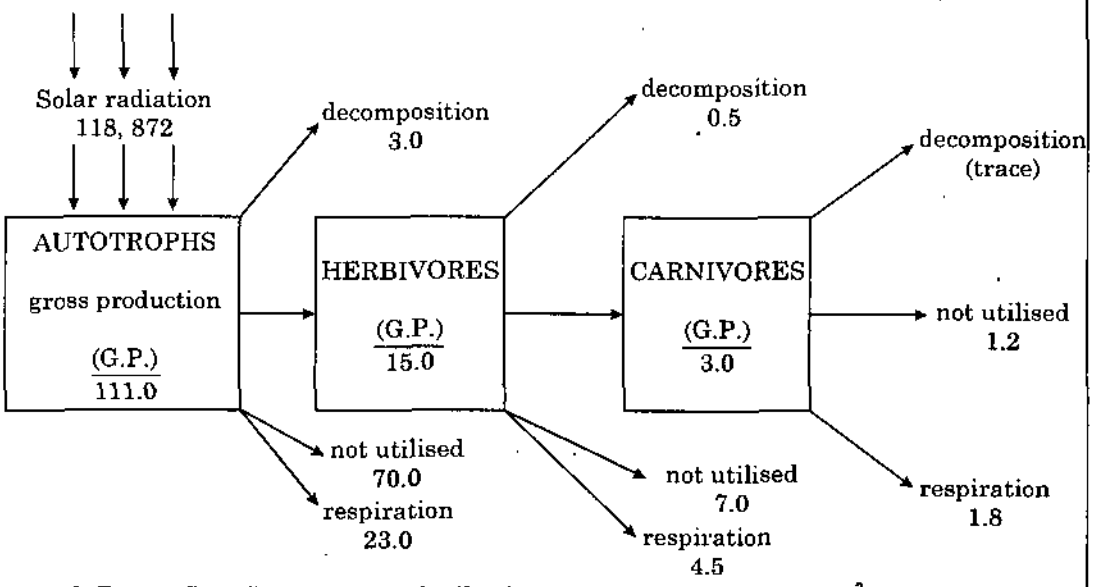


Fig. 3. Energy flow diagram for a lake (freshwater ecosystem) in g cal/cm²/yr (modified from Lindeman 1942)

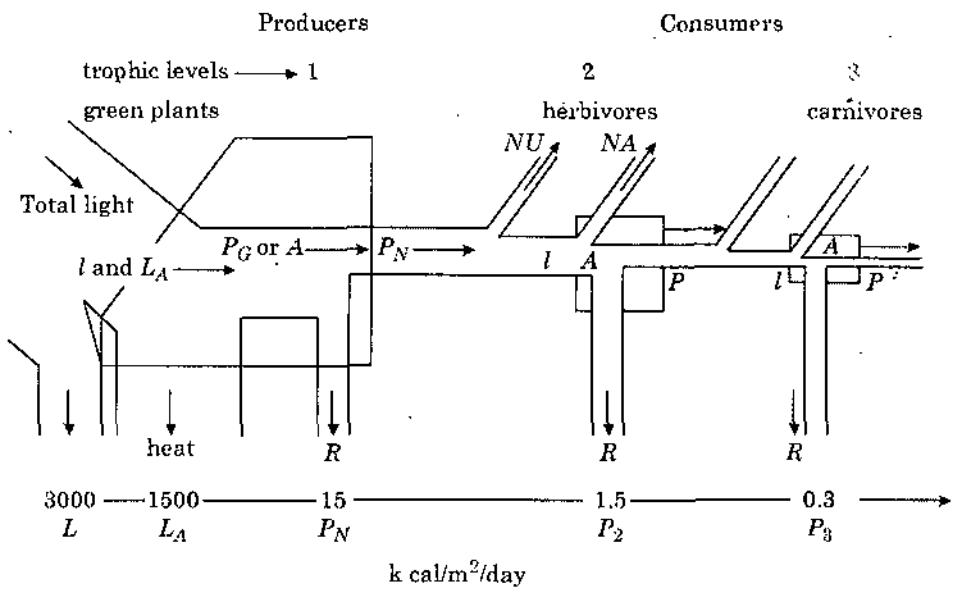


Fig. 4. A simplified energy flow diagram depicting three trophic levels (boxes numbered 1, 2, 3) in a linear food chain. I–total energy input; L_A – light absorbed by plant cover. PG – gross primary production; A – total assimilation; PN–net primary production; P–secondary (consumer) production; NU – energy not used (stored or exported); NA–energy not assimilated by consumers (egested); R–respiration Bottam line in the diagram shows the order of the magnitude of energy losses expected at major transfer points, starting with a solar input of 3,000 kcal per square meter per day. (After E.P. Odum, 1963).

about 60% of the carnivores energy intake is consumed in metabolic activity and the remainder becomes part of the not utilised sediments : only an insignificant amount is subject to decomposition. This 40% loss of energy can be compared with 30% by herbivores and 21% by autotrophs in this ecosystem.

In Fig. 3 and 4, the diagram of energy flow clearly shows unidirectional flow of energy and there occurs a progressive decrease in energy level at each trophic level.

In Fig. 4, the 'boxes' represent the trophic levels and the 'pipes' depicts the energy flow in and out of each level.

• SUMMARY

In any ecosystem, the composition of abiotic factors (environment) and biotic factors (species of plants and animals) never remain stable, but dynamic : Ecologycal development or succession accounts for the dynamicity of a ecosystem and can predict the prospectives of it. This process takes place in an order and results from modification of the physical environment by the community and vice-versa. Succession follows a general sequence of the steps starts from a bare area to climax. Succession can be different types as primary succession and secondary succession. On the basis of dominance, it can be autotrophic or heterotrophic succession. In a pond primary autotrophic succession occurs. Ecological energetics is the other aspect of an ecosystem which explains the energy flow from one trophic level to the other. Energy flow is always unidirectional and follows the rules of thermodynamics in an ecosystem.

Key words : Succession, dynamicity, climax, ecological energitics, trophic level, thermodynamcis.

• STUDENT ACTIVITY

1. Make a model of energy flow in any ecosystem.

• TEST YOURSELF

Short Answer Questions

1. What is succession ? Describe the causes, trends and basic types of succession.
2. Define succession. Give an account of general process of succession in nature.
3. Give an account of the sequential stages of a typical hydroscre (Pond).
4. What is ecosystem energetics. Describe the energy flow in a typical ecosystem.

Long Answer Questions

5. Describe the ecesis.
6. Describe the climax stage in pond ecosystem.
7. Write the kinds of ecological succession.
8. Write the characteristic features of ecological energetics.

Objective Quesitons

(1) Ecological succession takes place :
(a) suddenly (b) in a sequence of stages
(c) st once (d) none of these

(2) Reed – swamp stage in a pond is :
(a) floating stage (b) initial stage
(c) amphibious stage (d) none of these

(3) Planktons are :
(a) pioneer communities (b) climax communities
(c) seral communities (d) all of these

(4) Energy flow is :
(a) bidirectional (b) multidirectional
(c) unidirectional (d) all of these

(5) Sun is the :
(a) ultimate source of energy of an ecosystem
(b) one of the sources of radiation
(c) both of (a) and (b) (d) none of these

(6) Energy of a trophic level :
(a) always less from its precursive trophic level
(b) increases from its precursive level
(c) is equal to the precursive level
(d) none of the above

(7) Energy flow follows the rules of :
(a) chemical kinetics (b) thermodynamics
(c) mechanics (d) all of these

UNIT

3

ECOLOGICAL ADAPTATIONS IN ANIMALS

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Classification of animals on the basis of ecological adoptation :
  (i) Aquatic animals or hydrocoles.
  (ii) Passive or gliding type flight and active flight.
  (iii) Xerocoles.

3.1 INTRODUCTION

All living organisms react to the environmental conditions and this reaction leads to variations in their behaviour, morphology, anatomy and physiology. By the course of time, they undergo in a process of adjustments by which an organism accommodates itself to its environment. Such characters of the organism, which provide it with the capacity to tolerate the stresses of environment and allow it to utilize the environment to its maximum advantage are known as adaptations. Animals are classified into the following three categories on the basis of ecological adaptation :

(1) Aquatic adaptations
(2) Volant adaptations
(3) Desert adaptations

3.2 AQUATIC ADAPTATIONS

This kind of adaptations occur in those animals which live in water habitat viz. fresh, brackish or sea water. They are called aquatic animals or hydrocoles. On the basis of their phylogeny, they are either primary or secondary aquatic animals. Primary aquatic animals include protozoans, sponges, coelenterates, some annelids, molluscs and arthropods, echinoderms and chordates such as cephalochordates, urochordates, cyclostomes and fishes. Secondary aquatic animals includes some molluses (pila), amphibians, river turtles, crocodiles, some birds and some mammals.

(1) Primary Aquatic Adaptations

Body contour : The form of body depends upon the habits of life. The majority of fixed and partly sedentary forms have radially symmetrical body forms, *e.g.*, sponges, coelenterates, echinoderms etc. The active locomotor type have furiform, spindle-shaped elongated and worm like bodies. The spindle form is the characteristic of fishes and wavy, worm-like form is found in the annelids (Nereis).

Swimming organs : In protozoans and in coelenterates, there is no specialised organ found for active swimming. But in arthropods (prawn), annelids (heteronereis)

(Fig. 1) cephalopods (*Sepia, Octopus* and *Loligo*) and vertebrates, the specialized organs like parapodia, pleopods, fins etc. are found which facilitate active swimming.

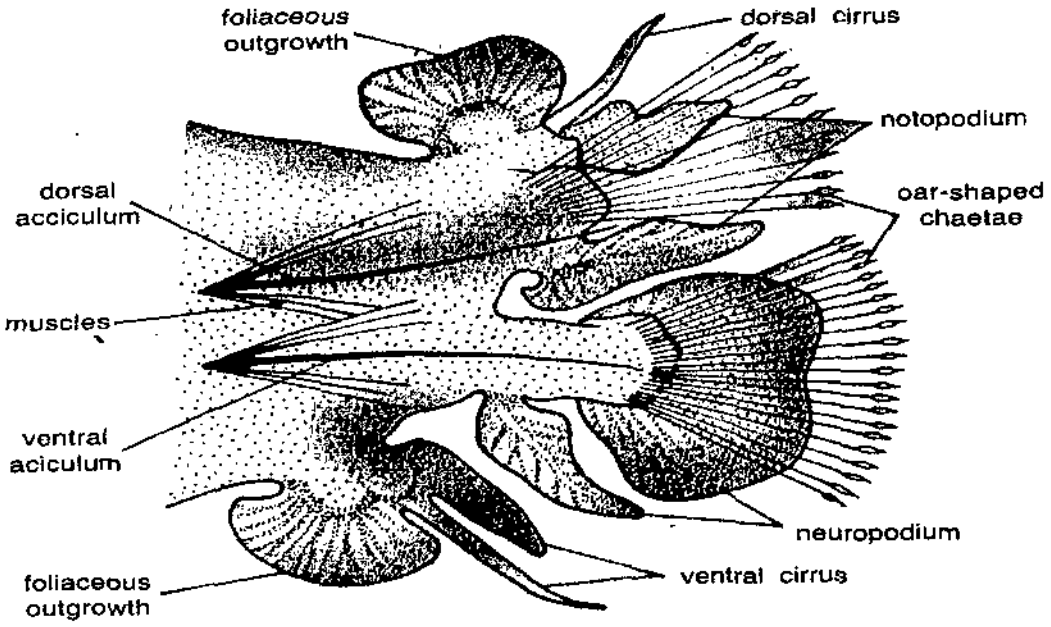


Fig. 1. Parapodium of *Heteronereis*.

Respiration : The exchange of respiratory gases takes place directly between blood and water outside in small animals. This kind of respiration takes place through general body surface. In large aquatic animals, special organs called branchia or gills are meant for respiration.

Air bladder : Advanced bony fishes contain air bladder (swim bladder) which serves as an accessory breathing organ and hydrostatic organ.

Lateral line sense organs : Fishes have lateral line system extending all over the body. It contains neuromost orgons which act as reheoreceptors.

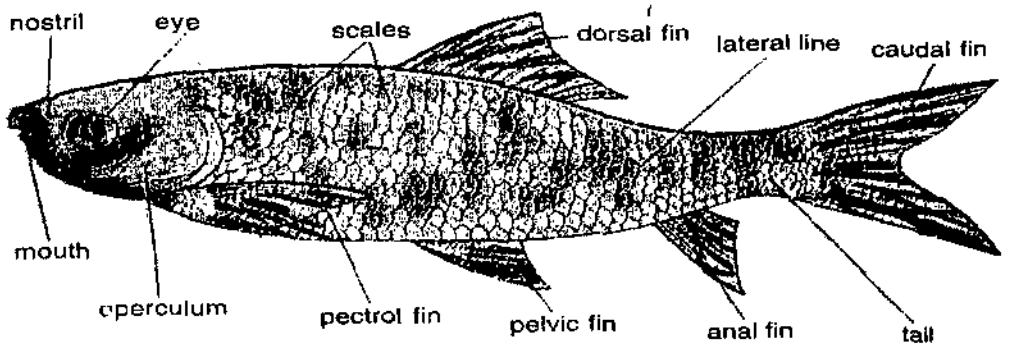


Fig. 2. *Labeo rohita*. A freshwater fish (called carp or rohu) of India.

Skin : Skin of fishes is rich in mucous glands and/or is protected with scales (Fig. 2).

(2) Secondary Aquatic Adaptations

Streamlined body : In these animals, the body shape is stream-lined like primary adapted forms. Neck constriction disappears and tail enlarges as in cetacea (*Whales, Dolphins*), sirenia (*Manatees* and *Dugongs*), pinnipedia (*Walrus* and *Seals*).

Enlargement of size : In these animals, the usual body size is large in comparison to terrestrial animals.

Submergence : All secondary aquatic animals need to develop capacity of submergence since swimming below water surface demands such an adaptation. For example, in whales the ribs are strongly arched, the lungs are massive, the external nostrils communicate with the median 'blow hole' which is closed.

Shortening of neck : There occurs reduction of length and mobility of neck.

Disappearance of external ears : In secondarily adapted aquatic animals, external ears (pinna) become disappeared as they cause hindrance in locomotion in water. Thus, ears are reduced in amphibious mammals and are lost in whales, tone seals and walruses.

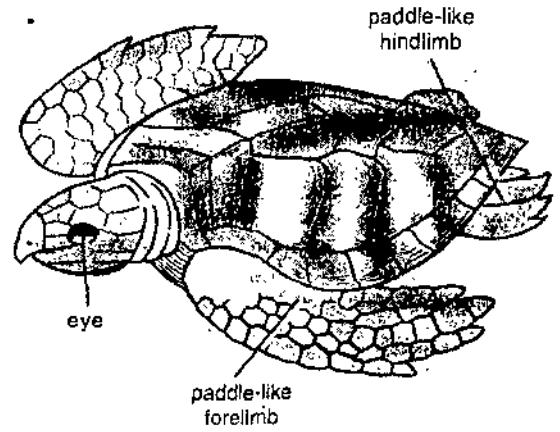


Fig. 3. Marine turtle hawks bill (*Chelone imbricata*)

Occurrence of locomotory paddles (fins) : In whales and ichthyosaurs, fleshy and fin like expansions of the body wall are found to help in propulsion. Pectoral paddles of whales and sirenians exhibit the following adaptations :

1. The restriction of movements corresponding to the elbow and wrist joints.
2. The fusion between digits.
3. Increase in the number of phalanges called hyperphalangy.
4. Increase in the number of digits for the increase of expanse of padding surface, called hyperdactyly.

Disappearance of hairs, skin glands, etc. : In whales and sirenians, the skin becomes naked due to loss of hairs. This loss is compensated by the formation of a fatty layer below the skin (blubber) for the retention of the body heat. The blubber also has a hydrostatic role (see fig. 4).

Mouth armament : The function of jaws in these animals is lost and teeth also become modified (homodont in dolphins) or absent.

Skull modification : In certain aquatic mammals (*e.g.*, dolphins, porpoises) the cranium is shortened and front part of the skull becomes elongated to acquire the shape of a rostrum.

Simplification of vertebrae : In these animals, the vertebrae tend to be simple with biconcave centra like the fishes. The articulation of vertebrae is also modified. The rib articulations are modified and are central *i.e.*, they are articulated to the centrum and are not articulated to the transverse process. Sacrum is also more or less reduced since it does not withstand and transmit the supporting impact of the hindlimbs as does in terrestrial forms.

Lightness of bones : The bones in aquatic forms are light and spongy. In whales, their interstices are filled with oil.

• VOLANT ADAPTATIONS

The volant adaptations are concerned with the flight. Volant adaptations must include modifications in the animals body for reducing the weight of the body and also for the formation of organs capable of executing flight. The flight may be of following two typs :

(1) Passive or gliding type flight : Gliding is characterised by leaping or jumping from a high point and held up by some sustaining organs, then to glide to lower level. Thus, there is no locomotive force

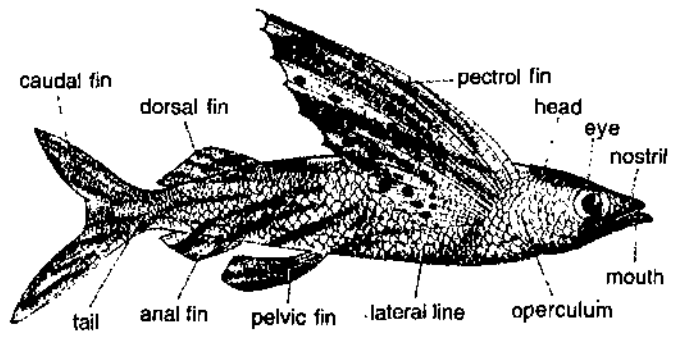


Fig. 4. *Exocoetus*.

other than gravity. Here the wings are made petazia which do not flap (*i.e.*, do not move up and down) by the muscular action (fig. 5). The gliding flights are performed by various lizards (Draco), fishes (exocoetus) (Fig. 4) birds (Ostriches), mammals such as flying phalangers (Fig. 6), flying squirrel (Fig. 7) and amphibians like rhacophorns (Fig. 8). All these forms are found to possess specialized organs meant for gliding. They can be patagia (skin folds) wings (pectoral fins modified) and webbing of feet.

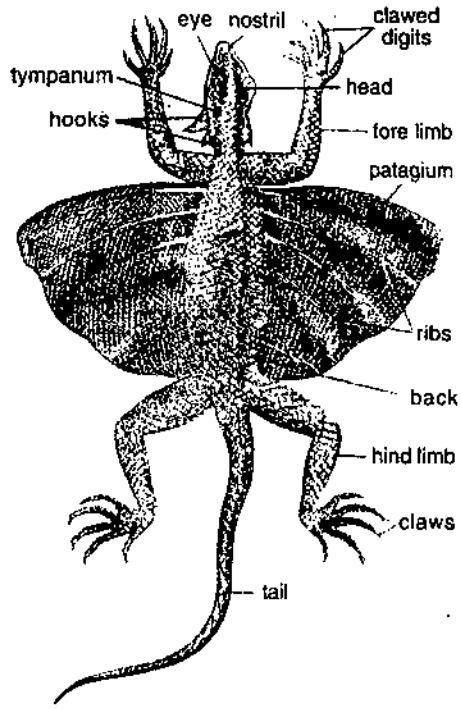


Fig. 5. Draco valans.

(2) Adaptations for active flying : It takes place by true wings or wings-like modification of certain organs. A variety of such modification are as folows :

Insect wings : In insects, the wings are made up of cuticle and are strengthened by thickenings, called veins. Typically, there are two pairs of wings developed on the dorsolateral sides of the *meso-* and *meta-*thoracic segments. The wing muscles are highly striated and are rich in mitochondria. The insect flight is affected by the flapping movement of the wings.

Bat wings : In bats, the fore limbs and hind limbs are modified into wings (Fig. 9).

Pterodactyl wing : In pterodactyl's wings, the radius and ulna bones are nearly equal. There is also present a pteroid bone which is directed towards the shoulder and is supposed to support the anterior margin of a prepatagium which lies in front of arm from the wrist to the neck (Fig. 10)

Bird wing : The wings of birds are most specialized of all modern wings. In a wing of bird, digits are reduced to three and these are fused together to help in flight (Fig. 11).

Other Volant Adaptations of Birds : Birds have the following adaptations for flight :

(1) Body contour : The streamlined body is spindle-shaped or boat shaped, encountering least aerial resistance and can easily be passed throuh the air. Thus the beak is pointed, head is compact, neck is long and mobile.

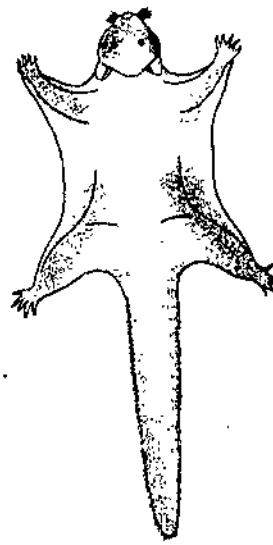
(2) Presence of feathers : The feathers forms the exoskeleton of birds. Birds' feathers are classified into quill feathers, contour feathers, down feathers and filoplumes. The presence of feathers on the wings facilitates their action and provides a sort of insulation for body.

(3) Wings : In birds, the forelimbs are modified into wings helping in flying. The hind limbs or legs are large and variously adapted for walking, running scratching, perching, food capturing and swimming.

(4) Pneumatization of bones : The bones of birds are hollow and airfilled. They also contain many air cavities. They also add buoyancy to the body during flight.

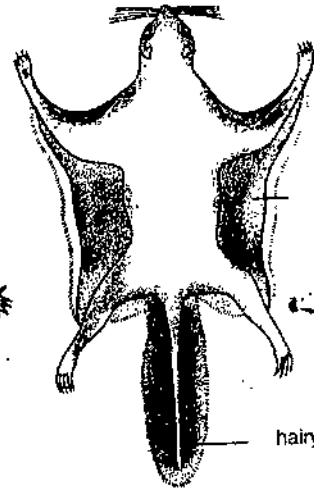
(5) Occurrence of flight muscles and keeled sternum : Different kinds of flight muscles, which connect the wings with limb bones are found to facilitate flight in the birds. Each wing is depressed or lowered by an enormous muscle called pectoralis major. It is elevated or raised by pectoralis minor. The sternum or breast bone is well developed and bears a median keel or carina for the attachment of pectoralis muscles.

(6) Air sacs in the body : Air sacs are found in the body of birds which help in respiration and serve as balloons to provide lightness and buoyancy to the body. Air sacs also help in internal perspiration to regulate the body temperature.



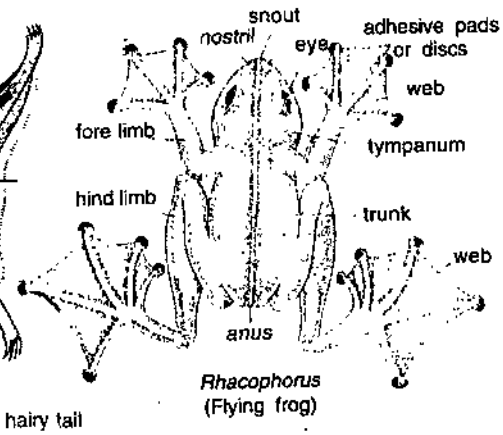
Petaurus
(Flying phalanger)

Fig. 6



Sciuropterus
(flying squirrel)

Fig. 7



Rhacophorus
(Flying frog)

Fig. 8

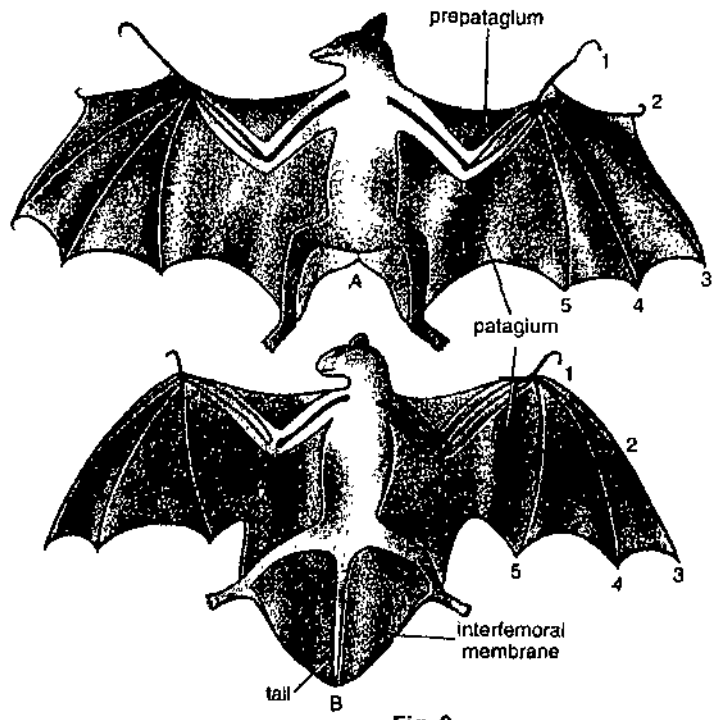
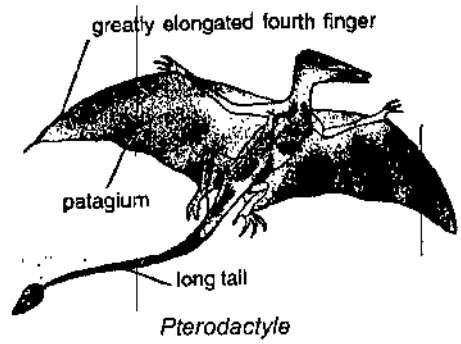


Fig. 9



Pterodactyle

Fig. 10

(7) Brain and sense organs' specificity : In bird's cerebrum and optic lobes are well developed and olfactory lobes are reduced. Bird's, eyes are large and bear

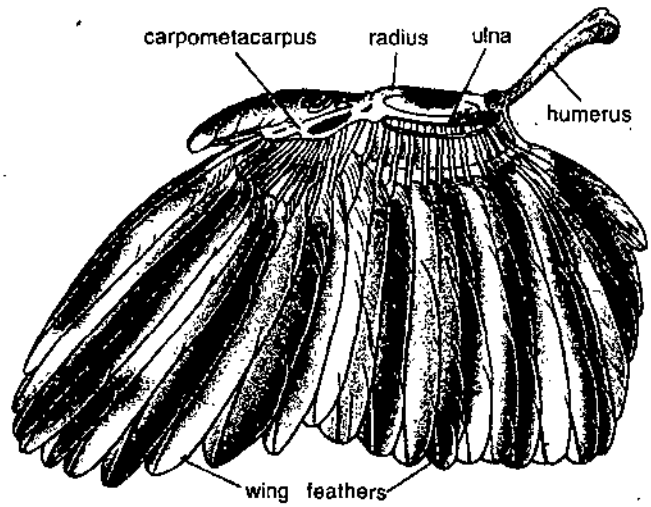


Fig. 11. Wing of pheasant, showing the two "bastard quills" (afetr Lull, 1957)

characteristic sclerotic plates to resist variable air pressure. Eyes also contain pectens for accomodation of sight.

(8) Beak : The horny beak compensates the function of forelimbs in the birds.

(9) Single ovary : In order to reduce the weight of the body, only a single functional ovary is present in the birds.

(10) Absence of urinary bladder : Birds are urecotelic and excrete semisolid wastes. They don't have urinary bladder which again adds in reduction of body weight (Fig. 12).

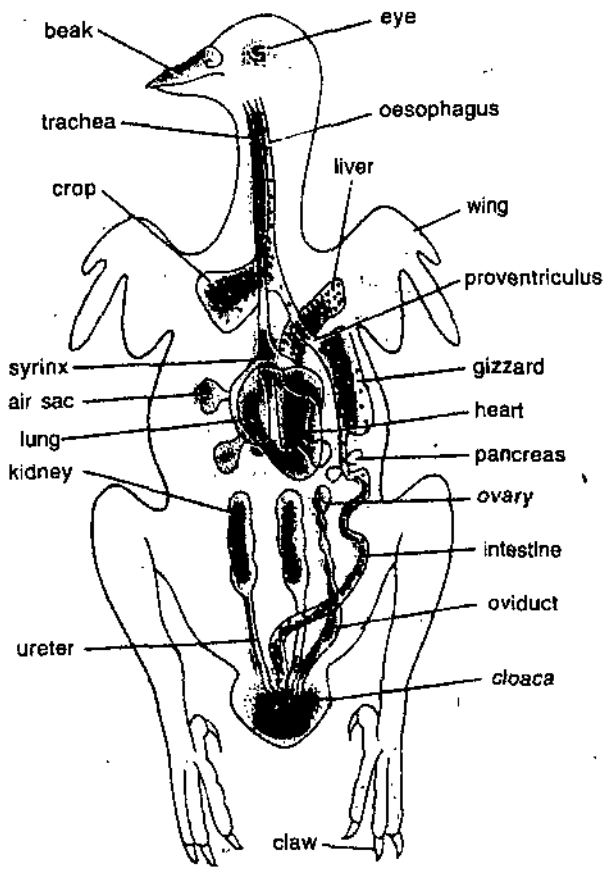


Fig. 12. Various volant adaptations of a female bird.

• DESERT ADAPTATIONS

In deserts, animals (Xerocoles) generally possess all kind of adaptation in order to combat heat and scarcity of water. The chief adaptations are as follows :

(1) Moisture getting : In the desert, animals are adapted in a variety of ways in order to collect the little amount of water, wherever it is available. The skin of sand lizards absorbs rain water like a blotting paper. Its skin is spiny which checks perspiration (Fig. 13). A few animals like rabbit, tortoise and wood rat eat succulent plants to fulfil their water needs. Carnivorous animals feed on their prey for food and water.

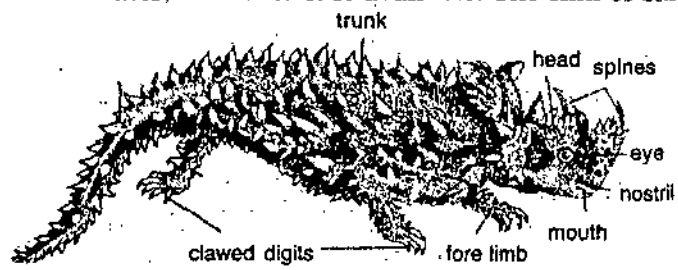


Fig. 13.

(2) Moisture conservation : Desert animals are very much adapted in order to conserve the available moisture in the body. These adaptations are as follows :

(a) Camel can drink water in bulk in a single gulp, upto 50 litres. Camel excretes highly concentrated urine and dung. It perspires very little and its breathing rhythm is very slow.

(b) Some animals like horned toad have hard and rough skin and Moloch has scales and spines all over the body surface.

(c) Uromastix (desert lizard) stores water in large intestine.

(d) Desert insects have wax proof skin.

(e) To conserve water, desert animals remain in burrows during day time and come outside during night.

(3) Self defence against scorching sun : Desert animals protect themselves from extreme heat of deserts in the following ways :

(a) In burrowing reptiles, the nostrils are directed upward instead of forward.

(b) The eyes of Typhlops are overhung by the sheath.

(c) In lizard Mabya, the lower lip becomes enlarged with a transparent window in it.

(d) The ear opening of desert animals is eithr small or protected by fringes or scales or they may be abolished.

• SUMMARY

All living organisms interact with environmental conditions and modify to their morphology, behaviour, physiology and anatomy in order to be best suited in the environment. These modifications are called ecological adaptations. According to kind of prominent habitats, the adaptations are also of three kinds – Aquatic, Volant and Desert adaptations. In aquatic environment, animals possess various kinds of morphological adaptations in body shape, size, presence of different kinds of fins. Gill are specialized organs for respiration. In volant adaptations, animals show different kinds of flight adaptations. The desert environment is characterized by the heat and scarcity of water. Desert animals possess various kinds of adaptations in order to obtain much water, to conserve water and to combat the scorching heat of the sun.

Keywords : Adaptation, habitat, aquatic, volant, desert, scarcity.

• STUDENT ACTIVITY

1. Make a model of desert habitat and desert animals to show desert adaptations.

• TEST YOURSELF

Long Answer Type Questions :

1. Write an account of primary aquatic adaptations.
2. What is adaptation ? Give an account of volant adaptation.
3. Give an account of desert adaptations.
4. What are primarily aquatic animals.
5. What are secondarily aquatic animals.
6. Write a short note on patagia.
7. Write a short note on wings of birds.

Objective Type Questions :

1. Fishes are :
   (a) primary aquatic (b) secondary aquatic
   (c) first primary and then secondary (d) none of these
2. Air bladder helps in :
   (a) respiration (b) hydrostatic balance
   (c) both of (a) and (b) (d) none of these
3. Locomotory paddle fins are found in :
   (a) whales (b) fishes
   (c) star fish (d) birds
4. Blubber is found in :
   (a) reptiles (b) fishes
   (c) whale (d) none of these
5. The absence of pinna in aquatic mammals is :
   (a) adaptation (b) loss by an accident
   (c) they are absent in mammals (d) none of these
6. Gliding flight is found in :
   (a) draco (b) excocoetus
   (c) ostriches (d) all of these
7. Pectoralis major is a :
   (a) flight muscle (b) tendous
   (c) leg muscle (d) chest muscle

Ans. **1.** (a) **2.** (c) **3.** (a) **4.** (c) **5.** (a) **6.** (d) **7.** (a)

UNIT

4

BIOGEOCHEMICAL CYCLES

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Water cycle : global water or hydrological.
- Oxygen cycle, carbon cycle and nitrogen cycle.
- Biological fixation and physical fixation of N_2.
- Nitrogen fixation from organic matter.
- Sulphur cycle and phosphorus cycle.

• 4.1 INTRODUCTION

According to Vernadsky (1934), the cyclic movemnts of chemical elements of the biosphere between the organism and the environment are referred to as "bio-geochemical cycles". The atoms of each element such as carbon, hydrogen, oxygen nitrogen, phosphorus, calcium and the rest are taken from the environment, made a part of several other organisms, are returned to the environment to be used over again. In biogeochemical word 'Bio' refers to living organisms and 'geo' to the rocks, soil, air, and water of the earth.

These chemical elements move through the food chain of ecosystem and constitute the organic phase of the biogeochemical cycle. The second phase of cycle is abiotic which is again divided into sedimentary phase and an atmospheric phase. The abiotic phase of the cycle consists of soil, water and air which act as natural reservoir of these elements. In some cycles such as nitrogen, the atmospheric phase is more important than the sedimentary. In others, such as phosphorus the atmospheric phase is essentially non-existent. In still others, such as sulphur, both phases are present and their relative importance depends on other environmental factors. Bio-geographic cycles that have dominant atmospheric phases are often called atmosphere reservoir cycles; those whose sedimentary phase is dominant are termed as sediment reservoir cycles.

• 4.2. TYPES OF BIOGEOCHEMICAL CYCLES

There are two types of biogeochemical cycles, the gaseous and the sedimentary. In gaseous cycles, the main reservoir of nutrients is the atmosphere and the ocean. In sedimentary cycles, the main reservoir is the soil and the sedimentary and other rocks of the earths crust. Both involve biotic and abiotic agents, both are driven by the flow of energy and both are tied to the water cycle.

• 4.3. WATER CYCLE

Water cycle or hydrologic cycle is maintained by living organisms atmosphere and earth. Water forms an important component of both environment and living organisms of an ecosystem. The hydrologic cycle is deriven by solar energy and gravity. From all the water bodies of the earth and the oceans, water evaporates continuously due to solar energy. The atmospheric water vapour produced by this means can then condense around particles of dust in the air, often called nucleation particles. The atmosphere has a limited capacity for holding water vapour, this causes the precipitation under the influence of gravity. Eventually, the hydrologic cycle can be defined as an alternation of evaporation and precipitation, with the energy used to evaporate the water being dissipated as heat in the atmosphere as the water condenses (Fig. 1).

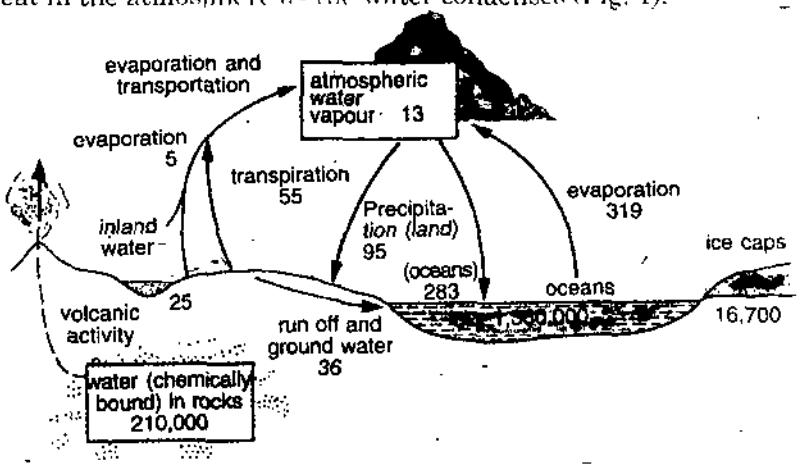


Fig. 1. Global water or hydrological cycle. Most of the storage of water is as the oceans but most of the flux is to and from the atmosphere unit stores, 10^{18} g : fluxes, 10^{18} g.

Almost 95% of the total water is present in chemically bounded forms into the rocks and does not cycle. Of the remaining 5%, about 97.3% is present in oceans, about 21% in the form of ice and the rest is fresh water on the earth surface.

The hydrologic cycle on land, thus includes evaporation of water from earth's surface and leaf surface → formation of clouds → precipitation → surface runoff + accumulation of water as ground water → return of water to sea via direct evaporation and cloud formation and so on.

• 4.4. GASEOUS CYCLES

(1) The Oxygen Cycle : The cycling of oxygen is very complex. It circulates in the biosphere in the form of CO_2 freely. In other forms, oxygen combines with nitrogen compounds to form nitrates, with iron to ferric oxides and with many other minerals to form various other oxides. In these states, oxygen goes out of circulation temporarily. The major supply of free oxygen which suports life occurs in the atmosphere. Two sources of atmospheric oxygen are photodissociation of water vapours and photosynthesis. The major utilization of atmospheric oxygen is respiration by all the living beings. The photosynthesis and respiration are cyclic and keep the quantity of oxygen in balance in the atmosphere.

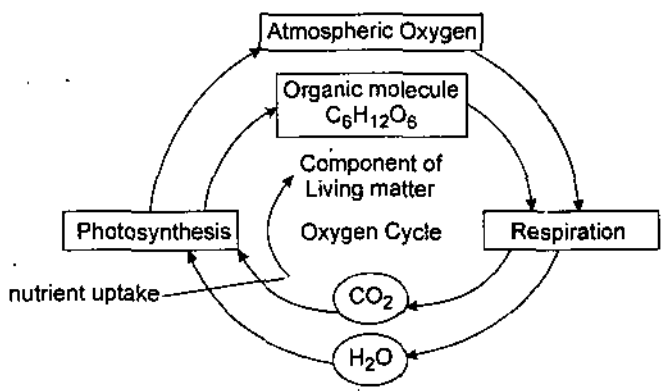


Fig. 2. The Oxygen Cycle.

(2) The Carbon Cycle : The CO_2 is the basic constituent of organic compounds and major element of photosynthesis. All the green plants fix atmospheric CO_2 in the form

of carbohydrates, that subsequently may be converted in other organic compounds such as polysaccharides, proteins and lipids. This fixed form of CO_2 (food) travels along with the food chain of the ecosystem. Plants and animals release some of CO_2 back into atmosphere through respiration.

$$\frac{1}{6} C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{Energy}$$

The released CO_2 as a by-product of plant and animal respiration is again used by plants in photosynthesis. This is the basic carbon cycle which is simple and complete. The stored organic compounds in the body of plants and animals undergo decomposition on death. Decomposers break down dead material with the release of carbon back into the carbon cycle. In atmosphere, its presence is 0.03% only (Fig. 3).

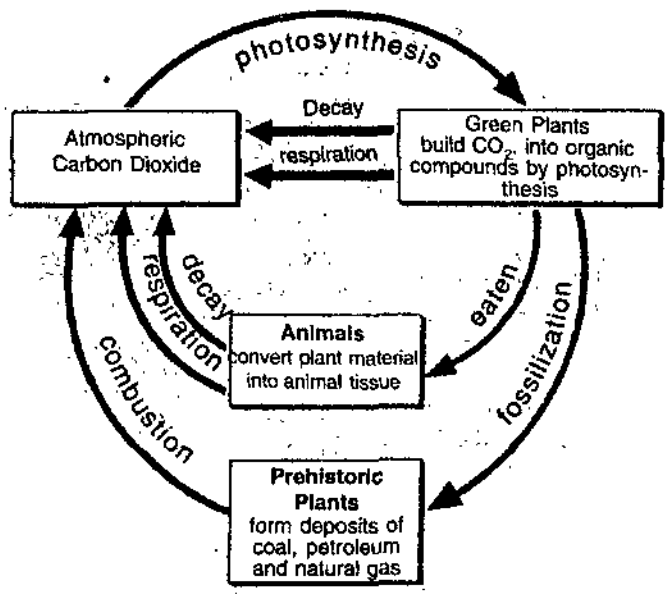


Fig. 3. The carbon cycle

(3) The Nitrogen Cycle : Nitrogn is an essential constituent of different biological significant organic molecules such as amino acids and proteins pigments, nucleic acids and vitamins. It is also the major constituent of the atmosphere comprising about 79% of it.

The molecular N_2 however, is present in plenty amount in the atmosphere but is unavailable to the living organisms. To be used biologically, the free molecular nitrogen has to be fixed and fixation requires an input of energy. It takes place in two ways :

(I) Physical fixation of N_2 : This process needs high-energy which is obtained from cosmic radiation meteorite trails, and lightining. In the first step, molecular nitrogen (N_2) splits into two atoms $N_2 \rightarrow 2N$. This free reactive nitrogen then reacts with hydrogen and oxygen to form ammonia and nitrates.

$$2N + 3H_2 \xrightarrow{\text{High energy}} 2NH_3$$

$$2N + 3O_2 \xrightarrow{\Delta + E} 2NO_3$$

This fixation takes place in the air and resulting ammonia and nitrates are carried to the earth with rain water.

(a) Deamination : The amino group ($-NH_2$) is liberated from organic molecules to form ammonia, which is called deamination.

(b) Nitrification : Certain specific bacteria, most notably of the genus nitrosomonas can oxidize ammonia to nitrites (NO_2) by the reaction :

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 2H^+$$

This reaction takes place in the soil, in lake or sea water or sediments. As fast as nitrite is produced, other bacteria nitrobacter can combine nitrite with oxygen to form nitrate (NO_3) by the reaction :

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

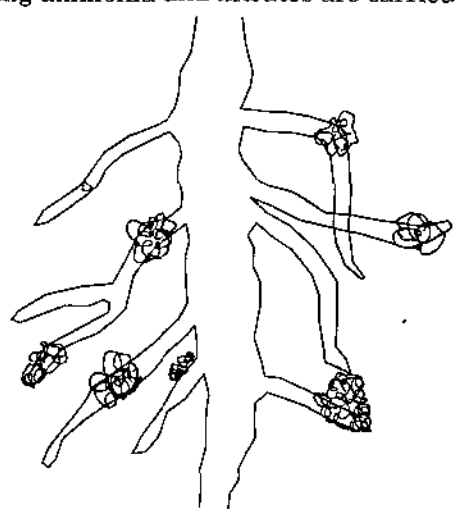


Fig. 3. Root nodules of a legume plant

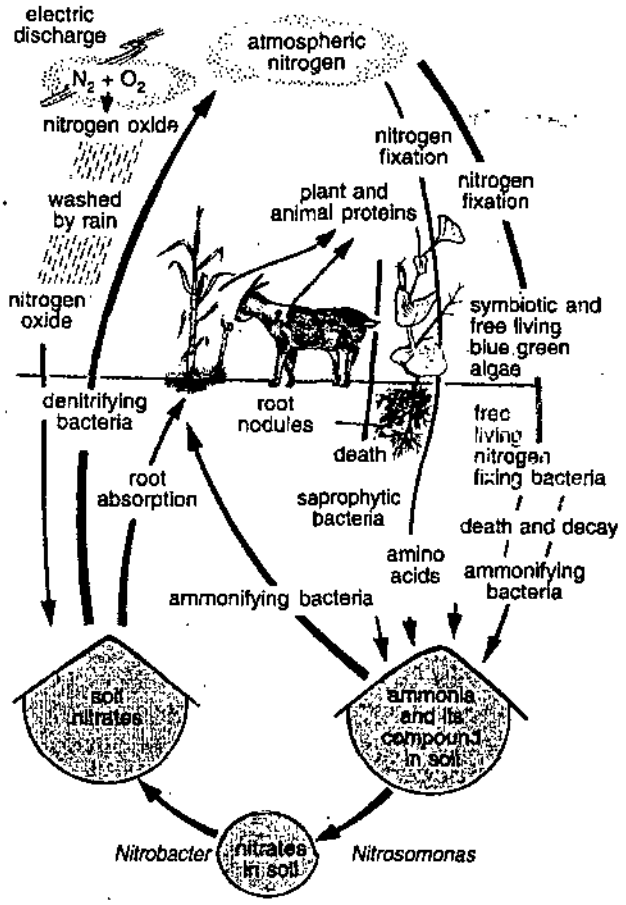


Fig. 4. The nitrogen cycle.

Both of these reactions are called nitrification. Finally nitrates are taken up by the autotrophs at the beginning of food chain.

(II) Biological fixation of N_2 : This method contributes about 90% of fixed nitrogen of earth. Some bacteria; fungi and blue green algae can extract molecular nitrogen from the atmosphere and combine it with hydrogen to form ammonia. The nitrogen fixing bacteria free living in the soil viz., Azotobacter and clostridium, blue-green algae free living in water viz., Nostoc, Calothrix and Anabaena fix atmospheric nitrogen in nitrates. Other symbiotic bacteria viz., Rhizobium live in the roots of legumes, and other angiosperms also fix atmospheric N_2 (Fig. 4).

Recently, certain lichens (collematunaeforme, and Peltigera rufescens) are also found to play a role in N_2 fixation (Henriksson, 1971). Lichens with nitrogen fixing ability possess nitrogen fixing blue green species as their algal component.

Nitrogen fixation from organic matter : The nitrogenous wastes and carrion of animals are degraded by the detritus organisms. It takes place in the following steps :

Denitrification : Under certain circumstances, nitrates are either not produced in the nitrogen cycle or it is degraded before it can be utilized by autotrophs. Degradation of nitrates is called denitrification and may be important when oxygen concentration is low. Denitrifying bacteria such as Pseudomonas can use the energy of the nitrate ion to derive their metabolism, and in so doing, they break the nitrate down to nitrite, ammonia or molecular nitrogen.

$$C_6H_{12}O_6 + 12NO_3^- \rightarrow 12NO_2 + 6CO_2 + 6H_2O$$

$$C_6H_{12}O_6 + 8NO_2^- \rightarrow 4N_2 + 2CO_2 + 4CO_3 + 6H_2O$$

$$C_6H_{12}O_6 + 3NO_2^- \rightarrow 3NH_3 + 6CO_2 + 3OH^-$$

If denitrification is significant in an ecosystem, nitrite is transitory and is also degraded into either ammonia or molecular nitrogen.

Cycling of Nitrogen in the Ecosystem : The sources of inputs of nitrogen under natural conditions are the bacterial, and physical fixation of the atmospheric nitrogen. In terrestrial ecosystem, nitrogen, largely in the form of ammonia and nitrate is taken up by plants, which convert it into amino acids and proteins. Animals eat the plants and utilize the amino acid from the plant proteins in the synthesis of their own proteins and other cellular constituents. the excreta of animals and dead matter of plants and animals undergo the process of deamination nitrification and denitrification to release back the molecular N_2 into the atmosphere. Thus, this fixation and denitrification process constitute a dynamic equilibrium system in the ecosystem Fig. (4).

• 4.5. SEDIMENTARY CYCLES

Sedimentary cycles involving mineral cycles vary from one element to another, but essentially it consists of two phases the salt-solution phase and the rock phase.

The living organisms of the ecosystems, fulfil their mineral requirements from mineral solutions in their environment. Other animals acquire the bulk of their minerals from plants and animals they consume. After the death of living organisms, the minerals are returned to the soil and water through the action of the organisms and process of decay. There are different kinds of sedimentary cycles depending on the kinds of elements but following two cycles are very significant for an ecosystem.

(1) Sulphur Cycle : Sulphur, like nitrogen, is an essential part of proteins and amino acids and is characteristic of organic compounds. It exists in a number of states like elemental sulphur 'S', sulphides, sulphur monoxide, sulphite and sulphates. Of these three are important in nature — elemental sulphur, sulphides and sulphates. The sulphur cycle involves both sedimentary and gaseous phases. The gaseous (atmospheric) phase of sulphur cycle is less pronounced and it permits circulation on the global scale.

Sulphur enters the atmosphere from several sources — the combustion of fossil fuels, volcanic erruptions, the surface of the oceans and gases released by decomposition. Initially, sulphur enters in the atmsophere as H_2S, hydrogen sulphide, which quickly converts into SO_2, a volatile form of sulphur dioxide. This atmospheric SO_2 soluble in water is carried back to earth in rainwater as weak sulphuric acid,

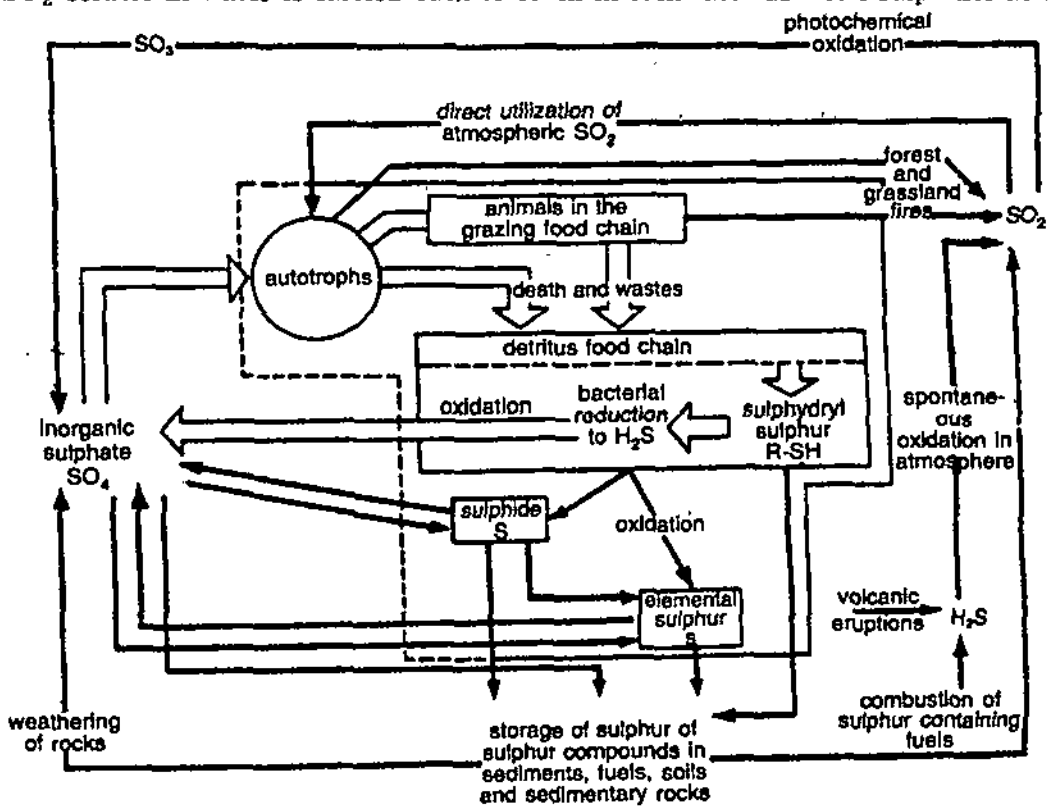


Fig. 5. Sulphur cycle.

H_2SO_4. In this soluble form, plants absorb the sulphur to incorporate into certain organic molecules, such as proteins. From the producers, it is transferred to the consumer animals, with excess being excreted in the faeces.

Excretion and death of living beings carry sulphur back to the soil and to the bottom of ponds, lakes and seas. The dead matter and excreta is acted upon by bacteria of detritus food chain. In the process of decomposition, bounded sulphur dissociate from the organic componunds and converts into H_2S. In an aerobic environment, the H_2S is oxidized to sulphates by bacteria specially adapted to perform this conversion.

$$H_2S + 2O_2 \rightarrow SO_4^{--} + 2H^+$$

This sulphate can be reused by the autotrophs. In anaerobic condition, in the presence of infrared radiation, some photosynthetic bacteria use H_2S to produce carbohydrates and oxidize sulphide either to elemental sulphur or to sulphate

$$6CO_2 + 12H_2S + h\nu \rightarrow C_6H_{12}O_6 + 6H_2O + 12S$$

$$6CO_2 + 12H_2O + 3H_2S + h\nu \rightarrow C_6H_{12}O_6 + 6H_2O + 3SO_4^{--} + 6H^+$$

Elemental sulphur can also be utilized by other bacteria to form sulphate. If oxygen is present, the reaction is rapid.

$$2S + 3O_2 + 2H_2O \rightarrow 2SO_4^{--} + 4H^+$$

In presence of nitrates, it is oxidised as :

$$6NO_3^- + 5S + 2CaCO_3 \rightarrow 3SO_4^{--} + 2CaSO_4 + 2CO_2 + 3N_2$$

Fig. 5 shows the sulphur cycle in the ecosystem.

(2) Phosphorus Cycle : Phosphorus cycle has no atmospheric phase. It occurs naturally in environment as phosphate either as soluble inorganic phosphate ions, as soluble organic phosphate, as particulate phosphate or as mineral phosphate.

The ultimate source of phosphate in the ecosystem is crystalline rocks. As these are eroded phosphate is made available to living organisms, generally as ionic phosphates. Autotrophs absorb it through roots and incorporate into organic food. this food transfers to the consumers through the food chain in the same fashion as in nitrogen and sulphur.

In the detritus food chain, the phosphate is released back into the soil in the form of inorganic ionic phosphate. Plants reuse it or it can be sedimented into the soil or bottom of the aquatic ecosystem. The phosphorus cycle is depicted in the fig. 6.

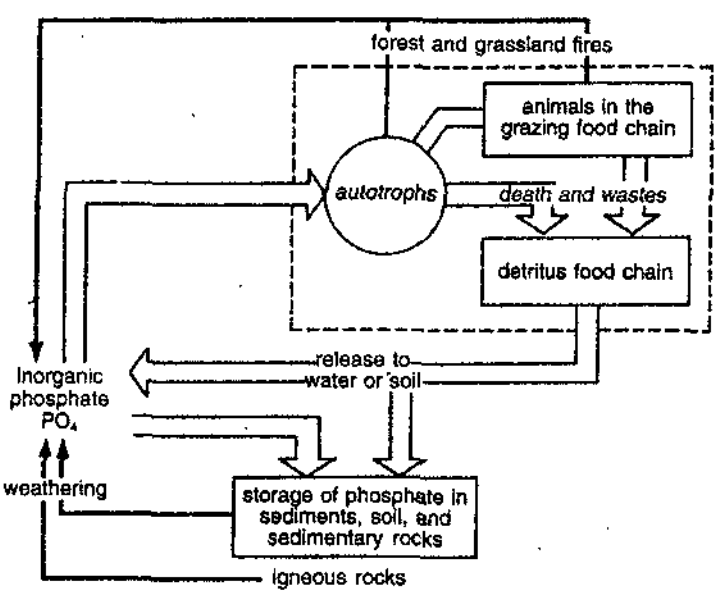


Fig. 6. Phosphorus cycle.

Thus the biogeochemical cycles of different gases and elements are closed and sustain themselves in a cyclic manner. To keep the cycles go on, the new matter is not

required but it does require energy, for the energy cycle is not closed. The source of energy (Sun) is external to the ecosystem and its flow is unidirectional. Chemical substances, on the other hand, are finite and have their origin inside the ecosystem, thus they must continuously cycle within the system.

• SUMMARY

In 'biogeochemical' word 'Bio' refers to the living organisms and 'geo' refers to the rocks, soil, air, and water of the earth, chemical means chemical elements. This cycle is the backbone for the dynamicity of an ecosystem. Biogeochemical cycles have two phases — one is biotic phase in which chemical elements move through the food chain of ecosystem and another one is abiotic phase consisting of sedimetary and atmospheric phases soil, water and air, the components of abiotic phase are natural reservoirs of these elements. Various types of biogeochemical cycles such as — water cycle, oxygen cycle, carbon cycle, sulphur cycle, phosphorus and nitrogen cycle etc. are the important cycles which operate side by side in an ecosystem. All the biogeochemical cycles are closed and sustain themselves in a cyclic manner. The continuous operation of these cycles requires energy from an external source (Sun) and the flow of energy within the ecosystem is unidirectional.

Keywords : Biogeochemical, elements, sedentary, ecosystem.

• STUDENT ACTIVITY

1. Make a model of global water or hydrological cycle.

• TEST YOURSELF

Long Answer Questions :

1. What are biogeochemical cycles ? What role do they play in the ecosystem ?
2. Describe nitrogen cycle with suitable examples.
3. Describe phosphorus cycle of an ecosystem.

Short Answer Questions

4. What is carbon cycle ?
5. Wha is water cycle ?
6. What is sedimentary biogeochemical cycles ?
7. What is gaseous biogeochemical cycles ?

Objective Questions

1. The percentage of chemically bound water is :
   (a) 95% (b) 97% (c) 5% (d) 2%
2. Plants absorb nitrogen in the form of :
   (a) nitrites (b) Nitrates (c) molecular nitrogen (d) ammonia

3. Nitrification involves :
   (a) Formation of nitrates (b) Formation of nitrites
   (c) Both of (a) and (b) (d) None of these
4. Plants absorb sulphur in the form of :
   (a) sulphates (b) sulphides
   (c) hydrogen sulphide (d) sulphur
5. Biogeochemical cycles are :
   (a) closed & self sustainable (b) unidirectional and dependent
   (c) bidirectional (d) none of these
6. Symbiotic bacteria are :
   (a) nitrosomonas (b) nitrobactor
   (c) azotobactor (d) rhizobium
7. Rhizobium in root nodules of legume plants fix :
   (a) armospheric N_2 (b) sedentary N_2
   (c) soil nitrites (d) soil nitrates

Ans. **1.** (a) **2.** (b) **3.** (c) **4.** (a) **5.** (a) **6.** (d) **7.** (a)

UNIT

5

ENVIRONMENTAL POLLUTION

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- *Air pollution : Composition of air, measures of air quality and sources of air pollution like* SO_2, CO, NO, O_3, flurocarbons, hydrocarbons, ammonia, fluorides; lead, zinc, mercury etc.
- Global ecological problems : green house effect, acid rain , hole in ozone layer, aerosols.
- Water pollution, ecological effects of water pollution, sewage pollution, BOD test, industrial pollution, thermal pollution, silt pollution.
- Biomagnification, marine pollution, reutilization and recycling of waste, land pollution, radioactive pollution, noise pollution.
- Prevention and control of pollutions.

5.1. INTRODUCTION

Environmental pollution has been rising as a world issue and attracts attention on the global level. Most of the countries are facing pollution as an ecological crisis. Pollution is an undesirable change in the physical, chemical or biological characteristics of our air, land and water that may or will harmfully affect human life or that of desirable species, our industrial processess, living conditions and cultural assets(Odom, 1971). In other words, pollution is the unfavourable alteration of our environment, largely as a result of human activities (Southwick, 1976).

Any substance which causes pollution is called a pollutant. A pollutant may thus include any chemical or geochemical (dust, sediment, grit etc.) substance, biotic component or its product, or physical factor (heat) that is released intentionally by man into the environment in such a concentration that may have adverse harmful or unpleasent efects. A pollutant has also been defined as "any solid, liquid or gaseous substance present in such concentration as may be or tend to be injurious to the environment.

5.2. ENVIRONMENTAL POLLUTANTS

There is a variety of principal pollutants which pollute our air, water and land. These are as follows :

- **Deposited matter :** smoke, tar, dust, grit etc.
- **Gases :** Oxides of nitrogen (NO, NO_2) sulphite (SO_2), carbon monoxide, halogen etc.
- **Acid droplets :** Sulphuric acid, nitric acid etc.
- **Aluorides**
- **Metals :** Mercury, lead, iron, zinc, nickel, tin, cadmium, chromium etc.
- **Agrochemicals :** Various kinds of pesticides and fertilizers.

- **Complex organic compounds :** Benzene, ether, benzpyrens etc.
- **Photochemical oxidants :** Photochemical smog, ozone, peroxyacetyl nitrate (PAN), peroxybenzoil nitrate (PB_2N), nitrogen oxides, aldehydes, ethylene etc.
- **Solid wastes**
- **Radioactive waste**
- **Noise**

• 5.3. KINDS OF POLLUTION

Various types of pollution are classified in different ways. On the basis of the type of environment being polluted, we may recognise air pollution, water pollution, land pollution, marine pollution etc. However on the basis of the kind of pollutant involved, we may have sulphur dioxide pollution, fluoride pollution, carbon monoxide pollution, smoke pollution, lead pollution, mercury pollution, solid waste pollution, radioactive pollution, noise pollution etc.

Kinds of Pollutants

Of the variety of pollutants, we recognise the following two basic types of pollutants : nondegradable and biodegradable (Odum, 1971).l The materials and poisons, such as aluminium cans, mercurial salts, long chain phenolic chemicals and DDT that either do not degrade or degrade only very slowly in the natural environment are called nondegradable pollutants. These pollutants not only accumulate but are often "biologically magnified" as they move in biogeochemical cycle and along food chain. The biodegradable pollutants include domestic sewage, heat etc. Which can be rapidly decomposed under natural conditions. They create problms when they accumulate (*i.e.,* their input into the environment exceeds their decomposition).

1. AIR POLLUTION

Air pollution can be defined as the presence of the substances which are not present naturally in the atmosphere or present naturally but are in much smaller concentrations, and that may harm living organisms directly or indirectly. Air pollution is one of the most dangerous and common kind of environmental pollution that is reported in most industrial towns and metropolitans of not only in India but in abroad also.

Composition of Air

The atmosphere is a mixture of many discrete gases in which varying quantities of tiny solid particles are suspended. With increasing height above sea level, the atmospheric pressure gradually decreases. The relative proportion of different gases is shown in table 1.

Besides gases, water vapours, dust particles, smoke, salts and other impurities microorganisms, pollen grains etc., are also present in the air in varying quantities in lower layer of atmosphere.

Table 1. Relative proportion of various gases (by volume) in atmosphere.

Gases	Percent	Gases	Percent
Nitrogen	78.0841	Crypton	0.00011
Oxygen	20.9486	Xenon	0.00009
Argon	0.9340	Hydrogen	0.00006
Carbondioxide	0.0318	Methane	0.000020
Neon	0.0018	Nitrous oxide	0.00005
Helium	0.0005	Ozone	0.000004

Measures of Air Quality

In our country, data on air quality have been collected by NEERI (1978–79, 1980–81). Although, there are several parameters to judge air quality generally three

— SO_2, NO_x and SPM (suspended particulate matter) are used which give a fair idea of pollution load carried by the air. NEERI collected data from Delhi, Kanpur, Mumbai, Nagpur, Hyderabad, Chennai, Cochin, Kolkata, Ahemdabad and Jaipur to assess the extend and nature of deterioration of air quality due to industrialization and urbanization. Each of the 10 cities was surveyed for residential, commercial and industrial situations.

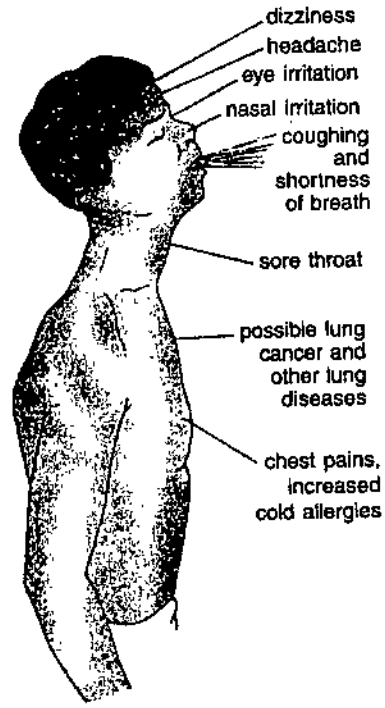


Fig. 1. Ailments caused in man by air pollution.

Sources of Air Pollution

Various kinds of natural and human activities are responsible for generating air pollutants. Nature adds a few natural pollutants, such as pollen, hydrocarbons released by negatation, dust, from deserts, storms, and volcanic activity. In human activities, industries, thermal power stations and automobiles are responsible to generate different kinds of air pollutants. These different kinds of air pollutants and their sources can be discussed as follows :

(A) Gaseous Pollutants

(a) Sulphur oxides and hydrogen sulphides: Naturally, the biological decomposition and volcanic eruption release these gases. They are also released artificially due to human activities such as smelting of sulphide containing ores, combustion of sulphur containing fuels such as coal and oil, petroleum refining and obtaining of geothermal energy. Sulphur dioxide pollution causes in human beings various types of injuries such as eye irritation, chest constriction, headache, vomiting and death from respiratory ailments (Fig. 1). This gas causes damage to higher plants forming necrotic areas on leaf. Plants are relatively more sensitive to SO_2 than are animals and man. thus threshold levels of SO_2 injury in plants are quite low as compared to animals and man (Table 2).

Table 2. Concentration of SO_2 producing threshold injury.

Category	SO_2 Concentration (ppm)	
	Short term exposure for one hour daily	Long term exposure for one hour daily
Plants	0.5–2.0	0.01–0.05
Animals	0.5–3.0	0.02–0.10
Man	1.0–4.0	0.05–0.02

In most of the plants, leaf area collapses under intense exposure to SO_2 (Fig. 2).

(b) Carbon monoxide : It is released chiefly from the combustion of fossil fuels in automobiles. In other sources stoves, furnaces, open fires, forests and bush fires, burning coal mines, factories, power plants etc. are important which give off carbon monoxide (CO). In all big cities of the world the automobile emission contributes 80% CO in the atmosphere.

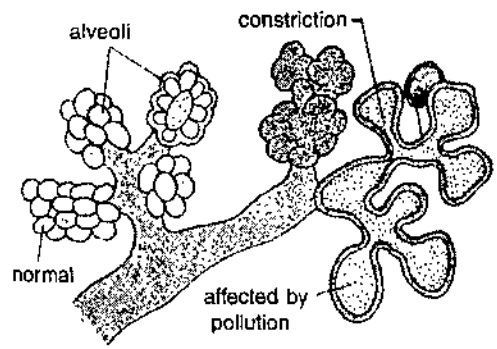


Fig. 2. Effect of sulphur dioxide and other air pollutants on the bronchial tubes of human lungs.

In man, CO produces headache, dizziness, inability to distinguish time intervals, nausea, ringing in the ears, heart palpitation, pressure in chest and difficulty in breathing. This gas combines with haemoglobin of blood to form carboxy-

haemoglobin in RBC which reduces its oxygen carrying capacity to all parts of body and thus causing asphyxia. At about 200 ppm for 6-8 hrs., there begins headache and reduced mental acuity : above 300 ppm, there begins throbbing headache followed by vomiting and collapse : above 500 cause unconsciousness and above 1000 ppm, there is death.

The accepted maximum allowable concentration (MAC) for occupational exposure is 500 ppm for 8 hrs.

(c) Nitrogen oxides : The natural sources of nitrogen oxides are anaerobic bacterial breakdown of nitrogenous compounds, forest fires and lightening. Fossil fuel combustion in automobiles and power generators also contribute to oxides of nitrogen. About 95% of nitrogen oxide is emitted as NO and remaining 5% as NO_2

In man, NO_2 causes nose and eye irritation and pulmonary oedema and hemorrhage. In plants, NO_2 brings about bifacial necrosis leading to collapse of leaves, enhancement of green colour followed by chlorosis and extensive leaf drop. Ultimately there occur an increases in fruit drop and decrease in fruit crop.

Photochemical Smog : In the atmosphere, nitrogen dioxide is reduced by ultraviolet light to nitrogen monoxide and atomic oxygen :

$$NO_2 \longrightarrow NO + O$$

Atomic oxygen reacts with oxygen to form ozone :

$$O_2 + O \longrightarrow O_3$$

Ozone reacts with nitrogen monoxide to form nitrogen dioxide and oxygen, thus closing the cycle :

$$NO + O_2 \longrightarrow NO_2 + O_2$$

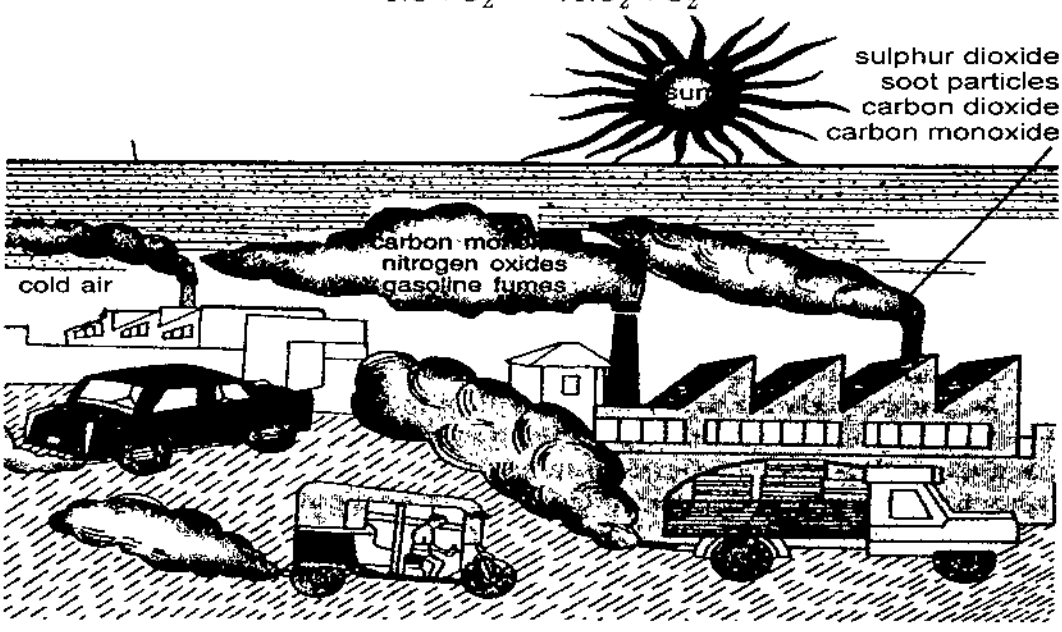


Fig. 3. Formation of the smog and its climatic effects

Sometimes in the presence of sunlight, the atomic oxygen also reacts with a number of reactive hydrocarbons (such as methane, ethane, toluene etc. all of which originate from burning of fossil fuels or directly from plants) to form reactive intermediates called radicals. These radicals then take part in a series of reactions to form still more radicals that combine with oxygen, hydrocarbons, and NO_2. As a result of all these reactions, ozone accumulates and a number of secondary pollutants are formed such as formaldehyde, adehydes and peroxyacetyl nitrate or PAN ($C_2H_3O_5N$). All of these compounds

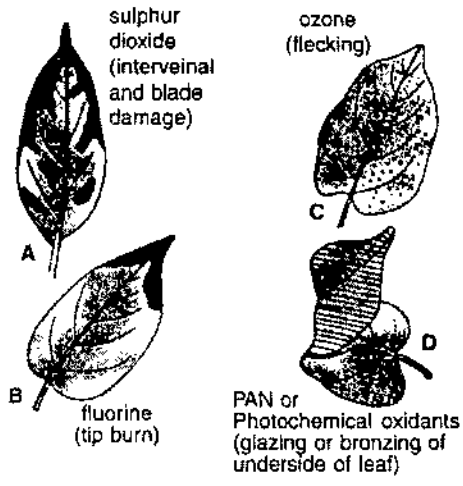


Fig. 4. Injuries caused to plant leaves by SO_2 (A), HF (B), O, (C) and PAN (D)

collectively form photochemical smog. Ozone PAN and nitrogen dioxide are its chief constituents (Fig. 3).

(d) Ozone : It is universally accepted that the ozone layer in the stratosphere protects us from the harmful UV radiations of sun. But ozone near the earth's surface in the troposphere creates pollution problem. Increase in O_3 concentration near earth's surface is toxic to plants reducing crop yield significantly. It also has adverse effects on human health (Table 3).

Table 3. Effects of Ozone (O_3) on human health

Concentration (ppm)	Effects observed
0.2	No ill effects.
0.3	Nose and throat irritation
1.0–3.0	Extreme fatigue after 2 hrs.
9.0	Severe pulmonary oedema

In plants, O_3 enters through stomata and produces visible damage to leaves and results in decrease in yield and quality of plant products. Thus, O_3 results in necrotic flecking of upper surface of leaf (Fig. 4C), general chlorosis and bronzing, premature senescence of plants, precocious dropping of older leaves, reduced growth of shoots and roots, suppression of nodulation, reduction in seed set and yield. Ozone causes shrinkage of nuclei and cytoplasm or mesophyll cells which become granular and results in increased intercellular space (Fig. 5).

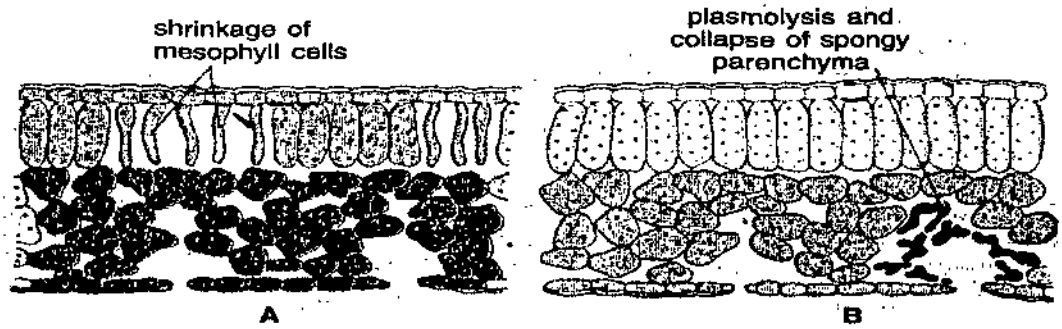


Fig. 5. A-Affect of ozone on the palisade layer of leaf; B = collapse of spongy parenchyma in the region of substomatal cavity due to PAN.

(e) Flurocarbons (Hydrogen fluoride) : Natural sources of fluorides in the atmosphere are active volcanoes. In anthropogenic, sources are petroleum refining, aluminium, steel and electrochemical reduction plants, blast furnaces, brick kilns and tile, glass etching and superphosphate fertilizer and corrode all body passages.

Fluoride burns the tip of plant leaves (Fig. 4B). Its low percentage amounts impair plant growth, result in excessive dropping of bloom and young fruits, development of small, partially or completely seedless fruits and premature formation of soft red flesh and splitting of peach. In human being, it irritates and corrodes all body passages.

(f) Hydrocarbons : These are benzene, benzpyrene and methane. Biological decomposition of organic matter, spill and seepage from natural gas and oil fields and volatile emissions from plants are some major natural causes for their release. Incomplete combustion of fuels, automobile exhaust, petroleum refineries, agricultural burning, motor fuel marketing, manufacture of exposes and cracking of natural gas in petrochemical plants (as a blow-off emissions) constitute the man made sources that emit hydrocarbons. Ethylene causes yellowing and occassional necrosis of leaves, chlorosis of floral buds, inhibition of terminal growth, epinasty of leaves and decrease in the amount of chlorophyll and carotenoids. Aniline also cause necrosis and abscission of leaves.

In man, hydrocarbons bring about irritation of mucous membrane, brochial constriction and eye irritation. Benzpyrene is said to cause lung cancer. Methyl isocyanate gas when accidentally leaked out from the storage tanks of the pesticide

factory in Bhopal on December 2, 1984 had killed over 3,000 persons and seriously affecting lakhs of residents.

(g) Hydrogen chloride : This pollutant is released from combustion of coal, paper, plastics, chlorinated hydrocarbons, accidental spill from the chemical manufacturing plants and ignition of solid-fuel rocket engines in plants, hdyrogen chloride causes plasmolysis and collapse of epidermal cells of leaves and thereby results in abaxial glazing of leaves.

(h) Ammonia : The main anthropogenic sources of this gaseous pollutants are refrigerators, precooler systems of cold storage, manufacture of dyes, explosives, lacquers (varnishes) and anhydrous ammonium fertilizers and nitric acid and domestic incineration. In plants, it affects the root and shoot growth, bleaching of leaves, rusty spots on leaves and flowers. In man it inflames upper respiratory passages.

(B) Particulate Pollutants

(a) Fluorides : The particulate fluoride originates in the same way as the gaseous fluorides. They settle and accumulate on the grass and other vegetation. They are less toxic to plants causing occasional leaf tip burns. However, ingestion by cattle of various fluorine compounds falling on forage, causes fluorosis, a disease characterized by abnormal calcification of bones and teeth eventually resulting in loss of teeth, body weight and in lameness.

Fluoride pollution in man and animals is mainly through water. In our country, fluorosis is a public health problem in states of Gujarat, Rajasthan, Punjab, Haryana, U.P., Andhra Pradesh, Tamilnadu, Karnataka and some areas of Delhi. Globally it is a problem of various other countries such as USA, Italy, Holland, France, Germany, Spain, Switzerland, China, Japan and Some African and latin American Countries.

(b) Lead : Lead is released into air with the exhaust of combustion of gasoline in the automobiles. About 75% of lead burnt in gasoline comes out as lead halides through tail pipe in exhaust gases. Of this about 40% settles immediately on the ground and the rest 60% gets into air. The lead level of air in air quality guide of WHO is 2 $\mu g/m^3$. This level is already crossed in many Indian cities and in various countries of world. For example, in Kanpur and Ahemdabad, lead level varies between 1.05 to 8.3 $\mu g/m^3$ and 0.59 to 11.38 $\mu g/m^3$, respectively. Road side plants and animals are found to contain high concentrations of lead in tissues, and this has a sublethal effect on the health and longivity of the animal. Traffic policemen also show occupation hazards of pollution. High lead accumulation in the tissues of human body interferes with development and maturation of erythrocytes (RBC) and causes anaemia. Chronic exposure to lead leads to stippled red blood cells having impaired capacity for oxygen transportation (Fig. 5). Being a cumulative poison, it disrupts the functioning of cells and organs of the muscular, circulatory and nervous systems binding with the cellular enzymes and coagulating, proteins, thereby, results in nausea weakness and dizziness. It also damages liver, kidney and gastro intestine and induces abnormalities in fertility and pregnancy.

(c) Mercury : It is a liquid volatile heavy metal which is found in rocks and soil. It is released into air though the industries of fungicides, paints, cosmetics, paper pulp etc. The MAC values are not known. However inhalation of 1 mg/m^3 of air for three months may lead to death. Nervous system, liver, eyes are damaged. Other symptoms of mercury toxicity, are headache, fatigue, anxiety, leathergy, loss of appetite etc.

(d) Zinc : It is not a natural component of air, occurs around zinc smelters and scrap zinc refineris. Coper, lead and steel refineries also release some zinc into the air. Zinc in air occurs mostly as white zinc oxide fumes which is toxic to man.

(e) Cadmium : It occurs in air due to industries and human activities. Industries engaged in extraction, refining, electroplating and welding of cadmium containing materials and those in refining of copper, lead and zinc are the major sources of cadmium in air. Cadmium occurs in the air in the form of oxide, sulphate or chloride compounds. It is poisonous at very low levels and is known to accumulate in human liver and kidney cadmium causes hypertension, emphysema and kidney damage. It may also act as carcinogen in mammals.

(f) Particulate matter : The word particulate has been derived from particle and includes all solid or liquid substances primarily in the air. It is of two types :

Suspended particulate matter : These are smaller than 10 microne. They are generated by various industrial processes, combustion and black shoot.

Dust fall : These particles are larger than ten microne. Thy are emitted into the air by physical procsses such as grinding and abrasion, a soot and fly ash (or PFA = Pulverised fly ash) from fuel combustion.

Dust may be inorganic and organic in nature Inorganic dust, containing silica and trapped metals, is the main pollutant in mining, quarrying and stone cutting operations. Organic dust raised in cotton textile mills, ginning plants, coir retting and processing, saw mills and plywood industries are also potentially toxic with properties of sensitization of persons exposed to them.

Particulates emitted from various manufacturing units cause in plants, premature fall of needles, higher puberty of leaves, formation of more stomata and trichomes, reduction in number and size of cobs and weight of seeds, necrotic lesions etc. In human beings, dust particles, sometime become health hazards as they may lead to diseases such as allergic asthma, bronchitis, emphysema and even fibrosis of lungs. Cotton dust causes occupational disease Byssinosis, very common to India.

Global Ecological Problems

At gross level, air pollution causes two worldwide problems — contamination of the upper atmosphere and the alteration of weather and climate. We can discuss some global ecological problems as a consequnce of air pollution.

(a) Green house effect : Air pollution also affects weather on a continental or global basis. Many gaseous pollutants and fine aerosols reach the upper atmosphere, where they have basic effects on the penetration and absorption of sunlight.

Since CO_2 is confined exclusively to the troposphere, its higher concentratin may act as serious pollutant : under normal concentration of CO_2, the temperature at the surface of the earth is maintained by the energy balance of the sun rays that strike the planet and heat, that is radiated back into space. However, when there is an increase in CO_2 concentration, the thick layer of this gas prevents the heat from being re-radiated out. This thick CO_2 layer thus functions like the glass panels of a green house (or the glass windows of a motor car) allowing the sunlight filter through but preventing the heat from being re-radiated into outer space. This is so called green house effect.

The spectral properties of CO_2 in the atmosphere are such that : it tends to prevent the long wave radiations (*i.e.*, infrared heat radiation) from earth from escaping into outer space and deflect it back to earth. The latter has an increased temperature at surface (Turk *et. al.*, 1974). This phenomenon is called atmospheric effect (Lee, 1974) or greenhouse effect (Southwick, 1976; Smith, 1977) (Fig. 6).

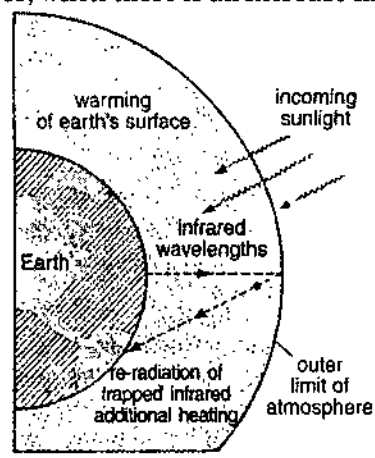


Fig. 6. The green house effect of carbondioxide.

Nearly 100 years ago, the CO_2 level was 275 ppm. Today it is 350 ppm and by the year 2035 or 2040, it is expected to reach 450 ppm. Imagine the earth's temperature. CO_2 increases the earth's temperature by 50% while CFCs are responsible for another 20% increase. The heat trap provided by atmospheric CO_2 probably helped to create the conditions necessary for the evolution of life and the greening of earth. Compared to moderately warm planet, Mars, with too little CO_2 in its atmosphere is frozen cold and Venus with too much is a dry furnace.

The excess CO_2 to some extent is absorbed by the oceans. But with the industrialization of west and increased consumption of energy, CO_2 was released into atmosphere at a faster rate than the capacity of oceans to absorb it. Thus its concentration increased. According to some estimates CO_2 in air may have risen by 25% since the middle of 19th century. It may even be doubled by 2030 A.D.

Some analysts believe that changes in the earth's mean temperature will be apparent by 2050, when the temperature would increase by 1.5 to 4.5°C. According to one projection, changes will be the least in the tropics and the most at the poles. So, Greenland, Iceland, Norway, Sweden, Finland, Siberia and Alaska will be among the most affected. The polar icecaps would melt. the floating Western Antarctica ice sheet could begin to melt. A rise of five degrees would raise the sea level by five meter within a few decades, threatening all the densely populated coastal cities from Shanghai to San Francisco. It is suggested that North America would be warmer and drier. Th U.S. would produce less grains. On the other hand, North and East Africa the Middle East, India, West Australia and Mexico would be warmer and wetter, enabling them to produce more grain. Rice-growing season as well as area under rice cultivation could increase. However, this may not happen as higher surface temperature will increase the evaporation of water, thus reducing grain yield. According to U.S. scientist, George Woodwell, India's annual monsoon rains may even cease altogether.

According to an estimate, if all the ice on the earth should melt 200 feet of water would be added at surface of all oceans, and low-lying coastal cities as Bangkok and Venice would be inundated. A rise in sea level of 50-100 cm caused by ocean warming would flood low-lying lands in Bangladesh and West Bengal. Due to greenhouse effect, there may occur more hurricanes and cyclones and early snow melts in mountains causing more floods during monsoon. According to some, within next 25 years or so, there will be rise in sea level by 1.5 to 3.5 meter and in Bangladesh alone 15 million people will have to move or drown. Low-lying cities of Dhaka and Kolkata may be inundated.

Besides, the five emerging environmental issues (new technologies, red tides, diesel pollution, acid fog and threats to Antarctica), that the UNEP has been able to identify, the one that has proved the most vexatious, and disquieting is the greenhouse effect of global warming. It is caused by the build-up in the atmosphere of CO_2 and other toxic gases discharged by industry and agriculture. If unchecked, it could alter temperature, rainfall and sea levels of the earth. The UNEP has appropriately chosen the slogan **"Global Warming : Global Warning"** to alert the people on World Environment Day, June 5, 1989. The cost of defense (reduction of gas emissions and research to identify the hardest hit regions and plan of coastal defence) would be enormous : in the region of *$ 100 billion or more for a one meter rise in sea level. The problem is that most* vulnerable areas in developing world do not have economic resources. The hardest hit may be developing world, which discharge 2/5ths of the global carbon emissions each year which itself is increasing by over 100 million tonnes a year.

(b) Acid rain : an invisible threat : We have seen that the oxides of sulphur and nitrogen are important gaseous pollutants of air. These oxides are produced mainly by *combustion of fossil fuels, smelters, power plants, automobile exhausts, domestic fires* etc. These oxides are swept up into the atmosphere and can travel thousands of kilometers. The longer they stay in the atmosphere, the more likely they are to be oxidised into acids. Sulphuric acid and nitric acid are the two main acids, which then dissolve in the water in the atmosphere and fall to the ground as acid rain or may remain in atmosphere in clouds and fogs.

Acidification of environment is a man-made phenomenon. The acid rain is, infact, a cocktail of H_2SO_4 and HNO_3 and the ratio of the two may vary depending on the relative quantities of oxides of sulphur and nitrogen emitted. On an averages 60-70% of the acidity is ascribed to H_2SO_4 and 30–40% to HNO_3. The acid rain problem has dramatically increased due to industrialisation. Burning of fossil fuels for power generation contributes to almost 60-70% of the acidity is ascribed to H_2SO_4 and 30-40% of total SO_2 emitted globally. Emission of NO_x from anthropogenic sources ranges between 20-90 million tonnes annually over the globe. Acid rains have assumed global ecological problem, because oxides travel a long distance and during their journey in atmosphere, they may undergo physical and chemical transformation to produce more hazardous products.

Acid rains create complex problem and their impacts are far reaching. They increae soil acidity, thus affecting land flora and fauna; cause acidification of lakes and streams

thus affecting aquatic life, affect crop productivity and human health. Besides these, they also corrode buildings, monuments, statues, bridges, fences, railings etc. British Parliament building also suffered damage due to H_2SO_4 rains. Due to acidity, levels of heavy metals as aluminium, manganese, zinc, cadmium, lead and copper in water increase beyond the safe limits. Over 10,000 lakes in Sweden have become acidified. Thousands of lakes in U.S.A., Canada, Norway have become unproductive due to acidity. Fishes population has decreased tremendously, and there are deaths of salman trout etc. The fish areas (lakes) are now **fish graveyards.**

Many bacteria and blue green algae are likely to die due to acidification, thus disrupting the ecological balance. In West Germany nearly 8% of the fish died and nearly 18 million acres of forests critically afflicted by acid rains. Forests in Switzerland, Netherlands and Czechoslovakia have also been damaged by acid rains. Nutrients like calcium, magnesium, potassium have been leached away from soil by acids.

Acid rains are a great threat to British environment as to Central Europe and Southern Scandinavia. In 1974, acid rains over Scotland were found to be more sour than vinegar (pH 2.4), The H_2SO_4 shower, 500 times more acidic than it should naturally be stood as a world record in four years. Much of the falling snow in Britain is now highly acidic. If it does not melt, it may turn into a pollution time bomb. Several rivers are acidic.

Acid rains are carried away by prevailing wind to elsewhere where precipitation takes place. The oxides may be produced at one place, and the affect elsewhere by turning into acids. The two acid victims are Canada and Sweden, Canada gets acid rains from petrochemical units in North America. Heavy winds pick up acid rain from factories of Britain and France to Sweden. Equally grim are the acid rain in Norway, Denmark and W. Germany. It is said that 90% of the acid rain of Norway and 75% of Sweden are due to drifted acid rain oxide. Acid rains are thus becoming a major political issue.

Though, acidity of rain water is yet to be adequately monitored, developing countries like ours may soon have to face the acid rain problem. The acid rain is fast spreading to developing world where tropical soils are much more vulnerable than those of Europe. It appears that acid rain problem is on the avil in India. Industrial areas with the pH value of rain water below or close to the critical value have been recorded in Delhi, Nagpur, Pune, Mumbai and Kolkata. This is due to sulphur dioxide from coal-based power plants and petroleum refinery. According to a study made by B.A.R.C. Air Monitoring Section; the average pH value of acid rain at Kolkata is 5.80, Hyderabad 5.73, Chennai 5.85, Delhi 6.21 and Mumbai 4.80. The situation may even worsen in future due to increased installation of thermal power plants by NTPC, and consequent increase in coal consumption. According to an estimate total emission of SO_2 in India from fossil fuel buring has increased from 1.38 million tonnes in 1966 to 3.20 million tonnes in 1979, a 21% increase as compared to corresponding increase of only 8.4% in U.S.A. during the same period. There is urgent need for proper regular monitoring to provide timely warings about acidification of air environment.

(c) Hole in Ozone layer (Threat to protective effect of ozone) : Ozone protects us from the harmful UV-radiations from the sun. Inspite of being in such a small proportion (0.02–0.07 ppm), it plays a major role in climatology and biology of the earth. It filters out all radiations below 3000 Å. Thus O_3 is intimately connected with the life-sustaining process. Any depletion of ozone would, therefore, have catastrophic effects on life systems of the earth. Over the last few years, it could be realised that the O_3 concentration of earth's atmosphere is thinning out. What has caused this depletion?

We have already pointed out that O_3 layer by absorption of UV radiation heats the stratosphere, causing the temperature inversion. This temperature inversion limits the vertical mixing of pollutants. However, in spite of this slow vertical mixing, some pollutants enter the stratosphere and remain there for years until they react with ozone and are converted to other products. These pollutants thus deplete ozone in the stratosphere. Major pollutants responsible for this depletion are chlorofluorocarbons (CFCs), nitrogen oxides (coming from fertilisers) and hydrocarbons. CFCs are widely used as coolants in air conditioners and refrigerators, cleaning solvents, aerosol propellants and in foam insulation. CFC is also used in the fire extinguishing equipment. They escape as aerosol in the stratosphere. Jet engines, motor vehicles,

nitrogen fertilisers and other industrial activities are responsible for emission of CFCs, NO_x etc. The supersonic aircrafts flying stratosphere heights cause major disturbance in O_3 levels. The threat to O_3 is mainly from CFCs which are known to deplete O_3 by 14% at the current emission rate. On the other hand, NO_x would reduce O_3 by 3.5%. The nitrogen fertilisers release nitrous oxide during denitrification. Depletion of O_3 lead to serious temperature changes on the earth and consequent damage to life-support system.

Depletion of ozone in stratosphere causes direct as well as indirect harmful effects. Since, the temperature rise in stratosphere is due to heat absorption by ozone, the reduction in ozone would lead to temperature changes and rainfall failures on earth. Moreover 1 per cent reduction in O_3 increases UV radiation on earth by 2%. A series of harmful effects are caused by an increase in UV radiation. Cancer is the best established threat to man. When the O_3 layer becomes thinner or has holes, it caused cancers, especially relating to skin like melanoma. A 10% decrease in stratospheric ozone appears likely to lead a 20–30% increase in skin cancer. The other disorders are cataracts, destruction of aquatic life and vegetation and loss of immunity. Nearly 6000 people die of such cancers in USA each year. Such, cases increased by 7% in Australia and Newzealand.

Apart from direct effects, there are also indirect effects. Under greenhouse effect conditions, plants exposed to UV radiation showed a 20-50% reduction in growth reduction in chlorophyll content and increase in harmful mutations. Enhanced UV-radiation also impairs fish productivity.

In India, no such effect has been made to monitor O_3 concentration in major cities but the scene is not quite satisfying. Emissions from automobiles are about 1.6 million tonnes, which are likely to increase in coming years due to increased dependence on coal and oil for several uses. Burning of these fuels causes emissions of NO_x and hydrocarbons necessary for oxidant formation. On the other hand, the same pollutants are instrumental in ozone depletion. In both instances, human effects are noticed on earth. Ozone pollution is likely to become a major global problem during the coming decades. We expect governments throughout the world to cooperate in dispelling the dangers of the global threat from ozone depletion in a stratosphere and ozone production near the earth's surface.

(d) Aerosols — The Black Clouds of Pollutants over the Indian Ocean : The haze, seven times the size of India over the Indian ocean has developed over the northern Indian ocean including Antarctica. This thick layer of pollutants is infact black clouds of aerosols that could have serious effect of rainfall and the onset of monsoon through its effect on cloud formation. These particles could be emanating from any source — diesel and industrial emissions, biomass burning for cooking, forest fires and even dust. These particles, the aerosols may affect agricultural yield by blocking sunlight and affecting monsoon patterns due to alteration in regional climate. Western and North-western India is becoming drier, while Eastern and Southern India becoming wetter.

Commonly known as suspended matter, aerosols are best described as tiny liquid or solid particles floating in the air. Aerosols are particles, about a millionth of a centimetre in diameter, consisting of sulphates, soot, organic carbon, and mineral dust (Table 4).

Table 4. Composition of a typical aerosol

Component	Percent value
Potassium	2
Sea-salt + nitrate	1
Minor inorganics	2
Mineral dust	10
Sulphate	32
Ammonium	8
Fly ash	5
Black carbon	14
Organics	26

Sources of Aerosols

Aerosol sources are of **two types** — primary and secondary. **Primary** aerosols are emitted directly as tiny particles, such as smoke from forest or bush fires, soot from *burning fossil fuels in industries vehicles, trains, aeroplanes*, airborne dust and sea salt particles produced when sea spray dries out. Secondary aerosols are produced from gaseous precursors. Chemical reactions in the air, convert the primary gaseous pollutants (SO_2, N_2O) into gases with reduced volatility, some of which condense into particulates. Emissions arising from vegetation (as pollen grains, plant debris) and microbial particles (algae, bacteria, viruses etc.) also form secondary aerosols. These are biogenic aerosols. The tiny particles can range in size from 0.01 μm to several tens of micrometre. Under normal conditions, the majority of aerosols form a thin haze in the lower atmosphere where they are washed out by rain within a week or so. A severe volcanic eruption can push large amount of aerosols into the upper atmosphere.

Threats from aerosols

- Harmful to human health, being easily passed to lungs.
- Heavy cloud formation, affecting world's major fresh water bodies, as lakes, *groundwater supplies*, glaciers etc.
- Alteration in temperature and climate, affecting rainfall and monsoon patterns.
- Reduced agricultural yield.

Fine particles less than 2.5 μm in diameter are believed to damage human health, because they move past to the lungs introducing infections microbes to lung tissues. Dust particles as large as 10 μm (diam) can deposit in the lung airways and cause bronchial airway constriction. Particles upto 4 μm can be inhaled and interfere with the lung function by penetrating into gaseous exchange region of the lungs.

Prevention and Control of Air Pollution : We have accounted in detail the sources of air pollutants and their ill effects on plants and animals in the previous section. There is an urgent need to take steps to control pollution at source (prevention) as well as after the release of pollutants in the atmosphere.

The control of emissions can be realised in number of ways. Five separate possiblities for control are shown in figure 7.

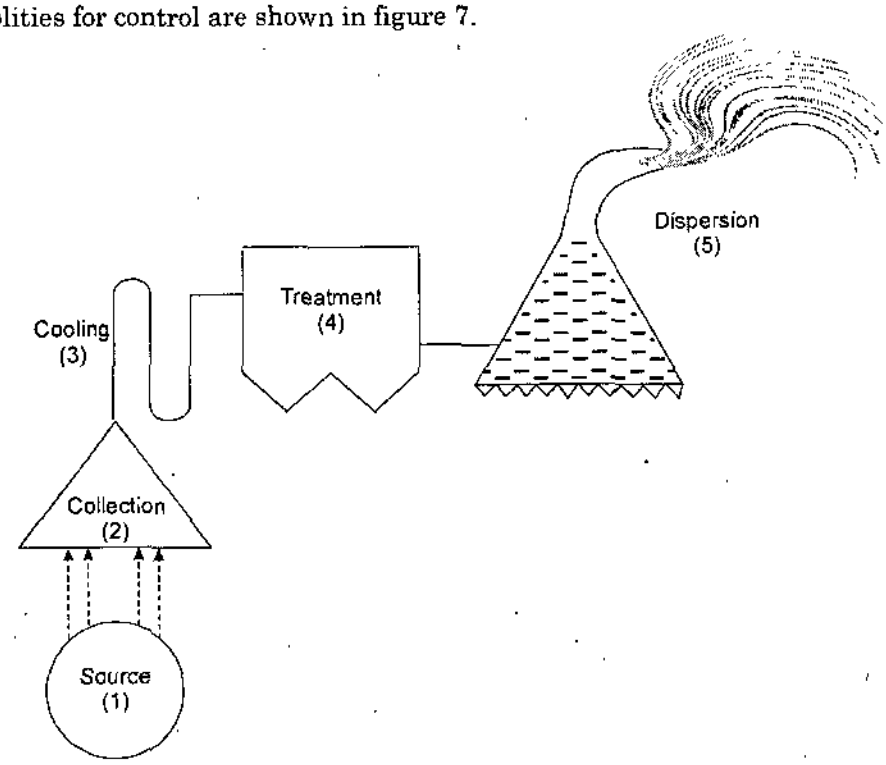


Fig. 7. Five points of control of possible emission of air pollution.

(a) The correction of the source of pollutants : This is the easiest solution to the problem of air pollution, where we can stop the guilty process of release of pollutants. It is a preventive measure. Here, we can correct the source in a way to minimize the

release of pollutants. For instance the gasoline combustion in autovehicles release lead into the air, the most reasonable solution is simply to eliminate the lead in the gasoline before using in the vehicles. The source has been corrected and the problem solved. In addition to a change of raw material, a modification of the process might also be used to achieve the desired result.

Strictly speaking, such measures as process change, raw material conversion or equipment modification to meet emission standards are known as controls.

(b) Collection of pollutants : This is a crucial step of control measures. Automobiles are most dangerous because their emitted pollutants can not be readily collected. In all kinds of industries and man made sites, the measures are and should be taken to the best level for collection of pollutants for their treatment before release into the air.

(c) Cooling of pollutants : The exhaust gases to be treated are sometimes too hot for the control equipment and the gases must first be cooled. This can be done in three general ways : dilution, quenching or heat exchange coils (Fig. 8).

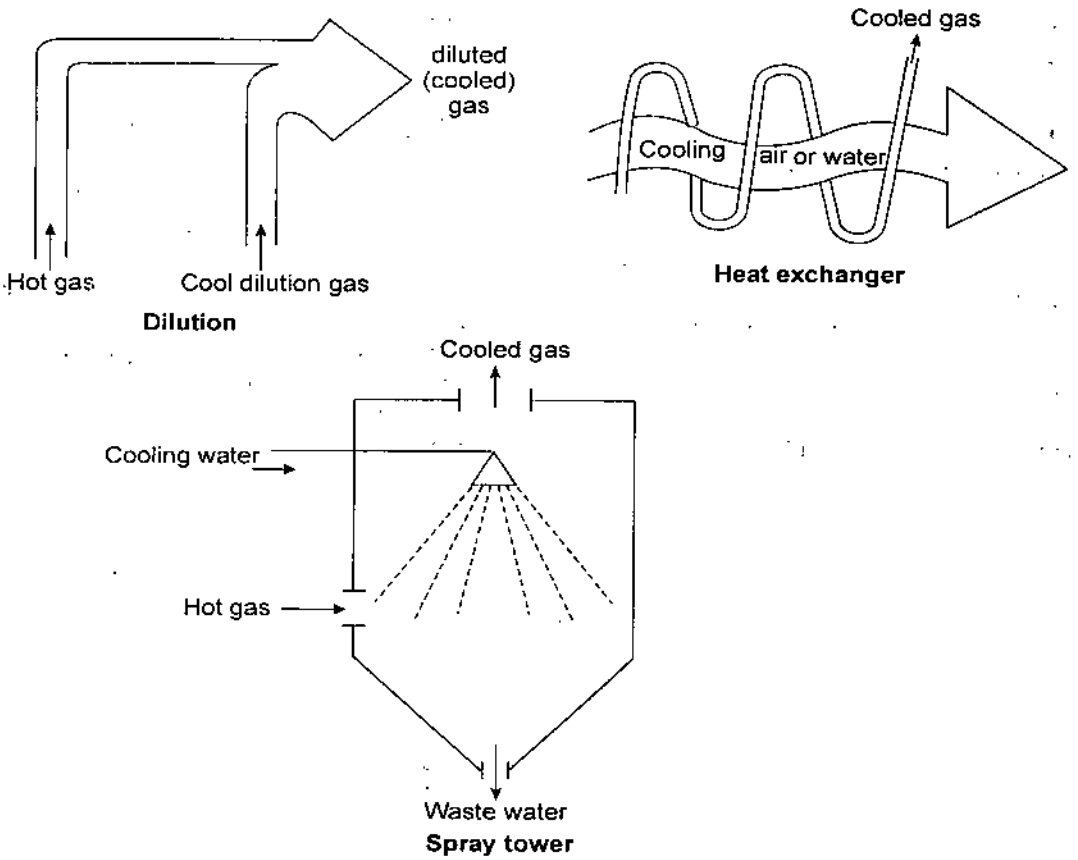


Fig. 8. Device of cooling hot waste gases.

(d) Treatment of pollutants : Some of the treatment measures can be discussed as follows :

Setting chambers : These chambers are large spaces where large particulate matter of the emission settles down.

Cyclones : These are widely used for removing large particulates. The dirty air is blasted into a conical cylinder but off the centerline. This creates a violent swirl within the cone, and the heavy solids migrate to the wall of the cylinder where they slow down due to friction and exist at the bottom of the cone. The clean air is in the middle of the cylinder and exits out from the top.

Bag filters : Bag filters are fabric bags which collect all the particulates from the dirty air. Bag filters are widely used in many industries, but are sensitive to high temperature and humidity.

Wet collectors : These are simply spray towers and is an effective method for removing large particulates.

Electrostatic precipitators : These are widely used in power plants. The particulate matter is removed by charged electrons moving between two electrodes. The collected particulates on the pipe are then removed by banging the pipes with hammer.

Gass scrubber : These are simply wet collectors as described above but are used for dissolving the gases.

Adsorption : In this method, activated carbon is used to capture pollutants. These are mostly used to remove organic pollutants.

Incineration : It is a method for removing gaseous pollutants by burning them to CO_2, H_2O and inerts. This works only for combustible vapours.

Catalytic combustion : It involves the use of a catalyst to adsorb or chemically change the pollutants.

(e) Dispersion of pollutants : Dispersion is the dilution of pollutants in the air. This dispersion takes place horizontally as well as vertically. Dispersion or diffusion is the process of spreading out the emission over a large area and thus reducing the concentration of the specific pollutants.

Prevention and Control of Vehicular Pollution

(a) Though many of the above said control methods can also apply to moving sources as well such as automobiles. Emission control techniques for the internal combustion automobile engines include tune-ups, catalytic reactors, and engine modifications. This type of control can be attained by (1) using new proportion of gasoline and air (2) More exact timing of fuel feeding (3) using gas additives to improve combustion (4) by injecting air into the exhaust to convert exhaust compounds into less toxic substances, and by (5) correcting the engine design and/or fixing cessation device to improve combustion with the existing design. Complete elimination of three main pollutants namely CO, NO_x and hydrocarbons can be attained by either updating the presnt design of engines or by making appropriate changes in devices for improving combustion.

In recent years, I.K. Bharti of Mumbai has claimed to have devised a simple attachment (by the patent name thermoreactor) to curb air pollution by mother vehicle. Various other devices such as positive cranckase ventilation value and catalytic convertor have ben developed in U.S.A. to reduce exhaust emissions by automobiles.

(b) Control of evaporation from fuel tank and carburettor : This can be performed by (1) collection of vapours with activated charcoal when the engine is turned off. (2) subjecting the gasoline in the tank to slight pressure to prevent the gas from evaporation and (3) developing low volatile gasoline that does not evaporate easily.

(c) Use of filters : Filter can be used to capture and recycle the escaped gases (hydrocarbons) from the engine.

Control of Air Pollution through Law : In our country, there have been several legislative measures both at state and central Govt. levels to prevent and control different types of air pollution :

(1) Bengal Smoke Nuisance Act, 1905.

(2) The Motor Vehicle Act, 1938.

(3) The Gujarat Smoke Nuisance Act, 1953.

(4) The Prevention and Control of Air Pollution Act, 1981, 1987.

(5) The Environmental (Protection) Act, 1986.

(6) The Motor Vehicles Act, 1988.

2. WATER POLLUTION

Water is among the basic needs to ensure life on the earth. Water is a great solvent chemically. Therefore, even the highest quality distilled water contains dissolved gases and to a slight degree solids.

The term water pollution is referred to any type of aquatic contamination between following two extremes : (1) a highly enriched over productive biotic community, such as a river or lake with nutrients from sewage or fertilizer (cultural eutrophication) or (2) a body of water poisoned by toxic chemicals which eliminate living organisms or even exclude all forms of life (Southwick, 1976).

Normally water contains two types of impurities — dissolved and suspended. Dissolved impurities are gases (H_2S, CO_2, NH_3 etc.) and (Ca, Mg, Na salts). Suspended matter includes clay silt and sand and even microbes. Polluted waters are turbide, unpleasant, foul smelling, unfit for drinking, bathing and washing or other purposes. They are harmful and source of many diseases as cholera, dysentery, typhoid, hepatitis etc.

Types of Water Pollution : According to the source of water or kind of water body, the water pollution may be surface water pollution, ground water pollution, soil water pollution etc. and river pollution, lake pollution, estuarine pollution, coastal water pollution, open ocean pollution etc.

Kinds and Sources of Water Pollutants : The main sources which cause water pollution are domestic sewage and oxygen demanding wastes, infectious microbes, plant wastes, agrochemicals and power and industrial plants. Each type of water pollution affects the abiotic and biotic factors of different aquatic systems in different degrees and its ultimate effect on man remains quite drastic in medical, aesthetic and economical sense. Some of the well known ecological effects of water pollution are :

(a) Sewage Pollution : Contamination of fresh water and shallow offshore seas by sewage is called sewage pollution. Sewage includes mostly biodegradable pollutants such as human faecal matter, animal wastes and certain dissolved organic compounds (*e.g.*, carbohydrates, urea etc.) and inorganic salts such as nitrates and phosphates of detergents and sodium, potassium, calcium and chloride ions. Under natural processes, most of the biodegradable pollutants of sewage are rapidly decomposed, but, when they accumulate in large quantities, they create problem *i.e.*, when their input into environment exceeds the decomposition or dispersal capacity of the latter. Most cities of well developed. Countries such as USA, Britain etc., and some cities of India have evolved certain engineering systems such as, septic tanks, oxidation ponds, filter beds, waste water treatment plants and municipal sewage treatment plants for the removal of microbes, organic compounds and other pollutants from the sewage, before it is tapped into river or sea.

BOD (Biological Oxygen Demand) Test : BOD can be defined as the amount of oxygen required for biological oxidation by microbes in any unit volume of water. The test is done at 20°C for at least five days. BOD value generally approximates the amount of oxidisable organic matter (such as sewage and other organic wastes, animals and humans excreta, all of which are called oxygen demanding wastes) and is, therefore, used as a measure of degree of water pollution and waste level. Thus due to addition of sewage and waste, oxygen level is depleted which is reflected in terms of BOD value of water.

The number of microbes as Escherichia coli (bacterium) also increases tremendously and these also consume most of the oxygen. The number of bacteria as E. coli in unit volume of water is also taken (called E. coli index) as a parameter of water pollution. The quantity of oxygen in water (called dissolved oxygen or DO) along with BOD is indicated by the kind of organism present in water.

Eutrophication : According to Hutchinson (1969), the eutrophication is a natural process which literally means "well nourished or enriched". It is a natural state in many lakes and ponds which have a rich supply of nutrients, and it also occurs as part of the aging process in lakes, as nutrients accumulate through natural succession, Eutrophication results in the 'bloom' of microorganisms and aquatic vegetation when the supply of nutrients exceeds a certain level.

Most secondary sewage treatment plants, though precipitate solids and inactivate most bacteria in domestic sewage, yet they do not remove the basic nutrients such as ammonia, nitrogen, nitrates, nitrites and phosphates. These nutrients stimulate algal

growth and lead to plankton blooms. Some plankton blooms, particularly these of blue green algae produce abnoxious odour and taste in water. Others, such as the dinoffagellate blooms or 'the red tide' of southern coastal regions, produce toxic metabolic products which can result in major fish kills.

Effects of Sewage (Organic) Pollution on Aquatic Animal Life : Organic pollution tends to bring about changes in formal composition in a fresh water ecosystem. Nymphs of stone flies and many flies are the first to disappear from water which has high organic pollution. As pollution increases, caddisfly larvae and many fish which require high levels of environmental oxygen move into less polluted area of the stream. Shrimps, water flees, leeches, snails and most of the fish vanish as the pollution becomes severe. At such levels of pollution, there is very little of dissolved oxygen and the animals present are chironomid larvae (blood worms) and the oligochaete worms Tubifex (Fig. 9). Some decomposing plants are known to produce toxin as strychnine which kills animals including cattle.

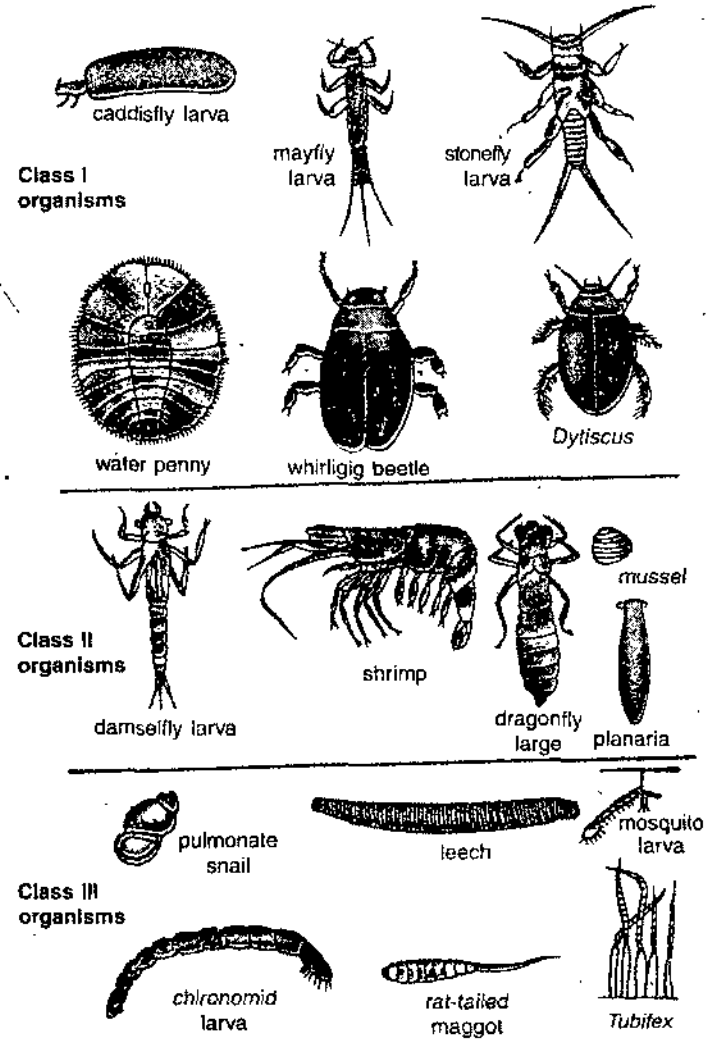


Fig. 9. Classes of stream fauna used as pollution indicators.

(b) Industrial Pollution : Most of Indian rivers and fresh water streams are seriously polluted by industrial waste of effluents (Table 4). Effluents are the liquid waste materials that are released from different kinds of industries. Such Industries include petro-chemical, fertilizer factories, oil refineries, pulp, paper, textile, sugar and steel mills, tanneries, distilleries, coal washeries, synthetic material plants for drugs fibres, rubber plastic etc. All of these chemicals of industrial wastes are toxic to animals and many cause death or sublethal pathology of the liver, kidneys, reproductive system, respiratory system or nervous system in both invertebrates and vertebrate aquatic animals (Wilbur, 1969).

Effluents contain many kinds of heavy metals like Na, Cu, Cr, Cd, Hg, Pb etc. which are very toxic to the aquatic fauna life. Mercury was responsible for the Minamata epidemic that caused several deaths in Japan and Sweden. The tragedy had occurred due to consumption of heavy mercury contaminated fish (27 to 102 ppm, average 50 ppm) by the villagers.

(c) Thermal Pollution : Various industrial processes may utilize water for cooling and resultant warmed water has often been discharged into streams or lakes. Coal or oil fired generators and atomic energy plants release a large amount of waste heat which is carried away as hot water and causes thermal pollution or calefaction (warming). Thermal pollution produces distinct changes in aquatic biota. Some adverse effects of aquatic pollution on aquatic life include (i) early hatching of fish eggs (ii) failure of trout eggs to hatch (iii) failure of salmon to spawn (iv) increase in BOD, *i.e.*, solubility of oxygen is reduced causing deoxygenation (v) change in diurnal and seasonal behaviour and metabolic responses of organisms (vi) significant shift in algal forms and other organisms towards more heat tolerant forms (this leads to decrease in species diversity. (vii) affect changes in macrophytes and (viii) migration of some aquatic forms.

(d) Silt Pollution : A result of intensive agriculture, earth moving for construction projects, poor conservation practices and down pour with resultant floods is the increased production of silt in streams and lakes. This load of particulate matter cuts down primary productivity by decreasing the depth of light penetration. Silt may also interrupt or prevent the reproduction of fish, by smothering eggs laid on the bottom.

Table 5. Some Indian rivers and their major sources of pollution.

	Name of the river	Sources of pollution
1.	Kali at Meerut (U.P.)	Sugar mills; distilleries; paint, soap, rayon, silk, yarn, tin and glycerine industries.
2.	Yamuna near Delhi	D.D.T. factory, sewage, Indraprastha Power Station, Delhi.
3.	Ganga at Kanpur (U.P.)	Jute, chemical, metal, and surgical industries; tanneries, textile mills and great bulk of domestic sewage of highly organic nature.
4.	Gomati near Lucknow (U.P.)	Paper and pulp mills; sewage.
5.	Dajora in Bareilly (U.P.)	Synthetic rubber factories.
6.	Damodar between Bokaro and Panchet	Fertilizers, fly ash from steel mills, suspended coal particles from washeries, and thermal power station.
7.	Hoogly near Kolkata (W.B.)	Power stations; paper pulp, jute, textile, chemical mills, paint, varnishes, metal, steel hydrogenated vegetable oils, rayon, soap, match, shellack, polythene industries and sewage.
8.	Sone at Dalmianagar (Bihar)	Cement, pulp and paper mills.
9.	Bhadra (Karnataka)	Pulp, paper and steel industries.
10.	Cooum, Adyar and Buckinghum canal (Madras)	Domestic sewage, automobile workshops.
11.	Cauvery (Tamil Nadu)	Sewage, tanneries, distilleries, paper and rayon mills.
12.	Godavari	Paper Mills.
13.	Siwan (Bihar)	Paper, sulphur cement, sugar mills.
14.	Kulu (between Mumbai and Kalyan)	Chemical factories, rayon mills and tanneries.
15.	Suwao (in Balrampur)	Sugar industries.

(e) Water pollution by agrochemicals: Agrochemicals include various kinds of fertilizers, pesticides and herbicides which are frequently used in agriculture. When water flows on the surface of crop fields, these agrochemicals go into water bodies and cause water pollution. These toxic chemicals have created health hazards not only for livestock and wild life but also for fish. other aquatic organisms, birds and mammals including man.

Ecologically pesticides, and herbicides have created two major problems which were not previously anticipated. In the first place many of them have persisted and accumulated in the environment and have harmed or contaminated numerous animals or plants not intended to be targets. Secondly, many of them have directly or indirectly affected human health.

Biomagnification or bioamplification : Many of pesticides such as DDT, aldrin and dieldrin, have a long life time in the environment. They are fat soluble and generally not biodegradable. They get incorporated into the food chain and are ultimately deposited in the fatty tissues of animals and man. In the food chain, because of their build up, they get magnified in the higher trophic levels (called biological magnification or biological amplification). The pesticides have been in use during last 50 years. Their targets are insects pests, fungi, nematodes and rodents which damage crops. But these pesticides have created great problems for non-target organisms consisting largely of beneficial species such as earthworms, honey bees, fish, amphibia, some reptiles, birds, mammals and man.

The phenomenon of biological magnification is also reported for certain other pollutants such as heavy metals like lead, mercury and copper and radioactive substances (or radionuclides) as strontium-90.

(f) Marine Pollution : All that what is carried by rivers ultimately ends up in the seas. On their way to sea, rivers receive huge amounts of sewage, garbage, agricultural discharge, biocides, heavy metals etc. These are all added to sea. Besides these discharge of oils and petroleum products and dumping of radionuclides waste into sea also cause marine pollution. High quantity of plastic is also being added to sea and oceans.

The pollutants in sea may become dispersed by turbulence and ocean currents or concentrated in the food chain. They may sediment at he bottom by processes like adsorption, precipitation and accumulation.

In marine water, the most serious pollutant is oil, particularly when afloat on sea. A *spill in oil or petroleum product due to accident or a deliberate discharge of oil polluted* waste brings about pollution. This pollution causes damage to marine fauna and flora including algae, fish, birds, invertebrates. About 50,000 to 250,000 birds are killed every year by oil.

Prevention and Control of Water Pollution : Biodegradable pollutants – alone are not responsible for water pollution (through BOD values). Besides these, the non-degradable or slow degrading pollutants are problematic and difficult to remove from the water sources. Some methods of control of water pollution can be discussed as follows :

(a) Stabilisation of the ecosystem : This is the most scientific way to control water pollution. The basic principles involved are the reduction in waste input (thus control at source) harvesting and removal of biomass, trapping of nutrients, fish management and aeration.

(b) Biological control : Currently water hyacinth (Eichhorna crassipes), an otherwise pernicious aquatic weed has come into prominence for purifying domestic and industrial waste water. The plant regenerates rapidly and has a tremendous capacity to accumulate heavy and even radioactive metals. It is efficient in absorbing nitrogen, phosphorus and similar chemical pollutants. The polluted water fed into reservoirs or lagoons with water hyacinth, becomes markedly clean and free from 75-90 percent of its pollutants. This plant has also been used as a new source of food, fertilizer and biogas (energy).

In other applications, certain bacteria can be used to purify waste water polluted with cyanides, and heavy metals. These bacteria not only withstand such in water but are also able to grow at high level of cyanides. Millions of these bacteria are introduced in each of the several rotating discs of the plants main processing units (Fig. 10). The sticky body surfaces of these bacteria pick up zinc, iron, and other metals from the industrial waste water as it passes over the plates. These bacteria also absorb cyanide so toxic to the fish and other aquatic life. Subsequently this water is passed through clarifier and filtered and then released into the streams.

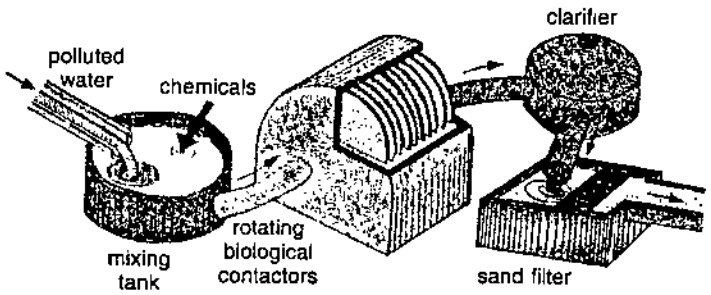


Fig. 10. The method of purification of water polluted with cyanide and heavy metals through bacteria.

(c) Reutilization and recycling of waste : Various kinds of wastes which include industrial effluents (as paper pulp or other industrial chemicals), sewage/sullage of municipal and other systems and thermal pollutants (waste water etc.) may be recycled to beneficial use. For example urban waste (sewage/sullage) may be recycled to generate cheaper fuel gas and electricity. NEERI is actively involved in operating such units and in development of suitable technologies for waste water reclamation through aquaculture, utilization of domestic and industrial waste water in agriculture and detoxification of phenol and cyanides in waste by biological means. One distillery in Gujarat is able to treat 4,50000 litres of waste daily and is generating energy equal to that produced by 10 ton of coal.

(d) Removal of pollutants : Various pollutants (radioactive, chemical, biological) present in water body can be removed by appropriate methods such as absorption electrodialysis, ion exchange, reverse osmosis etc. CSIR, New Delhi is actively engaged in development of such other techniques.

(e) Control through Law/Acts : Keeping in view, the need for environmental protection, various acts have been enacted by Indian Parliament. The water (Prevention and Control of Pollution) Act 1974, is one of them. The Central Board for Prevention and Control of Water Pollution (CBPCWP) was constituted in Sept. 1974. The Environment (Protection) Act 1986 was promulgated on 23 May 1986 to provide for the protection and improvement of environment and matters connected therewith.

3. LAND POLLUTION

Land pollution is caused by solid wastes and chemicals. The major sources of land pollution are the industries such as pulp and paper mills, sugar mills, oil refineries, power and heating plants, chemicals and fetilizer manufacturing units, iron and steel plants, plastic and rubber producing complexes and so on. Most of the industrial furnaces produce a grey powdery residue of unburnt material known as fly ash. The fly ash, cinders solid wastes and litter all are thrown away by industries and form huge mounds which spoil the landscape.

Our households too contribute a large amount of solid rubbish in the form of domestic wastes. Some common examples are groceries, food scraps, vegetables remains, packing materials, cans, cardboard cartons, rags, paper, cinders, ash, broken gadgets, wood, wornout furniture, metals, bones of dead animals, plastics, polythene bags, ceramics, glass, aluminium rubbr, leather, construction rubbish, bricks sand and other junk. All these heaps of garbage become a home of disease carrier animals and can be a reason of epidermics in human beings.

Control of Land Pollution : It should be necessary for the industries to install collectors to remove the particulate wastes (fly ash) from the chimneys. Appropriate methods should be developed to dispose off or utilize the other types of pollutants. The garbage, instead of burning in the open, can be used not only to produce energy but also as filter for cement, bricks, asphalt and paving, some of these wastes, if properly sifted and separated can even be recycled as raw material for other industries.

Another simplest method is crude tipping or open dumping, a common method used in most Indian cities. More satisfactory is controlled tipping or the sanitory landfill, which is recently adopted in Delhi for solid waste disposed.

4. RADIOACTIVE POLLUTION

Radioisotopes are elements with unstable atomic nuclei; that is, they decompose with ionizing radiation in the form of alpha or beta particles or gamma rays. Several radioisotopes such as radium-226, Uranium-235 or 238, thorium 232, potassium-40, or carbon-14, occur naturally in rocks and soil. While the fission products of atomic bomb fall out, nuclear reactors and other radiation sources release more than 450 radioactive isotopes, only a few are of major environmental concern. These are primarily argon-41, Cobalt-60, Caesium-137, iodine-131, krypton-85, Strontium-90, tritium and plutonium 239 (Bebbington, 1973).

Within biotic community and ecosystems, these radioactive elements may become dispersed or accumulated, depending upon the biological activity of the element and period of radioactivity of the isotope. Strontium-90 behaves like calcium in biogeochemical cycles. It is absorbed by plants, ingested by animals and deposited in bone tissues close to blood forming tissue. Radioactive phosphate, caesium, and iodine 132 also can readily accumulate in plants and animals through natural food chains.

Although, isotopes may accumulate in human tissues as well as those of plants and animals. It is not established at the present time whether current levels of isotopes in human tissues represent serious health hazards to man (Southwick, 1976, Smith, 1977).

5. NOISE POLLUTION

Noise is primarily a feature of cities and is defined as sound without value or any sound that is undesired by the recipient. Noise levels in many urban industrialized situations are known to be deleterious to human health and efficiency, with effects on the sense organs, cardiovascular glandular and nervous systems.

There exists a long list of sources of noise pollution including different machines of numerous factories, industries and mills, different kinds of auto and motor vehicles, aircrafts, ships, trains, loud speakers, social gatherins, loud pop-music etc. Noise can be measured by a sound meter and is expressed in a unit called the decible (dB). The quietest sound that the human ear can detect (zero decibles) is called the threshold of hearing. Kolkata, Mumbai and Delhi are regarded to be noisest cities in the world, where the average noise level was 90 decible in 1975.

Noise causes disturbances in the atmosphere which, in turn, interferes with the systems of communication. It affects our peace of mind, health and behaviour. Sudden loud note can cause acute damage to the ear drum and the tiny hear cells in the internal ear, whereas prolonged noise results in temporary loss of hearing or even permanent impairment. Noise is known to flush the skin, constrict stomach muscles and produce ulcers, heart disease, high blood pressure, nervousness and other defects in sensory and nervous system.

Prevention and Control of Noise Pollution : Though, it is almost difficult to completely get rid of the malady of noise pollution in the current electronic age. The means of noise control are (a) to manipulate the source so as to reduce (b) to interrup the path of transmission and (c) to protect the recipient.

Legislation and public awareness are essential. Nobody should be permitted to create noise in silent zones or during night. The path of the sound can be interrupted by using various materials, and plants that absorb the sound energy. Acoustic materials and mufflers can also be used to protect oneself. Under noisy situations, one may hold his hand over his ears or simply can use ear plugs or cotton plugs to reduce much hazards of noise pollution.

• SUMMARY

Pollution is a worldwide environmental problem. Pollution is an unfavourable alteration of our environment, largely as a result of human activities. Any substance which causes pollution is called a pollutant. Pollutants are of two kinds – one is biodegradable and the other one is non-biodegradable. Pollution may be discussed under the headings of water pollution, air pollution, land pollution, noise pollution and radioactive pollution. All kinds of pollution pose threats to the plants as well as animal

life on the basis of their type and extent. Air pollution is causing some global ecological problems like green-house effect, Global warming, aerosols, photochemical smog, acid rains etc. These problems attract the attention of people of world and necessitate the world leaders and scientific community to take steps to control the pollution. Several global negotiations and treaties on the environment protection have been signed to curb this problem. Further, in each country, separate legislation had been enacted to curb the pollution effectively.

Keywords : Pollution, biodegradable, radioactive, global.

• STUDENT ACTIVITY

1. Describe the sources of pollutants that cause pollution of the river or pond in your city/town.

• TEST YOURSELF

Long Answer Questions

1. Define pollution. Give an account of environmental pollutants of different kinds of pollution.
2. Give an account of sources and pollutants of air pollution. Suggest suitable methods of control of air pollution.
3. What are aerosols ? Write a short account of the sources of aerosols and the environmental problems due to them and their control measures.
4. Write a detailed account of water pollution and its control.
5. Write an essay on acid rain and its ecological effects.

Short Answer Questions

Write short notes on the following :

1. Minamata disease.
2. Greenhouse effect.
3. Photochemical smog.
4. Thermal pollution.
5. Noise pollution.
6. Radioactive pollution.

Objective Questions

1. Non-degradable pollutant is :
   (a) domestic sewage (b) dust and grit
   (c) DDT (d) none of these
2. Air quality measures the level of :
   (a) SO_2, NO_x and SPM (b) CO_2
   (c) N_2 (d) all of these
3. Acid rain includes :
   (a) phosphoric acid (b) sulphuric and nitric acid
   (c) carbonic acid (d) boric acid
4. The pollutant that causes green house effect is :
   (a) SO_2 (b) CO_2 (c) NO_2 (d) PO_4
5. The major pollutant of peeling of ozone layer is :
   (a) CFC (b) CO_2 (c) O_2 (d) NO_2
6. Minamata disease is caused by :
   (a) mercury pollution (b) lead pollution
   (c) cadmium pollution (d) radio isotope pollution

Ans. 1. (c) **2.** (a) **3.** (b) **4.** (b) **5.** (a) **6.** (b).

UNIT

6

WILDLIFE MANAGEMENT

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Ten biogeographic zones according to the dominant species of flora and fauna in India.
- Endangered species, vulnerable species, rare species and threatend species.
- The aims of wildlife management.
- Tiger project, Gir lion project, Crocodile breeding project, Snow leopard project, Elephant project.
- Biosphere reserves and IBWL.

• 6.1. INTRODUCTION

India is one of the twelve mega-biodiversity countries of the world. The other countries are, Mexico, Columbia, Brazil, Peru, Ecnador, Zaire, Medagascar, Indonesia, Malaysia, China and Australia.

Literally meaning of wildlife is the living things that are neither human nor domesticated, especially the game animals, birds, and fishes hunted by man. Indian subcontinent is unique in having great natural beauty in its different biomass and also possessing a rich and diverse wildlife fauna. It includs about 123 families of terrestrial vertebrates. According to an estimate, there are 400 species of mammals, 1200 species of birds, 350 species of reptiles and more than 29,70,000 species of insects.

• 6.2. BIOGEOGRAPHIC ZONES OF INDIA

India is divided into 10 biogeographic zones according to the dominant species of flora and fauna (table 1).

Biogeographic zone	Biotic province	Total area (km)
1. Trans-Himalayan	Upper region	186,200
2. Himalayan	North-West Himalaya	69,000
	West Himalaya	72,000
	Central Himalaya	123,000
	East Himalaya	83,000
3. Gangetic plain	Upper Gangetic plain	206,400
	Lower Gangetic plain	153,000
4. Desert	Kutch	45,000
	Thar	180,000
	Ladakh (cold)	–
5. Semi-Arid	Central India	107,600
	Gujarat-Rajwara	400,400
6. Deccan Peninsula	Deccan Plateau South	378,000
	Central Plateau	341,000
	Eastern Plateau	198,000
	Chhota Nagpur	217,000
	Central Highlands	287,000
7. Western Ghats	Malabar Coast	59,700
	Western Ghat Mountains	99,300
8. North-East India	Brahamputra Valley	65,200
	North-Eastern Hills	106,200
9. Islands	Andaman Islands	6,397
	Nicobar Islands	1,930
	Lakshadweep Islands	180
10. Coasts	West Coast	6,500
	East Coast	6,500

• 6.3. NECESSITY OF CONSERVATION OF BIODIVERSITY

Popular interest in protecting the world's plants and animal species has intensified during the last 20 years. The conservation of wildlife is required for the following benefits :

(1) The wild life helps us in maintaining the 'balance of nature'. Once this equilibrium is disturbed, it leads to many ecological problems. The destruction of carnivores or insectivores often leads to the increase in herbivores which, in turn, affects the forest vegetation or crops.

(2) The wild life can be used commercially to earn more and mroe money, it can increase our earning of foreign exchange by ecotourism.

(3) The preservation of wild life helps many naturalists and behaviour biologists to study morphology, anatomy, physiology, ecology, behaviour biology of the wild animals under their natural surroundings.

(4) The wild life provides best means of sports and recreation.

(5) The wildlife of India is our cultural asset and has deep-rooted effect on Indian art sculpture, literature and religion.

• 6.4. CONCEPT OF THREATENED SPECIES

The International Union of Conservation of Nature and Natural Resources (IUCN) has categorized the rare species of plants and animals for conservation purpose. This classification is based on :

(i) the present and past distribution of the species or taxa.

(ii) abundance and quality of natural habitat.

(iii) the decline in the density of population in course of time and

(iv) the biological and ecological values of species.

According to this system, the following categories have been identified :

(1) Endangered (E) species : These are species or taxa, which are in danger of extinction and which may not survive if the adverse factors continue to operate. The species whose number has been reduced to a critical level or their habitats have been drastically reduced in such a way that they are in the instant danger of extinction.

(2) Vulnerable (V) species : The species or taxa likely to move into the endangered category in the near future if the causal adverse factors continue to operate. These are species whose populations have been seriously decreased and whose ultimate security is not assured and also those whose populations are still abundant but are under threat throughout their range.

(3) Rare (R) species : These are species with small populations in the world. At present, these species are not endangered and vulnerable but are at risk. These species are usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range.

(4) Threatened (T) species : The term 'threatened used in the context of conservation of the species which are in any one of the above categories, viz., endangered, vulnerable or rare.

Th most threatened reptiles, birds and mammals of India have been listed in table 2.

Table 2. Threatened reptiles, birds and mammals of India.

	Amphibians and Reptiles		Birds		Mammals
1..	*Tylotriton varmcosus* (Himalayan Newt or Salamander)	1.	*Choriotis nigriceps* (The great Indian bustard)	1.	*Presbytis pileatus* (Capped langur)
2.	*Varanus salvator*	2.	*Cairina cutalata* (The white winged wood duck)	2.	*Macaca silensus* (Lion tailed macaque)
3.	*Crocodilus palustris* (Marsh crocodile)			3.	*Hylobates hoolock* (White browed gibbon)
4.	*Crocodilus porosus* (Estuarine crocodile)			4.	*Panthera tigris tigris* (Tiger)
5.	*Gavialis gangeticus* (Gharial)			5.	*Panthera leo persica* (Lion)
				6.	*Panthera pardus* (Leopard)
				7.	*Panthera unicia* (Snow leopard)
				8.	Clouded leopard
				9.	*Felis marmorata*
				10.	*Felis bengalensis* (Golden cat)
				11.	*Felis bengalensis* (Leopard cat)
				12.	*F. silvestris ornata* (Desert cat)
				13.	*F. viverrina* (Fishing cat)
				14.	*F. caracal* (Caracal)
				15.	*F. Lynx* (Lynx)
				16.	*Arctictis binturong* (Binturong)

				17.	*Prionodon pardicolar* (Spotted linsang)
				18.	*Canis lumps pallipes* (Indian wolf)
				19.	*Melursus ursinus* (Sloth bear)

• 6.5. REASONS FOR DEPLETION OF WILD LIFE

Many wild animals became extinct due to various human and natural activities :

(1) Absence of cover or shelter to wild animals.

(2) Due to deforestation for cultivation, road-building, railway routes, dam construction or for urbanization, occurs reduction in the area for free monument of wild animals which retards reproductive capacity of certain wild animals such as deer, bison, rhino, tiger etc.

(3) Destruction and fragmentation of natural habitats of wild animals due to the developmental activities of human being is the main cause of depletion.

(4) Environmental pollution also causes the depletion of wild life and biodiversity.

• 6.6. WILD LIFE MANAGEMENT

The wildlife management aims at :

(1) Protection of natural habitats through controlled, limited exploitation of species.

(2) Maintenance of the viable number of species in protected areas.

(3) Establishment of Biosphere Reserves for plant and animal species.

(4) Protection through legislation. Wildlife can also be preserved by :

(i) Improving the existing protected areas as sanctuaries, national parks etc.

(ii) Imposing restriction on export of rare plant and animal species and their products.

(iii) Educating public for environmental protection at all levels of education.

(5) Various natural calomities also causes sometimes the extinction of some species.

(6) Hunting of wild animals for food, recreation, hide, fur, plumage, tusk, horn etc., have cause destruction of wild life.

• 6.7. MODES OF WILD LIFE CONSERVATION

In India, the following measures have been undertaken for the wild life management.

Legal Protection of Species and Habitat

India was probably the first country to enact a Wild Life Protection Act. The Wild Birds and Animals Protection Act was passed in 1887 and was repealed in 1912. For gaine protection in the states in 1927. The Forest Act XVI was enacted. Indian Board for wild life was established in 1952 and this was followed by setting up of wild life Boards in different states. In 1972. new Wild Life Protection Act was passed. Under this act possession, trapping, shooting of wild animals alive or dead, serving their meat in eating houses, their transport and export are all controlled and watched by special staff (Chief Wild Life Warden and authorised officers). This Act prohibits hunting of females and young ons. Under this Act, threatend species are absolutely protected and the rest afforded graded protection according to their state of population size.

Ex-situ Conservation of Wild Life

This is the conservation of wild life outside their natural habitats, which includes :

(1) Botanical Gardens/Arboreta/Herbal Gardens.

(2) Seed (Germplasm) Banks.

(3) Pollen Banks/Seman Bank/Ovum Bank

(4) Biotechnology use (Tissue culture, genetic engineering etc.) —

(5) Gene Banks : These include Indian National Gene Bank (INGB), National Bureau of Plant Genetic Resources (NBPGR), National Bureau of Animal Genetic Resources (NBAGR), National Bureau of Fish Genetic Resources (NBFGR) etc.

In situ conservation (A network of protected areas) :

(1) Wildlife Sancturaies

(2) National Parks

(3) Biosphere Reserves

(4) Tiger Reserves

(5) Ramesar Sites

• 6.8. PROTECTED AREA NETWORK OF INDIA

In situ conservation of wildlife is a comprehensive system of protected areas. There are different categories of protected areas which are managed with different objectives for bringing benefits to the society. These include (i) national parks (ii) sanctuaries (iii) biosphere reserves (iv) nature resources (v) natural monuments and (vi) cultural landscapes etc. These areas may vary considerably in size, design, purpose and effectiveness of management (Table 3) but together form a solid basis of conservation of biological diversity.

Table 3 : Protected areas

	National Park	Santuary	Biosphere reserve
1.	Hitched to the habitat for particular wild animal species like tiger, lion, hangul, rhino etc.	Generally species-oriented as citrus, pitcher plant, Great Indian Bustard.	Not hitched to anyone, two or more species, but to the whole ecosystem, *i.e.*, totality of all forms of life, *i.e.*, ecosystem-oriented.
2.	In India, the size range is 0.04 to 3162 sq. km. Most common (in about 40%) is 100 to 500 sq. km. In 15% is 500 to 1000 sq. km.	Size range is 0.61 to 7818 sq. km. Most common (in about 40%) is 100 to 500 sq. km. In 25% is 500 to 100 sq. km.	Size range over 5670 sq. km.
3.	Boundaries circumscribed by legislation.	Boundries not sacrosant.	Boundaries circumscribed by legislation.
4.	Except the buffer zone, no biotic interference.	Limited biotic interference.	Except the buffer zone, no biotic interference.
5.	Tourism permissible.	Tourism permissible.	Tourism normally not permissible.
6.	Research and scientific management lacking.	Lacking	Managed
7.	So far no attention to genepools and conservation.	So far no attention.	Attention given

• 6.9. NATIONAL PARKS AND SANCTUARIES

Till June 1989, there were 67 national parks and 394 sanctuaries with a total area of about 1,41,298 sq. km. representing roughly 4% of the country's geographic area. 'state-wise break up of NP and sancturies till June 1988 is shown in Table 4. There have been further additions and till June 1992 thee were 73 national parks and 416 sanctuaries. By the year 2000, there were 88 NP and 490 sanctuaries in India covering an area of 1.53 lakh km^2.

Fig. 1. Location of some national parks in India.

NATIONAL PARKS IN INDIA

India is one of the major mega diversity conuntries in the world, India houses a good number of wildlife species found nowhere else on this globe, India is a natural place for the wildlife enthusiasts of the world. The reasons are simple but exciting. India currently has 88 national parks.

These national parks, in turns, house largest number of tigers found in the world, largest number of one-horned rhinos found in the world, now almost extinct Asiatic lions, and a large percentage of elephants. These wildlife animals are but only a part of more than 500 species of mammals who have made India their natural home. Apart from the mammals, India is also blessed with over 2000 species of birds, over 500 speacies of reptiles and amphibians and around 30000 species of insects including colourful butterflies.

Table 4. state/union territories-wise break-up of the sanctuaries and national parks (June 1988)

Name of State/UT	No. of sanct-uaries	Area (sq. km.)	No. of national parks	Area (sq. km.)	No. of NP's & Sants	Area of NP's & Sants (sq. km.)	Remarks
1. Andaman & Nicobar	94	455.98	6	361.57	100	817.55	
2. Andhra Pradesh	16	9672.53	–	–	16	9672.53	
3. Arunachal Pradesh	4	1474.25	2	2307.82	6	3782.07	
4. Assam	8	551.87	2	420.00	10	1371.87	
5. Bihar	14	3985.14	1	979.27	15	4064.41	Area of two sanctuaries not available
6. Chandigarh	1	25.42	–	–	1	25.42	
7. Delhi	1	13.20	–	–	1	13.20	
8. Goa	4	263.32	1	107.00	5	370.32	
9. Gujarat	12	16824.65	4	580.45	16	17405.10	
10. Haryana	6	130.45	–	–	6	130.45	
11. Himachal Pradesh	28	2478.36	2	2411.00	30	4889.36	
12. Jammu & Kashmir	13	5309.67	4	3810.17	17	9119.74	
13. Karnataka	18	3785.58	5	2400.38	23	6185.96	
14. Kerala	11	271.44	3	963.51	14	2234.95	
15. Madhya Pradesh	31	22475.35	11	6283.56	42	28758.91	
16. Maharashtra	11	12867.69	5	2173.33	16	5041.02	
17. Manipur	–	–	2	81.30	2	81.30	
18. Meghalaya	3	29.20	2	288.01	5	317.21	
19. Mizoram	1	681.00	–	–	1	681.00	
20. Nagaland	4	223.89	–	–	4	223.89	
21. Orissa	16	6727.01	1	303.00	17	7030.01	Area of one national park not available
22. Punjab	5	253.24	–	–	5	253.24	
23. Rajasthan	21	5509.80	4	3856.53	25	9366.33	
24. Sikkim	4	96.29	1	850.00	5	946.29	
25. Tamil Nadu	10	2654.39	2	2.71	12	5657.10	
26. Tripura	2	189.09	–	–	2	189.09	
27. Uttar Pradesh	14	6785.24	5	2560.47	19	9345.71	
28. West Bengal	16	1476.08	3	2751.16	19	4227.24	
Total June 1988	368	107310.13	66	33988.14	424	141298.27	
Till June 1992	416		73		489		
Till 2000	490		88		578	153000	

Some of the national parks are given below :

- Bandhavgarh National Park, Umaria District, Madhya Pradesh.
- Bandipur and Nagarhole National Parks, Karnataka.
- Bhalulpong National Park, Arunachal Pradesh.
- Bharatpur Bird Sanctuary, Bharatpur, Rajasthan.
- Corbett National Park, Uttrakhand.
- Dachigam National Park, J&K.
- Dibru Saikhowa National Park, Assam.
- Dudhwa National Park, U.P.
- Gahirmatha Turtle Sanctuary, Orissa.
- Gir National Park, Gir, Gujarat
- Hemis High Altitude National Park, J&K.
- Kanha National Park, Mandla, Madhya Pradesh.

- Kaziranga National Park, Bokakhat (23-kms), Asam.
- Manas Wildlife Sanctuary, Barpeta, Assam.
- Milroy or Pabha Sanctuary, Assam.
- Namdhapha National Park, Arunachal Pradesh.
- Nameri National Park, Assam.
- Nandankanan Zoo, Orissa.
- Panna National Park, Chattarpur, Madhya Pradesh.
- Periyar Wildlife Sanctuary, Kumily, Kerala
- Rajaji National Park, Uttrakhand.
- Ranthambore National Park, Near Sawai Madhopur, Rajasthan.
- Simplipal National Park, Orissa.
- Sundarbans National Park, Piyali, West Bengal.
- The Great Himalayan National Park, H.P.
- Velvadhar Blackbuck Sanctuary, Gujarat.
- Wild Ass Sanctuary, Gujarat.

• 6.10. SPECIAL PROJECTS FOR ENDANGERED WILDLIFE

Tiger Project

There were about 40,000 Royal Bengal tigers in 1909-10. This number was reduced to 2500 by the year 1982. As a result of the recommendations of a Task Force of the IBWL, this project was initiated as a Central Sector Scheme on 1st April, 1973 was nine tiger Reserves (total area 13,017 sq. km. located in different kinds of habitats in nine states. Two more Reserves were later added till 1980 raising the tally to 11 Resrves (total area, 15,800 sq. km.) in ten states, the project covering about 0.49% of total geographic area of the country. A core zone of a minimum 300 sq. km. was identified in each Reserve alongwith a sizeable extent of buffer zone. Four more Reserves were added in 1983 resulting in an increase of the total area under the project from 15,800 sq. km. to 24,712 sq. km. with a corresponding increase in the core area of reserves from 5,142 sq. km. to 8,608 sq. km. In 1987 one more, Dudwa Reserve in U.P. was brought under the project with Dudwa National Park in Kishanpur Sanctuary as its core area, raising the number of Tiger Reserves to 16 in 12 states covering over 26000 sq. km. The seventeenth Tiger Reserve was established in Tamil Nadu during 1988 at Kalakad and Mundanthurai Sancturaies as its core area. The total area of this reserve is 800 sq. km. (571 sq. km. as core and 219 sq. km. as buffer).

Besides tiger, this Reserve is rich in orchids and ferns and also a safe home to other endangered species like the lion-tailed macaque, Nilgiri langur, Nilgiri tahr, wild elephant, guar and leopard. Eighteenth Tiger Reserve was established in 1990, Valmiki (Bihar). Thus, till 1992, there were 18 Tiger Reserves in the country in 13 states, covering an area of 28609 sq. km. This figure increased to 28 Tiger Reserves in 2000 spreading over in 17 states covering an area of 37761 sq. km. Is tiger vanishing ? The statewise break-up of Tiger Reserves is shown in Table 5.

Table 5. Names of the tiger reserves in tiger range states with year of creation and area (till the year 2000).

	Year of creation	Name of tiger reserve	State	Total area (sq. km.)
1.	1973-74	Bandipur	Karnataka	866
2.	1999-2000	Nagarhole (extension)		643
3.	1973-74	Corbett	Uttar Pradesh	1316
4.	1973-74	Kanha	Madhya Pradesh	1945
5.	1973-74	Manas	Assam	2840
6.	1973-74	Melghat	Maharashtra	1677
7.	1973-74	Palamau	Bihar	1026
8.	1973-74	Ranthambhore	Rajasthan	1334
9.	1973-74	Similipal	Orissa	2750
10.	1973-74	Sundarbans	West Bengal	2585
11.	1878-79	Periyar	Kerala	777
12.	1978-79	Sariska	Rajasthan	866
13.	1982-83	Buxa	West Bengal	759
14.	1982-83	Indravati	Madhya Pradesh	2799
15.	1982-83	Nagarjunsagar	Andhra Pradesh	3568
16.	1982-83	Namdapha	Arunachal Pradesh	1985
17.	1987-88	Dudhwa	Uttar Pradesh	811
18.	1999-2000	Katerniaghat (extension)		551
19.	1988-89	Kalakad-Mundanthurai	Tamil Nadu	800
20.	1989-90	Valmiki	Bihar	840
21.	1992-93	Pench	Madhya Pradesh	758
22.	1993-94	Tadoba-Andheri	Maharashtra	620
23.	1993-94	Bandhavagarh	Madhya Pradesh	1162
24.	1994-95	Panna	Madhya Pradesh	542
25.	1994-95	Dampha	Mizoram	500
26.	1998-99	Bhadra	Karnataka	492
27.	1998-99	Pench	Maharashtra	257
28.	1998-99	Pakhui	Arunachal Pradesh	862
29.	1999-2000	Nameri	Assam	344
30.	1999-2000	Bori, Satura, Pachmari	Madhya Pradesh	1486
Total				37761

Paradoxically, the population of tigers decreased during last 10 years or so which is apparent from the figures given below :

Year	No. of tiger	Year	No. of tiger
1972	1827	1997	3508
1979	3015	2002	3642
1984	4005	2005	< 2000
1989	4334	2010	?
1993	3750		

Gir lion project

The Gir forest in Saurashtra peninsula of Gujarat is unique as the only surviving habitat of the Asian lion *Panthera leon persica*. At present in whole of the Asia, this lion is found only in Gir forest of Gujarat. Clearing of forest for agriculture, excessive cattle grazing and other factors led to decline in the lion population.

A five years plan scheme was thus prepared in 1972 by the Govt. of Gujarat for this project. The total area of Gir sanctuary is now 1412.12 sq. km. The central core of about

140.40 sq. km. was constituted as a National Park in 1975. In 1978, an additional area of 118.13 sq. km. was declared as National Park incrasing the area to 258.71 sq. km. Ultimately, the entire sanctuary was declared as National Park.

As a result of this, there has been increase in the lion population. In 1968, there were 177 lions in the Gir. This number incrased to 180 in 1974.

Crocodile breeding project

The project arose from a proposal for development of a crocodile farming industry in India. Dr. H.R. Bustard, in FAO expert on crocodile breeding and management was invited as a consultant to the country in 1974. Based upon his advice, the project was initiated on 1,4,1974. There are three species of crocodiles in India (i) saltwater or estuarine crocodile (*Crocodylus porosus*), (ii) freshwater, swamp crocodile or mugger (*C. palustris*), and (iii) gharial (*Gavialis gangeticus*).

Crocodile population declined worldwide in postwar period. Crocodile hunting is legally banned in India. Work on the project was begun on 1.4.1975 in Orissa. Gharial eggs were hatched for the first time in captivity anywhere in the world at Tikerpada. Distt. Dhenkanal, Orissa in June 1975. A small batch was also hatched at Kurkrail, near Lucknow same year. Crocodile husbandry work was undertaken with a view to sanctuary developmnt. A total of 16 crocodile rearing centres have been developed in the country in eight states (1975-1978). Eleven sanctuaries have been declared under the project, two of which among the largest sanctuaries in the country (Krishna Sanctuary in A.P. 3600 sq. km. and Chambal Sanctuary, a tri-state sanctuary in U.P., M.P. and Rajasthan, 5400 sq. km). Maximum number (5) of sanctuaries is in A.P. By 1981, more than 1000 crocodiles were raised in captivity from eggs hatched by the project have been released in nature.

Gharial rehabilitation began in 1977 with the release of 26 animals in Mahanandi River, Orissa. By 1980, 107 animals had been released in the river where wild population had declined to five.

Rhinos conservation

The centrally sponsored scheme "Conservation of Rhinos in Assam" was introduced in 1987 and is continued for effective and intensive management of rhino habitats.

Snow-leopard project

This is being taken to create 12 snow-leopard reserves throughout the Himalayas.

Elephant project

This was launched in 1992 with the aim at ensuring long term survival of identified viable population of elephants. A line has been drawn to restore the lost and degraded habitats of elephant including creation of corridors for their migration, migration of man-elephant conflict and establishment of data base on the migration and population dynamics of elephants. It also aims at improving quality of life of people living around elephant habitats through sustainabl development.

The states are being provided assistance for ensuring long term survival of identified viable population of elephants in their natural habitats. The project is being implemented in 13 states-viz. Andhra Pradesh, Arunachal Pradesh, Assam, Jharkhand, Karnataka, Kerala, Meghalaya, Nagaland, Orissa, Tamil Nadu, Uttrakhand, Uttar Pradesh and West Bengal.

Biosphere Reserves

Biosphere Reserve Programme was launched by UNESCO in 1971 undr its "Man and the Biosphere Programme (MAB). The purpose of the formation of biosphere reserve was to conserve in situ all forms of life, along with its support system in its totality. The following are the objectives of the Biosphere Reserve Programme (BRP).

- Conserve representative samples of ecosystem.
- Provide long-term in-situ conservation of genetic diversity.
- Promote and facilitate basic and applied research and monitoring.

- Provide opportunities for education and training.
- Promote appropriate sustainable management of the living resource.
- Disseminate the experience so as to promote sustainable development elsewhere, and
- Promote, World Conservation Strategy.

Biosphere reserves include natural, minimally disturbed, man modified and degraded ecosystems. For management purposes, the biosphere reserve areas are divided into : (i) core zone, which represents natural and minimally disturbed ecosystems. (ii) Manipulation (foresty) zone which includes the man made forests and selected felling areas (iii) Manipulation (tourism) zone which includes area earmarked for tourism, education and training. Foresty and tourism zones constitute the buffer zones of the reserve (iv) Manipulation (Agriculture) zone which includes tribal settlements and other cultivated lands and (v) Restoration zone which includes degraded areas selected for restoration to natural or near natural conditions. Agriculture and restoration zones together constitute the flexible transition zone or zone of cooperation.

Comprehensive guidelines were finalized for effective implementation of the Biosphere. Reserve Programm for their management, ecodevelopment of data base and implementation of social welfare plans. Till the year 2005 fourteen biosphere reserves were setup in the country (Fig. 2, Table 6).

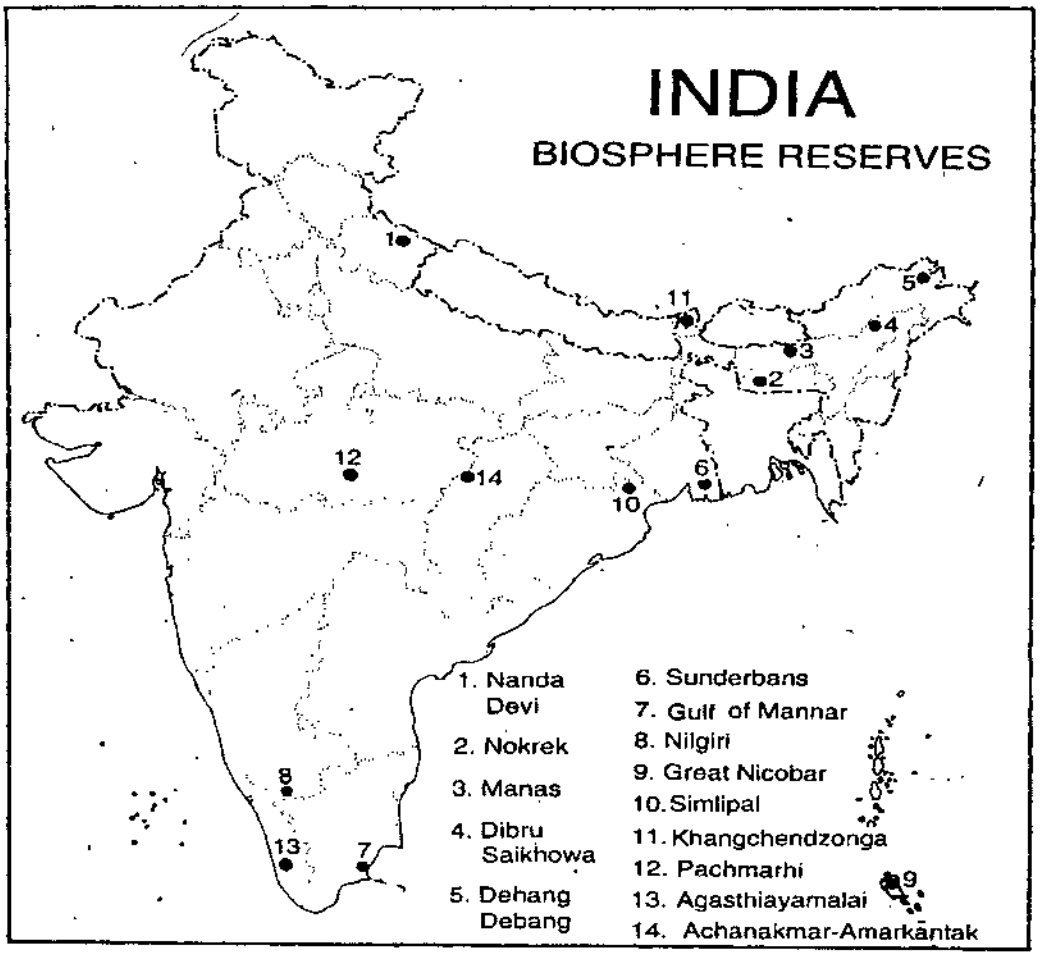


Fig. 2. Map showing the location of biosphere reserves in India till the year 2005.

Table 6. List of biosphere reserves in India till the year 2005

	Name	Date of establishment	Area (Km^2)	Location
1.	Achanakamar-Amarkantak	2005	**3835.51** (Core 551.55; Buffer 3283.86)	Covers parts of Anupur and Dindori Districts of M.P. and parts of Bilaspur District of Chhattisgarh state.
2.	Agasthiayamalai	12.11.2001	**1701** (area expanded on 30.3.2005)	Neyyar, Peppara and Shendurney Wildlife and Parts of Thirunelveli and Kanya Kumari Districts in Tamil Nadu and Thiruvanaathapuram, Kollam and Pathanmthitta in Kerala. Sanctuaries and their adjoining areas in Kerala.
3.	Dehang-Dibang	02.09.1998	**5111.50** (Core. 4094.80; Buffer 1016.70)	Part of Siang and Dibang Valley in Arunachal Pradesh—East Himalayas
4.	Dibru-Saikhowa	28.07.1997	**765** (Core 340; Buffer 425)	Part of Dibrugarh and Tinsukia Districts (Assam)—East Himalayas
5.	Great Nicobar	06.01.1989	**885** (Core 705; Buffer 180)	Southern most, islands of Andaman and Nicobar (A&N Island)—Islands
6.	*Gulf of Mannar	18.02.1989	**10,500** Total Gulf area (area of Islands 5.55)	Indian part of Gulf of Mannar between India and Sri Lanka (Tamil nadu)—Coasts
7.	Khangchendzonga	07.02.2000	**2619.92** (Core 1819.34; Buffer 835.92)	Parts of Khangchendzonga hills and Sikkim—East Himalayas.
8..	Manas	14.03.1989	**2837** (Core 391; Buffer 2446)	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamprup and Darang Districts (Assam)—East Himalayas.
9.	*Nanda Devi	18.01.1988	**5860.69** (Core 712.12; Buffer 5,148.570; T. 546.34)	Part of Chamoli, Pithoragarh, and Bageshwar Districts (Uttrakhand)—West Himalayas
10.	*Nilgiri	31.09.1986	**5520** (Core 1240; Buffer 4280)	Part of Wayand, Nagarhole, Bandipur and Madumalai, Nilambur, Silent Valley and Siruvani hills (Tamil Nadu, Kerala and Karnataka)— Western Ghats
11.	Nokrek	01.09.1988	**82** (Core 47.48; Buffer 34.52)	Part of Garo hills (Meghalaya)—East Himalayas.
12.	Pachmarhi	03.03.1999	**4926**	Part of Betul, Hoshangabad and Chindwara Districts of Madhya Pradesh— Semiarid Gujarat Rajputana.
13.	Simlipal	21.06.1994	**4374** (Core 845; Buffer 2129; Transition 1400)	Part of Mayurbhanj District (Orissa)—Deccan Peninsula
14.	*Sunderbans	29.03.1989	**9630** (Core 1700; Buffer 7900)	Part of delta of Ganges and Brahamaputra river system (West Bengal)—Gangetic Delta.

*Recognised by UNESCO on World Newtork of Biosphere Reserves.

Remesar sites

The Ramesar sites represent different aquatic habitats and are named so after the Ramesar convention held in 1971 for protection of wetlands of international importance. In India, a total of 16 Ramesar sites have been identified, covering about 1.1 million hectare, including the Andaman and Nicobar Islands.

Ex-situ as well as in situ conservation is being followed by non-government as well as government organizations.

Non-Government organisations

There are a number of non-government voluntary national and international organizations actively dedicated to wildlife conservation. Principal organizations are :

Bombay Natural History Society (BNHS), Mumbai : It was founded in 1883, engaged in collection of information and specimens of fauna and flora of India, Burma and Ceylon.

Wildlife Preservation Society of India (WPSI), Dehradun : It was formed in 1958 with several objectives of wildlife management.

World Wide Fund for Nature, India : The World Wildlife Fund, Indian National Appeal was launched in India in 1969 at the time of the XIIth General Assembly of the International Union of Conservation of Nature and Natural Resources, held at Delhi. WWF-International was formed in 1961, with its Headquarters at Glands, Switzerland, and controlled by a board of Intrnational Trustees. It has set up National Appeals in several countries. WWF in India was founded with a Board of eight Trustees and has its Headquartrs in Mumbai. It has supported the well-known "Project Tiger" and other similar projects.

Government organisations

A number of Wildlife Acts have been made from time to time by State as well as Union Government for wildlife conservation. Some of these are :

- Madras Wild Elephant Preservation Act. 1873.
- All India Elephant Preservation Act, 1879.
- The Wild Birds and Animals Protection Act, 1912.
- Bengal Rhinoceros Preservation Act, 1932.
- Assam Rhinoceros Preservation Act, 1954.
- Indian Board for Wildlife (IBWL), 1952.
- Wildlife (Protection) Act. 1972, amended in 1983, 1986, 1991.
- Establishment of National Parks, Sancturaries and Zoological Gardens.
- India became a party to CITES (Convention of International Trade in Endangred Species of Wild Flora and Fauna) in 1976.
- Indian National Man and the Biosphere Committee, 1972 for Biosphere Reserve.
- Projects to conserve individual endangered species like crocodiles (1954), lion (1972) and tiger (1973).
- National Wild Life Action Plan, 1982 endorsed by IBWL.
- Forest (Conservation) Act. 1980, amended in 1988.
- The Environment (Protection) Act. 1986.
- The Biodiversity Act. 2002, implementd in 2004.
- The National Environmental Policy, 2006.

Indian Board of Wildlife (IBWL)

This is the main advisory body of Govt. of India. It was first constituted in 1952 as an advisory body under the name Central Board of Wildlife. Later it was re-named as IBWL. At its first meeting, the Board made a recommendation for unified legislation for wildlife conservation in India. The Wildlife (Protection) Act was enacted in 1972, which has been adopted by all states.

The Wildlife (Protection) Act. 1972 and the provisions of the Convention on International Trade in Endangered Species (CITES) and Export and Import Policy of

India are continued to be enforced through the offices of the Regional Deputy Directors of Wildlife Preservation located at Delhi, Mumbai, Kolkata and Chennai with the help of State Wildlife Wings and the Customs Departments. The Wildlife (Protection) Amendment Bill, 1991 was passed by the Parliament and promulgated as Act no. 44 of 1991, after it had received the ascent of the President of India on 2.10.1991. The new provisions of the Act regarding setting up of the Zoo authority, protection of rare and endangered species would be enforced under this Act.

Indian Board of Wildlife was reconstituted in January 1991, under the Chairmanship of the Prime Minister. The functions of IBWL are as follows :

- To advise Central and State Governments for promotion of conservation and effective control of poaching of wildlife.
- To advise on the setting up of national parks, sanctuaries and zoological gardens.
- To advise the Govt. on policy regarding export of living animals, trophies, skins, furs, feathers and other wildlife products.
- To review the progress in the field of wildlife conservation in the country and suggest measures for improvement.
- To promote public interest in wildlife and on need of its preservation in harmony with natural and human environment.
- To assist and encourage the formation of Wildlife Societies and to act as Central Coordinating Agency for such bodies.
- To advise Central Government on any matter that it may refer to the Board.

• 6.11. CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

Convention on Biological Diversity (CBD) as an international treaty came into existence in 1987 which is nothing but a combination of already existing conservation treaties like, Convention on International Trade in Endangered Species (CITES), the Ramesar Convention and the convention on migratory species.

The objective of CBD is the sustainable use of its components, and the fair and equitable sharing of the benefits, arising out of the utilization of genetic resource and appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies and appropriate funding.

• SUMMARY

Biodiversity means the variety of species of all living plants, animals and microbes. The conservation of biodiversity includes principal aspects of wildlife management. Our country has a rich heritage of wild life tourism, hunting and other usuage. India is one of mega diversity countries among 10 countries in the world. It is divided into 10 biogeographic zones according to geography of the region and its flora and fauna. The extinction of species and depletion in the biodiversity is the most serious aspect of biodiversity conservation programmes. The necessity of the conservation of biodiversity lies in the bnefits of having biodiversity. There are various modes of the conservation of biodiversity which includes in situ and ex-situ conservation methods, enactment of various laws for protection, International treaties etc. Various government and non-government agencies are working actively and on large scale towards the conservation of Biodiversity.

Keywords : Biodiversity, wildlife, conservation, biogeographic, extinction, treaty.

• STUDENT ACTIVITY

1. Do an assignment about the details of biogeographic zones in India and their account of biodiversity.

• TEST YOURSELF

Long Answer Questions

1. What is biodiversity ? Describe the necessity of the conservation of biodiversity.
2. What is the protected area network ? Give the names of principal national parks established in India.
3. Write an account of special projects for endangered species.

Short Answer Questions

1. Write the name of biogeographic zones of India.
2. What are threatened species ? Name of them.
3. What are the cause of depletion in biodiversity ?
4. What is ex-situ conservation of biodiversity ?
5. What is in-situ conversion of biodiversity.
6. What are the National park, sanctuary and biosphere reserve.

Objective Questions

1. Chambal sanctuary is meant for the conservation of :
   (a) elephants (b) tigers (c) crocodiles (d) wild Ass
2. Nanda Devi Biosphere reserve is situated in :
   (a) Uttrakhand (b) Uttar Pradesh
   (c) Punjab (d) Madhya Pradesh
3. Gir forest in Gujarat is meant for conservation of :
   (a) tiger (b) lion (c) elephant (d) crocodile
4. What is CBD ?
   (a) Convention on Biodiversity
   (b) Centre of Biological Development
   (c) Convention on Biological Development
   (d) None of the above
5. BNHS is a :
   (a) NGO for wildlife conservation (b) A programme of T.V.
   (c) A documentary film (d) All of these
6. Ramesar convention is :
   (a) A treaty for protection of grasslands
   (b) A treaty for forest protection
   (c) A treaty for protection of wetlands
   (d) All of them

Ans. 1. (c) 2. (a) 3. (b) 4. (a) 5. (a) 6. (c)

UNIT

7

CONCEPT OF EVOLUTION, ORIGIN OF LIFE ON EARTH

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Organic, inorganic, chemical, biological and molecular evolutions and origin of life and species.
- Theories of spontaneous generation and special creation theory with experiments in opposition of theory.
- Cosmozoic theory, Oparin's theory and Miller's experiment.
- Structure of cosmos, primitive earth, prebiotic synthesis and evolution of progenote.
- Origin of RNP, plasma membrane and progenate, DNA world.

7.1. INTRODUCTION

The living world comprises a rich divrsity of animal, plant and microbial life. All the living organisms appear to be well-fitted (or adopted) for the environmental conditions in which they live. The term evolution is derived from two Latin words – *e* = form : volvere = to roll and means the act of unrolling or unfolding, *i.e.*, the doctrine according to which higher forms of life have gradually arisen out of lower. The term evolution was first used by an English philosopher Herbert Spencer.

Evolution is a dynamic process which has been defined as a gradual orderly change from one condition to another. The principle of evolution implies the development of an entity in the course of time through a gradual sequence of changes, from a simple to a more complex state. In other words, it maintains that the different kinds of organisms that we see today have evolved from common ancestors over millions of years. Charles Darwin (1859) has defined evolution as "descent with modification" differing *i.e.*, closely related species resembling one another because of their inheritance. Now, most of the evolutionary biologists envisage that the present day biodiversity of the planet earth have evolved during the past history of earth by undergoing the following two steps of evolutionary process.

(1) Inorganic, chemical or molecular evolution and origin of life : The first step of the evolution is the origin of life from the non-living (chemical) matter of the planet earth, which is called chemical evolution. About 4600 millions years ago, by self assembly process different simple inorganic molecules formed from different elements : simple inorganic molecules gave origin to organic micromolecules (amino acids) and macromolecules (proteins). Certain macromolecules developed the ability of self duplication and aggregated to form first primitive living systems, called eobionts. Eobionts evolved into prokaryotic cells which formed the kingdom Monera.

(2) Organic and biological evolution and origin of species : The second step of evolution was started from the culmination point of chemical evolution (*i.e.*, origin of life). *The concept of organic evolution* holds that all the varied kinds of animals and plants which are now known, have developed out of earlier types by completely natural, gradual but continuous changes during the passage of time. According to G.L. Stebbins (1976), organic evolution is a series of partial or complete and irreversible transformations of the genetic composition of populations, based principally upon altered interactions with their environment.

The product of organic evolution is the origin of species, or evolution of old species into new species. The branch of biology which incorporates in it, the studies concerning the problems of chemical evolution and origin of life and organic evolution and origin of man and other present day species of the plant. Earth, is called evolutionary biology.

• 7.2. ORIGIN OF LIFE

The kind of evolution which includes evolution from atoms and molecules to simple and then complex substances and from these to still more complex ones capable of self duplication, has been termed as inorganic, molecular or chemical evolution. The most significant outcomes of chemical evolution are the origin of biologically important macromolecules such as proteins and nucleic acids (RNA and DNA), origin of life and an environment to sustain life on the planet earth.

A Historical Account of Origin of Life : In ancient time, due to uncritical observations, people throught religionsly and some philosophers put forward the following theories about origin of life :

(1) Special creation theory : According to this theory, the life is mysterious force *or vital spirit that set living things completely apart from the non-livings. The concept* of special creation was propagated by most of the religions books and preachers. According to Bible, for instance, world was created within six natural days. Planets were created on third day, fish and fowl on the fifth day and animals on the sixth day. Lastly human beings were created first man then woman.

Different schools of Indian philosophy and Hindu religion have dscribed the origin of life from God, Brahma.

(2) Theories of spontaneous generation : For centuries, the concept of spontaneous generation of life from non-living matter enjoyed a lot of acceptance and was a principal doctrine about origin of life. In Europe, it was commonly believed that living matter could spontaneously develop from non-living materials. Infestations of worms, flies, fungi and other organisms appeared regularly in food and organic matter without any apparent explainations. In ancient egypt, the conviction prevailed that the layer of humus deposited by the Nile in its flood stage could give birth to living creatures. When it was warmed by the sun, frogs, toads, snakes and mice were formed. *Thus, in sacred books of India there is description of the sudden emergence of various* parasites flies and beetles from sweat and manure.

Experiments in Opposition of the Theory : Several scientists had opposed the theory of spontaneous generation by their experiments which can be discussed one by one. During the late seventeenth century, an Italian doctor Francesco Redi (1626–1968) was the first to come forward with experimental refutation of this theory. In his experiments, he placed meat or fish underclean muslin coverings and demonstrated that while flies laid eggs on muslin maggots or larvae appeared only when those eggs were transferred to the meat and allowed to hatch. He concluded that maggots came only from pre-existing flies and were not spontaneously generated by any other forms of material.

Experiments were later conducted by Antony van Leeuvienhock (1632–1732) demonstrating once again the spontaneous generation of microbes.

Another Italian scholar Abbe Spallanzani in 1765 tested the theory of spontaneous generation of microbes. He prepared flasks of meat broth which was boiled for several hours and then sealed. The broth remained clear for months and when the seals were broken and the broth tested, it was shown to be free of microbes. Spallanzani's

experiments were neither conclusive nor satisfying to many of his contemporary scientists. Some claimed that by boiling he had driven out a vital force necessary for spontaneous generation. The experiments of Prestly and Gaylussac also support the opposition of Spallanzani.

After about 200 years of Spallanzani, Louis Pasteur (1822–1895) definitely proved through irrefutable evidence that the formation of microorganisms from various broths

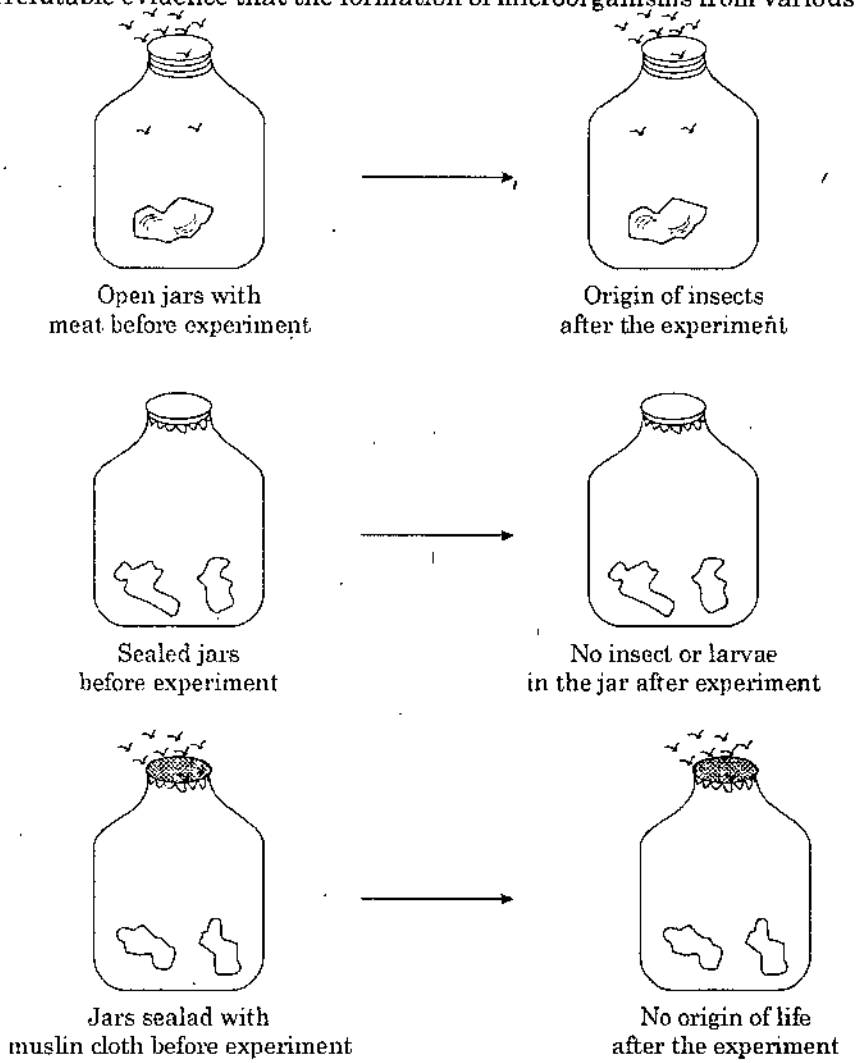


Fig. 1. Redis experiment.

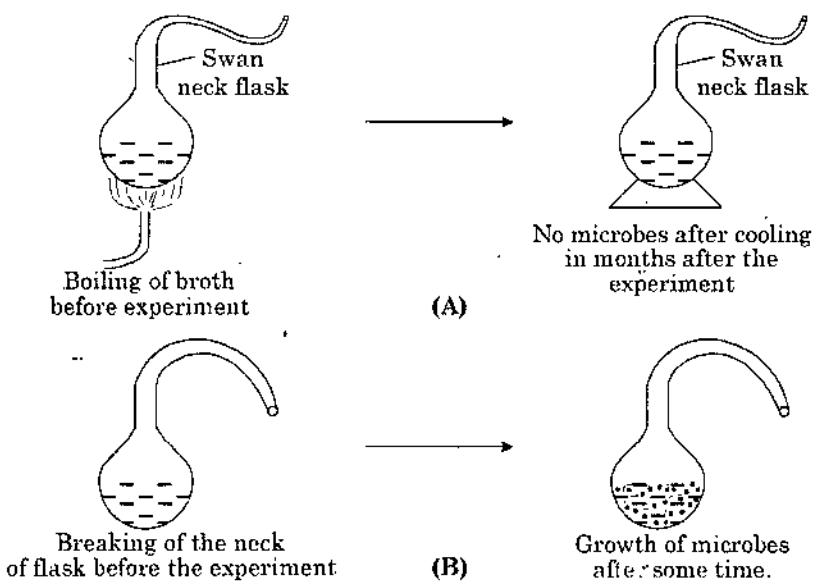


Fig. 2. Pasteur's experiment

solutions of organic substances was simply impossible. He also explained the sources of errors in the experiments conducted by earlier workers. All attempts to disprove Pasteur's observations were in vain. However, there was no final solution to explain the origin of life.

(3) Cosmozoic theory : Some scientists of nineteenth century assumed that this planet was seeded from space. One of such theories called cosmozoic theory or hypothesis of panspermia was developed by Richter (1865) and then supported by Thomson, Helmholtz (1884), Van Tieghem (1891) and others. According to this hypothesis, meteorites tavelling through the earth's atmosphere are strongly incandescent only on the surface, while it remains cold. Thus the embryos of organisms inhabiting meteorites or the planets from which they were formed were preserved alive in the interior of meteorites, finding fertile soil on earth, and grew and evolved to produce all the species now present.

(4) Oparin's theory of origin of life : Since Pasteur's time, countless generations of students have been taught not to believe in spontaneous generation. However, Pasteur's experiments revealed only that life can not arise spontaneously under conditions that exist on earth today. In 1924, a Russian biochemist A.I. Oparin presentd coacervate model to explain the origin of life in his book "origin of life on earth". According to him, origin of life occurred along the origin and evolution of earth and its atmosphere. The primordial atmosphere of earth had water, methane and ammonia from which as a result of a series of changes, a colloidal body called 'coacervate' and containing a mixture of biologically important macromolecules like protein, lipids, nucleic acids etc. were formed (Fig. 3). These coacervates though were not living, but they behaved in a manner similar to biological systems by being subjected to natural selection, by being chemical directive and by having the capacity of reproduction by fragmentation.

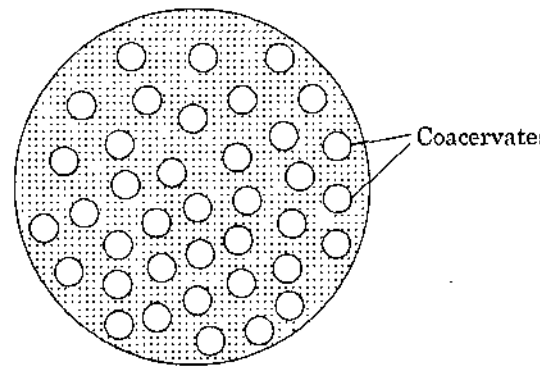


Fig. 3. Coacervate droplets

Miller's Experiment in Support of Oparin's Hypothesis : In 1953, Stanley Miller then at the University of Chicago and a student of Nobel Laureate Harold Urey, synthesized organic compounds under conditions resembling the primitive atmosphere of the earth. He took water vapour, methane hydrogen and ammonia (later three in the ratio of 1 : 2 : 2) in a closed apparatus. Such a gas mixture was circulated through a close apparatus by steam from boiling water and subjected to an electric spark discharge (75,000 volt) between tungsten electrodes. The electric discharge duplicated the effects of violent electrical storms in the primitive universe. The gas mixture was then condensed and added to the boiling water for recirculation; any non-volatile substance that appeared would accumulate in the water. This apparatus was permitted to run for a week. The results were spectacular. Several amino acids were synthesized (*e.g.*, alanine, glycin, glutamic acid, aspartic acid, valine and leucine; in both *D*- and *L*-forms) and a number of other organic compounds such as hydrogen cyanide (HCN), aldehyde and cyano-compound ($-C \equiv N$), appeared; 15 per cent of the carbon in the gas mixture became incorporated into these compounds.

Miller's instructive experiments have been successfully repeated by a number of investigators and enlighted the way of molecular theories of origin of life.

(5) Theory of protenoid microspheres : In 1964, Sidney W. Fox put forward a theory of formation of protenoid microspheres from the monomers (amino acids) in the prevailing conditions of primitive earth. He heated a mixture of amino acids to temperature of 160–200°C for varying periods of time. He obtained stable proton like macromolecules which he termed protenoids. These protenoids aggregate into small spherical cell like units which he termed protenoid microspheres. Their size remained

in between the range of 0.5–0.7 μm diameter. They are found to have catalytic activity such as degradation of glucose and this enzymatic activity of them is partially lost during heating.

The model of protenoid microsphere for protocells is widely accepted because of its following significance : (1) Such portenoid microspheres arise from monomers rather than form polymers obtained from organisms already in biota, as is true for the usual experiments with coacervate droplets. (2) This model suggests that protenoids are informational and it shows the origin of communication which may be inter cellular or intergenerational communication. In fact, it suggests its simultaneous origin of both types of communication.

• 7.3. PROCESS OF ORIGIN OF LIFE

We can discuss the origin of life with the origin of earth crust to hold the life simultaneously. The principal steps are as follows :

(1) Structure of cosmos : Our universe or cosmos is made up of several kinds of galaxies. Each galaxy includes hundreds of billions of stars with their accompanying planets and satellites. Our galaxy is the milky way, which is composed of 100 billion stars besides sun and its planets (*viz.*, solar system). In our solar system, the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. All the planets of solar system rotate around their axes and revolve around the sun in elliptical paths determined by the gravitational force.

(2) Primitive earth : According to Bigbang hypothesis, we believe that the cosmos *is originated as a gigantic explosion in a primordial fireball which below matter,*

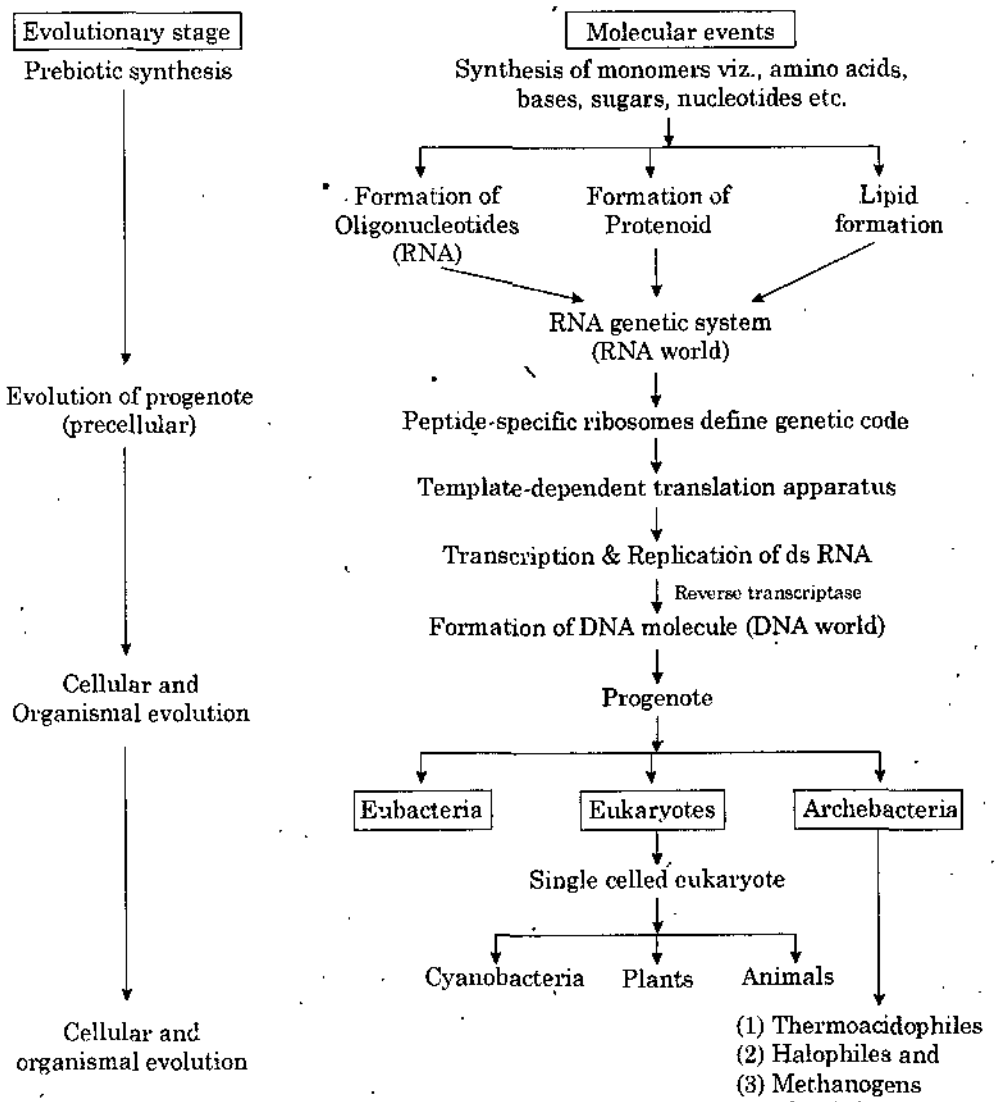


Fig. 4. Flow chart to explain the chemical evolution and origin of life.

scattering in an ever expanding volume. Clouds of dust and gases chiefly helium and hydrogen spread through the space, thinned in some regions and dense in others. Stars can be formed from the condensation of such clouds including our sun also. From the matter of protosun, planets of a solar system originate in the same way. The solar satellites, including the earth and presumably the other planets and asteroids and the earth's moon as well, appear to date from about 4.6 billion years ago.

(3) Prebiotic synthesis : The core of the primitive earth melted from heat of condensation but the outer crust cooled quickly except where convection or volcanic erruptions brought heat and mass from the molten ore to the surface. The early atmosphere was strongly reducing in character, containing primarily hydrogen, methane, ammonia and water. The crust and atmosphere of the primitive earth cooled slowly, and the first shallow seas were formed as the less volatile gases including water, rained back down to earth. The oceans formed as a result of millions of years of torrential rain. The rains eroded the rocks and washed minerals (such as chlorides and phosphates) into the seas. The stage was set for the combination of the varied chemical elements. Chemicals from the atmosphere mixed and reacted with those in waters to form a wealth of hydrocarbons (compounds of hydrogen and carbon). Water, hydrocarbons and ammonia are the raw materials of amino acids, which, in turn,.are the building blocks for the larger protein molecules. Thus in the primitive seas, amino acids accumulated in considerable quantities and became linked together to form proteins or oligopeptides (prebiotic synthesis).

Energy sources for this prebiotic synthesis were UV rays (ultraviolet) from the intense solar radiations penetrating through the thin ozone-free atmosphere, electric discharges such lighting from rainstrom and intense dry heat from volcanic activity etc.

There are several evidences that suggest an anoxic atmosphere of the primitive earth. After millions of years, the oxygen accumulated in the atmosphere by photo dissociation of water vapour and photosynthesis. It is commonly believed that the bulk of free oxygen was produced by plants. Before the advent of life, and indeed until plant biomass became large, this source of oxygen was absent or unimportant.

One final evidence that oxygen was not originally present in the early atmosphere and, therefore, was not dissolved in early oceans, is that organic compounds are stable in the presence of hydrogen (that is under reducing conditions) but are quickly destroyed in the presence of oxygen. This indicates that compounds required as precursors or building blocks for living systems must have originated and accumulated in a reducing environment.

Primitive Sea Served as Broth for the Prebiotic Synthesis : Classical experiments of Miller (1953) have established that organic compounds can be formed without the intervention of living organisms. Thus it appears likely that the sea of the primitive earth spontaneously accumulated a rich mixture of organic molecules. In the absence of living organisms and oxygen, the organic compounds would have been stable and would persist for countless years. The sea became a sort of dilute organic soup or broth. In this organic soup of cauldron molecules collided and reacted to form new molecules of increasing levels of complexity. Proteins capable of catalysis or enzymatic activity had to evolve and nucleic acid molecules capable of self replication must also have developed.

(4) Evolution of progenote : The precellular evolution involved the following three main steps :

(i) Origin and evolution of RNA world : The living cells are an orderly system of chemical reactions (which are directed by enzymes) that has the ability of reproduction. Current consensus is that the machinery for self-replication (that is self-duplicating nucleic acids) evolved before the development of the metabolic (enzymatic) machinery of the cell. It is likely that self-replicating polynucleotides (nucleic acids) slowly became established in the primordial earth some 3.5 billion years ago. In the absence of proteinaceous enzymes in the prebiotic environment, less efficient catalysts in the form of minerals or metal ions would be sufficient to promote the reactivity of the nucleotide precursors. It is postulated that errors continually occurred in the copying process and that seqdeuence of nucleotides in the original polynucleotide molecule became altered

on many occassions. Large number of polynucleotide variations undoubtedly maladapted. Just as organisms today compete for available resources, molecules with different nucleotide sequences competed for the available nucleotide precursors in promoting copies of themselves. Any new mutant sequence with a replication rate higher than the antecedent sequence could be the "fittest" and prevail. *Natural selection (or differential reproduction), thus, operated on population of molecules as it did later on population of organisms.*

The highlights of RNA would include (i) distinction between genomic and functional RNA molecules, (ii) recruitment of exons into transcription; (iii) inclusion of introns in most genes; (iv) no regular cell growth; and (v) formation of membranes (Fig. 5).

(ii) Origin and evolution of ribonucleoprotein (RNP) : Certain polynucleotides not only specified their own sequences, but apparently directed the synthesis of macromolecules of an entirely different types — namely, polypeptides (proteins). In present-day organisms, RNA guides protein synthesis, which suggests that the nucleotides of RNA (not DNA) were the first carriers of genetic information. Thus, RNA established a primitive genetic code for ordering amino acids into proteins. Evidently, the genetic code — the translation of nucleotide sequences into amino acid sequences — became established at a very early stage of organic evolution. The universality of the genetic code in present-day organisms attests to the early origin of genetic code.

The highlights of RNP world include (i) origin of primitive tRNA, rRNA and aminoacyl-tRNA synthetase enzyme; (ii) evolution of template-dependent translation apparatus (the mRNA) and transcription and replication of segmented double-stranded RNA genomes.

(iii) Origin of plasma membrane : A selective advantageous RNA molecule would be one that directs the synthesis of a protein that accelerates the replication of that particular RNA (*i.e.*, RNA polymerase). However, a protein specified by a particular variant of RNA could not foster the reproduction of that kind of RNA unless it is retained in the immediate vicinity of the RNA. The free diffusion of proteins could be prevented if some form of a compartment evolved to enclose or circumscribe the specific protein made by a particular RNA. All present-day cells have a limiting plasma membrane composed principally of phospholipids and proteins. Most probably, the **first cell** was formed when polarised films of phospholipids formed soap-like bubbles enclosing aggregations of complex macromolecules. Specifically, a membranous structure arose that encircled a self-replicating aggregation of RNA and protein molecules. Once bounded by a limiting membrane, a given RNA molecule could be assured of propagating its own special protein molecules.

(iv) DNA world : At some later stage in the evolutionary process. DNA took the place of RNA as the repository of the gnetic information. This step may have occurred due to evolution of an enzyme called inverse transcriptase. In other words, the genetic code was stored in DNA rather than RNA. Today, RNA molecules serve essentially their primal function; directing protein synthesis. Thus, in modern cells, genetic information is stored in DNA, transcribed into RNA, and translated into protein. An endless permutation of nucleic acid and proteins has fostered an enormous richness of life.

Thus, evolutionary highlights of DNA world include (i) evolution of multiple pieces of DNA, (ii) stable storage of information in DNA; (iii) sure existence of plasma membrane; and (iv) growth and division.

(v) Origin of progenote : The precellular stage of organization has been termed **progenote.** The nature of progenote is uncertain. It might have been a functional, slow replicating, independently evolving organism, or it might have been an amorphous group of primitive transcription units plus a primitive transcription and translation apparatus from which many different cell lineages evolved; three of which have survived to the present day (*i.e.*, archaebacteria, urkaryote and eubacteria). The progenote contained DNA, most genes with introns, a slow growth and heterophic nutrition.

The first living system (the progenote) drew upon the wealth of organic materials in the sea broth. Organisms that are nutritionally dependent on their environment for ready-made organic substances are called **heterotrophs.** The primitive one-celled heterotrophs probably had little more than a few genes, a few proteins and a limiting plasma membrane. The heterotrophs multiplied rapidly in an environment with a copious supply of dissolved organic substances. However, the ancient heterotrophs could survive only as long as the existing store of organic molecules lasted. Eventually, living systems evolved the ability to synthesize their own organic requirements from simple inorganic substanes. Thus, in the course of time, **autotrophs** arose, which were able to manufacture organic nutrients from simpler molecules.

However, primitive autotrophs would require a whole array of enzymes to direct a multistep chain of metabolic reactions involved in the synthesis of a protein. Indeed, it would be too much to expect that all the necessary enzymes evolved at the same time. **Norman H. Horowitz** (1959) has proposed that the chain of steps in a complicated chemical pathway evolved backward. Let us analyse his concept in the following way :

Retrograde evolution : According to **Horowitz,** an organism might acquire, by successive mutations, the enzymes required in a biosynthetic pathway in the reverse order from that in which they normally appear in a sequence. In other words, evolution began with the end product of the pathway and worked backward, one step at a time, toward the beginning of the reaction chain. The total pathway became constructed when the organism had trapped from its surroundings all of the intermediate precursors of the reaction.

For instance, let us suppose that an organic compound O is synthesized through the following steps, where A through D represent precursors :

$$A \rightarrow B \rightarrow C \rightarrow D \rightarrow O$$

The first primitive heterotroph, lacking synthetic ability, would require the presence of O in its environment. This essential organic compound, continually being used by the heterotroph, would ultimately become rare, if not exhausted. If a mutation occurred that granted the heterotroph an ability to catalyze the reaction from D to O, then the organism would no longer remain dependent on the availability of O in the environment. Indeed, in an environment where O had become depleted, the new mutant would have a survival or selective advantage over the ancestral type and replace it. As the new mutant reproduced, D in turn would become scarce. Another mutation might occur in the mutant, converting it to a still newer form capable of catalyzing the reaction C to D. At this juncture, both the first mutant and the newly arisen mutant could live together in a close mutual (symbiotic) relationship establishing the first two-gene systems.

The intimate two-gene combination would be able to survive and reproduce in the presence of C and D. As other compounds in synthetic pathway become progressively rarer, additional mutations for their synthesis would be favourably selected. Ultimately, a multigenic system would evolve capable of directing the synthesis of O from inorganic substance A by way of intermediate products B, C and D. At first glance, it might appear that an unreasonable number of mutational events has been involved. But it should be recalled that mutations occur normally and continually in living organisms. In fact, the capacity of mutation should be regarded as an essential property of life.

(vi) Adaptive radiation of progenote : The first simple **autotroph** arose in an anaerobic world, one in which little free oxygen was available. The primitive autotrophs obtained their energy from the relatively inefficient process of **fermentation** (the breakdown of organic compounds in the absence of oxygen). In addition to provide available energy in the form of ATP, such fermentative reactions could also be developed to provide reducing power in the form of NADH that could be used to derive biosynthetic reaction (Fig. 6).

(i) Glucose + ADP → Lactate + ATP (*e.g., Lactobacillus*)

(ii) Glucose + ADP → Ethanol + Lactate + CO_2 + ATP (*e.g., Leuconostoc*)

(iii) Glucose + ADP → Ethanol + CO_2 + ATP (*e.g., Zymomonas*)

(iv) Lactate + ADP → Propionate + Acetate + ATP + CO_2 (*e.g., Clostridium*)

Fig. 5. Some fermentation reactions producing ATP and examples of prokaryotes which perform them (after King, 1986).

Thus, the early fermentative autotrophs were much like our present-day anaerobic bacteria (*Lactobacillus,* etc.) and yeast. The metabolic processes of the anaerobic autotrophs resulted in the liberation of large amount of carbondioxide (CO_2) into the atmosphere. Once this occurred, the way was paved for the evolution of organisms that could use (CO_2) as the sole source of carbon in synthesizing organic compounds and could use sunlight as the only source of energy. Such organisms would be the photosynthetic cells.

Early photosynthetic cells probably split hydrogen containing compounds, such as **hydrogen sulphide (H_2S).** In other words, as is still performed today by anaerobic green/purple sulphur bacteria, hydrogen sulphide is cleaved into hydrogen and sulphur. The hydrogen is used by the cell and synthesize organic compounds, and the sulphur is released as a waste product (as evidenced by the earth's great sulphur deposits. In time the process of photosynthesis was refined so that water (H_2O) served as the source of hydrogen. The result was the release of oxygen (O_2) as a waste product. At this stage, free oxygen became established for the first time in the atmosphere.

The first organism to use water as the source of hydrogen in photosynthesis were the blue-green algae (cyanobacteria). Since blue green algae were active photosynthesizers atmospheric oxygen accumulated in increasing amounts converting reducing primitive atmosphere into oxidizing atmosphere. Many primitive anaerobic bacteria incapable of adapting to free oxygen, remained in portions of environment that were anaerobic. such as sulphur springs and oxygen free muds. Today, there are bacterial types that are anaerobic as well as aerobic.

Geological evidence indicates that free oxygen began to accumulate in the atmosphere about two billion years ago. The rising levels of atmospheric oxygen set the stage for the appearance of one celled eukaryotic organisms, which arose at least one billion years ago. Then within the comparatively short span of 600 million years. the one celled eukaryotes evolved in various directions to give rise to wealth of multicellular life forms inhabiting the earth.

• SUMMARY

Evolution is a dynamic process which has been defined as a gradual orderly change from one condition to another. Through this process different kinds of organisms that we see today have evolved from common ancestors over millions of years. For centuries, the puzzle of origin of life on earth remain unsolved. People believed in stories given in sacred books of different religions. The theories of special creation spontaneous and generation enjoyed a great acceptance to explain origin of life till seventeenth century. In nineteenth century, Pasteur's experiments put final fulstop to the propagation of these theories. In 1924 I.A. Oparin explained origin of life *vs.* origin of earth by his coacervate model. His theory of chemical evolution of life enjoyed a wide acceptance and later on supported by experiments of S. Miller. Syndney F. Fox (1964) showed the formation of protenoid microspheres initially as a result of chemical evolution. In the modern time, the molecular evolution theory of origin of life *vs.* origin of earth has solved this puzzle finally and is supported by several evidences.

Kywords : Evolution, origin of life, coacervate, protenoid, microspheres.

• STUDENT ACTIVITY

1. Depict the molecular evolution theory of origin of life on a model.

• TEST YOURSELF

Long Answer Questions

1. Describe how life originated on earth ?
2. Describe different theories for the origin of life on earth. Discuss in detail the Oparin's theory regarding the origin of life.
3. Describe the concept of evolution.

Short Answer Questions

1. Describe coacervates.
2. Describe protenoid microspheres theory.
3. Describe the evolution of RNA genetic system.
4. Describe primitive atmosphere of earth, free of oxygen.
5. What is evolution ?

Objective Questions

1. The theory of spontaneous generation was based on :
   (a) centrifugal force (b) vital force
   (c) gravitational force (c) none of these
2. Who's experiments finally ends the theory of spontaneous generation ?
   (a) Pasteur's experiment (b) Redi's experiment
   (c) Spallanzani's experiment (d) All of these
3. Swan necked flasks were used by :
   (a) L. Pasteur (b) F. Redi (c) Spallanzani (d) S. Miller
4. Coacervates were :
   (a) water droplets (b) fat droplets
   (c) droplets of different colloids which show some vital activities
   (d) none of these
5. Protenoid microspheres were :
   (a) molecular aggregates of protenoids (b) molecular aggregates of RNA
   (c) RNP (d) molecules of proteins and DNA
6. The atmosphere of primitive earth was :
   (a) free of N_2 (b) free of CO_2 (c) free of lightening (d) free of oxygen
7. The energy source in Miller's experiments was :
   (a) heat (b) electric discharge (c) hot water (d) none of these
8. Who postulated the theory of protenoid microsphere ?
   (a) Oparin (b) S.W. Fox (c) Miller (d) Darwin
9. The first evolved genetic system was :
   (a) RNP world (b) DNA world (c) RNA world (d) all of these
10. What are progenotes ?
   (a) Precellular form of life (b) Unicellular form of life
   (c) Multicellular form of life (d) All of these

Ans. 1. (b) **2.** (a) **3.** (d) **4.** (c) **5.** (a) **6.** (d) **7.** (b) **8.** (b) **9.** (c) **10.** (a).

UNIT

8

THEORIES OF ORGANIC EVOLUTION

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Lamarck's theory : Examples and significance of Lamarckism, neo-lamarckism.
- Darwin's theory : Critical analysis and demerits of Darwinism, theory of Pangenesis.
- Modern synthetic theory : natural selection and origin of new species.

• 8.1. INTRODUCTION

The modern theory of molecular evolution of origin of life now has been very much accepted and established.

Another principal concept of evolution is organic evolution which starts from the culmination point of origin of life. The concept of organic evolution holds that all the varied kinds of animals and plants which are now known have developed out of earlier life forms by completely natural, gradual but continuous changes during the passage of millions of years. The product of organic evolution is the 'origin of species', or evolution of old species into new species. There are several theories which have been put forward from time to time to describe the process of organic evolution and origin of species.

(1) Lamarck's theory

(2) Darwin's theory

(3) Modern synthetic theory

• 8.2. LAMARCK'S THEORY

Theory of Inheritance of Acquired Characters (Lamarckism) : This theory was propounded by French naturalist, Jean Baptiste de Lamarck (1744–1829). The theory states "modification which the organism acquires in adaptation to the environment which it meets during its lifetime are automatically handed down to its descendents and so become part of heredity". In 1809, Lamarck published "Philosophic Zoologique" in which he described his evolutionary ideas as follows :

(a) Internal forces of life tend to increase the size of the organism : New structures appear because of an 'inner want' of the organism, *i.e.*, the internal force of life tend to increase continuously the size of an organism and its component parts.

(b) Direct environmental effect over living organisms : The organs of an animal became modified in appropriate fashion in direct response to a changing environment.

(c) Use and disuse : The various organs became greatly improved through use or reduced to vestiges through disuse.

(d) Inheritance of acquired characteristics : Such bodily modifications, in some manner, could be transferred and impressed on the germ cells to affect future generations.

Thus Lamarck believed that organic changes seen in animals were brought by the influence of environment on the gradual change of species due to their tendency to become more and more perfect.

Examples of Lamarckism

1. The deer-like ancestor of giraffe lived in places (Africa) where the ground was almost invariably perched and without grass. Obliged to browse upon trees, it was continually forced to stretch upwards (Fig. 1) habit maintained over long periods of time by every individual of the race had resulted in the forelimbs becoming longer than the hind ones, and neck so elongated that a modern giraffe can raise his head to a height of eighteen feet without taking his forelimbs off the ground.

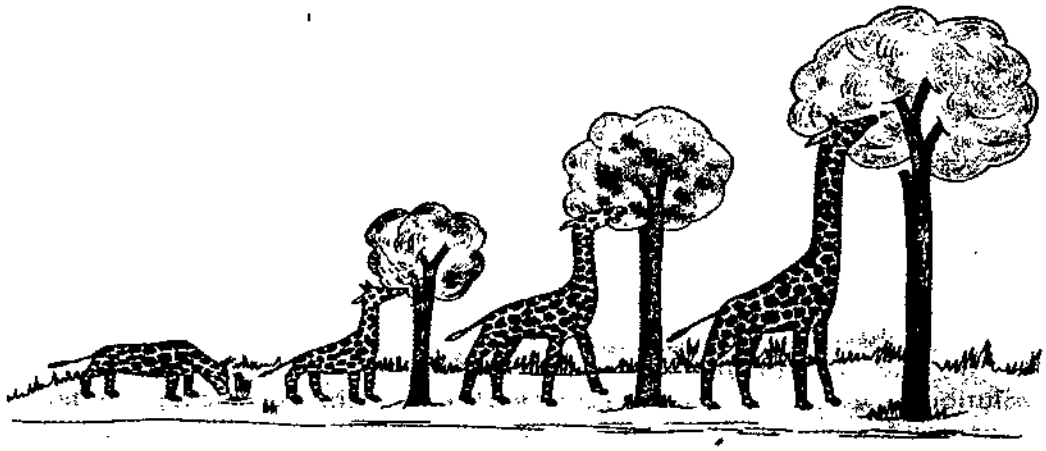


Fig. 1. Evolution of giraffe according to Lamarck.

2. Flat fishes (Deep sea fishes) present at the bottom of sea where there is no sunlight, led an inactive life, lying on one side of the body. The eye of that side (lying towards bottom) migrated towards upper side and, thus, both eyes are on one side of the body.

3. The whales lost their hindlimbs as the consequence of the inherited effect of disuse.

4. The wading birds (*e.g.*, Jaiana) developed its long legs through generations of sustained stretching to keep the body above the water level.

5. Snakes have elongated body accompanied by loss of limbs. The continuous creeping through holes and crevices made limbs continuously useless for locomotion with the result that limbs became completely lost in snakes.

6. Eyes are reduced in moles since they live underground. In cave animals also, eyes might become functionless and might even disappear.

7. For plants, Lamarck accepted the theory of his compatriot S. Helaire, who developed the notion that plant form is shaped by the combined effects of the environment.

There are other evidences such as vestigial organs in living animals due to disuse. Claws in carnivora, sensitive skin and tactile points on the ventral side of the body and callosities of palm in hard workers exemplifying Lamarck theory.

Significance of Lamarckism : It was the first completely comprehensive mechanistic the theory that was offered. Furthermore, it was the theory that lent itself to predictions and therefore, to testing. This Lamarckian theory enjoyed popular acceptance for near about 70 years, because it was exemplified by many common examples. Most persons know that exercise results in larger muscles.

Critical Analysis of Lamarck's Propositions : After having published his theory in 1802, Lamarck courageously defended it throughout his life. However, it was criticized during his lifetime and afterwards. The following main criticisms of his postulates, one-by-one are as :

1. The first postulate suggests a tendency for increase in size. While the evolutionary trend in certain groups may be associated with increase of size, there are a number of cases, where evolution proceeded not only without any increase in size but rather through a reduction in size. Many ferns and conifers which became extinct were gigantic trees and the more highly evolved flowering plants are really much smaller in size.

2. The second Lamarkian principle that new organs result from new needs, is quite manifestly false. In the case of plants, Lamarck believed that the environment acted directly upon the plant, causing the production of such new characters as might adapt the plant to its environment. In the case of animals, he believed that the environment acted through the nervous system; in other words, the desire of the animal leads to the formation of new structures. In its crudest form, this would mean that the man who mused *"Birds can fly, so why can't I*? should have sprouted wings and taken to the air.

3. The third Lamarckian principle that organs will develop due to use and degenerate due to disuse, may be correct as far as growth of an organ within the lifetime of an individual is concerned. For example, it is a commonly observed fact that if muscles are put to use these would develop. However, this principle is meaningful only when it is studied in relation to the following fourth principle.

4. The fourth and final proposition of Lamarck was that the inheritance of characters is acquired during the lifetime of the individual. This principle has been tested by many biologists who have devised many types of experiments for it and have found it entirely incorrect. Certain experiments which have discredited it are as follows:

(a) The noted German scientist August Weismann was the first person who for the first time made a definite distinction between heritable changes and those which cannot be inherited. In 1890, he performed some experiments to test if characters may disappear due to disuse. This he did by cutting the tails (mutilation) of white mice for more than 20 generations to see if this has any effect on tail length. The measuring of tail length of the off springs of 20 successive generations, revealed that on an average, the tails were not shorter. It means that, acquired character (cut tail) was not inherited.

(b) Castle and Phillips performed transplantation experiments to show that environment has no effect on heredity. In one of the experiments, they transplanted the ovary of a black female guinea pig into the body of white female guinea pig and the recipient female was mated with a white male guinea pig. They found that all the individuals from this pair were black. This shows that the environment does not affect the heredity as had been suggested by Lamarck.

(c) Loeb artificially fertilized the eggs of sea urchin by certain chemical stimuli and these parthenogenetically fertilized eggs produced the generations, the members of which possessed no parthenogenesis.

(d) Boring of ears and nostrils in Indian women has been continued as the tradition from centuries but their offsprings do not show any trace of holes in ears and nostrils.

(e) The Chinese bound the feet of their women for many generations, yet this has not resulted in any modification of the feet of present-day Chinese women.

(f) Jewish boys (and also Muslim boys) have been circumcised for thousands of years, but this has not resulted in a tendency toward the reduction of the prepuce in them.

All the aforesaid cases and experiments clearly showed that Lamarckian theory is not tenable.

Neo-Lamarckism

The evolutionsists who support the Lamarckian doctrine of inheritance of acquired characters come under the heading of **neo-Lamarckian.** Among the new-Lamarckian notable supporters are **Cope** (1840-1897), **Giard** (1846-1908), **Packard, Spencer** and **McBride** tried to modify Lamarckism in order to make it acceptable. These neo-Lamarckians considered that adaptation is universal. It arises as a result of casual relationship of structure, function and environment. Changed environmental conditions alter habits of organisms, hence, in response to new habits, organisms acquire new structures in place of old structures. Consequently, variations among

animals have become distinct. These variations have finally become engrained in the heredity of the race. The kind of argument is, in fact, a modified version of Lamarckian principles, because it has omitted Lamarck's view that of a general perfecting tendency in evolution. It stressed direct action of environment on organic structure. For example, according to Neo-Lamarckians, the development of fur on skin by animals as protection against cold weather, is the consequence of changed environment from warmer to colder state only. But if the environment reverts to normal state, the fur would also disappear. To account it, Neo-Lamarkism included also the effects of use and disuse. Based on this, neo-Lamarkians have rejected natural selection as the sole mechanism of evolution. On the other hand, they believed in the interplay of structure, function and environment as the whole truth of evolution. However, no evolution of today is adherent to Neo-Lamarckism.

The following are the evidences of transmission of acquired characters :

(a) Mc Dougall conducted learning experiments in rats and from the results obtained he tried to suggest that learning as an acquired character can be inherited. During his experiments, the rats were dropped into a tank of water from which there were two exists, one lighted and one dark, but not always the same one. A rat leaving by the lighted exit received an electric shock, while one leaving by the dark exit received no shock. Thus, the number of trials required for a particular rat to learn always to select the dark exit constituted a measure of the speed of learning. These rats were then bred and their descendants were similarly studied. It appeared that the speed of learning increased from generation to generation and, so, **McDougall** concluded that learning, an acquired trait *par excellence,* is inherited.

Some serious criticisms have been raised against McDougall's experiments. It is suggested that genetic constitution of rats was not controlled. Moreover, in the progeny of control rats not subjected to these learning tests, the learning habit was found to change the same way as in the treatments. So, it was said that some unanalyzed changes in the technique may be responsible for the recorded increase in the speed of learning. Lastly, the most strange aspect about McDougall's experiment is, that the same experiments, when repeated in other laboratories, never gave similar results.

(b) F. B. Sumner reared the white mice at 20°C to 30°C, because of which they developed longer bodies, tail and feet. When these mice were bred at lower temperatures their offsprings showed their normal proportions of size.

(c) Lindsey subjected certain cold-blooded animals, warm-blooded animals and plants to usual environmental conditions and found that environment affects certain changes in these organisms and these acquired modifications were inherited up to some extent in their offsprings.

(d) Guver and **Smith** induced the hereditary changes in the eyes of foetuses of rabbit by simply destroying lens of living female with a needle *in situ*. The antilens serum has been produced in the blood of these animals.

(e) Griffith and **Detlefson** reared rats in cages placed on rotating table for several months. Consequently, they became adapted to the rotating condition to such an extent that when rotation was stopped, they showed signs of nystagmus (dizziness) and other physiological conditions. This condition was inherited for several generations.

(f) Various acquired diseases described by **Brewn Sequard** are inherited from generation to generation. For example, exophthalmia was caused in parents by injuring in brain the restiform body. This disease was, later on, inherited to several generations. The other diseases such as **haematoma** and dry gangrene are produced by injury to the restiform body near the rib of calamus. Later, these were found to be inherited.

(g) Kammer worked on the taild amphibian proteins anguinus which lives in complete darkness in the water of underground cave. It was blind and colourless. He brought proteins in daylight due to which it became coloured (brown & black) which passed on to its progeny. Eyes of proteins also developed normally in daylight. This showed that they change in environmental conditions, induced changes in the animals and the acquired characters were inherited.

Theory of Natural Selection (Darwinism) : More than a century ago, in 1859, Charles Robert Darwin (1809–1882) gave the biological world the master key that unlocked all previous preplexities regarding the mechanism of organic evolution. The concept of natural selection was explained clearly and convincingly by Darwin in his masterpiece book – "The origin of species".

Darwin worked as a Naturalist on the ship H.M.S. Beagle, heading into a voyage of 4 years to explore the nature. Darwin was appointed there to provide a collection of material representing the natural composition of the areas visited. He visited many islands of Atlantic ocean, some coasts of south America and some islands of South Pacific, of which Galapagos Islands are the most important. During his five years, Darwin recorded almost everything he observed and sent an enormous amount of material back to England.

Facts that influenced Darwin's Thoughts : During the period in which Darwin massed his evidence and developed his natural selection theory, many things affected his thinking, of which some in particular deserve to be mentioned here :

(1) During his voyage, Darwin observed a variety of facts. To analyse and explain these observations, the book of Charles' Leyll's "Principles of Geology" given by his mentor John Henslon as a parting gift helped him a lot. Darwin was impressed by Lyell's emphasis on the great antiquity of the earth's surface (rocks), and gradually came to conclusion that the characteristics of organisms as well as the surface of the earth could change over a vast span of time.

By analyzing the living and extinct forms of some species in the plains of Argentine Pampas and the Galapages Islands, he revealed the facts that species gradually became modified with time, and that not a species survived through the ages. He also concluded that living species have ancestors and species change not only in time but also with geographical distance.

Galapagos Islands and Darwin's Finches : The Galapagos consists of an isolated cluster of rugged volcanic islands in the eastern pacific on the equator about 600 miles west of the Ecuador. During his visit on the Galapagos, Darwin was greatly motivated and impressed by the diversity and distinctive forms of life. One of the most unusual animals is the giant land dwelling tortoise, which may weigh as much as 275 kg, grow to 183 cm in length, and attain an age of 200 to 250 years. In Spanish language, tortoise is called by the name 'Galapago after which the islands were named. Drawin noticed geographical variation in the population of tortoise from island to island. In isolation, Darwin reasoned, each population had evolved its own distinctive features. Yet, all the island tortoises showed basic resemblances not only to each other but also to relatively large tortoises on the adjacent mainland of South America. All this communicated to Darwin that island tortoises shared a common ancestor with the mainland forms.

The geographical variations were also observed in the population of small black birds known today as Darwin's finches (Fig. 2). Darwin observed that the finches were different on the various islands, yet they were obviously closely related to each other. Darwin concluded that finches were derived from an ancestral stock that had emigrated from the mainland to the volcanic islands and had undergone profound changes under the different conditions of the individual islands. Apparently, a single ancestral group can give rise to several different varieties of species.

Idea of Artificial selection : In the late 1830's, Darwin attended the meetings of animal breeders and intently read their publication. Animal breeders were conversand with the variability in their pet animals and dwelled on the technique of 'artificial selection'. Thus the breeders selected and perpentuated those variant types that interested them or seemed useful to them.

Impact of Malthus book : Having explained the origin of variation (although incorrectly), Darwin wondered how artificial selection (a term familiar then only to animal breeders) could be carried in nature. There was no breeder in nature to pick and choose. In 1838, Darwin found the solution in Thomas Robert Malthus book "An Essay on the Principle of Population" in which Malthus asserted that the reproductive

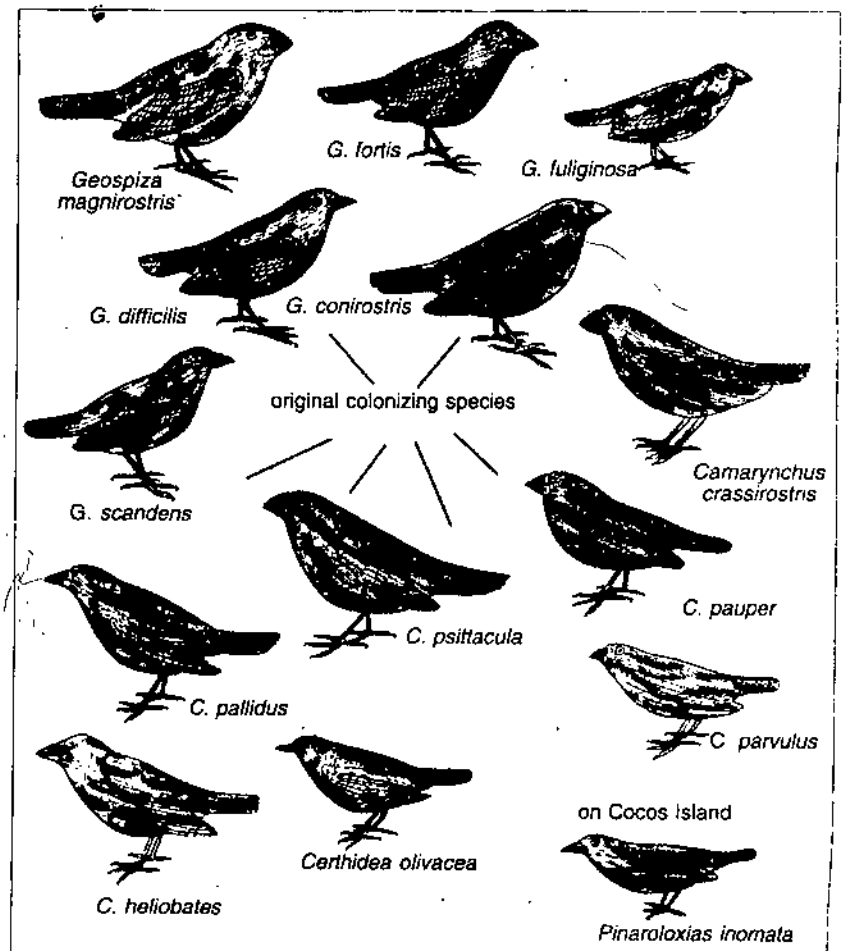


Fig. 2. Darwin's finches.

capacity of mankind far exceeds the food supply available to nourish an expanding human population. Human compete among themselves for the necessities of life.

Impact of Wallace's Communication : Alfred Russel Wallace (1823-1913) independently conceived of the idea of natural selection. In June 1858, Wallace sent Darwin a short essay "On the tendency of varieties to depart indefinitely from the original type" and asked him for his opinion to present it to the Linnaean Society. Darwin was amazed on receiving Wallace's essay, as both of them were conceptualating the same theory of 'natural selection'. Upon the insistence of the geologist Charles Lyell and the botanist Joseph Hooper, Darwin prepared an abstract of his conclusions for joint publication with Wallace's essay. Wallace's essay and a portion of Darwin's manuscript, each containing remarkably similar views, were read simultaneously before the Linnaean Society in London on July 1, 1858.

• 8.3. DARWIN'S THEORY

Darwin-Wallace Theory of Natural Selection : This theory was based on the following concepts :

(1) The universal occurrence of variation : In all the living, things variations are found. Even the siblings do not bear much similarity.

(2) An excessive natural rate of multiplication : Every species, in the absence of environmental checks, tends to increase in a geometrical manner. With any check, a population multiply at exponential rate. Such a great reproductive potential of different species may be easily observed in nature. It has been estimated that a common Atlantic coast oyster may shed as many as 80 million eggs in one season. A solmon produces 28,000 eggs in a season. Darwin calculated that even a pair of elephants which are known to have lowest reproductive rate could, in the absence of any checks, have 29 million descendants at the end of 800 years.

Thus, more organisms of each kind are born than can possibly obtain food and survive. Since, the number of each species remains fairly constant under natural conditions, it must be assumed that most of the offsprings of any species remained alive and reproduced they would soon crowd all other species from the earth.

(3) Struggle for existence : Since more individuals are born than can survive there is an intraspecific and interspecific competition for food, mates and space along with environmental struggle for survival.

(4) Survival of the fittest : Some of the variations exhibited by living things make it easier for them to survive; others are handicaped which brings about the elimination of their procedures. This idea of "the survival of the fittest" is the core of the theory of natural selection.

(5) The inheritance of the variations : The survived individuals from the struggle of existence only could get the chance to reproduce and transmit or inherit that advantageous variation in their descendents. The less fit will tend to be eliminated before they have reproduced.

Successive generations tend to become better adapted to their environment; as the environment changes, further adaptations occur. The kind of selection of fit individuals and allow them to reproduce is called 'natural selection'. The operation of natural selection over many generations may produce descendents which are quire different from their ancestors, different enough to be separate species.

Critical Analysis of Darwinism : With the appearance of Darwin's book in 1859, a variable storm of criticism broke out and many people became interested in his presentation. The concept of natural selection was opposed primarily on ethical and religions grounds. But the sheer weight of evidence and the logic of Darwin's presentation finally convinced a majority of the educated people. The concept of evolution affected many aspects of man's thinking and it will continue to do so.

Demerits of Darwinism : Besides its numerous merits, Darwinism has the following demerits :

(a) The theory of natural selection does not account for the beginning of organs, which may first appear as the veriest rudiments having as yet not selection value. In other words, it remains concerned with the survival of the fittest, but not for arrival of the fittest.

(b) Over-specialization in certain cases like extinct Irish deer in which huge antlers outweigh the entire skeleton, or the immense spiral tusks of the Jefferson mammiath or the minute fidelity of certain mimicking insects such as kallima, or huge dinosaurs of Mesozoic : all cannot be explained on the basis of continuous variations and natural selection. These organs or body structures should not have reached such a harmful stage, if natural selection was operating. However, such cases of over specializations have been explained by Darwin on the basis of discontinuous variations or sports which, according to him do not play any role in evolution.

(c) Natural selection cannot account for degeneracy. To say an organ is no longer useful and hence, disappears, is to state the effect and not the cause. If under changed conditions, a character built up by natural selection becomes a menace, the reversal of selection can accomplish its removal but this will not suffice where the characteristic is an indifferent one.

(d) One of the classical objections to natural selection is that new variations would be lost by 'dilution' as the individuals possessing them bred with others without them.

Theory of Pangenesis : In 1868, Darwin had postulated the hypothesis of pangenesis to explain the inheritance of acquired variations. According to this theory, all the cells in the body of an animal produced miniatures of themselves. These miniatures, called gemmules or pangens shed into the blood stream and carried to the sex glands (*viz.*, reproductive organs, the testes and ovaries), where they were assembled to form sex cells – the eggs or sperms. Later when a fertilized egg undergoes development, according to the concept, the pangens present are responsible for the particular features of the new individuals.

In year 1875, Galton made this hypothesis untenable by presenting several experimental proofs. He and others at later time made a series of experiments involving blood transfusions and later transplants of ovaries between black and white varieties of rabbits and chickens. Gametes produced by the transplanated ovaries were consistent with the phenotype of the individual in which the ovary originated and not with the animal currently carrying the ovary. Blood transfusion had no effect on the gametes produced. These experiments readily demonstrated that the pangenesis hypothesis was incorrect.

• 8.4. MODERN SYNTHETIC THEORY

Neo-Darwinism or Modern Synthetic Theory : During later, half of 19th century different concepts of heredity came forward to explain the course of importance of the characters. This knowledge and advancement in different subjects like Weismann's theory of Germ plasma, Hugo de Vries mutation theory and the rediscovery of Mendal's law contributed a lot in understanding the concept of evolution. All these advancements in cytology, genetics, cytogenetics, population genetics and evolution gave a way for the formulation of a coherent theory called modern synthetic theory around 1930s by S. Wright, H.J. Muller, Th. Dobzhansky, R.B. Goldschmidt, J.S. Huxley, R.A. Fisher, J.B.S. Haldane, E. Mayer and G.L. Stebbins.

This theory of evolution involves five basic processes — mutations, variations, heredity, natural selection and isolation.

In addition, three accessory processes affect the working of these five basic processes. **Migration** of individuals from one population to another as well as **hybridization** between races or closely related species both increase the amount of genetic variability available to a population. The effects of **chances** acting on small populations, may alter the way in which natural selection guides the course of evolution (Stebbins 1971).

1. Mutation : Alteration in the chemistry of gene (DNA) is able to change its phenotypic effect (*i.e.*, nature of polypeptide) is called **point mutation** or gene mutation. Mutation can produce drastic changes or can remain insignificant. There are equal chances of a gene to mutate back to normal. Most of the mutations are harmful or deleterious and lethal but not all. Most of the mutant genes are recessive to normal gene and these are able to express phenotypically only in homozygous condition. Thus, point mutations tend to produce variations in the offspring.

2. Variation (Recombination) : The nature of genetic variations caused by reshuffling of genes during sexual reproduction (recombination) was very little known at the time of Darwin. **Recombination** — that is, new genotypes from already existing genes — is of several kinds : 1, the production of gene combinations contained in the same individual two different alleles of the same gene, or the production of heterozygous individuals (meiosis); (2) the random mixing of chromosomes from two parents to produce a new individual (sexual reproduction); (3) the mixing of a particular allele with a series of genes not previously associated with it, by an exchange between chromosomal pairs during meiosis, called **crossing over** , to produce new gene combinations **Chromosomal mutations** such as polyploidy, deletion, duplication, inversion and translocation also result in variation.

3. Heredity : The transmission of characteristics or variations from parent to offspring, is an important mechanism of evolution. Organisms possessing hereditary characteristics that are helpful, either in the animal's native environment or in some other environment that is open to it, are favoured in the struggle for existence. As a result, the offsprings are able to benefit from the advantageous characteristics of their parents.

4. Natural selection : Natural selection brings about evolutionary change by favouring differential reproduction of genes. Differential reproduction of genes produces change in gene frequency from one generation to the next. Natural selection does not produce genetic change, but once genetic change has occurred it acts to encourage some genes over others. Further, natural selection creates new adaptive

relations between population and environment, by favouring some gene combinations, rejecting others and constantly moulding and modifying the gene pool.

The working of natural selection are exceedingly complex because of the range of organizational levels at which it functions. Selection discriminates among available reproducible biotic entities to produce more efficiently adapted units. Natural selection operates upon every stage in the life history of an organism. It produces non-random differential reproduction of biological units and may affect any biotic entity from the molecular to the community level. Examples of levels at which natural selection makes differential discrimination are the following : **intermolecule, intergene, interchromosome, intergamete, interindividual** (Darwinian selection), **interdemic, interracial, interspecific** and **intercommunity.** Darwinian selection may result from differential natality among others.

5. Isolation : Isolation of organisms of a species into several populations or groups under psychic, physiological or geographical factors is supposed to be one of the most significant factors responsible for evolution. **Geographical isolation** includes physical barriers such as high mountains, rivers, oceans and long distances preventing interbreeding between related organisms. **Physiological barriers** help in maintaining the individuality of the species, since these isolations do not allow the interbreeding amongst the organisms of different species. This is called reproductive isolation.

Speciation (origin of new species) : The populations of a species present in the different environments are segregated by geographical and physiological barriers, accumulate different genetic differences (variations) due to mutations (both point and chromosomal), recombination, hybridization, genetic drifts and natural selection. These populations, thus become different from each other morphologically and genetically and they become reproductively isolated forming new species.

• SUMMARY

After understanding the concept of origin of life, another problem arised about the origin of species or organic evolution. To explain organic evolution, various theories had come forward, among which the prominent ones are Lamarck's theory, Darwin's theory and Modern synthetic theory. Lamarck proposed the theory of inheritance of acquired characters but faced a lot of criticism against his theory. In 1859, Darwin had proposed the theory of natural selection to explain the concept of organic evolution. Darwin's theory was backed up by solid evidences and scientific rationals. However, the survival of fittest, one postulate of his theory received a great religious opposition. During his life, Darwin had defended courageously his theory by postulating further new theories. Theory of pangenesis was one of them. Although, the debate continuously went on but the fact of natural selection was accepted to all.

In the light of new advancement in various disciplines like cytology, genetics, population genetics such as rediscovery of Mendal's law, Weismann's germ plasm theory and Hugo de Vries mutation theory a number of pro-Darwinian scientific presented neo-darwinism or modern synthetic theory to explain the origin of species. This theory is widely accepted and recognized.

Keywords : Origin of life, origin of species, modern synthetic theory, natural selection, pangenesis, mutation theory.

• STUDENT ACTIVITY

1. Make a chart of Darwin's finches.

• TEST YOURSELF

Long Answer Questions

1. Define and describe the hypothesis of "Inheritance of acquired characters".
2. Give an account of Lamarckism with the evidence in support and against the theory.
3. Give a detailed account of Darwin's theory of 'Natural selection'.
4. What is modern synthetic theory ? Explain it.

Short Answer Questions

1. What is artificial selection ?
2. Write critical opposition of Lamarck's theory.
3. Explain the Galapagos islands.
4. Write a short note on Darwin's finches.
5. What is theory of Pangenesis ?

Objective Questions

1. The name of Lamarck's book is :
   (a) Theory of Philosophy (b) Philosophie Zoologique
   (c) Zoologic philosophy (d) None of these
2. 'Origin of species' was written by :
   (a) Lamarck (b) Weismann
   (c) Darwin (d) Hugo de Vries
3. Darwin's finches were :
   (a) different varieties of a species of birds
   (b) tortoise species on Galapagos islands
   (c) varieties of Dogs
   (d) varieties of snakes
4. Mutation theory was proposed by :
   (a) Weismann (b) C.D. Vries
   (c) Tschermak (d) Hugo de Vries
5. 'An essay on the Principle of Population' was written by :
   (a) Malthus (b) Lamarck
   (c) Lyell (d) J. Henslow
6. 'Modern synthetic theory' explained successfully in addition to Darwin's theory :
   (a) the source of variation
   (b) natural selection
   (c) other natural forces of speciation
   (d) all of these

Ans. 1. (b) **2.** (c) **3.** (a) **4.** (d) **5.** (a) **6.** (d).

UNIT

9

CONCEPT OF SPECIES AND SPECIATION

STRUCTURE

- Introduction
- Speciation
- Differences between allopatric and sympatric speciation
  - Summary
  - Student Activity
  - Test Yourself

LEARNING OBJECTIVES

After going through this unit you will learn :

- Certain general characteristics of animal species.
- Instantaneous speciations through ordinary mutation and macrogenesis.
- Instantaneous speciations through chromosomal aberrations and polyploidy.
- Allopatric and sympatric speciations and differences between them.

• 9.1. INTRODUCTION

The entire course of evolution depends upon the origin of new populations (species) that have greater adaptive efficiency than their ancestors.

A species may be defined as an interbreeding population, which is reproductively isolated from other similar but morphologically distinguishable population. In other words, a species may be considered as an isolated pool of genes flowing through space and time, constantly adapting to changes in its environment as well as to the new environments encountered by its extensions into other geographical regions. Certain general characteristics of animal species are the following :

1. Each species is an isolated pool of genes possessing regional (racial, population) characteristics in gene complexes which are interconnected by gene flow.

2. Each species fills an ecological niche not exactly utilized by another species.

3. Each species remains in process of continually adjusting to its environment.

4. Each species possesses a constellation isolating mechanism that directly or indirectly prevents exchange of genes with related species.

5. Each species has the capacity to give rise to new species provided some form of geographical or spatial isolation gives its isolates an opportunity to develop a unique gene pool without being swamped by gene flow from the parental species.

• 9.2. SPECIATION

Speciation means the formation of species (Mayr 1970). In other words, speciation means the splitting of a single species into several, that is, multiplication of species.

Modes of Speciation

According to Mayr (1970), true speciation or multiplication of species may occur by the following agencies :

A. Instantaneous speciation (through individuals) :

1. Genetically

(a) By single mutation in asexual "species"
(b) By macrogenesis
2. Cytologically, in partially or wholly sexual species
(a) By chromosomal mutations or aberrations (translocation, etc.)
(b) By polyploidy
B. Gradual speciation (through populations) :
1. Geographical speciation
2. Sympatric speciation.

A. Instantaneous Speciation

The process of instantaneous speciation may be defined as the production of a single individual (or the offspring of a single mating) that is reproductively isolated from the species to which the parental stock belongs and that is reproductively and ecologically capable of establishing a new species population. It can be achieved by the following methods :

1. Instantaneous Speciation through Ordinary Mutation

Mutation is a genetic phenomenon of such relatively high frequency that in a higher animal with more than 10,000 gene loci almost every individual will be the carrier of a new mutation. Such mutations merely increase the hterozygosity of a population; they do not lead to the production of new species. Any mutation drastically affecting reproductive behaviour or ecology will be selected against, if it lowers the viability, or will displace the original allele if it is of higher viability. In neither case will there be any origin of discontinuities. It is evident that ordinary mutation cannot produce new species in sexually reproducing species.

Certain phenomena among rotifers, cladocerans and nematodes suggest the occasional occurrence of **asexual speciation by mutation.** For example, in the rotifer order *Bdelloidea,* there occurs no male individual in entire order and so it is assumed that the ancestral species of this order was parthenogenetic. This ancestral species evolved into over 200 species, about 20 genera and 4 families only due to asexual speciation by mutation.

Vegetative reproduction by growth and splitting, thus, might offer a favourable condition for instantaneous speciation. This form of reproduction, however, occurs only in some of the lowest groups of animals, such as sponges, coelenterates (hydroids), turbellarians and bryozoans, groups in which the taxonomy is as yet too uncertain for a study of speciation.

2. Instantaneous Speciation through Macrogenesis

The sudden origin of new species, new higher taxa, or quite generally of new types by some sort of **saltation** (a change by leap across a discontinuity) has been termed **macrogenesis.** The macrogenesis theory of speciation has been supported by some geneticists such as **Goldschimdt** (1940, 1948) and **Schindewolf** (1936, 1950). According to this theory, the production of a new type of a complete genetic reconstruction (macrogenesis) or by a major **"systemic mutation"** or **macromutations** is the crucial event in speciation. Such an event will produce a **"hopeful monster"** (as **Goldschmidt,** 1940 called it) which will become the ancestor of a new evolutionary lineage. The believers of macrogenesis theory also proposed that all new types appear in the fossil record suddenly and abruptly. These types are not connected with the ancestral types by intermediates, they claim, and cannot be derived from them by gradual evolution.

All these views of macrogenesis theory have been bitterly criticized by many modern evolutionists. The basic objection to macrogenesis theory is that it can never be proved by any kind of evidences, because it is obviously impossible to witness the occurrence of a major jump, particularly one that achieves simultaneously reproductive isolation and ecological compatibility. Further, **Simpson** (1953) and **Rensch** (1960) have criticized this theory by showing palaeonological evidences which clearly suggest that one 'type'

can be derived from a previously existing one. Moreover, modern genetic studies have shown that the production of a monster or freak individual due to mutation does not provide the raw material for speciation, as such freak individuals have low viability, do not get any mate for sexual reproduction and subsequently fail to establish reproductive isolation from normal members of the parental population. Therefore, macrogenesis is a poor source of speciation (**Mayr,** 1963, 1970).

3. Instantaneous Speciation through Chromosomal Aberrations

Closely related species often differ more conspicuously in their karyotype than in their morphology. Among aspects of the karyotype that differ are chromosome number; the number of metacentric or acrocentric chromosomes; the presence and kind of paracentric or pericentric inversion; or of supernumerary chromosomes, and just about every aspect of chromosomal aberrations. Visualizing this fact most cytogeneticists believed that chromosomal mutations have a significant role in the causing of instantaneous speciation. This belief is based on two assumptions : (1) that the degree of difference displayed by two species requires a speciation process of such drastic dimensions that only chromosomal mutation can qualify, and (2) that reproductive isolation between two species cannot be achieved without chromosomal reorganization. Now, it is known that chromosomal rearrangements in most cases does not produce new species, however, only in few cases it produces speciation.

(i) Chromosomal rearrangement without speciation : Except deleterious chromosomal mutations, most kinds of chromosomal aberrations (mutations) lead to **chromosomal polymorphism** rather than to the development of isolating mechanisms. The paracentric inversion of *Dorsophila* is a well-known example of such chromosomal polymorphism. Yet each species has its own speciesspcific polymorphism, and only very rarely do even the most closely related species share the same chromosomal polymorphism. This fact underlines the drastic nature of the chromosomal aberration during much of speciation. This phenomenon suggests that there is no necessary correlation between chromosomal mutations and speciation, since either can occur without the other.

(ii) Speciation coinciding with a chromosomal mutation : If the chromosomal mutations during speciation would not have some selective (evolutionary) advantage, they would not have occurred so frequently in nature. Consequently, they have the following two advantages in chromosomal species — (a) chromosomal mutations have the potential to serve as (or contribute to) isolating mechanisms, and (b) the locking up and protection of a particularly favourable gene complement through a chromosomal mutation may create a new **supergene** as **Wallace** (1959) first of all recognized it. Both of these components of chromosomal speciation can subsequently be improved by natural selection, either during a period of segregation in a geographic isolate or during subsequent **parapatric** speciation or by both processes. The term **parapatric** stands for the population or species which remain geographically in contact but not overlapping and rarely or never interbreeding (**Mayr,** 1970).

(a) Chromosomal mutations as potential new isolating **mechanisms.** Any change in the structure of the chromosomes is called chromosomal mutation or chromosomal aberrations, whether it is an **inversion, translocation, duplication,** or any other change in the linear sequence of the genes or in the mechanics of the chromosome (for instance, spindle attachment). Chromosomal mutations (mostly inversions) are estimated to occur at a rate of 1 in 1000. Most of these are sufficiently deleterious to be eliminated at once, that is, before the mutation's carrier can reach reproductive age. Other kinds of chromosomal mutations are capable of giving rise to a system of balanced polymorphism and they will be retained in the population. In addition, there is a third class of chromosomal mutations which appears to reduce the **fecundity** (a term used for reproductive potential as measured by the quantity of gametes, particularly eggs, produced) of the heterozygotes to some extent. The heterozygotes containing some kind of chromosomal mutation that seems important in speciation, usually encounters the following difficulties during meiosis (gametogenesis) : (i) meiotica synapsis (partial failure of chromosome pairing), or (ii) malorientation of

multivalents at the first meiotic metaphase, or both. Both of these difficulties lead to the production of gametes carrying chromosomal deletion or duplication or broken or acentric chromosomes and, thus, lead to a significant reduction in the fecundity of male hybrids.

Unlike **gene** or **point mutations,** chromosomal mutations usually have no effect on the visible phenotype of the individual, so they are difficult to detect. Further, unlike the heterozygotes containing point mutations, the heterozygote of chromosomal mutations are not shielded by dominance and such heterozygotes with their meiotic difficulties are the prime target of selection (**John** and **Lewis,** 1969). Finally, chromosomal mutation is not a change in the DNA programme, but a change in the linear sequence of genes (duplication or deletion). The most frequent chromosomal change is the **fusion** of two acrocentric chromosomes into a single metacentric chromosome. The result is the reduction in chromosome number. A trend toward such a reduction is widespread among animal taxa. For instance, the most primitive isopods have 28 haploid chromosomes and this number is independently reduced through fusion to the lower number of 8 in several unconnected lines. It is now clear that most differences in chromosome number between closely related species of animals are the result of such fusion.

If only fusions have occurred during evolution, soon all species would have only a single pair of chromosomes. Obviously, there should be some opposing mechanism which may increase the chromosome number. The seemingly simplest such process would be the exact reverse of fusion, that is **fission** (or disassociation) of a metacentric chromosome into two acrocentrics. Most cytologists doubted such fission to occur. However, increase in the chromosome number (not due to polyploidy) whatever the mechanism, is frequent in animal evolution and many well play an important role in speciation (see **Mayr,** 1970).

(b) Chromosomal mutation and the production of new supergenes : It becomes now clear that gene contents rather than mechanical qualities, as discussed in preceding heading, determine in many cases whether or not a new gene arrangement can establish itself in a population. Most structural rearrangements of chromosomes inhibit or prevent crossing over in heterozygotes. A new gene arrangement may "lock up " a coadapted gene sequence and, by protecting it from crossing over, create a new **supergene** (**Mayr,** 1963). **Wallace** (1959) pointed out the bearers of such protected chromosomes or chromosome segments being members of peripheral populations, are better adapted for the marginal environment to the species border than are genotypes from centre of the species range. To him, the most important aspect of the chromosomal reorganization is the protection from disruptive recombination that it affords certain new supergenes. Chromosomal mutation, thus, is an instrument of ecotypic adaptation.

It is evident that these two aspects of chromosomal mutation—the production of mechanical incompatibilities and development of new supergenes—reinforce each other. There will be a steady selection for an improvement of the adaptation supergene and this will tend to produce an increase in genic heterozygote inferiority. This, in turn, will strengthen the effectiveness of the cyto-mechanic isolation mechanisms.

4. Instantaneous Specification through Polyploidy

Polyploidy is a multiplication of the normal chromosome number. It is very widespread among plants and is an important mechanism of speciation in the plant kingdom (**Stebbies, 1950, Grant** 1963). Except conifers, one-third of all species of plants have arisen by polyploidy. Among animals, the polyploidy is much rarer. Among animals, it occurs only in those groups which reproduce parthenogenetically. In few parthenogenetically reproducing animal groups such as lumbricid earthworms, turbellarians and in certain groups of weevils polyploidy is the principal method of speciation.

B. Gradual Speciation

Gradual speciation is the gradual divergence of populations until they have reached the levels of specific distinctness. Two modes of gradual speciation have been

postulated — (i) one involving geographical separation of the diverging populations (**geographic speciation**), and (2) the other involving divergence without geographic separation (**sympatric speciation**).

1. Geographic or Allopatric Speciation

Geographic or allopatric speciation states that in sexually reproducing animals, a new species develops when a population that is geographically isolated from the other populations of its parental species acquires during this period of isolation characters and promote or guarantee reproductive isolation after the external barriers break down (**Mayr,** 1942). The geographic speciation is the almost exclusive mode of speciation among animals, and most likely the prevailing mode even in plants, is now quite generally accepted.

For example, suppose there is a large assemblage of land snails subdivided in three geographical aggregations or races. *A*, *B* and *C*, each adapted to local environmental conditions (Fig. 1). Initially there exists no barrier separating the populations from each other and where race *A* meets race *B* and race *B* meets race *C*, interbreeding occurs. Zones of interbreeding individuals are, thus, established between the races, and the width of these zones depends on the extent to which the respective populations intermingle.

Now suppose, some striking physical feature (barrier) such as great river, forging its way through the territory and effectively isolating the land snails of race *C* from those of race *B*. These two populations may be spatially separated from each other for an indefinitely long period of time, affording an opportunity for race *C* to pursue its own evolutionay course. Two poulations that are geographically separated, such as *B* and *C* in our pictorial model, are said to be allopatric. After eons of time, the river may dry up and the hollow bed may eventually become filled in with land. Now, if the members of population *B* and *C* were to extend their ranges and meet again, one of the two things might happen : 1. The snails of the two populations may freely interbreed and establish once again a zone of intermediate individuals. 2. The two populations may no longer be able to interchange genes. If two assemblages can exist side by side without interbreeding, then the two groups have reached the evolutionary status of separate species. A species is a breeding community that preserves its genetic identity by its inability to exchange genes with other such breeding communities. In our pictorial model fig. (1), race *C* has become transformed into a new species *C*.

2. Sympatric Speciation

This is the prevailing mode of specialtion and occurs without geographic isolation. It is based on two postulates : (a) the establishment of new populations of a species in different ecological niches within the normal cruising range of individuals of the parental population and (b) the reproductive isolation of the founders of the new population from individuals of the parental population. Gene flow between daughter and parental population is postulated to be inhibited by intrinsic rather than extrinsic factors. The concept of sympatric speciation is far older than that of geographic speciation and goes back to pre-darwinian days.

According to Mayr (1970), geographic (allopatric) speciation is the only important means for gradual multiplication of species because sympatric speciation is not supported by strong evidences.

• 9.3. DIFFERENCES BETWEEN ALLOPATRIC AND SYMPATRIC SPECIATION

The theories of sympatric and allopatric speciation agree in their emphasis on the importance of ecological factors in speciation. They differ in the sequence in which the steps of the speciation process follow each other. The theory of allopatric speciation lets an extrinsic event which separates the single gene pool into several gene pools, with the ecological factors playing their major role after the populations have become geographically isolated. According to the theory of sympatric speciation, the splitting of the gene pool is itself caused by ecological factors, and any spatial isolation of the populations formed thereby is a secondary, later phenomenon (Fig. 1).

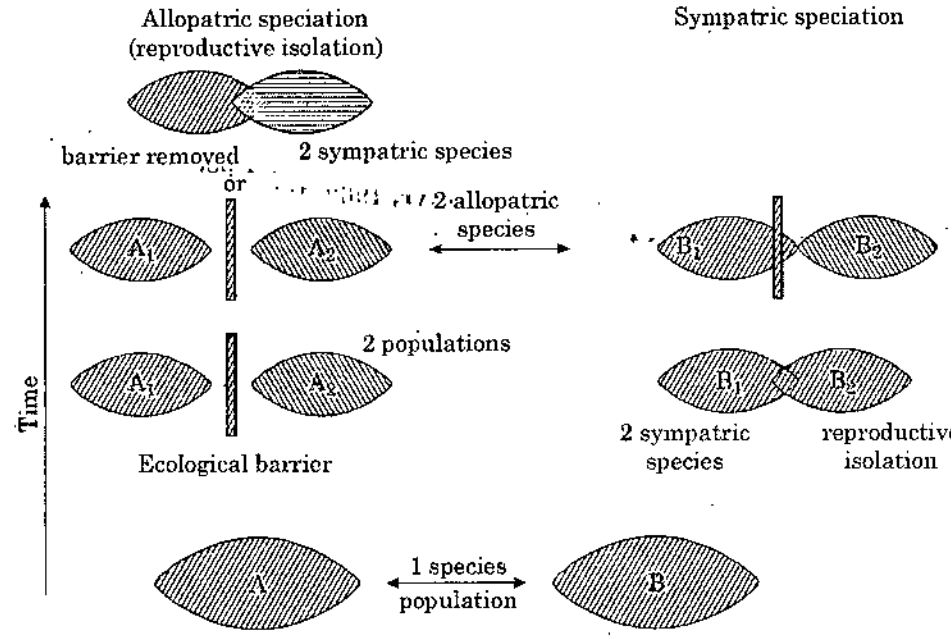


Fig. 1. Comparison of the process of allopatric and sympatric speciation.

• SUMMARY

A species is an interbreeding population which is reproductively isolated from other similar but morphological distinguishable populations. The formation of species is called speciation. In its restricted sense, however speciation means the splitting of a single species into several, that is multiplication of species. There are several modes of speciation suggested, including parapetric, allopatric and sympatric speciation. Only allopatric mode of speciation is supported by evidences and well studied in some species. Other modes of speciation are hypothetical mainly.

Keywords : Species, speciation, parapetric, allopatric, sympatric.

• STUDENT ACTIVITY

1. Prepare a seminar presentation of allopatric speciation.

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• TEST YOURSELF

Long Answer Questions

1. What is species ? Describe allopatric speciation in detail.
2. What is speciation ? Describe different methods of speciation.

Short Answer Questions

1. What are species and speciation ?
2. What is parapatric speciation ?
3. What is sympatric speciation ?
4. Differentiate between allopatric and sympatric speciation.

Objective Questions

1. A species is :

   (a) outbreeding population (b) interbreeding population

   (c) not a population (d) none of these

2. Speciation is :
   (a) multiplication of species (b) extinction of a species
   (c) both of (a) and (b) (d) none of these
3. Allopatric speciation occurs through :
   (a) geographical isolation (b) instantaneous mechanisms of isolation
   (c) mutational isolation (d) all kinds of isolation

Ans. 1. (b) **2.** (a) **3.** (a).

UNIT

10

INTRODUCTION TO ETHOLOGY, PATTERNS OF BEHAVIOUR

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Study of animal behaviour : Motivation, FAP, learning behaviour and imprinting behaviour.
- Concepts of behaviour genetics and evolution of behaviour.
- Presentation of prey by male cupid fly to female.
- Transportation of nesting material.

5.1. INTRODUCTION

Ethology is the study of animal behaviour. Initially animal behaviour was studied by non-professionals, generally by nature lovers, only for the past few decades, it has drawn attention of scientists. Gradually, a new branch 'ethology' has been developed to study animal behaviour. Thus, ethology is the scientific, biological and specific study of behaviour of animals. The word behaviour is usd to refer all externally recognizable changes that bring about communication and which can release behaviour patterns in other animals viz. movement patterns of whole body or portions, facial expressions, body postures, vocalization, as well as changes in colouration, release of odour etc. are all included in behaviour.

It has not been easy to define behaviour in totality. It has been defined differently by various workers.

(1) Observable and quantifiable events constitute behaviour. It is a directional activity necessary for survival.

(2) The behaviour of an animal is defined as the totality of its movements, sound emissions and body postures; also the externally noticeable changes such as colour change secretions of odorous substances that serve bilateral communication and can therefore release other behaviours in the partner.

(3) Behaviour is the response of living matter to some form of stimulus.

(4) Behaviour includes all those processes by which an animal senses the external world and adopts itself to that environment.

(5) Movement of whole animal because of some external stimulus is known as its behaviour or activities of an animal's effector organs (muscles) is called behaviour.

(6) Behaviour is always a combined result of the actions of many body organs.

(7) Behaviour includes all movements, gestures, postures, changes of colour and vocalization displayed by an animal.

The science of animal behaviour is still considered in its infancy. It has been studied extensively for last 50 years only. It still has a very long way to go because it is not so

easy to observe the behaviour of various animals, they behave in a bewildering variety of ways; in fact the range of animals' behaviour patterns is as great as the variety of animals found on this earth with many different shapes, sizes and colours which took generations of zoologists to describe and classify them; none of the species are identical nor do they behave alike. Not only this, there can be many different types of behaviours in one individual of a species.

Konard Lorenz and Niko Tinbergen formulated a number of concepts on which the study of animal behaviour has been based.

(1) Motivation : Motivation is a hypothetical state of the individual organism that arouses a goal directed activity. Mood, drive, urge or readiness of an animal to perform a certain behaviour, is motivation. There is a certain motivational level for every instinctive behaviour and this value declines when the act is performed, then rises again. At different times, the animals respond in different ways to the same stimulus. In an example, a hungry dog would get up, sniff here and there, look around for food, at this time motivational level or the urge for eating food is at the highest level. When it finds goal, *i.e.*, food it starts eating and after eating a full meal, the motivational level goes down to its minimum level. This dog will not eat for next few hours. By this time, the motivational level rises to its maximum, the dog would start looking for the goal *i.e.*, food once again and all these steps would be repeated (Fig. 1). Thus, dog would respond to food differently when he is hungry or full. This is true not just with food, but almost all instinctive behaviours (determined by genes) are regulated by motivation. There seems to be an urge or internal drive to elicit a particular behaviour at particular time.

Motivation to perform a particular behaviour is deduced from the strength and frequency of the behaviour itself, which is called motivational analysis. The majority of behaviour patterns can be assigned to four larger motivational systems : feeding, reproduction, fight and flee. The psychologists have divided a drive into three phases :

(1) Search for goal (appetitive or searching behaviour).

(2) Orientation around the goal and achieving the goal (consummatory behaviour).

(3) Quiescent period (refractory behaviour).

The biological significance of drive mechanism or motivation is to remind the animal about when a behaviour should occur and to prepare an animal to perform a particular behaviour.

(2) Fixed Action Pattern (FAP) : Fixed Action Patterns, are the behavioural patterns which are basically determined by genes and exhibited automatically by any animal without having seen or learnt from conspecifics or performance of a behaviour even when the animal has been raised in isolation, when a wasp supplies its young with caterpillars or a pregnant mouse builds a nest, they are not guided by conspecifics.

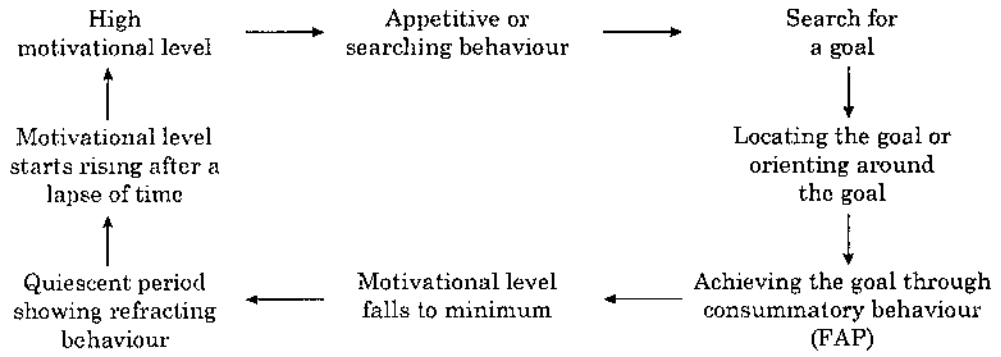

Fig. 1. Schematic explanation of motivation.

Among animals, there are many instances of elaborate behaviour which are found throughout a species and are not acquired through previous experience or learning. These acts are Fixed Action Patterns and are also known as consummatory action innate, instinctive, inborm or inherent behaviour. By definition, FAP is species specific, stereotype sequence of co-ordinated motor actions. The animals can perform them without having previous experience and without having seen another species member (conspecifics) do it.

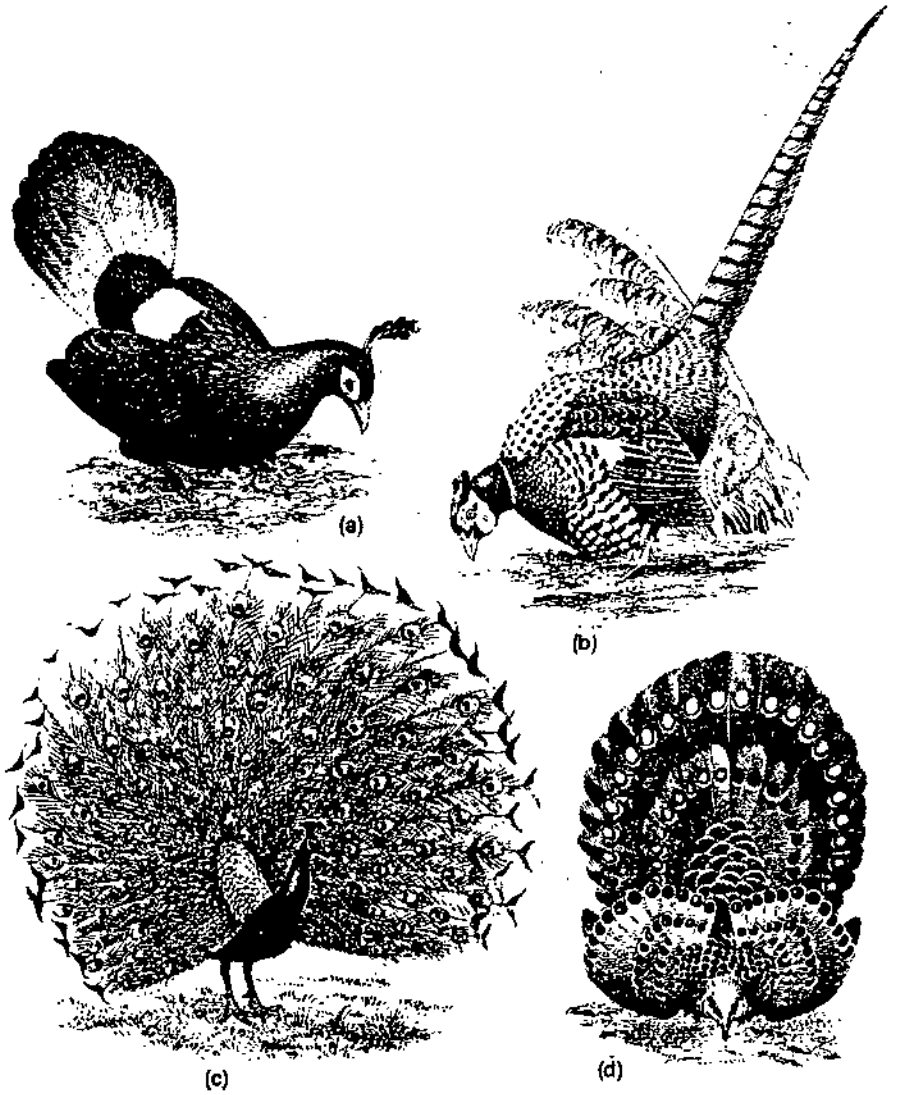

Fig. 2. Courtship display in birds. (Collins, 1986)
(a) Himalayan monal, (b) Ring necked pheasant, (c) Common peacock, (d) Burmese peacock.

There are innumerable number of behaviourable acts in the entire animal kingdom which are transferred through genes. These acts are already preprogrammed in the central nervous system through the genetic material. The elaborate courtship displays in most of the animals, mating, feeding patterns nest building (Fig. 2), parental care, vocalizations : songs of crickets, birds, and whales, wing cleaning in insects and birds, territoriality and aggression in sticklebacks and Europian robin males, lek formation in sage grouse, construction of web by spider and of pendulum nest by weaver bird (Fig. 3), all fall into this category. The most common example which comes across is of dancing peacock. The peacocks start dancing as they see peahens during the breeding season, they do not learn dancing by watching conspecifics.

The Fixed Action Patterns show the following properties :

(A) Constancy or stereotype : FAP are found to be same in all members of a species (stereotype) and can not be influenced in performance by external stimulae. The instinct behaviour (FAP) involves complex, and often highly rigid patterns of behaviour.

(B) Resistant to phylogenetic changes : FAP are extremely conservative in evolution of a species. It is assumed that once they have appeared in a species, they are resistant to phylogenetic changes occurring through evolution.

(C) Need sign stimulus for release : A characteristic feature of FAP is that they are elicited by simple but specific stimuli, which are known as sign stimuli.

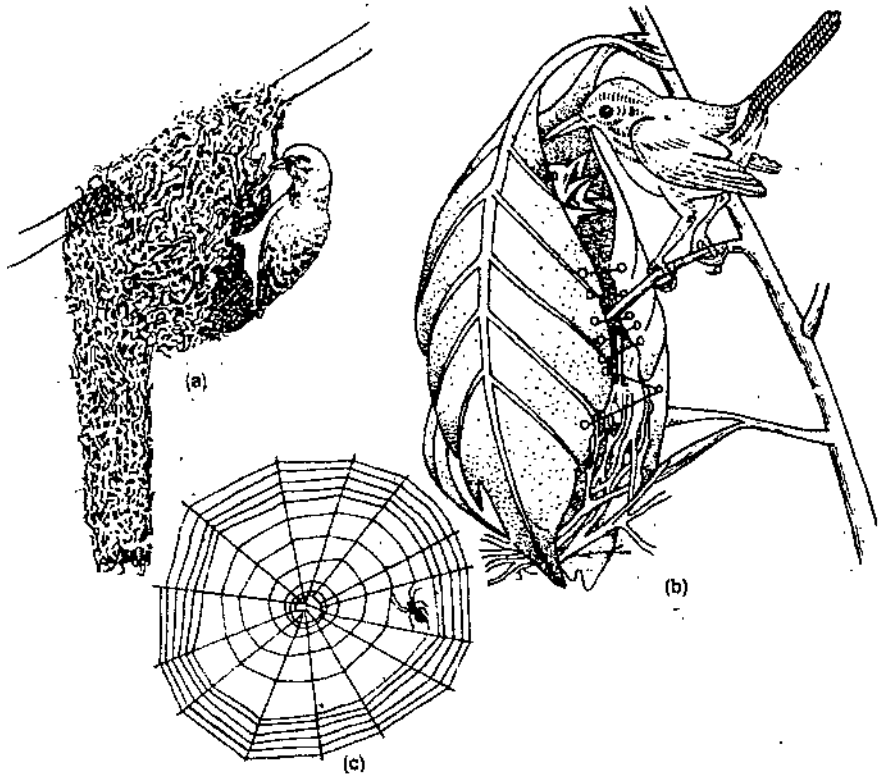

Fig. 3. Construction of nest by weaver bird (a), tailor bird (b), and formation of web by spider (c) (Z – 23).

(3) Learning behaviour : It is the process by which an activity originates or is changed through reacting to an encountred situation or any change in behaviour as a consequence of experience is learning behaviour. All animal forms from protozoans to primates learn. There are two major categories of behaviour–innate and learned and there is an adaptive significance attached to both these categories. Certain behaviours are essential to survive viz. feeding, drinking, sex, maternal aggression and escape etc. Hence their basic components are transferred genetically. The other major advantage of having innate behaviour is for those animals who either live solitary or have a short span of life, the first ones do not want to see conspecifics and the second ones do not get enough chance to see the conspecifics.

It is almost impossible to differentiate between innate and learned behaviours in an adult animal without performing experiments in isolation. Probably, the most spectacular instance of learning has been found among island populations of the Japanese macaques (Macaca fuscata).

Learning in animals can be of two types :

(a) Flexible : which includes habituation, trial and error, classical and instrumental. As the name suggests this kind of learning is flexible to further changes and experiences.

(b) Restricted : This includes a very special type of learning called imprinting once it is established, it is comparatively resistant to further changes. It plays an important role in the development of many behaviours in almost all higher animals.

(4) Imprinting behaviour : The animals learn through their own experience, through observation and imitation throughout their lives, but there are some phases in an animal's life when it is likely to be sensitive to some typical learning processes.

Many animals and even human beings pass through such a period when certain learning experiences are far more significant than at other times. This means that if an individual encounters the same kind of experience outside this period, perhaps it may not learn it at all. K. Lorenz (1935) was the first one to notice this type of learning and he coined the term — "imprinting" for such a behaviour.

In early life of many animals, a period starts as soon as they are hatched or born. This period varies from days, weeks, months or years depending upon the species.

During this time, also known as the critical period, they learn to identify or recognize their parents by following them, according to Schultz it is known as filial imprinting, if following is carried out uninterrupted, this knowledge is utilized by the animals later in their adult life to recognize mates known as sexual imprinting. Imprinting has profound influence on animals, social behaviour. Though, it sounds strange that how a thing which is learnt so early in the life can influence adult behaviour ? But it is true, that there is a critical period in early childhood when an individual can learn certain things, once this period is over those particular behavioural patterns cannot be learnt. K Lorntz observed that newly hatched precocial birds (which start walking immediately after hatching e.g., chicks and ducklings) follow the first moving object they encounter, usually they are their parents but with incubator reared birds it is likely to be human being. If ducklings begin their walk by following a man, they will continue to follow a man in preference to adult ducks throughout their life. Moreover, they behave as if man belongs to the same species. These birds may even court a man taking him as a mate. Zoo authorities know that hand reared animal preferred courting their caretakers and such animals had poor reproduction when they were allowed to remain with their conspecifics.

The birds can recognize the shape, size and colour of the model. If they are imprinted with a wooden block they will not follow a toy duck. Further, according to E. Hess (1964), the more difficulty a duckling has in following a model, the stronger it will imprint on that model. Also a moving and noisy model is more effective. Socialization and an animal's ability to become a part of a social group are largely determined by early experiences. Human children may become shy loners if between 2 to 6 years they are not part of some social group *i.e.*, a school. H.F. Harlow described "Deprived Syndrome" in young rhesus infants. The syndrome is expressed by general restlessnss, aggressive reaction, extensive apathy and lack of exploratory behaviour, as adults most of these animals were unable to mount and copulate. 'According to Lorenz, imprinting is a unique form of learning because of the following factors :

(1) It takes place only during a brief sensitive period early in the life.

(2) It has great stability, often lasting for the rest of the animal's life.

(3) It influences the animal's adult social and sexual behaviour.

Concept of Behaviour Genetics : There are some of the evidences which suggest that patterns of behaviour can be transmitted from parents to offsprings via genes. In those species, in which parent upbringing is absent, any sort of complex behaviour that is spontaneously expressed is very likely to be genetic. For example, a male cupid fly catches a prey, forms a cocoon around it and presents it to female before copulation, female cupid fly will open up the cocoon and eat the prey, in the meantime male will copulate (Fig. 4).

Fig. 4. Presentation of prey try male eupid fly to female.

All this has to be done within the few weeks of its adult life. Such complex behaviours would hardly be accomplished by learning, it is assumed that the entire sequence of behavioural steps followed by cupid flies is coded in the fly's genes.

The example of the hygienic honeybee is a particularly dramatic instance of the genetic control of behaviour.

Certain honeybee strains are 'hygienic', if their larva or pupa dies inside a cell in the hive, the workers uncap the seal and remove the dead animal, whereas in 'Unhygienic' strains this behaviour does not occur. Among themselves, both these strains breed true to their type. If they are mated experimentally, hybrids between hygienic and unhygienic strains are all unhygienic. If these hybrids are mated to hygienic bees, four types of progeny result (Table 1.).

Table 1. Cross between hygienic and unhygienic strains of honeybee

UURR (Unhygienic) × uurr (hygienic)

UU = Do not uncap the cell
RR = Don't remove the dead larvae
uu = remove the cap
rr = remove the dead larvae

Uu Rr ..... (F_1 gene)
(Unhygienic)

UuRr × uu rr (cross breeding)

Gametes	UR	Ur	uR	ur
ur	Uu Rr	Uu rr	uu rR	uu rr
	(1)	(2)	(3)	(4)

..... (F_2 generation)

Four types of progency are :

(1) Those which neither uncap nor remove the dead body, *i.e.*, unhygienic.

(2) Those which do not uncap, but if the experimentar does so, remove the dead body.

(3) Those which uncap the cells containing dead larvae, but don't remove the dead body.

(4) Those which uncap and also remove the dead body, *i.e.*, hygienic.

The fascinating point is that what seems on first site to be a complex behavioural pattern can be understood on the basis of action of just two genes.

An interesting cross breeding experiment between two species of love birds was conducted by William C. Dilger (1962) of Cornell university. One of these species had the peculiar habit of cutting up strips of leaf or bark for its nest and then tucking them in the feathers of its rump, and in that way carrying them to the nest site. The other species used to carry its nesting materials in its bill (Fig 5). The hybrids between these two species carried material both ways. They started off by carrying most of the nesting material tucked in the rump feathers, but this was less efficient than transporting by bill, it kept falling out, and they subsequently learnt to use their bills more and more.

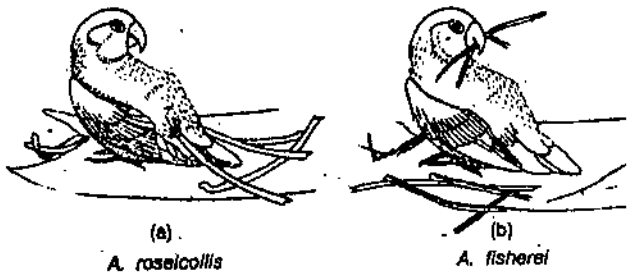

Fig. 5. Transportation of nesting matrial in loe-birds of genus agapornis.

Concept of Evolution of Behaviour : There is no direct evidence of the evolution of behavioural patterns as fossils do not behave yet there is a great deal of indirect evidence which allows us to say something about the way behaviour has evolved. As in any other evolutionary process, we can assume that new behavoural developments did not take place by sudden leaps and bounds but through small changes and stages of adaptations. In animals today, we see the combination of structural adaptation and refined behaviour patterns developed through many generations which enable every individual to survive. For example, certain animals, like the screech owl and sphinx moth have developed behavioural traits that provide each of these with two distinct

lines of defence against predator. Both these species are nocturnal and rely primarily on camouflage to protect them while resting during the day.

Many animals gain protection by initiating physical structure and behaviour similar to objects regarded as inedible by predators. A twig caterpillar has evolved the physical dimensions and markings of a real twig-unless it remains as still as a part of the tree, a predator will not be fooled and the insect will be eaten, candid fish in the Amazon basin, resembles dead dry leaves and can float motionless for hours to escape the notice of larger fishes and predatory birds, similarly some grasshoppers resemble fresh grass etc.

Studies of evolution often involve comparisions between closely related species. By studying the behaviour of many species of bees Karl von Frish was able to suggest a likely course of evolution from solitary ancestor, through various intermediates, to the social structure of hive. In a species another species, the young hatch while their mother is still laying eggs, some will help the mother before she leaves. In bumble bees, the young ones which hatch to help mother remain small and less fertile and finally comes the species where mother lays eggs, young come out that remain sterile and all of them live together with mother to form a complex social group.

It is widely accepted that all behavioural patterns that are learnt or preprogrammed are for the individual's benefit, in other words, any behaviour performed by a particular animal must be directly useful to it. In terms of evolution, all individuals behave to increase their own **"genetic fitness".** It is measured in the currency of offspring and is given in terms of the number of its offspring expected to survive to the reproductive age. In other words, it is a measure of the number of **copies of genes.** An **animal contributes** towards the hereditary composition of the generation. The animal behaves to increase its own fitness irrespective of other individuals of the same group or clan. Here **"fitness"** does not mean the **physical fitness,** an animal could be physically very fit, but if it does not reproduce and leave its genes through progeny in the population it will remain an **evolutionary flop.** That means an individual should behave in such a way so as to maximize its **reproductive success.** That way all individuals should be **selfish,** they should be concerned about themselves only. Then why should animals live in social groups ? What is the process by which they form bonds between members of a family, leading to **mutual support** and **cooperation** ? Could we not argue that each individual according to the rules governing evolutionary process, should be concerned primarily with its own reproduction. Why things like **Altruism** (sacrifice) and **cooperation evolved** in social animals ?

Altruism is, when an animal facilitates the reproductive chance of a conspecific at the expense of its own, Altruism may include any things from sharing food when food is scarce to defending others at the risk of the animal's own life.

Why some of the bees give their lives in a suicide attack while proctecing sister bees of the hive ? Squirrels, deer, and some monkeys do risk their lives by drawing attention of the hawk and big predatory cats while giving out alarm calls to others. There must, therefore, be circumstances under which altruistic behaviour can be advantageous. The clue to the origin of most of altruistic behaviour in the animal kingdom lies in such behaviour – which are being directed toward one's blood relatives. Aunts of elephant calves and lion cubs protect and nurse them. The animals often tend to be altruistic towards other animals which share in common, a large fraction of their hereditary units or genes by virtue of common ancestory. For example, a person might be willing to throw away his own life to save the lives of two full brothers but he may not be willing to do so to save the lives of three strange persons. Altruistic behaviour, could be explained on the basis of **"kin-selection"** in which any individual would sacrifice its own reproductive success for the sake of its kinds or relatives who share some proportion of its genes. In other words, the same genes must be passed on or propagated, either through individual or through a kin.

The help is not rendered to related animals alone. In the troops of the African olive baboon, quite unrelated males may get together to help each other when predators attack. Baboon males are big in size and often when they get together they may kill a leopard. This kind of cooperation held at the time of need is like "you scratch my back and I will scratch yours". Or "you help me this time and I will help you whenever you need me", therefore, safe-guarding their own genes.

Organisms without any social tendencies are very rare. We know of few animals that avoid all contact with others of their species, yet they have to come together in order to breed. Oyster bank, swarm of grasshopper, schools of herrings, flocks of starlings, the brood colonies of gulls, pack of wolves, herds of antelopes, pride of lion, and group of monkeys are few examples of social tendencies. The non-social behaviours may have just provided root for the growth of higher social life.

• SUMMARY

Ethology is the scientific, biological and specific study of behaviour of animals. Behaviour cannot be defined in totality in one sentence. All kinds of expressions (facial and body) movements, various secretions and communications can be defined under the name of different kinds of behaviour. Konard Lorenz and Niko Tinbergen formulated different kinds of concepts to explain different kinds of behaviour. Motivation, FAP, learning, imprinting and social are the principal behaviours which have been studied and explained in different animals. The genetic base behind the animal behaviour has also been evidenced and studied. There is a great deal of indirect evidences which show evolutionary trends in animal behaviour.

Keywords : Ethology, Konard Lorenz, motivation, imprinting.

• STUDENT ACTIVITY

1. Demonstrate motivation or goal oriented behaviour in animals by a model.

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• TEST YOURSELF

Long Answer Questions

1. Define learning behaviour in animals and differentiate it from instinct or innate behaviour.
2. Define the concept of behavioural genetics.
3. Describe in detail the imprinting in animals.

Short Answer Questions

1. Write short notes on stereotype-species specific actions.
2. Define altruism in animals.
3. What is kin selection ?
4. Write about the type of learning behaviour.

Objective Questions

1. The study of behaviour is called :
   (a) mythology (b) ethology (c) ecology (d) mycology
2. Motivation is called :
   (a) goal oriented behaviour (b) learning behaviour
   (c) instinct behaviour (d) all of these
3. Motivation is an :
   (a) urge (b) internal drive
   (c) both of (a) and (b) (d) none of these
4. Instinct behaviour is :
   (a) monotyped (b) polytyped (c) stereotyped (d) all of these
5. Learning behaviour can be :
   (a) fixed (b) flexible (c) restricted (d) both of (b) and (c)

Ans. 1. (c), **2.** (a) **3.** (c) **4.** (c) **5.** (d)

UNIT 11

SOCIAL ORGANIZATION IN ANIMALS

STRUCTURE

LEARNING OBJECTIVES

After going through this unit you will learn :

- Characteristics of social groups and behaviour.
- Properties of organized societies : communication, cohesion, division of labour, permanence and impermeability.
- Monogamy, polygamy and promiscuity.
- Advantages of social organization.
- Society of lions and society of monkeys.

• INTRODUCTION

Social organization is a characteristic of some species. It ranges from simple short term interaction between male and female lizards during the breeding seasons to the complex, stable societies of monkeys and apes. Social organization of a group depends on the total number of individuals, their age, sex, sex ratio and number of adult males and these in turn depend on many important factors like abundance, availability, dispersion of food, predation, pressure, types of habitat and mating strategies are the other important factors. Not all the groups of animals are truly social. There is a clear distinction in mere aggregation or association and true societies. Alverdes (1927) defined association as — chance gatherings produced solely by external factors, *e.g.*, insects gather around a source of light for mating or groups formed by simultaneous attraction to a common source, rather than to each other, *e.g.*, earthworms collect under a rock for moisture and protection or human spectators at a sporting event. Association is a temporary union of animals. Groups of aggregations are formed largely by non-breeding individuals based on a mutual attraction *e.g.*. school of fishes, large wildebeasts and zebra herds are also called as survival groups. Alverdes considered societies to be genuine communities which exist in virtue of some particular social instincts. An animal society is a relatively permanent union of individuals held together by mutual attraction of its members.

According to Tinbergen, any interaction between one individual of a species with another member of same species is known as 'social behaviour'. This behaviour includes all those behaviours that influence or are influenced by other members of the same species. A true society will involve more than a mated pair, *i.e.*, adults, sub-adults, juveniles, infants of different age sex classes. It will mean a stable group whose members intercommunicate extensively and bear some relatively permanent social relationship to one another. Vertebrate social groups are organized differently from insect societies. The most profound difference is in the higher proportion of reproductive individuals and the absence of sterile casts in vertebrate groups. Wilson (1975) and Brown (1975) independently proposed the following characteristics of social groups and behaviour :

(1) The first and most obvious characteristics of social behaviour involves the number of animals of the same species that actively come together or remain together in a group.

(2) Social behaviour depends in part on the length of time or part of the life cycle that the group remains together.

(3) The physical proximity between each other in a society concerns the "energy actually spent in social behaviour. Many animals, although physically grouped together, none the less may spend much of their time or energy in behaviour that would be more properly classed as individual rather than as social behaviour, *e.g.*, a group of wildebeests in Africa may be grazing together or more together or remain together but they function at individual level.

(4) Reciprocal communication is considered necessary as a mechanism for attracting and keeping the members of a group together. The communication may be visual, auditory, objectory or tactile.

(5) Much social behaviour is marked by a division of labour and social structure or what is frequently referred to as roles.

(6) A feature of social group in many species is an 'overlap of generations' that is families or part of families may stay together. Parents defend or protect their young ones.

(7) Altruism is the highest level of social behaviour in any social organization of animals. In extreme forms of altruistic behaviour, it includes even the sacrifice of one's life and reproduction.

Eisenberg (1965) also proposed four properties of organized societies :

(i) Communication : All organized societies have some forms of complex communication system. The members of a social group make gestures, postures, change colour, raise hair, vocalization, indicate messages by touching each other or have some

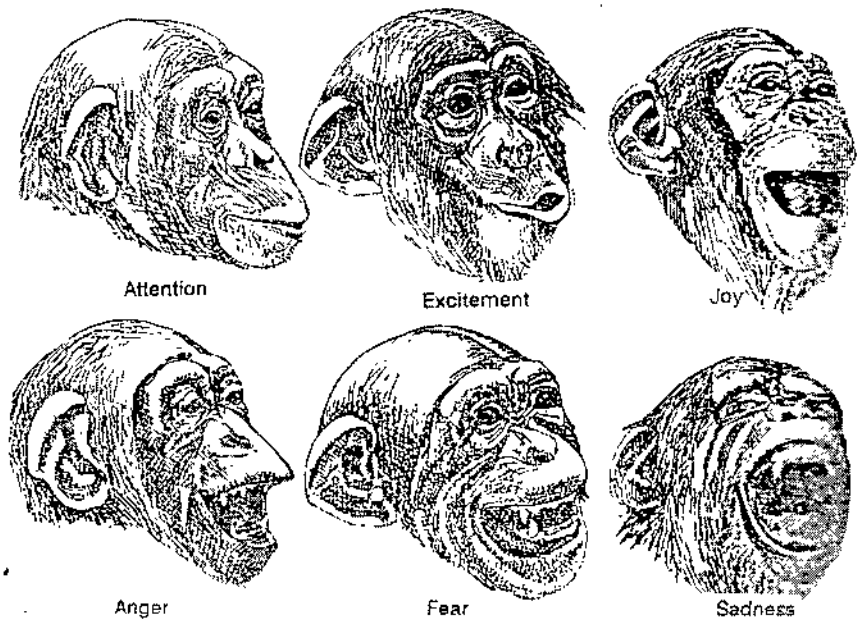

Fig. 1. Facial expression in chimpanzees. (Life/Time Publ.)

specialized forms like ecolocation in bats, tail and waggle dance in bees. Communication in higher animals is generally elaborate and capable of putting across complex messages for example the facial expression alongwith vocalization in chimpanzees communicate various forms of emotions and messages (Fig. 1).

(ii) Cohesion : The individuals constituting a society tend to remain in close proximity to one another, *e.g.*, all the bees of a group live in one hive, the individuals in a heard of deer pride of lions and peck of wolves remain in close vicinity in a given home

range, the individuals in a troop of baberons while moving tend to remain in close proximity.

(iii) Division of labour : In organized societies, animals of different status sex or age groups have different functions in maintaining the society. Baboon and Macaque young adult males often serve as front or rear guard for group as the group moves, they are the ones to face predators. The old adult, dominant males remain in a more central place and they decide the foraging and resting areas, the function of females is to bear and bring up infants and care for youngs.

(iv) Permanence and impermeability : The individuals making up a society tend to be same. There is little migration from the group, in most mammals the core of the group is formed by females who are related to each other, the males come and go, otherwise the membership among females is permanent. Most organized societies resist immigration by outsiders.

Mating Groups or Mating strategies in Social Organization : Males and females of all organisms form mating relationship in a way that best enhances their reproductive success. Mating systems are most commonly classified according to the duration of pair bonding and the number of mates acquired by each sex. Mating groups have been broadly classified into monogamy, polygamy and promiscuity and there is further variation within each category.

(i) Monogamy : It is the simplest mating system because it involves the smallest number of animals. Prolonged association and essentially exclusive mating

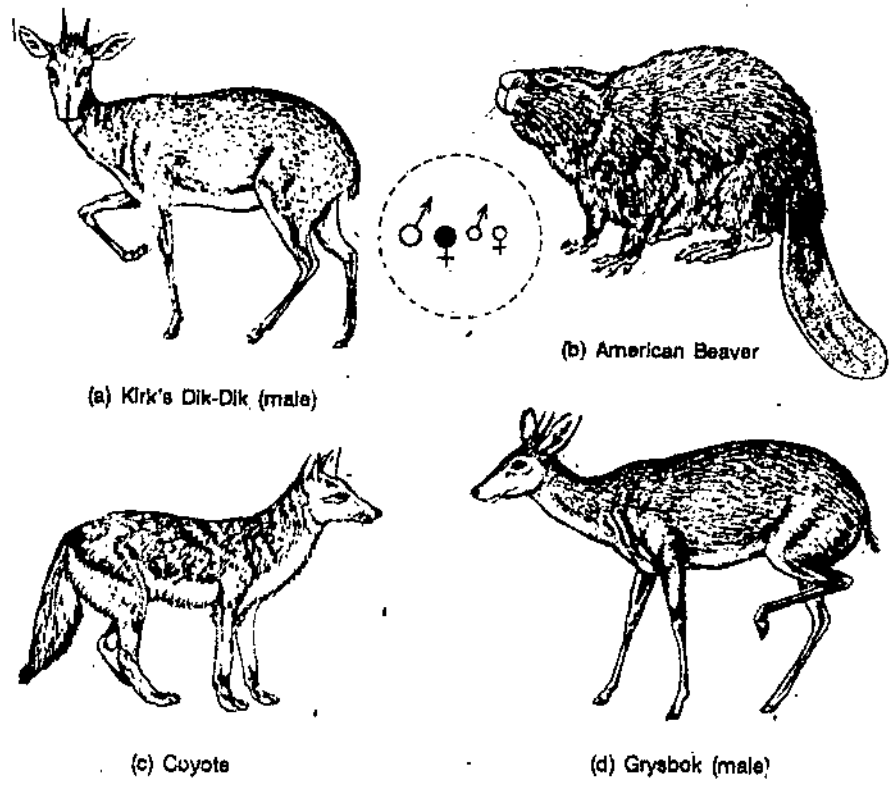

Fig. 2. Monogamous animals and their groupings.

relationship between one male and one female at a time is monogamy 90% birds, less than 4% mammals and only 20% human societies are truly monogamous. Monogamy can include lifelong breeding pairs that spend all time together, if the male dies then the new mate is accepted, *e.g.*, gibbon. Typically monogamous pairs are formed by dikdik, duikers, steenbok, grysbok (ungulates), songbirds, (Fig. 2) eagles, beavers, foxes, coyotes and swans.

Monogamy has been classified into three different ways based on (i) the extent of male parental investment, whether it is less, more or equal as compared to the female parent (ii) the extent of territoriality (spatial) (iii) temporal relationship.

(ii) Polygamy : In the broad sense, it includes any form of multiple mating relationship. Reproductive unit of one individual of one sex and several of another. It has two categories, polygamy and polyandry. In langurs, Lions, Kudus, and most of the deer and antelopes females form small social groups which are visited by males during the mating season. The rest of the males form all male groups.

(iii) Promiscuity : It refers to species in which no durable mating relationships are formed : members of both sexes mate randomly with several partners (Fig. 3). The two sexes don't form long term bonds or associations, the mating may or may not be multiple by promiscuous animals, the examples are grouse beers, wildbeasts, chimpanzees. Promiscuity can also be of different types as, broadcast promiscuity, overlap promiscuity, late or area promiscuity, and hierarchial promiscuity.

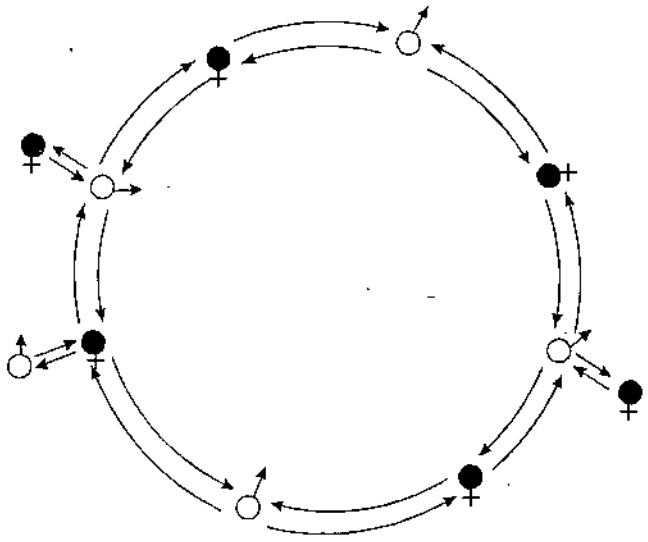

Fig. 3. Promiscuity.

Advantages of Social Organization : There are several advantages proposed with reference of ultimate ecological and social driving forces that lead to grouping and subsequently, to social behaviour.

(1) Autipredation : In a society, one or more individuals can detect a predator before the others and may be able to warn rest of the group members. For example, in a group of deers or monkeys one or two individuals will give alarm calls at the sight of approaching predators and the rest of the group members will take advantage of it, in a flock of birds alarm calls are given by a few individuals and the rest get the advantage.

Animals also show 'guard behaviour' in which one or a few individuals assume the role of watching for the entire group, thus freeing the others almost completely from the job of vigilance, *e.g.*, adult males of some of the monkey groups, *e.g.*, hanuman langur Presbytis entellus occupy the canopy and remain vigilant for intruding members of all male groups and/or for predators. Male baboons and pata monkeys often act as sentinels while other troop members forage.

Mutual vigilance has also been observed among the members of different species, *e.g.*, baboons, zebras, gazelles often forage together and each species responds to warning signals of each other.

Erratic fight and explosive scattering, fleeing along an unpredictable path is a common defensive tactic in social or herding animals. Mobbing, running away or fleeing is being the most commonly used antipredatory strategy among animals yet there are examples when adult animals, generally males mob a predator or form a defensive screen to scare it away.

(2) Feeding efficiency and information sharing : It is easier for a group of animals to catch a prey instead of catching it alone or cooperative foraging is beneficial. For example, for a group of monkeys, it is easier to locate a bonanza of fruits. Early in the morning, members of a monkeys, group will spread and roam around in search of food and even if one individual locates the food it communicates vocally to other members of the group who get the benefit of this information. By cooperative hunting even small carnivores like wild dogs, wolves can hunt big animals like elk, moose, mountain sheep and zebras, lions, hyenas, killer whales and some dolphins also get benefit of cooperative hunting. Lionesses also do most of the hunting together often in groups, in an organized way, some females will drive prey toward other lionesses lying

in wait. There are other numerous ways by which animals can maximize foraging success just by living in a group.

(3) Facilitation of reproduction : Group living improves reproductive success. For example, in solitary animals like rhino and orangutang, it is difficult for them to find a mate. They have to cover large areas in forest, spend time and energy to find a suitable mate. But it may be easier to find each other in a large social group. In a group watching others courting and mating initiates sexual behaviour in other members also.

Society of Lions

The lion is a migrant in India. It is believed that lion entered India from Persia about 6000 years ago and then spread in northern India. It always remained totally absent from south of India. The occurrence of lions in fairly good number was recorded along the banks of the Sabarmati river in Gujarat and around Mount Abu, Rajasthan in 1830's. No other big cat (tiger, leopard, cheetah) is as social as the lion. Lions live and hunt in families known as 'Pride' which comprise of about 20 or more individuals large and small of different age, sex classes, consisting of upto 3 adult males and 15 to 17 females and their young. The lions follow matriarchial system which is a form of society where the core of the group is formed by the related females, the males are accorded with temporary membership, they come and go. These related females stay together with strong family ties and with their recent offsprings.

The growing males leave the natal group and may join to form an all male group or would wander alone without the pride. The males roam around in large territories. As the breeding time approaches the dominant, adult males start associating themselves with the group of females (harem). Possession of harem is not easy : the males have to first establish their dominance among themselves then a dominant male takes over the harem from other weak males. The dominant male along with subdominant males stays with the females. One or two adult males mate with many consorting females in heat. The lion males extend their association with females over a long time whereas male tigers generally leave soon after mating. The adult male lions do not actively invest in rearing up the young ones, it is generally the responsibility of mother to feed them and train them for hunting. Lions prey on animals like gazelles, antelopes and zebra, but may also cooperate to kill larger mammals such as buffalo and giraffe.

Breeding occurs at anytime of year. A litter of 1 to 6 young, usually 2 or 3, is born after a gestation of 102 to 113 days. They are suckled for about 6 months, but after the first three months increasing proportion of their food comes from the kills of adults, the cubs are left behind with one or two adults while the rest of the pride goes off to hunt, if a kill in made, a lioness returns to take the pups to the hunting site. Once the cubs are over 4 months old, they accompany their mothers everywhere. The cubs get sexually mature by 18-20 months. Young males are driven away from the pride at about this age, but the growing females are retained back by the other female family members.

Society of Monkeys

1. Solitary, except for mother infant pair : Examples : Microcebus, galago, slow loris, slender loris, aye-aye (Fig. 4). These primates are forest dwellers, smaller in size, arboreal. Males are usually found solitary but they can be seen in following combinations as well : male and female; male and female with infants; female with infant; 1-2 subadults. Since they are mostly alone, their antipredatory device is concealment. They remain in one home range and may defend it actively.

2. Monogamous adult pairs with recent offsprings or nuclear families : Examples : Indri, mentawei, island langur, silvary marmoset, gibbon, dusky titi marmosets, tree shrews, red bellied lemur, mongoose lemur, ruffed lemur, night monkey (Fig. 5).

Nowhere among the social primates are females accorded more permanently privileged positions than among the monogamous species. There are some 37 of them, most of them are rare and endangered. They are inhabitants of tropical rain forest. Gibbons are found in south America. Their groups include 4-8 individuals consisting of an adult male and adult female and upto 4 young ones (Fig. 5). Male-female bonding is

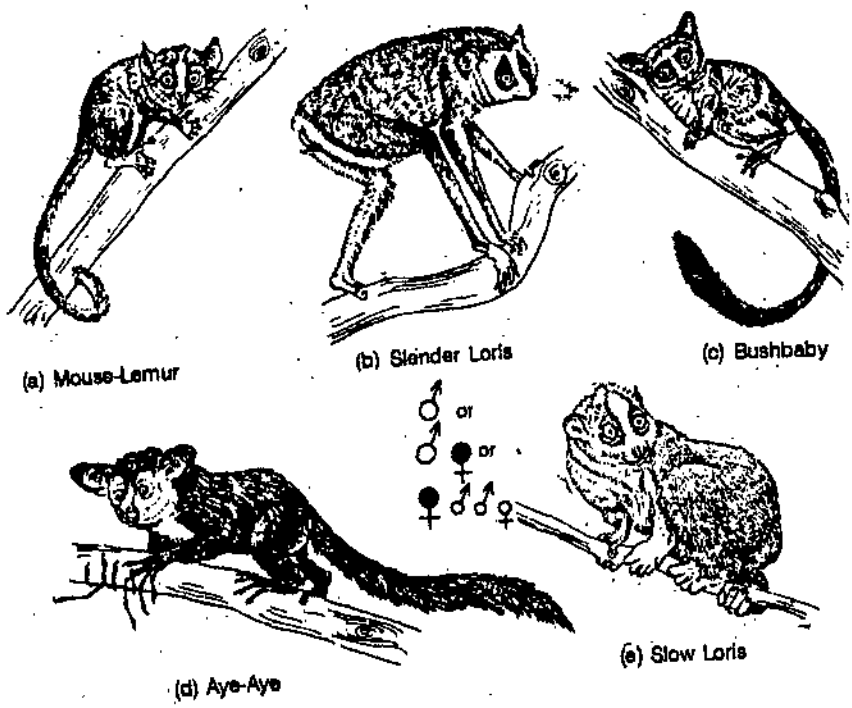

Fig. 4. Solitary primates.

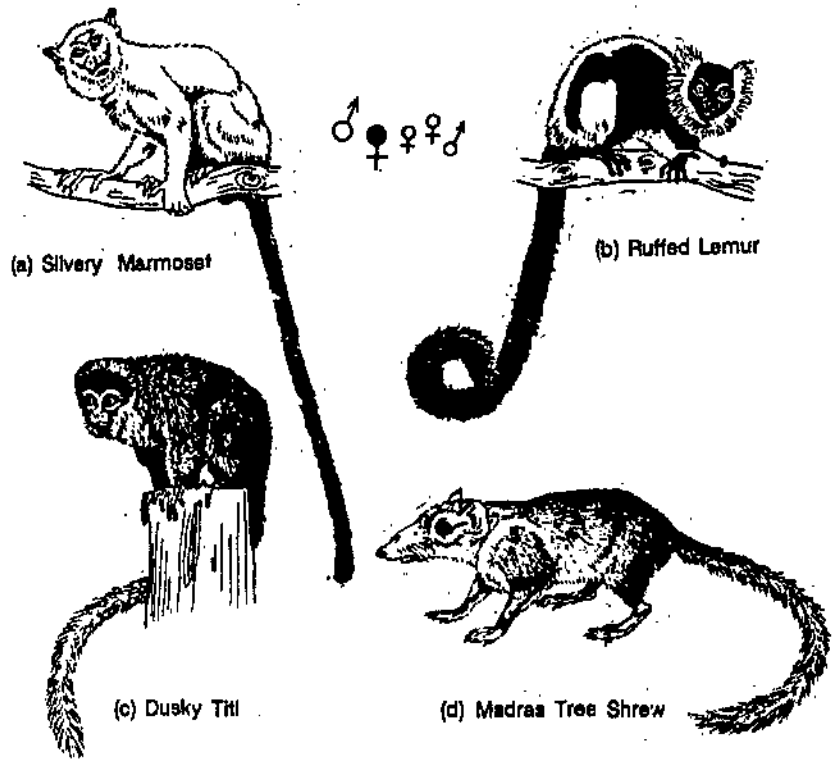

Fig. 5. Monogamous primates.

permanent and lasts life long. Nevertheless, it is true for gibbons, marmosets and mentawei langurs that partners who disappear are soon replaced. In such groups usually there is not much difference in the body size of male and female. They have equal dominance. Both of them (male and female) involve themselves in all activities with same intensity. Indri, a lemur, found in Madagascar are classically monogamous, no other primate comes so close to fulfilling proverb "love your wife as you love yourself, and honour her more".

3. Single male groups with bonded females and offsprings or unimale bisexual groups : Examples : *Erythrocebus patas,* hanuman langurs, red howler monkey, redtail monkey, blue monkey (Fig. 6).

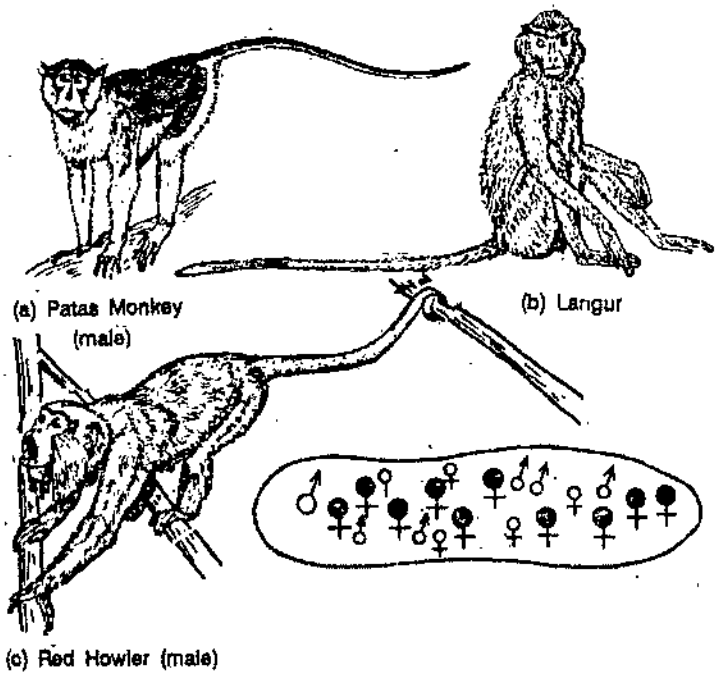

Fig. 6. Primates forming single-male, many females or unimale bisexual groups.

Typically they live in unimale bisexual groups, their group will have 20 to 100 individuals, there will be just one adult, fully grown, big sized dominant male popularly designated as **"overlord"** or **"resident male"**, rest of the group is formed by adult females, subadult females, male-female juveniles and infants. Growing males either leave their natal groups willfully or are chased away to form all male groups. Adult male is the leader and co-ordinator of group activity, he initiates and determines the direction of group movement and activities like where to go, when to feed, where to sleep. Males coordinate inter group relations by producing the loud, resonating calls, which is necessary for quick and effective gathering of a group and also to tell the neighbouring group that —"I am here and this area and harem belongs to me". This male is easily distinguished from rest of the individuals because of its large size and agility.

Erythrocebus patas are from Senegal to Sudan and Tanzania, they form groups of 20-30 individuals with one adult male and his harem. These monkeys live in dry Savannas and are truly terrstrial. If attacked they run away (fleeing) with great speed. The red howler (*Alouatta sensiculus*) is found in Columbia, Brazil and Bolivia, The male of the group occupies a territory, makes loud calls, and has a group of 10-15 females.

4. Many males with many females and offsprings or multimale bisexual groups. Examples : rhesus, gorilla, baboon, spider monkey, bearded saki, uakaris, wolly monkey, squirrel monkey (Fig. 7).

Typically there are 3-8 adult males in a group, each of which has 5-7 bonded females who remain with their infants. In a way there are many small units living together, thus forming a big group. Multimale bisexual groups are generally larger than other social groups. One such group can have upto 180 or even more individuals.

One of the reasons of origin of multimale bisexual groups is linked to their terrestrial nature. Millions of years ago when competition increased in trees, few of the primate species left the trees and came to the ground, where they became more vulnerable to predators; these primates increased the number of males, they increased the overall number of members in a group and they increased in both size as well, in addition, they developed powerful jaws and became more aggressive, because their antipredatory strategy was "fight the predator". There is a variation from the typical

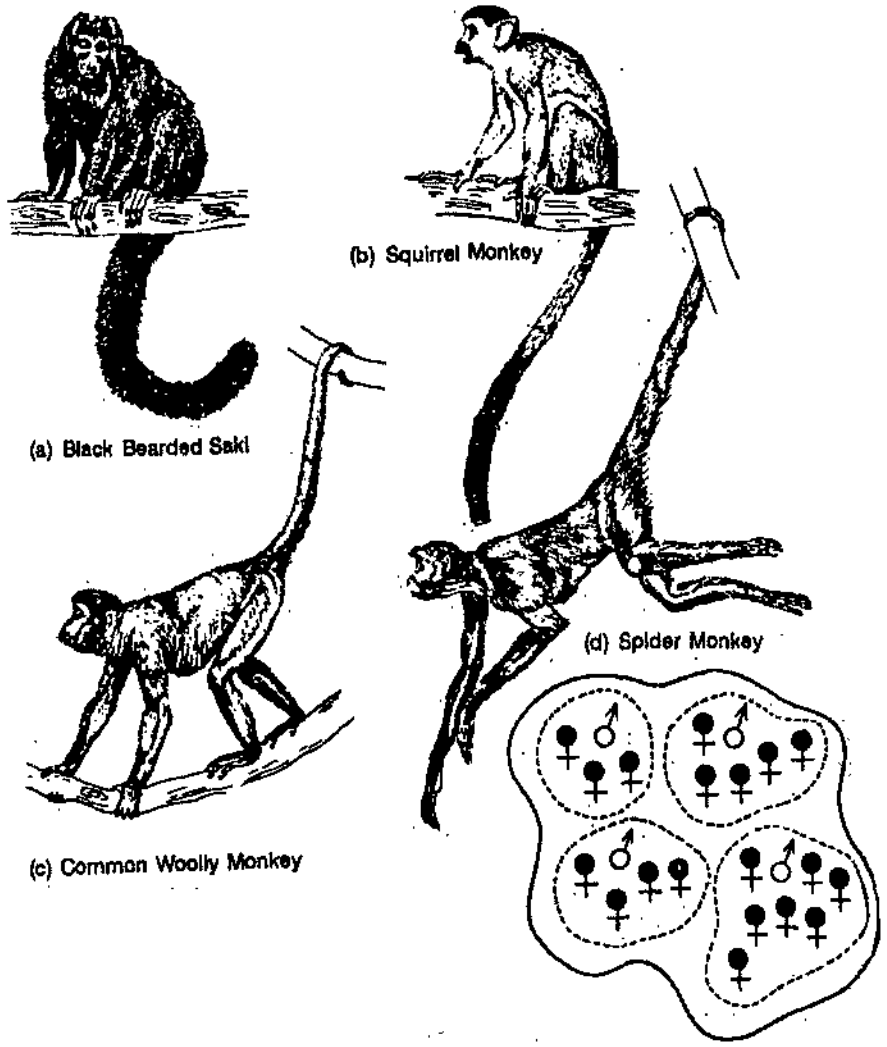

Fig. 7. Primates forming multimale bisexual groups.

type of grouping, the following is the broad category which indicates two major types within multimale bisexual grouping.

Those which do not divide in smaller feeding groups, *e.g.*, gorillas and hanuman langurs (Fig. 8a).

Those which divide daily into smaller feeding groups, *e.g.*, macaques [Fig. 8(e)] and baboons [Fig. 8(b), (c) and (d)].

In gorillas and hanuman langurs, the group is typically a multiple bisexual type with several males, all the members remain together. The males have dominance hierarchy, the most dominant is known as alpha, then beta, gamma and so on. There is a straight line status system among the adult males of a troop, however, there is no clearcut dominance system among females. In a typical group of gorillas of 20 individuals, the oldest and largest male, develops gray hair on his back and is called **"silver back"**, he is also the most dominant, rest of the males would be lower in status. Dominance consists of possession of right of way on a narrow path, or to a resting place or feeding site. Surprisingly and most unlike other primates, dominant male in gorillas is not very aggressive and all other males also have access to receptive females. There is no conflict for mating. These groups have also been called as **"age graded"** which means that there is only one oldest male, all other males are younger and are graded age-wise (Eisnberg, 1978).

In the next category of multimale bisexual groups come rhesus, hamadrya baboons, geladas and olive baboons which live in large groups of many males and many females. In these species, the group splits daily to form smaller family units of one male and

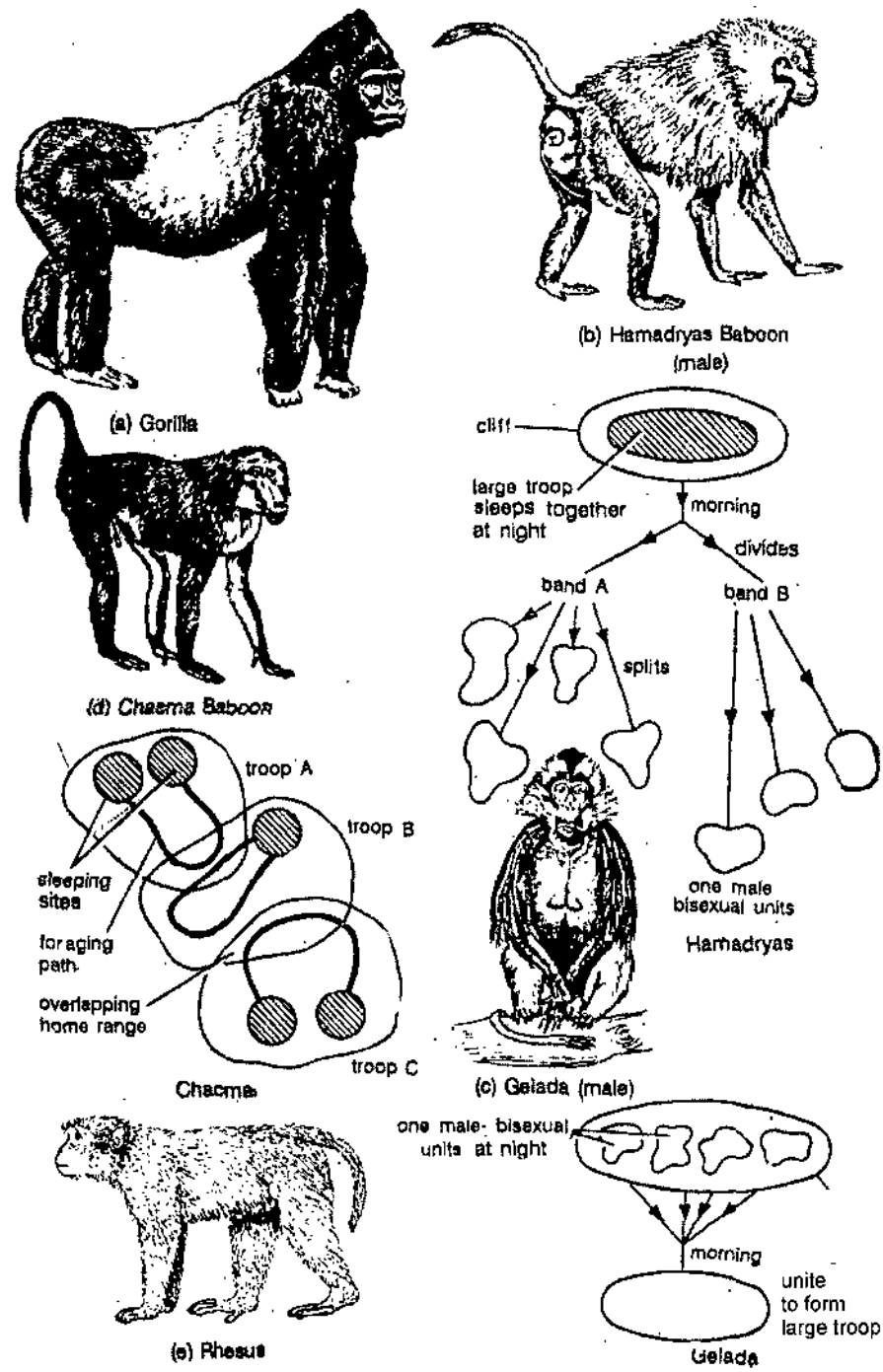

Fig. 8. Primates forming multimale bisexual groups.

many females. The rhesus is widely distributed in India, lives in large multimale bisexual groups [Fig. 8(c)].

5. Diffused social parties : *Examples : pygmy chimpanzee (Pan paniscus)* are found in Zaire and Chimpanzee (*Pan troglodytes*) are found from Guinea to Zaire, and in Uganda and Tanzania, form diffused social parties. Their social structure is more variable than other primates. They follow no strict social organization. They may be seen in bands of males, groups of females, with or without offspring, or form large troops of males and females with young, they may also be seen wandering alone (Fig. 9).

• SUMMARY

An animal society is a relatively permanent union of individuals held together by mutual attraction of its members. The basis of social life is the interaction of individual

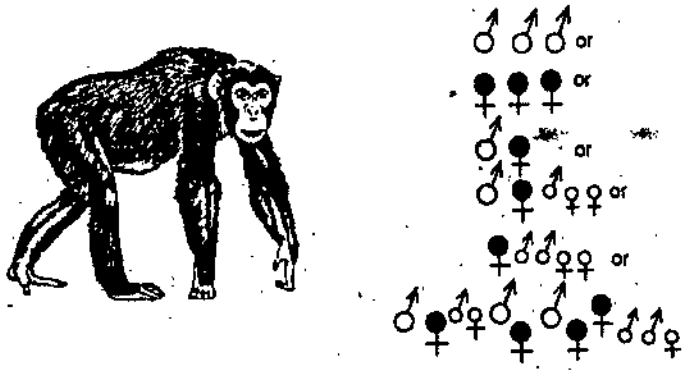

Fig. 9. Formation of diffused parties in chimpanzee.

members who exchange food, water, body care and sexual favours. The social organization itself can be temporary or permanent, seasonal or annual. A true society will involve more than a mated pair, *i.e.*, adults, subadults, juveniles, infants of different age-sex classes. It will mean a stable group whose members inter-communicate extensively and bear some relatively permanent social relationship to one another. Each member of any social organization has several advantages like antipredation, feeding efficiency and information sharing and reproduction facility. In mammals, studies have been made of lions, deer, antelopes, monkeys and other mammals. In lions, the society is most noisy and vocal and follow matriarchial system. The social system of most of the deer and antelopes is essentially matriarchial. In monkeys, several kinds of social grouping are found.

Keywords : Society, mated, adult, juvenile, social organization.

• STUDENT ACTIVITY

1. Collect photographs of lion to demonstrate the social organization in lions.

• TEST YOURSELF

Long Answer Questions

1. Define social behaviour. Write about the advantages of being social.
2. Describe various properties of social organization and elaborate on different types of mating strategies.
3. Write in detail about social organization in monkeys.

Short Answer Questions

1. Describe communication and cohesion in a social organization.
2. Describe mating strategies of a social group in short.
3. Write short note on 'antipredation' an advantage of social group.
4. Write a note on matriarchial system of a social organization.

Objective Questions

1. Sacrifice of one's life and reproduction for other members of society is :
   (a) mutualism (b) altruism (c) commosalism (d) none of these

2. Overlap of generation is :
   (a) a property of society (b) a property of animal life
   (c) a type of learning (d) all of these
3. Cohesion in a social group :
   (a) indicates distance between social groups
   (b) indicates hierarchy in a social group
   (c) indicates physical proximity between members of a society
   (d) indicates matriarchial system
4. Monogamy is found in :
   (a) 10% of birds (b) 100% of birds
   (c) 70% of birds (d) 90% of birds
5. The social system of lions, deers and antelopes is :
   (a) matriarchial (b) patriarchial
   (c) both of (a) and (b) (d) none of these

Ans. **1.** (b) **2.** (a) **3.** (c) **4.** (d) **5.** (a).