ECOLOGY

- Ecology (Gk. oikos – home, logos – study) is the branch of biology that deals with the inter-relationships amongst organisms and interactions between organisms and their environment. The term ecology is believed to have been coined by Ernst Haeckel (1869) although its first authentic use was made by Reiter (1885).
- Ecology has two main branches (i) Autecology/Species Ecology. The study of reciprocal relationships between every stage of development of a population/species and its environment is called autoecology. (ii) Synecology. It is the study of reciprocal relationships between composition, organisation and development of communities and their environment.
- Geneecology - Study of genetic composition and changes in relation to the origin of ecads, ecotypes, new species, etc.

ECOLOGICAL HIERARCHY

The hierarchy in the levels of organisation connected with ecological grouping of organisms is called ecological hierarchy or ecological level of organisation. There are no sharp lines or breaks in the functional sense amongst various levels of ecological hierarchy as the same individual is a component of population, biological community as well as ecosystem.

- Individual (Organism). It is a distinct living entity or distinct package which carries out all life processes in its body, separate from those in other individuals. Individual organism is the basic unit of ecological hierarchy as it continuously exchanges materials and information with its environment. New individuals develop from pre-existing ones. Hereditary characters are transferred during this process. The constituents of an individual cannot survive independently.
- Population. It is a grouping of similar individuals in a particular geographical area or space. The different populations of the same organism present in particular geographical areas are called local populations/demes. A local population adapted genetically to its particular environment is called ecotype. There may be several ecotypes of the same organism which show variations amongst them.
- Biological or Biotic Community. It is an assemblage of populations of different species of plants, animals, bacteria and fungi which live in a particular area and interact with one another through competition, predation, mutualism, etc.
- Ecosystem. It is a segment of nature consisting of a biological community and its physical environment both interacting and exchanging materials as well as energy, e.g., pond ecosystem.
- Landscape. It is a unit of land distinguished by a natural boundary and having patches of different ecosystem.
- Biome. A large regional unit delimited by a specific climatic zone, having a particular major vegetation zone and its associated fauna, e.g., tundra desert, temperate deciduous forest, tropical rainforest, ocean.
- Biosphere. It is biologically inhabited part of earth along with its physical environment consisting of lower atmosphere, land and water bodies.

CLIMATE

- The short term properties of atmosphere at a given place and time with respect to such conditions as heat, cold, sunshine, rain, cloud, wind, etc., is called weather.
Climate is the average weather conditions of a particular region of earth or area with regard to temperature, rainfall, air pressure, seasonal variations and weather extremes.

Four climate and vegetation zones have been recognised on the basis of mean temperature along the latitude.

A similar but miniature climate and vegetation zonation occurs over mountains along the increasing altitude. A high mountain in tropical area will have all the fours zones—tropical, subtropical, temperate and alpine (an equivalent to arctic/antarctic). A mountain in subtropical area will have only three zones (subtropical, temperate and alpine) while the one in temperate area would have only two zones (temperate and alpine).

However, variations occur in each zone due to changes in annual and seasonal precipitation. Therefore, vegetation and soil types are determined by two climatic factors, temperature and precipitation.

**Microclimate (Microenvironment)**
- It is the local variation of a climate that occurs in an area of limited size. Below a tree temperature is higher than the surroundings in winter while it is lower during summer. Canopy of tall trees is exposed to strong light and high temperature during the day while plants occurring below receive dim light, lower temperature and higher humidity.

**Habitat**
- It is a specific place/locality delimited by a combination factors, physical features and barriers where a community resides, e.g., pond, desert, river, valley, saline soil, etc.

**Microhabitat**
- It is part of the habitat having a specific property, e.g., forest floor, tree canopy, tree trunk, edge of a pond.

**Niche/Ecological Niche (Joseph Grinnel)**
- It is the functional role of a species or organism in an area depending on type of food and its availability, shelter, type of predator or timing of activity. Tadpole and adult frog occupy different ecological niches as the former is herbivorous and aquatic while the latter is carnivorous amphibian. Water Bug and Water Boatman live in shallow edges of ponds but occupy different niches as the former is predator while the latter is scavenger. Both Owl and Cat feed on Shrews, and Mice. They occupy the same niche because of being ecological equivalents though their habitats are different.

**Environmental Factors**
- The constituents of environment which directly or indirectly influence the form and functioning of organisms in any specific way are known as environmental factors. They are of two types—**abiotic** (physical) and **biotic**. The abiotic factors affect structure, life history, physiology and behaviour of organisms, e.g., atmosphere, air, light, temperature and precipitation, soil, topography, etc. The biotic factors mostly influence growth and reproduction, e.g., plants, animals, microbes.

**Atmosphere**
- **Atmosphere** is transparent gaseous envelope around the earth which extends upto 1600 km. It contains nitrogen (78.03%), oxygen (20.99%), noble gas argon (0.94%), carbon dioxide (0.036%) and traces of other gases with water vapours and dust particles present in the lower region.
- Water vapours absorb infra-red radiations (keeping the earth warm) and maintain hydrological cycle essential for maintaining life on earth. Other components which maintain heat balance of the atmosphere are CO₂ and ozone.

- **Atmosphere is divisible into four parts**: troposphere, stratosphere, mesosphere and thermosphere.
  - (i) **Troposphere**. It extends 8 – 16 km from surface of earth showing decreasing of temperature with height from 15°C to –57°C. Lapse rate of decrease in temperature is 6.4°C for 1 km. All climatic changes, cloud formation, dust particles, movement of air masses and water vapours are restricted to troposphere.
    - Top of troposphere which makes the transition between troposphere and stratosphere is called tropopause.
  - (ii) **Stratosphere**. It extends from 8 – 16 to 30 – 50 km. Clouds, dust particles and air masses are absent. Water vapours and CO₂ are very little.
    - Ozone occurs in concentration of up to 1.0 ppm, as compared to 0.05 ppm in troposphere.
    - Maximum ozone density is found between 15 – 30 km, at 23 – 25 km height above equator and 11 – 16 km height over poles. It is called ozone layer or ozonosphere.
Ozone layer has two variable holes, a larger over South Pole (Antarctica) and a minor one over north pole.

High speed jets usually fly in stratosphere, causing depletion of ozone.

Ozone protects earth by filtering out ultra-violet radiations.

Transition between stratosphere and mesosphere is called stratopause.

(iii) **Mesosphere.** It is present 50 – 100 km height. Temperature decreases from −2°C to −92°C. Gas molecules become charged.

(iv) **Thermosphere.** It lies between 100–500 km height. Temperature rises from −92°C to 1200°C. Ionised layers occur which are collectively called ionosphere. Ionosphere protects earth from cosmic rays.

**AIR/WIND**

- Lower part of atmosphere called air moves and forms wind due to uneven heating and rotation of earth. It has a direct mechanical effect and an indirect physiological effect.

**Physiological/Indirect Effect of Wind**

- **Desiccation.** Evaporative loss of water increases in wind. As a result plants often undergo wilting.
- **Reduced Growth.** Excessive evaporation reduces water availability for growth. Therefore, organisms remains dwarf.
- **Salt Spray.** Wind picks up salt rich water droplets over the sea and deposit the same over the surface of land organisms causing exosmosis and blocking of stomata.

**WATER**

- Only 3% is fresh water. 70% water (2.1% of total) is found as ice/snow, 22.4% (0.67%) as ground water while the remaining is present in lakes, rivers, etc.
- Water evaporates from oceans, ponds, lakes, ground, plants (as transpiration) and animals (as sweat and in breath). Water vapours condense and from clouds which precipitate to produce rain and snow. 90% of ocean evaporation returns to it as rain while 10% extra falls on land surface. This forms lakes, rivers and ground water.
- At any time atmosphere contains $0.13 \times 10^{12}$ G (1G = $10^{20}$ g) water vapours. Annual precipitation is around $4.46 \times 10^{20}$ G. This requires constant addition of water vapours and their condensation.
- Hydrologic cycle has two components, global and local. Local component is also called short cycle. It involves evaporation of water from an area, its condensation high up in the atmosphere and precipitation over the same area.
- Global component is long cycle that involves circulation of water vapours in the atmosphere, movement of clouds, precipitation, movement of water from one area to another. Hydrological or water cycle is energised by solar energy.
- Various aquatic habitats are sea (marine), estuary (estuarine), pond, lake (lentic) and rivers (lotic).
- Bottom is called benthic habitat while above bottom is the pelagic habitat.
- Organisms confined to bottom are called benthos.
- Pelagic organisms are differentiated into plankton (microscopic, drifting over surface), neuston (macroscopic, floating or swimming on or near water surface), nektom (actively swimming inside water), benthic (benthos) organisms are at the bottom or sea bed e.g. starfishes, snails, slugs, microorganisms, these are creeping or crawling and scavenger organisms. They are in darkness or in shallow water some light may penetrate.

**LIGHT**

- Part of light which is effective in photosynthesis is called photosynthetically active radiation (PAR). Its wavelength is 400 – 700 nm (0.4 – 0.7 μm).
- The energy spectrum ranges from cosmic rays to radiowaves. Just before entering the mesosphere the energy content of solar radiations is 2 cal/cm²/min. It is called solar constant.
- Ultraviolet rays have a wavelength of 100 nm – 320 nm) and (0.1 μm – 0.4 μm). They are of three types –UV-C (100 nm – 280 nm), UV-B (280–320 nm) and UV-A (320 – 390 nm). UV-C is lethal while UV-B is quite harmful.
- Fortunately, UV-C and 50% of UV-B are absorbed by ozone layer. Rather 52% of solar radiations are filtered out or scattered by components of atmosphere. Only 48% reach the earth.

**Effects of Light**

- Flowering is increased, Differentiation of various tissues and organs in response to light is called **photomorphogenesis**.
- Aphids develop wings in response to alternate light and darkness.
- In humans prolonged exposure to light causes **tanning** or darkening of skin. Some animals show seasonal colour changes.
- Flowers of some plants open or close in response to light and darkness. The phenomenon is called **photonasty**.
- **Nyctinasty** is folding of leaves in response to darkness.
- **Planaria** and earthworm generally show negative phototaxis.
- Most animals are active during a particular period of the day – **diurnal** (during day), **nocturnal** (at night), **auroral** (at dawn), **vesperal** (at dusk) and **crepuscular** (both at dawn and dusk).
- **Phenology** or the timing of seasonal activities of organisms (e.g., flowering migration) is usually controlled by photoperiodism.
- **Bird Migration.** Birds of colder areas of northern hemisphere begin their southward migration as the day lengths begin to shorten. Reverse journey is undertaken with the increase in day length.
- **Hibernation.** In temperate and subtropical areas, cold blooded or ectothermic animals undertake hibernation as the day length begins to shorten.
- **Flowering.** Most plants flower at a particular season in response to a particular photoperiod, e.g., spring, summer, autumn or winter.
- **Animal Breeding.** Turkeys, Ferrets, breed in response to lengthening of of days while goat, sheep, deer breed in response to shortening of days. Rabbits and guinea Pigs are day neutral.
- **Light Zones in Aquatic Habitats.** The is a light zonation in deep lakes and oceans.
- **Littoral Zone.** It is shallow coastal region. Light is able to pass through water and reach the bottom. Therefore, producers occur throughout from surface to bottom.
- **Limnetic Zone.** It is open water zone where water is very deep. Amount of oxygen and light decreases with depth. Limnetic zone is differentiated into three zones– photic, aphotic and abyssal.
- **Aphotic Zone.** It is zone of deep water below the photic zone and above the bottom to which light does not penetrate (except some U.V. rays). The zone is, therefore, in perpetual darkness. Producers do not occur in this part. Instead only consumers are found.
- **Abyssal Zone.** It is the bottom zone. In deep lakes and seas, the bottom is also in perpetual darkness.

**Temperature**

- Atmospheric temperature of a place depends upon its latitude, altitude, topography, slope aspect, season, vegetation and humidity. Vertical temperature gradient over earth’s surface or lapse rate is 6.4 – 6.5°C.
- There is a similar lowering of mean temperature from equator to poles – tropical, subtropical, temperate and arctic.
- Organisms living in these zones are respectively called **megatherms**, **mesotherms**, **microtherms** and **hekistotherms**.
- **Stenothermal** organisms live in areas where temperature remains near uniform throughout the year, e.g., warm tropics, sea shores. **Eurythermal** organisms can tolerate large scale variations in temperature. They live in areas where there are different temperatures at different times of the year.
- **Thermal Stratification in Lakes.** Deep lakes show three temperature strata.
  - **Epilimnion.** Upper stratum of water which is exposed to solar radiations. It is warmer during summer and cooler during winter.
  - **Metalimnion.** It is transition zone between epilimnion and hypolimnion. Maximum temperature change occurs in middle part of metalimnion called **thermocline**.
  - **Hypolimnion.** It is basal stratum where water is always cool but well above freezing point, e.g., 4°C.
SOIL

- It is the upper weathered humus containing part earth’s surface which can substain terrestrial plant life.
- **Weathering** or breaking of rocks into fine powder can occur due to atmospheric changes, mechanical forces (mechanical weathering), chemical changes (chemical weathering) and biological breakdown (biological weathering).
- The weathered mineral matter is changed to soil by the process of **pedogenesis** (pedology is science of soil) which involves **humification** (formation of humus), **evolution** (washing down or leaching) and **illuviation** (deposition in lower layers).
- **Residual soils** develop in situ.
- **Transported** soils are brought from other places through gravity (colluvial), running water (deposited at flood plains and called alluvial), wind (eolian = aeolian) and glacier (glacial soil).
- **Soil Profile.** It is cross-sectional appearance of morphologically and physico-chemically different layers or horizons superposed over one another. There are five horizons – O, A, B, C and D. A and B constitute solum.
- **O-Horizon.** It is surface layer of organic matter which lies above the true soil. It has two parts Aoo and Ao. Aoo (O1) is the upper subhorizon which consists of freshly deposited organic litter of fallen leaves, twigs, bark, animal remains and animal excretions. Ao (O2) is lower subhorizon which contains organic matter in various stages of decomposition.
- **A-Horizon.** It is dark coloured spongy top soil which is rich in mineral and organic matter, shows maximum biological activity and **humification**. Top soil is differentiated into A1 of dark colour and A2 of light colour (zone of eluviation).
- **B-Horizon.** Subsoil (or horizon of illuviation) with dark colouration in B1 and light colour in B2. It is mainly mineral zone. **Leaching** of minerals occur from A horizon.
- **C-Horizon.** Rich in moisture with irregular rock fragments or sedimentary deposits.
- **D/R-Horizons.** Bed rock.

**Soil Types**

- **Red Soils.** Most famous are acidic laterite soils which are deficient in lime, magnesium, phosphorus and potassium but rich inorganic matter, iron and aluminium, supports tea, coffee, rubber, cardamom, areca-nut and paddy.
- **Black Soils.** Also called **black cotton soils/regurs** with dark brown or black colour from organic matter, clay/hydrated iron and aluminium silicates and undifferentiated B-horizon.
- **Alluvial Soils.** Soil transported by mainly river water.
- **Terai/Babar Soils.** Mostly colluvial, (transported by gravity).

**Soil Composition**

- Inorganic Matter/Mineral Particles – 45%. Water – 25%. Air – 25%. Humus – 50%. Living Organism – Variable. Mineral particles are of four types. **Gravel** (find pebbles). 1 – 10 nm. **Sand** (Quartz or SiO2). 0.02 – 1.0 nm. **Silt** (very fine quartz grains). 0.002 – 0.02 mm. Clay (hydrated silicates of aluminium). Less than 0.002 mm.
- **Loam Soils.** The soils contain 20% clay, 40% silt and 40% sand. They have good nutritive status, aeration and hydration. Ideal for plant growth.
- **Soil pH.** Plants grow best in neutral or slightly acidic soils. Slight alkalinity is helpful in growth of grasslands and some crop plants like legumes.
- **Macropores.** Noncapillary pores of more than 20 μm diameter. Water percolation (gravitational flow) through macropores.
- **Micropores.** Capillary pores with diameter of μm or less. Hold water by capillarity. 30% in good soils.

**Soil Water**

- Part of entering the soil moves down to water table as **gravitational water.**
- The maximum amount of water, a soil can hold per unit dry weight after stoppage of gravitational flow is known as **field capacity.** (25 – 35% in loam soil). Water potential at field capacity is about -0.01 MPa (= -0.1 bar). Water in excess of field capacity causes **water logging.**
- **Permanent wilting percentage** (PWP) or **coefficient** (PWC) is that percentage of water present in per unit dry soil when the plants growing in it wilt.
At PWP water is mostly hygroscopic or held over the surface of particles including very narrow micropores of 0.2 μm or less. Water potential at permanent wilting point is –1.5 M Pa or –15 bars. Total soil water content or holard consists of two parts, chesard (water available to plants) and Echard (water not available to plants).

**Range of Tolerance**
- A factor that limits growth, development, reproduction or activity of an organism by its deficiency or excess is called limiting factor.
- According to law of tolerance (Shelford, 1911) the abundance and distribution of organisms is controlled by their limits of tolerance (critical minimum and critical maximum) to ecological factors.
- Range of tolerance (Shelford, 1991) is the range between critical minimum and critical maximum limits of environmental factor/factors influencing an organism.
- The response of an organism to the range of an environmental factor (e.g., sunlight, temperature, nutrient) shows a bell-shaped curve. In the central optimum part of the range is the optimum zone of tolerance which favours maximum fitness, growth, abundance and survival. The sides have zones of stress. Fewer individuals occur and survive in the zones of stress (limits of tolerance towards minimum and maximum of the factor/factors). They are not able to reproduce. The areas where ecological factor occurs below its critical minimum or above its critical maximum are called zones of intolerance or lethal zones. Organisms do not occur in the zones of intolerance.
- Range of tolerance for all the factors influencing a species is also known as ecological amplitude. It has an optimum area of range below and above which physiological stresses occur that culminate in the limits of tolerance.
- Organisms with wide range of tolerance are called eurytopic while the ones with narrow range of tolerance are called stenotopic.

**Ecological Adaptations**
- Ecotypes and Phenotypic Plasticity. Phenotype or physical expression is a product of interaction of expression of a genotype of an organism in a particular environment.
- Variations produced amongst individuals of a species due to influence of local conditions of a habitat are collectively called phenotypic plasticity. It results in the formation of ecotypes. Ecotypes are local populations of a species which are genetically adapted to a particular variations of environment. They differ in morphological and physiological characters. Although ecotypes of a species differ genetically, the differences are only minor so that they are interfertile.
- The transition area between two ecotypes shows a gradual change varied local populations which are genetically similar but differ in morpho-physiological traits to suit particular environment.

**Plant Adaptations**

**Types of Xerophytes**
- Ephemerals or Drought Escapers. The plants live for a brief period during the rains. The rest of the year is passed in the form of seeds, e.g., Euphorbia prostrata, Tribulus terrestris, Boerhaavia.
- Annual or Drought Evaders. The plants live for a months even after the stoppage of rains. For this they have modifications to reduce transpiration e.g., Echinops echinatus, Solanum surattense.
- Succulents or Drought Resistant. The plants have fleshy organs where water and mucilage are stored. Depending upon the organ where succulence occurs, the succulents show chylophyllly (fleshy leaves, e.g., Aloe, Agave), chylorhizy (fleshy roots, e.g., Asparagus) and chylocauly (fleshy stems, e.g., Opuntia, Euphorbia, Asparagus).
- Non-succulent Perennial Xerophytes or Drought Endurers. They are true xerophytes which actually tolerate drought conditions. They have smaller shoot system. The root system is very extensive. It may spread along the soil surface in order to absorb every drop of rain as well as dew. In a type of xerophytes called phreatophytes the roots are very deep. They reach the water table. Phreatophytes are, generally, used to locate ground water, e.g., Tamarix, Prosopis. Leaves or leaflets are often small, vertical, thick and leathery. They have either reflecting surfaces, e.g., Nerium or possess a coating of hair (e.g., Gnaphalium, Aerua). In grasses the leaves roll up during dry weather to reduce surface exposed for transpiration. In Capparis decidua the leaves are small and drought deciduous. In Casuarina the leaves are vestigial. Lamina vestigial while petiole enlargees to form phyllo-
in Australian species of *Acacia*. Leaves may possess prickles and spines. The plants contain anthocyanins, resins, gums, latex, proline (an amino acid) and chaperonins.

- **Proline** is useful in maintaining osmotic and water potential.
- **Chaperonins** are heat shock proteins which protect other proteins from denaturation at high temperature.

**HYDROPHYTES**

They live in abundance of water with at least their lower parts (roots etc.) and leaves immersed water.

- **Roots of Hydrophytes** are poorly developed/completely absent in *Wolffia, Ceratophyllum* etc. roots are poorly branched (e.g., *Pistia*); root hair absent or poorly developed (except in those which grow in mud), *Lemma minor* lacks root hairs. Root caps absent but **root pockets** may be present (e.g. *Eichhornia, Pistia, Trapa*).

**Anatomical adaptations of hydrophytes**

- Absence of cuticle over epidermis in submerged parts.
- **Stomata** absent (or functionless) in epidermis of submerged plants/plant parts but in plants with floating leaves (e.g. *Nymphaea*), stomata present only on the upper surface which is covered with waxy cuticle.
- **Aerenchyma** well developed; helps in buoyancy and gaseous exchange.
- **Epidermal cells** contain chloroplasts for maximum capturing of diffused light.
- **Mechanical tissues** like sclerenchyma/collenchyma are poorly developed/absent. However, sclerenchymatous sclereids may be present to provide strength.
- **Vascular tissues** poorly developed. In some plants, xylem is represented by only some tracheids. Sieve tubes are smaller.
- **Secondary growth** is absent.
- Vegetative propagation is common—by **runners** (e.g., *Marsilea*), **offsets** (e.g., *Pistia, Eichhornia*), **rhizomes** (e.g., *Typha*).
- Absorption of salts and water through entire surface; osmotic potential of cells is equal to or is slightly higher than external water; some amount of CO₂ and O₂ liberated during respiration and photosynthesis is stored in air chambers for use in photosynthesis and respiration, respectively.

**Types of hydrophytes**

- **Free floating** e.g. *Wolffia* (smallest Angiosperms), *Lemma, Spirodella, Pistia, Eichhornia, Azolla, Salvina*.
- **Submerged**
  - (i) **Suspended** e.g. *Utricularia, Hydrilla, Ceratophyllum, Najas*.
  - (ii) **Rooted** e.g., *Vallisneria, Elodea, Isoetes, Potamogeton*.
- **Emergent or rooted floating** (fixed at the bottom of water body by well developed roots but leaves/shoot are partly/completely aerial).
- With floating leaves e.g. *Nymphaea, Nelumbo, Trapa, Victoria, Nymphoides*.
- With erect shoots (amphibious or marshy plants): grow in shallow water along the margin of pond/lake e.g. *Ranunculus, Sagittaria, Monochoria, Typha, Marsilea, Cyperus*.

**Interesting points of some hydrophytes**

- *Eichhornia* (water hyacinth)—spongy and swollen petiole, water weed, originally belongs to America.
- *Lemma* (Duck weed)—thaloid plant body, 1–2 balancing roots.
- *Wolffia* smallest flowering plant, rootless.

**HALOPHYTES**

- Halophytes are special types of xerophytic plants which grow in saline soils with high concentrations of salts like NaCl, MgCl₂, MgSO₄ (hence **physiologically dry soil**).
- Halophytic communities growing on swamps are called **helophilous** halophytes. Helophilous communities are of two types: (i) **Salt swamp** and **salt desert**, (ii) **Littoral swamp forest**.
- Littoral swamp forests are most extensive, occur in all tropical seas particularly on flat, muddy shores. It is flooded with water either permanently or at high tide. Such swamp forests from a characteristic vegetation —
ADAPTATIONS IN ANIMALS

- **Migration**: It is a two-way movement of an animal group to other places for food, climate and other reasons. Migration is of three types—daily, seasonal, cyclic. The distance may be short or long. The longest distance travelled by an animal is that of sea bird Arctic Tern (*Sterna paradisaea*).

- **Periodic migration** occurs in locusts when their number increases beyond the feeding capacity of the homeland. Large populations migrate in search of food to various directions.

- **Camouflage** (Cryptic Appearance). It is the ability to blend with the surroundings or background. It is the most common type of adaptation by animals to remain unnoticed for protection or aggression, e.g., insects, reptiles and mammals.

- **Mimicry**. It is resemblance of one species with another in order to obtain advantage, especially, against predation. The species which is imitated is called *model* while the animal which imitates is known as *mimic* or *mimetic*. Model is either ferocious or distasteful to predator. Mimicry is of two types, *Batesian* and *Mullerian*.

- **Batesian Mimicry**. The mimic is defenseless. It has, however, resemblance to a dangerous or unpalatable model so that the predator usually does not prey upon it, e.g., Viceroy Butterfly mimics unpalatable toxic Monarch Butterfly.

- **Mullerian Mimicry**. It is resemblance to two animal species, especially insects, both unpalatable/ferocious, to their mutual benefit, e.g., Monarch Butterfly and Queen Butterfly.

- **Warning Colouration**. Dart frogs (*Phyllobates bicolor, Dendrobates pumilio*) found in tropical rain forests of South America are highly poisonous as well as brightly coloured to be easily noticed. Predators usually avoid them.

- **Echolocation**. Bats are nocturnal flying mammals which do not employ eyesight for location of their path, food, place of rest, etc. America are highly poisonous as well as brightly coloured echoes after striking various objects on the principle of sonar. Echoes are analysed by the bats to know their path.

- **Hibernation and Aestivation**. Hibernation or winter sleep and aestivation or summer sleep are quite common in ectothermal (cold blooded) animals. They, however, also occur in those warm blooded or endothermal animals which do not migrate from area of intense cold or heat. Frog, an ectothermal animal, shows both hibernation and aestivation.

- **Adaptations to Excessive Cold** (Cold Hardening). Sea animals cannot undergo hibernation. Sesile animals cannot migrate. These and some other animals protect themselves from excessive cold by developing cold hardness, e.g., branchies and molluscs of intertidal zones of cold areas. Several ice nucleating proteins in the extracellular spaces. The extra solutes which prevent freezing are glycerol and antifreeze proteins. They lower the freezing point of body fluids. Ice Fish (*Chaenoecephalus*) or Antarctic Fish (*Trematomus*) remains active even in extremely cold sea water due to this hardiness.

- **Adaptation to Water Scarcity**. Animal faced with water scarcity as found in arid or desert areas, show two types of adaptations reducing water loss and ability to tolerate arid conditions. Kangaroo/Desert Rat seldom drinks water. It has a thick coat to minimize evaporative desiccation. The animal seldom comes out of its comparatively humid and cool burrow during the day time. 90% of its water requirement is met from metabolic water (water produced by respiratory breakdown) while 10% is got from food. Loss of water is minimized by producing nearly solid urine and faeces. Camel has a number of adjustments to desert conditions—economical in water consumption, minimizing surface exposure, tolerance to fluctuations of temperature, no sweating till body temperature rises to 55°–66°C, maintenance of blood stream moisture with body cells capable of tolerating upto 40% dehydration. The animal produces dry faeces and concentrated urine. During period of nonavailability of water the animal stores urea and does not produce urine. When water is available, camel can rehydrate itself quickly by drinking large quantity of water, some 80 litres in 10 minutes.