[TOPIC 1] Organisms and their Environment

1.1 Ecology

Ecology is the branch of biology, which studies the interactions among organisms (biotic) and their physical (abiotic) environment. German biologist **Ernest Haeckel** (1869) coined the term **Ecology**.

Levels of Biological Organisation

The subject ecology is basically concerned with four levels of biological organisation. These are given below:

(*i*) **Organism** Living component of the environment at individual level and is basic unit of ecological hierarchy.

(*ii*) **Population** The sum total of all individuals of a species in a specific geographical area.

(*iii*) **Communities** Assemblage of all the populations of different species present in an area that interact among themselves.

(*iv*) **Biome** It is a large unit, which consists of a major vegetation type, associated fauna in a particular climatic zone. Tropical rainforest, deciduous forest, sea coast, deserts, etc., are the major biomes of India.

NOTE Other important terms used in ecology are:

Ecosystem Represents the organisms and their environment in a particular area.

Habitat It refers to a specific place or locality delimited by a combination of factors, physical features and barriers where a community dwells.

Niche The ecological niche of an organism represents the physical space occupied by it, the resources it utilises and its functional role in the ecological system.

Biosphere The surface of earth with all life forms, i.e. union of all ecosystems. It is a highly ordered system.

1.2 Environment

Ecology at organism level deals with how different organisms are adapted to their environment in terms of their survival and reproduction.

(*i*) Different biomes are formed due to:

(a) annual variations in the intensity and duration of temperature, due to rotation of earth.

(b) annual variations in precipitation (which include both rain and snow).

The major biomes of the world are desert, grassland, rainforest and tundra.

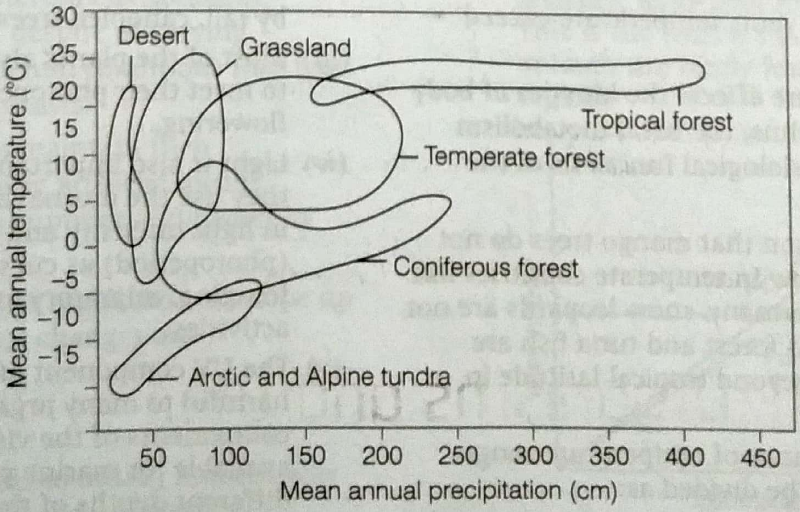

Figure 13.1 Biome distribution with respect to annual temperature and precipitation

(*ii*) Regional and local variations within each biome lead to the formation of a wide variety of habitats.

(iii) Life on earth exists in favourable habitats as well as in extreme and harsh habitats like scorching Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost polar regions, high mountain tops, boiling thermal springs and stinking compost pits and even in our intestine.

(iv) The biotic components of a habitat are pathogens, parasites, predators and competitors of the organism with which they interact constantly.

(v) The key abiotic elements that lead to variations in habitats are:

(a) Temperature (b) Water
(c) Light (d) Soil

Abiotic Factors

Temperature

Temperature is the major abiotic factor, which is most ecologically relevant.

(i) There is seasonal variation in average temperature of land.

(ii) It decreases progressively from the equator to the poles and from plain areas to the mountains.

(iii) The range of temperature varies from sub-zero levels in polar areas to >50°C at high altitude in tropical deserts during summer. In thermal spring and deep sea hydrothermal vents temperature exceed 100°C.

(iv) The temperature affects the kinetics of body enzymes and thus, the basal metabolism and other physiological functions of the organism.

(v) This is the reason that mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forest and tuna fish are rarely caught beyond tropical latitude in ocean.

(vi) Based on tolerance of temperature range, organisms can be divided as:

Eurythermal These can tolerate a wide range of temperature.

Stenothermal These organisms are restricted to a narrow range of temperature.

Water

Water is the next major important factor without which life cannot exist.

(i) The productivity and distribution of plants in an environment depend on amount of water available.

(ii) For aquatic organisms, the quality (chemical composition and pH) of water is important.

(iii) Salinity refers to salt concentration (measured in parts per thousand) of water. Salt concentration is less than 5 in land water, 30-35 in sea and more than 100 in some hypersaline lagoons.

(iv) Based on tolerance of range of salinity, organisms can be grouped as:

Euryhaline Organisms which can tolerate a wide range of salinity.

Stenohaline Organisms are restricted to a narrow range of salinity.

(v) Many freshwater animals cannot live for long in seawater and *vice versa* because of the osmotic problems they would face.

Light

Light is an essential factor for the process of photosynthesis performed by autotrophs.

(i) Oxygen is released during photosynthesis.

(ii) Many small plants like herbs and shrubs can perform photosynthesis under very low light conditions because they are overshadowed by tall, canopied trees.

(iii) Most of the plants also depend on sunlight to meet their photoperiodic requirement for flowering.

(iv) Light is also important for many animals as they use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, migratory and reproductive activities.

(v) The UV component of solar radiation is harmful to many organisms. All the colour components of the visible spectrum are not available for marine plants living at different depths of the ocean. So deep ocean plants can utilise UV rays to perform photosynthesis. That is why red algae are found deepest in water and green algae on surface water.

Soil

The nature and properties of soil vary from place to place. It depends on climate, weathering process and whether soil is transported or sedimentary and how its development occurred.

(*i*) The soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils.

(*ii*) The characteristics like pH, mineral composition and topography determine the vegetation of an area.

(*iii*) This in turn dictates the type of animals supported.

Responses to Abiotic Factors

Responses to abiotic factors determines how organisms can cope or manage with stressful conditions of the habitat.

(*i*) During the course of millions of years of their existence, many species would have evolved a relatively constant internal (within the body) environment that permits all biochemical reactions and physiological functions to proceed with maximal efficiency and thus, enhance the overall fitness of the species.

(*ii*) The organisms should try to maintain the constancy of its internal environment, i.e. **homeostasis**, despite of varying external environmental conditions that tend to upset its homeostasis.

(*iii*) Human beings can maintain their homeostasis by using artificial means (air conditioner in summer and heater in winter).

(*iv*) Ways by which other organisms can cope up with environmental changes are given below:

Regulator

(a) Some organisms maintain homeostasis by physiological and sometimes behavioural means.

(b) All birds and mammals and few lower vertebrates and invertebrates are capable of thermoregulation and osmoregulation.

(c) In mammals, during summer, sweating occurs profusely and the evaporation brings down temperature of the body.

(d) In mammals, during winter, shivering occurs which is a kind of exercise that produces heat and raises the body temperature.

Conformer

(a) About 99% of animals and almost all plants cannot maintain a constant internal environment. Their body temperature changes with the ambient temperature.

(b) In aquatic organisms, the osmotic concentration of the body fluids change with that of the osmotic concentration of the ambient water. These animals and plants are called **conformers**.

(c) Thermoregulation is energetically expensive for many organisms. This is specially true for small animals like sand shrews and humming birds.

Heat loss or gain is a function of surface area. Since, small animals have a larger surface area relative to their volume, they tend to lose body heat very fast when it is cold outside. At such times, they have to expend much energy to generate body heat through metabolism. This is the reason that very small animals are rarely found in polar regions.

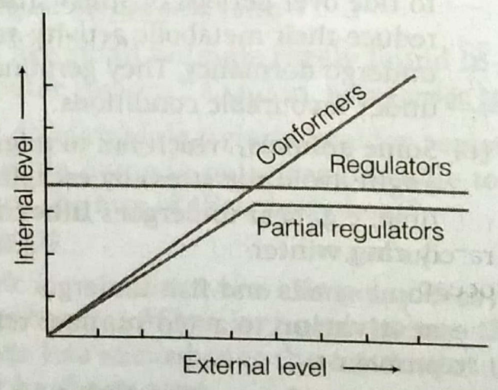

Figure 13.2 Diagrammatic representation of organismic response

(d) It can be concluded that during the course of evolution, some species have evolved the ability to regulate but only over a limited range of environmental conditions, beyond which they simply conform. These organisms are partial regulators.

Migrate

It is the temporary movement from a stressful habitat to a more hospitable area and return, when the stressful period is over.

(a) Many animals, particularly birds, during winter undertake long-distance migrations to more hospitable areas.

(b) Every winter the famous Keolado National Park in Bharatpur (Rajasthan) hosts, thousands of migratory birds coming from Siberia and other extremely cold Northern regions.

Suspend

(a) Under unfavourable conditions bacteria, fungi and lower plants slow down their metabolic rate and forms a thick-walled spore to overcome stressful conditions. These spores germinate under suitable environment.

(b) In higher plants, seeds and some other reproductive structures serve as means to tide over periods of stress. They reduce their metabolic activity and undergo dormancy. They germinate under favourable conditions.

(c) Some animals, which fail to migrate might avoid the stress by escaping in time, e.g. bear undergoes **hibernation** during winter.

(d) Some snails and fish undergo **aestivation** to avoid summer related problems.

(e) During unfavourable conditions, many zooplanktons in lakes and ponds enter **diapause** (a stage of suspended development).

1.3 Adaptation

It is any attribute of an organism, i.e. morphological, physiological or behavioural, that enables the organism to survive and reproduce in its habitat. Many adaptations have evolved over a long evolutionary time and are genetically fixed.

Some examples of adaptations are:

Adaptations in Kangaroo Rat

(*i*) The kangaroo rat in North American deserts is capable of meeting all its water requirements by internal oxidation of fat (water is a byproduct) in the absence of water.

(*ii*) It can concentrate its urine, so that minimal volume of water is used to expel excretory products.

Adaptations in Desert Plants

(*i*) Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits to minimise water loss through transpiration.

(*ii*) They have special photosynthetic pathway (CAM) that enables their stomata to remain closed during daytime.

(*iii*) Some desert plants like *Opuntia*, have no leaves. They are reduced to spines and photosynthesis occurs in flattened thick succulent green stems.

Adaptations in Mammals

(*i*) Mammals from colder climates generally have shorter ears and limbs to minimise heat loss. This is called **Allen's rule**.

(*ii*) In polar seas, aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces loss of body heat.

Adaptations at High Altitudes in Humans

(*i*) At high altitude places like Rohtang Pass near Manali (> 3500 m) and Mansarovar, in China occupied Tibet, people suffer from altitude sickness.

(*ii*) Its symptoms are nausea, fatigue and heart palpitations.

(*iii*) This is because at low atmospheric pressure of high altitudes, body does not get enough oxygen.

(*iv*) The relief occurs gradually due to acclimatisation.

(*v*) The body cope up with this low oxygen stress by

- increasing red blood cells production.
- decreasing the binding affinity of haemoglobin.
- increasing the breathing rate.

Adaptations in Desert Lizards (Behavioural Response)

(*i*) They absorb heat from the sun when their body temperature drops below the comfort zone.

(*ii*) They move into shade when the ambient temperature starts increasing.

(*iii*) Some species burrow into the soil and escape from the above ground heat.

Archaebacteria can survive in hot spring due to their cell wall structure. Many fishes can survive in Antarctic water due to the presence of antifreeze protein in their body.

[TOPIC 2] Population

Population can be defined as the total number of individuals of a species in a specific geographical area, which can interbreed under natural conditions to produce fertile offsprings and function as a unit of biotic community.

2.1 Population Ecology

It is an important area of ecology as it links ecology to the population genetics and evolution.

Population Attributes

These are certain characteristics of a population. Some of them are as follows:

Population Size or Density

Population size is the number of individuals of a species per unit area or volume. Population Density

$$(PD) = \frac{\text{Number of individuals in a region } (N)}{\text{Size of unit area in the region } (S)} \quad \text{or} \quad PD = \frac{N}{S}$$

Birth Rate or Natality

Birth rate or natality is expressed as the number of births per 1000 individuals of a population per year, e.g. if in a pond, there were 20 lotus plants last year and through reproduction, 8 new plants are added

Then, Birth rate $= \frac{8}{20} = 0.4$ offspring per lot , per year

Death Rate or Mortality

Death rate or mortality is expressed as the number of deaths per 1000 individuals of a population per year, e.g. if 4 individuals in a population of 40 fruitflies died during a specified time interval (say a week).

Death rate $= \frac{4}{40} = 0.1$ individual per fruitfly per week

Sex Ratio

Sex ratio is expressed as the number of females and males per 1000 individuals of a population in a given time, e.g. 60% females and 40% males in population.

Age Pyramid

(*i*) When the age distribution (per cent individuals of a given age or age group) is plotted for the population in which pre-reproductive age is at base, reproductive is in middle and post-reproductive is at top, we get a pyramid called **age pyramid**.

(*ii*) The shape of the pyramids reflects the growth status of the population that whether it is expanding (triangular shaped), stable (bell-shaped) or declining.

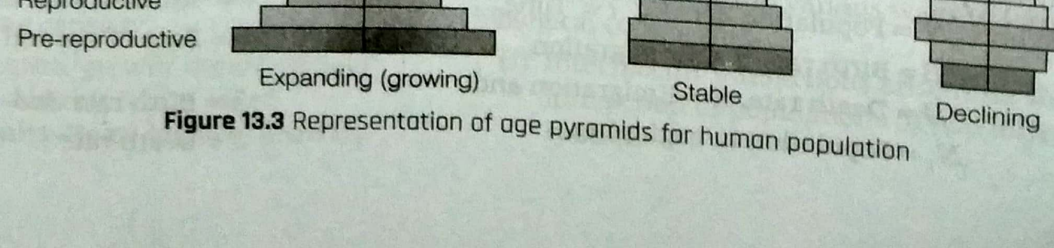

Figure 13.3 Representation of age pyramids for human population

Population Growth

(i) The size of a population for any species is not a static parameter.

(ii) It keeps changing with time, depending on various factors including food availability, predation, pressure and adverse weather conditions.

(iii) The population density depends on:

(a) **Natality** is the number of births during a given period in the population that are added to the initial density.

(b) **Mortality** is the number of deaths in the population during a given period.

(c) **Immigration** is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.

(d) **Emigration** is the number of individuals of the population who left the habitat and moved elsewhere during a given time period.

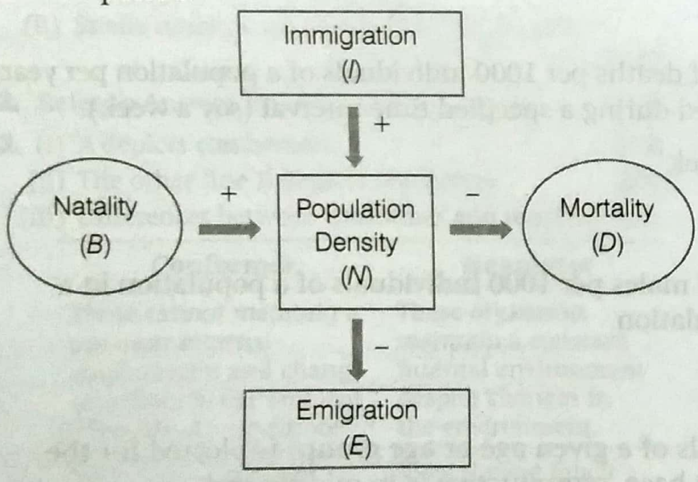

Figure 13.4 Factors influencing population density

(iv) **Population density** can be given by the following equation:

$N_{t+1} = N_t + [(B + I) - (D + E)]$ this is density at time $t + 1$.

Where, N = Population density, t = Time,

B = Birth rate, I = Immigration,

D = Death rate, E = Emigration and

N_t = Population in beginning.

The equation demonstrates that the population density will increase, if the number of births plus the number of immigrants $(B + I)$ is more than the number of deaths plus the number of emigrants $(D + E)$, otherwise it will decrease.

(v) Although total number is the most appropriate measure of population density. It is in some cases difficult to determine. So, in these cases, the per cent cover or biomass is a more appropriate measure of the population size, e.g. 200 *Parthenium* plants and a single huge banyan tree. In this case, the banyan tree produces much more biomass.

(vi) Total number is not an appropriate measure in case of huge population size.

(vii) Relative densities are sometimes used. For example, the number of fishes caught per trap is a good measure of its total population density in the lake. It is an indirect method to estimate population sizes. Other examples are the tiger census based on pug marks and faecal pellets.

(viii) **Growth curves** of population are of the following types:

(a) **Exponential growth** (A-curve) occurs normally when resources, i.e. food and space are unlimited.

- Equation for exponential growth can be

$$\frac{dN}{dt} = (b - d) \times N$$

Let $(b - d) = r$, then

$$\frac{dN}{dt} = rN \text{ or } N_t = N_0 e^{rt}$$

Where,

N = Population size,

N_t = Population density after time t

N_0 = Population density at time zero,

r = Intrinsic rate of natural increase

e = Base of natural logarithms (2.71828),

b = Birth rate and

d = Death rate

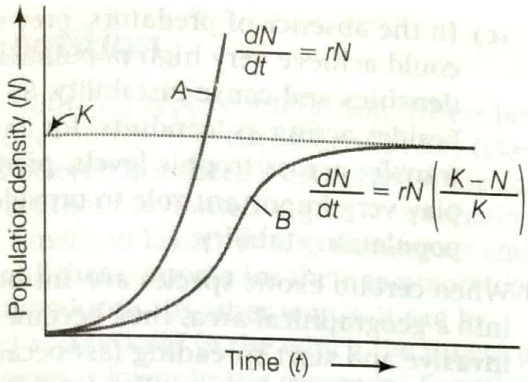

Figure 13.5 Population growth curve *A* when responses are not limiting the growth, plot is exponential, *B* when responses are limiting the growth, plot is logistic, *K* is carrying capacity

- r is an important parameter assessing impacts of any biotic or abiotic factor on population growth.
- In exponential growth, when N in relation to time (t) is plotted on graph, the curve becomes J-shaped as shown in graph.

(b) **Logistic growth** (B-curve) occurs when resources become limited at certain point of time, so no population can grow exponentially.

- Due to competition between individuals for limited resources, the fittest individual will survive and reproduce.
- In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. This is called **carrying capacity** (K) of a habitat.
- A population growing in a habitat with limited resources shows initially a **lag phase**, followed by phases of **acceleration** and **deceleration** and finally an **asymptote,** when the population density reaches the carrying capacity.
- The logistic growth shows sigmoid curve and this is also called **Verhulst-Pearl logistic growth.**

It can be shown by the following equation:

$$dN/dt = rN\left(\frac{K-N}{K}\right)$$

Where,
N = Population density at time t
r = Intrinsic rate of natural increase
K = Carrying capacity

- The logistic growth model is considered more realistic since, resources for growth of most animal populations are finite and become limited sooner or later.

Life History Variation

(*i*) **Darwinian fitness** (high r value) states that the populations evolve to maximise their reproductive fitness in the habitat in which they live.

(*ii*) Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy.

(*iii*) The **rate of breeding** varies from species to species, e.g. Pacific salmon fish and bamboo breed only once in their lifetime, while most birds and mammals breed many times in their life.

(*iv*) Some organisms produce a large number of small-sized offsprings (oysters, pelagic fishes), while birds and mammals produce a small number of large-sized offsprings.

(*v*) Ecologists suggest that life history traits of organisms have evolved in relation to the constraints imposed by the abiotic and biotic components of the habitat in which they live.

2.2 Population Interactions

Population interactions explain that in nature, animals, plants and microbes cannot live in isolation but interact in various ways to form a biological community.

(*i*) Interspecific interactions arise from the interaction of populations of two different species.

(*ii*) This interaction may be:

(a) Beneficial/positive (+)

(b) Detrimental/harmful (–)

(c) Neutral (neither harm nor benefit) to one of the species or both (0)

Population Interactions

Species A	Species B	Name of interaction
+	+	Mutualism
–	–	Competition
+	–	Predation
+	–	Parasitism
+	0	Commensalism
–	0	Amensalism

Some of the population interactions are as follows:

Predation

Predation is an interspecific interaction, where an animal called **predator** kills and consumes the other weaker animal called **prey**. This is a biological control method.

(*i*) It is the nature's way of transferring energy to higher trophic levels, which is fixed by plants, e.g. tiger and the deer.

(*ii*) Important roles of predators are:

(a) They keep prey population under control.

(b) They help in maintaining species diversity in a community by reducing the intensity of competition among prey species. For example, in American Pacific coast the star fish pisaster is an important predator. When all the fishes were removed from an area more than 10 species of invertebrates became extinct within a year due to inter specific competition.

(c) In the absence of predators, prey species could achieve very high population densities and cause instability. So, besides acting as 'conduits' for energy transfer across trophic levels, predators play very important role to provide population stability.

(*iii*) When certain exotic species are introduced into a geographical area, they become invasive and start spreading fast because the invaded land does not have natural predators, e.g. prickly pear cactus introduced in Australia (1920s). It was controlled only after a cactus feeding predator was brought from its natural habitat.

(*iv*) If a predator is too efficient and over exploits its prey, then the prey might become extinct. Following it, the predator will also become extinct because of the lack of food.

(*v*) Prey species have evolved various defence mechanisms to lesser the impact of predation. Some of them are:

(a) Some species of insects and frogs are cryptically coloured (camouflaged) to avoid being detected easily by the predator. Some are poisonous and therefore, avoided by the predator.

(b) Phytophagous insects like monarch butterfly is highly distasteful to its predators (birds) because of a special chemical present in its body. The butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous plant (weed).

(c) Some plants have thorns or spines for defence mechanism, e.g. *Acacia*, cactus.

(d) Some plants produce highly poisonous chemicals like cardiac glycosides, nicotine, caffeine, quinine, strychnine, opium, etc. These are actually defence mechanisms against grazers and browsers. e.g. *Calotropis*.

Competition

Competition is a type of interaction, where both the species suffer. It occurs when species (closely related or even unrelated), compete for the same resources that are limited, e.g. in some shallow South American lakes visiting flamingoes and resident fishes compete for their common food, i.e. zooplanktons. In other words, it can be defined as a process in the which the fitness of one species is lower in the presence of another species.

(*i*) It may be:

(a) Intraspecific (within same species).

(b) Interspecific (between different species).

(*ii*) In interference/interspecific competition, the feeding efficiency of one species might be reduced due to the interfering and inhibitory the presence of other species, although the resources are plenty, e.g. when goats were introduced in Galapagos Islands, the Abingdon tortoise became extinct within a decade due to greater browsing efficiency of the goats.

(*iii*) **Competitive release** is a phenomenon, in which a species whose distribution is restricted to a small geographical area because of the presence of competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed.

(*iv*) **Connels' elegant** field experiments showed that on the rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* dominates the intertidal area and excludes the smaller barnacle *Chathamalus* from that zone.

(*v*) **Gause's competitive exclusion principle** states that two closely related species competing for the same resources cannot coexist indefinitely and the competitively inferior one will be eliminated eventually (true if resources are limiting).

(*vi*) **Resource partitioning** states that if two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging patterns. In this relation, McArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and coexist due to behavioural differences in their foraging activities.

Parasitism

Parasitism is the mode of interaction between two species in which one species (parasite) depends on the other species (host) for food and shelter and in this process damages the host. In this process, one organism is benefitted (parasite), while the other is being harmed (host).

(*i*) Adaptation methods of a parasite are:

(a) Parasite is host-specific in a way that both host and parasite tend to coevolve.

(b) Loss of unnecessary sense organs.

(c) The presence of adhesive organs or suckers.

(d) Loss of digestive system.

(e) High reproductive capacity.

(*ii*) The life cycles of parasites are often complex, involving one or two intermediate hosts or vectors to facilitate parasitisation of its primary host, e.g.

(a) **Human liver fluke** (a trematode parasite) depends on two intermediate hosts (a snail and a fish) to complete its life cycle.

(b) **Malarial parasite** (*Plasmodium*) needs a vector (mosquito) to spread disease to other hosts.

(*iii*) Majority of parasites harm the host. They reduce the survival, growth and reproduction ability of the host and reduce its population density. By making it physically weak, they render the host more vulnerable to predation.

(*iv*) Parasites can be of the following two types:

(a) **Ectoparasites** feed on the external surface of the host organism for food and shelter. Examples are the lice on humans, ticks on dogs, copepods, *Cuscuta*, etc.

(b) **Endoparasities** live inside the hosts body at different sites like liver, kidney, lungs, etc., for food and shelter, e.g. tapeworm, liver fluke, *Plasmodium*, etc. The life cycles of endoparasites are more complex because of their extreme specialisation.

(*v*) **Brood parasitism** is a phenomenon in which one organism (parasite) lays its eggs in the nest of another organism, e.g. eggs of cuckoo (koel) and the crow resemble in the size and colour, to reduce the chances of the crow (host) detecting the foreign eggs (cuckoo's) and ejecting them out from the nest, cuckoo lays its egg in crow's nest.

(*vi*) Female mosquito is not considered as parasite because it does not complete its life cycle in human. It only gets nutrition from human body.

Commensalism

Commensalism is the interaction between two species, where one species is benefitted and the other is neither harmed nor benefitted.

Some examples of commensalism are:

(*i*) An orchid growing as an epiphyte on a mango tree. Orchid gets shelter and support from mango tree, while the mango tree is neither benefitted nor harmed.

(*ii*) Barnacles growing on the back of whale. Barnacles are benefitted to move to different locations for food as well as shelter, while the whales are neither benefitted nor harmed.

(*iii*) Egrets always forage close to where the cattle are grazing. Because, the cattle as they move stir up the bushes and insects are flushed out from the vegetation to be catched by cattle egrets.

(*iv*) Sea anemone has stinging tentacles and the clown fish lives among them. The fish gets protection from predators, which stay away from the stinging tentacles. The anemone does not appear to derive any benefit by hosting the clown fish.

Mutualism

Mutualism is an interaction that confers benefits on both the interacting species.

Some examples of mutualism are:

(*i*) **Lichens** represent an intimate mutualistic relationship between a fungus and photosynthesising algae or cyanobacteria. Here, the fungus helps in the absorption of nutrients and provides protection, while algae prepare the food.

(*ii*) **Mycorrhizae** are close mutual association between fungi and the roots of higher plants. Fungi help the plant in absorption of nutrients, while the plant provides food for the fungus.

(*iii*) Plants and animals also show mutual relationship. Plants need help from animals for pollination and dispersal of seeds. In return, plants provide nectar, pollens and fruits to the pollinators, e.g. the female wasp uses the fig fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing its larvae. The wasp pollinates the fig's inflorescence, while searching for suitable egg-laying sites. In return, fig provides the wasp some seeds as food for the developing wasp larvae.

(*iv*) Not all orchids offer rewards, e.g. mediterranean orchid *Ophrys* employs 'sexual deceit' to get pollinated by a species of bee. One petal of its flower bears an uncanny resemblance to the female of the bee in size, colour and markings. The male bee is attracted to what it perceives as a female, pseudocopulates with the flower. During that process, pollen is dusted from the flower. When the same bee pseudocopulates with another flower, it transfers pollen to it and pollinates the flower. This case indicates the process of **coevolution.**

Ammensalism

Ammensalism is an interaction between different species, in which one species is harmed and the other is neither benefitted nor harmed, e.g. *Penicillium*, a mould secretes penicillin, which kills bacteria but the mould itself remains unaffected.