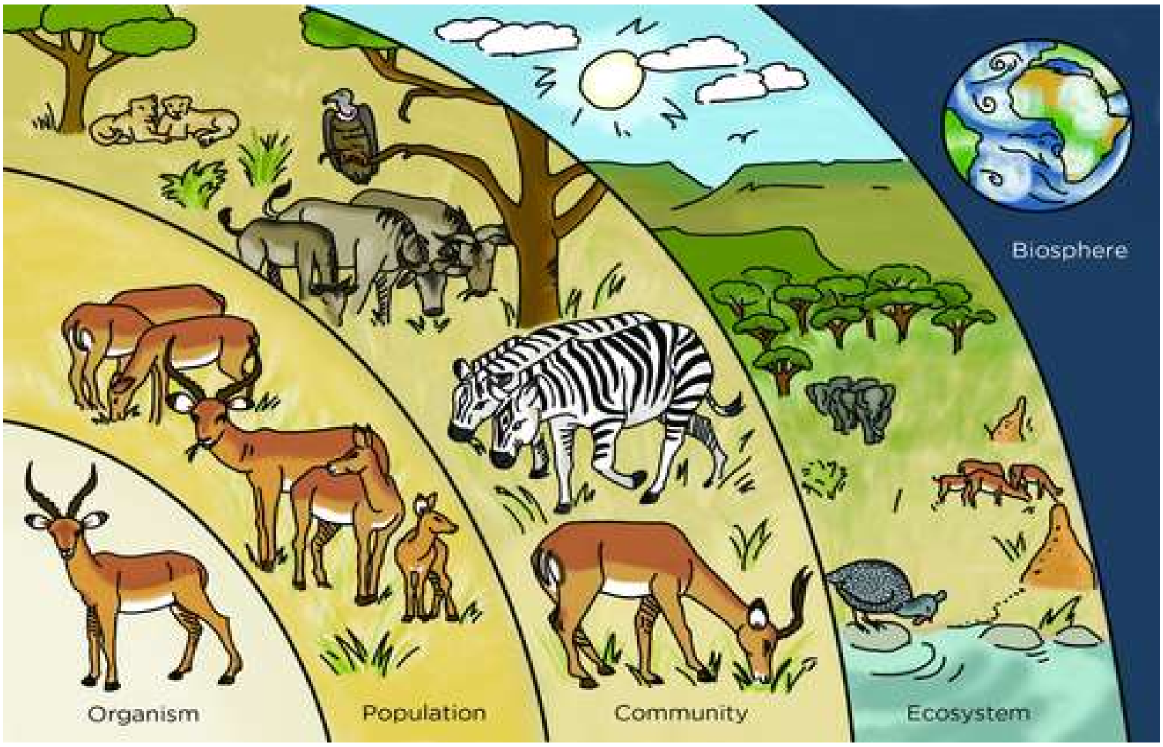
CHAPTER 13
ORGANISMS AND POPULATIONS

ECOLOGY

- Ecology is the branch of Biology which studies the interactions among organisms and between the organism and its physical (abiotic) environment.
- It consists of two branches.
  - **Autecology** and
  - **Synecology**.
- Autecology is the study of ecology at the level of species.
- Synecology is the study of ecology at the level of communities.

Organizational Levels of Ecology:

- Ecology is basically concerned with four levels of biological organization:
  - **organisms**,
  - **populations**,
  - **communities** and
  - **biomes**.
- In this chapter we explore ecology at the levels of organisms and population.



1. Organism:

- It refers to the living component of the environment at the individual level
- It forms the basic unit of study of ecology.

2. Population:

- It refers to the sum total of all organisms having similar features and potential to interbreed among themselves and produce fertile off-springs.

3. Community:

- It refers to the assemblage of all the populations of different species in a specific geographic area.

4. Biome:

- Biome is a large unit of ecology which consists of a major vegetation type and associated fauna in a climatic zone.
- Examples of biomes are:
  - Rain forest,
  - Deciduous forest,
  - Deserts,
  - Sea coast and
  - Grassland.
- There are also other biomes like:
  - Savannah (a mixed woodland-grassland ecosystem characterized by the trees being sufficiently widely spaced),
  - Tundra (a vast, flat, treeless Arctic region in which the subsoil is permanently frozen) and
  - Taiga (Taiga, generally referred to as snow forest, is a biome characterized by coniferous forests consisting mostly of pines, spruces, and larches. The taiga is the world's largest land biome).

ORGANISM AND ITS ENVIRONMENT

- An environment is termed as the sum total of all external conditions (biotic and abiotic) which influence the organisms in terms of survival and reproduction.
- Ecology at the organismic level deals with how different organisms are adapted to their environment in terms of their reproduction and survival and is basically **physiological ecology**.
- The factors like rotation of earth around the sun and tilting of earth on its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons.
- These seasonal variations together with annual variations in precipitation (both rain and snow) leads to the formation of major biomes such as desert, rain forest and tundra.
- The four major biomes of India are:
  - **Tropical Rain Forests**
  - **Deciduous Forests**
  - **Desert** and
  - **Sea Coast.**

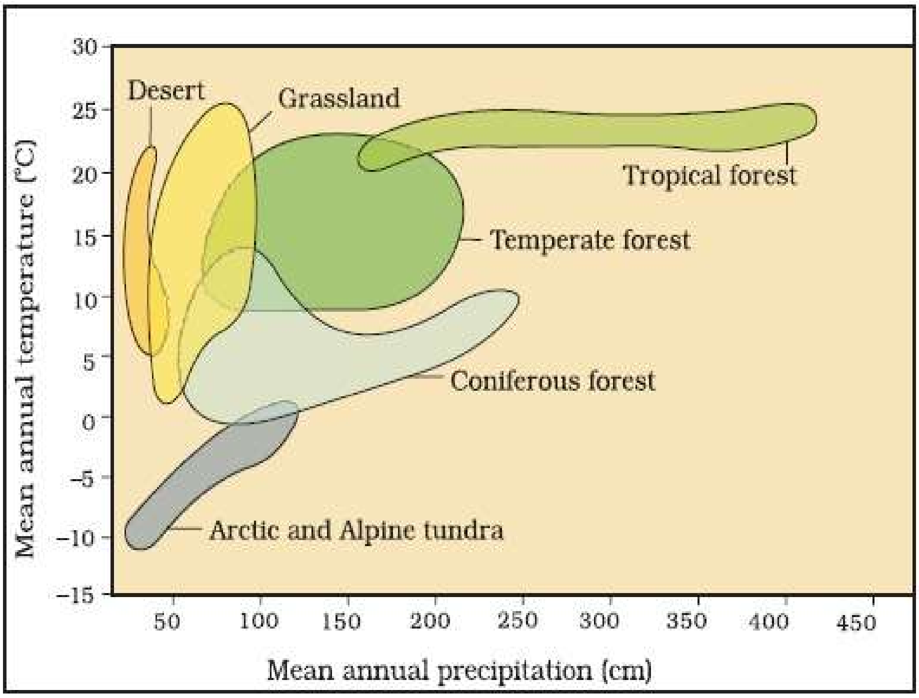
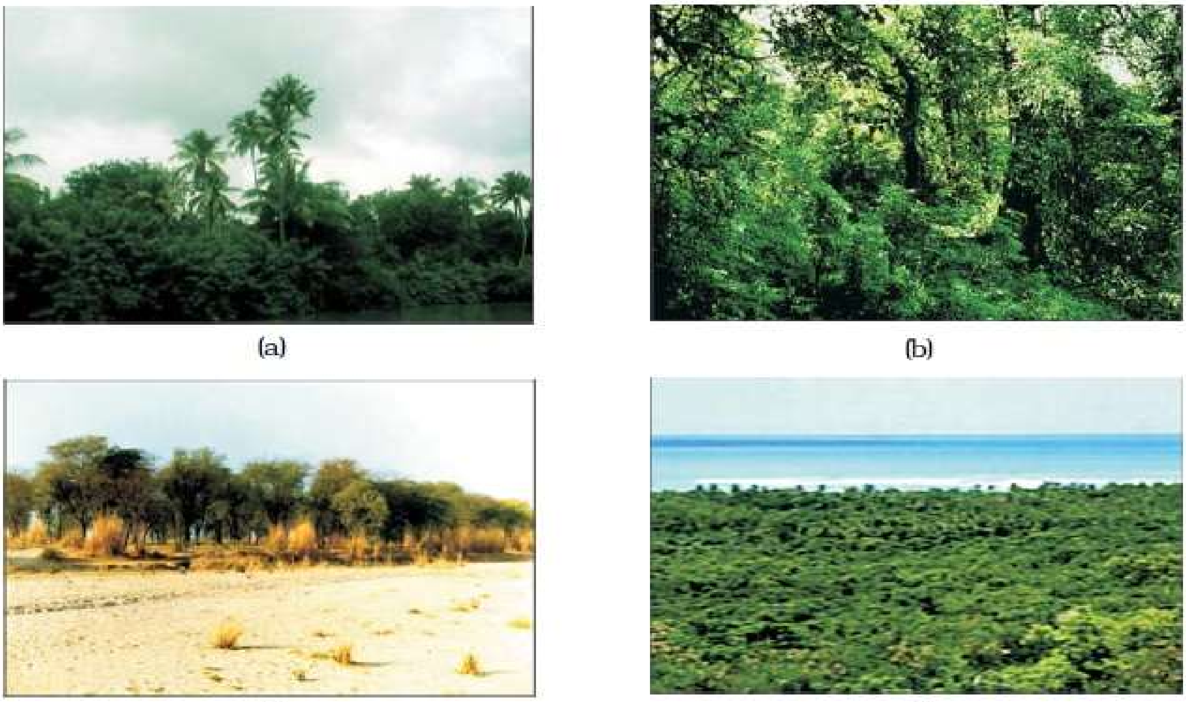


Figure 13.1 Biome distribution with respect to annual temperature and precipitation



(a) (b) (c) (d)

Figure 13.2 Major biomes of India : (a) Tropical rain forest; (b) Deciduous forest; (c) Desert; (d) Sea coast

- Regional and local variations within each biome lead to the formation of a wide variety of habitats.
- Life on earth exists not just in a few favourable habitats but even in extreme and harsh habitats such as:
  - scorching Rajasthan desert,
  - perpetualy rain-soaked Meghalaya forests,
  - deep ocean trenches,
  - torrential streams,
  - permafrost polar regions,
  - high mountain tops,
  - boiling thermal springs, and
  - stinking compost pits.
- Even our intestine is a unique habitat for hundreds of species of microbes.
- The habitat of an organism is completely characterized by two components or factors, **abiotic** and **biotic factors**.

- The major abiotic or physico-chemical factors include:
  - **Temperature**,
  - **Water**,
  - **Light** and
  - **Soil**.
- We must remember that the physico-chemical or abiotic components alone do not characterize the habitat of an organism completely; the habitat includes biotic components also:
- The major biotic components are:
  - **pathogens**,
  - **parasites**,
  - **predators** and
  - **Competitors.**
- These are the biotic components with which an organism interacts constantly.

ABIOTIC FACTORS

- A non-living thing or factor of the environment that influences the survival and reproductive functions of an organism is called an **abiotic factor**.
- Abiotic factors can determine which species of organisms will survive in a given environment.
- We shall now discuss about some important abiotic factors like
  - **Temperature,**
  - **Water,**
  - **Light** and
  - **Soil.**

Temperature:

- Temperature is the most ecologically relevant environmental factor.
- It varies seasonally on land and decreases progressively from the equator towards the poles and from plains to the mountain tops.

- It ranges from sub-zero levels in polar areas and high altitudes to >50^{0}C in tropical deserts in summer.
- There are also certain unique habitats such as thermal springs and deep-sea hydrothermal vents where the average temperatures exceed 100^{0}C.
- Physiological functions as well as geographical distribution of plants and animals are governed by the temperature conditions and their thermal tolerance.
- For example, mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forests and tuna fish are mostly found in tropical ocean waters.
- Physiological functions are affected because the change in temperature affects the enzyme kinetics or rate of enzymatic reaction which will in turn affect the metabolic activities and other physiological functions of the organisms.
- Based on the level of tolerance to temperature, organisms are grouped into two types:
  - **Eurythermal** and
  - **Stenothermal**.
- Organisms which can tolerate and thrive in a wide range of temperatures are called **eurythermal** organisms.
- Examples are most mammals and birds.
- On the other hand, organisms which can only tolerate a narrow range of temperature are called **stenothermal** organisms.
- For example, polar bear, amphibians, reptiles etc.

Water:

- It is the second most important factor influencing the life of organisms.
- Life on earth is known to have originated in water and is unsustainable without water.
- The productivity and distribution of plants is dependent on availability of water.
- The availability of water is so limited in deserts and because of that organisms need that special adaptations to live there.
- You might think that organisms living in oceans, lakes and rivers should not face any water-related problems, but it is not true.

- For aquatic organisms, pH, chemical composition and temperature of water are important.
- They are also affected by the salinity of the water.
- The salt concentration or salinity is less than 5 parts per thousand in inland waters, 30-35 parts per thousand in the sea and > 100 parts per thousand in some hypersaline lagoons.
- Based on their tolerance to salinity, organisms are classified as:
  - **Euryhaline** and
  - **Stenohaline**.
- Organisms which can tolerate a wide range of salinity are called **euryhaline** while organisms which can tolerate a narrow range of salinity are called **stenohaline.**
- Many freshwater animals cannot live for long in sea water because of the osmotic problems arising due to high salinity and vice versa.

Light:

- The significance of light lies in the fact that all autotrophs depend upon light as a source of energy for preparing their food by photosynthesis and release oxygen during the process.
- Therefore, light is an important factor for life to exist on earth.
- Small herbs and shrubs growing in forests are adapted to photosynthesis under very low light intensities because they are overshadowed by tall, canopied trees.
- Many plants are also dependent on sunlight to meet their photoperiodic requirement for flowering.
- Many animals too, depend upon diurnal (daily) and seasonal variations in light intensity and duration as cues for timing their foraging, reproductive and migratory activities.
- The availability of light on land is closely linked with that of temperature since the sun is the source for both.
- But, in deep oceans (>500m), the environment is perpetually dark.
- What, then is their source of energy?
- The energy source that sustains the deep-ocean ecosystem is not sunlight but rather the energy from chemical reaction (**chemosynthesis**).

- The spectral quality of solar radiation is also important for life.
- The UV component of light is harmful to many organisms.
- Different components of the visible spectrum are available for marine plants living at different depths of the ocean.
- This is why different types of algae, i.e., green, brown and red algae occur at different depth in the sea, that is in the upper, middle and deep layers of water respectively.

Soil:

- The nature and properties of soil in different places vary significantly.
- It is dependent mainly on the following factors:
- Climate,
- Weathering process,
- Whether soil is transported or sedimentary and
- Soil development process.
- Water holding capacity and percolation of the soil is determined by its various characteristics such as soil composition, grain size and aggregation.
- These characteristics of the soil along with other parameters such as pH, mineral composition and topography determine the type of plants that can grow in a particular habitat and the type of animals that can feed on them.
- Similarly, in the aquatic habitat, the bottom sediments and its characteristics often determine the type of benthic animals that can live there.

RESPONSES TO ABIOTIC FACTORS

- The above discussed abiotic factors like temperature, water light and soil are highly variable.
- Therefore, during the course of millions of years of existence, many species have evolved a relatively constant internal environment that permits all biochemical reactions and physiological functions to proceed with maximal efficiency and thus, enhance the overall 'fitness' of the species.
- These organisms can achieve the constancy by regulating the optimum temperature and osmotic concentration of body fluids, in accordance with varying external environmental conditions.

- This is what is known as **homeostasis.**
- In other words, Homeostasis, from the Greek words for "same" and "steady," refers to any process that living things use to maintain stable conditions necessary for survival.
- Living organisms cope with stressful conditions by any of the following four methods such as:
    - **Regulate**
    - **Conform**
    - **Migrate** or
    - **Suspend**.

(i) Regulate:

- Some organisms are able to maintain homeostasis (constant body temperature – thermoregulation and osmotic concentration - osmoregulation) by physiological and sometimes behavioural means.
- All birds and mammals, few lower vertebrates and invertebrates are **endotherms** (warm-blooded) as they have the mechanism for thermoregulation and osmoregulation for maintaining their homeostasis.
- Evolutionary biologists believe that the 'success' of mammals is largely due to their ability to maintain a constant body temperature and thrive whether they live in Antarctica or in the Sahara Desert.
- The mechanisms used by most mammals to regulate their body temperature are similar to the ones that we humans use.
- We maintain a constant body temperature of 37^0C.
- In summer, when outside temperature is more than our body temperature, we sweat profusely.
- The resulting evaporative cooling brings down the body temperature.
- During winter when the temperature is much lower than 37^0C, we start to shiver, a kind of exercise which produces heat and raises the body temperature.
- Plants, on the other hand, do not have such mechanisms to maintain their internal temperatures.

(ii) Conform:

- About 99% of animals and almost all plants cannot maintain a constant internal environment.
- Their body temperature changes with the ambient temperature, i.e., they are **ectotherms** (cold-blooded).
- In majority of aquatic animals, the osmotic concentration of their body fluids changes according to the surrounding water osmotic concentration.
- Such organisms are called **osmo-conformers**.
- Considering the benefits of a constant internal environment to the organism, we must ask why these conformers had not evolved to become regulators.
- Thermoregulation is energetically expensive for many organisms.
- This is particularly true for small animals like shrews and humming birds.
- Heat loss or heat 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 in cold environmental conditions.
- Then they have to spend lot of energy to generate body heat through metabolism.
- Due to this reason, very small animals are rarely found in polar regions.
- 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.
- Such organisms are called **partial regulators**.

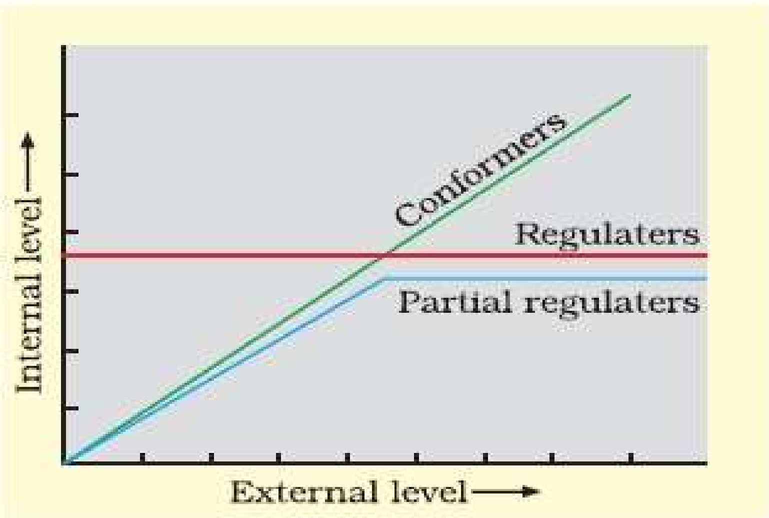


Figure 13.3 Diagrammatic representation of organismic response

(iii) Migrate:

- If an organism moves away temporarily from a stressful habitat to a more hospitable area and return when stressful period is over, the process is called **migration**.
- Many animals, particularly birds, during winter undertake long-distance migrations to more hospitable areas.
- For example, Keolado National Park in Bharatpur (Rajasthan) hosts thousands of migratory birds coming from Siberia and other extremely cold Northern regions every winter.

(iv) Suspend:

- Some bacteria, fungi and lower plants under unfavourable conditions form thick-walled spores to overcome stressful conditions.
- These spores germinate when suitable environment is available.
- In higher plants, seeds and some other vegetative reproductive structures (propagules) help to pass over periods of stress and in dispersal.
- They do so by reducing their metabolic activity and going into a state of 'dormancy'.
- Under favourable moisture and temperature conditions, they germinate to form new plants.
- Some organisms are unable to migrate.
- So, such organism especially the animals, might avoid the stress by escaping in time.
- These organisms suspend their metabolic functions during the stressful period and resume their functions at the return of favourable conditions.
- For example, bears undergo winter sleep called **hibernation** and certain animals like snails and fish undergo summer sleep known as **aestivation*.***
- Under unfavourable conditions many zooplankton species in lakes and ponds enter into a stage of suspended development called **diapause**.

ADAPTATIONS

- Any attribute of an organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat can be referred to as adaptation.
- These adaptations have led to the formation of some specialized and peculiar features.
- These features have evolved over a long period of time, through the process of natural selection.
- Thus, these adaptations become genetically fixed.

Adaptations in Plants

- Different plants show different anatomical or physiological adaptations.
- A few examples of adaptations in plants are as follows.

Adaptations in Desert (Xerophytic) Plants:

- Roots grow very deep to explore any possibility of available underground water.
- Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits (sunken stomata) to minimize water loss through transpiration.
- They also have a special photosynthetic pathway known as CAM (Crassulacean Acid Metabolism) that enables their stomata to remain closed during day time so as to minimize transpiration.
- Some desert plants like *Opuntia*, have no leaves; their leaves are reduced to spines and photosynthesis occurs in flattened stem.

Adaptations in Aquatic (Hydrophytic) Plants:

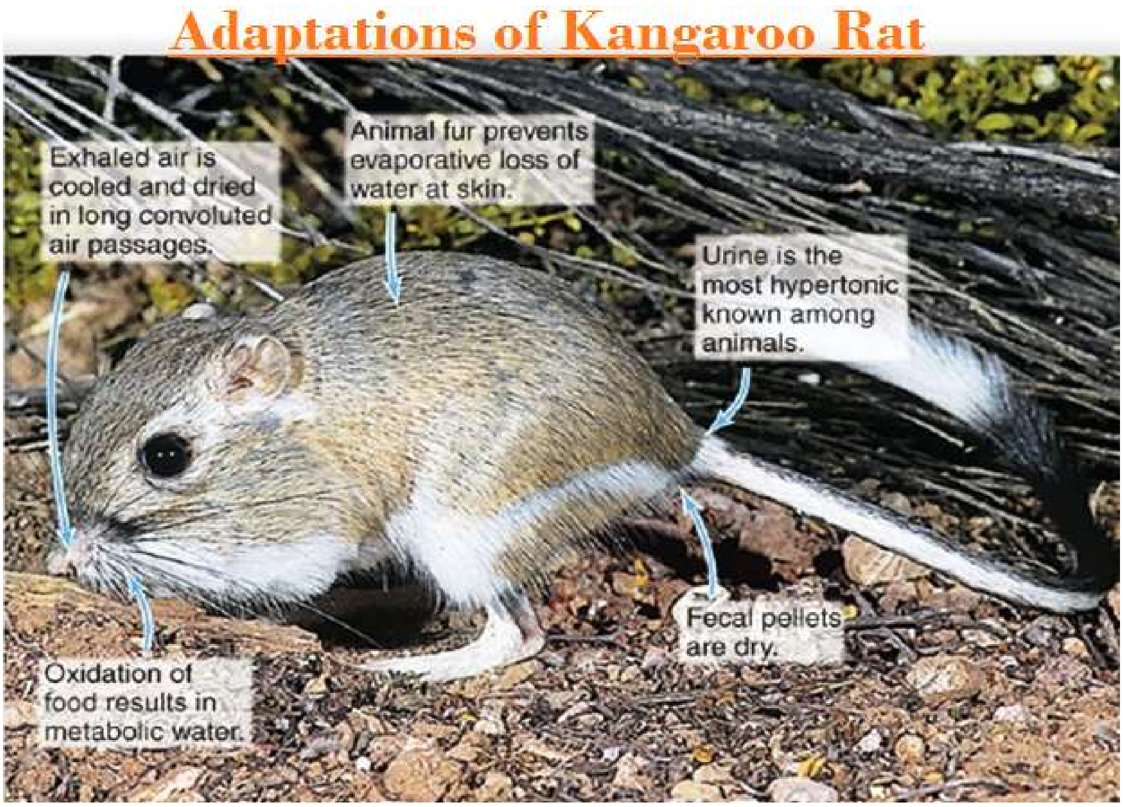
- Aquatic plants or hydrophytes have evolved special types of parenchyma tissues called aerenchyma for buoyancy and floating.
- They have covering of wax to avoid damage through water.
- Roots are generally absent in certain plants like *Hydrilla* and *Nymphaea* (Water Lily).

Adaptations in Animals

- Animals have different physiological and behavioural adaptations to environmental stresses.
- Some examples are given below.

Adaptations in Kangaroo Rat:

- In the absence of an external source of water, the kangaroo rat in North American deserts is capable of meeting all its water requirement by internal oxidation of its body fat (in which water is a by-product).
- It also has the ability to concentrate its urine so that minimal volume of water is used to remove excretory products.

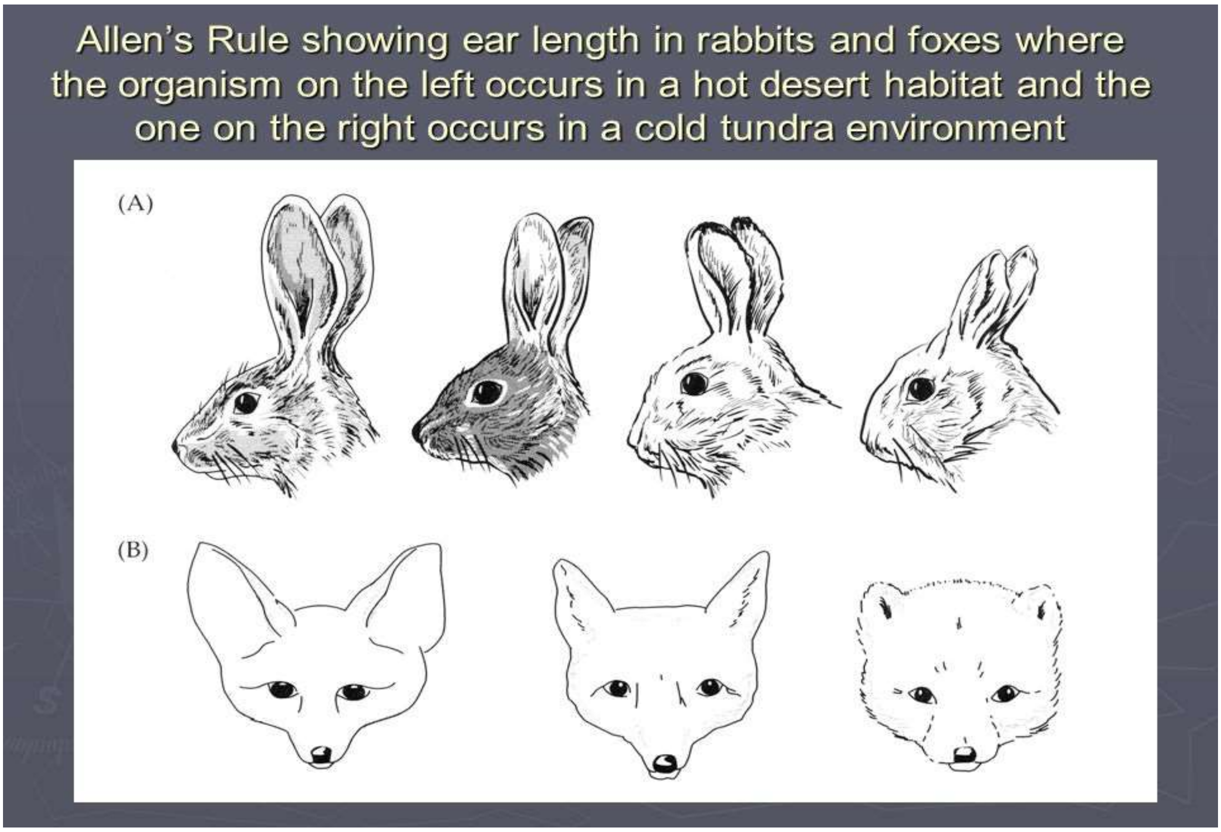


Adaptations in Desert Lizards:

- Desert lizards absorb heat from the sun when their body temperature drop below the comfort level and move into shade when the ambient temperature starts increasing.
- Some species burrow into the soil and escape from the above ground heat.
- These are behavioural resposes.

Adaptations in Mammals:

- Mammals from colder climates generally have shorter ears and limbs to minimize heat loss.
- This is called ***Allen's Rule***.
- In polar regions, aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces the loss of body heat.



Adaptations at High Altitudes in Humans:

- At high altitude places like Rohtang Pass near Manali (>3,500m) and Mansarovar, in China occupied Tibet people suffer from **altitude sickness.**
- The common symptoms of altitude sickness include nausea (an uneasiness of the stomach that often comes before vomiting), fatigue and heart palpitations (fast beating of heart).
- This is because at low atmospheric pressure of high altitudes, the body does not get enough oxygen.
- But gradually one gets acclimatized and stop experiencing altitude sickness.
- Our body copes up with this low oxygen stress by:
  - Increasing red blood cell production,
  - Decreasing the binding affinity of hemoglobin and by

- Increasing breathing rate.

- Tribal people living at high altitudes of Himalayas have higher RBC content than people living in plains.
- Certain bacteria like archaebacteria can flourish in places with temperature more than 100^0C such as, deep sea hydrothermal vents, hot springs, etc., with the help of certain enzymes they possess.
- These enzymes called thermostable enzymes, can withstand high temperature.
- Some invertebrates and fishes can tolerate temperatures below 0^0C by extra solutes like glycerol and anti-freeze proteins that lower the freezing point of body fluids.

POPULATIONS

- In nature, we rarely find isolated, single individuals of any species.
- Majority of them live in groups in a well-defined geographical area, share or compete for similar resources, potentially interbreed and thus they constitute a population.
- So, we say that, population is a set of individuals of a particular species, which are found in a particular geographical area and can interbreed.
- Although the term interbreeding implies sexual reproduction, a group of individuals resulting from even asexual reproduction is also generally considered a population for the purpose of ecological studies.
- All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond, are some examples of a population.
- Although an individual organism is the one that has to cope with a changed environment, it is at the population level that natural selection operates to evolve the desired traits.
- Therefore, **Population ecology** is an important area of ecology because it links ecology to population genetics and evolution.

Attributes of a Population:

- A population has certain attributes/features that an individual organism does not have.
- The most important attributes of a population are:

- **Birth rate** or **Natality**
- **Death rate** or **Mortality**
- **Population size** or **density** and
- **Sex ratio.**

1. Birth rate or Natality:

- It is the number of new individuals added to a population by birth per unit time.
- For example, suppose in a pond there were 20 lotus plants last year and through reproduction 8 new plants are added, taking the current population to 28.
- Then the birth rate in that population is calculated as:
- 8/20 = 0.4 offspring per lotus per year.

2. Death rate or Mortality:

- It is the number of individuals lost in a population due to death per unit time.
- For example, if in a laboratory population of 40 fruit flies, 4 individuals died during a specified time interval, say a week.
- Then the death rate in that population during that period is calculated as:
- 4/40 = 0.1 individuals per fruit fly per week.

3. Population size or density:

- It is the number of individuals of a species per unit area.
- It gives us an idea about how many individuals of a particular species is found in a given geographical area.
- Population size or density (denoted by N) of a region is obtained by dividing the number of individuals of a population in a region by the size of that area.
- The size of the population or population gives us the idea about the status of a population in that habitat.
- All ecological processes such as the outcome of competition among two species, the impact of a predator or the effect of pesticide application are investigated and evaluated in terms of any change in the population size.
- Although total number is generally the most appropriate measure of population density, it is in some cases either meaningless or difficult to determine.

- For example, if in an area there are 200 *Parthenium* plants but only a single huge banyan tree with a large canopy.
- Here, if we say that the population density of banyan is low relative to that of *Parthenium* plants, we would be underestimating the enormous role of the Banyan in that community.
- In such cases, the **per cent cover** or **biomass** is used to measure the population size.
- Total number is again not an easily adoptable measure if the population is huge and counting is impossible or very time-consuming.
- If you have a dense laboratory culture of bacteria in a petri dish what is the best measure to report its density?
- Sometimes, for certain ecological investigations, there is no need to know the absolute population densities; relative densities will serve the purpose.
- For instance, the number of fish caught per trap is good enough measure of its total population density in the lake.
- We estimate population sizes indirectly, without actually counting them or seeing them.
- The tiger census in our national parks and tiger reserves is often based on pug marks and fecal pellets.

4. Sex Ratio:

- Another attribute characteristic of a population is **Sex Ratio**.
- An individual is either a male or a female but a population has a sex ratio.
- It is the number of females and males per thousand individuals of a population in a given time.

POPULATION PYRAMID OR AGE PYRAMID

- A population pyramid or an age pyramid is a graphical representation of the distribution of various age groups in a population, which forms the shape of a pyramid when the population is growing.
- The age pyramids for human population generally show the age distribution of males and females in a combined diagram.
- The growth status of the population is reflected by the shape of the pyramids.

- There are three types of pyramids as follows:
  - **(a) Expanding,**
  - **(b) Stable** and
  - **(c) Declining.**

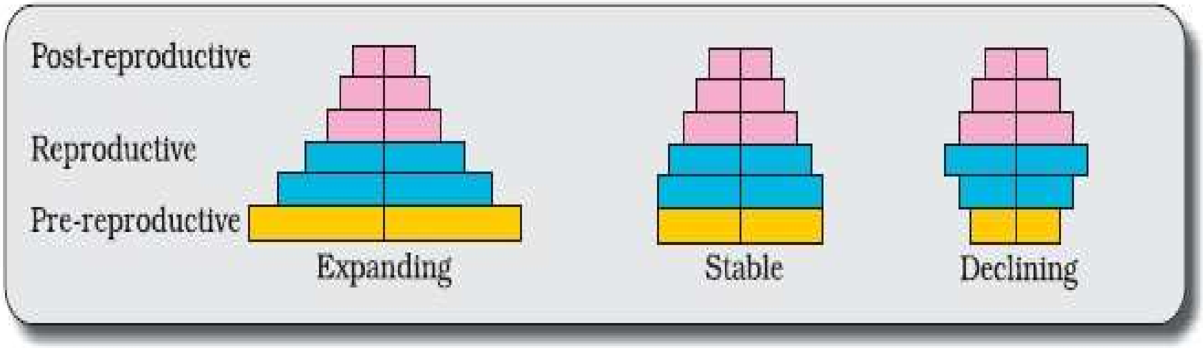
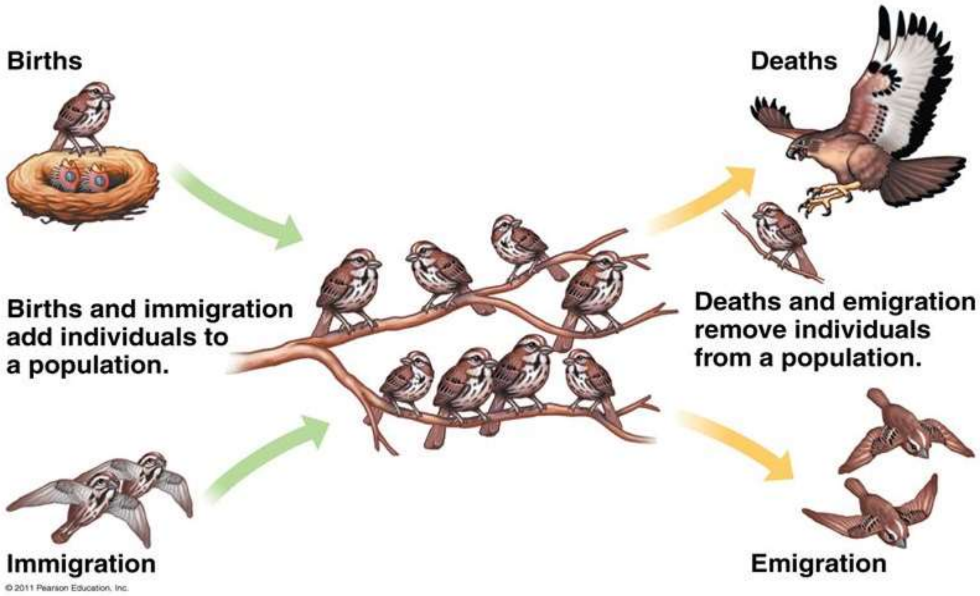


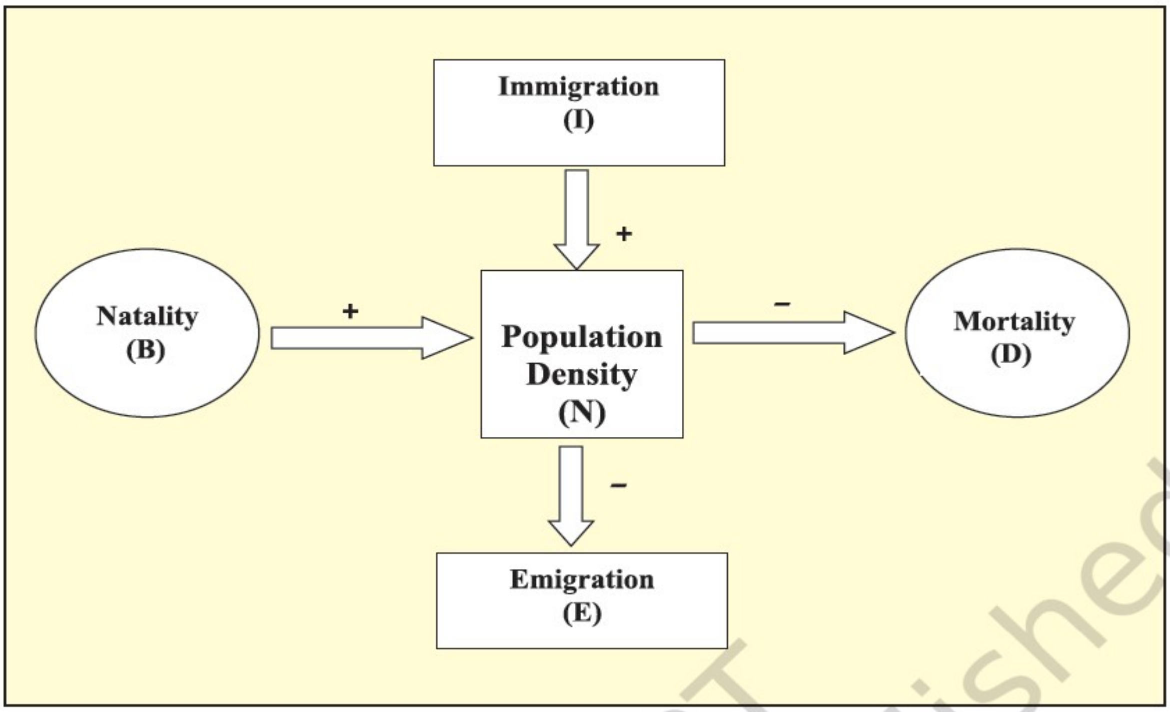
Figure 13.4 Representation of age pyramids for human population

POPULATION GROWTH

- The size of a population for any species is not a static parameter, it keeps changing with time.
- It depends on various factors such as food availability, predation pressure and adverse weather.
- The density of a population in a habitat during a given period fluctuates due to the four basic process such as:
  - **Natality,**
  - **Mortality,**
  - **Immigration** and
  - **Emigration.**
- **Natality** refers to the number of births during a given period in the population that are added to the initial density.
- **Mortality** is the number of deaths in the population during a given period.
- **Immigration** is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.
- **Emigration** is the number of individuals of the population who left the habitat and gone elsewhere during the time period under consideration.

POPULATION DENSITY IS DYNAMIC





- Out of these four, natality and immigration contribute to an increase in population density, while mortality and emigration contribute to the decrease in population density.
- So, if **N** is the population density at time **t**, then its density at time **t +1** is

$$N_{t+1} = N_t + [(B + I) - (D + E)]$$

- Where N = Population density, t = Time, B = Birth rate, I = Immigration, D = Death rate and E = Emigration.

- From the above equation we can see that 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.
- Under normal conditions, births and deaths are the most important factors influencing population density, the other two factors assuming importance only under special conditions.
- For instance, if a new habitat is just being colonized, immigration may contribute more significantly to population growth than birth rates.

Growth Models:

- We have been concerned about uncontrolled human population growth and problems created by it in our country.
- It is therefore natural for us to be curious if different animal populations in nature behave the same way or show some checks on growth.
- Perhaps we can learn a lesson or two from nature on how to control population growth.
- We actually get two patterns of population growth from nature, namely
  - **Exponential growth** and
  - **Logistic growth**.

(i) Exponential growth:

- Availability of resources like food and space is essential for the growth of a population.
- Their unlimited availability results in **exponential growth** of population as **Darwin** observed while developing his theory of natural selection.
- If in a population of size **N**, the birth rates (*per capita* births) are represented as ***b*** and death rates (*per capita* death rates) as ***d***, then the increase or decrease in population size (N) during a unit time period **t** will be:

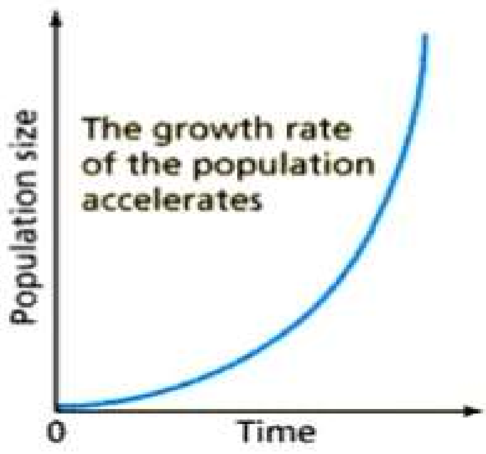
$$dN/dt = (b - d) \times N$$

- Let (b–d) = r, then

$$dN/dt = rN$$

- The '**r**' in this equation is called the 'intrinsic rate of natural increase'.

- It is a value is used by population biologists to calculate the rate of increase in populations.
- This value is also known as the **Malthusian parameter** or **Biotic potential**.
- This rate can be simply understood as the number of births minus the number of deaths per generation time, in other words, the reproduction rate less the death rate.
- It is different for different organisms.
- For example, its value is 0.015 for Norway rat and 0.02 for flour beetle.
- In 1981, the r value for human population in India was 0.0205.
- Find out what is the current value of 'r'.
- For calculating it, we need to know the birth rates and death rates.
- Current Intrinsic rate of natural increase of human population in India is 14.9 % which is equal to 14.9/1000 =0.0149
- The above equation **dN/dt = rN** results in a **J-shaped curve** when we plot population density (N) in relation to time (t).



J-shaped curve

- The integral form of the exponential growth equation is:

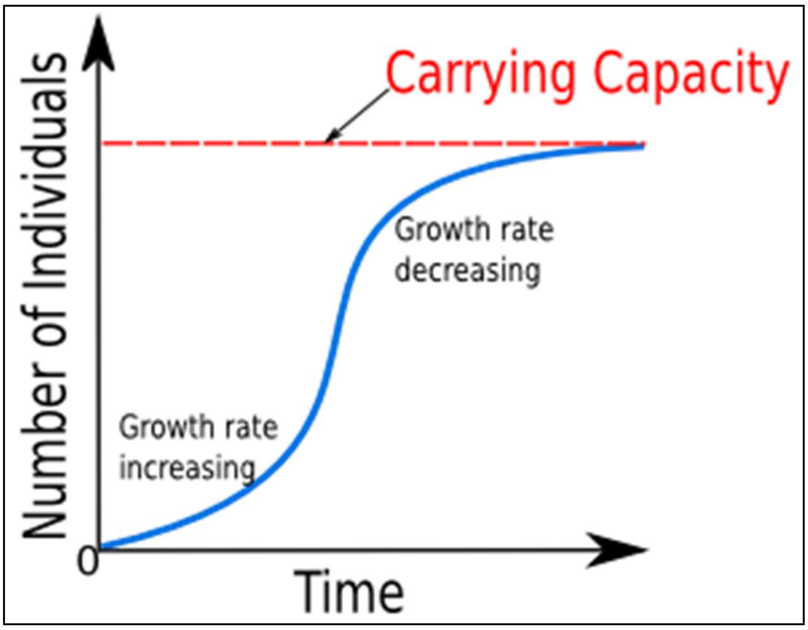
$$N_t = N_0 e^{rt}$$

- Where, N_t = Population density after time t
- N_0 = Population density at time zero
- r = intrinsic rate of natural increase
- e = the base of natural logarithms (2.71828)

- Any species growing exponentially under unlimited resource conditions can reach enormous population densities in a short time.
- Darwin showed how even a slow growing animal like elephant could reach enormous numbers in the absence of checks.

(ii) Logistic growth:

- Practically no population of any species in nature has unlimited resources at its disposal to permit exponential growth.
- This leads to competition between individuals for limited resources and finally the 'fittest' individual will survive and reproduce.
- Therefore, a given habitat has enough resources to support a maximum possible number of organisms, beyond which no further growth is possible.
- This is called the **carrying capacity** (**k**) for that species in that habitat.
- In other words, carrying capacity is the number of organisms of one species that an environment or habitat can support.



Sigmoid Curve

- When population density (N) is plotted in relation to time (t), a sigmoid curve is obtained.
- This type of population growth is called **Logistic Growth** and the equation describing logistic growth is called **Verhulst-Pearl logistic equation**:

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

- Where N = Population density at time t
- r = Intrinsic rate of natural increase
- K = Carrying capacity
- A population growing in a habitat with limited resources show initially a **lag phase**, followed by **phases of acceleration**, **deceleration** and finally an **asymptote** (an asymptote is a line or curve that approaches a given curve), when the population density reaches the carrying capacity (K).
- This model is more realistic in nature because no habitat can sustain exponential growth indefinitely as there will be competition for resources which are limited.

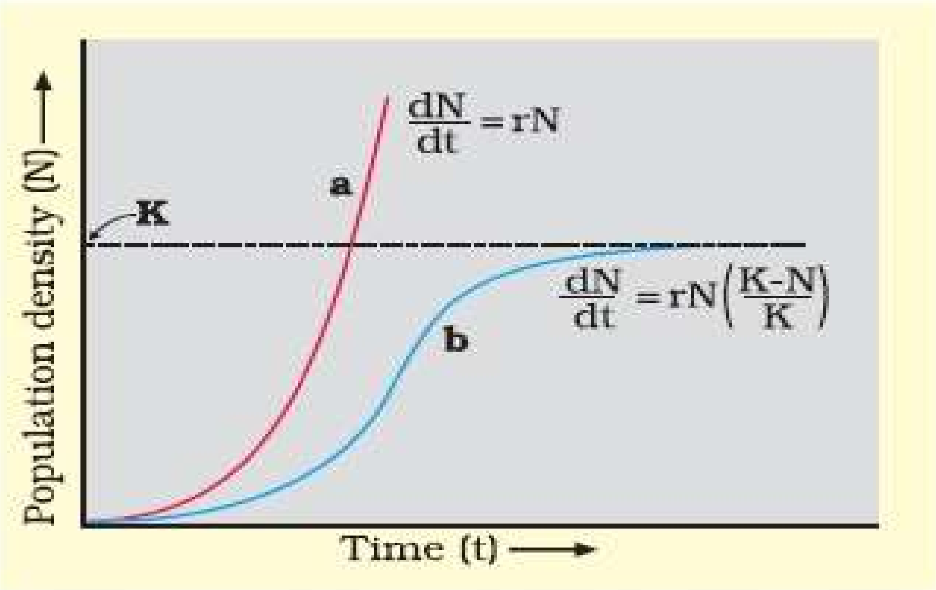


Figure 13.5 Population growth curve **a** when responses are not limiting the growth, plot is exponential, **b** when responses are limiting the growth, plot is logistic, **K** is carrying capacity

Problem:

- If a population has a carrying capacity of 900 and the intrinsic rate of increase is , what is the population growth when population is 435? What if the population is 850?
- Logistic growth of population can be calculated by using the formula dN/dt = rN(K-N)/K
- When the population is 435
- Logistic population growth is: 1x 435(900-435)900 = 225

- When the population is 850
- Logistic population growth is: 1x 850(900-850)900 = 47

Life History Variations:

- Populations evolve to maximize their reproductive fitness, also called Darwinian fitness (high r value), in the habitat in which they live.
- Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy.
- Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times during their lifetime (most birds and mammals).
- Some organisms produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals).
- So, which type of reproduction is desirable for maximizing fitness?
- According to Ecologists, life history traits of organisms have evolved in relation to the constraints or checks imposed by the abiotic and biotic components of the habitat in which they live.

POPULATION INTERACTIONS

- In nature, living organisms such as animals, plants and microbes cannot live in isolation.
- There is no such habitat on earth that is inhabited just by a single species.
- For any species, the minimal requirement is one more species on which it can feed.
- Even a plant species, which makes its own food, cannot survive alone; it needs soil microbes to break down the organic matter in soil and return the inorganic nutrients for absorption.
- And then, how will the plant manage pollination without an animal agent?
- So, in nature we see organisms interacting in various ways to form a biological community.
- Inter-specific interactions occur between the populations of two different species living together within a community.

- These interactions could be **beneficial** (+), **detrimental** (-) or **neutral** (0) as shown in the table below.

Name of Interaction	Species A	Species B
1. Mutualism	+	+
2. Predation	+	-
3. Parasitism	+	-
4. Commensalism	+	0
5. Competition	-	-
6. Amensalism	-	0

- Both the species benefit in **mutualism** and both lose in **competition** in their interactions with each other.
- In both **parasitism** and **predation** only one species benefit (parasite and predator, respectively) and the interaction is detrimental to the other species (host and prey, respectively).
- The interaction where one species is benefitted and the other is neither benefitted nor harmed is called **commensalism**.
- In **amensalism** on the other hand one species is harmed whereas the other is unaffected.
- Predation, parasitism and commensalism share a common characteristic– the interacting species live closely together.

(i) Predation:

- It is an interspecific interaction, where an animal called **predator** kills and consumes the other weaker animal called the **prey**.
- It is the nature's way of transferring energy to higher trophic levels, which is fixed by plants at the first trophic level.
- When we think of predator and prey, most probably it is the tiger and the deer that readily come to our mind, but a sparrow eating any seed is also a predator.
- Although animals eating plants are categorized separately as herbivores, they are, in a broad ecological context, not very different from predators.
- The important roles of predators are as follows:

(i) Predators keep prey populations under control

- In the absence of predators, prey species could achieve very high population densities and cause ecosystem instability.
- So, besides acting as 'conduits' (channels) for energy transfer across trophic levels, predators play very important role in providing ecosystem stability.
- For example, when certain exotic species are introduced into a geographical area, they become invasive and start spreading fast because the invaded land does not have its natural predators.
- **The prickly pear cactus** introduced into Australia in the early 1920's caused havoc by spreading rapidly into millions of hectares of rangeland (grazing land).
- Finally, the invasive cactus was brought under control by introducing its predator, a cactus-feeding moth (*Cactoblastis cactorum*), from its natural habitat (South America).
- This is an example of **Biological Pest Control**.

Prickly Pear Cactus

Cactus feeding Moth

(ii) Predators help in maintaining species diversity in a community

- They do this by reducing the intensity of competition among the competing prey species.
- For example, a starfish called ***Pisaster*** is an important predator found in the rocky intertidal communities of the American Pacific Coast.
- In a field experiment conducted by **Robert Paine** in 1966, he removed all the starfish from the intertidal area.
- It was found that more than 10 species of invertebrates became extinct within a year, because of an increase in inter-specific competition.

Robert Paine (1966)

- If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct because of lack of food.
- This is the reason why predators in nature are 'prudent'.
- Prey species have evolved various defense mechanisms to lessen the impact of predation.
- These are as follows:
- 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 predators.
- The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body.
- The butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous weed.
- For plants, herbivores are the predators.
- Nearly 25% of all insects are known to be ***phytophagous*** (feeding on plant sap and other parts of plants).
- The problem is particularly severe for plants because, unlike animals, they cannot run away from their predators.
- Plants therefore have evolved an astonishing variety of morphological and chemical defense mechanisms against herbivores.
- Thorns (*Acacia*, *Cactus*) are the most common morphological means of defense.
- Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.
- Weeds like *Calotropis* produces highly poisonous cardiac glycosides (organic compounds that increase the output force of the heart and increase its rate of contractions) and that is why you never see any cattle or goats browsing on this plant.
- A wide variety of chemical substances that we extract from plants on a commercial scale such as nicotine, caffeine, quinine, opium, etc., are actually produced by them as defenses against grazers and browsers.

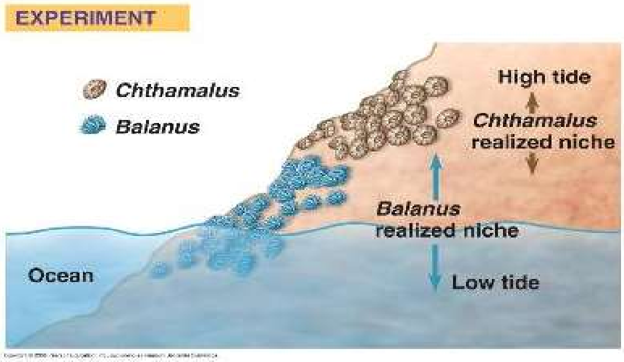
Calotropis

(ii) Competition:

- It is generally believed to occur when closely related species compete for the same resources that are limiting
- However, this is not always true.
- Some totally unrelated species could also compete for the same resource.
- For example, in some shallow South American lakes, visiting flamingoes and resident fishes compete for their common food, the zooplankton in the lake.
- Secondly, resources need not be limiting for competition to occur.
- In **interference competition**, the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources are plenty.
- For example, when goats were introduced in Galapagos Islands, the Abingdon tortoise became extinct within a decade due to the greater browsing efficiency of the goats.
- Therefore, competition can be best defined as a process in which the fitness of one species (measured in terms of its 'r' the intrinsic rate of increase) **is significantly lower in the presence of another species**.
- '**Competitive release**' provides another evidence for competition in nature.
- It is a phenomenon in which a species whose distribution is restricted to a small geographical area because of the presence of a competitively superior species is found to expand its distributional range dramatically when the superior competing species is experimentally removed.
- **Connell**'s 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.

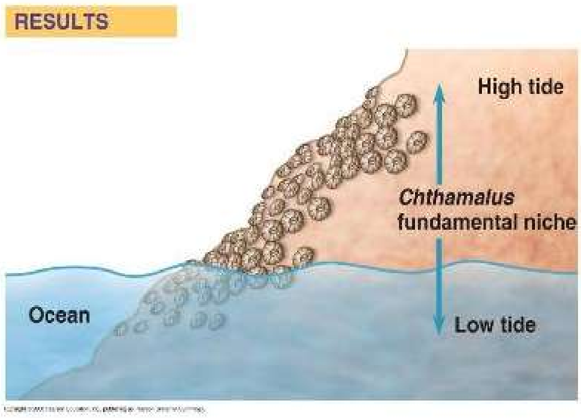
Experiment: Interspecific Competition

- In Scotland, Joseph Connell studied interspecific competition in these two barnacles.
- In places where both barnacles were present, he removed the *Balanus* barnacles from the rocks.

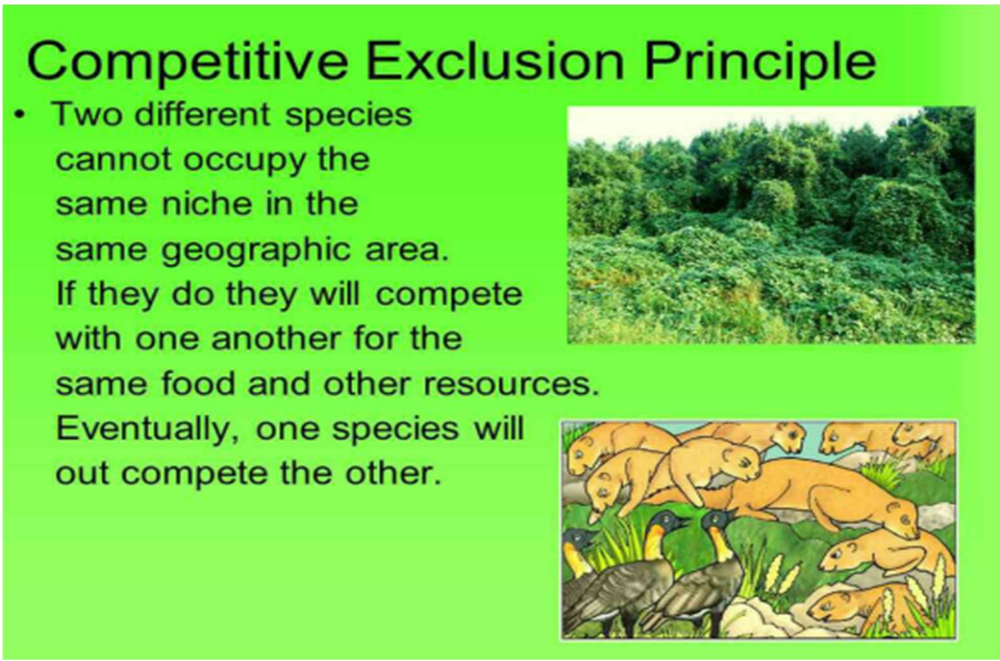


Experiment: Interspecific Competition

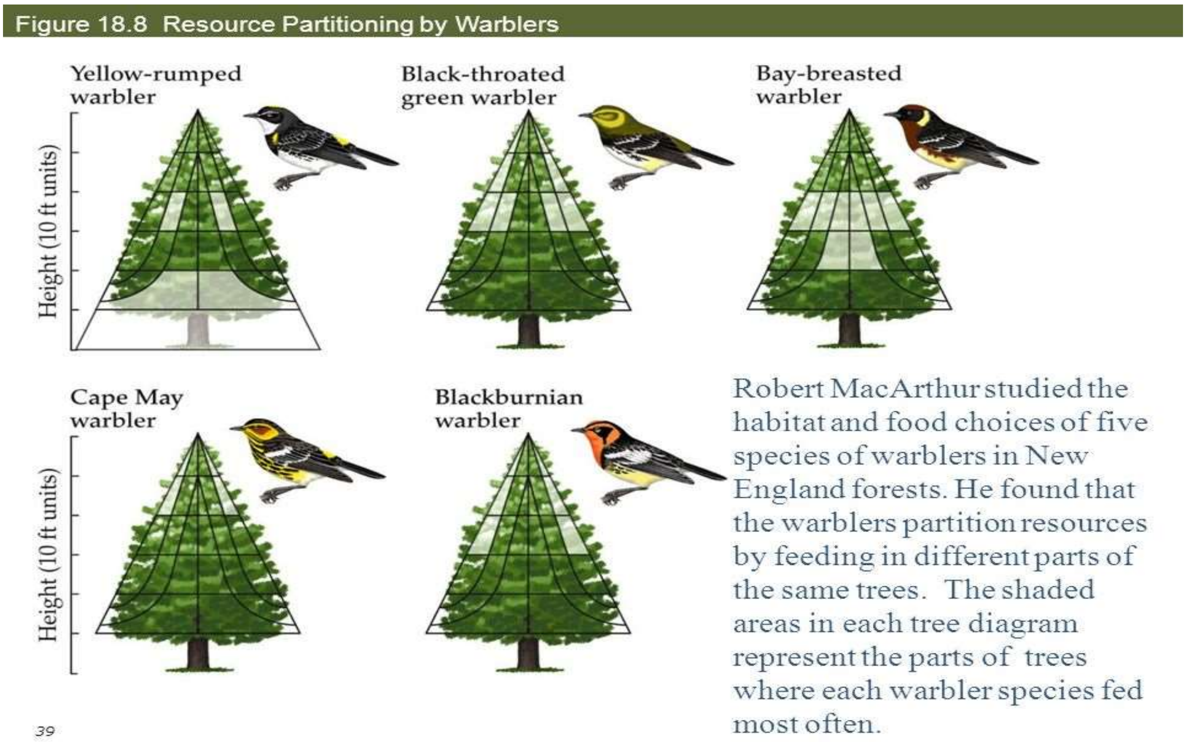
- When *Balanus* barnacles were removed, the *Chthamalus* barnacles moved down into the vacant area.
- This showed that *Balanus* was outcompeting *Chthamalus* in the lower zone.



- **Gause's competitive exclusion principle** states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior species will be eliminated eventually by the competitively superior species.
- For example, when goats were introduced in Galapagos Islands, the Abingdon tortoise became extinct within a decade due to the greater browsing efficiency of the goats.
- This may hold true in case of limited resources but not in other cases.



- More recent ecological studies do not support such gross generalizations about competition.
- They point out the fact that species facing competition might evolve mechanisms that promote co-existence rather than exclusion.
- One such mechanism is '**resource partitioning**'.
- If two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging patterns.
- **MacArthur** showed that five closely related species of **warblers** living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.



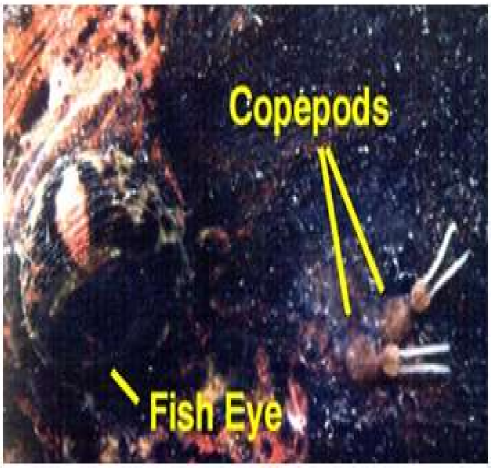
(iii) Parasitism:

- It is a mode of interaction between two species in which one species (parasites) depends on the other species (host) for food and shelter and damages the host.
- In this process, one organism is benefited and the other is being harmed.
- Many parasites are host-specific and both host and the parasite tend to co-evolve; that is, if the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to counteract and neutralize them, in order to be successful with the same host species.
- In accordance with their life styles, parasites evolved special adaptations such as:
  - loss of unnecessary sense organs,
  - presence of adhesive organs or suckers to cling on to the host,
  - loss of digestive system and
  - high reproductive capacity.
- The life cycles of parasites are often complex, involving one or two intermediate hosts or vectors to facilitate parasitisation of its primary host.
- For example, the human liver fluke (a nematode parasite) depends on two intermediate hosts (a snail and a fish) to complete its life cycle.
- The malarial parasite (*Plasmodium*) needs a vector (mosquito) to spread to other hosts.
- Majority of the parasites harm the host.
- They harm the host in the following ways:
  - They reduce the survival, growth and reproductive ability of the host.
  - They reduce its population density.
  - They may make the host more vulnerable to predation by making it physically weak.

Types of Parasites:

- Parasites are broadly divided into following two types:
  - **Ectoparasites** and
  - **Endoparasites**.

- Parasites that depend on the external surface of the host organism for food and shelter are called **ectoparasites**.
- Examples of external parasites include lice on human, ticks on dog, copepods on marine fishes and *Cuscuta*, a parasitic plant that grows on hedge plant.



- The female mosquito is not considered a parasite, although it needs our blood for reproduction.
- Can you explain why?
- An organism which is dependent on their host for nutrition is considered a Parasite.
- The mosquito could not be called parasite because it needs blood for reproduction not for nutrition.
- As we know male mosquito can survive on plant nectar, the female needs high amount of protein for egg laying so it craves for blood.
- **Endoparasites** are those parasites that live inside the host's body at different sites like liver, kidney, lungs, red blood cells, etc., for food and shelter.
- Examples of endoparasites include tapeworm, liver fluke, *Plasmodium* etc.
- The life cycles of endoparasites are more complex because of their extreme specialization.
- Their morphological and anatomical features are greatly simplified while their reproductive potential is very high.
- **Brood parasitism** in birds is an example of parasitism in which the parasitic bird lays its eggs in the nest of its host and lets the host incubate them.

- During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest.
- Example is that of cuckoo (koel, parasite) and crow (host).

Cuckoo's eggs in crow's nest

(iv) Commensalism:

- This is the type of interaction in which one species benefits and the other is neither harmed nor benefited.
- Some examples of commensalism are:
  - An orchid growing as an epiphyte on a mango tree gets shelter and nutrition from mango tree, while the mango tree is neither benefited nor harmed.
  - Barnacles growing on the back of a whale are benefited by getting moved to different locations for food as well as shelter, while the whale is neither benefited nor harmed.
  - The cattle egret and grazing cattle is a classic example of commensalism. The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and flush out insects from the vegetation that otherwise might be difficult for the egrets to find and catch.
  - Another example of commensalism is the interaction between sea anemone and the clown fish. Sea anemone has stinging tentacles and the clown fish live 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.

(v) Mutualism:

- It is a biological interaction between two species wherein both the species benefit from each other.
- Some examples of mutualism are:
    - **Lichens** represent an intimate mutualistic relationship between a fungus and photosynthesizing algae or cyanobacteria. Fungus helps in the absorption of nutrients and provides protection, while algae prepares the food.
    - **Mycorrhizae** show close mutual association between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant in turn provides the fungi with energy-yielding carbohydrates.
- The most spectacular and evolutionarily fascinating examples of mutualism are found in plant-animal relationships.
- Plants need the help of animals for pollinating their flowers and dispersing their seeds.
- Animals are paid 'fees' for the services that plants receive from them.
- Plants offer rewards or fees in the form of pollen and nectar for pollinators and juicy and nutritious fruits for seed dispersers.
- But the mutually beneficial system should also be safeguarded against 'cheaters', for example, animals that try to steal nectar without aiding in pollination.
- So, in order to safeguard this mutually beneficial system, plant-animal interactions often involve **co-evolution** of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another.
- For example, in many species of fig trees, there is a tight one-to-one relationship with the pollinator species of wasp.
- It means that a given fig species can be pollinated only by its 'partner' wasp species and no other species.
- The female wasp uses the 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 inflorescence while searching for suitable egg-laying sites.

- In return for the favour of pollination, the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

(a) (b)

Figure 13.6 Mutual relationship between fig tree and wasp: (a) Fig flower is pollinated by wasp; (b) Wasp laying eggs in a fig fruit

- Orchids show a bewildering diversity of floral patterns many of which have evolved to attract the right pollinator insect (bees and bumblebees) and ensure guaranteed pollination by it.
- Not all orchids offer rewards.
- The 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, 'pseudo-copulates' with the flower.,
- During this process the male bee is dusted with pollen from the flower.
- When this same bee 'pseudo-copulates' with another flower, it transfers pollen to it and thus, pollinates the flower.

- Here you can see how co-evolution operates.
- If the female bee's colour patterns change even slightly for any reason during evolution, pollination success will be reduced.
- In order to overcome this, the orchid flower co-evolves with the pollinator bees to maintain the resemblance of its petal to the female bee.

(vi) Amensalism:

- It is an interaction between different species, in which one species is harmed and the other species is neither benefited of nor harmed.
- The classic example of amensalism is that of the bread mould *penicillium*.
- *Penicillium* mould secretes a chemical called penicillin which kills bacteria, but the mould remains unaffected.
- Another example is that of black walnut (*Juglans nigra*), which secretes juglone, a substance that destroys many competing herbaceous plants within its root zone.

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