ORGANISMS AND POPULATIONS

Introduction:

- **Ecology** is the branch of science that deals with the study of the interactions among organisms and between the organism and its physical (abiotic) environment. It consists of two branches, autecology and synecology.
- In ecology, there are four levels of biological organizations - organisms, populations, communities and biomes.

Ecology and our world:

Ecology: The study of interactions between living things and their environment

Levels in ecology:

1. Organism	A single member of a species
2. Population	A group of individuals of a single species that live in the same area at the same time.
3. Community	A group of interacting populations.

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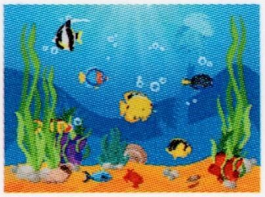
4. Ecosystem A biological community and all of the abiotic factors that affect it.

5. Biome A large area that is characterized by certain soil, elimates, plants, or animals.



6. Biosphere The portion of Earth that supports life.

Organism and its Environment:

- At organismic level, **physiological ecology** deals with the study of adaptation of organisms to their environment (biotic and abiotic components that surround and influences the organisms) in terms of survival and reproduction.
- Desert, rain forest and tundra are the major **biomes** which are formed by seasonal and annual variation in precipitation and temperature. Within each biome, a wide variety of habitats are formed by regional and local variations.

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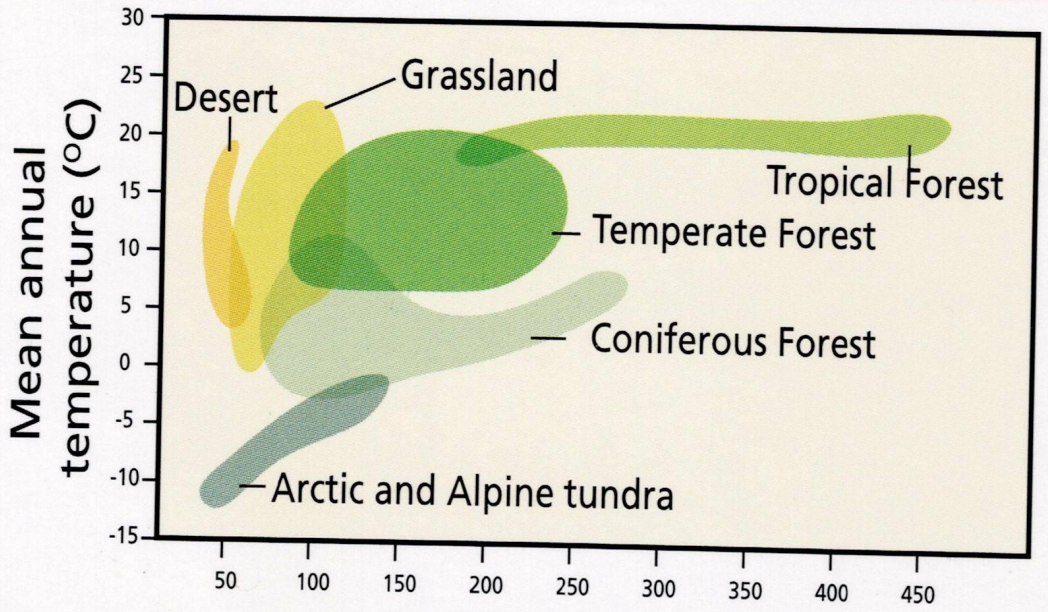

Biome distribution with respect to annual temperature and precipitation

Major Abiotic Factors of the Ecosystem:

Temperature:

- It is the ecologically most relevant environmental factor which decreases progressively from the equator towards the poles and from plains to the mountain tops.
- Temperature affects the kinetics of enzymes, basal metabolism and, latitudinal and altitudinal distribution of organisms.

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- Organisms which can tolerate and thrive in a wide and narrow range of temperatures are called **eurythermal** (most mammals and birds) and **stenothermal** (fish, reptile), respectively.

Water:

- The productivity and distribution of organisms is highly dependent on water. For aquatic organisms, the temperature, chemical composition and pH of water are very important.
- Organisms which can tolerate a wide and narrow range of salinity are called **euryhaline** (green crab) and **stenohaline** (shark), respectively.

Light:

- Plants require sunlight to produce food by photosynthesis and also to fulfill their photoperiodic requirement for flowering.
- Animals use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, reproductive and migratory activities.
- Not all the colour components of the visible spectrum reach at different depths of ocean. Thus, different algae like green, brown and red are found at different

depths such as in the upper, middle and deep layers of water, respectively.

Soil:

- The nature and properties of soil depends on the climate, weathering process, whether soil is transported or sedimentary and soil development process.
- Soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils, which along with parameters such as pH, mineral composition and topography determine the vegetation in any area.

Responses of Organisms Towards Abiotic Factors:

- Despite having highly variable external environment, organisms can achieve constancy of their internal environment. This process is called as **homeostasis**. The living organisms cope up differently with the abiotic factors by adopting following ways:

Regulate:

- Organisms maintain homeostasis by ensuring constant body temperature (**thermoregulation**), and constant osmotic concentration (**osmoregulation**). These are called as **endotherms**.

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- Thermoregulation is energetically expensive process. Therefore, small animals like shrews and humming birds rarely found in polar areas.
- These small animals have large surface area compared to their volume; therefore, they lose body heat fastly in colder environment and have to expend high energy to generate body heat.
- **Partial regulators** are those species which have evolved the ability to regulate only over a limited range, beyond which they simply conform.
- **Example:** Human beings regulate constant body temperature of 37°C by shivering in cold and sweating in heat.

Conform:

- Conformers cannot maintain a constant internal environment and their body temperature and osmotic concentration (especially in aquatic animals) changes with the surrounding temperature. These are called as **ectotherms**.
- **Example:** about 99 per cent of animals and nearly all plants.

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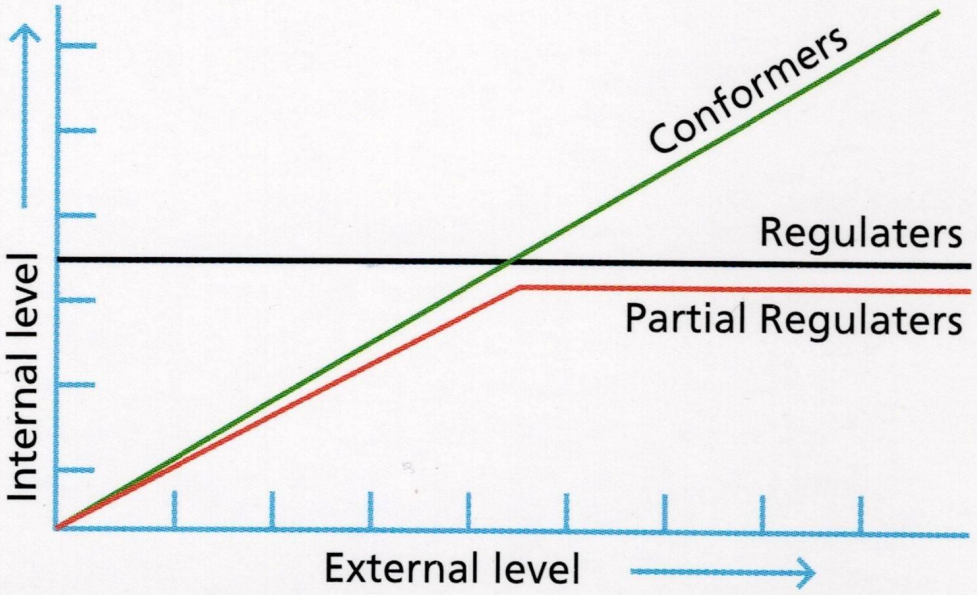

Diagrammatic representation of organismic response

Migrate:

- Organisms temporarily move from stressful habitat to hospitable area and return when stressful period is over.
- **Example:** Migration of birds during winters to Keoladeo National Park (Bharatpur), Rajasthan from Siberia.

Suspend:

- Organisms temporarily suspend their metabolic functions during unfavourable conditions and resume their normal functions during favourable conditions.
- **Examples:** Germination of thick-walled **spores** in bacteria and fungi, **dormancy** into seeds (angiosperms),

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Hibernation or winter sleep in bears, **Aestivation** or summer sleep in certain snails and fish, **Diapause** (stage of suspended development) in zooplankton.

Adaptations:

➔ Adaptation is morphological, physiological and behavioral attribute of the organism that enables the organism to survive and reproduce in its habitat.

Adaptations in desert plants:

➔ To minimize the water loss, these plants have thick cuticle, sunken stomata (arranged in deep pits), special photosynthetic pathway (Crassulacean Acid Metabolism), leaves reduced to spines (in *Opuntia*), roots grow deeply.

Opuntia

Adaptations in kangaroo rat of north american deserts:

➔ To reduce water loss through the body, they produce concentrated urine and also able to meet their water requirements through internal fat oxidation, which leads to the production of water as a byproduct.

Adaptations in mammals of cold climate:

➔ Generally have short ears and limbs to minimize heat loss. This is called as **Allen's Rule**. Aquatic mammals (seals) have a thick layer of fat/blubber (acts as an insulator) below their skin.

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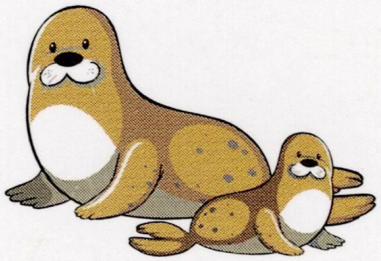
Adaptations in desert lizards (behavioural response):

➔ They bask in the sun when their optimum body temperature drops due to colder environment and move to shade during rise in the surrounding temperature. Some species burrow into the soil to hide and escape from the above ground heat.



Seal

Adaptations in humans at high altitudes (physiological response):

➔ At higher altitudes, people generally feel **altitude sickness**. Its symptoms are nausea, fatigue, heart palpitations due to low atmospheric pressure and oxygen. The people gradually get acclimatized by increasing RBCs production and breathing rate and decreasing the binding capacity of hemoglobin.

Population and its Attributes:

➔ **Population** can be defined as the group of individuals that live in a well-defined geographical area which share or compete for similar resources and potentially

interbreed. There are various attributes of population, which include:

Birth rate or natality:

- It is total number of birth of new individuals per unit of population per unit time.
- **Example:** If in a pond, there are 20 lotus plants last year and through reproduction 8 new plants are added. The current population = 28. Then, the birth rate = $\frac{8}{20} = 0.4$ offspring per lotus per year.

Death rate or mortality:

- It is total number of deaths of individuals per unit of population per unit time.
- **Example:** If in a laboratory population of 40 fruit flies, 4 individuals died during a week. Thus, death rate = $\frac{4}{40} = 0.1$ individuals per fruit fly per week.

Sex ratio:

- It is the total number of females and males per 1000 individuals of a population in a given time.

Age pyramid:

- It is the structure obtained when the age distribution, i.e., % individuals (males and females) of a given age or age group is plotted for the population.

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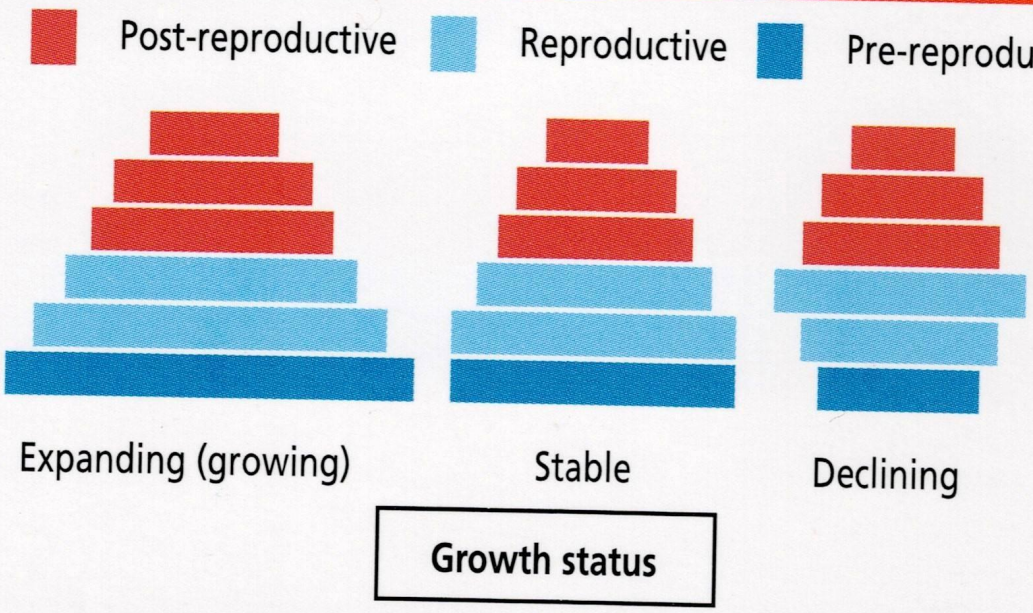

Representation of age pyramids for human populations

Population size or population density (N):

- It is the number of individuals of a species per unit area or volume.
- It can be measured by counting the number, per cent cover **or biomass**, relative population density, pug marks and fecal pellets for tiger census.

Population Growth:

- The population density in a given habitat during a given period depends on the changes in four basic processes such as, Natality, Immigration (both increases population), Mortality, Emigration (both decreases population).

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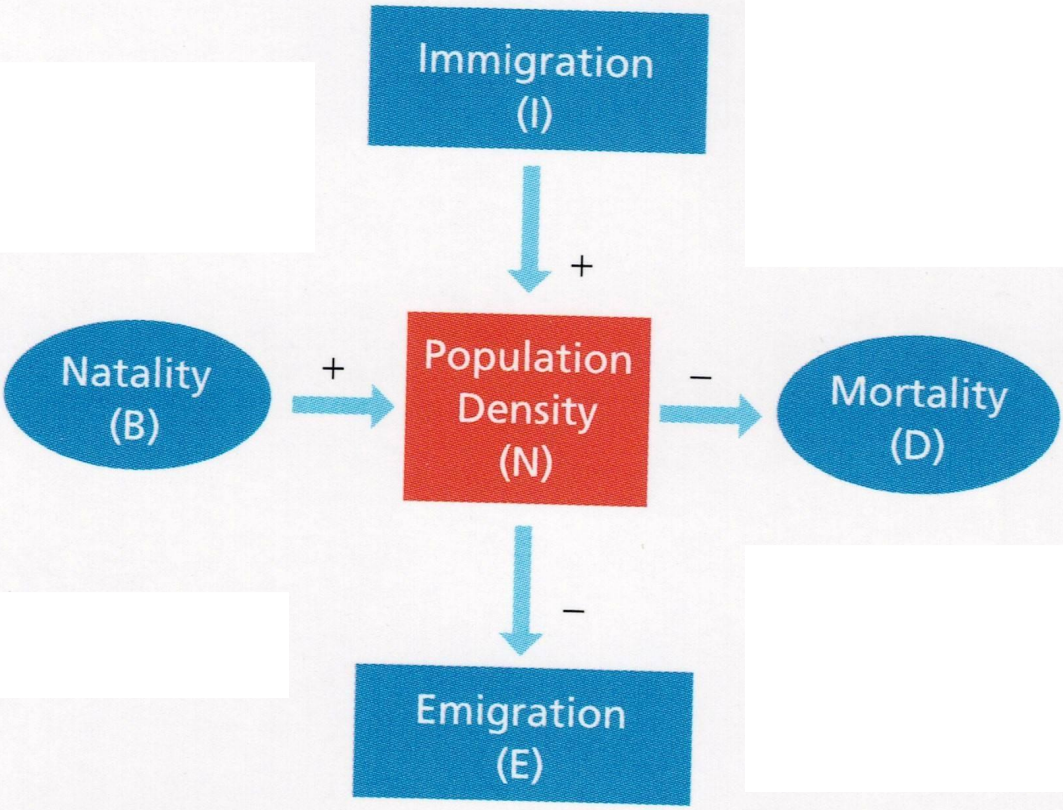
- Therefore, if N is the population density at a given time *t*, then its density at time $t + 1$ is, $\mathbf{N_{t+1} = N_t + [(B + I) - (D + E)]}$



- Immigration is the number of individuals of the same species that have entered into the habitat from outside during the time period under consideration.
- Emigration is the number of individuals of the particular population who left the habitat and moved elsewhere during the time period under consideration.

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Growth Models:

Exponential growth:

- This kind of growth occurs when food and space is available in unlimited amount.
- If in a population of size N, the birth rates is represented as '*b*' and death rate as '*d*'. Then increase and decrease in N during unit period time '*t*' will be $\frac{dN}{dt} = (b - d) \times N$, Let $(b - d) = r$ (intrinsic rate of natural increase), then $\frac{dN}{dt} = rN$
- The value for '*r*' in **Norway rat** is 0.015, and for the **flour beetle** is 0.12 and in 1981, its value for **human population** in India was 0.0205.
- 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 and *e* = Base of natural logarithms (2.71828)

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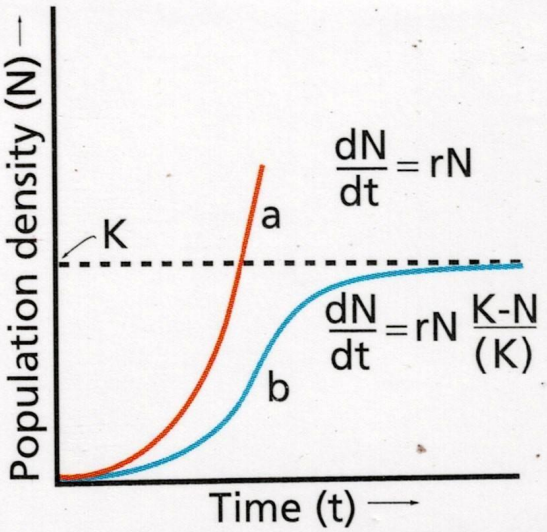

Population growth curves

a - exponential growth (J-shaped curve)

b - logistic growth (Sigmoid curve)

Logistic growth:

- This kind of growth occurs when food and space is available in limited amount and this results in competition between the individuals of a population.
- This type of growth initially shows a lag phase followed by phases of acceleration and de-acceleration and finally an asymptote, when the population density reaches the carrying capacity and beyond which no further growth is possible.
- **Verhulst-Pearl logistic growth equation** is $\frac{dN}{dt} = rN\left[\frac{(K-N)}{K}\right]$. Where, N = Population density

at time t, R = Intrinsic rate of natural increase and K = Carrying capacity.

Population Interactions:

- **Interspecific interactions** take place when populations of two different species interact with each other. It includes:

Name of interaction	Species A	Species B
Mutualism: Both species are benefitted (+)	+	+
Competition: Both species are harmed (–)	–	–
Predation: One (predator) is benefitted. Other (prey) is harmed	+	–
Parasitism: One (parasite) is benefitted. Other (host) is harmed	+	–
Commensalism: One is benefitted. Other is unaffected (0)	+	0
Amensalism: One is harmed. Other is unaffected	–	0

Predation:

- In this method, one animal (**predator**) kills and consumes the other weaker animal (**prey**).
- **Roles played by predators** in an ecosystem are:
  - Act as 'conduits' for the transfer of energy across trophic levels.

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- Control Prey population, e.g., the invasive prickly pear cactus in Australia was brought under control only after the introduction of cactus-feeding moth.
- Biological control of Agricultural pest.
- Maintain species diversity by reducing intensity of competition among prey species, e.g., in a field experiment, all the starfish *Pisaster* (predator) were removed from an enclosed intertidal area, which leads to the extinction of more than 10 species of invertebrates within a year. This happens because of interspecific competition.

- Predators are '**prudent**' in nature. If they over exploits the prey, it may lead to extinction of prey and as a consequence they will also become extinct.
- Preys evolve various defence mechanisms to lessen the impact of predation such as insects and frogs show camouflage, monarch butterfly releases distasteful and poisonous chemical, etc.
- Plants also evolve various morphological and chemical defences against herbivores such as Thorns of cactus and *Acacia*, *Calotropis* produce highly poisonous **cardiac glycosides**, produce chemicals such as nicotine, caffeine, quinine, strychnine, opium against grazers and browsers.

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Competition:

- It is the interaction either among the closely related species or among the unrelated species (flamingo and fish compete for zooplankton) for the same resources.
- In this process, fitness of one species ('*r*' value) is significantly lower in the presence of another species.
- **Evidences for competition** in nature can be depicted by the following:
  - The **Abingdon tortoise** in Galapagos Islands became extinct within a decade after goats were introduced on that island. It happens due to the greater browsing efficiency of goats.
  - **Competitive release:** It is the expansion of distributional range of a species when the competing species is removed.
  - **Connell's field experiments:** On the rocky sea coasts of Scotland, *Balanus* barnacle (larger and competitively superior) dominates the intertidal area and excludes the *Chthamalus* barnacle (smaller) from that zone. But when *Balanus* removed experimentally, *Chthamalus* colonized the intertidal zone.
  - **Gause's competitive exclusion principle:** Two closely related species competing for same resources cannot coexist indefinitely and the competitively inferior one will be eliminated."

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- **Resource partitioning:** Two competing species can co-exist if they avoid competition by choosing different feeding time and foraging patterns, e.g., MacArthur's demonstration of co-existence of warblers.

Parasitism:

- It is the interaction in which one species (parasite) depends on the other species (host) for food and shelter.
- Many parasites are **host-specific** and according to their lifestyles they evolve some 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, high reproductive capacity, etc.
- Parasites often have complex life cycles, e.g., human liver fluke (a trematode parasite) depends on - a snail and a fish (intermediate hosts) to complete its life cycle.
- Parasites may reduce the survival, population density, growth and reproduction of the host and make them physically weak and more vulnerable to predation.
- Parasites may be **ectoparasites** (live on external surface of the host), e.g., head lice on humans, ticks on dogs, etc. or **endoparasites** (live inside the body of the host), e.g., Liver fluke, *Plasmodium.*
- In brood parasitism, the parasitic bird lays its eggs in the nest of its host and lets the host incubate them, e.g., cuckoo lays eggs in crow's nest.

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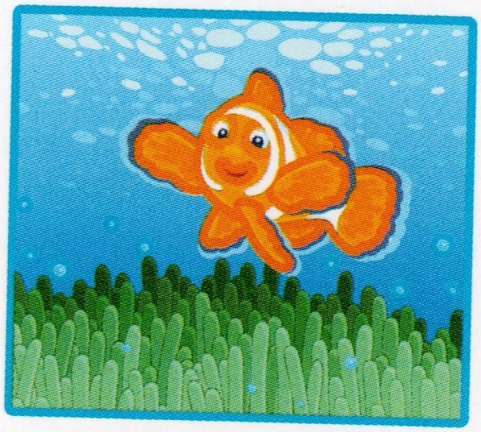
Commensalism:

Several examples are:



- An orchid growing as an epiphyte on a mango branch. The orchid gets shelter, while the mango tree is neither harmed nor benefitted.
- Barnacles (+) growing on the back of a whale (0).
- Cattle egret and grazing cattle. The egrets forage close to where the cattles are grazing. As the cattle graze, the vegetation insects come out and thus egrets are benefitted by easy detection and catching of insects.
- Clown fishes living among stinging tentacles of sea anemone. In this, clown fish are benefitted by getting protection from predators.

Mutualism:

- Several examples are fungi (absorption of nutrients, protection) and algae (prepares the food) in **Lichens**, fungi and roots of higher plants forms **Mycorrhizae**, Pollination of plants (give pollen and nectar to pollinators) by insects (disperse the seeds).

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- **Co-evolution of the mutualists:**
  - **Fig trees and wasps:** The female wasp is benefitted by using the fruit as an egg-laying site and also uses its developing seeds for nourishing its larvae. In return, the wasp pollinates the fig inflorescence while searching for suitable egg-laying sites.
  - **Mediterranean orchid *ophrys* and bee:** The flower shows 'sexual deceit' as one of its petals resembles female bee in size, colour and markings. So male bee 'pseudo copulates' with the flower and is dusted with pollen grains. When this bee 'pseudo copulates' with another flower, it transfers pollen to it and thus, pollinates the flower.

Amensalism:

- One organism (o) kills other organism (–) by Secreting some chemicals.
- **Example:** *Penicillium* (a mould), secretes penicillin (an antibiotic) that kills the bacteria but the mould remains unaffected.

TEST

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1. A rat population in a barn was studied by a biologist and he found that the average natality was 250, average mortality 240, immigration 20 and emigration 30. The net increase in population will be:
   (a) 10
   (b) 15
   (c) 05
   (d) Zero
2. Among the following factors, which one has a negative effect on the population growth rate?
   (a) Emigration
   (b) Immigration
   (c) Natality
   (d) Fecundity
3. Just as a person moving from Delhi to Shimla to escape the heat for the duration of the hot summer, thousands of migratory birds from Siberia and other extremely cold northern regions move to:
   (a) Keoladeo National Park
   (b) Corbett National Park
   (c) Western Ghats
   (d) Meghalaya

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Solutions:

1. **Option (d) is correct.**

   If N is considered as the population density at a given time *t*, then, $N_t = [(B + I) - (D + E)]$

   Therefore, $N_t = [(250 + 20) - (240 + 30)]$

   $= [270 - 270] = 0$ (Zero)

2. **Option (a) is correct.**

   Emigration is the number of individuals of the particular population who left the habitat and moved elsewhere during the time period under consideration. It leads to decrease in population and thus have negative effect on the population growth rate.

3. **Option (a) is correct.**

   During the winter season, thousands of migratory birds from Siberia and other extremely cold northern regions move to Keoladeo National Park (Bharatpur), Rajasthan.

TEST

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4. Which of the following is categorized as a parasite in true sense?

   (a) The cuckoo lays its egg in crow's nest

   (b) Human foetus developing inside the uterus draws nourishment from the mother

   (c) The female *Anopheles* bites and sucks blood from humans

   (d) Head louse living on the human scalp as well as laying eggs on human hair

5. The formula for exponential population growth is:

   (a) $\frac{dN}{rN} = dt$

   (b) $\frac{dt}{dN} = rN$

   (c) $\frac{dN}{dt} = rN$

   (d) $\frac{rN}{dN} = dt$

Solutions:

4. **Option (d) is correct.**

Parasites are the organisms which depend on the host for food and shelter. They may be ectoparasites (live on external surface of the host), e.g., head louse living on human scalp. On the other hand, cuckoo is not a true parasite, infact it's a brood parasite and *Anopheles* is a vector.

5. **Option (c) is correct.**

Exponential growth occurs when food and space is available in unlimited amount. Its formula is $\frac{dN}{dt} = rN$.

Where, d is the rate of change, N is the existing population size, r is the intrinsic rate of natural increase, t is the time, and $\frac{dN}{dt}$ is the rate of change in population size.

TEST

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6. The geometric representation of age structure is a characteristic of:
   - **(a)** Ecosystem
   - **(b)** Landscape
   - **(c)** Population
   - **(d)** Biotic community
7. In a field experiment carried out in an enclosed intertidal area, when all the *Pisaster* starfish were removed, what would be the result:
   - **(a)** Increase in diversity of invertebrate species.
   - **(b)** Replacement of *Pisaster* by other starfish.
   - **(c)** Extinction of many invertebrate species.
   - **(d)** Inability of the *Pisaster* to enter the area again.
8. Homeostasis is:
   - **(a)** tendency of biological systems to change with change in environment.
   - **(b)** tendency of biological systems to resist change.
   - **(c)** disturbance of self-regulatory system and natural controls.
   - **(d)** biotic materials used in homeopathic medicines.

Solutions:

6. **Option (c) is correct.**

The geometric representation of age structure is formed when the age distribution i.e., % individuals (males and females) of a given age or age group is plotted for the population. This can be of three types, expanding, stable and declining which depicts the growth status of the population.

7. **Option (c) is correct.**

In a field experiment carried out in an enclosed intertidal area, when all the starfish *Pisaster* (predator) were removed, it would lead to the extinction of more than 10 species of invertebrates within a year. This happens because of the interspecific competition.

8. **Option (b) is correct.**

Homeostasis is the tendency of biological systems to resist change. In this process, organisms maintain constancy of their internal environment i.e., within the body despite varying external environmental conditions.