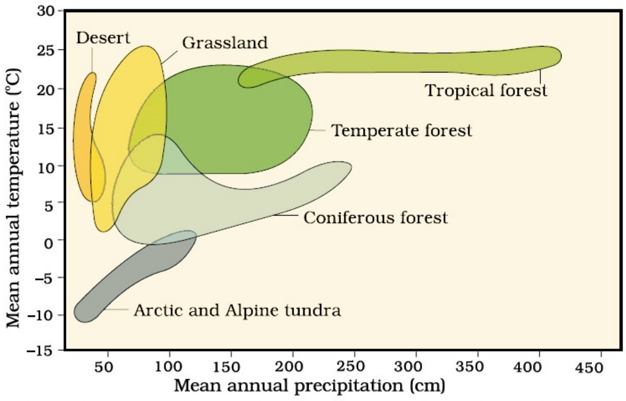
ORGANISMS AND POPULATIONS

Ecology is the study of interactions among organisms and between the organism and its physical (abiotic) environment. Ecology is concerned with 4 levels of biological organization: Organisms, Populations, Communities & Biomes.

ORGANISM AND ITS ENVIRONMENT

- **Physiological ecology** (Ecology at the organismic level) is the study of adaptation of an organism to environments in terms of survival and reproduction.
- The rotation of earth and the tilt of its axis cause annual variations in temperature & seasons. Major biomes (desert, rain forest, tundra etc.) are formed due to these variations & precipitation (rain & snow).



Biome distribution with respect to annual temperature and precipitation

- Regional and local variations within a biome lead to the formation of different habitats.
- Life exists even in extreme & harsh habitats. E.g. Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost (snow laden) polar regions, high mountain tops, thermal springs & compost pits. Our intestine is a habitat for many microbes.
- **The physico-chemical (abiotic) components** (water, light, temperature, soil etc.) & **biotic components** (pathogens, parasites, predators, competitors etc.) lead to variation of different habitats.
- The distinct role and position of an organism in its environment is called its **niche.** By this, each organism tolerates various conditions, utilises various resources etc.

Abiotic Factors

a. Temperature

- The most ecologically relevant environmental factor.
- Temperature on land varies seasonally. It gradually decreases from equator to the poles and from plains to mountain tops. It ranges from subzero levels (in polar areas & high altitudes) to >50^{0}C (in tropical deserts).
- Average temperature in thermal springs & deep-sea hydrothermal vents is above 100^0 C.
- Mango trees cannot grow in temperate countries (Canada, Germany etc.). There is no Snow leopard in Kerala forests. Tuna fishes are rare beyond tropical latitudes in the ocean.
- Temperature affects kinetics of enzymes, basal metabolism and other physiological functions of the organism.
- Based on range of thermal tolerance, organisms are 2 types:
  - **Eurythermal:** They can tolerate a wide range of temperatures.
  - **Stenothermal:** They can tolerate only a narrow range of temperatures.

b. Water

- It is the second most important factor.
- Desert organisms have special adaptations to limited water.
- Productivity & distribution of plants is dependent on water.
- For aquatic organisms, water quality (pH, chemical composition) is important. The salt concentration (salinity in parts per thousand) is less than 5 in inland waters, 30-35 in the sea and > 100 in some hypersaline lagoons.
- Based on the tolerance to salinity, organisms are 2 types:
  - **Euryhaline:** Tolerate a wide range of salinities.
  - **Stenohaline:** Tolerate only a narrow range of salinity.

  Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems.

c. Light

- Plants need sunlight for photosynthesis.
- Small forest plants (herbs & shrubs) are adapted to photosynthesize optimally under very low light because they are overshadowed by tall, canopied trees.
- Many plants depend on sunlight for photoperiodism (e.g. flowering).
- Many animals use diurnal and seasonal variations in light intensity and photoperiod for timing their foraging, reproductive & migratory activities.
- Sun is the ultimate source for light & temperature on land. Deep (> 500m) in the oceans, the environment is dark and there is no energy available from sun.
- The spectral quality of solar radiation is also important for life. The UV spectrum is harmful to many organisms. Not all the colour components of the visible spectrum are available for marine plants.

d. Soil

- Nature & properties of soil is differed due to climate, weathering, sedimentation, method of soil development etc.
- **Soil composition, grain size & aggregation** determine the percolation and water holding capacity of the soils.
- These characteristics and parameters like **pH, mineral composition & topography** determine the vegetation and animals in an area.
- In aquatic environment, the sediment-characteristics determine the type of **benthic animals.**

Responses to Abiotic Factors

- Organisms maintain a stable internal environment ***(homeostasis)*** despite varying external environmental conditions. This is possible by following processes.

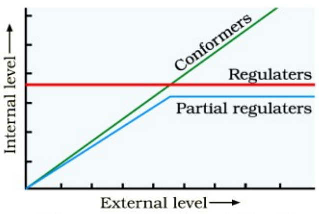
a. Regulate

- It is the maintenance of homeostasis by physiological & behavioural means. It ensures constant body temperature (thermoregulation), constant osmotic concentration (osmoregulation) etc. E.g. All birds & mammals, very few lower vertebrates and invertebrates.

- **Thermoregulation in mammals:** The success of mammals is mainly due to their ability to maintain a constant body temperature.
  In summer, when outside temperature is more than body temperature (37^0C), sweating occurs. This results in evaporative cooling and brings down body temperature.
  In winter, when the temperature is below 37^0C, shivering occurs. It produces heat and raises the body temperature.
- Most of the organisms are not regulators or are partial regulators because thermoregulation is **energetically expensive** especially for small animals (shrews, humming birds etc.). They have a larger surface area relative to their volume. So they lose body heat very fast when it is cold outside. Then they have to expend much energy to generate body heat. So, very small animals are rare in Polar Regions.

b. Conform

- 99% of animals and nearly all plants cannot maintain a constant internal environment. Their body temperature or osmotic concentration change with the surrounding conditions. They are called **conformers.**
- In aquatic animals, osmotic concentration of body fluids changes with that of the ambient osmotic concentration.



Diagrammatic representation of organismic response

c. Migrate

- Many animals like birds move away temporarily from stressful habitat to a more hospitable area and return when stressful period is over.
- E.g. During winter, Keolado National Park (Bhartpur, Rajasthan) hosts migratory birds coming from Siberia and other extremely cold northern regions.

d. Suspend

- In bacteria, fungi & lower plants, thick walled spores help to survive unfavourable conditions. Under suitable conditions, they germinate.
- In higher plants, seeds and some vegetative reproductive structures serve to tide over periods of stress by reducing their metabolic activity. They germinate under favourable moisture and temperature.
  In animals: Examples are
  - *Hibernation* of bears during winter.
  - *Aestivation* of some snails and fishes during summer.
  - *Diapause* (a stage of suspended development) of many zooplanktons in lakes & ponds.

Adaptations

- **Adaptation** is the morphological, physiological & behavioural attribute that enables an organism to survive and reproduce in its habitat.
- Many adaptations have evolved over a long evolutionary time and are genetically fixed.

Adaptations of kangaroo rat in North American deserts:

- Internal **fat oxidation** gives water as byproduct if there is no external source of water.
- Ability to **concentrate urine** so that minimal volume of water is used to remove excretory products.

Adaptations of desert plants:

- Presence of **thick cuticle** on leaf surfaces.
- **Sunken stomata** minimise water loss due to transpiration.
- **CAM photosynthetic pathway** enables their stomata to remain closed during day time.
- Desert plants like *Opuntia* have **no leaves** (they are reduced to spines). Photosynthesis is done by stems.

Adaptations of mammals:

- Mammals from colder climates have shorter ears and limbs to reduce heat loss. This is called **Allen's Rule.**
- 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.

Physiological and biochemical adaptations:

- ***Archaebacteria*** are found in hot springs & deep-sea hydrothermal vents where temperature is **>100^0C.** Many fish thrive in Antarctic waters (temperature is below 0^0C).
- Many marine invertebrates & fishes live at great depths in the ocean where the pressure is >100 times the normal atmospheric pressure.
- At a high-altitude place (>3,500 m) we feel ***altitude sickness.*** Its symptoms are nausea, heart palpitations & fatigue. This is due to low atmospheric pressure. So the body does not get enough O_2. Gradually, we acclimatize the situation and the body compensates low O_2 availability by increasing RBC & breathing rate and decreasing the binding capacity of hemoglobin.

Behavioural adaptations:

- Desert lizards bask in the sun and absorb heat when their body temperature is low, but move into shade when the ambient temperature starts increasing.
- Some species burrow into the soil to hide and escape from the above-ground heat.

POPULATIONS

- A **population** is a group of individuals of same species that live in a given geographical area, share or compete for similar resources and potentially reproduce.
- E.g. 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 etc.
- Population ecology is an important area of ecology as it links ecology to population genetics & evolution.

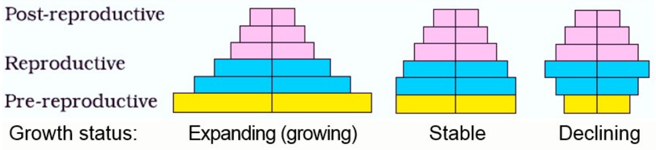
Population Attributes

- **Birth rates:** Refer to *per capita* births.
  E.g. In a pond, there are 20 lotus plants last year and through reproduction 8 new plants are added.

Hence, the current population = 28

The birth rate = 8/20 = 0.4 offspring per lotus per year.

- **Death rates:** Refer to *per capita* deaths.
  E.g. 4 individuals in a laboratory population of 40 fruit flies died during a week.
  Hence, the death rate = 4/40 = 0.1 individuals per fruit fly per week.
- **Sex ratio:** A population has a sex ratio.
  E.g. 60% of the population is females and 40% males.
- **Age pyramid:** It is the structure obtained when the age distribution (% individuals of a given age or age group) is plotted for the population.
  For human population, age pyramids generally show age distribution of males and females in a combined diagram.



Representation of age pyramids for human population

- **Population size or population density (N):** It is the number of individuals of a species per unit area or volume.
  E.g. population density of Siberian cranes at Bharatpur wetlands in any year is <10. It is millions for *Chlamydomonas* in a pond.
  Population size is also measured in **% cover or biomass.**
  E.g. In an area, 200 *Parthenium* plants and a huge banyan tree are seen. In such cases, measuring % cover or biomass is meaningful to show importance of banyan tree.
  Total number is a difficult measure for a huge population. In such cases, **relative population density** (without knowing absolute population density) is used. E.g. Number of fish caught per trap indicates its total population density in the lake.
  In some cases, indirect estimation of population sizes is performed. E.g. Tiger census in national parks & tiger reserves based on pug marks & fecal pellets.

POPULATION GROWTH

The population size changes depending on factors like food availability, predation pressure & weather.

Changes in population density give some idea about the population – whether it is flourishing or declining.

4 basic processes that fluctuate the population density:

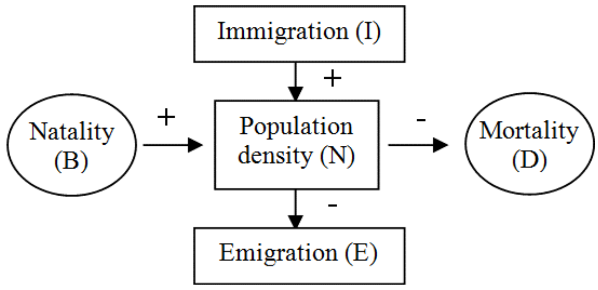
a. Natality (B): It is the number of births in a population during a given period.

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

c. Immigration (I): It is the number of individuals of the same species that have come into the habitat from elsewhere during a given time period.

d. Emigration (E): It is the number of individuals of the population who left the habitat and gone elsewhere during a given time period.

Natality & immigration increase the population density and mortality & emigration decrease the population density.



- If N is the population density at time t, then its density at time t +1 is

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

  Population density increases if B+I is more than D+E. Otherwise it will decrease.
- Under normal conditions, births & deaths are important factors influencing population density. Other 2 factors have importance only under special conditions. E.g. for a new colonizing habitat, immigration may be more significant to population growth than birth rates.

Growth Models

a. Exponential growth

- Resources (food & space) are essential for the unimpeded population growth.
- If resources are unlimited, each species shows its full innate potential to grow in number. Then the population grows in an exponential or geometric fashion.
- If population size = N, birth rates (*per capita* births) = *b* and death rates (*per capita* deaths) = *d*, then the increase or decrease in N during a unit time period t (dN/dt) will be

$$dN/dt = (b – d) \times N$$

Let (b–d) = r, then

$$dN/dt = rN$$

The r ('intrinsic rate of natural increase') is an important parameter for assessing impacts of any biotic or abiotic factor on population growth.

r value for the Norway rat = 0.015

r value for the flour beetle = 0.12

r value for human population in India (1981) = 0.0205

The integral form of the exponential growth equation is

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

Where,

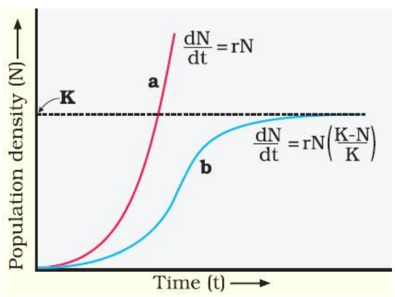
N_t = Population density after time t

N_0 = Population density at time zero

r = intrinsic rate of natural increase

e = the base of natural logarithms (2.71828)

Population growth curves



a = exponential growth (J-shaped curve)

b = logistic growth (Sigmoid curve)

b. Logistic growth

- There is no population in nature having unlimited resources for exponential growth. This leads to competition among individuals for limited resources.
- Eventually, the 'fittest' individuals survive and reproduce.
- In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. It is called **carrying capacity (K)**.
- A population with limited resources shows initially a **lag phase, phases of acceleration & deceleration** and finally an **asymptote**. This type of population growth is called **Verhulst-Pearl Logistic Growth.** It is described by 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

- Since resources for growth for most animal populations are limited, the logistic growth model is more realistic.

Life History Variation

- Populations evolve to maximise their reproductive fitness or Darwinian fitness (high r value). 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 (most birds and mammals).
- Some produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals).
- These facts indicate that life history traits of organisms have evolved due to limited abiotic and biotic components of the habitat.

Population Interactions

- Organisms interact in various ways to form a biological community.
- Interaction between two species is called **Interspecific interactions.** They include

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

- In predation, parasitism & commensalisms, the interacting species live closely together.

a. Predation

- In a broad ecological context, all carnivores, herbivores etc. are predators. About 25 % insects are *phytophagous.*
- If a predator overexploits its prey, then the prey might become extinct. It results in the extinction of predator. Therefore, predators in nature are 'prudent'.

Importance of predators:

- **Predators control prey populations.**
  When certain exotic species are introduced into a geographical area, they spread fast due to the absence its natural predators. E.g. Prickly pear cactus introduced into Australia (1920's) caused havoc by spreading. Later, it was controlled by introducing a cactus-feeding predator moth.
- Predators are used in **Biological control** methods.
- Predators **maintain species diversity** in a community by reducing competition among prey species.
  E.g. the predator starfish *Pisaster* in the rocky intertidal communities of American Pacific Coast. In an experiment, all these starfishes were removed from an enclosed intertidal area. It caused extinction of over 10 invertebrate species within a year, due to interspecific competition.

Defenses of prey species to lessen impact of predation:

- ***Camouflage*** (cryptic colouration) of some insects & frogs.
- Some are **poisonous** and so avoided by the predators.
- Monarch butterfly is highly distasteful to its predator bird. It is due to a special chemical in its body. It is acquired during its caterpillar stage by feeding on a poisonous weed.
- **Thorns** (*Acacia*, *Cactus etc.*) are the most common morphological means of defense of plants.
- Many plants produce chemicals that make the herbivore sick, inhibit feeding or digestion, disrupt its reproduction or kill it. E.g. *Calotropis* produce highly poisonous **cardiac glycosides.** Therefore cattle or goats do not eat it. **Nicotine, caffeine, quinine, strychnine, opium,** etc. are defenses against grazers and browsers.

b. Competition

- It is a process in which fitness of one species ('r' value) is significantly lower in presence of another species.
- Interspecific competition is a potent force in organic evolution.
- Competition occurs when closely related species compete for the same limited resources.
- Unrelated species can also compete for the resource. E.g. Flamingoes & fishes in some shallow South American lakes compete for zooplankton.
- Competition occurs in abundant resources also. E.g. In **interference competition,** the feeding efficiency of one species is reduced due to the interfering and inhibitory presence of other species, even if resources are abundant.

Evidences for competition:

- The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, due to greater browsing efficiency of the 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, there are 2 barnacle species: *Balanus* (larger & competitively superior) & *Chthamalus* (smaller). *Balanus* dominates intertidal area and excludes *Chthamalus.*

  When Connell experimentally removed *Balanus, Chthamalus* colonized the intertidal zone.

Gause's 'Competitive Exclusion Principle':

- It states that *two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually.* This may be true in limited resources, but not otherwise.
- Species facing competition may evolve mechanisms for co-existence rather than exclusion. E.g. resource partitioning.
- **Resource partitioning**: It is the division of limited resources by species to avoid competition. For this, they choose different feeding times or different foraging patterns. E.g. MacArthur showed that five closely related species of **warblers** living on a tree could avoid competition and co-exist due to behavioural differences in their foraging activities.

c. Parasitism

- Many parasites are **host-specific** (they can parasitize only a single host species). They tend to **co-evolve.** i.e., if the host evolves special mechanisms against the parasite, the parasite also evolves mechanisms to counteract them to remain with the same host species.
- **Adaptations of parasites:** Loss of sense organs, presence of adhesive organs or suckers to cling on to the host, loss of digestive system, high reproductive capacity etc.
- Life cycles of parasites are often complex. E.g.
  - Human liver fluke depends on 2 intermediate hosts (a snail & a fish) to complete its life cycle.
  - Malarial parasite needs mosquito to spread to other hosts.
- Parasites harm the host. They may reduce the survival, population density, growth and reproduction of the host. They may make the host physically weak and more vulnerable to predation.

Types of parasites:

1. Ectoparasites

- Parasites that feed on the external surface of host. E.g.
  - Lice on humans.
  - Ticks on dogs.
  - Ectoparasitic Copepods on many marine fishes.
  - *Cuscuta* plant on hedge plants.
- *Cuscuta* has no chlorophyll and leaves. It derives its nutrition from the host plant.
- Female mosquito is not considered a parasite, because it needs our blood only for reproduction, not as food.

2. Endoparasites

- Parasites that live inside the host body at different sites (liver, kidney, lungs, RBC etc).
- The life cycles of endoparasites are more complex.
- They have simple morphological & anatomical features and high reproductive potential.

Brood parasitism in birds:

- Here, the parasitic birds lay eggs in the nest of its host and lets the host incubate them.
- During evolution, eggs of the parasitic bird have evolved to resemble the host's egg in size and colour. So the host bird cannot detect and eject the foreign eggs easily.
- E.g. Brood parasitism between **cuckoo and crow.**

d. Commensalism

Examples:

- Orchid (+) growing as *epiphyte* on a mango branch (0).
- Barnacles (+) growing on the back of a whale (0).
- Cattle egret (+) & grazing cattle (0). The egrets forage close to where the cattle are grazing. As the cattle move, the vegetation insects come out. Otherwise it is difficult for the egrets to find and catch the insects.
- Sea anemone (0) & clown fish (+). Stinging tentacles of sea anemone gives protection to fish from predators.

e. Mutualism

Examples:

- **Lichen:** It is a mutualistic relationship between a fungus & photosynthesizing algae or cyanobacteria.
- **Mycorrhizae:** Associations between fungi & the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant provides the fungi with carbohydrates.
- **Mutualism b/w plant & animal through pollination and seed dispersion:**

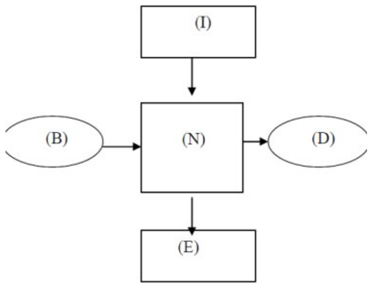
  Examples:

  1. **Fig trees & wasps.** The fig species is pollinated only by its 'partner' wasp species. Female wasp pollinates the fig inflorescence while searching for suitable egg-laying sites in fruits. The fig offers the wasp some developing seeds, as food for the wasp larvae.
  2. **Orchids** show diversity of floral patterns. They can attract the right pollinator insect **(bees & bumblebees)** to ensure pollination. Not all orchids offer rewards.
  3. **'Sexual deceit' of *Ophrys*** (Mediterranean orchid). One petal of its flower resembles female bee in size, colour & markings. So male bee 'pseudocopulates' with the flower and is dusted with pollen. When this bee 'pseudocopulates' with another flower, it transfers pollen to it.

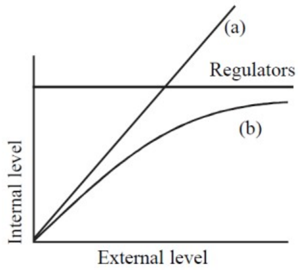
     If the female bee's colour patterns change slightly during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

MODEL QUESTIONS

1. All freshwater animals cannot live for long in sea water or a marine organism in freshwater. Give reason.
2. Observe the figure below:



    a. Expand N, B, D, I & E
    b. When will population density increase?
    c. List two factors which influence population density under normal conditions.
3. Observe the graphical representation of organismic response and name a & b.



4. Different responses made by organism to cope with the stressful situations are given below. Arrange them in columns.

Regulate	Change of body temperature according to external environment
Conform	Hard and resistant spores /hibernation
Migrate	Sweating and shivering to maintain body temperature
Suspend	Moving to hospitable area

5. Match the following

Name of Interaction	Type of Interaction	Examples
Mutualism	+ –	*Cuscuta*
Competition	+ +	*Vanda*
Pararitism	+ 0	*Flemingoes & fisher*
Commensalism	– –	*Lichen*

6. It is common sight in villages where cattle egrets & grazing cattle are found in close association.
    a. What kind of interaction do they show?
    b. Give an example of such an interaction from plants.