

CUET (UG) Biology Notes: Organisms and Populations

1. Population Attributes

A population is a group of individuals of the same species living in a well-defined geographical area, sharing or competing for similar resources, and potentially interbreeding.

- **Birth and Death Rates:** Unlike an individual which has birth and death, a population has birth rates (natality) and death rates (mortality). These are expressed as a change in numbers (increase or decrease) with respect to members of the population (per capita births and deaths).
- **Sex Ratio:** An individual is either male or female, but a population has a sex ratio (e.g., 60% females and 40% males).
- **Age Pyramids:** A population at any given time is composed of individuals of different ages. If the age distribution (percent individuals of a given age or age group) is plotted for the population, the resulting structure is called an age pyramid.
 - For human populations, age pyramids generally show age distribution of males and females combined.
 - The shape of the pyramids reflects the growth status of the population:
 1. Expanding: Broad base (high proportion of pre-reproductive individuals).
 2. Stable: Bell-shaped (pre-reproductive and reproductive individuals are almost equal).
 3. Declining: Urn-shaped (low proportion of pre-reproductive individuals).

2. Population Growth

The size of a population is dynamic. Its density (N) changes in a given habitat during a given period due to four basic processes:

1. **Natality (B):** Number of births during a given period (increases N).

2. **Immigration (I):** Number of individuals of the same species that have come into the habitat from elsewhere (increases N).
3. **Mortality (D):** Number of deaths in the population during a given period (decreases N).
4. **Emigration (E):** Number of individuals who left the habitat and went elsewhere (decreases N).

Fundamental Equation: $N(t+1) = N(t) + [(B + I) - (D + E)]$

A. Exponential Growth

Occurs when resources (food and space) are unlimited.

- Equation: $dN/dt = (b - d) \times N$
- Let $(b - d) = r$, then:
 $dN/dt = rN$
(Where "r" is the "intrinsic rate of natural increase" - a very important parameter for assessing impacts of any biotic or abiotic factor on population growth).
- Integral Form: $N_t = N_0 \times e^{(rt)}$
(Where N_t = Population density after time t; N_0 = Population density at time zero; e = base of natural logarithms, approx 2.71828).
- Curve Shape: Results in a J-shaped curve.

B. Logistic Growth (Verhulst-Pearl Logistic Growth)

Occurs when resources are limited, leading to competition. A given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. This limit is called nature's Carrying Capacity (K).

- Equation: $dN/dt = rN [(K - N) / K]$
- Curve Shape: Results in an S-shaped (Sigmoid) curve. This model is considered more realistic since resources for growth for most animal populations are finite and become limiting sooner or later.

3. Life History Variation

Populations evolve to maximize their reproductive fitness, also called Darwinian fitness (high "r" value), in the habitat in which they live. Under particular selection pressures, organisms evolve towards the most efficient reproductive strategy.

- **Breeding Frequency:**

- Breed only once in their lifetime (Pacific salmon fish, bamboo).
- Breed many times during their lifetime (most birds and mammals).
- Offspring Size and Number:
 - Produce a large number of small-sized offspring (Oysters, pelagic fishes).
 - Produce a small number of large-sized offspring (Birds, mammals).

(Note: + = beneficial, - = detrimental, 0 = neutral)		
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A. Predation (+ / -)

- Function: Acts as a conduit for energy transfer across trophic levels and keeps prey populations under control.
- Prey Defenses:
 - Animals: Camouflage (cryptic coloration) to avoid detection. The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical acquired during its caterpillar stage by feeding on a poisonous weed.
 - Plants: Morphological (thorns in Acacia and Cactus). Chemical (Calotropis produces highly poisonous cardiac glycosides; hence, cattle or goats never browse on it).

B. Competition (- / -)

- Gause's 'Competitive Exclusion Principle': States that two closely related species competing for the same limiting resources cannot co-exist indefinitely, and the competitively inferior one will be eliminated eventually. (e.g., Abingdon tortoise in Galapagos Islands became extinct after goats were introduced due to the goat's greater browsing efficiency).
- Resource Partitioning: If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different foraging patterns. (e.g., MacArthur showed that five closely related species of warblers co-existed by changing their foraging behavior).

C. Parasitism (+ / -)

- Many parasites have evolved to be host-specific. They often lose unnecessary sense organs, gain adhesive organs/suckers, lose their digestive system, and have high reproductive capacity.
- Ectoparasites: Feed on the external surface (lice on humans, ticks on dogs, marine copepods on fishes, Cuscuta plant on hedge plants).


4. Population Interactions

In nature, animals, plants, and microbes do not and cannot live in isolation but interact in various ways to form a biological community.

Interaction	Species A	Species B
Mutualism	+	+
Competition	-	-
Predation	+	-
Parasitism	+	-
Commensalism	+	0
Amensalism	-	0

- Endoparasites: Live inside the host body (liver fluke, Plasmodium). Their life cycles are highly complex.
- Brood Parasitism: Found in birds. The parasitic bird (Cuckoo/Koel) lays its eggs in the nest of its host (Crow) and lets the host incubate them. The eggs resemble the host's eggs in size and color to reduce the chances of the host bird detecting and ejecting them.

3. Plant-Animal Relationships: Plants need animals for pollinating their flowers and dispersing their seeds. In return, plants offer nectar, pollen, or juicy fruits.
4. Fig and Wasp: A strict one-to-one relationship. The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites, and the fig offers the developing seeds as food for the wasp larvae.
5. Sexual Deceit (Ophrys and Bee): The Mediterranean orchid Ophrys employs sexual deceit. One petal of its flower bears an uncanny resemblance to the female of the bee species in size, color, and markings. The male bee is attracted to it, "pseudocopulates" with the flower, and dusts pollen onto it.



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D. Commensalism (+ / 0)

- Examples:
 1. An orchid growing as an epiphyte on a mango branch.
 2. Barnacles growing on the back of a whale.
 3. Cattle egret and grazing cattle (egrets forage close to cattle, as the cattle flush out insects from the vegetation).
 4. Sea anemone (has stinging tentacles) and the clownfish (lives among them for protection from predators).

E. Mutualism (+ / +)

- Examples:
 1. Lichens: Intimate mutualistic relationship between a fungus and photosynthesizing algae or cyanobacteria.
 2. Mycorrhizae: Associations between fungi and the roots of higher plants.