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Introduction

Biological Hierarchy and Ecology

- Living world is diverse and complex with levels: macromolecules, cells, tissues, organs, organisms, populations, communities, ecosystems, biomes.
- **Ecology**: Study of interactions among organisms and with abiotic environment.
- Term coined by Ernst Haeckel (1866); Ramdeo Misra is Father of Ecology in India.
- **Ecological hierarchy**: Levels of ecological organisation; individual organism is the basic unit.

Memory Aids

- Ecology = Organism + Environment interactions.
- Hierarchy: Organism → Population → Community → Ecosystem → Biome.

Quick Checkpoints

- What is ecological hierarchy?
- Who coined the term ecology?
- Basic unit of ecological organisation?

Organism and its Environment

Organismic Ecology and Biomes

- Physiological ecology studies organism adaptations for survival and reproduction.
- Seasonal and annual precipitation variations form major biomes: desert, rainforest, tundra.
- Local variations create diverse habitats within biomes.
- Life exists in extreme habitats: deserts, rainforests, deep ocean, polar regions, thermal springs, intestines.
- Key habitat factors: temperature, water, light, soil.

- Habitat includes abiotic (physico-chemical) and biotic components (pathogens, predators, competitors).
- Organisms evolve adaptations via natural selection to optimize survival and reproduction.
- **Niche**: Range of tolerance, resource use, and functional role of an organism.
- Weather: short-term atmospheric conditions; Climate: long-term regional atmosphere.
- Microclimate: local climatic conditions.
- Habitat: specific locality where a community lives.
- Niche: specific part of habitat occupied by a species; no two species share the same niche.
- Niche overlap: sharing resources; Niche density: species abundance in habitat.

Memory Aids

- Habitat = Where organism lives; Niche = How organism lives.
- Weather = short term; Climate = long term.
- Niche is unique to each species.

Quick Checkpoints

- Define niche and habitat.
- Difference between weather and climate?
- What factors define a niche?

Major Abiotic Factors

Temperature

- Ranges from subzero in polar/high altitudes to >50°C in tropical deserts; thermal springs exceed 100°C.
- Affects enzyme kinetics, metabolism, activity, physiology.
- Thermal tolerance influences species distribution.
- Types by temperature tolerance:
 - **Eurythermal**: tolerate wide temperature range (e.g., mammals, birds, *Artemesia tridentata*).
 - **Stenothermal**: tolerate narrow temperature range (e.g., polar bear, lizards).
- Types by body temperature regulation:

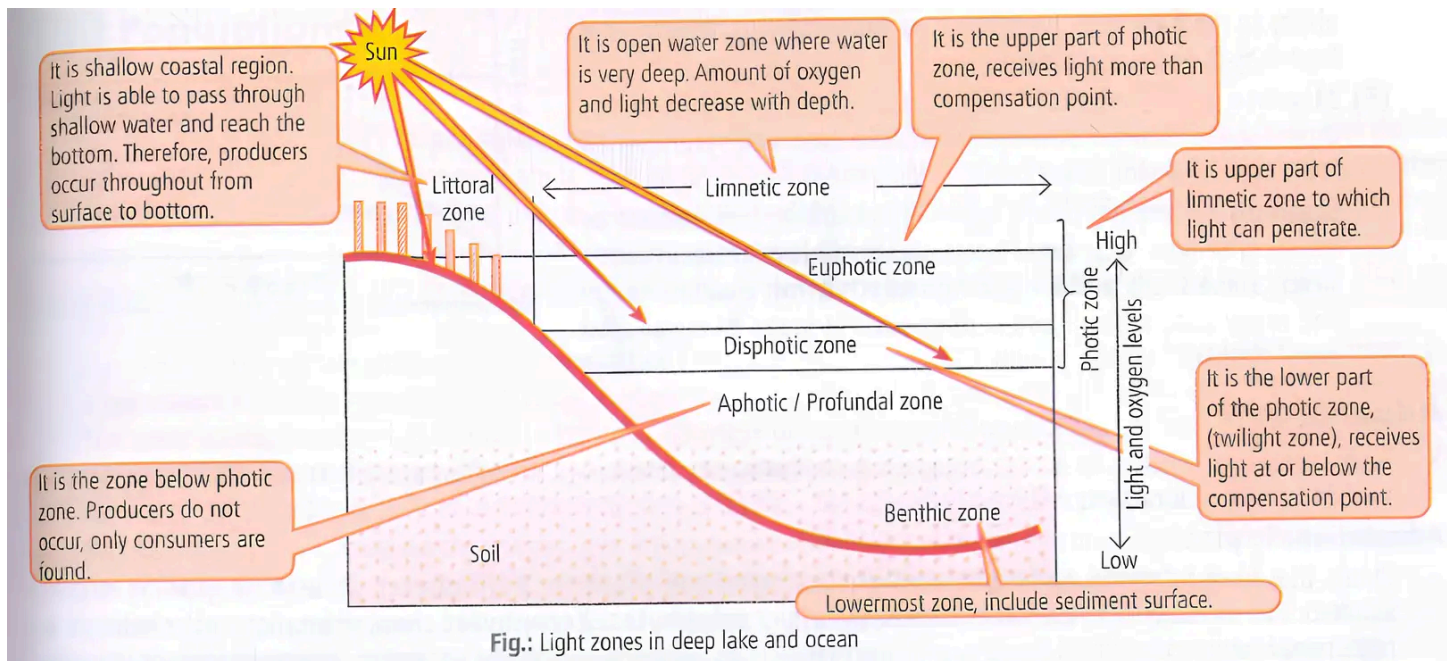
- **Poikilothermal:** body temp varies with environment; ectothermic (e.g., reptiles, amphibians).
- **Homoiothermal:** constant body temp; endothermic (e.g., birds, mammals).
- Temperature affects photosynthesis, respiration, reproduction, growth in plants; metabolism, distribution, behavior in animals.

Water

- Water quality (pH, chemical composition) important for aquatic life.
- Salinity varies: <5 ppt inland, 30-35 ppt sea, >100 ppt hypersaline lagoons.
- **Euryhaline:** tolerate wide salinity range (e.g., salmon).
- **Stenohaline:** tolerate narrow salinity range (e.g., shark).
- Freshwater and marine animals face osmotic challenges crossing habitats.
- Terrestrial plants by moisture availability:
 - Hygrophytes: wet areas, soft stems, large leaves with hydathodes.
 - Mesophytes: moist habitats, luxuriant growth (most crops).
 - Xerophytes: dry habitats, water loss adaptations (e.g., *Acacia*, *Casuarina*).

Light

- Life processes depend on light intensity, duration, quality.
- Photosynthesis requires sunlight; shade plants adapt to low light.
- Photoperiod cues animal behavior: foraging, migration, reproduction.
- Deep oceans (>500 m) are dark; different light zones exist in lakes/oceans.

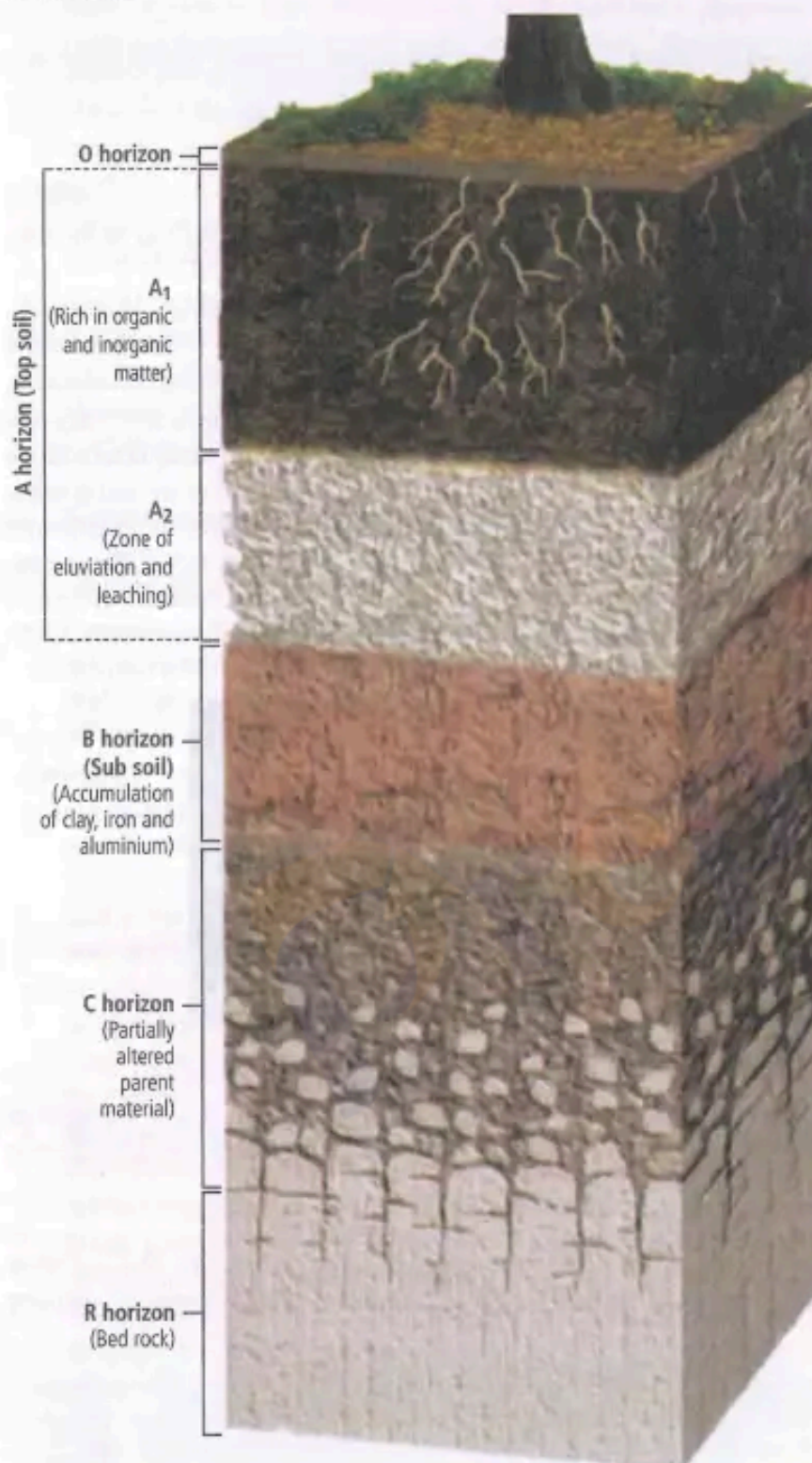


Soil

- Soil: upper weathered humus layer supporting terrestrial plants.
- Properties depend on climate, weathering, soil type (transported/sedimentary).
- Soil characteristics (composition, grain size, pH, minerals) affect vegetation.
- Soil profile: vertical layers (horizons) O, A, B, C, R.
- O horizon: organic litter; A horizon: topsoil rich in organic matter; B horizon: subsoil with clay, iron; C horizon: weathered rock; R horizon: bedrock.

Soil Profile

The appearance of different layers superposed one above the other in a vertical section of a soil from surface downward to the parent rock is called **soil profile**. Soil layers running roughly parallel to the surface which have distinctive structure and properties different from those of adjacent ones are called **soil horizons**.



It is the surface layer of organic matter which lies above the true soil. It has two sub-horizons, A_{00} (O_1) and A_0 (O_2). O_1 is the upper sub-horizon which contains freshly deposited organic debris of fallen leaves, twigs, bark, animal remains and animal excretions. O_2 is sub-horizon below O_1 and immediately above the top soil. It contains organic matter in various stages of decomposition thereby forming **humus**.

It is the uppermost horizon of the soil which contains mineral matter mixed with humus. It is therefore, light weight, spongy and dark in colour. Roots of most of the plants remain restricted to A-horizon. The horizon is rich in microorganisms. Therefore, the layer has very high biological activity. A horizon is divisible into subhorizons - A_1 and A_2 . A_1 is the uppermost sublayer which is dark in colour, rich in organic matter and inorganic nutrients. A_2 is second sub-horizon which is the area of maximum leaching or **eluviation**. As a result it is slightly lighter in colour and slightly deficient in inorganic nutrients.

It is also called **subsoil**. It receives various materials leached from topsoil. It is thus, the area of deposit of material or **illuviation**. The horizon is poor in aeration and biological activity. It is rich in plant nutrients including humus but illuviation also causes formation of compact and hard sublayers.

It contains irregular rock fragments. Biological activity is nil. The horizon is **saturated with moisture** and represents the **water table**.

Unweathered parent bed rock lies below C horizon

Memory Aids

- Temperature: Eurythermal = wide range; Stenothermal = narrow range.
- Water: Euryhaline = wide salinity tolerance; Stenohaline = narrow.
- Soil horizons: O (organic), A (topsoil), B (subsoil), C (weathered rock), R (bedrock).

Quick Checkpoints

- Define eurythermal and stenothermal organisms.
- What are the soil horizons?
- How does salinity affect aquatic organisms?

Responses to Abiotic Factors

Homeostasis and Coping Mechanisms

- **Homeostasis:** maintaining internal stability despite external changes.
- Organism responses:
 - **Regulators:** maintain constant internal conditions (e.g., birds, mammals).
 - **Conformers:** internal conditions vary with environment (99% animals, most plants).
 - **Partial regulators:** regulate partially, conform beyond limits.
 - **Migrate:** move to favorable habitats temporarily.
 - **Suspend:** escape unfavorable conditions via hibernation, aestivation, diapause.

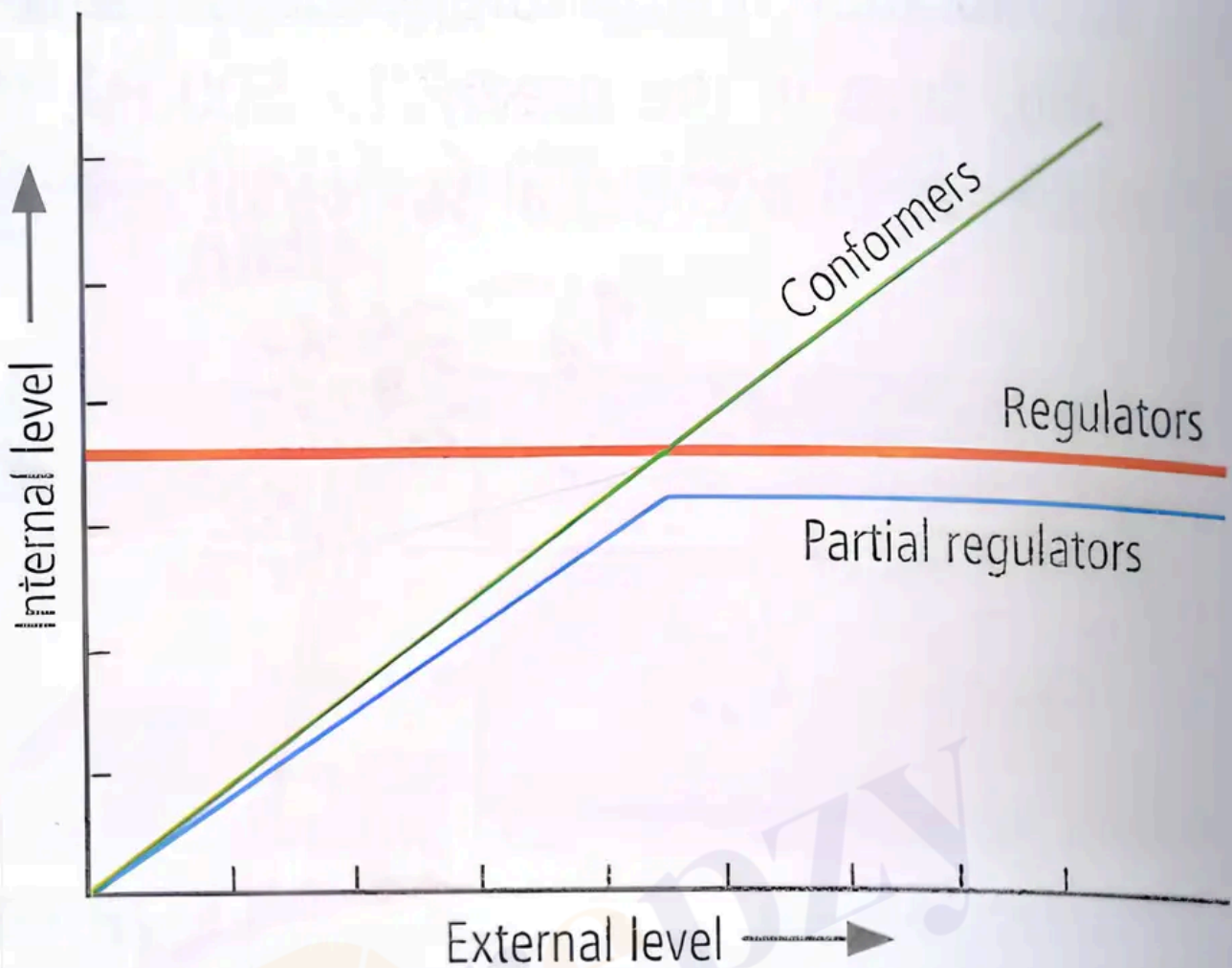


Fig.: Diagrammatic representation of organismic response

Memory Aids

- Regulators = constant internal state.
- Conformers = internal state matches environment.
- Partial regulators = intermediate response.
- Suspension = hibernation, aestivation, diapause.

Quick Checkpoints

- What is homeostasis?
- Difference between regulators and conformers?
- Examples of suspension strategies?

Adaptations

Plant Adaptations

- Adaptation: traits enabling survival and reproduction.
- **Sun plants (heliophytes)**: adapted to bright sunlight.
- **Shade plants (sciophytes)**: adapted to low light.
- **Xerophytes**: dry habitat adaptations; types:
 - Ephemerals (drought escapers)
 - Annuals (drought evaders)
 - Succulents (drought resistants)
 - Non-succulent perennials (drought endurers)
- Desert plants: thick cuticle, sunken stomata, CAM photosynthesis, leaf spines (e.g., *Opuntia*).
- **Hydrophytes**: mucilage-covered, reduced roots, aerenchyma present.
- **Halophytes**: tolerate saline soils, salt secretion, succulence, pneumatophores.

Animal Adaptations

- Adaptations can be short-term (tanning, heartbeat) or long-term (beak, claw).
- Most animal adaptations are physiological and behavioral.
- **Camouflage**: blending with environment to avoid detection.
- **Mimicry**: resemblance to another species for protection.
- Desert animals reduce water loss and tolerate arid conditions (e.g., kangaroo rat).
- Behavioral adaptations include activity timing and habitat use.

Memory Aids

- Allen's rule: shorter ears/limbs in cold climates.
- Bergman rule: larger body size in cold regions.
- Gloger's rule: darker skin in warm, humid areas.
- Jordan's rule: more vertebrae in cold-water fish.
- Rensch's rule: narrow wings in cold-area birds.

Quick Checkpoints

- Types of xerophytes?
- Difference between camouflage and mimicry?
- Examples of animal behavioral adaptations?

Populations

Population Attributes

- Population: Group of individuals of a species in a defined area sharing resources and potentially interbreeding.
- Includes asexual groups for ecological studies (e.g., bacteria in culture).
- Population has birth rate and death rate (per capita births and deaths).
- Sex ratio: Proportion of males and females in population (e.g., 60% females, 40% males).
- Age structure: Distribution of individuals in pre-reproductive, reproductive, and post-reproductive stages.
- Age pyramid types: Triangular (growing), Bell-shaped (stable), Urn-shaped (declining).
- Local population (demes): Subgroups in a specific area.
- Sister populations: Same species in different locations.
- Demography: Study of population size.

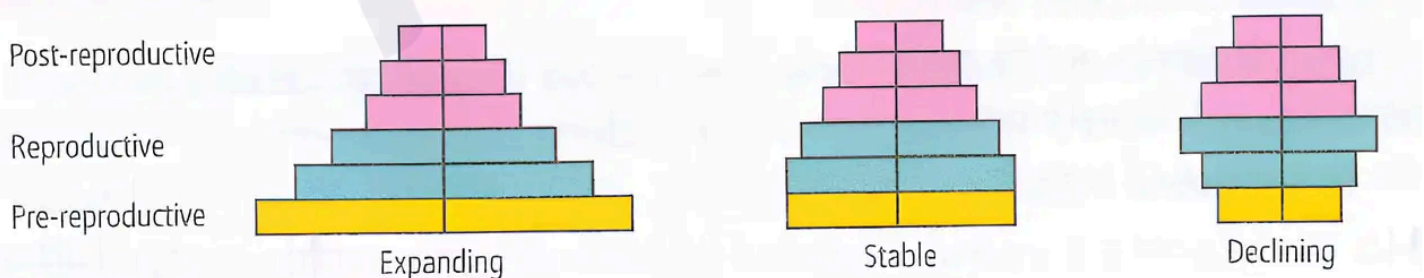


Fig.: Representation of age pyramids for human population

Memory Aids

- Population = Group + Interbreeding + Shared area.
- Sex ratio = % females vs males.
- Age pyramid shapes indicate growth trends.
- Demography = Population size study.

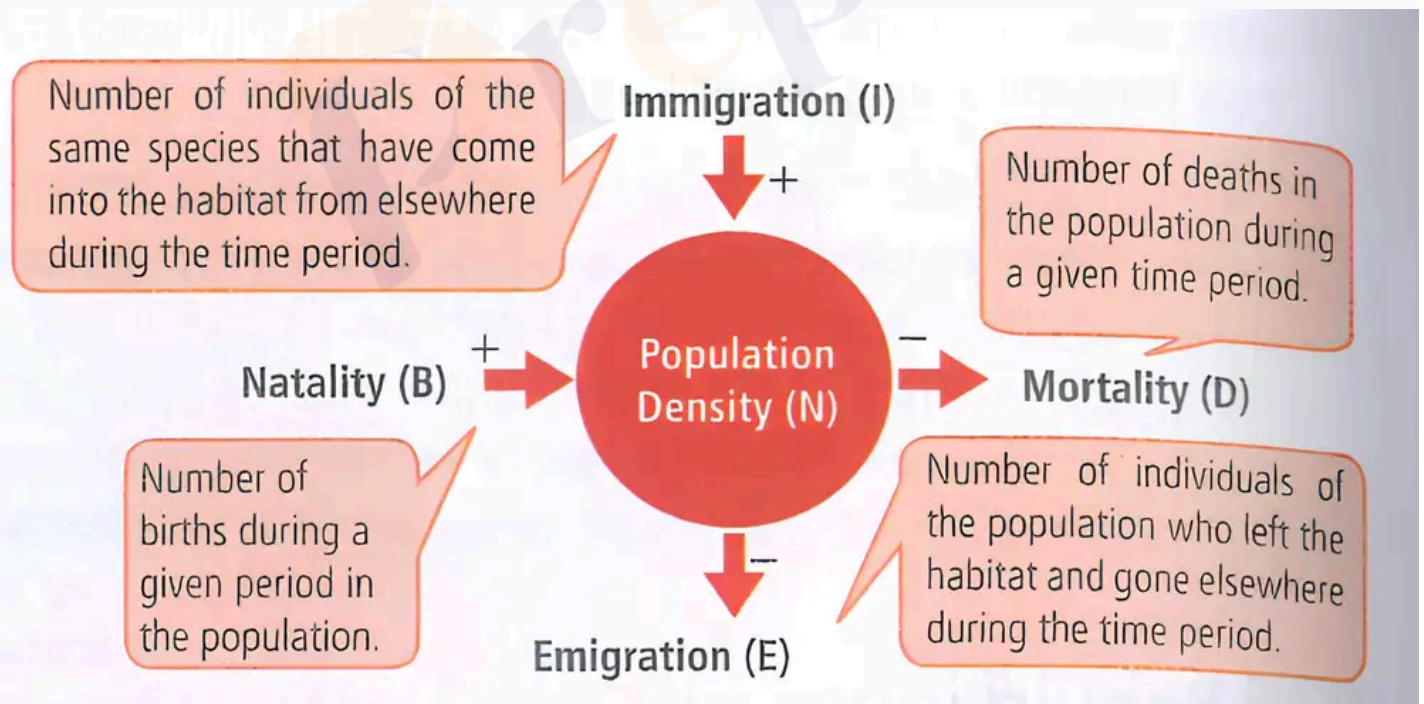
Quick Checkpoints

- What defines a population?
- How is sex ratio expressed?
- What are the three age groups in a population?
- What does a triangular age pyramid indicate?

Population Growth

Population Dynamics

- Population size changes over time due to food, predation, weather.
- Population density changes by natality (births), immigration (in), mortality (deaths), emigration (out).
- Population density = number of individuals per unit area or volume.
- Population size often estimated by indirect signs (e.g., tiger pug marks).



Memory Aids

- Population density = N .
- Increase factors: Natality + Immigration.

- Decrease factors: Mortality + Emigration.
- Indirect counting used for large populations.

Quick Checkpoints

- What factors increase population density?
- How is population density defined?
- Why use indirect methods for population size?

Growth Models

Exponential Growth

- Occurs when resources are unlimited.
- Population grows rapidly in J-shaped curve.
- Growth rate depends on intrinsic rate and current population size.

Logistic Growth

- Growth slows as population nears carrying capacity (K).
- Produces S-shaped (sigmoid) curve.
- More realistic model due to limited resources.

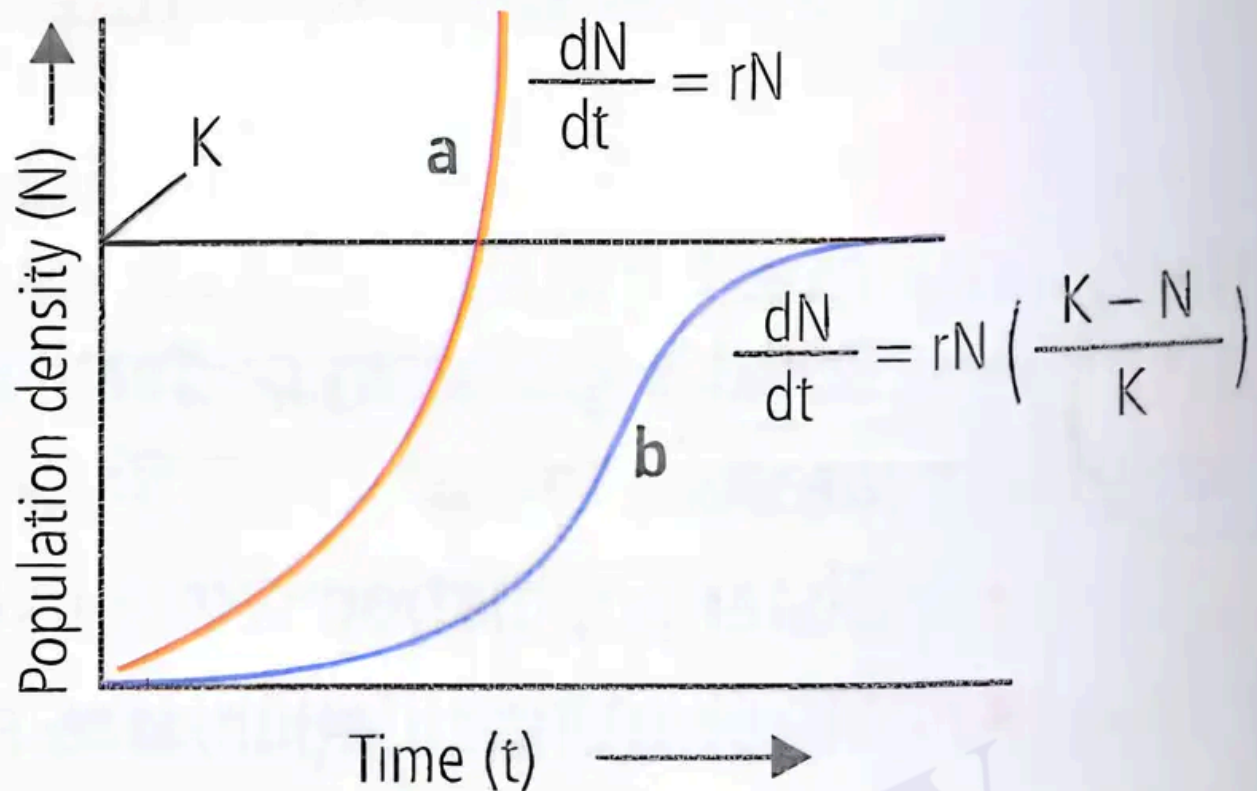


Fig.: Population growth curve; **a** when responses are not limiting the growth, plot is exponential, **b** when responses are limiting the growth, plot is logistic, K is carrying capacity

Memory Aids

- Exponential = unlimited growth, J-curve.
- Logistic = limited growth, S-curve, carrying capacity K.
- Carrying capacity = max population environment supports.

Quick Checkpoints

- What shape is exponential growth curve?
- What limits logistic growth?
- Define carrying capacity.

Life History Variation

Reproductive Strategies

- Populations evolve to maximize reproductive fitness (Darwinian fitness).
- Some species breed once; others breed multiple times.
- Offspring size and number vary: many small or few large.
- Life history traits adapt to habitat constraints.
- Biotic potential: max reproductive capacity in optimal conditions.
- k-selected species: large size, few offspring, long lifespan, low metabolism.
- r-selected species: small size, many offspring, short lifespan, high metabolism.

Memory Aids

- k-selected = K for "Kare" (care, fewer offspring).
- r-selected = Rapid reproduction, many offspring.
- Biotic potential = max reproduction under ideal conditions.

Quick Checkpoints

- What is biotic potential?
- Difference between k-selected and r-selected species?
- How do life history traits relate to habitat?

Population Interactions

Types of Interactions

- Intra-specific: within same species.
- Inter-specific: between different species.
- Positive interactions: mutualism, proto-cooperation, commensalism.
- Negative interactions: amensalism, competition, parasitism, predation.
- Interactions summarized by + (benefit), - (harm), 0 (neutral).

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

Memory Aids

- + / + = Mutualism
- - / - = Competition
- + / - = Predation or Parasitism
- + / 0 = Commensalism
- - / 0 = Amensalism

Quick Checkpoints

- What is intra-specific interaction?
- Give examples of positive interactions.
- What does + / - interaction indicate?

Predation

Predator-Prey Relationship

- Predators capture, kill, and eat prey species.
- Transfers energy to higher trophic levels and controls prey population.
- Herbivores are ecologically predators of plants.
- Invasive species spread fast due to lack of natural predators.
- Predators regulate prey populations, maintaining species diversity.
- Predators are 'prudent' to avoid overexploiting prey.
- Prey defenses: camouflage, toxicity (e.g., Monarch butterfly).
- Plants defend with thorns and chemical toxins (e.g., cardiac glycosides).

Memory Aids

- Predation = predator kills prey.
- Prey defenses: camouflage, poison.
- Plants use thorns and chemicals for defense.
- Predators maintain ecosystem balance.

Quick Checkpoints

- What is predation?
- How do prey avoid predation?
- Why are predators called prudent?

Competition

Competition Types

- Active demand for common resources by individuals of same or different species.
- Intraspecific: within species, more severe.
- Interspecific: between species, less severe.
- Competitive release: species expands range when competitor removed.

- Gause's competitive exclusion: two species cannot coexist if competing for same resource indefinitely.
- Resource partitioning: species avoid competition by using different resources or times.

Memory Aids

- Intraspecific = same species competition.
- Interspecific = different species competition.
- Competitive exclusion = no coexistence with same niche.
- Resource partitioning avoids competition.

Quick Checkpoints

- Define intraspecific competition.
- What is competitive exclusion principle?
- How do species avoid competition?

Parasitism

Parasite-Host Relationship

- Parasite obtains food from host, usually smaller and lives on/in host.
- Adaptations: loss of sense organs, adhesive organs, loss of digestive system, high reproduction.
- Ectoparasites: live on host surface (e.g., lice, ticks, *Cuscuta*).
- Endoparasites: live inside host (e.g., liver, blood parasites), complex life cycles.
- Brood parasitism: parasitic bird lays eggs in host nest; eggs mimic host eggs.

Memory Aids

- Ectoparasites: outside host.
- Endoparasites: inside host.
- Brood parasitism: egg mimicry in birds.

Quick Checkpoints

- What adaptations do parasites have?
- Difference between ectoparasites and endoparasites?
- What is brood parasitism?

Commensalism

One Benefits, Other Neutral

- One species benefits; other neither harmed nor benefited.
- Examples: orchid on mango, barnacles on whale, cattle egret with cattle.
- Sea anemone and clown fish: fish protected, anemone unaffected.
- Epiphytes: attach to trees but photosynthesize, called ectocommensals.

Memory Aids

- Commensalism = one benefits, other neutral.
- Epiphytes are ectocommensals.
- Classic example: cattle egret and cattle.

Quick Checkpoints

- What is commensalism?
- Give an example of ectocommensal.
- How does clown fish benefit in commensalism?

Mutualism

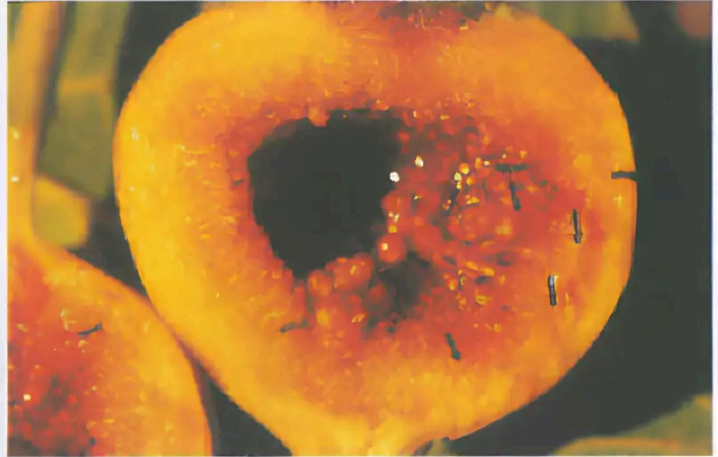
Mutually Beneficial Obligatory Relationship

- Both species benefit and cannot live separately.

- Examples: lichens (fungus + algae), mycorrhizae (fungi + plant roots).
- Plant-animal mutualism: pollination and seed dispersal with rewards.
- Fig tree and wasp: wasp pollinates and lays eggs; fig provides food and shelter.
- Ophrys orchid uses sexual deceit to attract bee pollinator.



(a)



(b)

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

Memory Aids

- Mutualism = both benefit, obligatory.
- Lichens = fungus + algae symbiosis.
- Fig-wasp = tight one-to-one pollination.
- Sexual deceit = orchid mimics female bee.

Quick Checkpoints

- What defines mutualism?
- Give examples of mutualistic relationships.
- How does fig-wasp mutualism work?

Amensalism

One Species Inhibits Another

- One species inhibits growth or survival of another without benefit or harm to itself.

- Example: *Grevillea robusta* produces chemicals inhibiting nearby seedlings.

Memory Aids

- Amensalism = one harmed, other unaffected.
- Example: chemical inhibition by plants.

Quick Checkpoints

- What is amensalism?
- Give an example of amensalism in plants.

Additional Note

- Protocooperation: Both benefit but can live separately (e.g., tick bird and rhinoceros).