Ch II · Organisms & Populations

अध्याय II · जीव और समष्टियाँ

Class 12 Biology · NCERT based · English + हिंदी · ✍️ revision notes

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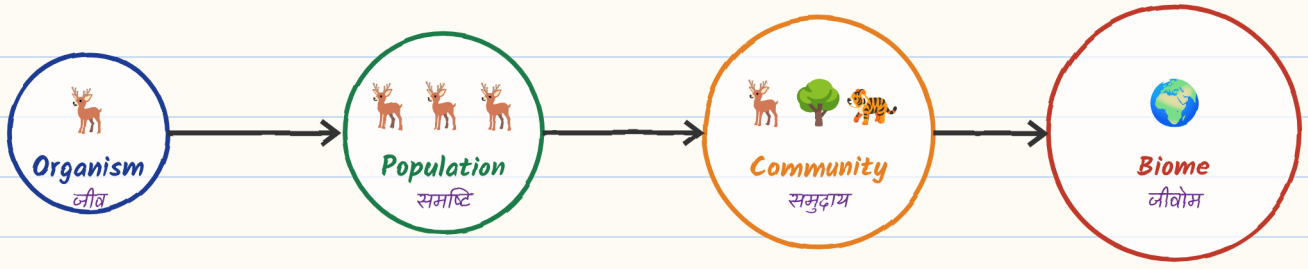
Introduction / परिचय

- **Ecology** (पारिस्थितिकी) = a subject which studies the **interactions among organisms** and **between organism & its physical (abiotic) environment**.
- Ecology is basically concerned with **four levels** of biological organisation:



Infographic: Levels of ecological organisation

📌 **Syllabus note:** In the rationalised NCERT book (2023 onwards), this chapter begins directly with **Populations**. The older section "Organism and its Environment" is no longer part of the CBSE syllabus.

I. Populations & their Attributes / समष्टि व उसके गुण

Population (समष्टि) = a group of individuals of a **species** living in a well-defined **geographical area**, that **share or compete** for similar resources & potentially **interbreed**.
e.g. cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate, lotus plants in a pond.

- Natural selection operates at the level of individual organisms, but evolution of desired traits takes place at the population level → population ecology is an important area linking ecology to population genetics & evolution.
- A population has certain attributes that an individual organism does not have. An individual may have births & deaths, but a population has **birth rates & death rates** (expressed as **per capita** births/deaths).

(a) Birth rate & death rate जन्म दर व मृत्यु दर

Birth rate (NCERT example): In a pond there are **20 lotus plants** last year; through reproduction **8 new plants** are added → current population = 28.
Birth rate = 8 / 20 = **0.4 offspring per lotus per year**.

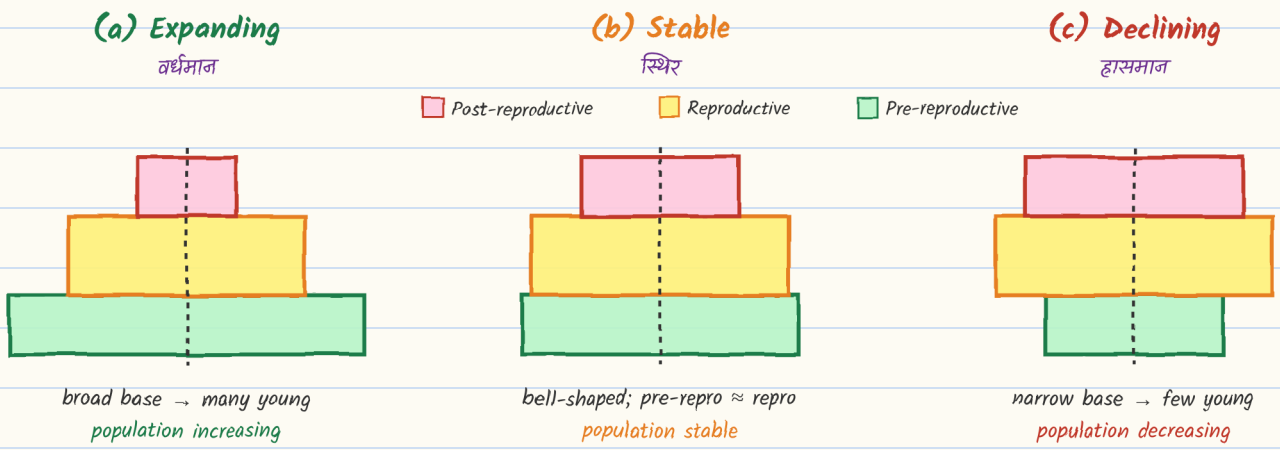
Death rate: If **4 individuals** in a lab population of **40 fruit flies** died during a specified time interval, say a week →
Death rate = 4 / 40 = **0.1 individuals per fruit fly per week**.

(b) Sex ratio लिंग अनुपात

An individual is either male or female, but a population has a sex ratio, e.g. **60% females & 40% males**.

(c) Age distribution & age pyramids आयु वितरण व आयु पिरामिड

At any given time, a population is composed of individuals of different ages. If age distribution (per cent individuals of a given age or age group) is plotted for the population, the resulting structure = age pyramid. For human population, age pyramids generally show age distribution of males & females in a combined diagram. Shape of pyramid reflects **growth status** of the population.



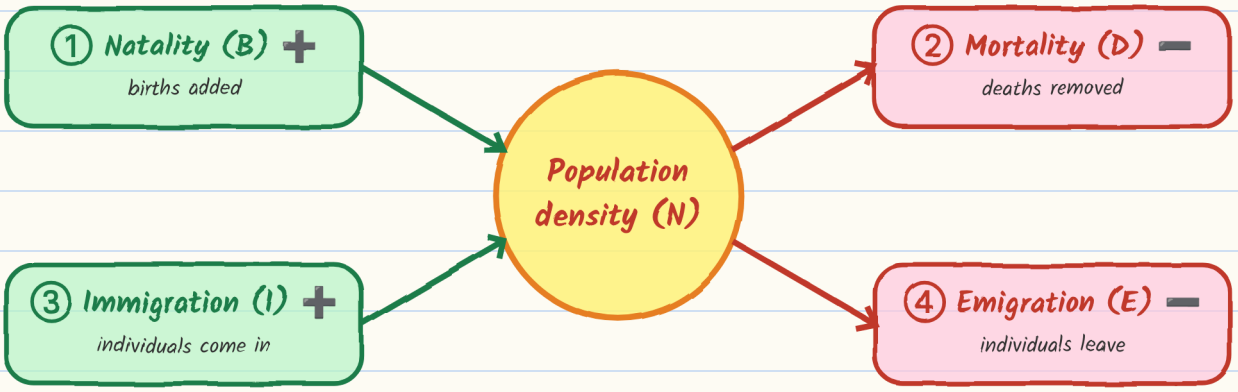
Infographic: Representation of age pyramids for human population · आयु पिरामिड

(d) Population density समष्टि घनत्व

- Size of population tells us about its status in the habitat. Population size, more technically called **population density (N)**, need not necessarily be measured in numbers only.
- Total number is generally the most appropriate measure but in some cases is either **meaningless or difficult** to determine.
- If in an area there are **200 *Parthenium* plants** but only a **single huge banyan tree** with a large canopy, stating that population density of banyan is low relative to Parthenium **underestimates** the enormous role of the banyan in that community. In such cases, per cent cover or biomass is a more meaningful measure.
- Total number is again not an easily adoptable measure if population is huge & counting is impossible or very time-consuming, e.g. dense lab culture of bacteria in a petri dish → measure **per cent cover**.
- Sometimes, for certain ecological investigations, there is no need to know absolute population densities; **relative densities** serve the purpose equally well, e.g. **number of fish caught per trap** is a good enough measure of its total population density in the lake.
- We are mostly obliged to estimate population sizes **indirectly**, without actually counting them or seeing them. e.g. tiger census in national parks & tiger reserves is often based on **pug marks & fecal pellets**.

2. Population Growth / समष्टि वृद्धि

Size of a population for any species is not a static parameter. It keeps changing with time, depending on various factors including food availability, predation pressure & adverse weather.



Infographic: Four basic processes affecting population density

- **Natality** (जन्मदर) = number of births during a given period in the population that are added to initial density.
- **Mortality** (मृत्युदर) = number of deaths in the population during a given period.
- **Immigration** (आप्रवासन) = number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.
- **Emigration** (उत्प्रवासन) = number of individuals of the population who left the habitat & gone elsewhere during the time period under consideration.

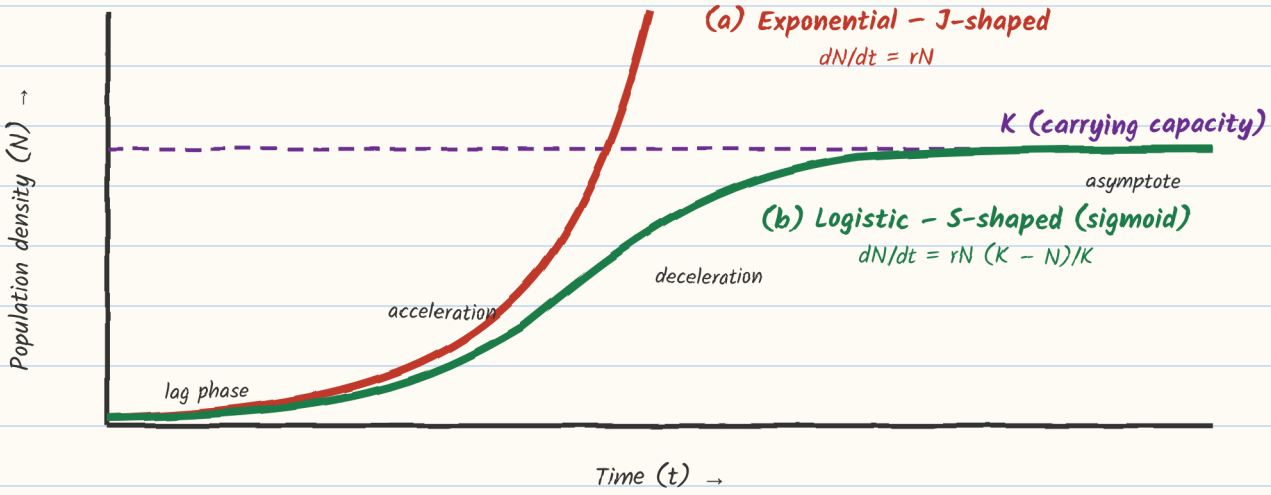
If N is population density at time t, then its density at time t+1 is:

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

Population density will **increase** if number of births plus number of immigrants (B + I) is more than number of deaths plus number of emigrants (D + E).

Under normal conditions, **births & deaths** are the most important factors influencing population density; other two factors assume importance only under special conditions, e.g. if a new habitat is just being colonised, **immigration** may contribute more significantly to population growth than birth rates.

Growth models वृद्धि मॉडल



Infographic: Population growth curves – (a) exponential (b) logistic · समष्टि वृद्धि वक्र

(a) Exponential growth चरघातांकी वृद्धि

- **Resource availability (food & space) is unlimited** → each species has ability to realise fully its innate potential to grow in number. Population grows in an exponential or **geometric** fashion.
- If in a population of size N, birth rates (not total number but per capita births) are represented as **b** and death rates (per capita) as **d**, then increase or decrease in N during unit time period t (dN/dt) will be:

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

Let $(b - d) = r$, then $dN/dt = rN$

Integral form: $N_t = N_0 e^{rt}$

N_t = population density after time t; N_0 = population density at time zero; r = intrinsic rate of natural increase; e = base of natural logarithms (2.71828)

- **r** = intrinsic rate of natural increase (प्राकृतिक वृद्धि की स्वाभाविक दर) – a very important parameter for assessing impacts of any biotic or abiotic factor on population growth.
- Magnitude of r: **Norway rat = 0.015**; **flour beetle = 0.12**. In **1981**, r value for human population in **India was 0.0205**.
- Plotting N in relation to time gives a J-shaped curve.
- 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 absence of checks.

(b) Logistic growth संभार तंत्र वृद्धि

- No population of any species in nature has at its disposal unlimited resources to permit exponential growth. This leads to **competition** between individuals for limited resources. Eventually, the "fittest" individual will survive & reproduce.
- In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. This limit = carrying capacity (K) (पोषण क्षमता) for that species in that habitat.
- A population growing in a habitat with limited resources shows initially a **lag phase**, followed by phases of **acceleration & deceleration** and finally an **asymptote**, when population density reaches carrying capacity.
- Plot of N in relation to time (t) results in a sigmoid (S-shaped) curve. This type of population growth = **Verhulst-Pearl Logistic Growth**:

$$dN/dt = rN\left((K - N) / K\right)$$

N = population density at time t; r = intrinsic rate of natural increase; K = carrying capacity

📌 **Exam Tip:** Since resources for growth for most animal populations are finite & become limiting sooner or later, the **logistic growth model is considered a more realistic one**. When $N = K \rightarrow (K - N)/K = 0 \rightarrow$ growth stops. When N is very small $\rightarrow (K-N)/K \approx 1 \rightarrow$ growth ≈ exponential.

Exponential growth	Logistic growth
Unlimited resources	Limited resources
J-shaped curve	S-shaped (sigmoid) curve
$dN/dt = rN$	$dN/dt = rN (K - N)/K$
No carrying capacity	Has carrying capacity (K)
Not realistic in nature	More realistic

3. Life History Variation / जीवन इतिहास विविधता

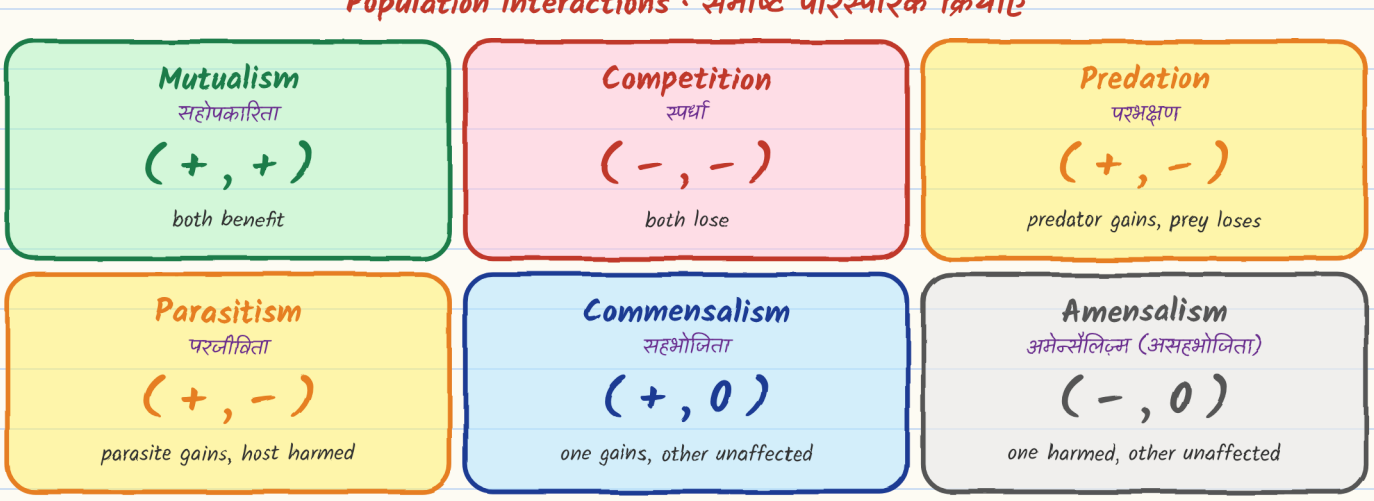
- Populations evolve to **maximise their reproductive fitness**, also called Darwinian fitness (high r value), in the habitat in which they live.
- Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy.

Strategy	Examples
Breed **only once** in their lifetime	**Pacific salmon fish, bamboo**
Breed **many times** during their lifetime	Most **birds & mammals**
Produce a **large number of small-sized** offspring	**Oysters, pelagic fishes**
Produce a **small number of large-sized** offspring	**Birds, mammals**

Ecologists suggest that life history traits of organisms have evolved in relation to the constraints imposed by the abiotic & biotic components of the habitat in which they live. Evolution of life history traits in different species is currently an important area of research.

4. Population Interactions / समष्टि पारस्परिक क्रियाएँ

- No species can survive alone in nature. Even a plant species, which makes its own food, cannot survive alone; it needs soil microbes to break down organic matter, animals for pollination & seed dispersal.
- Interspecific interactions arise from interaction of populations of **two different species**. They could be **beneficial (+)**, **detrimental (–)** or **neutral (0)** to one of the species or both.



Infographic: Types of population interactions (species A, species B)

Species A	Species B	Name of interaction
+	+	**Mutualism**
–	–	**Competition**
+	–	**Predation**
+	–	**Parasitism**
+	0	**Commensalism**
–	0	**Amensalism**

📌 **Key point:** Both parties benefit in **mutualism**; both lose in **competition**. In both **parasitism & predation** only one species benefits (parasite & predator) & the interaction is detrimental to the other (host & prey). Predation, parasitism & commensalism share a common characteristic – interacting species **live closely together**.

5. Predation / परभक्षण

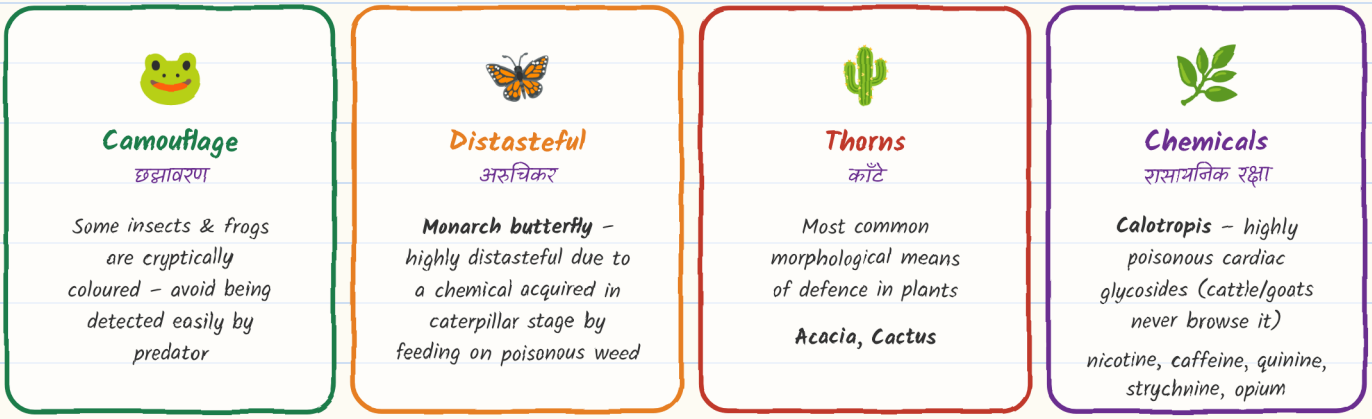
- Predation is nature's way of **transferring to higher trophic levels the energy** fixed by plants.
- When we think of predator & prey, most probably it is the tiger & deer that readily come to our mind, but a **sparrow eating any seed** is no less a predator. Herbivores are in a broad ecological context not very different from predators.

Roles of predators परभक्षियों की भूमिका

1. **Conduits for energy transfer** across trophic levels.
2. **Keep prey populations under control**. In absence of predators, prey species could achieve very high population densities & cause ecosystem instability.
    - When certain exotic species are introduced into a geographical area, they become invasive & start spreading fast because the invaded land does not have its natural predators. Prickly pear cactus introduced into **Australia in early 1920s** caused havoc by spreading rapidly into millions of hectares of rangeland. Finally, the invasive cactus was brought under control only after a **cactus-feeding predator (a moth)** from its natural habitat was introduced into the country.
    - **Biological control** methods adopted in agricultural pest control are based on the ability of predator to regulate prey population.
3. **Maintain species diversity** in a community by reducing intensity of competition among competing prey species.
    - In rocky intertidal communities of the **American Pacific Coast**, the starfish Pisaster is an important predator. In a field experiment, when all starfish were removed from an enclosed intertidal area, **more than 10 species of invertebrates became extinct within a year**, because of interspecific competition.

📌 **Prudent predator:** If a predator is too efficient & overexploits its prey, then the prey might become extinct & following it, the predator will also become extinct for lack of food. This is why predators in nature are **'prudent'**.

Prey defences against predation शिकार के रक्षा उपाय



Infographic: Defences of prey (animals & plants) against predators

- Prey species have evolved various defences to lessen impact of predation.
- Some species of insects & frogs are **cryptically-coloured (camouflaged)** to avoid being detected easily by the predator.
- Some are poisonous & therefore avoided by predators. Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body. Interestingly, the butterfly acquires this chemical during its **caterpillar stage** by feeding on a **poisonous weed**.
- For plants, herbivores are the predators. Nearly 25 per cent of all insects are phytophagous (feeding on plant sap & other parts of plants).
- Unlike animals, plants cannot run away from predators. So plants evolved morphological & chemical defences:
  - **Thorns** (*Acacia, Cactus*) – most common morphological means of defence.
  - Many plants produce & store chemicals that make the herbivore sick when eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.
  - *Calotropis* (weed growing in abandoned fields) produces highly poisonous **cardiac glycosides** → you never see any cattle or goats browsing on this plant.
  - A wide variety of chemical substances extracted from plants on a commercial scale (**nicotine, caffeine, quinine, strychnine, opium**, etc.) are produced by them actually as **defences against grazers & browsers**.

6. Competition / स्पर्धा

- Darwin was convinced that interspecific competition is a potent force in organic evolution.
- Commonly believed that competition occurs when closely related species compete for the same resources that are limiting, but this is not entirely true:
  - **Totally unrelated species** could also compete for the same resource: e.g. in some shallow South American lakes, visiting flamingoes & resident fishes compete for their common food,

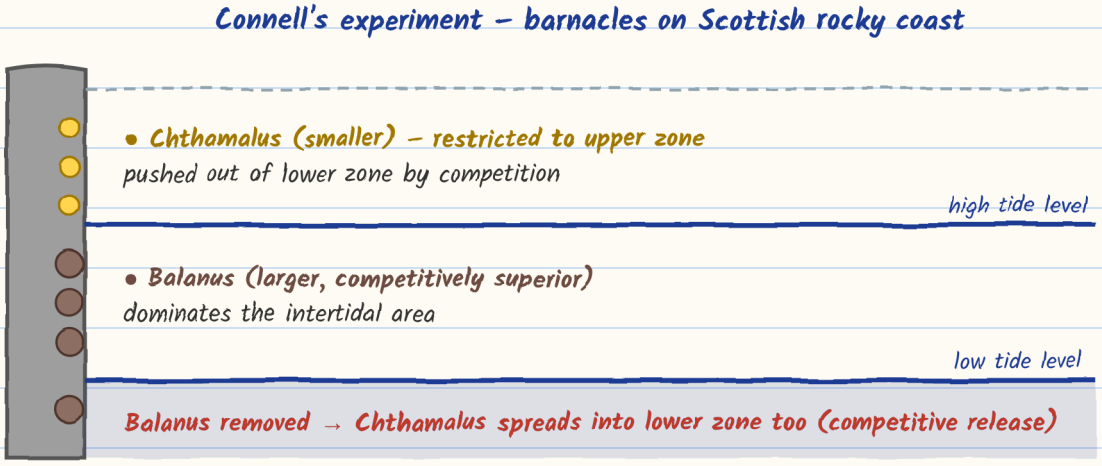
the **zooplankton** in the lake.

- Resources need not be limiting for competition to occur. In interference competition, feeding efficiency of one species might be reduced due to the interfering & inhibitory presence of the other species, even if resources (food & space) are abundant.

- Therefore, competition is 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 presence of another species**.

Evidences of competition in nature प्रकृति में स्पर्धा के प्रमाण

- Relatively easy to demonstrate in lab experiments (Gause & other experimental ecologists) when resources are limited, the competitively superior species will eventually eliminate the other species. But evidence in nature is not always conclusive.
- Abingdon tortoise in **Galapagos Islands** became extinct within a decade after **goats** were introduced on the island, apparently due to greater browsing efficiency of the goats.
- **Competitive release** (स्पर्धी मुक्ति): a species whose distribution is restricted to a small geographical area because of presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed.



Infographic: Connell's field experiment on barnacles

- **Connell's** elegant field experiments showed that on the rocky sea coasts of **Scotland**, the larger & competitively superior barnacle Balanus dominates the intertidal area & excludes the smaller barnacle Chthamalus from that zone.
- In general, **herbivores & plants** appear to be more adversely affected by competition than carnivores.

Gause's 'Competitive Exclusion Principle' (गाँसे का स्पर्धी अपवर्जन सिद्धांत):

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 if resources are limiting, but not otherwise.

📌 **Resource partitioning** (संसाधन विभाजन): Species facing competition might evolve mechanisms that promote co-existence rather than exclusion. If two species compete for 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 & co-exist due to **behavioural differences in their foraging activities**.

7. Parasitism / परजीविता

- Considering that parasitic mode of life ensures **free lodging & meals**, it is not surprising that parasitism has evolved in so many taxonomic groups from plants to higher vertebrates.
- Many parasites have evolved to be **host-specific** (can parasitise only a single species of host) in such a way that both host & parasite tend to **co-evolve**; i.e. if host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to counteract & neutralise them in order to be successful with the same host species.

Adaptations of parasites परजीवियों के अनुकूलन

1. **Loss of unnecessary sense organs**
2. Presence of **adhesive organs or suckers** to cling on to host
3. **Loss of digestive system**
4. **High reproductive capacity**

- Life cycles of parasites are often complex, involving one or two **intermediate hosts or vectors** to facilitate parasitisation of its primary host.
  - Human liver fluke (a trematode parasite) depends on **two intermediate hosts (a snail & a fish)** to complete its life cycle.
  - **Malarial parasite** needs a vector (**mosquito**) to spread to other hosts.
- Majority of parasites **harm the host**: they may reduce survival, growth & reproduction of host & reduce its population density. They might render host more vulnerable to predation by making it physically weak.

Type	Description	Examples
Ectoparasites (बाह्य परजीवी)	Feed on the **external surface** of host organism	Most familiar: **lice on humans**, **ticks on dogs**. Many marine fish infested with ectoparasitic **copepods**. *Cuscuta* – parasitic plant commonly found growing on hedge plants; lost its chlorophyll & leaves; derives nutrition from host plant
Endoparasites (अंतःपरजीवी)	Live **inside host body** at different sites (liver, kidney, lungs, RBCs, etc.)	Life cycles more complex because of extreme specialisation; morphological & anatomical features greatly simplified while emphasising their **reproductive potential**
Brood parasitism (अंड परजीविता)	Parasitic bird lays its eggs in the nest of its host & lets host incubate them	*Cuckoo (koel) & crow* – eggs of parasitic bird have evolved to resemble host's egg in size & colour → reduces chances of host bird detecting foreign eggs & ejecting them from nest. Watch the movements of koel & crow in breeding season (spring to summer)

8. Commensalism & Mutualism / सहभोजिता व सहोपकारिता

(a) Commensalism (+, 0) सहभोजिता

Interaction in which **one species benefits** and the **other is neither harmed nor benefited**.

Benefited (+)	Unaffected (0)	How
Orchid (epiphyte)	Mango tree	Grows on branch of mango
Barnacles	Whale	Grow on back of whale
Cattle egret	Grazing cattle	Egrets forage close to where cattle are grazing; as cattle move, they stir up & flush out insects from vegetation that egrets catch & eat
Clown fish	Sea anemone	Fish lives among the stinging tentacles of sea anemone → gets protection from predators which stay away from stinging tentacles

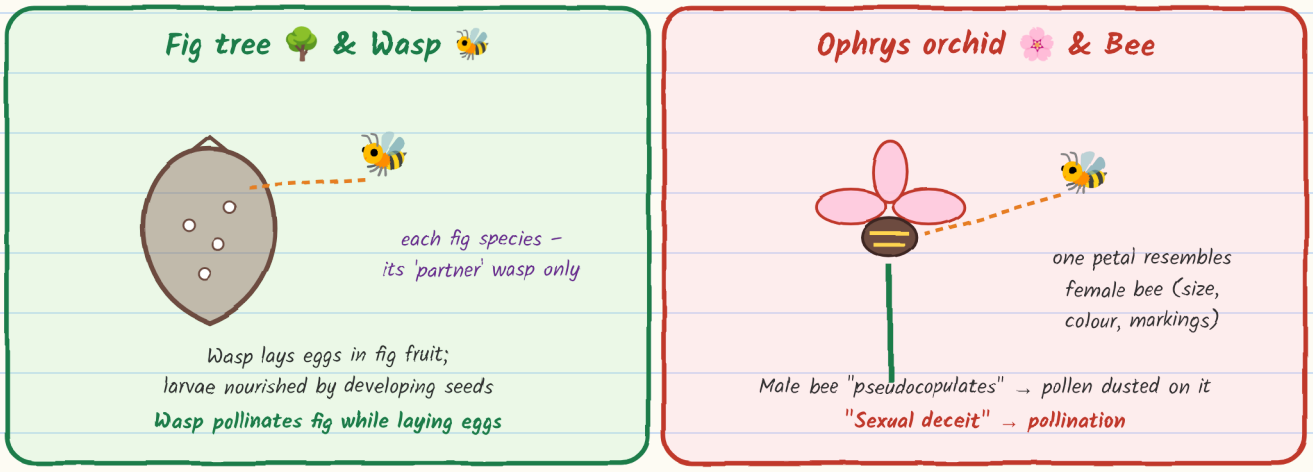
(b) Mutualism (+, +) सहोपकारिता

Interaction which **confers benefits on both** interacting species.

- *Lichens* represent an intimate mutualistic relationship between a **fungus** & **photosynthesising algae or cyanobacteria**.
- *Mycorrhizae* are associations between **fungi & roots of higher plants**. Fungi help plant in absorption of essential nutrients from soil, while plant in turn provides fungi with energy-yielding

carbohydrates.

- Most spectacular & evolutionarily fascinating examples of mutualism are found in **plant-animal relationships**. Plants need help of animals for **pollinating flowers & dispersing seeds**. Plants offer rewards or fees in the form of **pollen & nectar** for pollinators & **juicy & nutritious fruits** for seed dispersers.
- Mutually beneficial system should also be safeguarded against 'cheaters' (e.g. insects that might try to steal nectar without aiding in pollination) → plant-animal interactions often involve **co-evolution** of the mutualists.



Infographic: Mutualism – fig & wasp; Ophrys & bee

- **Fig trees & wasps**: many species of fig trees have tight one-to-one relationship with pollinator species of wasp. A given fig species can be pollinated **only by its 'partner' wasp species** and no other species. Female wasp uses the fruit not only as an **oviposition (egg-laying) site** but also uses the developing seeds within the fruit for **nourishing its larvae**. Wasp pollinates fig inflorescence while searching for suitable egg-laying sites. In return for favour of pollination, fig offers the wasp some of its developing seeds as food for developing wasp larvae.
- **Orchids** show a bewildering diversity of floral patterns, many of which have evolved to attract the right pollinator insect (bees & bumblebees) & ensure guaranteed pollination.
- **Mediterranean orchid** ***Ophrys*** employs 'sexual deceit' to get pollination done by a species of bee. One petal of its flower bears an uncanny resemblance to the **female of the bee** in size, colour & markings. The male bee is attracted to what it perceives as a female, **'pseudocopulates'** with the flower, & during that process is dusted with pollen from the flower. When this same bee 'pseudocopulates' with another flower, it transfers pollen to it & thus pollinates the flower.
- If the female bee's colour patterns change even slightly for any reason during evolution, pollination success will be reduced unless the orchid flower **co-evolves** to maintain resemblance of its petal to the female bee.

⚡ Quick Revision / त्वरित पुनरावृत्ति

Keyword	Remember
Birth rate example	8/20 = 0.4 offspring per lotus per year
Death rate example	4/40 = 0.1 per fruit fly per week
N_{t+1}	$N_t + [(B + I) - (D + E)]$
Exponential	$dN/dt = rN$; $N_t = N_0e^{rt}$; J-shaped
Logistic (Verhulst-Pearl)	$dN/dt = rN(K-N)/K$; S-shaped
r values	Norway rat 0.015; flour beetle 0.12; India 1981 – 0.0205
Breed once	Pacific salmon, bamboo
Prickly pear cactus	Australia 1920s – controlled by cactus-feeding moth
Pisaster	Starfish predator; removal → 10+ species extinct
Monarch butterfly	Distasteful – chemical from poisonous weed
Calotropis	Cardiac glycosides
Abingdon tortoise	Extinct due to goats (Galapagos)
Balanus vs Chthamalus	Connell – Scotland
Gause	Competitive exclusion principle
MacArthur	5 warbler species – resource partitioning
Human liver fluke	2 intermediate hosts – snail & fish
Cuscuta	Parasitic plant (no chlorophyll)
Koel & crow	Brood parasitism
Clown fish & sea anemone	Commensalism
Ophrys	Sexual deceit – pseudocopulation

⭐ Exam Corner / परीक्षा उपयोगी प्रश्न

1-Mark Questions 1M

Q1. Define population. / समष्टि की परिभाषा दीजिए।

→ Group of individuals of a species in a well-defined area that share/compete for resources & potentially interbreed.

Q2. What does 'r' represent in the equation dN/dt = rN?

→ Intrinsic rate of natural increase.

Q3. Name an organism that breeds only once in its lifetime.

→ Pacific salmon fish / bamboo.

Q4. Give an example of brood parasitism.

→ Koel (cuckoo) laying eggs in crow's nest.

Q5. Which plant produces cardiac glycosides as a defence?

→ Calotropis.

Q6. Write the interaction sign for commensalism and amensalism.

→ (+, 0) and (−, 0).

Q7. How are tigers counted in a census?

→ Indirectly, using pug marks & fecal pellets.

2/3-Mark Questions 2–3M

Q8. In a pond, there were 20 Hydrilla plants. Through reproduction 8 new plants were added in a year. Calculate the birth rate.

→ 8/20 = 0.4 offspring per plant per year.

Q9. Draw and explain the three types of age pyramids.

→ Expanding (broad base), stable (bell-shaped), declining (narrow base).

Q10. Why is per cent cover or biomass sometimes a better measure of population density than number?

→ e.g. 200 Parthenium vs one huge banyan tree; numbers underestimate banyan's role.

Q11. Differentiate exponential and logistic growth.

→ See comparison table (resources, curve, equation, K).

Q12. Explain the role of predators in an ecosystem with examples.

→ Energy transfer; control prey (prickly pear & moth); maintain diversity (Pisaster); biological control.

Q13. State Gause's competitive exclusion principle. How do species co-exist despite competition?

→ Statement; resource partitioning (MacArthur's warblers).

Q14. List four adaptations of parasites.

→ Loss of sense organs, suckers/adhesive organs, loss of digestive system, high reproductive capacity.

Q15. Explain the mutualism between fig and wasp.

→ Partner wasp pollinates fig while laying eggs; fig provides seeds as larval food.

Q16. How does the Mediterranean orchid Ophrys ensure pollination?

→ Sexual deceit; petal resembles female bee; male bee pseudocopulates; pollen transfer.

5-Mark Questions (5M) ★★★

Q17. Describe exponential and logistic growth models with equations and curves. Which is more realistic and why?

→ $dN/dt = rN$ (J-curve), $dN/dt = rN(K-N)/K$ (S-curve); logistic more realistic as resources are limited.

Q18. Explain how prey defend themselves against predators.

→ Camouflage, distastefulness (Monarch), thorns (Acacia, Cactus), chemicals (Calotropis, nicotine, caffeine, quinine...).

Q19. Describe the various population interactions with one example each.

→ Mutualism (lichens), competition (flamingo & fish), predation (tiger–deer), parasitism (Cuscuta), commensalism (orchid on mango), amensalism.

Q20. What is competition? Give evidences of competition in nature.

→ Definition (fitness 'r' lower); flamingoes & fishes; interference competition; Abingdon tortoise; Connell's barnacles; competitive release; Gause; MacArthur.

✏ **Diagrams to practise / अभ्यास हेतु चित्र:**

1. Age pyramids – expanding, stable, declining ⭐
2. Population growth curves – exponential & logistic ⭐

🎯 **Last-minute tips:** Write equations neatly with all terms defined · Use **(+,+)/(+,–)** signs while naming interactions · Learn NCERT examples by name (Pisaster, Balanus, Abingdon tortoise, Ophrys, Calotropis) · Birth/death rate numericals: per capita = new births ÷ initial population.

~ All the best! / शुभकामनाएँ! ~