Collegedunia NCERT Formula Sheet

Class 12 Biology (12th) — NCERT 2026-27 / Latest Edition

Chapter 11: Organisms and Populations

Quantitative ecology — abiotic factors, population attributes, growth equations, life-table arithmetic, interactions

Also see for this chapter: NCERT Solutions | Revision Notes | Exemplar Solutions

Chapter-Wide Key Quantitative Reference

Parameter / Symbol	Typical Value / Range	Biological Significance
Avg. solar constant at top of atmosphere	≈ 1361 W/m^2	Drives temperature & photosynthesis budgets
Thermal tolerance of most organisms	0–$45\,°$C	Eurythermal vs stenothermal classification
Salinity of fresh water / sea / hypersaline	< 5 / 30–35 / > 100 parts per thousand (ppt)	Euryhaline vs stenohaline classification
Hot springs / hydrothermal vents (Archaea)	up to 100–$115\,°$C	Thermophiles — enzymes are heat-stable
Polar / deep-sea / cold (psychrophiles)	$< 5\,°$C	Membrane lipids stay fluid
Human body core temperature	$\approx 37\,°$C (± 0.5)	Endothermic regulator
Allen's rule (mammals)	Polar mammals: shorter ears & limbs	Reduces surface area $\Rightarrow$ less heat loss
Kangaroo rat water budget	meets all need via internal fat oxidation	Extreme conformer-to-regulator adaptation
Population growth rate symbol r	$r = b - d$ (per capita; per individual per unit time)	Intrinsic rate of natural increase
Carrying capacity symbol K	habitat-specific maximum sustainable N	Asymptote of logistic curve
Sex ratio (humans, ideal)	$\approx 1{:}1$	Departures flag selective pressures
Age-pyramid classes	pre-reproductive / reproductive / post-reproductive	Shape predicts future N

1 11.1 Organism and Its Environment

This section frames **ecology** as the study of organism–environment interactions across four levels (organism, population, community, biome), and lists the major abiotic factors — temperature, water, light, soil — with their quantitative ranges.

Levels of biological organisation in ecology

Level	Definition
Organism	Individual; lowest level studied in ecology
Population	Group of *interbreeding* individuals of the same species in a defined area
Community	All populations of different species sharing a habitat
Biome	Major regional community defined by climate + vegetation (tundra, desert, etc.)

Each higher level emerges from the lower one. NCERT Ch 11 focuses on the first two; Ch 12 (Ecosystem) and Ch 13 (Biodiversity) cover the upper two.

Major abiotic factors — ranges

Factor	Typical range / unit	Why it matters
Temperature	-70 to $+115\,°$C on Earth	Sets enzyme kinetics; basal metabolic rate
Water (rainfall)	<25 cm/yr (desert) to >200 cm/yr (rainforest)	Limits productivity; defines biomes
Salinity	<5 ppt (fresh) to >100 ppt (hypersaline)	Drives osmoregulation
Light (PAR)	0 to $\sim 2000\ \mu$mol/m^2/s	Photosynthesis ceiling; photoperiod cues
Soil pH	~ 3 (peat) to ~ 10 (saline)	Nutrient availability; microbial activity

Each factor has a **tolerance range** (the band an organism can survive in) and an **optimum** (the band of peak performance). Organisms with wide ranges are prefixed **eury-**; narrow ranges, **steno-**.

Habitat vs Niche — the textbook distinction

Habitat = the physical place an organism lives ('address'). **Ecological niche** = the functional role of the species in that habitat — the full set of conditions (temperature, food, refuge, time of activity) + resources it uses + impacts it has ('profession'). *Two species in the same habitat occupy different niches* (Gause's competitive exclusion). The niche includes both *fundamental* (entire range without competitors) and *realised* (actual range with competitors) niches.

Eury- vs Steno- prefixes — quick decoder

Eury- = wide range; **Steno-** = narrow range. Apply to any abiotic factor: **eurythermal** / **stenothermal** (temperature), **euryhaline** / **stenohaline** (salinity), **euryhydric** / **stenohydric** (water), **euryphagic** / **stenophagic** (food).

2 11.2 Major Abiotic Factors & Responses

Four named ways an organism can cope with a stressful abiotic factor — **regulate**, **conform**, **migrate**, **suspend** — with adaptations underpinning each.

Four responses to abiotic stress

Response	Mechanism (with examples)
Regulate	Maintain constant internal milieu by physiological / behavioural means. Birds + mammals + few invertebrates (homeostasis).
Conform	Internal state varies with the external. $\sim 99\%$ of animals + nearly all plants. Cheaper energetically, but range is narrower.
Migrate	Move away temporarily to a hospitable habitat. Siberian crane $\rightarrow$ Keoladeo NP.
Suspend	Halt activity until conditions improve. Bears **hibernate** (winter); snails / fish **aestivate** (summer); zooplankton enter **diapause**; bacteria / fungi / plants form **spores / seeds / thick-walled cysts**.

Strategy choice depends on size, mobility, and energy budget. Small organisms rarely regulate — the surface-to-volume ratio makes heat / water loss prohibitive.

Surface-area-to-volume scaling — why size matters

For a sphere of radius r: $S = 4\pi r^2$, $V = \frac{4}{3}\pi r^3$

$$\frac{S}{V} = \frac{3}{r}$$

Smaller body $\Rightarrow$ **larger** S/V $\Rightarrow$ **faster heat & water loss** per unit mass. This is why tiny endotherms (shrews, hummingbirds) need enormous food intake and why polar mammals are large (**Bergmann's rule**) with short ears & limbs (**Allen's rule**).

Altitude sickness — atmospheric p_{O_2}

$p_{O_2}(\text{altitude}) = 0.21 \times P_{\text{atm}}(\text{altitude})$

Sea level: $P \approx 101$ kPa $\Rightarrow p_{O_2} \approx 21.2$ kPa.

At 3500 m: $P \approx 65$ kPa $\Rightarrow p_{O_2} \approx 13.7$ kPa ($\sim 65\%$ of sea-level).

Lowland visitor at altitude experiences **altitude sickness** (nausea, fatigue). The body acclimatises by raising **RBC count, breathing rate** and lowering haemoglobin's affinity for O_2 so that more is released to tissues.

Adaptations — definition & examples

An **adaptation** is any morphological, physiological, or behavioural attribute that boosts survival or reproduction in a habitat. Examples: *kangaroo rat* (Arizona) survives without drinking — meets all water need by metabolic oxidation of fat. *Desert plants* use **CAM photosynthesis** (stomata open at night) + thick cuticles + sunken stomata + spines instead of leaves. *Mammals in cold climates* use **blubber, fur, smaller ears** (Allen's rule), and *larger body size* (Bergmann's rule). *Fish at* ≥ 500 *m depth* have specialised enzymes and gas-filled bladders that withstand pressure.

Regulator vs Conformer — watch the % claim

NCERT states "**99%** of animals and nearly all plants are conformers." Only birds, mammals, and a few lower vertebrates / invertebrates are **regulators**. Don't claim "all mammals are regulators" as the converse of conformers — conformers vastly outnumber regulators.

3 11.3 Population Attributes

A **population** is more than the sum of its parts — it has *group-level attributes* that no individual can possess. Densities are estimated, rates are per capita, and age structures are graphed as pyramids.

Population density — definition & estimators

Density:

$$D = \frac{N}{A}$$

where N = number of individuals; A = area (or volume).

Per cent cover: when counting is impractical (e.g. banyan dominating a community), use the proportion of ground covered.

Relative density (proxy): trap counts per night, dung pellets per square, fish catch per net haul — valid for comparison even without absolute N.

Sometimes **biomass** is more meaningful than count — 200 *Lantana* bushes weigh less than 1 giant banyan, so the banyan "dominates" though density is lower.

Natality (birth) and mortality (death) rates

Crude birth rate (per capita): $b = \dfrac{B}{N \cdot \Delta t}$

Crude death rate (per capita): $d = \dfrac{D}{N \cdot \Delta t}$

where B, D = total births / deaths during interval Δt; N = average population during Δt.

NCERT worked example (lotus pond): 20 adults in $t = 0$, 8 new lotuses produced over a week $\Rightarrow b = 8/20 = 0.4$ offspring per lotus per week.

Per capita rates remove population-size bias — 8 births among 20 vs 8 among 200 tell very different stories.

Sex ratio and age distribution

Sex ratio = (# females) : (# males), or as % females. Departures from $1{:}1$ signal selection, infanticide, or differential mortality.

Age distribution = % of N in each age class. Three classes in NCERT:

pre-reproductive (PR), reproductive (R), post-reproductive (P).

Plotted as an age pyramid:
Expanding — broad PR base, narrow apex $\Rightarrow$ growing N
Stable — vertical sides $\Rightarrow$ steady N
Declining — narrow PR base, wide R/P $\Rightarrow$ shrinking N

Age structure is a **predictor of the next generation's size** — a broad pre-reproductive base guarantees future growth even if today's r is small.

Four population attributes — one-look summary

Attribute	Definition / formula
Density (N/A)	Individuals per unit area / volume
Birth rate (b)	Per capita births per unit time
Death rate (d)	Per capita deaths per unit time
Sex ratio	Females : males (or % females)
Age distribution	% in each age class (pre-, reproductive, post-reproductive)

These five together let you write the population equation in the next section — N at $t+1$ depends on density, both rates, sex ratio, and the age pyramid.

Birth rate $\neq$ change in population

A high birth rate does not guarantee population growth — death rate may be equally high. *Per capita growth rate* $r = b - d$ is the controlling quantity. If $b = d$, N is constant; if $b < d$, N shrinks.

4 11.4 Population Growth — Equations

Two textbook models drive this whole chapter. **Exponential growth** is the unconstrained ideal — resources unlimited. **Logistic growth** is what real populations follow once they bump into the carrying capacity K.

Population change equation — master form

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

where N_t = population at time t; B = births; I = immigrants; D = deaths; E = emigrants (all during $[t, t+1]$).

B and I *add*; D and E *subtract*. In closed populations $I = E = 0$, leaving only $B - D$ — the basis for the per-capita rate r.

Intrinsic rate of natural increase, r

$r = b - d$ (per capita; units: per individual per unit time)

Continuous-time growth:

$$\frac{dN}{dt} = (b - d)\,N = rN$$

r is the **intrinsic** rate of natural increase — a hallmark of the species in a given habitat. Norway rat: $r \approx 0.015$; flour beetle: $r \approx 0.12$; human (1981, India): $r \approx 0.0205$.

Exponential (geometric) growth — no resource limit

Differential form:

$$\frac{dN}{dt} = rN$$

Integrated form:

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

where N_0 = population at $t = 0$; $e \approx 2.71828$ (Euler's number).

Doubling time:

$$t_2 = \frac{\ln 2}{r} \approx \frac{0.693}{r}$$

Plot of N vs t is a **J-shaped curve**. Holds only briefly — food, space, or competitors eventually cap growth. The integrated form is critical for predicting bacterial / pest population sizes.

Logistic (Verhulst–Pearl) growth — resource-limited

$$\frac{dN}{dt} = rN\left(\frac{K - N}{K}\right)$$

where K = carrying capacity (max N the habitat can sustain).

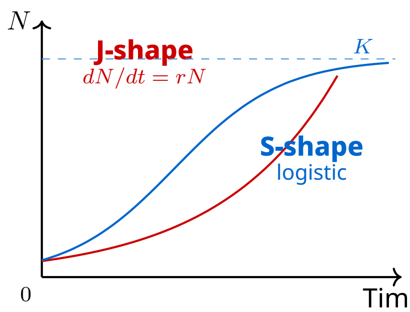
Integrated form: $N_t = \dfrac{K}{1 + \left(\dfrac{K - N_0}{N_0}\right) e^{-rt}}$

Plot of N vs t is a **sigmoid (S-shaped) curve**: slow start $\rightarrow$ near-exponential mid-phase $\rightarrow$ asymptotic plateau at K. The factor $(K - N)/K$ is **environmental resistance** — it drops to 0 as $N \rightarrow K$, halting growth.

Exponential vs Logistic — side-by-side

Property	Exponential	Logistic
Equation	$dN/dt = rN$	$dN/dt = rN(K - N)/K$
Integrated form	$N_t = N_0 e^{rt}$	sigmoid (see above)
Resources	Unlimited	Limited (K finite)
Curve shape	**J-shaped**	**S-shaped (sigmoid)**
Long-term N	$\to \infty$	$\to K$ asymptote
Realism	Brief windows only	More realistic for real ecosystems

NCERT calls the logistic model "more realistic" because no real habitat has unlimited resources — food, light, water, and territory always cap N at some K.



J vs S curves. Exponential (red) climbs without bound; logistic (blue) plateaus at carrying capacity K.

JEE/NEET extension — inflection point of logistic curve

The sigmoid's **inflection point** (steepest slope) sits at $N = K/2$, where $dN/dt = rK/4$ is the **maximum sustainable yield** (used in fisheries / forestry). Harvesting a population at $N = K/2$ removes individuals at the population's fastest replacement rate.

JEE/NEET extension — r, K selection

r**-selected** species: small body, short life, many small offspring, little parental care, high r (insects, weeds, bacteria). K**-selected** species: large body, long life, few large offspring, parental care, density near K (elephants, whales, humans). Tradeoff between **quantity** and **quality** of offspring.

r is a per-capita rate — don't multiply by N twice

r is defined as $b - d$ *per individual per unit time*. When writing $dN/dt = rN$, the N is the total population. Do NOT plug in $r \times N$ for b and again multiply by N — you'll double-count and end up with $dN/dt = rN^2$. Same caution applies inside the logistic term $rN(K - N)/K$ — the factor $(K - N)/K$ is dimensionless.

J vs S — 5-second recall

"J = Just go!" — unlimited resources, climbs forever.

"S = Slows at K" — the S literally sits down at the top, touching the carrying-capacity ceiling.

5 11.5 Life History & Life-Table Arithmetic

Evolution shapes **life-history traits** (when to breed, how many offspring, how often) to maximise lifetime reproductive output (fitness). Life tables condense survivorship + fecundity data; the net reproductive rate R_0 summarises both.

Life-history traits — evolved by natural selection

Traits selected for maximum Darwinian **fitness** (R_0 or r):

- Age at first reproduction (early vs late)
- Number of reproductive events — **semelparous** (one-shot: Pacific salmon, bamboo) vs **iteroparous** (repeated: humans, birds)
- Number of offspring per event (few large vs many small)
- Parental care (yes vs no)

No single combination is "best" — each is optimised by selection for the habitat. Oysters spawn millions of small eggs; great apes have one large offspring with years of care.

Life-table columns — standard symbols

Symbol	Meaning
x	Age class (e.g. 0–1 yr, 1–2 yr, ...)
n_x	Number alive at start of age x
l_x	Survivorship from birth to age x, $l_x = n_x/n_0$
d_x	Deaths during age x, $d_x = n_x - n_{x+1}$
q_x	Age-specific mortality, $q_x = d_x/n_x$
m_x	Per-capita fecundity (offspring per individual in age x)
$l_x m_x$	Realised reproduction (survivors $\times$ fecundity)

Life tables read top-to-bottom for one cohort. They are the bread-and-butter quantitative tool of demography.

Net reproductive rate, R_0

$$R_0 = \sum_{x=0}^{\infty} l_x\, m_x$$

Interpretation: expected lifetime number of female offspring per newborn female.

Decision rule:
$R_0 > 1 \Rightarrow$ population **grows**
$R_0 = 1 \Rightarrow$ population **stable**
$R_0 < 1 \Rightarrow$ population **declines**

R_0 collapses survivorship $\times$ fecundity into a single number — the demographic "bottom line." It is the discrete-generation equivalent of r in the differential model.

Survivorship curves — three types

Type	Shape & example
Type I	High survival in young + middle ages; sharp drop in old age. *Humans, large mammals.*
Type II	Constant mortality rate at every age (linear when l_x plotted on log). *Birds, small mammals, hydra.*
Type III	Heavy juvenile mortality; survivors live long. *Oysters, fish, most invertebrates with many small offspring.*

NCERT shows Type I and Type III as the two textbook extremes; Type II is the linear middle case. Plot is **log** l_x vs age x — curves differ in shape, not just scale.

JEE/NEET extension — generation time T and r link

Mean generation time: $T = \dfrac{\sum x\, l_x\, m_x}{R_0}$

Approximate intrinsic rate: $r \approx \dfrac{\ln R_0}{T}$

Lets you convert a life-table R_0 into the continuous-time growth rate r used in $dN/dt = rN$. Useful for matching demography to growth-curve fits.

6 11.6 Population Interactions

Six named interactions are classified by the sign of fitness effect (**+**, **–**, **0**) on each partner. Memorising the signs and the standard textbook example for each is the entire NEET footprint of this section.

Interaction matrix — by sign of effect

Interaction	Sp. A	Sp. B	Textbook example
Mutualism	$+$	$+$	Lichen (alga + fungus); mycorrhiza; pollination
Competition	$-$	$-$	Galapagos finches vs Abingdon tortoise (Connell barnacles)
Predation	$+$	$-$	Lion–zebra; *Cactoblastis* moth–*Opuntia* cactus
Parasitism	$+$	$-$	Liver fluke; *Cuscuta* on hedge; cuckoo brood parasitism
Commensalism	$+$	0	Cattle egret + grazing cattle; barnacles on whales; orchid on mango
Amensalism	$-$	0	Penicillium suppressing bacteria; bread mold $\rightarrow$ *Staphylococcus* (rare in NCERT example list)

NCERT highlights five major types (mutualism, competition, predation, parasitism, commensalism). **Amensalism** is named but rarely tested.

Gause's competitive exclusion principle

Statement: two species competing for the same limiting resource cannot coexist indefinitely — the competitively inferior one is eliminated.

Mathematical version (Lotka–Volterra competition):

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{12} N_2}{K_1}\right)$$

$$\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \alpha_{21} N_1}{K_2}\right)$$

where α_{12}, α_{21} = competition coefficients.

Connell's barnacle experiment on Scotland's coast: in absence of *Balanus*, *Chthamalus* expanded into the lower intertidal — a direct demonstration that one species kept the other out by competition.

Predator–prey Lotka–Volterra equations

$$\frac{dN}{dt} = rN - aNP \quad \text{(prey)}$$

$$\frac{dP}{dt} = b\,aNP - mP \quad \text{(predator)}$$

where N = prey, P = predator; r = prey intrinsic rate; a = capture efficiency; b = predator conversion efficiency; m = predator death rate.

Solutions are **coupled oscillations** — prey peak first, predator peak follows, then prey crash, then predator crash. Lynx–hare 9–10 yr cycle in Canada is the classic field example.

Defences against predation & herbivory

Group	Strategy
Prey animals	Camouflage (cryptic colour), warning colouration (Monarch butterfly), mimicry, hard shells, spines
Plants	Thorns (*Acacia*, cactus); chemicals — nicotine, caffeine, quinine, strychnine, opium, cardiac glycosides; calotropin (*Calotropis*) which is so toxic that cattle never browse on it

Plants cannot run — chemical defence has evolved as the dominant strategy. About **25% of all prescription drugs** are originally plant antiherbivore compounds.

Brood parasitism — the cuckoo example

Cuckoo (*Cuculus* sp.) lays eggs in the nest of a **host** (e.g. crow) and lets the host incubate them.

Coevolved trickery: cuckoo egg matches host's egg in size and colour to escape detection.

One of the cleanest natural-selection demonstrations — hosts that detect-and-reject mismatched eggs select for ever-better mimicry by the parasite, fuelling a coevolutionary arms race.

Mutualism — three textbook examples

Lichen = mutualism of alga (or cyanobacterium) + fungus.
Mycorrhiza = fungus (*Glomus* etc.) wrapping plant root — fungus gets sugars, plant gets P and trace nutrients.
Pollination = flowering plant (*Ophrys*, fig) + animal pollinator (bee, fig wasp). Fig + fig wasp is obligate — neither survives without the other.

Commensalism — three textbook examples

Cattle egret + grazing cattle: cattle stir up insects, egret eats them; cattle unaffected.
Barnacles on whale skin: barnacles get transport + food-rich water; whale unaffected.
Orchids on mango tree: orchid gets a perch; mango unaffected.

JEE/NEET extension — coevolution case study

Fig–fig wasp obligate mutualism: each fig species is pollinated by a single wasp species. The wasp lays eggs only inside that fig's flower; the larvae feed on developing seeds but leave enough for fig propagation. Loss of either species causes loss of the other — classic **species-specific coevolution**.

JEE/NEET extension — *Ophrys* sexual deception

The Mediterranean orchid *Ophrys* mimics the female of a specific bee species in both shape and **pheromone**. Male bee attempts to copulate (**pseudocopulation**) and ends up carrying pollen to the next flower. When the bee evolves to ignore the deception, the orchid's pollination crashes — a striking demonstration of **coevolutionary mimicry**.

Commensalism vs Mutualism — the sign test

Commensalism = one benefits, the other is **unaffected** $(+, 0)$. Mutualism = **both** benefit $(+, +)$. The orchid–mango pair is commensalism (mango unchanged); the fig–wasp pair is mutualism (both depend on each other). The defining test is whether the "unaffected" partner truly has zero net fitness effect.

Six interactions — sign-string mnemonic

"MC-PPC-A" with sign string $(++, --, +-, +-, +\mathbf{0}, -\mathbf{0})$:
Mutualism $(+, +)$ | **C**ompetition $(-, -)$ | **P**redation $(+, -)$ | **P**arasitism $(+, -)$ | **C**ommensalism $(+, 0)$ | **A**mensalism $(-, 0)$.
Five tested: drop amensalism if running out of time in MCQ.

Read the Full Revision Notes

Quick Reference — All Equations & Symbols

Concept	Equation / Symbol	Where
Population change	$N_{t+1} = N_t + (B + I) - (D + E)$	§11.4
Per capita birth rate	$b = B/(N \cdot \Delta t)$	§11.3
Per capita death rate	$d = D/(N \cdot \Delta t)$	§11.3
Intrinsic rate of increase	$r = b - d$	§11.4
Exponential growth (diff.)	$dN/dt = rN$	§11.4
Exponential growth (integ.)	$N_t = N_0 e^{rt}$	§11.4
Doubling time	$t_2 = (\ln 2)/r \approx 0.693/r$	§11.4
Logistic growth (diff.)	$dN/dt = rN(K - N)/K$	§11.4
Logistic growth (integ.)	$N_t = K/[1 + ((K - N_0)/N_0)\, e^{-rt}]$	§11.4
Max sustainable yield	at $N = K/2$, $dN/dt = rK/4$	§11.4
Density	$D = N/A$	§11.3
Surface-to-volume (sphere)	$S/V = 3/r$	§11.2
Partial p_{O_2} at altitude	$p_{O_2} = 0.21 \times P_{\text{atm}}$	§11.2
Survivorship	$l_x = n_x/n_0$	§11.5
Age-specific mortality	$q_x = d_x/n_x$	§11.5
Net reproductive rate	$R_0 = \sum l_x m_x$	§11.5
Generation time (extension)	$T = (\sum x\, l_x m_x)/R_0$	§11.5
Approx. r from life table	$r \approx (\ln R_0)/T$	§11.5
Competition (Lotka–Volterra)	$dN_1/dt = r_1 N_1 (K_1 - N_1 - \alpha_{12} N_2)/K_1$	§11.6
Predator–prey (prey)	$dN/dt = rN - aNP$	§11.6
Predator–prey (predator)	$dP/dt = b\,aNP - mP$	§11.6

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