Unit 13 · Ecosystem Ecology

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Ecology (Units 13–15 together): 6 of 75 marks, 1 short answer and 1 MCQ; with Floral Diversity and Vegetation a combined 26
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** short (5): the structural and functional aspects of a **pond ecosystem**
- **MCQ (1 mark)**
  - autecology or synecology; meaning of *oikos*
  - kind of factor (rain shadow: topographic); role of a fungus (decomposer)
  - name an interaction from +, −, 0
  - trophic level of an animal; first link of a detritus chain
  - which pyramid is inverted; why energy's never is
  - NPP from GPP and R; bacteria of nitrification, denitrification
  - kind and step of succession
- **Short (in parts)**
  - who coined "ecology"; sunlight, temperature, rainfall as factors
  - positive interactions; mutualism vs protocooperation; predation; intra- vs interspecific
  - pond ecosystem: structure and function
  - succession: types and process; nitrogen cycle

Key terms

Ecology (*oikos* home + *logos* study): interrelationships between organisms and their environment; first used by **Ernst Haeckel** (1866); Reiter (1885) in a book title.

Autecology: one species and its environment; **synecology**: a community and its environment.

Ecological factor: any abiotic or biotic factor affecting living things.

Biotic community: all organisms of a place.

Ecosystem (**Tansley**, 1935): structural and functional unit of ecology; organisms interacting with each other and their environment.

Trophic level: position in a food chain or web.

Food chain: line of eating and being eaten; **food web**: chains joined in a network.

Detritus: dead organic matter and wastes.

Ecological pyramid: number, biomass or energy at successive trophic levels; producers at the base.

Productivity: rate of biomass production per area per time (g/m^2 year, kJ/(m^2 year)).

Biogeochemical cycle: cyclic movement of nutrients between abiotic environment and biotic community.

Succession: gradual replacement of communities to a stable **climax community**; **pioneer**, **seral stages**, **sere**.

Ecological factors

Abiotic

1. **climatic**
   - **sunlight**: most important; energy source; photosynthesis, chlorophyll, stomata (transpiration); in animals vision, daily and seasonal rhythms, pigmentation, metabolism, migration
   - **temperature**: enzymes work in a range; plants: transpiration, respiration, photosynthesis, germination, flowering, growth; animals: reproduction, color; **hibernation** (black bears), **aestivation** (snails, lungfish), **migration**
   - **pressure**: falls with height (Everest ~⅓ of sea level, ⅓ the oxygen a breath)
   - **rainfall**: type, density of vegetation; much all year → evergreen forest; little → **xerophytic**; Annapurna south slopes wet, Jomsom in the **rain shadow** almost a desert
   - **humidity**: rate of transpiration, so water uptake, photosynthesis
2. **topographic**: **altitude** (~6 °C cooler per 1,000 m), **latitude**, **slope**, **aspect** (south slope sunnier, drier: pine; north: mossy oak); act through climate
3. **edaphic** (*edaphos*, ground): soil texture, organisms, temperature, pH, air, water

- Nepal: < 100 m to 8,849 m in ~200 km: tropical sal to alpine meadow and snow

Biotic

- **producers**: green plants; in water **phytoplankton**, algae, water plants
- **consumers** (heterotrophs): **primary** (herbivores: rats, rabbits, deer, grasshoppers), **secondary** (frogs, insect-eating birds, dragonflies, small fish), **tertiary** (snakes, big fish, tigers, hawks)
- **decomposers**: bacteria, fungi; dead matter → CO_2, water, ammonia, minerals

Species interaction

- **intraspecific**: same species (tigers fighting, bees in a hive); **interspecific**: different (tiger and chital)

Interaction	Partner 1	Partner 2	Example
mutualism (symbiosis)	+	+ **obligatory**	*Rhizobium* + legume; mycorrhiza; lichen
protocooperation	+	+ **not obligatory**	bees and flowers; myna or drongo on a buffalo
commensalism	+	0	orchid (epiphyte) on sal; remora on a shark
colonization	same species in a colony		*Volvox*, *Nostoc*
social organization	same species, division of labor		bees, wasps, ants, termites
parasitism	+	– (not killed at once)	mosquito, leech, tapeworm, *Cuscuta*
predation	+	– (killed, eaten)	tiger and chital, frog and insect, owl and mouse
competition	–	– (same limited resource)	weeds and rice; tigers and leopards
amensalism	0	–	*Penicillium* and bacteria

- positive: one or both gain, neither harmed; negative: at least one harmed
- **herbivory** (cow and grass): part eaten, plant lives; put with predation (+, –)

Ecosystem

- integrated working unit of living things and surroundings; any size
- **terrestrial** (forest, grassland, desert), **aquatic** (pond, lake, river, sea)

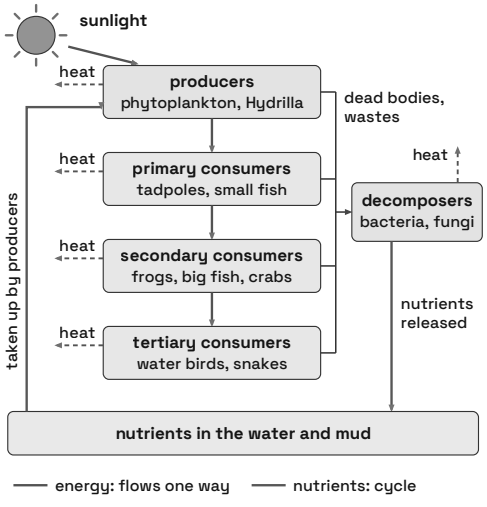
Pond ecosystem (self-sustaining, self-regulating)

Structure

- **abiotic**: water, dissolved minerals, O_2, CO_2, bottom mud, sunlight
- **producers**
  - **phytoplankton**: *Volvox*, *Spirogyra*, *Anabaena*, *Ulothrix*
  - **macrophytes**: *Chara*, *Hydrilla*, *Marsilea*, *Eichhornia*, *Lemna*
- **consumers**: primary (tadpoles, small fish, **zooplankton**, *Daphnia*); secondary (frogs, big fish, crabs); tertiary (egrets, kingfishers, water snakes, crocodiles)
- **decomposers**: bacteria, fungi in water and mud

Function

- plants turn **solar energy** → **chemical energy** of food (primary productivity)
- energy passes $T_1 \rightarrow T_2 \rightarrow T_3 \rightarrow T_4$ along a **food chain**; lost as **heat** at each step (respiration) → **one-way** flow
- **detritus** → detritus food chain; chains linked into a **food web**
- **nutrients** from water, mud, air → producers → consumers → decomposers → back: **biogeochemical cycling**



Pond: energy (red) flows one way, leaving as heat; nutrients (blue) cycle back to water and mud.

Forest ecosystem

- abiotic: soil, water, air, minerals, sunlight
- producers: trees, shrubs, herbs, climbers, lichens, mosses, algae

- consumers: primary (grasshoppers, caterpillars, rabbits, deer, monkeys, birds); secondary (wolves, jackals, frogs, lizards, birds); tertiary (tigers, leopards, hawks, eagles)
- decomposers in soil and litter; same energy flow and nutrient cycle
- sal litter → soil in 1–2 years; tropical forest nutrients mostly in plants and litter
- **energy flows** one way (sunlight in, heat out); **nutrients cycle**; an ecosystem needs constant sunlight, no new nutrients

Trophic levels and food chains

Level	Who	Forest	Pond
T_1	producers	grass, trees	phytoplankton, *Hydrilla*
T_2	primary consumers	grasshopper, deer	zooplankton, tadpoles
T_3	secondary consumers	frog, jackal	small fish, frog
T_4	tertiary consumers	snake, tiger, hawk	big fish, egret, snake

- omnivores at **several** levels (rice → T_2; fish of algae-eaters → T_4)
- seldom > 4–5 levels: ~10 % passes on; too little energy left
- arrows point from food to eater (way energy goes)

1. **grazing**: **living** plants → herbivores → carnivores; grass → chital → tiger; rice → grasshopper → frog → snake → eagle
2. **detritus**: starts from **dead matter**; leaves → earthworm → blackbird → hawk; more energy than grazing chain in a forest
3. **parasitic**: large host → smaller organisms on it; **hyperparasite**; tree → *Loranthus*; dog → fleas → *Leptomonas*

- **food web**: animals eat and are eaten by several kinds → switch foods → **stable**; more links, more stable

Ecological pyramids

	Number	Biomass	Energy
shows	number at each level	dry mass per m^2 (standing crop) at one moment	energy flow, kJ/(m^2 year)
grassland, pond	**upright**	grassland, forest **upright**	**always upright**
other shapes	forest **spindle** (one tree, many insects); parasitic chain, detritus chain **inverted**	pond, sea **inverted** (phytoplankton 4 g/m^2, zooplankton 21 g/m^2, English Channel)	never inverted
why	ignores size	phytoplankton eaten and replaced fast	heat lost at every step

- **ten percent law** (**Lindeman**, 1942, a lake): ~10 % to the next level (5–20 %); rest respiration, heat, uneaten
- e.g. rice 20,000 kJ → grasshopper 2,000 → **frog 200** → snake 20

Productivity

- **primary**: rate producers make organic matter
  - **GPP**: total made in photosynthesis
  - **NPP**: left after their respiration; available to herbivores, decomposers
  - NPP = GPP − R
- **secondary**: energy stored in consumers (growth, young)
- e.g. GPP 40,000, R 22,000 → NPP 18,000 kJ/(m^2 year), 45 %
- NPP (Whittaker, Likens 1975): rainforest ~2,200 g/m^2 year; farm ~650; open ocean ~125; desert ~90

Biogeochemical cycles

- elements: C, H, O, N, P, S, Ca…; structural or in enzymes; never used up
- **hydrological** (water); **gaseous** (reservoir air or sea: C, O, N); **sedimentary** (reservoir rocks, soil: P, Ca, S; slow, by weathering)

Carbon cycle

1. **photosynthesis**: $6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$; carbon enters the food chain
2. **respiration**: $C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O +$ energy
3. **decomposition**: CO_2; **methane** without oxygen (marsh, rice field)

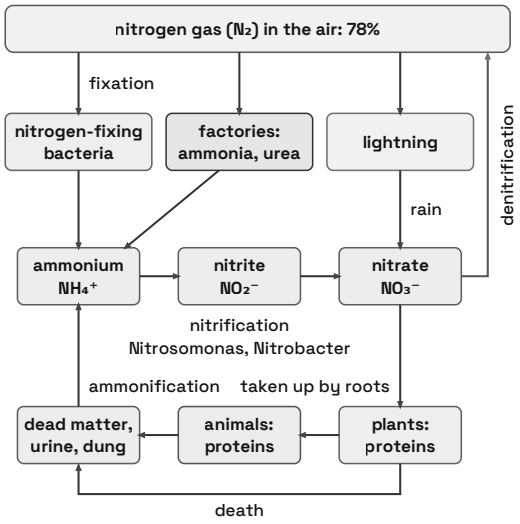
4. **combustion**: wood, fossil fuels (coal, oil, gas from buried remains); forests store carbon

- Keeling, Mauna Loa: 316 ppm (1959) → 427 ppm (2025)

Nitrogen cycle

- N in amino acids, proteins, DNA, RNA, chlorophyll, ATP, vitamins; air **78 %** N_2 (triple bond); plants take **NO_3^-** or **NH_4^+**

1. **fixation**: N_2 → usable compounds
   - **biological** (**nitrogenase**): symbiotic *Rhizobium* (legume nodules), *Anabaena* (*Azolla*), *Nostoc* (*Cycas*); free-living *Azotobacter*, *Clostridium*, cyanobacteria
   - **atmospheric** (lightning): $N_2 + O_2 \longrightarrow 2\,NO$; $2\,NO + O_2 \longrightarrow 2\,NO_2$; $4\,NO_2 + O_2 + 2\,H_2O \longrightarrow 4\,HNO_3$; $2\,HNO_3 + CaCO_3 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$
   - **industrial** (**Haber**, ~450 °C, ~200 atm, Fe): $N_2 + 3\,H_2 \rightleftharpoons 2\,NH_3$ → urea, ammonium sulphate, ammonium nitrate; Nepal imports all urea
2. **assimilation**: plants take NO_3^-, NH_4^+ → amino acids, proteins, nucleic acids → animals
3. **ammonification**: dead bodies, urine, dung → **ammonia** (*Bacillus ramosus*, *B. mycoides*, *Proteus vulgaris*); $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
4. **nitrification** (chemosynthetic bacteria)
   - $2\,NH_4^+ + 3\,O_2 \longrightarrow 2\,NO_2^- + 2\,H_2O + 4\,H^+$ (*Nitrosomonas*)
   - $2\,NO_2^- + O_2 \longrightarrow 2\,NO_3^-$ (*Nitrobacter*)
5. **denitrification**: **nitrate** → N_2 ($NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$); *Pseudomonas*, *Thiobacillus denitrificans*; **waterlogged** soils; N_2O a greenhouse gas
6. **sedimentation**: nitrate **leached** to rivers, sea, rocks; back only by weathering



Nitrogen cycle: fixation, nitrification, assimilation, ammonification, denitrification.

Succession

- causes: erosion, landslides, deforestation, fire, floods, volcanoes; driven by interactions and climate

Primary	Secondary
no soil, no life before	soil exists; life removed
bare rock, lava, dunes, glacier ground	abandoned field, burnt forest, landslide with soil
pioneers: **lichens**, then mosses	mosses, grasses, herbs (seeds, roots in soil)
very slow (centuries)	faster (decades)

Process

1. **nudation**: bare area formed (natural or human)
2. **invasion**: **migration** (seeds, spores arrive) → **ecesis** (germinate, grow) → **aggregation** (increase, group)
3. **competition and coaction**: for light, water, nutrients; species affect each other
4. **reaction**: organisms **change their environment** (humus, water, shade) → replaced by new species
5. **stabilization**: **climax community**

- rock sere: lichens → mosses → grasses, herbs → shrubs → trees (climax forest)
- Krakatau (1883): ferns, mosses by 1886; forest, ~270 plants by the 1930s
- Nepal: abandoned hill terraces back to forest; community forests

COMMON MISTAKES

✗ Reiter coined "ecology"
✓ **Haeckel** first used it (1866); Reiter in 1885.

✗ Energy cycles in an ecosystem
✓ energy **flows one way**; **nutrients** cycle.

✗ Pyramid of energy can be inverted
✓ **always upright**: heat lost at every step.

✗ Pyramid of number of a forest is upright
✓ **spindle-shaped** (one tree, many insects).

✗ Mutualism and protocooperation are the same
✓ both gain, but mutualism is **obligatory**.

✗ Denitrification turns ammonia into N_2
✓ it starts from **nitrate**.

✗ NPP is the total made by plants
✓ that is GPP; **NPP = GPP − R**.

✗ Primary succession starts on abandoned fields
✓ that is **secondary**; primary starts with **no soil**.