ECOLOGY

Ecology is the study of the relationship of living organisms with each other and their non-living environment. The study of ecology lays a foundation for understanding agriculture, forestry, fisheries, conservation, impact of human activities on the ecosystem and how to remedy these impacts.

Components of the Environment

These are the ***biotic*** and ***abiotic*** components.

Abiotic components

These are the ***nonliving things*** in an ecosystem that influence living organisms on land (terrestrial) and in water (aquatic) ecosystems. The major abiotic components are soil, air and light.

The non-living part of an ecosystem forms the abiotic environment.

The variations in the physical and chemical factors in the abiotic components that influence the activities of living organisms are the ***abiotic factors.***

Examples of abiotic factors:

i) **Climatic factors;** which include temperature, light, wind, humidity and rainfall.

ii) **Topography**; which refers to the nature of the landscape, which includes features like mountains, valleys, lakes etc.

iii) **Soil (edaphic) factors;** which include soil pH, soil air, inorganic particles, soil water, organic matter (dead organic matter and living organisms) and soil temperature.

iv) Other physical factors like fire and wave action on water bodies.

Effects of abiotic factors in ecosystems

1) Climatic factors:

i) Temperature: This affects physiological processes like respiration, photosynthesis, and growth in organisms which in turn influence their distribution.

- Alternate heating and cooling of rocks cause air to break and crack into small pieces and finally form soil.
- Very high or very low temperature changes in turn may result into migration of organisms like birds to avoid over heating or freezing.
- Low temperatures inactivate enzymes while excessive temperatures denature enzymes.
- High temperature increase transpiration and sweating.
- Low temperatures break dormancy of some plants.
- Temperatures stimulate flowering in some plants e.g. cabbage (vernalisation).
- Exposure to low temperature (stratification) stimulate germination in some seeds after imbibition.

ii) Rain fall: Amount of rainfall in a given area determines the abundance, distribution and types of plants in the area. The ecological significance of water include:

- Habitat for many aquatic organisms e.g. frogs, fish etc.
- Raw material for photosynthesis the main energy source for body processes of other organisms.
- It has a high latent heat of vaporization therefore acting as cooling agent for terrestrial organisms e.g. plants during transpiration and some animals during sweating.
- Agent for fruit, seed, spore, larva and gamete dispersal**.**

- It is required for seeds to germinate**.**
- Important factor in decay and decomposition; therefore increases recycling of nutrients in an ecosystem.

iii) Humidity:

- Amount of water in the atmosphere affects the rate at which water evaporates from organisms i.e. low humidity results into increasing evaporation while high humidity causes low rate of evaporation through stomata of leaves in plants. This affects distribution and abundance of specific plant species.
- Controls other activities of animals like feeding, hunting, and movements e.g. earth worms experience a larger ecological niche when the environment is humid.

iv) Wind/air currents:

It influences or affects the following:

- Dispersal or migration of flying mammals, winged insects; thus reducing the level of competition.
- Pollination.
- Dispersal of seeds and spores; increasing the spread of non-motile organisms e.g. fungi and some bacteria.
- Takes part in rain formation, current and wave formation in seas and lakes which enables distribution of mineral salts and oxygen in water bodies.
- Increase transpiration; thus promoting water and mineral salt uptake from the soil by plant roots.
- Increases evaporation and reduces sweating.
- Causes physical damage to vegetation and soils e.g. soil erosion.
- Increases water mixing thereby increasing dissolution of oxygen in aquatic bodies; this increases aerobic activities of organisms.

v) Light (intensity, quality and duration): Influences many physiological activities of organisms i.e.

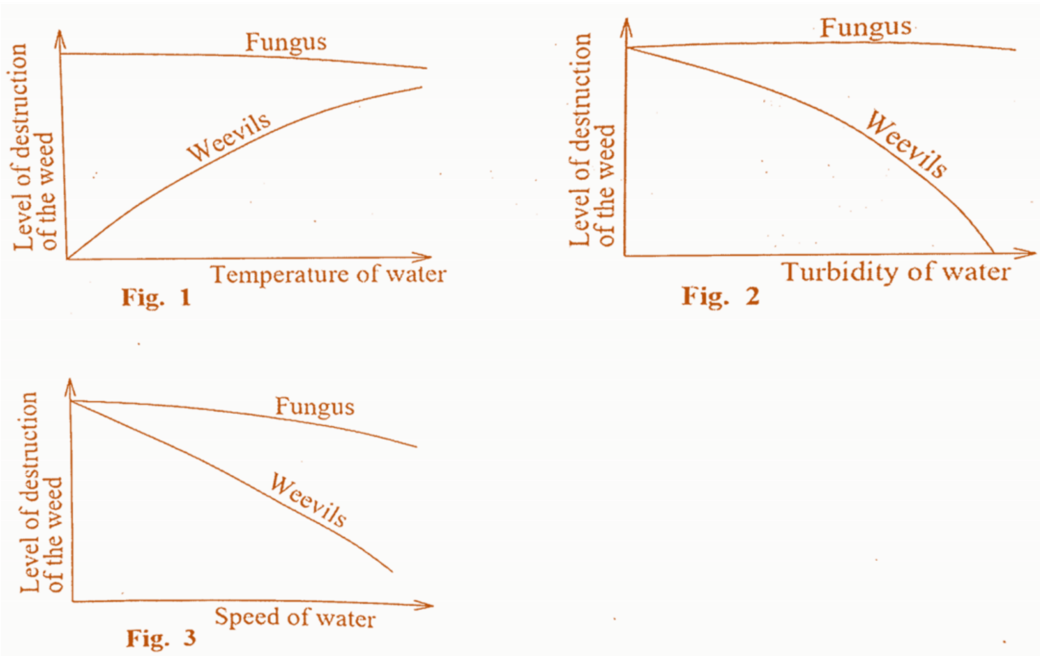
- It is a source of energy for photolysis (breakdown of water during photosynthesis).
- Induces flowering in long-day plants e.g. barley, but inhibits flowering in short day plants.
- Brings about stomatal opening in plants.
- Hunting and killing of prey by predators require certain levels of illumination and visibility.
- Courtship; with some animals preferring light so as to carry out courtship while others prefer darkness.
- Light breaks dormancy of seeds.
- Stimulates synthesis of vitamin D in mammals; where lipids (sterols) in the dermis are converted to vitamin D by UV light.
- Absence of light results in failure of chlorophyll formation in plants; a condition known as ***chlorosis*** i.e. plant remains yellow, and leaves fail to expand. It is also caused by iron deficiency and disease.
- Photoperiod affects migratory and reproductive behaviour in various animals e.g. sunlight polarized by water acts as a compass for migration of salmon fish.
- Necessary for the germination of certain seeds e.g. lettuce.

Sample question:

The water hyacinth Echhornia crassipes is a weed growing on many waters of Uganda. In the biological control of the weed on Lake Victoria, a fungal pathogen and weevils are employed. The characteristics of the fungus and the weevils in relation to their feeding behaviour is shown in Table **1**. Table **1**

Fungus	Weevils
Feeds on the water hyacinth alone	May feed on other plants other than the water hyacinth
Attacks only the green parts of the plant	Attacks all parts of the plant

The level of destruction of the weed by the fungus and the weevils under varying water conditions in temperature, turbidity and speed of water are shown in figures **1**, **2** and **3**. Study the information and answer the questions that follow.



a) From figure **1**, **2** and **3**, describe the level of destruction of the weed by each of the organisms under different conditions of water.

(i) Fungus

- *Level of destruction slightly decreases with increase in temperature.*
- *Level of destruction slightly decreases with increase in turbidity.*
- *Level of destruction drops slightly with increasing speed of water.*

(ii) Weevils

- *Effect of weevils increases with increase in temperature.*
- *Effect of weevils decreases with increasing turbidity.*
- *Effect of weevils decreases with increasing speed of water.*

b) From the information provided, suggest explanations for the level of destruction of the weed by each organism under different conditions of water.

i) Fungus

- *The fungus attacks the green part of the water hyacinth most of which is outside the water so is not affected by varying temperature of the water.*
- *Turbidity which reflects the quality of water in terms of dissolved oxygen does not affect the damage of the fungus because most of it is outside the water.*

- *The speed of water slightly reduces the effect of the fungus because moving water may cause brushing of leaves against each other thereby brushing off some amount of fungus from leaves.*

ii) Weevils

- *Weevils attack all parts of the water hyacinth thus warm temperatures increase their metabolic activity leading to increased feeding.*
- *Turbidity reduces activity of weevils because the higher the turbidity the less the amount of dissolved oxygen which reduces the metabolic activity of weevils. It also reduces visibility of edible parts of the plant.*
- *The faster the speed of the water the less the effect of weevils because fast moving water may dislodge or drown some weevils attached onto the water hyacinth plant together with their leaves.*

2) **Topography**: Refers to the nature of the landscape, which includes features like mountains, valleys, lakes etc.

- High altitude is associated with low atmospheric pressure, low average temperatures, increased wind speed, decreased partial pressures of oxygen, thus few organisms live permanently there.
- Slope reduces water logging and there is a lot of soil erosion preventing proper plant establishment especially at steep slopes.
- At low altitudes, average temperatures are high, high atmospheric pressure, partial pressures of oxygen are high, and in some places there is water logging thus very many species live permanently there.

3) **Edaphic (soil) factors:**

i) Soil pH:

- Influences physical properties of soil and availability of certain minerals to plants, thus affecting their distribution in soil; i.e. tea and coffee plants thrive well in acidic soils.
- Affects activity of decomposers e.g. in acidic medium, the rate of decomposition is reduced, subsequently recycling of matter in an ecosystem reduces.

ii) Water content:

- Presence of water which cannot be drained away leads to water logging and anaerobic conditions which affect mineral ion uptake by active transport, subsequently affecting osmotic uptake of water due to decreased osmotic potential gradient causing plants to dry out.
- Plants like rice, marshes, and sedges have developed air spaces among stem tissues allowing some diffusion of oxygen from aerial parts to help supply the roots.

iii) Biotic content:

- Microorganisms like bacteria and fungi carry out decomposition of dead organic material, therefore recycling nutrients back to the soil.
- Burrowing organisms e.g. earthworms improve drainage and aeration by forming air spaces in the soil.
- Earthworms also improve soil fertility by mixing of soil, as they bring leached minerals from lower layers within reach of plant roots.
- They also improve humus content, by pulling leaves into their burrows.
- Also press soil through their bodies making its texture fine.

iv) Air content:

- Spaces between soil particles is filled with air from which plant roots obtain oxygen by diffusion for aerobic respiration.
- Also essential for aerobic respiration by microorganisms in the soil that decompose the humus.

v) **Salinity:**

This is the measure of salt concentration in aquatic bodies and soil water.

- It determines the osmotic pressure of water; therefore the organisms have developed structural, behavioral, and physiological adaptations to osmo-regulate in the respective salt concentration.
- Mineral salts in water affect the distribution of plant species, which in turn affects the animals that depend on plants for food.
- Plants growing in soils deficient of certain salts, e.g. insectivorous plants in nitrogen deficient soils obtain nitrogen by feeding on insects.

Biotic components

These are the ***living things*** in an ecosystem. They are categorized as ***producers*** (plants), ***consumers*** (animals) and ***decomposers***.

1) Producers:

These are autotrophs capable of synthesizing complex organic food materials from simple inorganic food raw materials like carbon dioxide and water. Examples include plants like trees, shrubs and grass. In aquatic ecosystem; the producers are microscopic algae and blue green bacteria. Others are flagellates like euglena, volvox, chlamydomonas etc. They are collectively called ***Phytoplanktons*** (microscopic marine producers).

Some producers use chemical energy derived from breakdown of chemical compounds like sulphur to convert carbon dioxide and water into high energy compounds like carbohydrates e.g. sulphur bacteria i.e. they are **chemosynthetic**.

2) Consumers:

These are organisms that get energy and nutrients by feeding on other organisms or their remains. They are classified as;

i) Primary consumers (Herbivore):

A consumer that eats plants. E.g. insects, birds, most mammals (grazers), in aquatic ecosystem, they include; water fleas, fish, crabs, mollusks, and protozoans, collectively known as **zooplanktons** (microscopic marine consumers).

ii) Secondary consumers (**Carnivore):**

A consumer that eats other animals. E.g. birds of prey like eagle, kites, kingfishers; and lions, cheetahs, tigers, hyenas, snakes, big fish.

iii) Tertiary consumers:

These feed on both primary and secondary consumers. They can be predators that hunt and kill others for food or scavengers (animals that feed on dead organisms but do not kill them). E.g. vultures, hyenas, marabou stocks etc.

3) Decomposers:

A decomposer is an organism that feeds on dead organic matter.

They are classified into;

i) Detrivore/macro decomposer; an animal that eats detritus (dead and waste matter not eaten by consumers) E.g. earth worms, rag worms, mites, maggots, wood lice, termites etc.

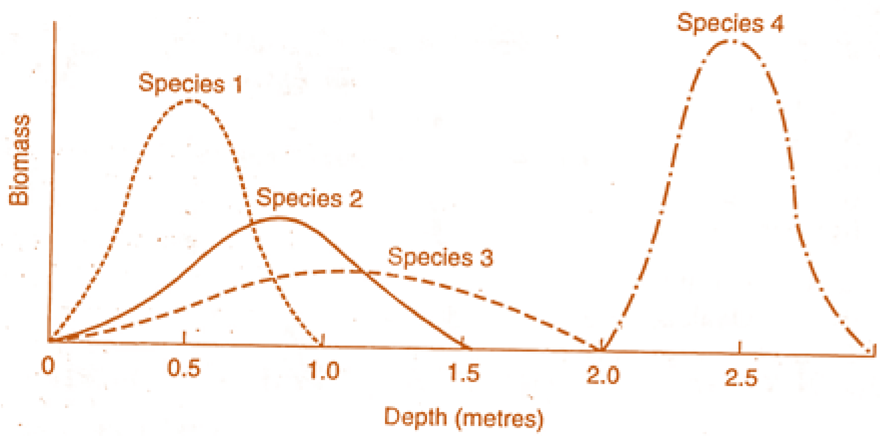
ii) Saprophyte: A microbe (bacterium or fungus) that lives on detritus.

Importance of decomposition

- It enables dead bodies to be disposed of, which, if left would accumulate everywhere.
- Recycles nutrients to be used by other organisms e.g. Mineral salts are released from dead bodies into soil for plant growth.
- Unlocks trapped energy in the body of dead organisms.

Practice question:

The distribution of four species of organisms at different depths in a pond was investigated and the data presented graphically as shown below.



a) *Giving your reasons, state which species is most likely to be the main primary producer?*
b) *Which species is most likely to be a secondary consumer? Give reasons for your choice?*

The Concept of Ecosystem

An ecosystem is an ecological unit consisting of a community of living organisms and its physical environment. Such a unit will consist of plants, animals and micro-organisms as well as non-living components like water, soil, air and light.
It also refers to the interaction between living organisms and non-living components of the environment or habitat to form a self-supporting system e.g:
Water (aquatic) ecosystems may be fresh water bodies (e.g. lakes, ponds, rivers) or marine water bodies (e.g. sea, ocean). Organisms in water may be of large size (nektons) e.g. fish, whales, turtles or very tiny (planktons) e.g. phytoplankton and zooplanktons.
Land (terrestrial) ecosystems include forests, deserts, savanna, etc.

Major activities taking place in an ecosystem

- Recycling of matter i.e. nitrogen cycle, carbon cycle, etc.
- Energy flow/transfer from producers, consumers and decomposers.
- Food interactions/food chain and water.
- Development and evolution of species of organisms (death due to competition and resistance due to competition/survival of the fittest).
- Population control/dynamics/cybernetic of the population.
- Succession.

Types of ecosystems

There are two major types of ecosystem, namely;
1. Terrestrial/land ecosystem
2. Aquatic ecosystem

Each of the two can further be grouped into several habitats.

Aquatic ecosystems

Aquatic ecosystems support a great diversity of life forms. Water occupies 50% of the earth's surface. Water provides a more constant and protective environment than land (desiccation, less affected by sudden and drastic changes in physical and chemical conditions, some change due to climatic or seasonal variation). It provides support and dissolved oxygen and nutrients to aquatic organisms.
Aquatic ecosystems are classified as the following depending on the concentration of salts they contain;
- Fresh water ecosystem
- Marine ecosystems
- Estuarine ecosystem

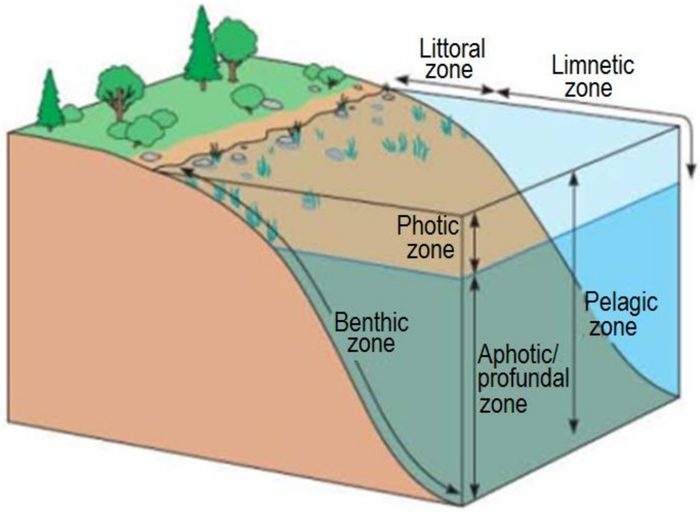
Fresh water ecosystem

Fresh water habitats occupy a small portion of the earth's surface as compared to marine and terrestrial habitats. However, fresh water habitats are of great importance to man for the following reasons:
- Cheapest source of water for domestic and industrial use.
- Provide the cheapest waste disposal systems.
- Harbor various animals.

Fresh water habitats can be classified into:

1) Lotic (running water bodies) e.g. rivers and streams
2) Lentic (standing water bodies) e.g. pond, lake and swamps

Structure of a lake/pond (Lake Zonation)



Note: The lake environment (lake zonation) is generally classified on the basis of three physical criteria; light penetration (photic and aphotic zones), distance from shore and water depth (littoral and limnetic zones), and whether it is open water (pelagic zone) or bottom (benthic zone).

i) **Littoral zone:** shallow water region with high light penetration. It has the highest productivity due to high carbon dioxide/oxygen and suitable temperatures.

ii) **Limnetic zone:** it's the open water zone to the depth of effective light penetration. The community here includes phytoplankton, floating insects and algae. Like littoral zone, productivity/net productivity is highest because of high effective light penetration, more dissolved gases, high temperatures at the surface and turbulence due to the high air content/wind so high photosynthesis. Dissolved nitrogen is fixed by nitrogen fixing bacteria and blue-green algae to make proteins. Dissolved carbon dioxide formed carbonic acid which results in formation of H^+, HCO_3^- and CO_3^{2-}.

iii) **Benthic zone:** receives little or no light. Light penetration decreases with depth and also net productivity decreases with depth.

iv) **Profundal zone:** this is the bottom most layer located below the light range of effective light penetration, receives no light at all, no dissolved gases, aerobic bacteria exists so little productivity. The productivity is due to water currents which tend to mix the upper layers with bottom layer and photosynthesis and chemosynthesis bacteria exist.

Ecological classification of fresh water organisms

Organisms in water can be classified depending on their life form which is based on their mode of life. The following terms are used:

1. **Neuston:**

   These are organisms resting or swimming on the surface of water. Such organisms may be supported by the surface film or cling to the surface film from beneath or swim in the upper waters. Examples include pond skaters, air breathing diving beetles, water boat men, floating plants like duck weed, bladder work, etc.

2. **Plankton (floating):**

   This is a mass of floating small plants (phytoplankton) and animals (zooplankton) whose movements and distribution are more or less dependent on currents. Their powers of locomotion are restricted to small vertical movements or to catching prey. Examples include arolia, Pistoia, water burg, tadpole, etc.

3. **Nekton:**
   These are free-swimming organisms that can swim against water currents. Some of them are small e.g. swimming insects while others are large e.g. bony fish, amphibians, etc.
4. **Benthos:**
   These are organisms attached or resting on the bottom or living in the bottom sediments. Most of them feed on fresh water organisms in ponds and lakes. They may also be classified depending on the sub habitat they occupy. Three zones are generally evident;
   i) Littoral zone:
   This is the shallow-water region with light penetration to the bottom. Such a zone is typically occupied by plants in natural ponds and lakes.
   ii) Limnetic zone:
   This is the open water zone to the depth of effective light penetration. The community in this zone is composed of plankton, nekton and sometimes Neuston. In shallow ponds, this zone is absent. The total illuminated depth including the littoral and limnetic zone is referred to as the euphotic zone.
   iii) Profundal:
   This is the bottom and deep water area which is beyond the depth of effective light penetration. This zone is often absent in ponds.

Factors affecting productivity of the lake

- Temperature
- Nutrient availability
- Salinity
- Water current
- Pollution

Warm temperature provide optimum medium for aquatic organisms distribution as well as enzymes involved in photosynthesis.
Cool temperature of bottom water inactivate enzyme and affect distribution of phytoplankton thus reduced productivity.
Availability of nutrients in water due to decomposition of organic matter like sewage, dead organisms and fertilizers washed off from farm and water would lead to algal blooming or **eutrophication**. This would instead increase productivity since phytoplanktons are many.

Limiting factors in fresh water ecosystems

Limiting factors restrict the distribution of living organisms hence preventing the colonization of otherwise favourable environment. The most important limiting factors in fresh waters are:

1. **Temperature:**
   Water has several unique thermal properties. Although temperature is less variable, it is a major limiting factor. Aquatic organisms have narrow tolerance. Temperature changes produce characteristic patterns of circulation which greatly influence aquatic life.
2. **Light penetration:**
   Penetration of light is often limited by suspended materials (turbidity). This restricts the photosynthesis zone. Plants cannot survive below the compensation level. Light penetration (turbidity) can be measured using a ***Secchi disc***. It a

plain white circular disc that is lowered from the surface until it just disappears from view. This ranges to about 40 cm in very clear waters.

3. **Water currents:**
Currents determine the distribution of vital gases, salts and small organisms. Water current is a limiting factor in fast flowing streams and on shores when it prevents colonization by weak swimming organisms.

4. **Dissolved gasses:**
Gases from the atmosphere dissolve in water at the surface. However, some gases are more soluble than the others. E.g. oxygen is 30 times less abundant in water than in air.
This limits the distribution of living organisms. The diffusion of dissolved gases through deep layers of water is very slow. In some places currents and wave action aid the diffusion, but in still waters, very little oxygen is transferred to lower levels. Once the little oxygen available is used up by decomposers, the effects may be disastrous to the whole community.
Dissolved nitrogen is used by nitrogen fixing bacteria and blue-green algae in the manufacture of proteins.
Effects of carbon dioxide are complex due to the formation of carbonic acid to form H^+ HCO_3^- and CO_3^{2-} ions. These combine with other dissolved substances in the water.

5. **Dissolved salts:**
Fresh water ecosystems show a considerable variation in salt content. This depends on the minerals present in drainage water from the surrounding land mass and activities of living organisms. Deposition of nutrients in water is known as eutrophication.
Nitrate and phosphate are the most limiting factors in fresh water ecosystems e.g. phosphorous is a limiting factor because the ratio of P to other elements in organisms is greater than the ratio in the primary sources of the biological elements. K, Ca, S and Mg may also act as limiting factors.

Biological classification of lakes

Biological classification of lake ecosystems depends on the circulation rates of inorganic plant nutrients in the lake. Three major types are recognized:

1. **Eutrophic lakes:** These are with waters relatively rich in plant nutrients. They have the following characteristics.
   - Have high surface area to volume ratio hence easy circulation.
   - They are relatively shallow with gentle slopping banks which can support wide belts of marginal vegetation.
   - Have relatively high phosphates and nitrates, i.e. they are very productive.
   - Due to emergent and submerged plants plus a lot of phytoplanktons, upper layers are rich in oxygen. The bottom layers are low in oxygen concentration since it is continuously being used for bacterial decomposition e.g. Lake Kyoga.
2. **Oligotrophic lakes:**

These are with low plant nutrients and are highly oxygenated. They have the following characteristics:
   - They have low surface area to volume ratio, hence limited circulation.
   - They are deep with steep rock sides.
   - Waters are low in plant nutrient but highly oxygenated.
   - Neither have extensive marginal vegetation nor organic bottom deposits which results in their low productivity e.g. Lake Tanganyika.

3. **Dystrophic lakes:** These have brown water where the bottom deposits of such lakes consist of un rotten organic matter which accumulates as heat. Productivity of such lakes is very low.

The pond ecosystem

The pond ecosystem is complex and is affected by several environmental conditions. The living organism and the nonliving environment are inseparable and the following can be recognized:

i) **Abiotic substances:**
These include basic inorganic and organic compounds e.g. water, CO_2, O_2, Ca, N, P, soil, etc. A small portion of the vital nutrients is in soil and available to organisms but much larger portion is held in the bottom sediments and in the organisms themselves. The rate of release of nutrients from the solids, solar input and other environmental factors determine the productivity of the entire ecosystem.

ii) **Producer organisms:**
There are two major types only; Rooted or large floating plants growing in shallow water e.g. papyrus and Phytoplankton distributed throughout the pond as deep as limnetic zone.
Note: in deep ponds and lakes, phytoplankton is much more important than rooted vegetable in the production of the basic food from the ecosystem (algal blooms)

iii) **Macro organisms:**
These include animals like insect larvae, crustacea, fish, etc. primary consumers feed on plants or plant remains e.g. zooplankton and benthos (molasses).
Secondary consumers e.g. predaceous insects and fish feed on primary or secondary consumers.
Detritivores e.g. worms, larvae and rotifers consume organic matter from upper layers.

iv) **Saprotrophic organisms:**
Aquatic bacteria, flagellates and fungi are distributed throughout the ponds, but are abundant at the bottom where plant and animal organic matter accumulates.
Dead organisms are rapidly broken down by detritus feeding organisms and microorganisms and their nutrients are released for re-use.

Terrestrial ecosystems

Regional climates interact with regional biota and substrate to produce large recognizable community units called biomass. A biome is identical with a major 'plant formation' but it is a total community unit in which both animals and plants are considered. The six major biomass of Africa include:

- Tropical rain forest
- Tropical savanna and grass land
- Desert
- Sahel region (semi-desert)
- Mountain forests
- Temperate region

The above form the major terrestrial ecosystems.

Tropical rain forest ecosystem

This is characterized by high temperatures of 25^0C and 35^0C and a high monthly rain fall distributed over 10 months of the year i.e. 200 and 400 cm^3 of rain fall annually. They are dominated by broad leaved evergreen trees which occupy low altitude zones near the equator (amazon, Congo, Malaysia, etc.).

Seasonal changes in breeding and other activities of plants and animals in a tropical rain forest are largely related to variations in rain fall and to a certain extent temperature.

Forest communities are well structured and contain specific plant and animal populations that interact in a complex fashion. Trees in the forest form three layers (stratification):

Emergent layer:

This consists of scattered, very tall emergent trees (80-100m) that project above the general level. They have wide spread, umbrella shaped crowns and huge buttresses. Examples are the Chlorophora excelsa (Mvule), mahogany, mbizia, etc.

Canopy layer:

This forms a continuous evergreen carpet 50-80m tall. The crowns of such trees are small compared to the emergent and buttresses are narrow.

Under Stoney layer:

This is the underlying layer of vegetation in a forest or wooded area, especially the trees and shrubs growing between the forest canopy and the forest floor. Plants in the understory comprise an assortment of seedlings and saplings of canopy trees together with specialist understory shrubs and herbs. This includes relatively short trees and young trees of the emergent and canopy layers. Ferns e.g. platycerium spp is common as an epiphyte high on trees. Other epiphytic plants include figs and orchids.

Ground layer:

This includes shrubs, herbs, lianas, shade loving plants with broad leaves and thallophytes e.g. lichen, mosses, liverworts and shade loving animals.

A much large proportion of animals live in the upper layers of the vegetation. These include birds, mammals, amphibians and others. Some animals are ground dwellers e.g. ants, butterflies, moths, snakes and other reptiles.

Tropical rain forests are rich in flora and fauna species e.g. a six square mile area can contain 20,000 species of insects. A tropical rain forest is the only major vegetation type which does not burn i.e. fire is not an ecological factor.

Variation in environmental factors (temperature, light, moisture) caused by the stratifications creates micro-habitat conditions. The ground layer receives light of low intensity approximately 10% of the total value received by the emergent. Ground layer plants are therefore adapted to such conditions.

The shade effect of the canopy layer cuts off the sun's rays, thus relatively lower temperatures are experienced in the lower layers.

Moisture is influenced by temperature as it increases rates of evaporation and transpiration. Underground plants are in a region of lower rates of evaporation and transpiration than those above them.

Crowded leaves on the upper layer of tree branches act as wind breaks so the interior of the forest is not windy. The relative humidity inside is relatively constant to the upper layers.

Adaptations of organisms living in tropical rain forest ecosystem

- Emergent and canopy layer trees prevent excessive transpiration by having leathery surface and adequate deposits of cuticle.
- Plants of the undergrowth have large thin leaves.
- Animals on the ground use the soil for protection against extreme condition.
- Arboreal animals possess special features that enable them to climb e.g. specialized feet in squirrels and the monkeys' prehensile tails.
- Some animals use camouflage for protection against predators.

Grass land ecosystem

Tropical savanna (grassland with scattered trees or clumps of trees) forms the grassland ecosystem in Africa. Grasslands are characterized by hot weather with a moderate temperature range. Rainfall is about 120cm^3 per annum which falls in one period, followed by a long period of drought.

Grassland ecosystems are dominated by grasses such as guinea grass, elephant grass, spear grass, and palms.

Animals include a variety of numerous hoofed mammals e.g. antelopes, elephants, zebra, giraffes which graze or browse on the vegetation. Others include predators like lions, cheetahs, scavengers like hyenas, jackals and culture insects most abundant during the dry season which include grasshoppers, termites, ants and locusts. Reptiles are abundant during the dry season and these include snakes, lizards, chameleons, tortoise, etc.

In the savanna grassland ecosystem, seasons are determined by rainfall. Other two factors include herbivore and fire. Trees and grass present must be resultant to drought and fire. This explains why the number of species in the vegetation is not large.

Grazing mammals are important in determining the flora composition of the community. Some species of grasses and other plants are more sensible to grazing pressure than others.

During the dry season, fire is a major ecological factor. It destroys non-resistant plant species like grasses but it also stimulates those with underground parts to grow. Trees develop a dense and shady canopy and grasses grow to high heights during the short rainy season.

Adaptations of organisms living in grassland ecosystem

- Savanna trees grow long tap roots and develop thick barks which enable them to survive the long dry season and resists fires. They have umbrella shaped canopies which shade the ground and limit loss of soil moisture. The leaves have thick surfaces which minimize the loss of water by transpiration.
- Grasses have durable roots which remain underground when the tops have been burnt away after a fire. They sprout again with the onset of the first rains in the following year.
- Animals usually migrate and hibernate.

Food chain and Food web

Food chain

A linear sequence of energy flow from producers through a series of organisms in which there is repeated eating and being eaten. Two types exist i.e.

Grazer food chain, starts with autotrophs (producers)/green plants which convert carbon dioxide & water into chemical compounds. These are grazed upon by herbivores. Energy is further transferred to carnivores. It can be in grass land or water body (aquatic). E.g.

Grass, millipedes, toads, snakes, hawks.

Green algae, haplochromies, tilapia, kingfisher bird.

Detritus food chain:

This is the one where the consumers obtain energy from fragments of dead decaying organic matter.

Exists in both aquatic and terrestrial habitats.

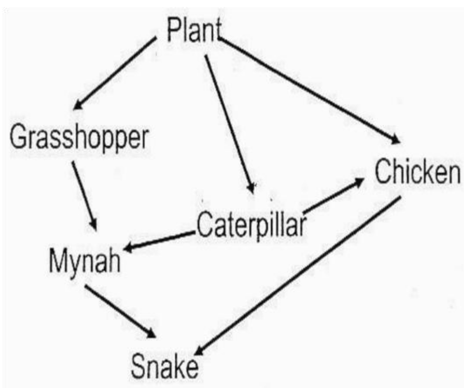
1st trophic level is occupied by a decomposing organic matter.

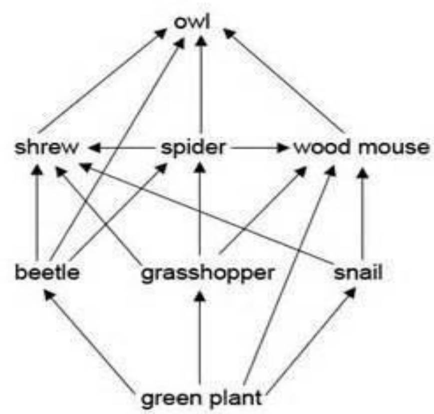
E.g Tree log → wood lice → toad → python

Dead animal, maggot, birds, python

Food web

This is a complex nutritional interrelationship that illustrates alternative food sources and predator for each organism. In a food web, there are several food chains.





Practice questions:

1) *Construct a food web using the following organisms: phytoplanktons, mosquito larvae, small fish, large fish, and crocodiles.*
2) *(a) With reference to a **named** ecosystem, what is meant by the following terms;*
    i) *Energy flow*
    ii) *Trophic levels*
    iii) *Food web.*

   (b). Discuss the interactions between the living and nonliving components of such an ecosystem.

   (c) What is an ecosystem?

NB. Techniques used in constructing food webs and food chains:

- Direct observation of organisms as it feeds so as to establish the organisms prey.
- Examination of stomach content through dissecting the animals' stomach.
- Faecal method; observation of faecal materials egested by an animal.
- Use of radioactive tracers to label the environment from which organisms obtain their food and then trace them in the organisms gut.

Ecological pyramids

These are histograms that provide information about feeding (trophic) levels in ecosystems. Three types exist i.e.

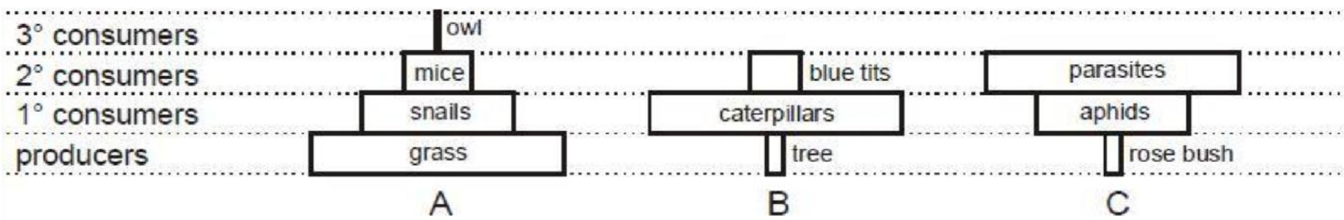
- Pyramid of numbers
- Pyramid of biomass

- Pyramid of energy

NB. *Length of a given bar is proportional to the number, energy or biomass at a given trophic level in a given area.*

1) Pyramid of numbers:

It is a histogram representing the numbers of different organisms at each trophic level in an ecosystem at any one time.



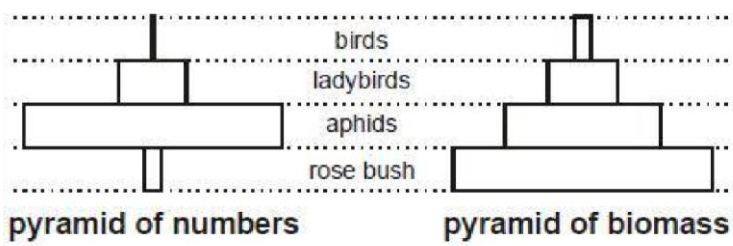
As a pyramid is ascended, the number of organisms decreases but the size of each individual increases. In some cases, the consumers may be more than the producers e.g in a parasitic food chain, inverted pyramids **B** & **C** are obtained, because parasites progressively become smaller and many along a food chain.

Limitations of pyramid of number

- Drawing the pyramid accurately to scale may be difficult e.g. where there a million plants.
- Pyramids may be inverted
- The trophic level of an organism may be difficult to ascertain.
- The young forms of species may have a different diet from adults.

2) pyramid of biomass:

This is a histogram showing the total dry mass of organisms present at each feeding level



Advantage:

Reduces the possibility of forming inverted pyramids because its construction depends on biomass of organisms

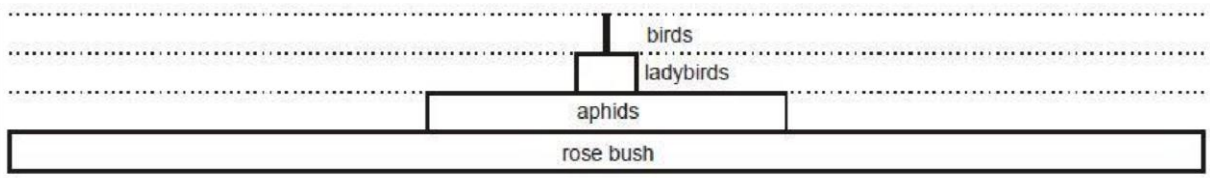
NB. Inverted pyramid of biomass is typical of an aquatic ecosystem because diatoms (phytoplankton) have a lower biomass but with higher productive rate (caused by so rapid turnover rate), therefore capable of supporting a larger biomass of zooplanktons.

Disadvantages/limitations of pyramid of biomass

- Does not allow for changes in biomass at different times of the year e.g. deciduous trees have larger biomass in summer than in winter when they shed off leaves.
- It does not take into account rate at which biomass accumulates e.g. a mature tree has a large biomass which increases over many years.
- Impossible to measure exactly biomass of the organisms in an ecosystem, because the sample used may not true representation of the whole population.
- Results may not be accurate, e.g. where killing is not allowed, the results are obtained by estimating the fresh mass.

3) Pyramid of energy flow:

It is a histogram showing the total amount of energy present at each feeding level. Because only a proportion of energy is in a trophic level is transferred to the next. Energy pyramids are never inverted nor do they have a central bulge.



Advantages of pyramid of energy flow

- It compares productivity because a time factor is incorporated.
- Biomass may not be equivalent to energy value, e.g. 1g of fat has many more kJ than 1g of cellulose or lignin.
- No inverted pyramids are obtained because of the automatic degradation of energy quality.
- The solar input of energy may be included as an extra rectangle at the base.

Disadvantage of pyramid of energy flow

- Obtaining the necessary data required in constructing pyramids of energy flow is difficult.

Energy flow through an ecosystem

The sun is the primary source of energy in the ecosystem.

Light energy is trapped by photosynthetic organisms (green plants, algae, and some bacteria), converted into chemical energy during photosynthesis.

It is then transferred from one feeding level to another through feeding relationships like ***food chains*** or ***food webs.***

Most of the energy from sun getting the earth's surface is reflected by vegetation, soil, and water or absorbed and radiated to atmosphere; leaving only between 5%-10% for the producers to make use of.

Along the food chain, only a small proportion of the available energy is transferred from one feeding level to another; much energy is lost as heat during ***sweating and evaporation***, ***excretion*** , ***respiration***, **egestion,** and some remains locked up in indigestible parts of the plant like cellulose, or bones, hooves, hair, skin etc. of animals.

At each trophic (feeding) level there is loss of energy because;

i) Some energy is used up during respiration.
ii) Some energy is lost from herbivores in form of indigestible plant material.
iii) Some organisms die before they are eaten.
iv) Some of the chemical energy is converted into other forms such as sound, light energy, heat energy, which easily escapes from the organisms.
v) Some plant parts are inaccessible to herbivores .e.g. roots.

At each trophic level, decomposers (saprophytes) such as bacteria and fungi break down dead organic matter to release some of the energy locked in it.

The number of organisms decrease at each successive feeding level because of the great energy losses, so the energy left in organisms is little to support large numbers of top consumers thus limiting the length of food chain not exceeding five trophic levels (feeding level in a food chain containing given amount of energy).

Trophic efficiency (ecological efficiency)

This is the percentage of energy at one trophic level that is converted into organic substances at the next trophic level. In an ecosystem, the amount of organic material manufactured by organisms is termed as ***productivity***. It can be measured using several methods i.e.

- Harvest crop,
- Through oxygen production of the given area of the ecosystem,
- Amount of carbon dioxide consumed during photosynthesis and
- Rate of consumption or use of raw materials.

Productivity can be divided into;

i) Gross productivity: is the total amount of energy and organic matter stored in an organism over a period of time.

ii) Net productivity: is the amount of energy and organic matter stored in an organism and passed onto the next trophic level.

iii) **Primary productivity**: Is the amount of energy and organic material stored in primary producers. It is measured in ***mass per unit area per unit time*** (kilogram per unit area per year, Kg/M /yr.).

The initial amount of energy incorporated into primary producers during photosynthesis per unit time is called ***Gross primary productivity (G.P.P)***.

The amount of energy transferred from primary producers to primary consumers per unit time is called ***Net Primary Productivity (N.P.P).*** It can as well be called dry mass of the harvest crop**.**

Therefore, GPP- assimilation (respiration & metabolism) =NPP.

iv) Secondary productivity: Is the amount of energy incorporated into the body of consumers. Also known as **Gross secondary productivity.**

Net secondary productivity is the amount of energy that can successfully be transferred from one consumer to another. Carnivores have a higher secondary productivity than herbivores because:

- Diet of carnivores is rich in proteins; easily digestible and therefore absorbed efficiently, allowing little energy to be lost. Herbivores' diet mainly consists of plant materials which are not easily digested.
- Carnivores do not have symbiotic microbes to consume part of the energy of their diet in their digestive tracts.
- Their faeces contain much less undigested matter.

Net secondary productivity is higher in exotherms than in endotherms because energy from absorbed food is used to replace the lost heat to their surroundings in order to maintain a constant body temperature unlike exotherms that depend mostly on behavioral means to maintain their body temperature.

Practice questions:

1. *Describe what is meant by the following terms:*
   i) Community
   ii) Ecosystem
   iii) Food chains
2. *Evaluate the use of studying food webs rather than food chains in ecology.*

3. *Consider the trophic levels of a pyramid of numbers and illustrate how energy is lost in passing through the levels.*
4. *The figure below represent pyramids of biomass and number of organisms in the same ecosystem, each of which is not drawn to scale.*

i) Explain why the relationships between the various trophic levels are different when comparing the two figures.

ii) What further kind of pyramid could be constructed to give additional information about the four trophic levels?

Biogeochemical Cycles (nutrient cycles)

These are processes by which chemical elements of a particular compound that constitute living matter are transferred between living organisms (biotic phase) and non-living environment (abiotic phase). They are driven directly or indirectly by incoming solar energy and gravity.

The Carbon cycle

Carbon is the most important element of the protoplasm. It is a major constituent of carbohydrates, proteins, fats and nucleic acids of all the cells of organisms. In the **nonliving** environment it is present in three main forms:

- As **carbon dioxide** in air and as dissolved form in water (lakes and oceans).
- As **carbonates** in the rocks in the earth's crust.
- As **carbon** in fossil fuels like coal and petroleum.

Fixation of carbon:

The carbon present in coal and petroleum and the one present in the form of carbonates in the rocks is not available till it is burnt or changed chemically.

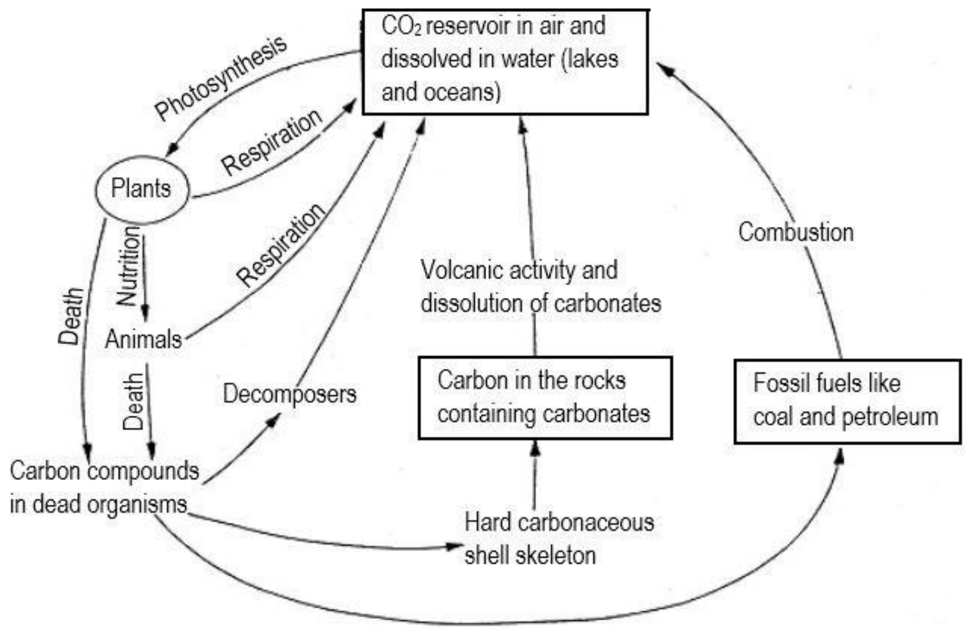
The carbon present in the carbon dioxide is the basic source which enters the organism through photosynthesis by plants and then to various organisms through the **food chain.**

Release of carbon back to the environment:

- Release as carbon dioxide during respiration in organisms.
- By decomposition of dead bodies and body wastes by microorganisms.
- By burning of wood and fossils fuels.
- By dissolution of carbonate rocks.
- By volcanic activity of rocks.

At times, large number of organisms get buried inside the earth like caving in of a dense forest during earthquake, then these organisms do not get decomposed but get transformed into coal or oil. Hence this carbon remains locked for millions of years till the coal or oil is burnt to release carbon back to environment.

Similarly the carbon present in the shells and skeletons as carbonates remains locked in rock for millions of years till it is put back to environment by dissolution or volcanic activity.



Effect of excessive carbon dioxide in the atmosphere

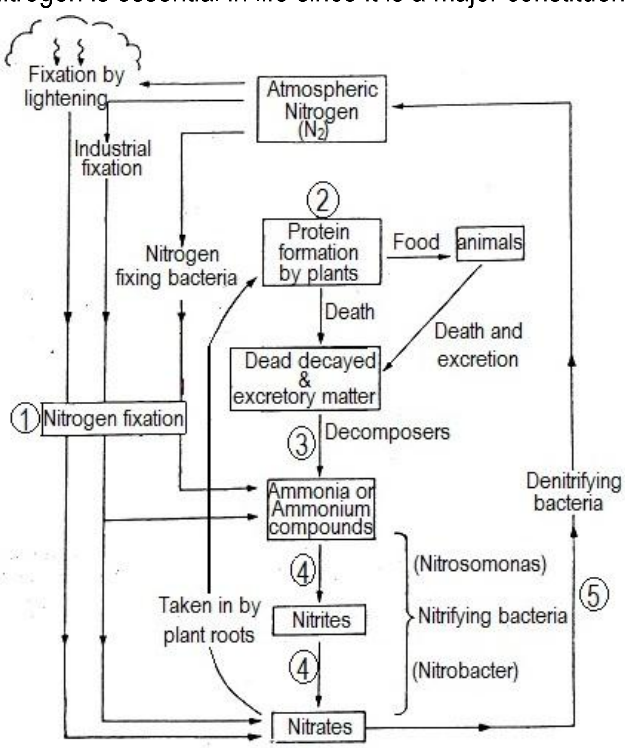
The carbon dioxide traps the infrared rays (long wave radiations) which are normally radiated back into space from the earth's surface. This trapping has led to the gradual warming of the earth and melting of ice caps.

Human activities affecting the carbon cycle

- Cutting trees and other plants that absorb CO_2 through photosynthesis increases carbon dioxide in the atmosphere.
- Burning of fossil fuels like coal, petroleum oil etc. and wood adds large amounts of CO_2 into the troposphere.

The Nitrogen Cycle

Nitrogen is essential in life since it is a major constituent of proteins, nucleic acids and chlorophyll molecules of cells.



1. **Nitrogen fixation:**
   The atmosphere is the largest reservoir and contains 79% of nitrogen, but it cannot be taken up by the organisms directly unless it is fixed. Some bacteria can combine free nitrogen into nitrates.

- Biological fixation by nitrogen fixing bacteria occurs when the nitrogen in soil is reduced to ammonium ions, catalyzed by nitrogen-fixing bacteria which may be free-living e.g. *Azotobacter* and *Clostridium* or symbiotic bacteria in root nodules like *Rhizobia* bacteria.
- Atmospheric electrical discharges in the form of **lightning** causes nitrogen and oxygen in the atmosphere to react and produce oxides of nitrogen, which dissolve in rainwater and fall to the ground as weakly acidic solutions.
- Industrial fixation by chemical fertilizer factories during the Haber's process.

2. **Nitrogen used by plants and animals:**
   Plants take in nitrates from soil and form proteins. When animals eat plants, the proteins are converted into animal proteins. The breakdown of proteins is excreted in the form of urea or uric acid or ammonium compounds. In the soil or in water, decomposition of the waste takes place and nitrogen is converted back to free nitrogen.
3. **Decomposition by microorganisms** like fungi and ammonifying bacteria. These convert wastes, decayed and dead bodies to ammonia or ammonium compounds.
4. **Nitrifying bacteria** like Nitrosomonas and Nitrobacter. They convert ammonium salts to nitrites then to nitrates through oxidation. Nitrates may be used by plants.
5. **Denitrifying bacteria** like pseudomonas which converts nitrates to molecular nitrogen.

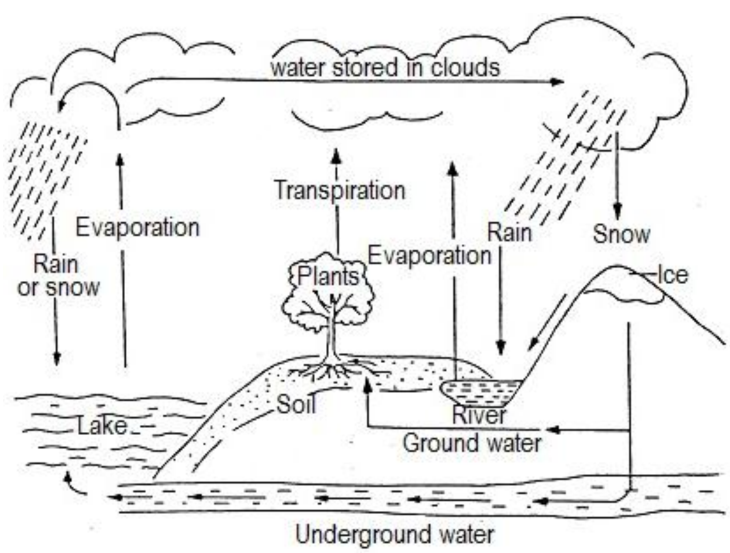
How human activities affect the nitrogen cycle

1) Burning of fuels forms nitric oxide, which reacts with atmospheric oxygen to form nitrogen dioxide gas that reacts with water vapour to form acid rain containing nitric acid. Nitric acid together with other air pollutants damages trees, corrodes metals and upsets aquatic ecosystems.
2) The inorganic fertilizers applied to soil are acted upon by anaerobic bacteria to release nitrous oxide into the stratosphere, where it contributes to ozone depletion and contributes to green-house effect.
3) Nitrogen is removed from top soil when we:
   - Harvest nitrogen-rich crops.
   - Irrigate crops.
   - Burn or clear grasslands and forests before planting crops.
4) Adding nitrogen compounds to aquatic ecosystems e.g. sewage algal blooming, which upon death, their decomposition causes oxygen shortage resulting into death of aerobic organisms e.g. some fish.
5) The accelerated deposition of acidic nitrogen containing compounds e.g. NO_2 and HNO_3 onto terrestrial ecosystems stimulates growth of weeds, which outcompetes other plants that cannot take up nitrogen as efficiently.

Water cycle (hydrological cycle)

This is powered by energy from the sun and by gravity, and it involves:

- Evaporation (conversion of water into water vapour).
- Transpiration (evaporation from leaves of the water extracted from soil by roots and transported throughout the plant).
- Condensation (conversion of water vapour into droplets of liquid water).
- Precipitation (rain, hail, snow and sleet/freezing rain).
- Infiltration (movement of water into soil).
- Percolation (downward flow of water through soil and permeable rocks to ground storage areas called aquifers).
- Runoff (down slope surface movement back to the sea to resume the cycle).



Practice questions:

1. *Describe the flow of energy and the cycling of carbon and nitrogen in any named ecosystem.*
2. *Suggest reasons why felling and removal of forest trees result in changes in the levels of nutrients in the soil.*
3. *Briefly describe three ways in which nitrogen is incorporated into a food chain.*

Ecological successions

A community is a group of interacting populations living in a given area and represents the living part of an ecosystem. Its functions are energy flow and cycling of nutrients. The structure of a community is always built up over a period of time until a stable climax community is established. Ecosystems are dynamic constantly changing in response to both physical and biological factors.

Ecological succession is a gradual change in community composition from the initial colonization of an area/habitat to establishing a relatively stable community. It is a fairly orderly process of changes of communities in a region or an area. It involves replacement in the course of time of the dominant species within a given area by other species.

Succession progresses gradually from a small number of colonizing species known as ***seres*** or seral stages (i.e. communities that replace one another in a given area are called seres).

Each sere has its own community of organisms until the terminal relatively stable and final stage community called climax community is established.

The **climax community** comprises of dominant or several co-dominant species which refers to species with the greatest collective biomass/productivity and physical size of individuals in a given area after some time (years).

At climax community the net productivity/biomass tends to remain constant but dependent on species number and population size.

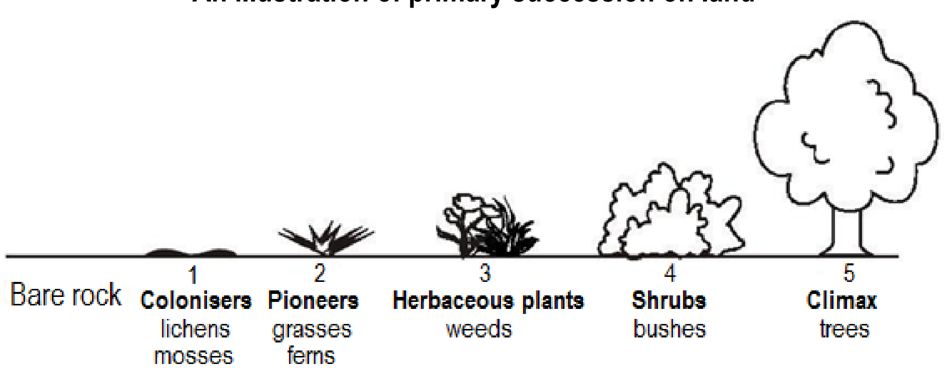
Types of ecological successions

1. Primary succession:

This is the gradual change in species composition of an area that has never had any vegetation growing on it.

It occurs on bare rocks exposed by erosion, newly cooled lava, newly created shallow ponds, sand dunes, abandoned highway or parking yard.

An illustration of primary succession on land



Description of Primary succession on land

Lichens and mosses attach to bare rocks and start forming soil by trapping wind- blown soil particles, producing tiny bits of organic matter and secreting mild acids that slowly breakdown the rock. Alternate heating and cooling also causes break down of rocks.

As patches of soil build up and spread, eventually the pioneer species are replaced by the early successional plants like small grasses and ferns whose seeds and spores respectively germinate after arriving by wind or in droppings of birds.

Some of their roots penetrate and break rocks into soil particles, and death and decay of small grasses and ferns increases nutrients in soil.

After a long period of time, the soil becomes deep, moist and fertile enough to support the growth of mid successional plant species like herbs, large grasses, low shrubs and small trees that need a lot of sunlight.

Late successional plant species (mostly trees that tolerate shade) later replace the mid successional plant species.

Unless natural or human processes disturb the area, a complex forest community remains.

Characteristics of the stages of primary succession

Early succession:

- Species grow very close to the ground and have low biomass.
- Species have short life span.
- Species are simple and small sized.
- Species diversity (number of species present in a habitat) is very low.
- Community is open i.e. allows space for other colonizers.
- Species may show symbiotic relationships to aid their establishment.
- Species are poor competitors and hence get replaced by higher, more demanding plants like grasses, shrubs and trees.
- The community is mostly is mostly composed of producers and a few decomposers.
- Net productivity is high.
- Feeding relationships are simple, mostly herbivores feeding on plant with few decomposers.

Late succession:

- ✓ Plants are of large size and complex.
- ✓ Species diversity is high.
- ✓ Community is a mixture of producers, consumers and decomposers.
- ✓ Biomass is high.
- ✓ Net productivity is low.
- ✓ Community takes a longtime to establish.
- ✓ Climax community is often determined by one dominant species.
- ✓ There is increased soil depth and nutrients.
- ✓ Interspecific competition is very high.
- ✓ There is little space for new species.
- ✓ The climax community is stable and is in equilibrium with its environment.
- ✓ Feeding relationships are complex, dominated by decomposers.

2. Secondary succession:

This is the gradual change in species composition of an area where the natural community of organisms has been disturbed, removed or destroyed but some soil or bottom sediment remains.

It occurs on abandoned farmlands, burnt or cut forests, heavily polluted streams, flooded land.

Due to some soil or sediment present, vegetation usually begins to germinate within a few weeks.

Seeds and spores can be present in the soil and can be carried from nearby plants by wind, birds and insects.

The ground may even contain resistant plants/vegetative organs of the colonizing plants that survived the changes.

Population and Natural Resources

Population dynamics

These are changes in population in response to environmental stress or environmental conditions.

A population is a group of organisms of the same species living together in a given place at a particular time.

Population growth patterns

Population grows when:

- Natality is greater than mortality.
- Immigration is greater than emigration.

Population growth may form a curve which is either:

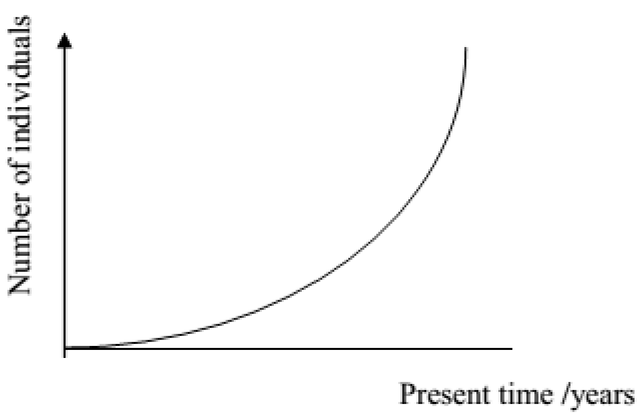
- Exponential population growth curve (J-shaped).
- Logistic population growth curve (Sigmoid/S-shaped).

Exponential population growth (J-shaped curve)

It is a theoretical population growth curve in which the population growth rate increases with time indefinitely.

Population growth starts out slowly and then proceeds faster and faster as the population increases.

It occurs when resources are unlimited and the population can grow at its intrinsic rate of growth (rate at which a population would grow if it had unlimited resources). However this is rare in nature because of limiting factors (environmental resistance).



Description:

Number of individuals (population) is small; their number increases gradually/slowly with time.

Later the population size increases rapidly/sharply/drastically with time.

Explanation:

Initially, the number of individuals increases gradually with time because the population size is small, thus few reproducing individuals, reproducing individuals are scattered within the environment, some may not have reached reproductive age, organisms are still getting used to their environment.

Later on, number of individuals increases rapidly because many individuals have now reached reproductive age and number of reproducing individuals now gets bigger.

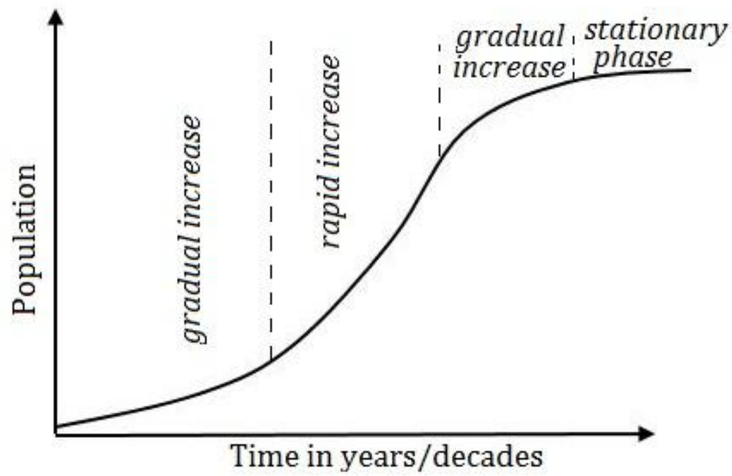
Logistic population growth curve sigmoid/s-shaped)

Population growth starts out slowly and then proceeds faster to a maximum (carrying capacity) and then levels off.

Population then fluctuates slightly above and below the carrying capacity with time.

The population stabilizes at or near the carrying capacity (K) of its environment due to environmental resistance (any factors that may prevent a population from increasing as expected e.g. predation, parasitism, and accumulation of toxic substances). The actual factors responsible for the shape of each phase depend on the ecosystem, and this can be illustrated by considering two contrasting examples: **yeast** in a flask (reproducing asexually), and **rabbits** in a field (reproducing sexually).

Sigmoid curve of growth of population (S curve)



Description (phase)	Yeast in a flask	Rabbits in grassland
Initial gradual increase.	Little growth while yeast starts synthesizing appropriate enzymes for new conditions. Slow growth because cells are getting used to conditions in the environment	Little growth due to small population. Individuals may rarely meet, so less mating. Slow growth because of few reproducing individuals
Rapid increase	Rapid growth. No limiting factors since relatively low density	Rapid growth. Few limiting factors since relatively low density.
Gradual increase	Slow growth due to accumulation of toxic waste products (e.g. ethanol) or lack of sugar.	Slow growth due to intraspecific competition for food/territory, predation, etc.
Stationary phase	Population is stable (fluctuates slightly above and below the carrying capacity). Cell death is equivalent to cells formed	Population is stable (fluctuates slightly above and below the carrying capacity). Death rate is equivalent to the birth rate.

How population density affects population growth

(a) **Density dependent factors**, are those factors whose effectiveness depends on number of individuals present in a unit space. The more individuals there are in the population, the greater the percentage of population that dies or fails to reproduce. These include; diseases, predation, competition for food, parasitism, pollution (accumulation of wastes) etc.

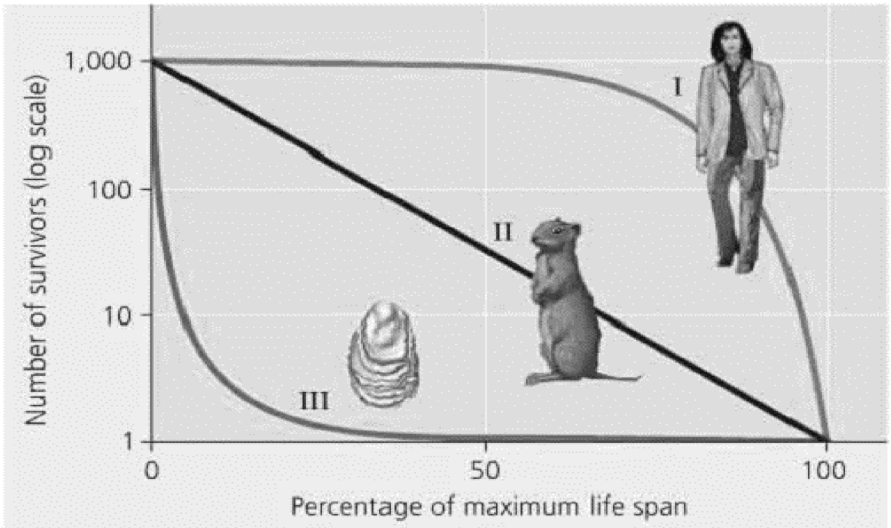
(b) **Density independent factors,** are those whose effectiveness is not related to the density of the population. Any change in the factor affects the same proportion of the population regardless of population density. They include; temperature, rainfall, light, floods, soil nutrients, fires, drought, hurricanes and habitat destruction e.g. clearing a forest or fishing in a wetland, pesticide spraying. They are mainly abiotic factors.

Survivorship

This is the percentage of an original population that survives to a given age.

Survivorship curve is a graph which shows the number (or percentage) of surviving individuals of each age group of a population for a particular species.

Types of survivorship curves/different patterns of population dynamics



(I) **Late loss curves:** Occurs in Humans, elephants, rhinoceroses, mountain sheep. These are organisms with stable populations close to carrying capacity of the environment (K). They produce few young ones which are cared for until reproductive age, thus reducing juvenile mortality and therefore enabling high survivorship to a certain age, then high mortality at later age in life.

(II) **Constant loss:** Many song birds, lizards, small mammals and hydra. This is characteristic of species with intermediate reproductive patterns with a fairly constant rate of mortality in all age classes and thus a steadily declining survivorship curve. There is an equal chance of dying at all ages. These organisms face a fairly constant threat from starvation, predation and disease throughout their lives.

(III) **Early loss curves:** Occurs in annual plants, most invertebrates and most bony fish species; with a high intrinsic rate of increase. They produce many offspring which are poorly cared for resulting into high juvenile mortality. There is high survivorship once the surviving young reach a certain age and size.

Importance of plotting survivorship curves

- Enables determination of mortality rates of individuals of different ages and hence to determine at which age they are most vulnerable.
- Enables identification of factors causing death at different ages so as to plan regulation of population size

Determination of population size of organisms

Importance of estimating population size

- Enables monitoring of population growth.
- Enables determination of habitat requirements of species.
- Enables determination of carrying capacity in the area. i.e. determine whether existing population are likely to be sustainable.
- Enables determination of age structure, and sometimes sex ratio of a population.

- It enables projection of how population size is likely to change with time for proper planning e.g. determining the peak populations of organisms e.g. mosquitoes enables control measures to be prepared.

Factors to consider before counting organisms

- The area of land or volume of water or air under study should be determined.
- The nature of vegetation cover of the habitat.
- Size of organisms under study.
- Facilitation in terms of equipment to be used.
- Behavior of the organism e.g. their level of hostility and excitement when disturbed.
- Topography of the area.
- Type of habitat, terrestrial/aquatic.
- Risks involved during the exercise.
- Seasonal changes and its effect on organisms.

Methods of determining population size of organisms

1) Total count:

This is the physical counting of every individual of a population in a specified area of ground. It is effective for large animals living in unconcealed (exposed) habitats. It includes;

- Direct counting method (using a low flying aircraft)
- Aerial photography, etc.

i) Direct counting method using a low flying aircraft:

Used to determine population of large animals.

Requirements:

An air craft e.g. a helicopter, survey map of the area, stationary and binoculars

Procedure:

An air craft is flown at low altitude over the study area a long several strips of known area.

The number of organisms of given species under study is obtained by direct counting and recorded. This is repeated several times. The average population density for all the sample is then calculated.

Advantages:

- It gives a quick estimate of the population size.
- It reduces the risk of attacks from aggressive animals e.g. lions, buffalos, etc.
- Other studies on the population such as feeding habits, reproductive behavior, and predation can be carried out simultaneously.

Disadvantages:

- It is expensive since it requires sophisticated air craft and skilled man power.
- The sound made by the air craft may scare some animals which may hide in concealed areas e.g. under the trees.
- It's greatly hampered by some weather conditions e.g. fog, misty or cloudy weather.
- Can only be used on large animals and those in open grass lands.
- Not easy in very hilly areas.
- Calculations involved may cause inaccuracy.

ii) Aerial photography:

Requirements: Low flying air craft and a good camera.

Procedure:

- Photographs are taken from a low flying air craft over the whole study area.
- Photographs are then developed, printed and number of animals in each photograph counted
- Population density is then expressed as number per unit area.

Note: advantages and disadvantages are the same as direct counting.

2) Counting by sampling:

This is when the number of organisms is determined in several sample plots that represent a known fraction of the total area under investigation from which estimation of the total population size of the whole area is made by simple calculations

Sample counting is applied when the number of the organisms is large, covers a large area or where the behavior of organisms does not allow easy contact.

i) Capture mark release recapture method (Lincoln Index):

This method is used on highly mobile animals like fish, small animals like mammals e.g. rats, birds, arthropods e.g. insects like butterflies, moth, grass hoppers.

Requirements: Suitable traps, suitable tags/label e.g. aluminum discs for fish, permanent ink for rats/mice.

Procedure:

- Traps are set up randomly over study area.
- After some time, the traps are observed for any captures made, a count is made for all animals captured in this first occasion, noted as $\mathbf{N_1}$.
- They are all marked using a suitable label or tag e.g. placing an aluminum disc on the ear of a mammal (rat).
- These animals are then released back to their natural environment.
- After allowing sufficient time for the population to mix thoroughly, the traps are set up again all over the study area.
- A count is made of all animals captured on the second catch noted as $\mathbf{N_2}$.
- A count is made of how many animals captured on the second catch have marks/labels; i.e. those that have been recaptured. Noted as $\mathbf{N_3}$.
- The estimated total population **(P)** of animals in the area is then estimated using the ***Lincoln index*** as follows;

$$P = \frac{N1 \ x \ N2}{N3}$$

Where P-estimated total population of the area

N_1- number of individuals captured on the first occasion.

N_2- number of individuals captured on the second catch.

N_3- number of individuals recaptured on the second catch.

Assumptions made when using the capture mark Release recapture method

- That organisms mix randomly within the population.
- That the time allowed for random mixing is enough.
- That changes in population size due to immigration, emigration, death and birth are negligible.
- That the movement of organisms is restricted geographically.
- That there is even dispersing of organisms within the study area.
- That the mark does not hinder the movement of organisms or make them conspicuous to predators.
- There are few, if any, deaths and births within the population.
- The mark or label is not lost or rubbed off during the investigation.

Disadvantages/limitations

- ✓ It's only reliable when the organisms' range of movement is relatively restricted and defined.
- ✓ Animals often move in groups whose members recognize one another and avoid mixing with those of other groups.
- ✓ Many animals have particular localities where they confine, so the marked animals may not spread widely.
- ✓ Loss of marked individuals reduces those recaptured and this causes inaccuracy.
- ✓ The label may psychologically or physically disturb the organism.

Example:

In an attempt to estimate the number of tilapia in a small lake, 625 tilapia were netted, marked and released. One week later, 873 were netted of which 129 tilapia had been marked. What is the estimated population size of tilapia?

$$P = \frac{N1\ x\ N2}{N3}$$

$$P = \frac{625\ x\ 873}{129}$$

P=4230 tilapia

Assignment: In an investigation of a fresh water pond, 35 water bugs (**Notonecta**) were caught, marked and released. Three days later 35 water bugs were caught and 7 were found to be marked.

a) What is the approximate size of population of water bugs in the pond? Show your working.

b) Give three reasons why capture-recapture is unlikely to be an accurate way of assessing the size of water bugs.

ii) Use of a quadrat:

This is suitable for slow moving animals and grass.

Requirements: Metallic, plastic or wooden frame of a known area (frame quadrat) e.g. 1m^2

Procedure:

- The frame is randomly thrown several times in an area under investigation. (The larger the number of sample quadrats the more reliable the results will be).
- All individual within a quadrat are counted each time.
- Population density is expressed as the average figure per metre squared.
- Total population is got by multiplying the average with the total area under investigation.

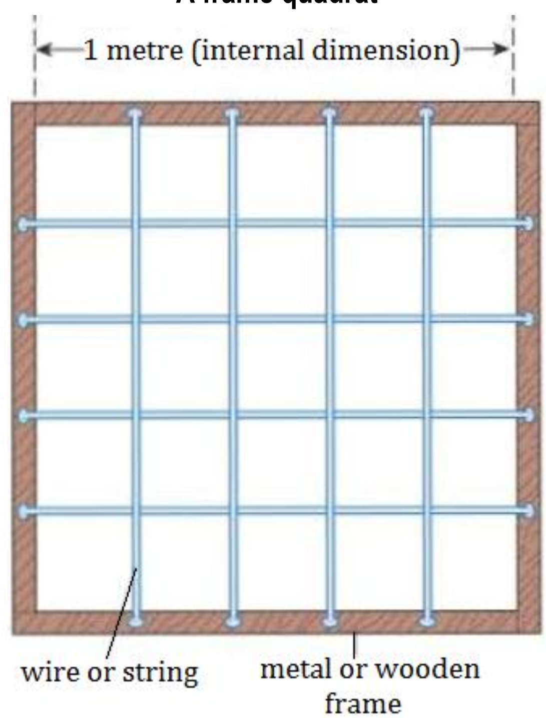
Advantages:

- ✓ It's accurate
- ✓ It enables comparison of different areas and species.
- ✓ It provides an absolute measure of abundance.

Disadvantages:

- Its time consuming.
- It's not suitable for first moving animals.
- It's not suitable for large sized animals.
- Some plants e.g. grass species are indistinguishable and may disturb.

A frame quadrat



Regulation of population size

Population size is naturally maintained at their normal carrying capacity depending on the resources in a given habitat. These populations are controlled by homeostatic means depending on the density controlled factors e.g. food, pests, diseases, predators etc.

The population itself initiates the control measure i.e. an increase in population stimulates environmental resistance which brings the population back to normal, and a decrease in population below carrying capacity, environmental resistance decreases, thus causing an increase in the number of organisms e.g. predator –prey relationship.

Methods of population control

1) Biological control method:

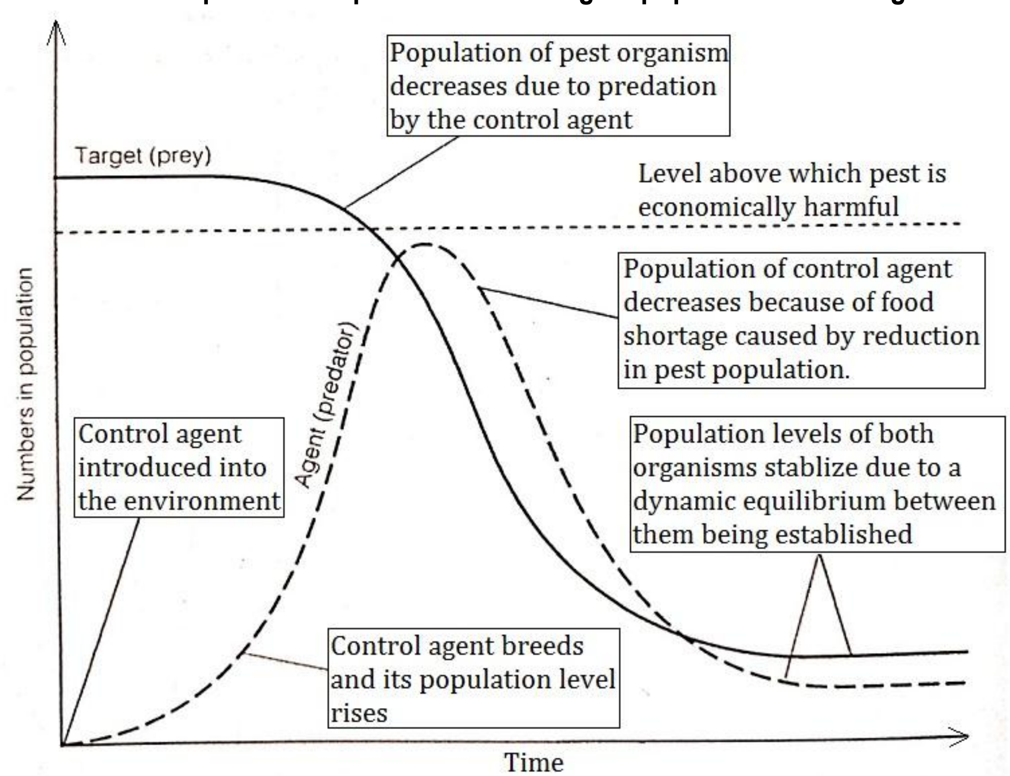
This is the eating or weakening of a pest species or weeds using other organisms called **control agents** like natural predator, parasite or pathogen. It is a means of managing populations of organisms which compete for human food or damage the health of humans or livestock. The aim is to bring the population of a pest down to a tolerant level by use of its natural enemies. A beneficial organism (the agent) is deployed against an undesired one (the target).

Thus method is very specific thus non-target (useful) organisms are not affected.

The aim is not to eradicate the pest; this could be counter-productive. If the pest was reduced to such an extent that it no longer provided an adequate food source for the predator, then the predator in turn would be eradicated. The few remaining pests could then increase their population rapidly, in the absence of the controlling agent, a situation known as **pest resurgence**.

The ideal situation is where the controlling agent and the pest exist in balance with one another, but a level where the pest has no major detrimental effect.

General relationships between pest and control agent populations in biological control



Biological control method can be used to:

- Control vector population.
- Control parasites.
- Control pathogens (bacteria& virus)
- Control some plants e.g. weeds
- Control pests.

Examples are:

- Using cats to eat rats.
- Using beetles to feed on the water hyacinth on Lake Victoria.
- Placing fish in ponds to eat mosquito larvae.

Steps involved in biological pest control

- ✓ Identifying the pest and tracing its origins, i.e. where it came from.
- ✓ Investigating the original site of the pest and identifying natural predators, parasites or pathogens of the pest.
- ✓ Testing the potential control agent under careful quarantine to ensure its specificity.
- ✓ Mass culturing of the control agent.
- ✓ Development of the most effective distribution / release method for the control agent.

2) Use of pesticides:

A ***pest*** is an organism which is in competition with humans for food or soil space, or is potentially hazardous to health or causes annoyance. ***Pesticides*** are poisonous chemicals which kill pests, and they are named after the pests they destroy; hence herbicides kill weeds, insecticides kill insects, fungicides kill fungi, rodenticides kill rodents such as rats and mice.

Properties of an ideal pesticide

- Should **not persist** but be unstable enough to breakdown into harmless substances. It should not have long-term effects.
- Should be **specific** so that only pest species is killed and harmless to all others.
- Should **not accumulate** either in specific parts of an organism or as it passes along food chains.
- Should **have effective control** of the pest under field growing conditions.
- Should be **easy to apply** at the correct dosage.

Problems of using insecticides

- ✓ Accidental misuse of toxic chemicals results in death of humans and domestic animal.
- ✓ Many are non-specific, killing non-target species, particularly natural predators of the pest species.
- ✓ Pest resistance occurs i.e. genetic variation enables a few individuals in the pest population to survive and may quickly reproduce.
- ✓ There is pest replacement i.e. since most crop are susceptible to attack by more than one pest species, and the pesticide may be more deadly to one species than another, elimination of one species may simply allow another species to assume major pest proportions.
- ✓ **Pest resurgence** may occur i.e. non-specific pesticides may kill natural predators as well as pests, and so a small residual pest population may multiply quickly without being checked.
- ✓ **Bioaccumulation** (some molecules of the pesticide may be stored in specific organs or tissues at levels higher than would be expected) and **biological magnification** (the pesticide may get more concentrated as it passes along the food chains and webs) may occur. E.g. If Dichlorodiphenyl trichloroethane, DDT is sprayed on plants, to kill green flies, some

survive, and absorb the chemical into their bodies. When eaten by small birds, DDT accumulates and when birds are eaten by other predators, e.g. birds of prey, the accumulation of DDT reaches a level which burns up and kills the final consumer.

Practice Questions:

1. What is a biological pest control?
2. What consideration must be made before application of biological pest control method?
3. State two ways in which the chemical control method can upset an ecosystem.
4. Suggest three characteristics of a good pesticide.
5. The table shows the amount of DDT in plants per million found in a variety of organisms associated with fresh water lake.

Site of DDT measurement	Amount of DDT in parts per million
water	0.0003
phytoplankton	0.002
zooplankton	0.004
Herbivorous fish	0.39
Carnivorous fish	0.89
Fish eating birds	14.2

a) (i). Calculate how many times DDT is more concentrated in carnivorous fish compared with its concentration in water
(ii) What do the results in a (i) show?

b) Explain why the concentration of DDT changes from water to carnivorous fish?

c) Explain how a pest sprayed with a pesticide may flourish afterwards?

6. In an aquatic ecosystem which was affected by an insecticide, analysis of energy flow and concentration of the insecticide in each trophic level in a food chain was made. The results were shown in the table below.

Energy flow	pesticide
Producers	0.04
Herbivores	10
Carnivore 1	50
Carnivore 2	75

a) Explain why from producers to consumers:
   i) Level of insecticide increases.
   ii) The flow of energy decreases.

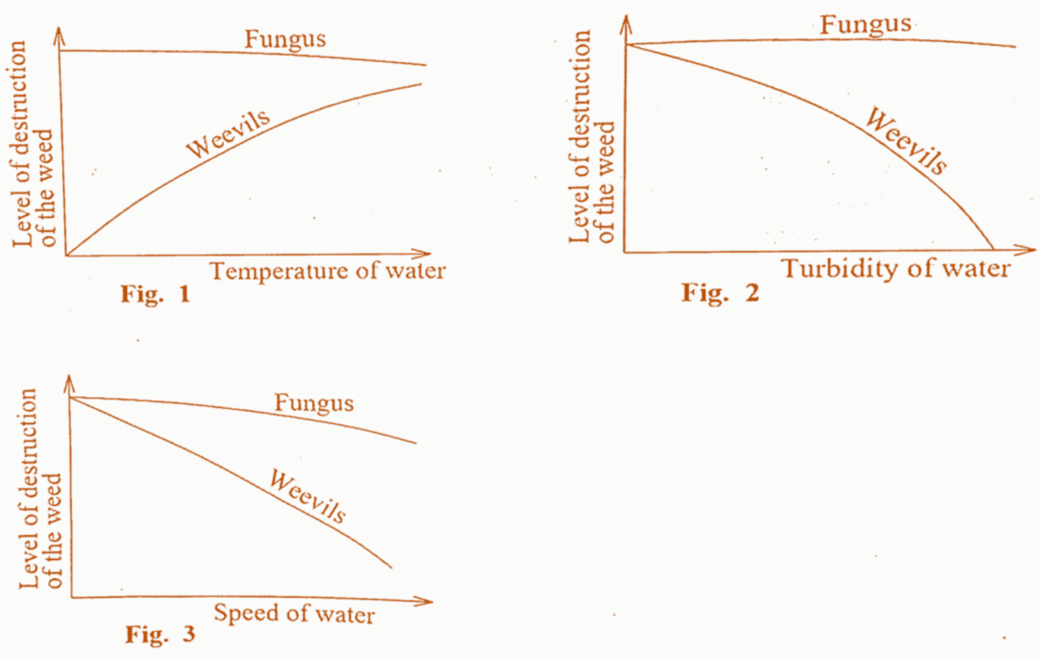
b) Give three ecological problems that may arise from the use of pesticides.

WORKED OUT EXAMINATION QUESTION

The water hyacinth Echhornia crassipes is a weed growing on many waters of Uganda. In the biological control of the weed on Lake Victoria, a fungal pathogen and weevils are employed. The characteristics of the fungus and the weevils in relation to their feeding behaviour is shown in Table **1**. Table **1**

Fungus	Weevils
Feeds on the water hyacinth alone	May feed on other plants other than the water hyacinth
Attacks only the green parts of the plant	Attacks all parts of the plant

The level of destruction of the weed by the fungus and the weevils under varying water conditions in temperature, turbidity and speed of water are shown in figures **1**, **2** and **3**. Study the information and answer the questions that follow.



a) From the information provided, suggest explanations for the level of destruction of the weed by each organism under different conditions of water.

Fungus:

- *The fungus attacks the green part of the water hyacinth most of which is outside the water so is not affected by varying temperature of the water.*
- *Turbidity which reflects the quality of water in terms of dissolved oxygen does not affect the damage of the fungus because most of it is outside the water.*
- *The speed of water slightly reduces the effect of the fungus because moving water may cause brushing of leaves against each other thereby brushing off some amount of fungus from leaves.*

Weevils:

- *Weevils attack all parts of the water hyacinth thus warm temperatures increase their metabolic activity leading to increased feeding.*
- *Turbidity reduces activity of weevils because the higher the turbidity the less the amount of dissolved oxygen which reduces the metabolic activity of weevils. It also reduces visibility of edible parts of the plant.*
- *The faster the speed of the water the less the effect of weevils because fast moving water may dislodge or drown some weevils attached onto the water hyacinth plant together with their leaves.*

b) From the information provided, give advantages that the

i) Fungus has over the weevils in destroying the weed.

- *Fungus is specific so destruction of hyacinth is more intense while weevils feed on other plants so reducing their effect on the hyacinth.*
- *Fungus is not affected by turbidity, speed of water and temperature.*

ii) Weevils have over the fungus in destroying the weed.

- *Weevils attack all parts of the water hyacinth making destruction of the hyacinth more complete while the fungus attacks only the green parts leaving some parts undamaged.*

Natural resources

A natural resource is anything not made by man obtained from the environment to meet human needs and wants. They support life and are needed for survival and prosperity. They are found in air, water, land, minerals, plants and animals.

Classification of natural resources

Type of natural resource & its definition	Examples
i) **Inexhaustible resources:** Resources that are not likely to be exhausted by man's activity or their use.	Solar energy, wind, tidal energy. Water may get diminished in rivers or lakes if not used properly.
ii) **Renewable resources:** Resources that reappear or replenish (replaced) themselves by quick recycling and replacement within a reasonable time.	Fresh water, fresh air, fertile soil, wild life and plants (Forests, grasslands). *Underground water, forests and wild life if not managed properly can become non-renewable.*
iii) **Non-renewable resources**: Resources that exist in a fixed quantity or stock in the earth's crust. They lack the ability of recycling and replacement.	Fossil fuels (e.g. coal, petroleum), metallic minerals (e.g. copper, iron, aluminium) and non-metallic minerals (e.g. salt, clay, sand, phosphates).

Measures for energy conservation and for reduction of wastage

- Development of alternative sources like non-conventional energy to reduce man's dependence on fossil fuels.
- Use of solar energy in the form of solar cookers, solar heaters, solar –battery driven cars, etc.
- Use of bio-gas plants to utilize agricultural and animal wastes for energy.
- Generation of energy from hydroelectric, wind and tidal power to be explored extensively.
- Planting of more fuel wood trees and shrubs by local communities at a wide scale.

Reasons of depletion of land resources

- Soil erosion due to deforestation and then human activities.
- Salination, waterlogging, acidification and alkalization make the soil unfit for agriculture.
- Construction of dams, roads, and railways, urban encroachment, industrialization and mining.

Living resources

1. Microorganisms

Microorganisms are useful as well as harmful to the mankind.

Economic importance of microorganisms

- They are used in industries to produce alcohol, methane, vitamins, antibiotics and a number of other compounds.
- Nitrogen-fixing bacteria can fix nitrogen and are useful in agriculture.
- They are used for fermentation of fruit juices, butter and cheese.
- Many forms are being modified by mutation or other technique to serve some useful purpose for mankind.
- Many act as decomposers and help in recycling of materials.
- Many cause diseases in plants, animals and humans.

2. Plants

They the basic products and provide food to the whole living world. They also provide wood, clothing, shelter, medicines, paper, and rubber, vegetable oils for man and raw materials for many industries.

The land plants are broadly classified as forests, grass lands, shrubs and crop lands.

Reasons for depletion of plant resources

- Deforestation for urbanization and industrialization.
- Overgrazing by domestic animals.
- Conversion of climax communities to croplands for food.
- Environmental pollution due to industrialization.

All these and many more indirectly affect plants as a result of various human activities which all lead to depletion of vegetation. Many species of flowering and non-flowering plants have been put in the category of endangered species.

3. Animals

Animals are also renewable resources and help in maintaining ecological balance.

Animal resources are very important in maintaining ecological balance for the following reasons:

- A large number of insects and many animals help in pollination and dispersal of fruits and seeds.
- They provide food, fibres, leather, silk honey, manure, chemicals and other useful things for human beings.
- They form a part of a food chain in the ecosystem.
- Many animals are able to decompose the dead and decayed and help in recycling of materials.
- Animals being heterotrophic help in the biodegradation of organic compounds.
- Animals like rats, monkeys and guinea pigs are used for experimental purposes.

Conservation of natural resources

What is conservation?

Conservation is the management of the Earth's natural resources by humans in such a way that maximum use of them can be made in the future. This involves active intervention by humans to maintain ecosystems and biodiversity. It is therefore a dynamic process that entails careful management of existing resources and reclamation of those already damaged by human activities.

The main reasons for conservation are:

- **Personal:** To maintain our planet and therefore our life support system.
- **Ethical:** Other species have occupied the Earth far longer than we have and should be allowed to coexist with us. Respect for living things is preferable to disregard for them.
- **Economic:** Living organisms contain a gigantic pool of genes with the capacity to make millions of substances, many of which may prove valuable in the future. Long-term productivity is greater if ecosystems are maintained in their natural balanced state.
- **Cultural and aesthetic:** Habitats and organisms enrich our lives. Their variety adds interest to everyday life and inspires writers, poets, artists, composers, and others who entertain and fulfill us.

Rare and endangered species

More than a thousand species of vertebrates and other animal species are on the verge of ***extinction***. Therefore to prevent the continued extinction of species due to human activity we must:

- Identify the species at greatest risk.
- Investigate why they have become vulnerable.
- Attempt to remedy the problem.

Species with small populations either restricted geographically with localized habitats or with widely scattered individuals are described as ***rare species***. They are at risk of becoming rarer, but they are not in immediate danger of extinction.

Species that are under threat of or actually declining in number, or species which have been seriously depleted in the past and have not yet recovered are described as ***vulnerable species***.

Species whose numbers have been greatly reduced and are likely to become extinct if the factor causing their numbers to decline is not removed are described as ***endangered species.*** There numbers are very low and in considerable danger of becoming extinct.

Extinct species are those which cannot be found in areas they recently inhabited nor in other likely habitats

How organisms become endangered

- Habitat destruction through deforestation, bush burning, swamp reclamation e.g. the Uganda cranes breeds in wetlands, when such wet lands are destroyed, their existence is threatened.
- Hunting and collection e.g. elephants are hunted for their ivory, rhinos for their horns and python for its skin hence threatening their survival.
- Indiscriminate killings for sport and poaching of animals for their products to satisfy short term motives of man.
- Some organisms are massively destroyed due to their being health hazards to man. E.g. vectors like mosquitoes and water snails are killed because they are dangerous to man.
- Competition between exotic and local breeds. In cattle, exotic breeds are preferred because of their high breed vigor reducing the number of local breeds greatly to near extinction.
- Process of natural selection where some species are better adapted to the conditions of the environment than others, those less adapted are likely to reduce in number.
- Stiff predation pressure where the predator has a preferred prey, the preferred prey will be over consumed leading to its population to decline.
- Pollution e.g. oil spills, excessive use of fertilizers due to industrialization resulting into release of dangerous gases which lead to death of animal species.

Note: large mammals are more prone to extinction than small mammals because of the following reasons:

- Large animals need more food than small ones therefore in conditions of food scarcity they are likely to die which reduces their numbers up to extinction.
- Problems in achieving fast enough locomotion so that prey fails to escape from predators or predators fail to catch prey and die due to lack of food.
- Food specialization limits range of consumed food, population may be wiped in case of sudden shortage of food.
- Large animals are normally at the end of a food chain so get less energy and also accumulate more stable pesticides e.g. DDT.

Conserving endangered species

To ensure that organisms that are endangered get conserved, the following can be done:

- Development of national parks and nature reserves. These may preserve a vulnerable food source to the animal e.g. bamboo forests are preserved because they are the sole source of food to the Chinese giant panda and the thick forests which are habitats for gorillas, chimpanzees and baboons.
- Legal protection for endangered species by making it illegal to collect or kill endangered species.
- Development of commercial farms which produce sought out after goods e.g. sheep and deer farming may produce enough material (wool) to satisfy the market and so remove the necessity to kill these animals in the wild.
- Breeding endangered species in zoos and botanical gardens. Endangered species may be bred in the protected environment and when numbers have been sufficiently increased they may be reintroduced into the wild.
- Removal of animals from threatened areas by humans or by natural disasters such as floods and resettling them in more secure habitats.
- Control of introduced species into a country by humans often require strict control if they are not to outcompete the indigenous species.
- Ecological study of threatened habitats by careful analysis of all natural habitats if they are to be managed in a way that permits conservation of a maximum number of species.
- Pollution control measures such as smoke emissions, oil spills, over use of pesticides, fertilizer run off, all help to prevent habitat and species destruction.
- Recycling of materials to reduce pressure on natural resources from which raw materials are obtained. For instance materials obtained through mining. These activities often destroy sensitive habitats either directly or indirectly through dumping of waste which is toxic or the development of roads to transport such materials.
- Education. It is important to educate the people in ways of preventing habitat destruction and encouraging the conservation of organisms.
- Restricting urban and industrial development.
- Establishing sperm banks and seed stores to maintain a high biodiversity.

Interdependence

This is the interaction among organisms in the environment. Organisms interact in the following ways:

1. Competition:

This is a relationship whereby two individuals of the same species or different species struggle to obtain resources which are in limited supply.

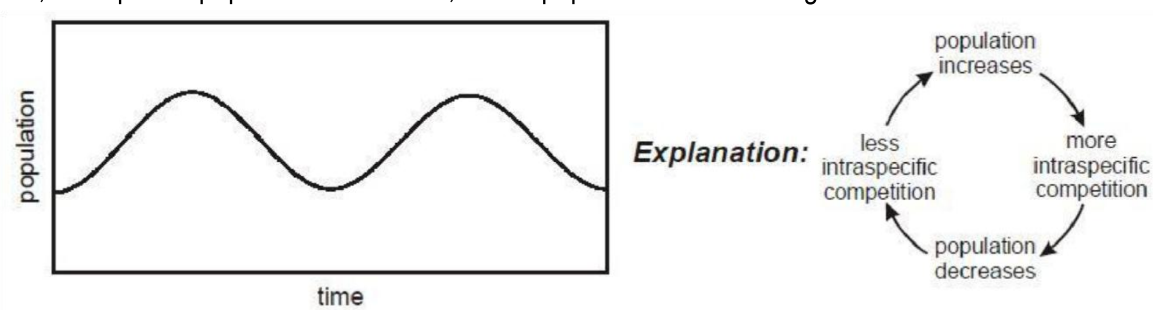
E.g. plants competing for light, carbon dioxide, water, minerals, pollinators, and sites for spores and seeds to germinate while animals compete for food, mates, breeding sites and shelter from predators.

Types of competition

i) Intraspecific competition:

This is the competition between members of the same species for the same resources. Intraspecific competition tends to have a stabilizing influence on population size.

If the population gets too big, intraspecific population increases, so the population falls again. If the population gets too small, intraspecific population decreases, so the population increases again.



ii) Interspecific competition:

This is the competition between members of two or more different species for food, space, good hiding place, water, sunlight, nesting sites or any other limited resource.

Competition is very intense when there is significant overlap of niches, and in this case one of the competing species must;

- Migrate to another area if possible.
- Shift its feeding habits or behaviour through natural selection and evolution.
- Suffer a sharp population decline or
- Become extinct in that area, otherwise two species can never occupy exactly the same ***ecological niche***.

An ecological niche is the role and position any species has within its habitat, and its interactions with living and non-living environment. A niche describes how an organism meets its need for food and shelter, how it survives, and how it reproduces. Due to competition for resources, niches can be divided into two types, i.e. realized niche and fundamental niche.

Realized niche: This is the actual space that an organism inhabits and the resources it can access as a result of limiting pressure from other species like superior competitors. It occurs in the presence of predators, competitors and parasites which limits the habitat and roles performed by an organism. It is smaller in size.

Fundamental niche: This is the entire set of conditions under which an animal can survive and reproduce itself. It occurs in the absence of predators, competitors and parasites thus allowing the organism experience a larger habitat and perform a variety of roles.

Gause's competitive exclusion principle

Gause's competitive exclusion principle states that where two different species competing for the same resource cannot co-exist, so the weaker species is outcompeted to extinction.

According to **Georgy Gause's (Russian biologist) competitive exclusion principle**; "no two species can occupy the same ecological niche."

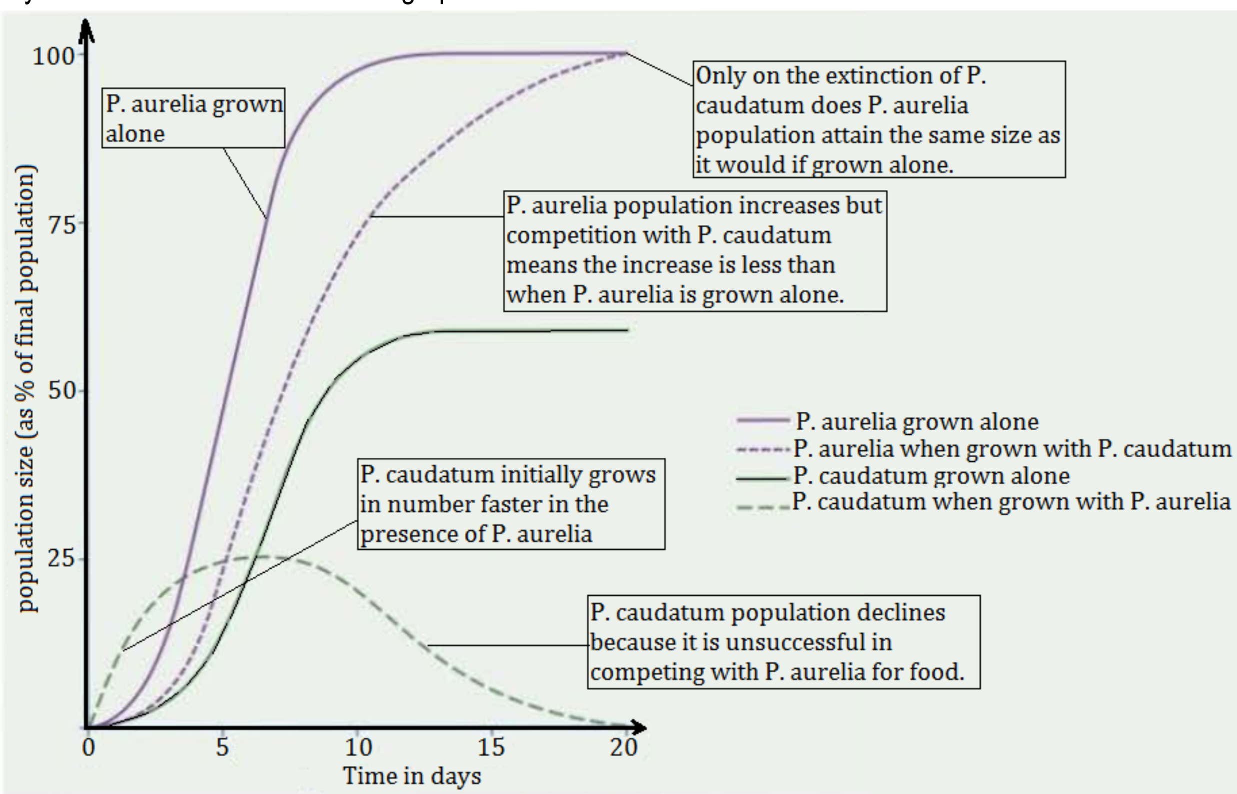
For example

i) Two species of flour beetles, *Tribolium castenum* and *T. confusum* were kept in the laboratory in bottles of flour acting as a habitat and providing food for them under variable temperature conditions (24^0C - 34^0C) and humid conditions (very humid 70% and 30%).

Observation: At high temperatures and in very humid conditions, *Tribolium castenum* succeded better while at low temperatures and in very dry conditions, *T. confusum* did better.

Whatever the conditions, **only one** of the species eventually survives.

ii) In an experiment, two species of a genus of unicellular organism called Paramecium aurelia and P. caudatum were grown separately in different test tubes that contained yeast as a source of food. The two species were again grown together in the same test tube with yeast as a food source. In each case the population of both species were measured over a period of 20 days. The results are shown in the graph below:



Observation:

When cultured separately, each species has maximum population coming almost constant with time due to:

- Presence of toxic wastes which can poison paramecium.
- Heat generated during respiration may kill some paramecium.
- Decrease in food measures.

When the two species of paramecium are cultured together, *Paramecium aurelia* gets competitive advantage over *P. caudatum* and after several days, *P. caudatum* gradually decreases and later decreases rapidly until its excluded hence competitive exclusion principle. *P. caudatum* therefore goes to extinction.

The competitive advantages of *P. aurelia* are:

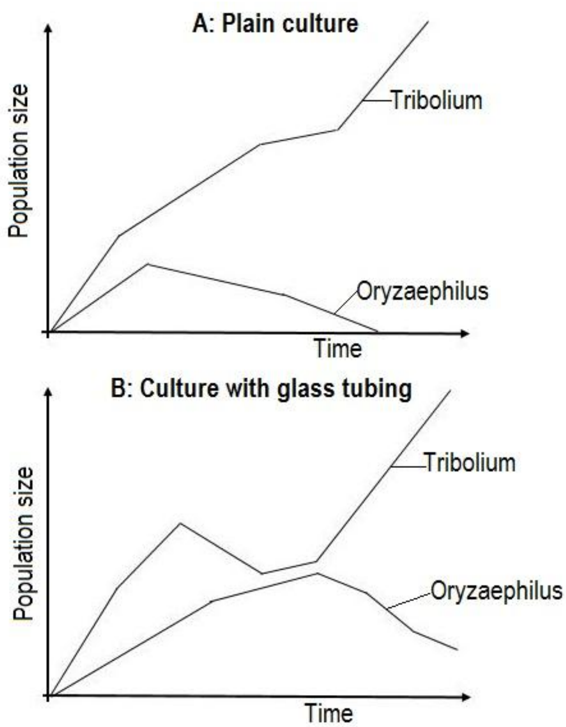
- High rate of reproduction.
- High growth rate.
- Good nutrient absorptive capacity or greater efficiency in obtaining food.
- Being small, it requires less food hence can easily survive when food is scarce.
- Survivorship, long life span.

How species reduce or avoid competition through resource partitioning

Some species that are in competition for the same resources have evolved adaptations that reduce or avoid competition or an overlap of their *fundamental niches*. Resource partitioning decreases competition between two species leading to increased niche specialization.

Resource partitioning is where two different species co-exist and share the same resources and both species survive. It is the dividing up of scarce resources so that species with similar needs use them at different times, in different ways or in different places.

The graphs below show the results of experiments carried out on two species of flour beetle, *Tribolium* and *Oryzyephilus*, which were grown together in slightly different environments. In ***figure A***, *Tribolium* and *Oryzaephilus* were grown in plain flour culture while in ***figure B*** they were grown in a culture which had glass tubings. For each experiment four adult beetles of each species were introduced in the culture and the population size of each species was determined at regular intervals.



Observation:

A: In plain culture,the population size of *Tribolium* increases as that of *Oryzaephilus* decreases to extinction due to higher reproductive potential or growth rate of *Tribolium* hence putting *Oryzaephilus* at a disadvantage in terms of competition for food/flour. At the end of the experiment the population size of *Tribolium* increases rapidly in the absence of *Oryzaephilus* due to reduced competition for food/flour/habitat

This is the **Gause's competitive exclusion principle** where two different species competing for the same resource cannot co-exist, so the weaker species is outcompeted to extinction.

B: In culture with glass tubings, the glass tubings provide a microhabitat for *Oryzaephilus* and hence giving it some advantage to compete with *Tribolium*.

In the middle of the experiment, population size of *Oryzaephilus* increases gradually as that of *Tribolium* is decreasing rapidly due to increased inter-specific competition.

At the end of the experiment, population size of *Tribolium* increases rapidly as that of *Oryzaephilus* deceases since *Tribolium* is a better competitor.

However the population size of *Oryzaephilus* does not decrease to extinction due to some *Oryzaephilus* avoiding direct competition from *Tribolium* by utilizing the microhabitats provided by the glass tubings.

This is known as **resource partitioning** where two different species share the same resource and allow co-existence so that both species survive.

Examples of resource partitioning

- When living in the same area, lions prey mostly on larger animals while leopards on smaller ones.
- Hawks and owls feed on similar prey, but hawks hunt during the day and owls hunt at night.
- Different species of eagles in a forest feed at different times of the day e.g. bald headed eagles are most active early mornings and evenings while the white-breasted eagles feed vigorously towards noon.
- When three species of ground finches of Galapagos Islands occur on separate islands, their bills tend to be the same intermediate size, enabling each to feed on a wider range of seeds, but where they co-occur, there is divergence in beak size to suit each finch species to feeding on seeds of either small, medium or large size, but not all sizes.
- In an abandoned field, drought tolerant grasses with shallow, fibrous root system grow near the soil surface to absorb moisture; plants with a taproot system grow in deeper soil while those with a taproot system that even branches to the topsoil and below the roots of other species grow where soil is continuously moist.

Practice Question:

a) Explain the role of competition in regulating the size of population.

b) Duck weed grows on or near the surface of ponds. Its growth can be measured by counting the number of fronds. Two species of duckweed, Lemna trisulca and Lemna minor were grown separately, and together in identical beakers in the laboratory.

	Total number of fronds.			
	Species grown separately		***Species grown together***	
Days	***L. trisulca***	***L. minor***	***L. trisulca***	***L. minor***
0	*30*	*30*	*30*	*30*
16	*63*	*78*	*48*	*105*
36	*126*	*142*	*84*	*234*
46	*177*	*225*	*84*	*324*
54	*165*	*276*	*48*	*360*
60	*129*	*219*	*45*	*354*

i) Draw graphs to compare the rates of growth of the two species when grown separately and when grown together.

ii) What do the graphs suggest about the growth rate of the two species grown separately?

iii) Account for this difference.

iv) Offer an explanation for the interaction of the two species when grown together.

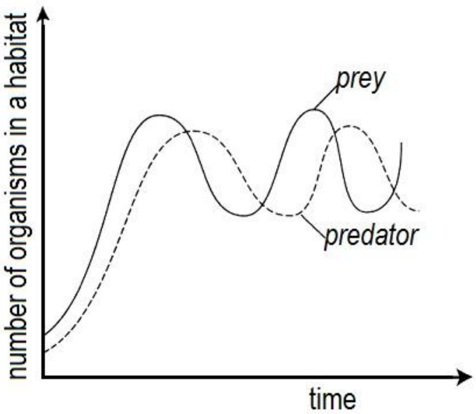
v) Account for the changes in the growth rate between 46 and 60 days for Lemna trisulca.

2. Predation:

This is a relationship whereby members of one species (the predator) feed on all or part of a living organism of another species (the prey). Therefore, predators are only found where there is prey e.g. herbivores are found where there is suitable plant material.

A predator is an animal that feeds on another live organism. **A prey** is the live organism that is fed on by the predator.

The graph showing the predator-prey relationship



Description:

Initially, the population of the prey is higher that the population of the predator.

Within a short time, both populations of prey and predator increase rapidly.

The population of the prey reaches a maximum earlier than the predator population.

As the prey population decreases rapidly, the predator population continues to increase gradually for a short time to a maximum after which it decreases rapidly.

As the predator population continues to decrease, the prey population starts to increase rapidly, followed by a rapid increase in predator population. The cycle is repeated.

Explanation:

At the beginning, there are more prey than predator to provide food to the predators.

When the predator population is low, they get enough food and few preys are eaten so they both increase rapidly.

The large number of preys provides food to predators, so they reproduce fast and increase in numbers. The increased predator population eats many preys and the prey population crashes.

The decrease in prey numbers causes the predators to starve and even their reproduction reduces, so the predator numbers crash.

Finally, the very low number of predators allows the prey population to recover, causing the cycle to start again.

Evolutionary significance of predator–prey

Predation usually eliminates the unfit (aged, sick, weak). This gives the remaining prey access to the available food supply and also improves their genetic stock hence, enhances the chances of reproductive success and longtime survival, thus pass on their good traits to their off springs which can improve their evolution.

How predators are suited for capturing prey

- They have keen eyes for locating prey e.g. wolves, African lions hunt in groups.
- Praying mantis, chameleon have cryptic coloration/camouflage that enable them to walk to prey unnoticed.
- Nocturnal predators e.g. bats have highly developed sense for detecting sound made by prey.
- Some snakes which have glands to secrete poison (venom) which the fangs inject into prey to immobilize it (prey).
- Web-spinning spiders use their silky cob webs to catch small sized ground walking or flying insects.
- Some have soft pads at the bottom of their feet so that they are not easily detected as they walk towards prey
- Some have stinging cells which paralyze their prey e.g. sea anemones
- Have long and sharp canines which pierce and kill prey
- Well-developed limbs which increase the speed of locomotion to chase and capture prey.

Significance of Predation

i) Determines distribution and abundance of the prey because:
   - An increase in the number of predators results into decrease in the number of prey.
   - Predators will always be found in places of their potential prey.

ii) Predation leads to dispersal of animals which reduces competition since it involves movement of animals from place to place.

iii) Predation is a biological control method.

How prey species are suited to avoid predation

- ✓ Ability to run, swim or fly faster.
- ✓ Possession of highly developed sense of sight or smell alerting the presence of predators.
- ✓ Possession of protective shells e.g. in tortoise and snails for rolling into armor-plated ball.
- ✓ Possession of spines like in porcupines or thorns (cacti and rose-bushes) for pricking predators.
- ✓ In some lizards tails break off when attacked, giving the animal enough time to escape.
- ✓ Other preys gain some protection by living in large groups e.g. schools of fish, herd of antelope, flocks of birds.
- ✓ Some prey scare predators by puffing up e.g. blowfish, or spreading wings e.g. peacock.
- ✓ The flesh of some slow-moving fish is poisonous e.g. porcupine fish.
- ✓ Some preys secrete poisonous or repellant substances e.g. scorpions, caterpillars, some grasshoppers and Culex mosquito eggs
- ✓ The electric fish Malapterurus (a cat fish) produces high voltage discharge that shocks any predator that makes contact with it.
- ✓ Other preys employ alarm signals and calls e.g. ants, various fish, small birds and mammals.
- ✓ Group defense occurring among those that live and feed in herds like the Buffalos.
- ✓ Some prey species discourage predators by secreting chemicals that are poisonous (e.g. oleander plants), irritating (e.g. bombardier beetles), foul smelling (e.g. stinkbugs and skunk cabbages) or bad tasting (e.g. monarch butterflies and buttercups).
- ✓ Some species gain protection to avoid predation by mimicking (looking and acting like) other species that are distasteful to the predator. ***Batesian mimicry*** occurs when the palatable species mimics other distasteful species e.g. viceroy butterfly mimics the poisonous monarch butterfly, the harmless hoverfly mimics the painful stinging wasp while ***Mullerian mimicry*** occurs when both the mimic and mimicked are unpalatable or dangerous e.g. the five spot Burnet and related moths.
- ✓ Some prey ***camouflage*** by changing colour e.g. chameleon and cuttlefish, or have deceptive colours that blend with the background e.g. arctic hare in its winter fur blends into snow.

Camouflage is the use of any combination of materials, coloration or illumination for concealment either by making animals difficult to see or by disguising them as something else. It exists in the following forms:

i) **Warning colouration**:
Conspicuous colouring that warns a predator that an animal is unpalatable or poisonous e.g. poisonous frogs have hot colours like red and orange, some snakes, monarch butterflies, and some grasshoppers.

ii) **Disruptive colouration/patterning**:
This works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability e.g. a group of zebras**.**

iii) **Cryptic colouration:**
This allows an organism to match its background and hence become less vulnerable to predation e.g. chameleon.

3. Symbiosis:

Symbiosis (from Greek, *sumbíōsis*, "living together", from *sún*, "together", and bíōsis, "living") is any type of a close and long-term biological interaction between two different biological organisms, be it ***mutualistic, commensalistic***, or ***parasitic***.

The organisms, each termed a **symbiont**, may be of the same or of different species. It can also be defined as "the living together of unlike organisms".

The term was subject to a century-long debate about whether it should specifically denote mutualism, as in lichens. Biologists have now abandoned that restriction.

Symbiosis can be ***obligatory***; which means that one or more of the symbionts entirely depend on each other for survival, or ***facultative*** (optional); when they can generally live independently.

Symbiosis is also classified by physical attachment. When symbionts form a single body it is called ***conjunctive symbiosis***, while all other arrangements are called ***disjunctive symbiosis***.

When one organism lives on the surface of another, such as head lice on humans, it is called ***ectosymbiosis***; when one partner lives inside the tissues of another, such as *Symbiodinium* within coral, it is termed ***endosymbiosis.***

Forms of symbiotic relationships

i) Parasitism:

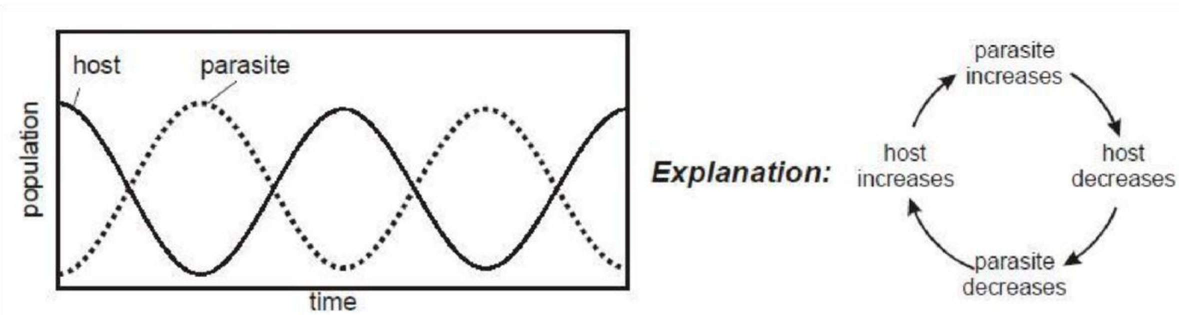
An organism called **parasite** obtains part or all its nutrients from the body of another organism of different species called **host.**

The parasite is usually smaller than its host in size.

Parasites do not usually kill their hosts, but the host suffers harm.

Many parasites live permanently on (ecto parasites) or in their hosts (endo parasite) while some visit their hosts only to feed.

Some parasites are **facultative**, live on or in the host for some time e.g. Pythium (a fungus) that causes damping of seedlings, on killing the seedlings, lives as a saprophyte on their dead remains and others are obligate (live on or in the host for their entire lives)



ii) Mutualism:

This is an interspecific association in which both organisms benefit.

Examples include.

- Cellulose digesting bacteria in the gut of ruminants such as goats, cattle and sheep. Ruminants obtain sugars and amino acids while bacteria obtains shelter and food.
- Leguminous plants e.g. clover and nitrogen fixing bacteria (rhizobium). The plants obtain nitrates while bacteria obtains shelter, sugars and vitamins.
- Mycorrhiza (fungus and root of higher plants) .In **ectotrophic mycorrhiza**, the fungus forms a sheath covering lateral roots of forest trees such as oaks, beech, conifers, while depending on photosynthesis by the tree to provide organic materials. **Endotrophic mycorrhiza** involves most of fungi inside the root of orchids with the fungi digesting lignin and cellulose in the soil; and passing the end products into the roots of plants.

- Lichens; algae and fungus. Algae carries out photosynthesis providing nutrients to the fungus while the algae is protected by the fungi from intense sunlight and desiccation, minerals absorbed by the fungus are also passed onto the algae.

iii) Commensalism:

This is an association between organisms of different species in which one benefits while the other neither benefits nor harmed. E.g. cow and white egrets, epiphytes and host plant, etc.

4. Pollination and dispersal:

Pollination is an ecological interaction because plants and animals interact with each other. Insects transfer pollen grains from anthers to stigma.

Dispersal of seeds and fruits introduces new plants to new habitats and this minimizes competition among species.

Both interactions between the flowering plants and animals like insects, birds and bats may be highly elaborate and species specific. This co-evolution ensures that the distribution of the plants with their pollinations or agents of dispersal are related. E.g. arum lily flowers are pollinated by dung flies.

Co evolution *is a long term evolutionary adjustment of two or more groups of organisms that facilitate those organisms living with one another.* Examples include:

- Many features of flowering plants have evolved as a result of dispersal of plant's gametes by insects and insects have in turn evolved special traits for obtaining nectar.
- Grasses have evolved the ability to deposit silica in their leaves and stems to reduce their risks of being grazed, large herbivores have in turn evolved complex molars with enamel ridges for grinding up grass.

5. Antibiosis:

This is the secretion by organisms of chemical substances into their surrounding that may be repellant to members of the same species or different species e.g. penicillium (a fungus) secretes antibiotics that inhibit bacterial growth, ants release pheromones to warn off other members of a species in case of danger.

Two types exist:

i) **Intraspecific antibiosis** secretion by organisms of chemical substances into their surrounding that may be repellant to members of the same species e.g. male rabbits secrete pheromones from their submandibular salivary glands that are used to mark territory as a warning to other bucks that the territory is occupied.

ii) **Interspecific antibiosis** secretion by organisms of chemical substances into their surrounding that may be repellant to members of the different species e.g. penicillium (a fungus) secretes antibiotics that kill or prevent the bacterial growth.

Effects of Human Activities on Ecosystems

Of all living organisms, humans exert most influence on the distribution and survival of other species through a multitude of activities like pollution, deforestation, farming, construction etc.

Pollution

It is the release of substances or energy into the external environment in such quantities and for such duration that may cause harm to living organisms or their environment.

Pollutants include; noise, heat and radiation as different forms of energy, many chemical compounds and elements and excretory products.

The parts of external environment affected include air, water and land.

Harm caused by pollutants.

- Disruption of life support systems for living organisms.
- Damage to wild life, human health and property.
- Nuisances such as noise and unpleasant smells, tastes and sights.

Types of pollution

They are: Air pollution, Water pollution, Thermal pollution and soil pollution.

Air pollution

Pollutant	Source(s)	Effects/ consequences	Control measures
1. Carbon monoxide	Motor vehicle exhausts, Incomplete combustion of fossil fuels, tobacco smoking, etc.	• Prevents oxygen usage by blood by forming carboxy-haemoglobin, which may cause death. • Small concentrations cause dizziness and headache	• Efficient combustion of fuels in industry and homes. • Avoid smoking. • Vehicle exhausts gas control.
2. Sulphur dioxide	Combustion of Sulphur containing fuels, oil and coal gas	✓ Causes lung diseases, irritation of eye surface, and asthma resulting into death if in high concentrations. ✓ Forms acid rain which increases soil PH. ✓ Reduces growth of plants and kills lichens. Note: *Lichens are indicator species for sulphur dioxide pollution.* *The presence of many lichen species indicates low level of sulphur dioxide pollution in that area.*	✓ Use of Sulphur free fuel e.g. natural gas. ✓ Installation of Sulphur dioxide extraction units in industrial chimneys.

Pollutant	Source(s)	Effects/ consequences	Control measures
3. **Ozone depletion:** Between 15 and 40 km above the earth is a layer of **ozone** which is formed by the effect of ultra-violet (UV) radiation on oxygen molecules. In this way, a large amount of the potentially harmful UV radiation is absorbed and so prevented from reaching the earth's surface. However, this beneficial ozone layer is being damaged by atmospheric pollution.	A number of pollutants can affect the ozone layer, the **chlorofluorocarbons (CFCs)** being the best known. CFCs are used in refrigerators, as propellants in aerosol sprays, and make up the bubbles in many plastic foams, e.g. expanded polystyrene.	• UV radiation causes skin cancer. • CFCs are contributing to global warming (greenhouse effect).	Ban on the use of old refrigerators and all materials that contain CFCs.
4. Smoke	✓ House smoke and soot. ✓ Motor vehicle exhausts. ✓ Tobacco smocking. ✓ Incomplete combustion of refuse in incinerators and bonfires.	✓ Causes lung diseases when inhaled. ✓ Sunlight barrier hence reducing photosynthesis. ✓ Stomatal blockage hence reducing photosynthesis. ✓ Damages clothes, cars and buildings hence costly to clean.	✓ Usage of smokeless fuels ✓ Efficient combustion ✓ No smoking ✓ Vehicle exhausts gas control
5. Dust	Solid fuel ash, soil, quarrying, mining, etc.	Lung diseases, stomatal blockage, stunted growth of plants and smog. Smog forms when temperature inversion occurs (layer of warm air traps cool air containing dust and smoke close to the earth's surface)	• Installation of dust precipitators in industrial chimneys. • Efficient combustion. • Wearing of face masks by factory workers.
6. Carbon dioxide:	Motor vehicle exhausts and combustion of fossil fuels	Increased carbon dioxide causes greenhouse effect (the warming up of the earth's atmosphere as a result of the blanket of carbon dioxide, preventing escape of solar radiation higher into space).	Planting more green plants, reduction in combustion of fossil fuels by relying on alternative sources of energy e.g. solar energy.
7. *Oxides of Nitrogen*	Car exhaust emissions and industrial fuel gases	• Acid rain formation • Contribute to greenhouse effect	Car exhaust control

Pollutant	Source(s)	Effects/ consequences	Control measures
8. *Chlorofluorocarbons (CFCs).*	Aerosol propellants, refrigerators, air conditioner coolants, expanded plastics. E.g. bubbles in plastic foam used for insulation and packaging.	Enters stratosphere, the chlorine reacts with ozone hence reducing the ozone layer and permitting greater penetration of UV light to cause global warming. UV radiation also causes skin cancer.	Ban on the use of old refrigerators and all materials that emit CFCs.
9. *Noise*:	Discos, road traffic, running engines, machines, aero planes, firearms, etc.	• Hearing impairment • Total deafness. • Nervous disorders	• Effect laws against excessive noise. • Put on ear muffs and plugs while in very noisy areas.
10. Radioactive leakage.	Nuclear weapons and nuclear power fuels.	Ionizing radiation causes cancer	Nuclear power controls

Greenhouse effect and global warming

Greenhouse effect is a description of the condition which results when greenhouse gases i.e. gases in the troposphere (atmosphere's inner most layer extending about 17km above sea level) like carbon dioxide, water vapor, methane and nitrous oxide allow mostly visible light, some infrared radiation and ultraviolent radiation from the sun to pass through the troposphere to the earth, which transforms this solar energy to longer-wave lengths-infrared radiation (heat) which then rises into the atmosphere.

Molecules of greenhouse gases absorb and emit this heat into the troposphere as even longer-wave-length infrared radiation, which causes a warming effect of the earth's surface and air.

The tropospheric gases act like a glass of large green house surrounding the earth.

Global warming is the observed average global temperature rise of 0.8^0C since 1900 as a result of the enhanced natural greenhouse effect.

The origins of greenhouse gases are:

- Combustion of fossil fuels by motor engines and industries releases carbon dioxide and methane into the troposphere.
- Deforestation and clearing of grasslands reduces the uptake of carbon dioxide in photosynthesis.
- Ruminant fermentation produces methane, which is released into troposphere.
- Use of aerosol propellants which contain CFCs that are 105 times worse than carbon dioxide as greenhouse gases.
- Cultivation of rice in swamps and muddy fields causes anaerobic fermentation which produces methane.
- Use of inorganic fertilizers cause the release of nitrous oxide.

Effects of global warming

✓ Rise in sea level due to melting of polar ice and thermal expansion of seas.
✓ Altered temperature gradients cause cyclones and heavy rains as water evaporates quicker.
✓ Species migration which are likely to cause pests/diseases to extend their ranges.
✓ Reduced cropped fields due to drier weather.
✓ Increased crop yields because of more rainfall and longer growing seasons in some regions.
✓ Flooding low-lying islands and coastal cities.
✓ Extinction of some animal and plant species.
✓ Increased death of human population.
✓ Greatly increased wild fires in areas where the climate becomes drier.

Acid rain

Formation:

Combustion of fossil fuels releases sulphur dioxide and nitrogen oxides into the atmosphere. Catalyzed by ammonia and unburnt hydrocarbons, these oxides react with water in the clouds to form solutions of *sulphuric acid* and *nitric acid*, which make up acid rain.

Effects:

- Hydrogen ions bound to soil particles are displaced into runoff water by the SO_4 ions from sulphuric acid, causing formation of soft exoskeletons, which results into death of invertebrates.
- Aluminum ions are displaced from soil by SO_4 ions into water where it interferes with gill functioning in fish causing their death.
- Aluminum ions are displaced from soil by SO_4 ions into water are toxic when absorbed by plants.
- The leaching action of acid rain removes calcium and magnesium ions from soil causing poor formation of middle lamella and chlorophyll in leaves.
- Contributes to humans respiratory diseases such as bronchitis and asthma.
- Can leach toxic metals such as lead and copper from water pipes into drinking water.
- Damages statues and buildings.
- Decreases atmospheric visibility, mostly because of sulphate particles.
- Promotes the growth of acid-loving mosses that can kill trees.
- Loss of fish population when the pH lowers below 4.5.

Prevention:

- ✓ Installation of SO_2 extraction units (wet scrubbers) in chimneys of industries.
- ✓ Cleaning up of exhaust emissions by encouraging several pollutants to react with one another to give less harmful products in catalytic converters.
- ✓ Reduce coal use.
- ✓ Increase use of renewable resources.
- ✓ Tax emissions of sulphur dioxide, “polluter pays principle” should be adopted everywhere.

Water pollution

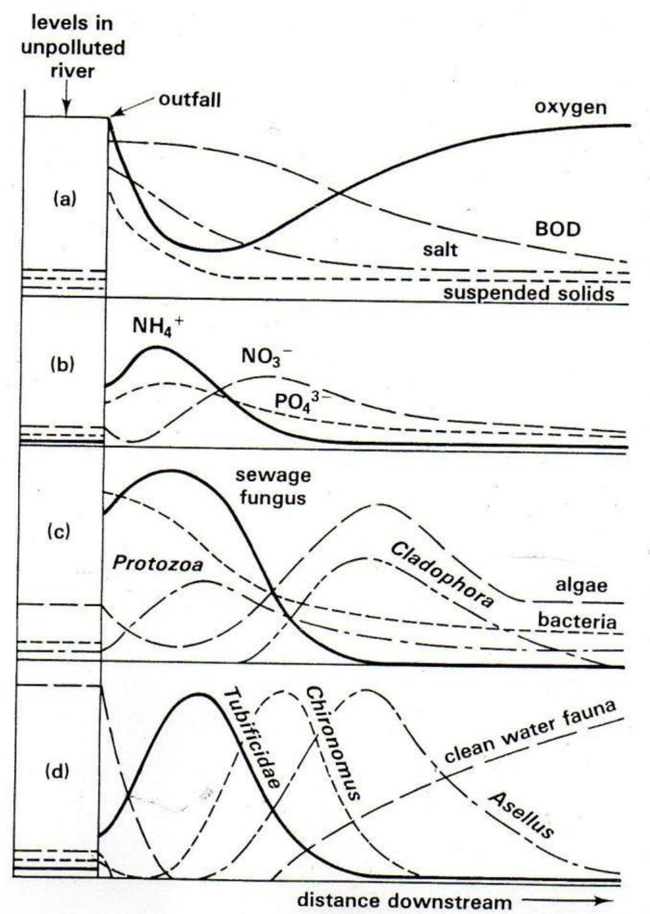
Sewage discharge into rivers

Sewage is liquid waste (composed of faeces, urine, water, detergents and other substances) from industries and/or homes carried through pipes called **sewers**.

Effects of untreated sewage discharge into rivers

Discharge of untreated sewage into a river has an immediate effect on the aquatic environment, causing many changes in both the **abiotic** and **biotic components**. Some of these changes are due to specific chemical pollutants (e.g. heavy metals such as cadmium from industrial processes, and pesticides from agriculture) with the effects varying according to the chemicals present in the discharge.

Variation of components in a river on discharge of untreated sewage



i) *Dissolved oxygen and B.O.D (Biochemical oxygen demand)*:

B.O.D is the amount of dissolved oxygen needed (or demanded) by aerobic microorganisms to break down organic material present in a given water sample of water at a certain temperature over a specific time period. It is usually measured as the mass (in mg) of oxygen used by $1dm^3$ of water stored in darkness at 20^0C for 5 days.

B.O.D indicates the oxygen not available to more advanced organisms. Therefore a high B.O.D indicates anaerobic conditions (low oxygen availability).

Variation downstream:

- Dissolved oxygen level is high in unpolluted water; decreases rapidly at sewage discharge to the minimum; and then increases gradually downstream, returning to a normal level further downstream.
- B.O.D is very low in unpolluted water, increases rapidly at sewage discharge then decreases gradually downstream.

Explanation:

- Decomposition of organic components of sewage by aerobic bacteria coupled with reduced photosynthesis because of low illumination caused by suspended solids in sewage rapidly reduce oxygen (cause oxygen sag) and create a high BOD at outfall.
- The gradual increase of dissolved oxygen downstream is because of increased photosynthesis and dissolution from atmosphere.
- The death of aerobic bacteria due to reduction in organic substances decreases BOD downstream.

ii) *Suspended solids:*

Suspended solids are very few before outfall, increase rapidly at the sewage discharge but progressively decrease downstream.

Explanation:

Sewage discharge adds decomposable organic matter into the water at the point of discharge, the progressive decrease downstream is due to bacterial consumption and dilution by water.

iii) *Living organisms* e.g. aerobic bacteria, sewage fungus (filamentous bacteria), algae (cladophora) and higher plants.

Variation downstream:

- Aerobic bacteria are very few before, but very many at outfall, then their population decreases rapidly immediately and gradually after out fall downstream.

- Sewage fungus is contained in sewage population; increases to a maximum immediately after outfall, but decreases rapidly downstream to very low level.
- Algae and higher plant populations decrease rapidly to a minimum at outfall but increase rapidly a short distance downstream and return to normal further downstream.

Explanation:

✓ Sewage contains aerobic bacteria that feed on organic substances, but population falls as availability of oxygen and nutrients diminishes.

✓ Population increases at outfall because the sewage fungus thrives in anaerobic conditions and is very tolerant at high ammonia concentrations.

✓ The rapid decrease in population results from reduced photosynthesis because of the turbidity caused by suspended solids, the rapid increase is because of the high concentrations of nitrate ions and increased illumination because suspended solids reduce and water becomes clearer.

iv) *Ammonium, nitrate and phosphate ions:*

Ammonium, nitrate and phosphate ions concentration is very low before out fall.

NH_4^+ ions increase rapidly at discharge; more rapidly to a maximum just after outfall; then decreases first rapidly and later gradually to a very low level downstream.

NO_3 ions first decrease gradually to a minimum concentration after outfall, gradually increase to a maximum a short distance downstream, then decreases gradually further downstream.

PO_4^{3-} ion concentration increases rapidly at discharge, gradually just after outfall to a maximum, then decreases gradually to a very low level downstream.

Explanation:

✓ Sewage contains NH_4^+ ions. Putrefying bacteria convert organic nitrogen-containing compounds in sewage to NH_4^+ just after outfall. Downstream, NH_4^+ ions are converted to NO_3^- by nitrifying bacteria and further downstream there is dilution by water.

✓ NO_3^- ions first decrease due to consumption by sewage fungus abundant at outfall, then gradually increase because NH_4^+ ions are converted to NO_3^- by nitrifying bacteria, then decrease gradually due to consumption by plants and algae.

✓ Sewage contains PO_4^{3-} ions from detergents and decomposition of organic matter, yet the consumption by autotrophs is very low at outfall, accounting for the high PO_4^{3-} ions concentration.

✓ PO_4^{3-} ion gradual decline downstream is caused by absorption by the progressively increasing populations of autotrophs and storage in sediments.

v) ***Clean water fauna*** *e.g. stonefly nymphs, may fly larvae, caddis fly larvae, asellus (fresh water louse, Chironomus (bloodworm), Tubifex and rat –tailed maggots (*not indicated on the graph but it can be sketched basing on tolerance to pollution)***.*** These organisms are indicator species of unpolluted, well oxygenated water.

Indicator species are organisms requiring particular environmental conditions or set of conditions in order to survive and provide information about the environment e.g. can be used in ecological investigations to find out about both the present and past conditions of soil and climate.

Variation downstream:

The populations of clean water fauna are high before outfall, decrease rapidly to zero at outfall only appearing and increasing to normal with distance downstream.

- *Asellus* population decreases rapidly to zero at outfall, only appearing and increasing rapidly to a maximum a short distance downstream after which it decreases rapidly.
- Tubifex population increases rapidly to a maximum at outfall and then decreases rapidly downstream.
- Chironomus population increases rapidly to a maximum at a slightly longer distance from outfall and then decreases rapidly downstream.

Explanation:

- ✓ Clean water species cannot tolerate anaerobic conditions at outfall, populations increase downstream because oxygen and food become available.
- ✓ *Asellus* cannot tolerate anaerobic conditions at outfall and therefore dies and migrates to the relatively less polluted water downstream where it shrives.
- ✓ The increase in population of Tubifex, and Chironomus is because they are relatively inactive to reduce oxygen demand and because they have haemoglobin with very high affinity for oxygen enabling them to be tolerant to anaerobic conditions. The increase in their population downstream indicates the level of pollution in the water. Tubifex, is the most tolerant to anaerobic conditions, followed by rat tailed maggots and Chironomus. The decrease in population downstream is partly due to predation.

Note: Flowing Rivers naturally undergo self-purification to recover from pollution through a combination of dilution and biodegradation, but the recovery time and distance depend on:

- Volume of incoming degradable wastes in sewage.
- Flow rate of the river.
- Temperature of the water.
- pH level of the water.
- Existing population of microorganisms.

Addition of inorganic chemicals, plant nutrients and sediments into lakes.

Pollutant	Examples	Main sources	Harmful effects
Plant nutrients	Nitrate (NO_3^-), phosphate ($PO_4$3-) and ammonium (NH_4^+) ions. The nutrient enrichment of water bodies is termed ***eutrophication***	• Raw sewage discharge, detergents and other chemical release from industries. • Leaching of inorganic fertilizers e.g. NPK from farmland.	• Rapid growth of algae and green protists (algal bloom). • Reduces light penetration in water leading to death and decay of algae, which depletes water of dissolved oxygen, killing fish and other aerobic animals. • Excessive levels of NO_3^- if drank in water lowers the oxygen carrying capacity of blood and kill unborn children and infants **("blue baby syndrome").**
Sediment	Soil and silt	Land erosion	✓ Can cause turbidity/cloudiness in water; light penetration is reduced therefore reduce photosynthesis. ✓ Settle and destroy feeding and spawning grounds of fish. ✓ Clog and fill water bodies, shortening their lifespan. ✓ Disrupt aquatic ecosystems. ✓ Carry pesticides, bacteria and other harmful substances into water.

Inorganic chemicals	• Acids. • Compounds of toxic metals like lead (Pb), mercury (Hg), arsenic (As) and selenium (Se). • Salts e.g. NaCl in ocean water	Surface runoff, industrial effluents and household cleaners	• Drinking water becomes unusable for drinking and irrigation • Lead and Arsenic damage the nervous system, liver and kidneys • They harm fish and other aquatic life • They lower crop yields • They accelerate corrosion of metals exposed to such water.

Purification of polluted water for domestic use (safe water supply)

Safe water supply is water that should not contain any pathogenic organisms or toxic or corrosive chemicals. An account of the process of water purification is described below:

1. Water is stored for several weeks in storage reservoirs. Here, the aquatic organisms eat microbes, ultraviolet light kills some, and oxygen kills obligate anaerobes.
2. Water is screened to remove floating debris. Vertical iron bars are used and the collected material can be raked off.
3. Aeration; water is sprayed upwards to aerate it and kill anaerobic bacteria.
4. Filtration; there are two types of filters, slow filters and pressure filters. A filter bed consists of layers of sand and stones of graded sizes, with the largest at the bottom. Water is allowed to fall through this as in a gravity-fed slow filter or it is forced through under high pressure. A gelatinous film composed of micro-organisms forms in the upper few inches of the sand and this removes many harmful bacteria. The layered stones provide mechanical filtration.
5. The water is chlorinated to kill all pathogenic bacteria.
6. Water is tested for impurities.
7. The clean water is pumped to high storage reservoirs.
8. Water flows downhill or pumped under very high pressure in pipes to households.

Practice questions:

1) *What do you understand by a safe water supply and what tests are used to demonstrate that water is suitable for drinking?*
2) *Describe the chief process involved in the conversions of polluted river water, coming from an industrial town into water fit for domestic use.*
3) *Explain man's influence on natural habitats.*
4) *Indicate those activities of man that have resulted in air and water pollution and discuss some of the measures which may be used to prevent further pollution.*

Heat (thermal) pollution

Main human sources:

Use of water as a coolant in industrial processes e.g. electricity generating plants.

Harmful effects:

- Lowers dissolved oxygen levels since solubility of most gases reduces with temperature.
- Hot water speeds up metabolism which increases BOD.
- Accelerated microbial activity leads death of fishes.

- When a power plant shuts down for repair or opens, fish and other aquatic organisms adopted to a particular temperature range can be killed by the abrupt change in water temperature. This is known as **thermal shock**.
- Some aquatic animals may migrate to water with favorable temperature.
- Offensive odours due to anaerobic decomposition.

Note: Effects of eutrophication are more severe in water bodies where thermal pollution occurs because of;

i) Increased decomposition of organic matter and metabolism, which raise the demand for oxygen by higher organisms.
ii) Reduced dissolved oxygen levels in water.

Soil pollution and land degradation

Soil pollution can occur due to various direct and indirect ways which include:

- Dumping of industrial wastes.
- Excess use of agrochemicals in the form of pesticides and fertilizers.
- Dumping of discarded wastes like paper, food and plastics.
- By air pollution like acid rain.
- By water pollution like pollutants finding their way to soil.

Soil pollutant and their effects

Pollutants	Effect
Pesticides, herbicides and fertilizers	• Cause death of microorganisms, animals and certain plants. • Affect soil fertility. • Several non-biodegradable by-products find their way to animals and man through food chain and have serious long term damaging effects. Some may be cancerous.
Excretory products of organisms and digested sewage sludge used as manure.	Number of pathogens present in the wastes contaminate the soil. Cause health hazards for man and domestic animals.
Salts of iron, lead, copper, mercury, arsenic.	Toxic to both plants and animals.
Discarded food, paper, carcasses, aluminium and plastics.	Damage the landscape and also affect the flora and fauna.

Control of soil pollution

i) Construction of transfer stations at different points in a city for bulk transfer of refuse to discharge sites to speed up removal.
ii) Materials like paper, glass and plastics should be recycled to decrease the volume of refuse and to conserve the natural resources.
iii) Use of chemical fertilizers should be reduced. Bio fertilizers and manure should be used in their place.
iv) Instead of pesticides, biological control of pests be used where possible.

Land degradation

Land degradation is the reduction or loss in the productive capacity of the land and loss of the biological or economic productivity and complexity resulting from natural processes, land uses or other human activities and habitation patterns.

Causes of land degradation

i) Soil erosion

It can be due to natural causes like floods, high wind, ocean waves and glaciers or due to man-made activities like over grazing, felling of trees, monoculture, over cropping or improper tilling.

A grass cover is an excellent binding material that stops the soil erosion. Ploughing loosens the soil and increases erosion. Soil erosion is high in Bududa, Kasese and Bundibugyo where the terrain is mountainous.

ii) Deforestation

All over the world, forests are being destroyed or degraded as a result of human activities. When forests disappear, so do the soils on which they stood and the peoples and species which lived in them. Firewood, on which many people depend is scares in most developing countries and is becoming scarcer as forests fall.

Deforestation is responsible for between a quarter and a third of CO_2 humanity has added to the atmosphere to date, increasing the risk of global warming.

iii) Shifting cultivation

"The earth will not continue to offer its harvest, except with faithful stewardship. We cannot say we love land and then take steps to destroy it for use by future generations."