ECOLOGY

Ecology is the study of the relationship between living organisms and their environment or surrounding.

The living organisms are the **flora** and **fauna**. Ecological studies can be directly towards a particular organism or a single species, communities or an ecosystem. The word ecology originates from a Greek word 'oikos' meaning a home. Two types of ecological studies namely autecology and synecology are commonly carried out.

Autecology is the study of the relationship between a single species in relation to its environment.

Synecology is the study of the relationship between communities or different populations of organisms in a given environment i.e. the study of the relationship between all plants and animals in a particular area to the environment.

Terms used in ecology

1. **Species**

   This is a group of organisms or individuals capable of interbreeding to produce fertile off springs.

2. **Population**

   This is a group of organisms or individuals of the same species which occupy a particular area or habitat at the same point and time. The population size of a given species changes with time and changes in environmental factors.

3. **Habitat**

   This is a place or physical area where the organism or species lives in an ecosystem.

4. **Community**

   This refers to all populations that occupy a particular area at a given time. This implies that all plants, animals and fungi in a particular area form a community therefore a community is a group of plants and animals of different species living together in a certain environment i.e. plant and animal communities.

5. **Ecological niche**

Ecological niche refers to the particular part of the habitat where an organism lives, the role it plays, its feeding habits and how it interacts with other organisms in the habitat and the total environmental factors affecting the organism in the ecosystem.

Fundamental niche is the entire set of conditions under which an animal/organism(population, species) can survive and reproduce itself. It occurs in the absence of predators, competitors, and parasites; allowing the organism experiences a larger habitat and performs a variety of roles.

Realized niche is the set of conditions actually used by a given animal/organism(population, species) after interaction with other species. It occurs in the presence of predators, competitors, and parasites; limiting the habitat and roles performed by an organism. Realized niche is smaller than fundamental niche.

6. **Ecosystem**

An ecosystem is a natural unit of environment composed of living (biotic) and non-living (abiotic) components whose interactions lead to a self-sustaining system.

Such a unit will consist of plants, animals and micro-organisms as well as non-living components like water, soil, air and light. **e.g.** in a pond or aquatic ecosystem, a forest ecosystem(terrestrial ecosystem).

7. **Biosphere**

This is part of the earth inhabited by living organisms. The biosphere is divided into two major regions namely;

i. Aquatic regions; made up of fresh water (lakes and ponds, rivers and streams, wetlands), marine water(oceans) , and estuaries.

ii. Terrestrial regions covering a few meters deep in the soil and a few kilometers into the atmosphere.

The biosphere is subdivided into **bio-geographical regions** each inhabited by distinctive species of plants and animals that are favored by unique conditions of such areas.

Bio-geographical regions are also subdivided into particular areas called '**biomes**'.

8. **Biome** refers to a large ecological area on earth's surface with distinctive plant and animal groups which are adapted to that particular environment.

Biomes include; ***tropical rain forests***, ***tundra regions*** (ground is frozen much of the year and vegetation is sparse), ***Hot and dry desert regions*** (evaporation is high and there is too much heat), ***cold deserts***(precipitation coming from colder water sources than rain, such as snow or ice), ***temperate region*** (winters and summers).

 Organisms have developed adaptations to live in each of the biomes.

The biome is further divided into zones e.g. forests biome forms the **ground level** (consisting of millipedes & earthworms) and **canopy zone** (consisting of birds & monkeys); The lake forms the limnetic zone, littoral zone, benthos and profundal zone, each zone supporting a particular type of organisms.

Ecotones are boundary zone between two biomes or ecosystems where one merges into the other.

THE STRUCTURE OF THE ECOSYSTEM /COMPONENTS OF AN ECOSYSTEM/FACTORS INFLUENCING ENVIRONMENTS AND HABITATS

a) Abiotic components/factors/ non living things: these are physical and chemical factors that influence living organisms on land (terrestrial) ecosystems and in water (aquatic).

Examples of abiotic components:

i. **Climatic factors**, which include; Temperature, Light, Wind, Humidity, rainfall etc

ii. **Soil (edaphic) factors** e.g. Soil pH, Soil air, Inorganic particles, Soil water , Organic matter (dead organic matter and living organisms), Soil temperature etc

iii. **Topography**

iv. Other physical factors e.g **fire** and **wave action** etc

ROLE OF abiotic factors/ INFLUENCE of abiotic factors on the distribution and abundance of organisms

(a) ***Climatic factors***

i. Temperature

o Affects physiological processes (respiration, photosynthesis, and growth etc) in organisms which in turn influence their distribution.

o Ultimate heating and cooling of rocks cause air to break and crack into small pieces and finally form soil.

o These changes in turn may result into migration of organisms e.g birds to avoid over heating or freezing.

o Low temperatures inactivate enzymes while excessive temperatures denature enzymes.

o High temperature increase transpiration and sweating

o Low temperatures break dormancy of some plants.

o Temperatures stimulate flowering in some plants e.g cabbage (vernalisation).

o Exposure to low temperature(stratification) stimulate germination in some seeds after imbibitions.

Organisms have evolved to have structural, physiological and behavioral adaptations to maintain their temperature in an optimum range.

Adaptations Of Animals For Life In Hot And Dry Deserts.

Structural adaptations,

 Large body extremities e.g ear lobes; to increase surface area over which heat is lost.

 Small sized; to increase the surface area to volume ratio, for heat loss

 Some animals like the camel, have long skinny non fatty legs to increase heat loss during locomotion

  Little or no fur to reduce on insulation, and increase amount of heat lost
  Thin subcutaneous fat layer under the skin to increase heat loss from the body
  Have tissues tolerant to extreme temperature changes, maintaining the body's main functions

Physiological adaptations
 Enzymes work under a high optimum temperature range to maintain metabolism during day and night.

Behavioral adaptations
 Most are nocturnal, i.e most active at night, when temperatures are relatively low.
 Aestivation(seasonal response by animals to drought or excessive heat during which they become dormant, and the metabolic rate followed by body temperature fall to the minimum required for maintaining the vital activities of the body) ; allows them to survive extremes of hot temperatures e E.g. African lungfish burrows into mud till the dry season ends, earthworms , garden snails , desert rats, termites also aestivate
 Movement with some body parts raised to minimize direct contact with hot grounds e.g desert snakes.
 Salivation of the neck and legs; increasing heat loss by evaporation e.g tortoise.

Adaptations Of Animals For Life In Cold Environments
Structural adaptations
  Thick layer of fat under the skin; to increase on insulation by avoiding heat loss
  Small body extremities to reduce the surface area over which heat is lost
  Large sized; thus small surface area to volume ratio; reducing amount of heat lost to the surrounding
  Thick fur; to increase on insulation
  Tissues tolerant to extreme changes in temperature; maintaining thei normal functions in the body

Physiological adaptations
  Enzymes work under a high optimum temperature range to maintain metabolism during day and night

Behavioral adaptations
  Hibernation(is seasonal response by animals to cold temperature durig which they become dormant, body temperature and metabolic rate fall to the minimum required for maintaining the vital activities of the body) The animals, said to be in 'deep sleep' ably reduce energy needs to survive the winter when food is scarce allowing them survive extreme cold conditions e.g in polar bears.
  Gathering in groups to warm themselves e.g penguins

ii. Rain fall;
o Amount of rainfall in a given area determines the abundance, distribution and types of plants in the area

Ecological significances of water
 Habitat for many aquatic organisms e.g frogs, fish etc
 Raw material for photosynthesis; main energy source for body processes of other organisms
 High thermal capacities ; acting as cooling agent for terrestrial organisms e.g plants during transpiration, some animals during sweating.
 Agent for fruit, seed, spore, larva and gamete dispersal
 Condition for germination
 Highly transparent; therefore allowing light to reach acquatic organisms, for photosynthesis; and aquatic predators to locate their prey
 Important factor in decay and decomposition ; therefore increases in 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 to increasing evaporation while high humidity causes low rate of evaporation; through stomata of leaves in plants.

Accordingly , organisms within areas of low humidity are adapted to avoid excessive loss of water by;

  Having reduced number of sweat glands e.g in kangaroo rat.

  Presence of leaf spines in cactus plants; to reduce surface area over which water is lost through transpiration.

o Controls other activities of animals like feeding, hunting, and movements e.g earth worms experience a larger ecological niche when the environment is humid.

o Controls opening and closure of stomata; therefore affecting rate of photosynthesis and transpiration.

iv. Wind / air currents;

It influences the following,

o dispersal or migration of flying mammals, winged insects; thus reducing the level of competition.

o Pollination

o Dispersal of seeds and spores; increasing the spread of non-motile organisms e.g fungi and some bacteria.

o Takes part in rain formation

o Current and wave formation in seas and lakes enables distribution of mineral salts.

o Increase transpiration; thus promoting water and mineral salt uptake from the soil by plant roots

o Increases evaporation and reduces sweating.

o Causes physical damage to vegetation and soils e.g soil erosion.

o Increases dissolution of oxygen in aquatic bodies; thereby increasing aerobic activities of organisms.

v. Light (intensity, quality, and duration)

Influences many physiological activities of organisms and behavioral responses i.e

  It is a source of energy for photolysis (breakdown of water during photosynthesis.).

  Absence of light causes etiolation (elongation of shoot inter nodes).

  Induces flowering in long-day plants e.g. barley, but inhibits flowering in short day plants.

  Phototropism, by redistributing auxins on the darker sides of shoots and roots, with cells on darker side elongating more than those on illuminated side.

  Germination; some seeds are positively photoblastic; germination only in presence of light while other do not require light to germinate.(are negatively photoblastic)

  Stomatal opening and closure; with most plant species opening their stomata during day(when there is light) and closing during night (in absence of light/darkness).

  Predation ; (hunting and killing of prey by predators require certain levels of illumination and visiblility)

  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

  It enables the mechanisms photoreceptions in eyes

  Absence of light results in failure of chlorophyll formation in plants i.e. plant remains yellow, and leaves fail to expand.

  Photoperiod affects migratory and reproductive behaviour in various animals e.g. sunlight polarised by water acts as a compass for migration of salmon fish.

  Necessary for the germination of certain seeds e.g. lettuce

(b) ***Edaphic(soil) factors,***

o Soil formed by chemical and physical weathering of rocks, possess both **living components**(living organisms like bacteria, fungi, algae and animals like protozoans, nematodes earthworms, insects, burrowing mammals) and **non living components (**particles of various sizes).

o Also present are; mineral salts, water, organic matter, and grasses.

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 reduced.

ii. Water content;

- Varies markedly in any well defined soil,
- Any finely drained soil holding much water as possible is said to be at full capacity
- Addition of more water which cannot be drained away leads to water logging; and anaerobic conditions , affecting 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 root tissues , allowing some diffusion of oxygen from aerial parts to help supply the roots.

(c) ***Topography***.;

o Refers to the nature of the landscape, which includes features like mountains, valleys, lakes etc.

o High altitude is associated with, low atmospheric pressure; low average temperatures,; increased wind speed; decreased partial pressures of oxygen, thus few organisms live permanently here.

o Slope reduces water logging and there is a lot of soil erosion preventing proper plant establishment especially at steep slopes

o At low altitudes, average temperatures are high, high atmospheric pressure, partial pressures of oxygen are high, and in some places there is water logging.

Assignment. Describe different adaptations of organisms that live in high altitude.

FIRE AS AN ECOLOGICAL FACTOR

It’s a very important ecological factor with both constructive and destructive effects. It may be caused by man intentionally or carelessly or it may be natural. It’s particularly important in Californian forests, eucalyptus forests of Ethiopia, savannah grasslands, Mexican grasslands.

TYPES OF FIRES

Natural fires:

These are set up by natural catastrophes e.g lightening, eruptions, high radiant rays.

Artificial fires:

These are fires set up by man either carelessly or intentionally.

Prescribed fires:

These are fires set up under ecological management e.g bush burning. In such a case, preventing methods are deduced before set up the fires.

Wild fires:

These are fires where the source is known.

Head fires:

These are fires burning in the direction of winds. Head fires tend to be faster and the flames/ heat is concentrated above the surface, thus may be referred to as **canopy fire.**

Back fires:

These are fires burning in the direction opposite to the direction of wind. The flames/heat is more concentrated on the ground thus may also be referred to as **ground fire.** It is more destructive compared to head fires.

Early fires:

These are fires set up at the beginning of dry season.

PROPERTIES OF FIRES

Fire intensity:
It is the heat content of the fire and it depends on the environmental factors e.g wind, temperatures and as well as the amount and vegetation.
Fire spread:
This refers to the area covered by the fire.
Fire severity:
This is measured in terms of the major vegetation destroyed by the fire.
Fire duration:
This is the time taken by the fire to destroy a particular area.
Factors that control the effectiveness of fire

i) **Kind and amount of fuel:**
Tall grasses produce much fire more than heavily grazed areas. However, forest fires are more vigorous than grass fires and they cause much more destruction. This is due to the amount of fuel that takes time to be completely burned.

ii) **Weather conditions:**
During the rainy season fires do not spread very far and become wild but in a dry season fires are more wild, strong and destructive.

iii) **Topography:**
Fires are fastest uphill and slowest downhill therefore the effect of fire on soil is greatest on fires downhill rather than uphill.

iv) **Frequency of burning:**
Continued burning has a more permanent destructive effect. It does not only destroy vegetation cover but kills soil and fauna.

v) **Direction of fire:**

Back fire burning against the wind direction is more severe on the soil than forward fire burning with the wind direction

ECOLOGICAL EFFECTS OF FIRE
Fire is a density independent ecological factor with both positive and negative effects.
Positive effects/constructive effects:
-It improves on soil fertility, when organic matter is burnt down, nitrates and phosphate compounds are added to the soil in form of ash.
-It is a method of controlling undesirable plant (weed) species in some plantations e.g sugar canes, sisal, eucalyptus, e.t.c.
-It can be used to kill pests and parasites.
-It encourages growth of useful plants e.g spear grass.
-It breaks dormancy in some leguminous plant seeds whose seed coat are so hard and oxygen and water can't penetrate easily.
-It improves on food productivity in terms of quality and palatability. This is because after burning, the new species which grow are soft, tender, and palatable and have ahigh protein content.
-It increases visibility such that game viewing becomes easy for the predators, game viewers to see each other clearly.
Negative effects/destructive effects of fire:
-It causes physical injury to plants and animals which leads to their death. Some slow moving organisms e.g earthworms, catepillars, snails e.t.c will die and this results into reduction in biodiversity.
-It may disrupt social activities such as mating, hunting.
-It also destroys habitats for animal species i.e the vegetation cover which shelters them is burnt down.
-Removal of vegetation cover encourages soil erosion which leads to loss of fertility.
-When fires destroy the palatable species of leaves, it leads to scarcity of food to herbivores.
-It may lead to the development of some resistant plant species which are not palatable to grazers.
-It leads to migration of animals making them to concentrate in small areas thereby increasing competition among themselves.

-Fire yields particles due to incomplete combustion which when mixed with fog in the atmosphere causes smog which impedes visibility.
-Some of the particles such as carbon monoxide are toxic and may cause respiratory disorders. Carbon monoxide also causes irritation of the eyes.
-Some particles released in the atmosphere such as carbon dioxide form a thermal blanket which traps heat on the earth's surface hence contributing to global warming.
-It disrupts the hydrological cycle (water cycle), since it destroys vegetation which would contribute to rain formation.
-It also disrupts the nitrogen cycle by killing nitrogen fixing bacteria.
-When fire kills decomposers, organic pollutants accumulate and recycling of matter is hindered.
-Fire changes/destroys backgrounds e.g barks of trees, rocks and other surfaces. Background refers to the general texture and pattern of the environment surrounding a given organism. Many organisms tend to blend with their environment which makes them unlikely to be seen by their predators or preys, the concept is known as **camouflage.** If the background is changed, it exposes the prey to their predators or the predators to their prey.

b). Biotic component/Biotic factors:
Biotic components are the living organisms in an ecosystem.

Biotic factors are factors involving interaction between the different living organisms e.g. **competition**, **predation**, **antibiosis**, **dispersal, pollination, mimicry, human influence**.

Competition
Organisms compete with each other for food, water, light, minerals, shelter and a mate. They compete not only with members of other species – **interspecific competition** – but also with members of their own species – **intraspecific competition**. Where two species occupy the same ecological niche, the interspecific competition leads to the extinction of one or the other – the **competitive exclusion principle.**

Predation
The distribution of a species is determined by the presence or absence of its prey and/or predators. The predator–prey relationship is an important aspect in determining population size.

Antibiosis
Organisms sometimes produce chemicals which repel other organisms. These may be directed against members of their own species. Many mammals, for example, use chemicals to mark their territories, with the intention of deterring other members of the species from entering. Some ants produce a type of external hormone called a **pheromone** when they are in danger and, in sufficient concentrations, this warns off other members of the species. The chemicals may also be directed against different species. Many fungi, e.g. *Penicillium*, produce **antibiotics** to prevent bacterial growth in their vicinity.

Dispersal
Many organisms depend upon another species to disperse them. Plants in particular use a wide variety of animal species to disperse their seeds.

Pollination
Angiosperms utilize insects to transfer their pollen from one member of a species to another, and a highly complex form of interdependence between these two groups has developed.

Mimicry
Many organisms, for a variety of reasons, seek to resemble other living organisms. Warning mimicry is used by certain flies which resemble wasps. Potential predators are warned off the harmless flies, fearing they may be stung.

Human influence
Humans influence the distribution of other organisms more than any other single species. As hunters, fishers, farmers, developers and polluters, to name a few activities, they dictate which organisms grow where.

The biotic components / living organisms of ecosystems can be grouped into;
1. Producers:
  are autotrophs capable of synthesizing complex organic food materials from simple inorganic food raw materials e.g carbon dioxide and water.
  Examples include; large green terrestrial plants e.g trees, shrubs, grass. For aquatic ecosystem, the producers are microscopic algae, blue green bacteria. Others are flagellates like euglena, volvox, chlamydomonas etc. They are collectively called **Phytoplanktons (**microscopic marine producers)
NB; 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:

  Are organisms that get energy and nutrients by feeding on other organisms or their remains .
  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
  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
(iv) **Omnivores**: A consumer that eats both plants and animals .e.g. man, pigs,etc
3. Decomposers:
  An organism that feeds on dead organic matter.
Classified into;
(i) **Detritivores/ macro decomposers**;
  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) Saprotrophs/**Saprophytes**:
  Organisms, e.g. some bacteria and fungi that feed on dead decaying organic matter/detritus by releasing enzymes onto the substance which carry out extracellular digestion and then soluble organic products of digestion are absorbed.

Functions taking place in the ecosystem

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

HOW THE SUN SUSTAINS LIFE ON EARTH

- Lights and warms the planet.
- Supports photosynthesis in plants and some bacteria.
- Powers the cycling of matter.
- Drives the climate and weather systems that distribute heat and fresh water over the earth's surface.

THE FATE OF SOLAR ENERGY REACHING THE EARTH

Because of the small size, the earth receives only about one-billionth of the sun's out put of energy, much of the energy being either reflected away or absorbed by chemicals in the atmosphere.

Most of the energy that reaches the atmosphere is: (i) visible light (ii) infrared radiation-heat (iii) ultra violet radiation that is not absorbed by ozone.

The incoming energy (i) warms the troposphere and land (ii) evaporates water and cycles it through the biosphere (iii) generates winds (iv) is captured by green plants, algae and bacteria to fuel photosynthesis and make the organic compounds that most forms of life need to survive.

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 reaching 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, lignin or bones, hooves, hair, skin etc of animals.
- 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; limiting the length of food chain(not exceeding five trophic levels(feeding level in a food chain containing given amount of energy).

ENERGY BUDGETS

An energy budget shows the percentage allocation of energy consumed by an individual organism to the various processes in the body such as respiration, growth and reproduction.

TERMS ASSOCIATED WITH ENERGY BUDGETS

Productivity in ecosystem

 Is the amount of organic material manufactured by photosynthetic organisms.

Productivity in an ecosystem can be measured using several methods i.e;

-Amount of Crop harvest

-Through oxygen production of the given area of the ecosystem.

-Amount of carbon dioxide consumed during photosynthesis.

.-Rate of consumption or use of raw materials.

<u>Gross primary productivity (GPP)</u>

It is the rate at which producers convert solar energy into chemical energy stored in organic substances.

It is the total amount of energy fixed by producers per unit area of photosynthetic surface per unit time. Productivity may be expressed as units of energy (e.g. $kJm^{-2}yr^{-1}$ or kCal $m^{-2}yr^{-1}$), or units of mass (e.g. kg $m^{-2}yr^{-1}$)

GPP is greatest: (i) in shallow ocean waters near continents (ii) along coral reefs where abundant light, heat and nutrients stimulate the growth of algae. (iii) Where upwelling currents bring nitrogen and phosphorus from the ocean bottom to the surface.

GPP is lowest in: (i) deserts due to low precipitation and intense heat (ii) the open ocean due to lack of nutrients and sunlight except near the surface.

<u>Net primary productivity (NPP)</u>

It is the rate at which energy for use by heterotrophs or consumers is stored in new organic substances.

NPP is the energy that remains to be used by consumers after producers have used part of GPP for their own respiration.

NPP = GPP – (respiration + metabolism)

NPP most productive ecosystems are:

(i) Estuaries (ii) Swamps and marshes (iii)Tropical rainforests

NPP least productive ecosystems are:

(i) Open ocean (ii) Tundra – arctic and alpine grasslands (iii) Desert.
Despite its low net productivity, the open ocean produces more of the earth's NPP per year than any other ecosystem because of its large size

Secondary production

It is the rate at which energy is used to make new biomass in consumers.
This the energy remaining in heterotrophs available for production (growth, repair and reproduction) after losses through egestion, excretion and respiration

Biomass

It is the dry weight of all organic matter contained in organisms per unit area of ground or water
Biomass is expressed as g/m^2.

Standing biomass (Standing crop biomass)

It is the dry weight of all organic matter contained in organisms per unit area of ground or water **at a given moment in time**.

Trophic Efficiency/ Ecological Efficiency

Is the percentage of energy at one trophic level that is converted into organic substances at the next trophic level.
Trophic efficiencies range from less than 1% (e.g. herbivores eating plant material) to over 40% (e.g. zooplanktons feeding on phytoplanktons)

NOTE:

a) Of the energy received by the earth, averagely less than 3% is fixed by green plants.
b) Energy transfer from producer to primary consumer is typically in the order of 5 – 10% of Net Primary Production (a loss of 90 – 95% occurs) because:
(i) Much of plant biomass (NPP) is indigestible to herbivores – e.g. no animal enzymes can digest lignin and cellulose.
(ii) An individual herbivore may not eat much of the plant biomass – e.g. roots may be inaccessible.
c) Energy transfer from primary consumers (herbivore) to secondary consumers (carnivores) is typically 10 – 20% of herbivore biomass (a loss of 80 – 90% occurs).
This is more efficient than in (b) above because:

(i) Animal tissue is more digestible than plant tissue;
(ii) Animal tissue has a higher energy value
(iii) Carnivores may be extremely specialized for prey consumption.

But still less than 100% because:

(i) Some animal tissue e.g. bones, hooves, hides is not readily digestible;
(ii) Feeding is not 100% efficient – much digestible material e.g. blood and food fragments may be lost to the environment.

d) The number of trophic levels (feeding levels) rarely exceeds five because:
The more trophic levels in a food chain or web, the greater the cumulative loss of usable energy as it flows through the various trophic levels, leaving very little energy to support organisms feeding at the high trophic levels.
This explains why:
(i) There are few top carnivores e.g. eagles, hawks, tigers, white sharks **(ii)** Such species are first to suffer when the systems that support them are disrupted **(iii)** These species are so vulnerable to extinction.
e) The longest food chains can only be supported by an enormous producer biomass e.g. in oceans.

FOOD CHAINS AND FOOD WEBS

A food chain is a linear nutritional relationship with repeated eating and being eaten.

There are two types of food chains i.e. grazing food chains and detritus food chins

Grazing food chains start with green plants while **detritus food chains** begin with dead organic matter e.g. in temperate forests.

Primary producer → primary consumer → secondary consumer → tertiary consumer
(1st trophic level) (2nd trophic level) (3rd trophic level) (4th trophic level)

Examples of grazing food chains:

i) Algae → mosquito larvae → Tilapia → Nile perch → Human being
ii) Phytoplankton →zooplanktons →small fish →big fish →crocodile

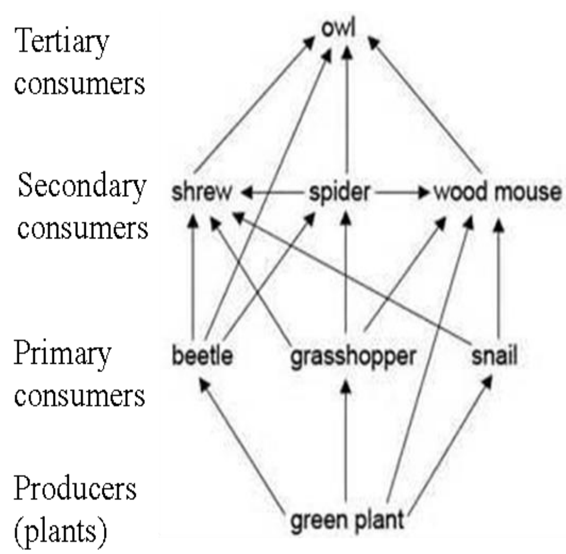
Examples of detritus food chains:

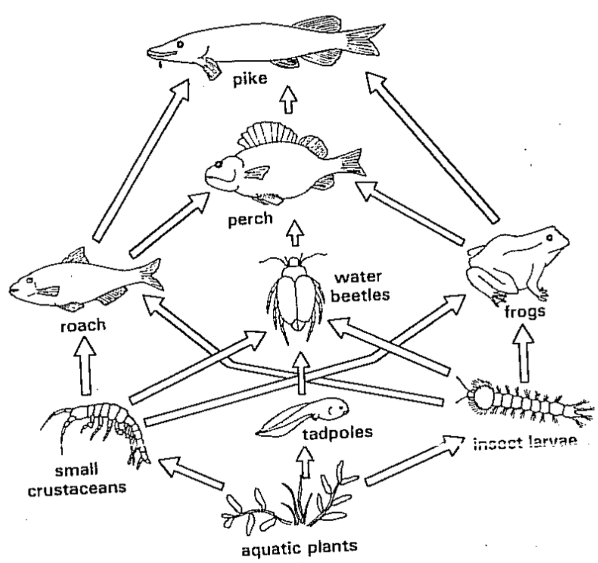
iii) Leaf litter → earthworms→ birds → hawk
iv) Dead animal → blow fly maggots → frog → snake

N.B: Think of many more other food chains!

FOOD WEB

This is a complex nutritional relationship showing alternative sources of food for each organism in a food chain i.e. a complex network of food chains linked to one another.





QN: Considering any group of organisms in a given ecosystem, Draw a given number of food chains and use them to construct a food web.

TROPHIC LEVELS

These are feeding steps found in living systems. In complex natural systems, organisms whose food is obtained from producers by the same number of steps or feeding levels are said to belong to the same trophic level. The green plants which are the producers are, occupy the first trophic level. The plant eaters called primary consumers occupy the second trophic level while carnivores that feed on primary consumers occupy the third trophic level. In some cases, carnivores of the third trophic level are eaten by other carnivores and these occupy the fourth trophic level. Decomposers occupy the fifth trophic level.

Applications of food chains and food webs

For identification of some animals that feed on pests of our crops, domestic animals or other injurious ones. This can be used biologically to control pests.

ECOLOGICAL PYRAMIDS

These are histograms that provide information about trophic levels in ecosystems. There are three types of ecological pyramids i.e pyramid of numbers, pyramid of biomass and pyramid of energy.

i) Pyramid of numbers; It is a histogramatic representation of the numbers of different organisms at each trophic level in an ecosystem at any one time.

The number of organisms at any trophic level is represented by the length (or area) of a rectangle.

Generally, as the pyramid is ascended, the number of organisms decreases, but the size of each individual increases.

Disadvantages/Limitations:

i) Drawing the pyramid accurately to scale may be very difficult where the range of numbers is large e.g. a million grass plants may only support a single top carnivore.

ii) Pyramids may be inverted; particularly if the producer is very large e.g. an oak tree or parasites feed on the consumers e.g. fleas on a dog.

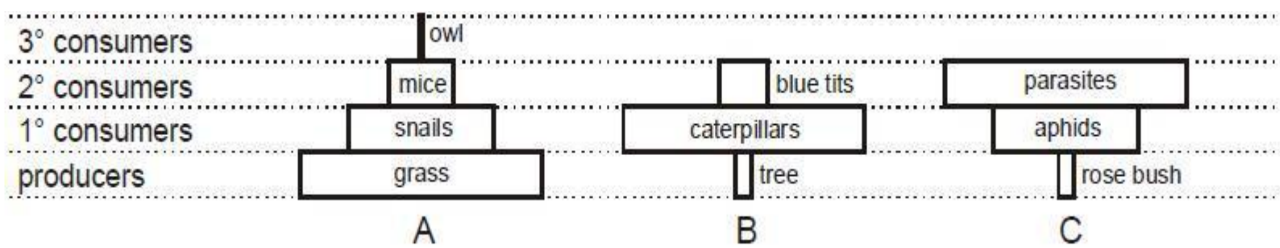
iii) The trophic level of an organism may be difficult to ascertain.

iv) The young forms of a species may have a different diet from adults, yet they are considered together.

NB. Most ecological pyramids of numbers are always upright. However, in some cases, they may bulge in the middle or be inverted e.g.

a) Where a tree is supporting a large number of caterpillars; which in turn support a few birds.

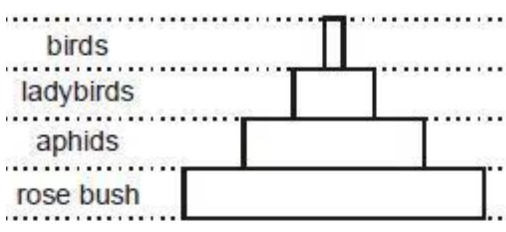
b) Where a single plant supports a number of aphids which in turn support numerous parasites leading to a totally inverted pyramid.



ii)Pyramid of biomass

- This is a diagrammatic representation of the biomass of organisms at each trophic level at a particular time.
- Biomass is the amount of living matter at a given trophic level in a unit area of an ecosystem or habitat. It is usually determine by dry weight of an organism.

NB. The biomass deccreases at each successive trophic level.



pyramid of biomass

Advantages

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

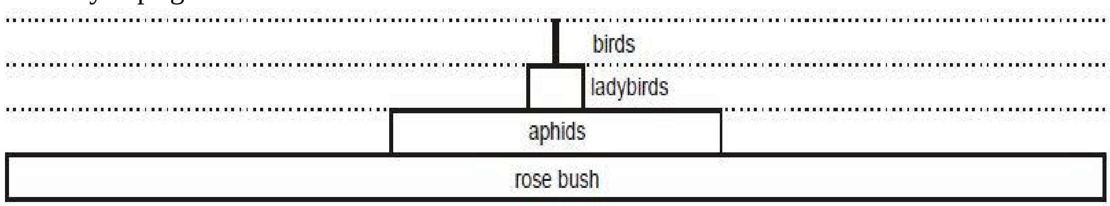
NB. An inverted pyramid of biomass can occur if the producer level includes organisms with a high turnover rate (rapid reproduction) so that they have a high productivity over a period of time e.g. in open water of oceans, the zooplankton biomass can exceed that of phytoplankton because the zooplanktons eat the phytoplanktons almost as fast as they are produced, so the producer population is never very large.

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.
- 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.

iii)Pyramid of energy

- It is a histogram showing the energy content of the organisms at each trophic level. Energy values may be expressed variously e.g. $kJm^{-2}yr^{-1}$ or kCal $m^{-2}yr^{-1}$.
- This is the best way of representing relationships and ecological productivity between organisms in different trophic levels.
- N.B. The energy decreases as it is transferred from one trophic level to another since it is lost as heat during; respiration, egestion, death and decomposition. Therefore, the pyramid of energy is always upright.



Advantages

- 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.
- ✓ It eliminates scale problems encountered when constructing a pyramid of numbers.

Disadvantage:

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

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.

TERMS USED IN POPULATION STUDIES:

Population size: Number of individuals in a population.

Population density: Total number of organisms of a species per unit area (land) or per unit volume (water)

Population growth: A change in the number of individuals (increase-positive or decrease-negative)

Population growth rate; Change in number of individuals per unit time

Birth rate (natality): Number of new individuals produced by one organism per unit time (Humans: per year). Expressed as the number of individuals born in a given period for every 1000 individuals e.g 36 births per 1000 people per year.

Death rate (mortality): Number of individuals dying per unit of time per unit of population (humans: number of deaths per 1000 per year e.g. 20 deaths per 1000 people per year)
Environmental resistance: All the environmental factors acting jointly to limit the growth of a population.
Carrying capacity: Maximum number of individuals of a given species that can be sustained indefinitely in a given area of land or volume of water.
Age structure/distribution*;* is the proportion of individuals of each age in a population.
The young-age group before reproduction
Middle age- reproductive age
Old age-age after reproductive stage
Immigration: Movement of individuals into a population from neighboring populations.
Emigration: Departure of individuals from a population.
Rare species: Species with small populations either restricted geographically with localized habitats or with widely scattered individuals.
Endangered species: Species with low population numbers that are in considerable danger of becoming extinct.
Extinct species: Species, which cannot be found in areas they previously inhabited nor in other likely habitats
Population distribution/dispersion - distribution of organisms in a habitat.

POPULATION, POPULATION GROWTH AND POPULATION GROWTH CURVES

Population size change as a result of natality, mortality, migration in and out of the population.

Types of population

1. **Open population**

   This is the one in which density changes as a result of the interaction of mortality, natality, migration and emigration. It occurs in a natural environment.

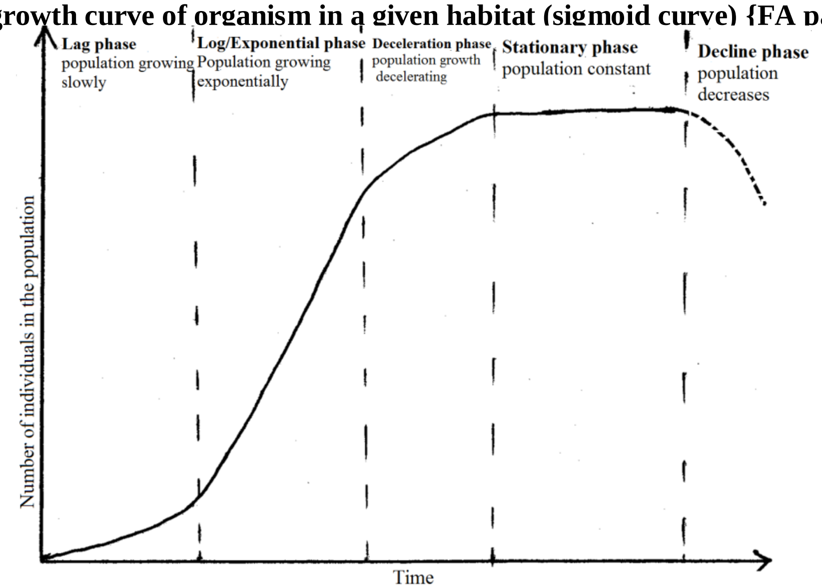
2. **Closed population/cultured populations**

   This is one in which density changes are the result of natality and mortality with neither food nor wastes being allowed to enter or leave the given environment. It occurs in laboratory settings and game reserves/cultured populations.

   Population growth

   Natural populations start with small size and gradually increases to a climax/carrying capacity where it is no longer growing/increasing. At this point the population undergoes a number of changes as a result of the changes in the environmental factors.

   Population growth curve of organism in a given habitat (sigmoid curve) {FA page525}



1. **Lag phase:**

This is the period of low growth rate because the reproducing individuals are few and may be widely dispersed. The members are still adjusting to the environmental conditions. There is plenty supply of nutrients, space, oxygen and low or few wastes.

2. **Exponential/log phase:**

This is the phase of fast increase in the population/increased rate of growth because the individuals are used to the environment, majority have reached their reproductive potential and there is no limiting factors such as food, space, oxygen hence the organisms are able to grow and reproduce at fast rate. Birth rate exceeds death rate.

3. **Decelerating phase:**

During this phase the population growth rate decreases. This is because environmental resistance sets in, increasing the death rate and/or decreasing the birthrate. The environmental resistance is due to limiting factors such as shortage of food nutrients, over-crowding, accumulation of toxic waste products, predation and competition for the available resources amongst the individuals.

4. **Stationary phase:**

This is also called the equilibrium stage. Birth rate and death rate exactly balance each other resulting in equilibrium. The environment/habitat has reached its carrying capacity and the population size becomes stable or attains its climax.

Carrying capacity

Carrying capacity of a population refers to the maximum number of the individuals of a population which the resources in a particular environment can support maximally at a given time. At carrying capacity, changes in environmental factors such as food supply, decline/reduced rainfall, fluctuation in temperature or an outbreak of epidemics, temperature, etc. results in an increased death rate which over powers the birth rate hence leading to a fall in the population. This is known as a **decline phase**.

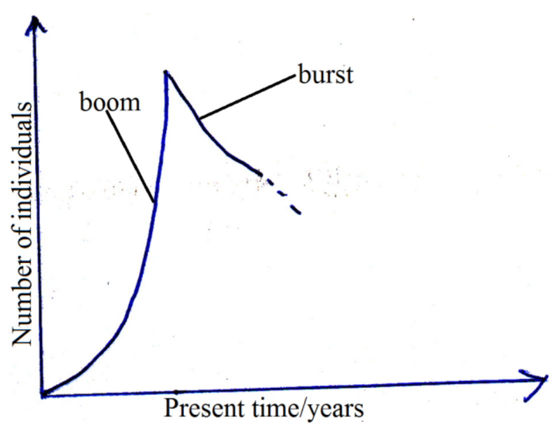
Types of growth curves

There are two basic forms, i.e**. J-shaped** growth curve and **S-shaped (sigmoid)** growth curve.

The above curves where there is a lag phase, log phase/exponential phase, stationary and decline phase describes a sigmoid curve as a result of changes in both density dependent and density independent factors.

J-shaped growth curves/boom and burst curves

This describes a situation in which after the lag phase/population growth continues in an exponential form until when it stops abruptly. Such growth is density dependent. The crash (abrupt stoppage/burst) may be caused by factors like seasonality i.e. end of breeding season of the organism or of prey species. The crash may also be due to human interaction like application of insecticides to control pests, herbicides to control weeds.



Examples

1. Bidens pilosa (black jack)
2. If cats totally fed on prey/rats. The removal of prey results in the crash of the predator/cat population.

Factors that influence population growth

Collectively the factors which limit population growth are termed as **environmental resistance** and are grouped into two.

(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**, habitat destruction e.g. clearing a forest or fishing in a wetland, pesticide spraying. They are mainly abiotic factors.

NOTE:

Population grows and declines in size. The size of population increase is determined by the reproductive potential of the concerned organism and by environmental resistance.

The biotic potential/reproductive potential is the maximum number of off springs that can be produced by a species under ideal conditions or is the rate of reproduction given unlimited environmental resources. The biotic potential of a species depends on a number of factors which include the following

- ❖ Off spring; the maximum number of off springs per birth.
- ❖ Capacity for survival; the chances the organisms' off springs will reach reproductive age.
- ❖ Procreation; the number of time per year the organisms reproduces.
- ❖ Maturity; the age at which reproduction begins.
- ❖ Male to female ratios in the population.
- ❖ Age structure; age at which reproduction is high e.g. in man at 45, chances of producing become minimal.

Environmental resistance refers to the sum total of limiting factors, both biotic and abiotic which act together to prevent the biotic potential from being obtained or all the factors that tend to reduce population numbers, such as diseases, parasites and pests, predation, limited food supply, heat, light, fire outbreak, limited space, regulatory mechanisms like intraspecific competition and behavioral adaptation, human activities e.g. encroaching on swamps, wet lands, forests, road construction(separates ecosystems).

FACTORS FOR EXPONENTIAL HUMAN POPULATION GROWTH:

1. High fertility rate especially in the human female. The human female has got the potential for conceiving every month and is easily to receive a male at any time.
2. Sufficient resources.
3. Improved maternity facilities and sanitation leads to low death rates.
4. Improvement in technology especially in Agriculture.
5. Early marriages.
6. Traditional beliefs since children are a source of prestige and wealth (practice of polygamy).
7. No observation of birth control methods.
8. Political stability which has led to decrease mortality rate.

WAYS IN WHICH POPULATION IS BEING CONTROLLED INCLUDE:

Birth control methods such as use of condoms, contraceptive pills, intra-uterine devices, tubal ligation and vasectomy, use of spermicides, abortion, government policies which limit number of children, etc.

SURVIVORSHIP CURVES

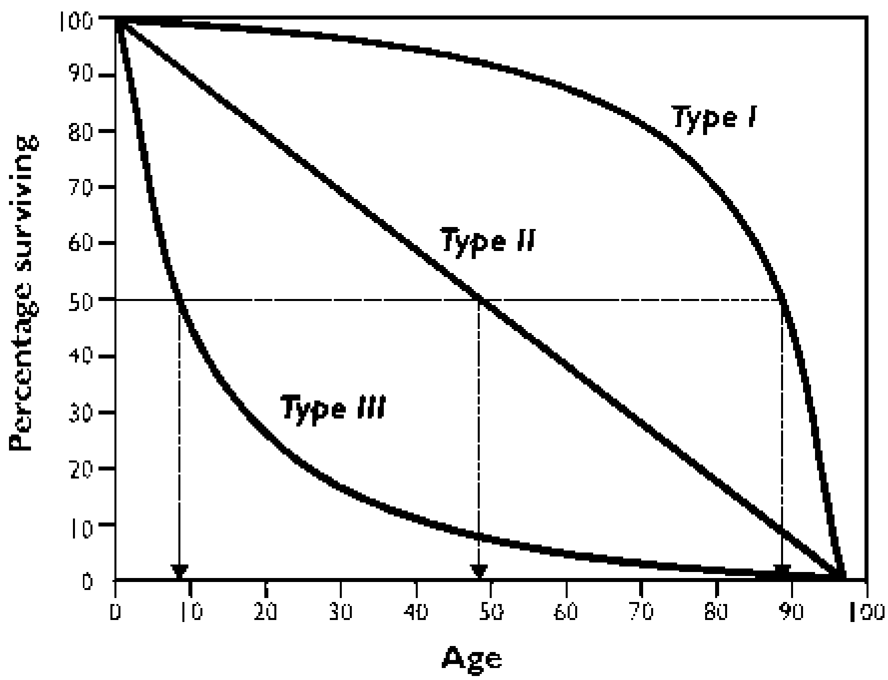
For any population size to remain consistent at least two off springs from each male and female pair on average must survive to reproductive age.

The percentage of individuals that die before reaching reproductive age i.e pre-reproductive mortality (infant mortality) is a major factor determining population size.

A survivorship curve is a curve showing the number of individuals who survive per thousand of population through each phase of life. It shows the effect of mortality and natality among age groups under environmental conditions.

Note: different species have different characteristic survivorship outcomes depending on their pre-reproductive mortality.

Types of survivorship curves/different patterns of population dynamics



Three kinds of shapes are found, illustrated by the three idealized curves on the graph.

• *In* ***type I curves(Late loss curves)*** there is a long life expectancy, with low infant mortality and most of the cohort dying in old age. Type I curves are shown by large mammals and Industrial human societies, where families are small and there is a high investment in parental care.

• *In* ***type II curves(Constant loss curves)*** there is an intermediate life expectancy and a roughly constant death rate regardless of age. Type II curves are shown by animals that are equally susceptible to predation or disease at any age, such as small mammals and many birds.

• *In* ***type III curves(Early loss curves),*** there is a short life expectancy, with most of the cohort dying in infancy and few surviving to old age. Type III curves are shown by animals that do little or no parenting and produce large numbers of offspring to compensate, such as insects, amphibians and fish. They are also shown by pre-industrial human societies with poor healthcare and high infant mortality.

These three curves represent extreme cases, and in practice many countries show intermediate curves.

THE "r" AND "k" STRATEGIES

r – is the maximum rate of increase of population,
k – is the number of organisms able to live in the population when it is in equilibrium..
An **r-selected population** is one in which the maximum rate of increase of the population is important. An r-selected population can take advantage of a favorable situation by having ability to increase its population rapidly. This means having many offspring which under normal circumstances die before reaching maturity. It is associated with type III survivorship curve.
Similarly, **k-selected population** is associated with a steady carrying capacity. K – Selected populations have few and well cared young ones and tend to associate with type I and type II survivorship curves.

ESTIMATING POPULATION SIZE AND POPULATION DENSITY

Population size can be estimated in various ways which include;
(1) Direct counting/census method, **(2)**Quadrat method, **(3)**Transect method, **(4)**Capture-mark release recapture method (the Lincoln index), **(5)**Pitfall method, **(6)**Sweep net method.

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 eg 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

(a)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; (i) **Direct counting method** (using a low flying aircraft) (ii)**Aerial photography** (iii)**Drive and count** (iv)**Strip census, (v) Heamocytometer(**for microorganisms e.g bacteria, yeast).

(i)Direct counting method using a low flying aircraft

Used to determine population of large animals.

Requirements

(i)An air craft e.g. a helicopter(ii) Survey map of the area (iii)Stationary (iv) 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
- Other studies on the population such as feeding habits, reproductive behavior, and predation can be carried out simultaneously.
- It reduces the risk of attacks from aggressive animals eg lions, buffalos, etc

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

(i) Low flying air craft (ii) 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

NB; **advantages and disadvantages are as seen above (direct counting**)

(**iii) Drive and count method**

Requirements

(i)Man power (ii)Stationary

Procedure

A number of people drive animals into a particular space/area and count them.

Advantages

i. It is quick and more accurate especially for slow moving animals and those that live in herds e.g. antelopes.

ii. There is reduced likelihood of not counting an animal or counting a given animal more than once.

Disadvantages

-It cannot be applied to aggressive animals e.g. lions, tigers, etc

-Limited to slow moving animals

-Restricted to animals moving in herds

(iv) Stripe census

Requirements

(i) Map of the area (ii) Vehicle

Procedure

- While driving , animals are counted in a given strip /besides the road.
- The number of organisms in each strip is obtained by direct counting and the population density of the strip is obtained.
- Such is repeated for several strips and the average population density for the strips is calculated.
- The population of total population of the area given is calculated as ;**average population area of each strip x total area**.

Advantages

- It's quick
- It's cheap compared to aerial means

Disadvantages

- Moving vehicles scare away animals that may run into hiding
- Some animals avoid roads and paths commonly used by man in the park.
- There is increased likelihood of counting fast moving animals more than once.
- Very many counts have to be made so as to come out with a reliable number.

N.B: Read about counting the number of bacteria and/yeast cells (microorganisms) using a haemocytometer. {B.S third edition page 387}.

(b) 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 eg insects like butterflies, moth, grass hoppers.

Requirements

(i) Suitable traps (ii) 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 **N1**.
- 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 **N2**.
- 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 **N3**.
- The estimated total population **(P)** of animals in the area is then estimated using the Lincoln index as follows;

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

Where P-estimated total population of the area

N1- number of individuals captured on the first occasion.

N2- number of individuals captured on the second catch.

N3- 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.

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?

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

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

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 quadrat

This is suitable for slow moving animals and grass.

Requirements

(i)Metallic, plastic or wooden frame of a known area e.g. 1m2 (ii) Stationary

Procedure

The frame is randomly thrown several times in an area under investigation.

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

(i) It's accurate (ii) It enables comparison of different areas and species. (iii) It provides an absolute measure of abundance.

Disadvantages

(i)Its time consuming. (ii) It's not suitable for first moving animals. (iii) It's not suitable for large sized animals. (iv) some plants e.g. grass species are indistinguishable and may disturb.

(iii) Removal method

This is suitable for small organisms like insects and rats within a known area of grassland or volume of water.

After sweeping with a heavy net, counting and recording of the animals captured is done without replacement.

The procedure is repeated several times and gradually decreasing numbers of organisms and cumulative number of organisms captured is noted.

A graph of number of animals captured per sample against the previous cumulative number of animals captured is plotted and extrapolation of the line of the graph is made to the point at which no further animals would be captured, from which the population is estimated. E.g.

Sample no	**Number of organisms in the sample**	**Cumulative sample size**
1	120	120
2	93	213
3	60	273
4	35	328

GRAPH of number of organisms in sample against cumulative sample size{B.S pg363}

Assignment
Suggest and describe the suitable methods for estimating the population size of the organisms below. Give reasons for your choice of each method and outline the associated limitations.
a) **Fish in a pond** (b) **Terrestrial plant** (c) **Large mammals**

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
(a) Biological control method
This is the eating or weakening of a pest species or weeds using other organisms called **control agents** e.g. natural predator, parasite or pathogen .E.g.. (i) Using cats to eat rats, (ii) using beetles to feed on the water hyacinth on Lake Victoria, (iii) placing fish in ponds to eat mosquito larvae.
Biological control aims at bringing the pest population to a level where they are economically un harmful.
Biological control method can be used to; (i) control of vector population (ii) control of parasites (iii) control of pathogens (bacteria& virus) (iv)control of some plants e.g. weeds (v) control of pests.
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.

NB. Biological control of population is very specific, thus useful organisms are not affected.
(b) Chemical method.
Involves use of chemicals by humans to eradicate harmful organisms
Are named according to the target organisms e.g. herbicides kill weeds, insecticides kill insects, fungicides kill fungi.
Properties of an ideal pesticide:
- Should be biodegradable / non-persistent so that toxic products are not left in or on crop plants.
- Should be specific so that only pest species is killed.
- Should not accumulate either in specific parts of an organism or as it passes along food chains.
- Should effectively control 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 in this case the natural predator of the pest may be killed to larger extent (or even to complete elimination) and so a small residual pest population which is resistant may multiply quickly without being checked by the predator hence increasing to a higher population than before the pesticide was applied..

- **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.

N.B: Read about ecological characteristics of pesticides and pest resurgence. {B.S 3rd Edition, Pages 334-336}

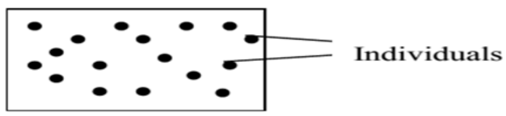
DISTRIBUTION OF ORGANISMS (POPULATION DISPERSION)

Dispersion refers to the structure/distribution of individuals or organisms within an area.

There are 3 forms of dispersion:

1. **Random dispersion/distribution**

This is relatively rare in nature. It occurs where the environment is very uniform in terms of resources and there is no tendency of organisms to aggregate. There is equal and even distribution of resources. There is low or no competition.

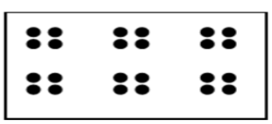


2. **Clumped distribution/aggregate/clustered**

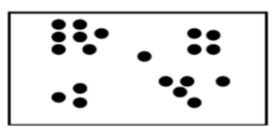
It's the naturally occurring type of distribution where individuals tend to aggregate at a particular point on the habitat. It's due to;

i) Distribution of resources that are not regularly distributed due to climate and soil factors.
ii) Social behaviour like termites and bees have division of labour among members, animals that live in colonies like buffalos, baboons, monkeys, etc. Clumps could be irregular or regularly distributed.

Clumped Regular pattern:

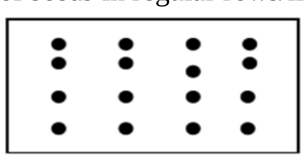


Clumped Irregular pattern or random:



3. **Uniform/regular distribution**

This occurs where intraspecific competition is severe. However, man artificially can induce it through agricultural practices e.g. planting of seeds in regular rows/lines.



Many communities are dominated by clumped patterns of distribution for several reasons:

i) Effects of parent plant i.e. seeds may not be dispersed far from the parent plant hence plant seedlings are usually found near the parent plant.
ii) Distribution of environmental factors. These are not uniform for all areas.
iii) Species interrelations i.e. a species may be depending on another directly e.g. epiphytes.
Animals exhibit dispersion in form of territorial behaviours. A territory is a defined area owned by a group of animals/family and defended against other members of the same species.

iv) Natural barriers like rivers and rift valley restrict animals in particular areas e.g. bush backs, chimps and elephants.

Importance of dispersion in animals

- Individuals acquire a home/nest/habitat within which they can live and breed.
- Uniform dispersion ensures that individuals are spread out such that resources like food, breeding grounds become enough.
- Chances of obtaining a mate is increased since males attract females into their territories.
- Reduces distances moved away from home to search for food, mate, etc. this saves energy, time and prevents exposure to predators.

Note: Dispersal is the movement of individuals/organisms or their seeds, parts into or out of the population or habitat to a different locality/area.

Importance of dispersal

- New or depopulated areas are colonized.
- It increases the rate of gene exchange/gene mixing between populations via mating.
- It may prevent extinction and or speed up population growth.
- Determines the overall distribution/dispersion among individuals of a given population.

POPULATION HISTOGRAMS

Population growth curves only show how populations change over time but don't tell or show the age distribution of the members. The population histograms show or represent population of an organism in terms of its age structure and the proportion of males and females at a specific instant in time (sex ratios).

Age distribution/structures

It's the proportion of the individuals of different ages in their population. It is an important factor because it influences mortality and natality.

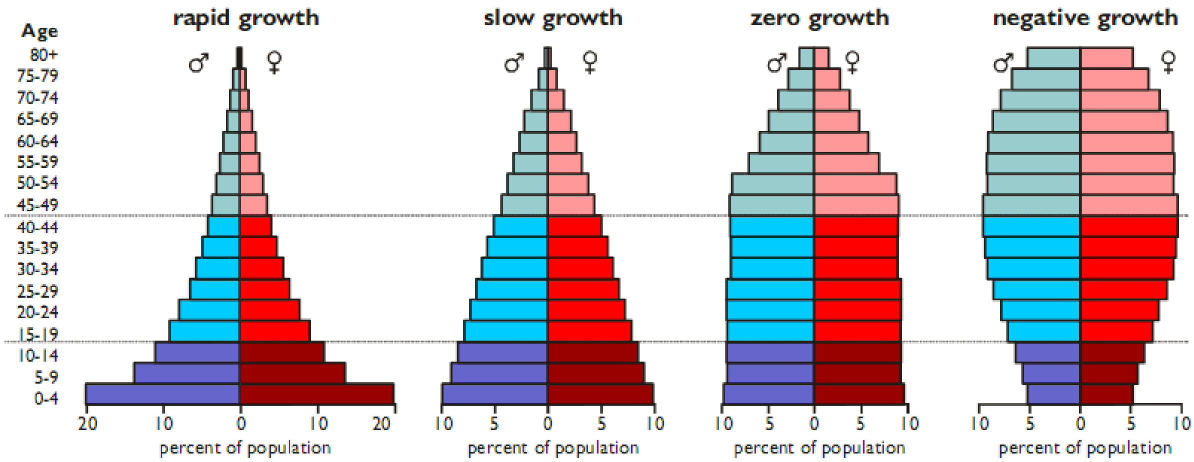
The age of different animals can be determined by:

i) Observing the teeth and bones of organisms.
ii) Observing horns, claws, and scales, etc. depending on the type of animals or organisms. E.g. fish some show annual increment in size and number of scales.
iii) In invertebrates and some vertebrates, weight and size are used to determine the age of an individual.
iv) Observing annual rings(distinctive concentric rings of tissues) in plants.

Types of ecological ages

1. **Pre-reproductive age**; represent organisms that are below the reproductive age (e.g between 1-14 years for humans).
2. **Reproductive age**; shows organisms of the population able to mate or reproduce.
3. **Post-reproductive age**; represent members that are old enough to reproduce {e.g. 65+ years in humans}.

The relation duration/time of each one age varies with different species and conditions of survival in a given locality. Age structure is studied using the age sex graph or population pyramids. It deals with relationships in number between males and females of age groupings.



The shape of an age pyramid tells us about the future growth of the population and about life expectancy.

• The wider the base of the pyramid, the faster the population growth. Imagine the wide bottom bars moving up the pyramid over time into the reproductive age band (leading to a high population of individuals in the reproductive age).

• A pyramid with a narrow base indicates a declining population since there will be fewer reproducing individuals in the near future.

• The steeper the pyramid, the longer the life expectancy. An age pyramid with a wide base that declines quickly and has a narrow tip indicates high infant mortality and a short life expectancy. A more rectangular shape with a broader tip indicates long life expectancy.

INTERACTION WITHIN THE POPULATIONS

COMPETITION

This is an interaction between two or more living organisms where they strive for the same resource which is in short supply. The resource may be food, sunlight, water, space, breeding mates, etc.

Competition causes organisms to adapt themselves in various ways. The adaptations can be structural, physiological and behavioural.

TYPES OF COMPETITION

a) Intraspecific competition:

Intraspecific competition is competition for resources between members of the same species. This is more significant than interspecific competition, since members of the same species have the same requirements/demands and compete for exactly the same resources. .

b) Interspecific competition

Interspecific Competition is competition for resources (such as food, space, water, light, etc.) between members of different species. Interspecific competition tends to be less fierce than intraspecific competition.

COMPETITIVE EXCLUSION PRINCIPLE

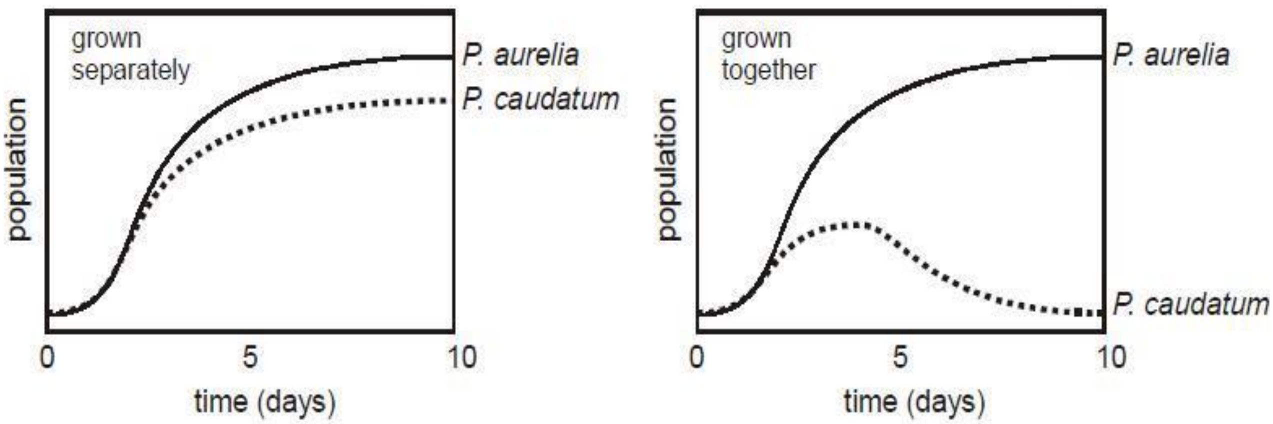
The closer the ecological niches of the competing organisms, the more fierce is the competition.

Co-existence between two species which compete is impossible. To avoid severe/stiff competition and extinction the two different species occupy different ecological niches. This is called **competitive exclusion principle**.

It states that,“***no two organisms can occupy the same ecological niche when they compete for the same resources. If they did so, one would be out-competed thus becomes rare or even extinct***.”

The niche concept was investigated in some classic experiments in the 1930s by Gause. He used flasks of different species of Paramecium, which eats bacteria. In his first experiment, he first bred the two species

in different cultures. Each of the two species increased in number following the normal sigmoid curve, only that the number of *P. Aurelia* was greater than that of *P. caudatum.*
Gause then cultured the two species in the same culture flask. The two were then counted each day and recorded.
Initially, both species grew in number and eventually *P. caudatum* declined showing that it was a weak competitor. It had been out-competed by *P. Aurelia* which is a stronger competitor.
The success of *P. Aurelia* may be attributed to its small size. Being smaller, it requires less food and is thus able to survive when food is scarce. Its success is also attributed to its faster reproductive rate or greater efficiency in obtaining food. The results obtained were represented graphically as follows.



Consequences of competition
- ❖ Weak competitors are eliminated or extinction of species or migration.
- ❖ It results in feeding habits/feed on food nutrients which they used not to feed on.
- ❖ It affects pollination between certain plants and specific insects.
- ❖ Gene loss or change in gene frequency.

HOW SPECIES REDUCE OR AVOID COMPETITION THROUGH RESOURCE PARTITIONING
Resource partitioning 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.
Resource partitioning may take several forms, for example
(a) **Specialization of morphology** and behavior for different foods, such as the beaks of birds which may be modified for picking up insects, drilling holes, cracking nuts, tearing flesh and so on.
(b) **Vertical separation** (stratification), such as canopy dwellers and forest floor dwellers.
(c) **Horizontal separation**, such as the occupation of different microhabitats.

□ □ 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.

Examples of resource partitioning:
(1) When living in the same area, lions prey mostly on larger animals while leopards on smaller ones.
(2) Hawks and owls feed on similar prey, but hawks hunt during the day and owls hunt at night.
(3) Each of the five species of common warblers (insect-eating birds) minimizes competition with the others by **(i)** spending atleast half its feeding time in a different part of spruce tree branches e.g. some hunt at the extreme top, others at the lower portion, some mid way etc **(ii)** Consuming somewhat different insect species.

(4) 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.
(5) 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.
(6). 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.
NB:
i) The more that two species in the same habitat differ in their use of resources, the more likely they can coexist.

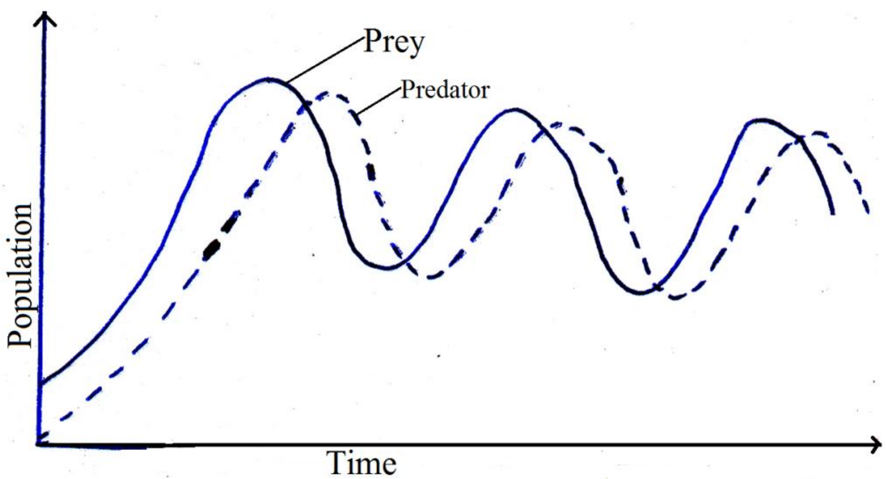
PREDATION

Predation is a feeding relationship where one organism of a given species, the predator, hunts, kills and feeds on another organism, the prey of another species.

The growth and decline of the population of such organisms depend on the number of each group in an ecosystem.

Note: Normally the numbers of predators tend to lag behind than those of prey because predators being larger have a slower rate of increase.

Graph showing relationship between predator-prey populations



Initially prey population grows at a faster rate than the predator. The predators feed on the prey, thus increasing in number due to reproduction in presence of abundant food (prey). The increased predator population increases the feeding pressure on the prey, thus reducing their population.

A reduced prey population triggers off competition among predators for the available food(prey) and even the prey organisms become rare/hard to locate; thus some predators begin to die off due to starvation, hence reducing in number.

When predator populations decrease, the feeding pressure on prey is decreased, thus more prey reproduce and multiply in number and their population increases. The large numbers of preys provide more food and therefore food becomes available for predators again.

Thus the population of prey and predator affects each other which bring about fluctuation in the growth of their populations.

Importance of predation

- Predation maintains populations within the carrying capacity of their habitats and lessens the sudden explosion of prey species within a population.
- Predation is a mechanism by which excess animal productivity is re distributed by conversion into other animal tissues at higher trophic levels.
- Predation maintains ecosystem health and balance as predators feed on herbivores, often targeting sick individuals and thereby keeping disease down, and disposing off carcasses.

Evolutionary significance of predation

  Predation usually eliminates the unfit (aged, sick, weak) individuals. 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 long time survival, thus pass on their good traits to their off springs which can improve their evolution.

Adaptations of predators suited for capturing prey

  Have keen eyes for locating prey e.g kites, hawks can see a mouse in tall grass from a great height above the ground.

  Preying 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 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 e.g cats.

 Some have stinging cells which paralyse their prey e.g hydra, 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.

Adaptations of prey species 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 eg in tortoise and snails for rolling into armour-plated ball.

  In some lizards, the tail breaks off when attacked giving the animal (lizard) time to escape.

  Possession of spines (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.

  Some prey **camouflage** by changing colour e.g. chameleon and cuttlefish, or having deceptive colours that blend with the background e.g. arctic hare in its winter fur blends into snow.

NB. 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***.
Exists in various forms;
(i) **warning colouration** , conspicuous colouring that warns a predator that an animal is unplalable or poisonous e.g poisonous frogs, some snakes, monarch butterflies, and some grasshoppers(ii) **disruptive colouration/patterning** , works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability e.g. group of zebras
(iii) cryptic colouration allows an organism to match its background and hence become less vulnerable to predation e.g chameleon.

  Some prey species discourage predators with 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 prey species have evolved warning colouration – contrasting pattern of advertising colours that enable predators to recognise and avoid such prey e.g. the poisonous frogs, some snakes, monarch butterflies and some grasshoppers.
 Some species gain protection to avoid predation by mimicking (looking and acting like) other species that are distasteful to the predator e.g. the non-poisonous viceroy butterfly mimics the poisonous monarch butterfly. **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.
 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, culex mosquito eggs
 The electric fish Malapterurus (a cat fish) produces high voltage discharge of up to 350v 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

NB: Predation;
-Determines distribution and abundance of the prey because (i) an increase in the number of predators results into decrease in the number of prey.(ii) predators will always be found in places of their potential prey.
-leads to dispersal of animals which reduces competition, since it involves movement of animals from place to place.
-is a biological control method.

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 & 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.

NB: ***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; (i) 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 (ii) 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.

ANTIBIOSIS

Antibiosis is the secretion by organisms 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.e(i) **intraspecific antibiosis** secretion by organisms 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 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.

SYMBIOSIS

The term symbiosis means literally 'living together'. In other words, ***symbiosis is the living together in close association between two or more organisms of different species.***

Many associations involve three or more partners. Nutrition is commonly involved. The common types of symbiotic relationship are; **mutualism**, **commensalism** and **parasitism**.

(a) Mutualism

Mutualism is a close association between organisms of different species(an interspecific interaction) in which both partners benefit.

Examples of mutualistic associations are: nitrogen fixation by bacteria in the root nodules of legumes; the digestion of cellulose by microorganisms in the digestive systems of termites and ruminant mammals; the exchange of nutrients in mycorrhizae associations of fungi and the roots of plants; and photosynthesis by unicellular algae in corals. The interaction between termites and the microorganisms in their digestive system is an example of *obligate mutualism,* in which at least one species has lost the ability to survive without its partner.

(b) Commensalism

This is an interaction between organisms of different species in which one partner benefits but the other receives no harm and no benefit.

For instance, cowbirds and cattle egrets feed on insects flushed out of the grass by grazing bison, cattle, horses, and other herbivores. Because the birds increase their feeding rates when following the herbivores, they clearly benefit from the association. Much of the time, the herbivores may be unaffected by the relationship.

PARASITISM

Parasitism is a close relationship between two organisms of different species in which one organism, normally called **parasite** obtains nutrients from and harms a larger living organism called host. The parasite is normally smaller than the host.

Parasites which **live on the outer surface** of the host are termed **ectoparasites** e.g ticks, fleas and leeches. Such organisms do not usually live in a fully parasitic existence.

Those that **live within a host** are **endoparasites** e.g plasmodium, the tapeworm Taenia, and the liver fluke Fasciola.

If the organism has to **live parasitically at all times**, it is said to be an **obligate parasite** for example the Fungus-like organism Phytophthora which causes potato blight.

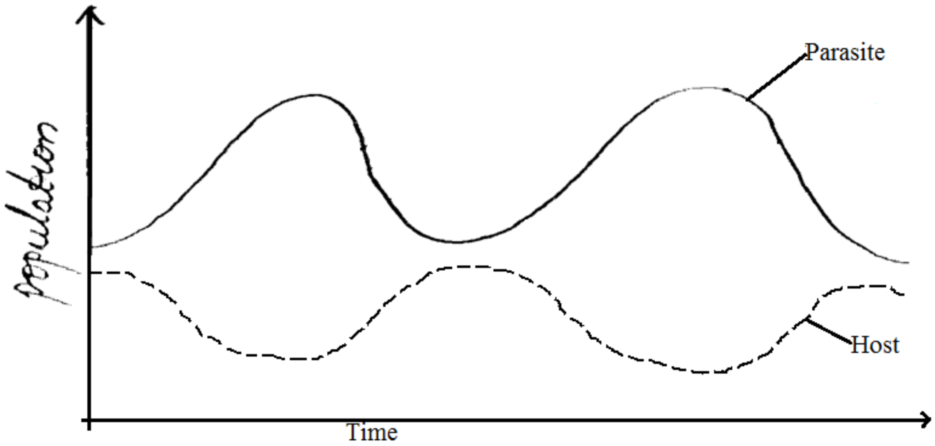
On the other hand, **facultative parasites** are Fungi that **can feed either parasitically or saprophytically**, for example *Candida albicans* which causes thrush in humans(the disease is marked by white patches in the oral cavity mainly in infants) and Pythium(a fungus) that causes 'damping-off' of seedlings, on killing the seedlings, lives as a saprophyte on their dead remains.

Some parasites exploit different hosts at the different stages of their lifecycles. ***Definitive host (final host / primary host)*** is the host in which a parasite attains sexual maturity.

Intermediate host (secondary host) is the host in which a parasite passes one or more of its asexual stages; usually designated first and second, if there is more than one.

N.B:

A successful parasite must never kill its host because it means its own death. Parasites and their hosts have a close symbiotic relationship, so their populations also oscillate. If the population of the parasite increases, they kill their hosts, so their population decreases. This means there are fewer hosts for the parasite, so their population decreases as well. This allows the host population to recover.



Effects of parasites to hosts

- Ectoparasites cause skin irritations and wounds.
- Suck blood from host causing anaemia.
- Gut parasites deprive the host of its nutrients.
- Gut parasites e.g tapeworms can block the alimentary canal causing constipation.
- Cause diseases to host e.g *Phytophthora infestans* causes potato blight.

Challenges / Dangers faced by ectoparasites	**Challenges / Dangers faced by endoparasites**
Failure to cling on the host to avoid being dislodged. Failure to obtain nutritive molecules from the host. -Failure to find the right host for dispersal to their final host	Failure to penetrate the host Failure to obtain nutritive molecules from the host. Destruction by the digestive enzymes and immune responses of the hosts. Complete elimination or extinction. Fluctuating environment e.g. low oxygen tensions, excess heat, solute concentration, darkness etc. -Failure to find the right host for dispersal to their final host

GENERAL ADAPTATIONS OF PARASITES

Structural adaptations
 Possession of penetrative devices for host entry e.g. fungal haustoria, cutting teeth in hook worms *Ancylostoma duodenale*)
 Possession of nutrient suckers e.g. leech
 Development of digestive-resistant outer covering to avoid host's enzyme attack e.g. *Ascaris* and *Taenia* etc.
 Camouflaging morphology to increase survival chances e.g. brown ticks on brown cattle.
 Possessionof specialised mouth parts in some ecto-parasites to suck hosts e.g. sharp stylets in aphids and tsetse flies.
 Possession of specialised haustorial structures in Cuscuta (Dodder plants) for obtaining nutrients from the host

 Degeneration of non-essential organs e.g. no feeding organs, no locomotory organs, no alimentary canal to reduce body size and fit in intestines /blood vessels and for reducing energy expenditure on such organs for example *Fasciola hepatica* (liver fluke), tape worm, hook worm etc.

Physiological adaptations

 Production of enzymes to digest the host's tissues during penetration into the host e.g. fungi and plasmodium
 Production of anticoagulants by blood feeding parasitic animals such as mosquitoes and ticks to avoid blood clotting during feeding.
 Highly tolerant to fluctuating environment e.g. anaerobic respiration in areas of low oxygen tensions, high temperatures, darkness and pH changes in places where they live e.g. most endoparasites.
 Rapid means of escape which increases their chances of survival e.g. fleas and mosquitoes.
 Production of much mucus for resisting digestion by host's enzymes.
 Some endoparasites produce chemicals to protect themselves against the immune response of the host.

Reproductive adaptations

 Someare hermaphrodites with the ability to carry out self fertilisation to increase the rate of reproduction e.g. *Fasciola*, *Taenia*.
 Some asexually reproduce for high rate of reproduction to avoid extinction.
 Release of sexually mature forms of the parasites as free living organisms e.g. in some parasitic animals such as the horse hair worms
 Production of large number of infective agents such as eggs, cysts, and spores which increase survival chances to avoid extinction e.g. tape worms.
 Development of reproductive bodies that are highly resistant when out of the host to survive adverse conditions e.g. cysts in amoeba, fungal spores, etc.
 Use of intermediate host (vector) for their transfer to primary host e.g. plasmodium in female anopheles mosquito to man.
 Some parasites localise the strategic points for propagation to the next host e.g. HIV which causes AIDS is localised in the sex organs.
 Some use hereditary transmission for increased spreading i.e. some parasites infect the ovary of primary host which lays parasite infected eggs.

LIFECYCLES OF SOME COMMON PARASITES

Lifecycle of *Ascaris lumbricoides* (roundworm)	**Adaptations of *Ascaris* to parasitic life**
Adult female in lumen of ileum lays about 200,000 eggs daily, which are passed out in faeces. Fertile eggs **embryonate** and become infective after about **three** weeks, (***optimum conditions:*** moist, warm, shaded soil). On being swallowed by humans, eggs hatch into larvae, which invade intestinal wall, and are carried via the portal, then systemic circulation to lungs. Larvae mature further in lungs (10 to 14 days), penetrate alveolar walls, ascend the bronchi to the throat, and are swallowed into gut. Upon reaching the ileum, they develop into adult worms. Between 2 and 3 months are required from ingestion of the infective eggs to **oviposition** by the adult female. Adult worms can live 1 to 2 years.	Degeneration of structures reduces space occupied. Possession of digestive-resistant cuticle resists destruction by the host's enzymes. Ability to position itself in a habitat where it gains maximum nourishment. Eggs have protective/resistant shell which is their main ineffective and resistant stage. Tolerance to oxygen deficient environment Ability to copulate within the intestines followed by the laying of very many eggs increases survival chances.

Lifecycle of *Taenia sp.* (Tapeworm)	Adaptations of *Taenia* to parasitism
Humans are the definitive hosts for *T. saginata* and *T. solium*. Eggs or **gravid proglottids** are passed out in faeces; Cattle (*T. saginata*) and pigs (*T. solium*) become infected by ingesting vegetation contaminated with eggs or gravid proglottids. In the animal's intestine, the **oncospheres** hatch, invade the intestinal wall, and migrate to striated muscles, where they develop into **cysticerci**. A cysticercus can survive for several years in the animal. Humans become infected by ingesting raw or undercooked infected meat. In the human intestine, the cysticercus develops over 2 months into an adult tapeworm, which can survive for years. Adult tapeworms attach and stay in small intestine by their scolex. The adults produce proglottids which mature, become gravid, detach from the tapeworm, and migrate to the anus or are passed in the stool (approx 6 per day). The eggs contained in the gravid proglottids are released after the proglottids are passed with the feces.	Has hooks and suckers for holding tightly onto ileum wall. Flattened body increases surface area for absorbing its host's digested food Degeneration of structures reduces on space occupied. Lays many eggs to increase survival chances. Hooks for boring through the gut of the host Eggs have a thick shell for resisting enzyme destruction. Being hermaphrodite increases reproductive rate

Hygienic practices for controlling endoparasites

 Avoid eating infected under cooked meat
 Through proper disposal of sewage which prevents these worms from spreading
 Through cooking meat thoroughly for example prolonged heating destroys the tapeworm bladders
 Regular deworming to flush the worm out of the wall of the intestines in faeces.
 Through regular meat inspection before it is consumed by man.
 By prohibition of the discharge of raw sewage into inland waters and seas.

PLASMODIUM – THE MALARIA CAUSING PARASITE

There are approximately 156 named species of *Plasmodium* which infect various species of vertebrates. Four species are considered true parasites of humans, as they utilize humans almost exclusively as a natural intermediate host: *P. falciparum, P. vivax, P. ovale* and *P. malariae*.

LIFE CYCLE OF *PLASMODIUM*

 Malaria parasite life cycle involves **humans** as **intermediate** host and adult female **anopheles** mosquito as **definitive** host.
 During a blood meal, a malaria-infected female ***Anopheles*** mosquito releases **sporozoites** into human blood.
 On reaching the liver, **sporozoites** infect liver cells and mature into **schizonts**, which rupture and release **merozoites**.
 After this initial replication in the liver (**exo-erythrocytic schizogony**), the parasites undergo asexual multiplication in the erythrocytes (**erythrocytic schizogony**).
Merozoites infect red blood cells, the ring stage **trophozoites** mature into **schizonts**, which rupture releasing **merozoites**.
 Some parasites differentiate into sexual **erythrocytic** stages (**gametocytes**).
 Blood stage parasites are responsible for the clinical manifestations of the disease.
 The gametocytes, male (**microgametocytes**) and female (**macrogametocytes**), are ingested by an *Anopheles* mosquito during a blood meal.
 The parasites' multiplication in the mosquito is known as the **sporogonic cycle**.
 While in the mosquito's stomach, the **microgametes** penetrate the **macrogametes-generating zygotes**.
Zygotes become motile and elongated (ookinetes), invade the midgut wall of the mosquito to develop into **oocysts**.
Oocysts grow, rupture, and release **sporozoites**, which enter the mosquito's salivary glands.

 Inoculation of thesporozoites into a new human host perpetuates the malaria life cycle.

LIFE CYCLE OF *PHYTOPHTHORA INFESTANS* *Phytophthora* produce two kinds of spore i.e. diploid **oospores**, formed sexually from fusion of haploid **antheridia** and **oogonia,** and **chlamydospores** formed asexually. Both types of spore have thick cell walls for surviving harsh conditions.
 Under cool wet conditions,*Phytophthora* spores (**oospores** or **chlamydospores**) germinate to form hyphae or directly produce sporangia.
 Sporangia release free swimming**biflagellated zoospores,** which travel in moisture at the surface of leaves, and in soil.
 On reaching plant root or leaf surface a zoospore forms a cyst.
 The encysted zoospore then germinates to form hyphae on the host surface, which penetrates plant leaf or root tissues to absorb nutrients.
 After*Phytophthora* infects the plant, it produces **sporangia** and **zoospores** which further infect other tissues of the same plant or nearby plants.
 Sexual reproduction occurs when positive and negative mating types are present.
Haploid nuclei of **antheridium** and **oogonium** fuse together when the **antheridium** enters the **oogonium** to form a **diploid oospore**, which develops into a **sporangium** and the cycle will continue as is would asexually.

Differences between predation and parasitism

Predation	**Parasitism**
A predator feeds on the whole organism	A parasite feeds on certain tissues of the host.
A predator feeds on the prey very fast	Parasitism is a slow process
A predator has to look for its prey	In parasitism, it is the adult parasite which passes on the larva to the host
A predator is larger than its prey	A parasite is smaller than its host.
A predator does not get shelter from the prey	The parasite gets its shelter from its host.
A predator kills its prey very fast	A parasite may not or may kill its host after a very long time.

BIOGEOCHEMICAL CYCLING (NUTRIENT CYCLING)

This the process by which chemical compounds of a particular element that constitutes living matter are transferred between living organisms (biotic phase) and non-living environment (abiotic phase).

These cycles driven directly or indirectly by incoming solar energy and gravity include the carbon, nitrogen, phosphorus, oxygen, Sulphur and hydrological (water) cycles, but a few have been considered below.

The earth’s chemical cycles also connect past, present and future forms of life. Just imagine:

i) Some of the carbon atoms in your skin may once have been part of a leaf.

ii) Some of the oxygen molecules you just inhaled may have been inhaled by a person at Jesus’ time!

1. HYDROLOGICAL (WATER) CYCLE

The water cycle is powered by energy from the sun and by gravity, and it involves the following main processes:

a) **Evaporation** (conversion of water into water vapour)

b) **Transpiration** (evaporation from leaves of the water extracted from soil by roots and transported throughout the plant)

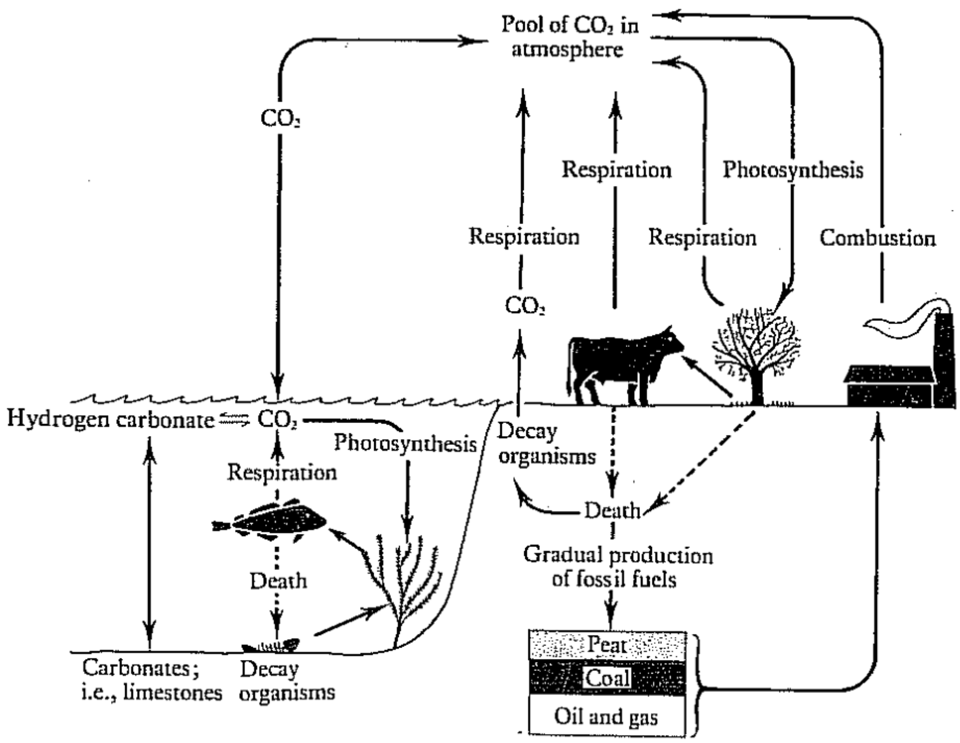
c) **Condensation** (conversion of water vapour into droplets of liquid water)

d) **Precipitation** (rain, hail, snow and sleet)

e) **Infiltration** (movement of water into soil)

f) **Percolation** (downward flow of water through soil and permeable rocks to ground storage areas called aquifers)
g) **Runoff** (downslope surface movement back to the sea to resume the cycle)

2. CARBON CYCLE



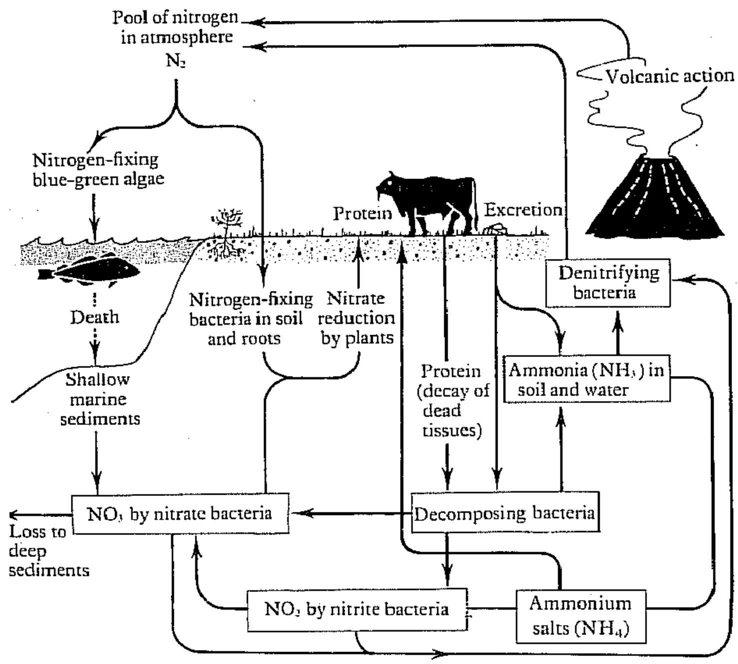
The carbon cycle is based on carbondioxide gas, which makes up 0.036% of the volume of the troposphere and is also dissolved in water.
Carbon fixation involves the reduction of carbondioxide to large organic molecules during photosynthesis and chemosynthesis.
During **aerobic respiration**, the carbon in glucose and other complex organic compounds is converted to carbondioxide into the atmosphere or dissolves in water.
Over millions of years, **buried deposits of dead plant** debris and bacteria are compressed between layers of sediment to form the **carbon-containing fossil fuels** e.g. coal, oil and natural gas, which **when burnt** release carbondioxide into air.
In aquatic ecosystems, carbondioxide may (i) **remain dissolved** (ii) **be utilised in photosynthesis** (iii) react **with water to form carbonate ions** (CO_3^{2-}) and bicarbonate ions (HCO_3^-). As water warms, more dissolved carbondioxide returns to the atmosphere.
In marine ecosystems, some organisms take up dissolved carbondioxide molecules, carbonate ions (CO_3^{2-}) and bicarbonate ions (HCO_3^-) and these ions react with calcium ions (Ca^{2+}) to form calcium carbonate ($CaCO_3$) to build their shells and skeletons.
When the animals with calcium in shells and skeletons die and drift into deep bottom sediments of oceans, immense pressure causes limestone and chalk to form after a very long period of time.
Weathering processes release a small percentage of carbondioxide from limestone into the atmosphere

HOW HUMAN ACTIVITIES AFFECT THE CARBON CYCLE

i) Clearing of trees and other plants that absorb CO_2 through photosynthesis results in its increased concentration.

ii) Burning of fossil fuels and wood adds large amounts of CO_2 into the troposphere.

3. **NITROGEN CYCLE**



Nitrogen is the atmosphere's most abundant element, with chemically **unreactive nitrogen gas** making up 78% of the volume of the troposphere. However, N_2 cannot be absorbed and metabolized directly by multicellular plants and animals.

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 e.g. nitric acid.

Nitrogen fixation occurs when the nitrogen in soil is reduced to ammonium ions, catalysed by nitrogen-fixing bacteria which may be free-living e.g. Azotobacter, symbiotic in root nodules e.g. Rhizobium or cyanobacteria e.g. Nostoc.

Nitrification occurs when ammonium compounds in soil are converted first to nitrite ions by Nitrosomonas bacteria and later to nitrate ions by Nitrobacter bacteria.

Ammonification (putrefaction) occurs when decomposers e.g. some bacteria and fungi convert nitrogen-rich organic compounds, wastes like urea and dead bodies of organisms into ammonia and ammonium ion-containing salts.

Assimilation occurs when inorganic ammonia, ammonium and nitrate ions are absorbed by plant roots to make DNA, amino acids and protein.

Denitrification occurs when mostly anaerobic bacteria e.g. Pseudomonas denitrificans and Thiobacillus denitrificans in water logged soil and deep in ocean, lake and swamp bottoms convert ammonia and ammonium ions back into nitrite and nitrate ions, and then into nitrogen gas and oxygen. Nitrogen gas is released into the atmosphere while oxygen is used for the respiration of these bacteria.

HOW HUMAN ACTIVITIES AFFECT THE NITROGEN CYCLE

Burning of fuels forms nitric oxide, which reacts with atmospheric oxygen to form nitrogendioxide gas that reacts with water vapour to form acid rain containing nitric acid. Nitric acid together with other air pollutants (i) damages trees (ii) corrodes metals (iii) upsets aquatic ecosystems.

The inorganic fertilizers applied to soil are acted upon by anaerobic bacteria to release nitrous oxide into the stratosphere, where it (i) contributes to ozone depletion (ii) contributes to green house effect.

Nitrogen is removed from top soil when we (i) harvest nitrogen-rich crops (ii) irrigate crops (iii) burn or clear grasslands and forests before planting crops

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.

The accelerated deposition of acidic nitrogen containing compounds e.g. NO_2 and HNO_3 onto terrestrial ecosystems stimulates growth of weeds, which outcompete other plants that cannot take up nitrogen as efficiently.

ECOSYSTEM DEVELOPMENT

Ecosystems are not static but dynamic entities. As an ecosystem lives, its structure and function tends towards equilibrium and so its stability.

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. Or

Ecological succession 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. Or

It's the establishment of a sequence of different communities in a particular area over a period of time.

Communities succeed each other in an orderly sequence in which such successive stage i.e. it's dependent on the one that precede it.

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. These temporary communities consists the seral stages/seral communities).

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

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 succession

1. Primary succession
2. Secondary succession

Primary succession: It occurs during the colonization of uninhabited area or where no life previously existed e.g. volcanic islands, bare rocks, sand dunes, lake shore, river banks, bare pavements, bare soil surface, dry area devoid of vegetation, ponds, swamps.

An example of succession on a rock:

On a bare rock/bare pavement **several seral stages** are identified.

Lichens (an association of algae and fungi) are **the pioneer community** to be established first. They are able to utilize the low moisture, nutrients, and ions on rock surface. The hyphae of the fungi penetrate the tiny pores on the rock providing a firm attachment and absorbing inorganic nutrients from the rock while the algae provide organic food since it is photosynthetic.

Bacteria and fungi also aided by weathering loosen rock surface by the process of rock decay. Their decaying bodies (algae/fungi and bacteria) add humus to the loosened rocks to form sedimentary soils.

The loosened rock is now able to support less drought resistance **second colonizers, usually mosses**. The mosses are anchored by their rhizoids in the thin layer of soil from which they obtain the tiny organic and inorganic nutrients and water/moisture.

The growth of mosses further loosens the rock surfaces. Also death of some moss plants add nutrients to the soil due to decay by saprophytic organisms, more soil is formed which can now support the growth of **ferns, herbs and grass** species.

Small animals like insects, molluscs, earth worms, and small rodents come in and burrow into the soil causing further break down of rocks.

More herb and grass seeds germinate becoming predominant to replace proceeding growth of mosses.

Much more soil is formed from further rock break down and decay of dead plant materials and they in turn provide suitable conditions for **large woody shrubs** to begin to grow in the newly fertile formed soils.

Eventually as a thicker layer of soils develops, shrubs get replaced by **deciduous trees** with deeper roots that penetrate crevices/cracks. The seeds of the trees become germinated/grow in the created suitable conditions by their parents' previous plants and animal colonizers and the mature forest community develops which becomes self-sustaining, hence forming the climax community.

Note:

As the number of tree species increase, there is increased modification of the micro climates in the habitat e.g. shade increases, making light demanding shrubs to disappear and are replaced by light tolerant species of trees. The tolerant species of trees finally form the climax vegetation. The savanna grass land and forest ecosystems are the dominant terrestrial ecosystems.

Secondary succession

This is the establishment of communities on areas/habitats previously occupied by developed communities but has been destroyed such as burnt farm, playground fire cleared, forests destroyed by natural disaster like hurricanes(extremely large, powerful and destructive storms), drought, volcanic eruption, floods, human activities like fires, cultivation, overgrazing.

Such areas have seeds/spores, organs of vegetative reproduction/propagation, rhizomes and abundant nutrients in soil to support life. The successions are called secondary seres.

Often the first green plants on a burnt wood ash are the mosses that form an extensive green carpet. Within carpet the seeds of herbaceous and woody plants germinate. A new herbaceous layer grows, and followed by shrubs and trees. Each dominant plant community has associated dominant animal population within it. The climax community persists for a long time until when factors that favour invasion of better adapted forms of organisms set in.

The climax vegetation makes efficient use of resources of the community ensuring indefinite self-sufficiency i.e. a community maintaining itself.

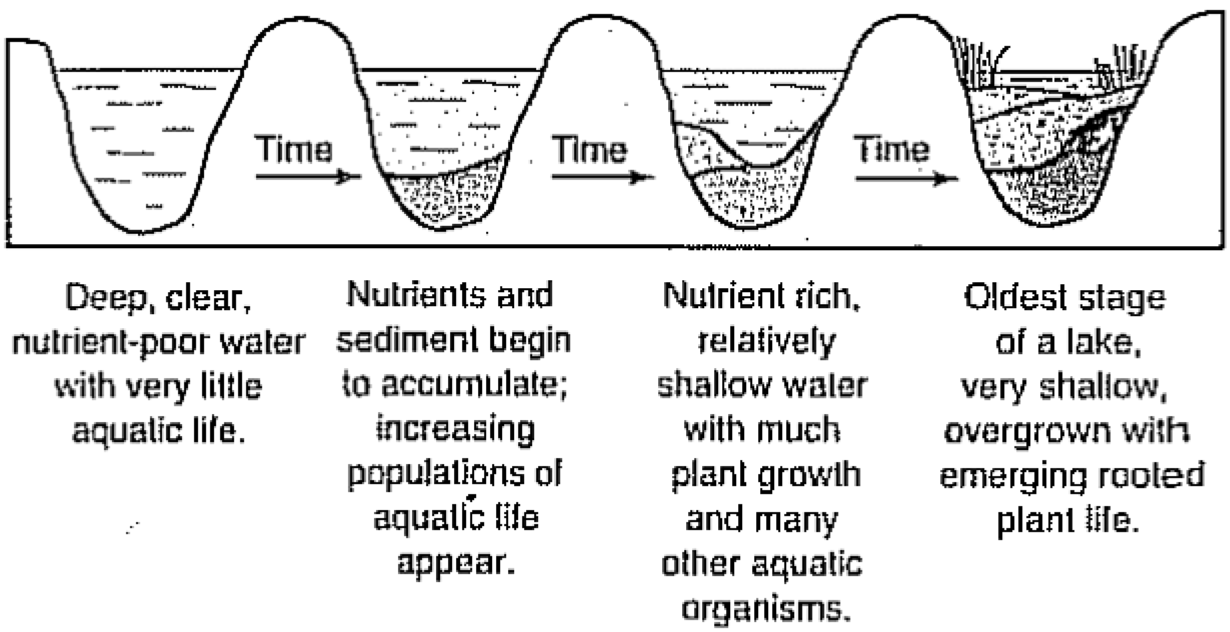
A similar secondary succession takes a short time to reach climax community. This is because the soil is already formed and supports growth of a wide range of plants immediately.

Note:

Both primary and secondary succession is affected by the animal (fauna) and flora (plants) of the surrounding environment/areas through dispersal and migration.

ECOLOGICAL SUCCESSION IN A LAKE

The diagram shows a number of stages in an ecological succession in a lake.



Assinment: Describe the major stages in an ecological succession in a lake.

GENERAL FEATURES OF PRIMARY SUCCESSION

1. The composition of the species in the climax community is predetermined by the species composition of the surrounding vegetation, soil types and climate.
2. The species in one seral stage modify the soil in such a way that favours establishment of the organisms in the next seral stage. The new species achieves dominance and out-competes the former. The process continues until a climax community is reached
3. The complexity of the organisms during succession increases towards a climax community.
4. Biomass or gross productivity increases towards a climax community where it stabilizes.
5. Net production increases until it attains its maximum at the grass community. Then it starts decreasing until it stabilizes at the climax community.
6. Species diversity also increases unti the grass community, but when the shrubs and thickets begin to establish themselves and later on trees, then diversity of the species begins to to decrease and stabilizes at the climax community.
7. There is progressive development of soil with increasing organic matter and soil depth towards a climax community.
8. There is a general increase in the microhabitats and ecological niche towards a climax community

Factors affecting the number and diversity of species reaching an area/colonization

- Geographical barriers like mountain ranges/ river/lake/rift valley.
- Ecological barriers like unfavorable habitats separating areas of favorable habitats.
- Distance over which dispersal must operate.
- Size and nature of invasion areas.

KEYSTONE SPECIES

A keystone species is a species that has a disproportionately large effect on its environment relative to its abundance. A keystone species is often a dominant predator whose removal allows a prey population to explode and often decreases overall diversity.

Such species are described as playing a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community.

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.

TERRESTRIAL ECOSYSTEMS

The six major biomes of Africa include:

- Tropical rain forest
- Tropical savanna and grassland
- 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. 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, albizia, 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.

Understoney layer:

This includes relatively short trees 20-40m tall 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. 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

- ❖ Emergent and canopy layer trees prevent excessive transpiration by having leathery surface and adequate deposits of cuticle.
- ❖ Plants of the undergrowth have broad thin leaves increasing surface area for absorption of light and reducing diffusion distance.
- ❖ 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, 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

- ❖ 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 some hibernate during unfavourable conditions.

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

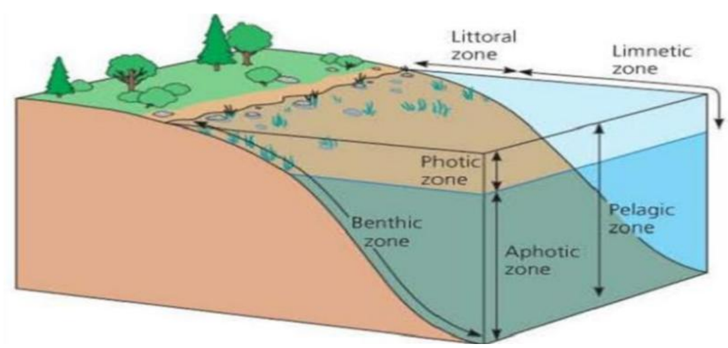
Fresh water habitats occupy a small portion of the earth's surface as compared to marine and terrestrial habitats. However, fresh water habitats are of great importance to man for the following reasons:

- ❖ Cheapest source of water for domestic and industrial use
- ❖ Provide the cheapest waste disposal systems
- ❖ Habour 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 light penetration, 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.

iii) **Profundal zone:** receives little or no light. Light penetration decreases with depth and also net productivity decreases with depth. Profundal is part of the pelagic zone which lies below the range of effective light penetration/photic zone/limnetic zone.

iv) **Benthic zone:** this is the bottom most, 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 photosynthetic and chemosynthetic 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.

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.

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 (wide littoral zone).
- ❖ 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 they are highly oxygenated.

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 unrotten 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.

Limiting factors in fresh water ecosystems/ Factors affecting productivity of the lake

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 can be measured using a ***Secchi disc***. It consists of a white 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.

CATEGORIES OF PLANTS ACCORDING TO WATER CONDITIONS OF HABITAT

Hydrophytes

Hydrophytes are plants that grow in regions, where, there is plenty of fresh water supply (i.e. Pond, pool, lake, river and marshes) or wet soils. Four major types of hydrophytes occur and these include;

1. Free floating hydrophytes

These plants float freely on the surface of water but are not rooted in the soil. These plants are in contact with both water and air e.g. Water hyacinth(Eichhornia), Nile cabbage(Pistia).

2. Floating but rooted hydrophytes

These hydrophytes are rooted in the mud but their leaves and flowering shoots float on the water surface. E.g. water lilies.

3. Submerged hydrophytes

These are plants which grow below the water surface and not in contact with atmosphere.

They are either **free floating submerged** hydrophytes. E.g. Ceratophyllum, and Utricularia. or

Rooted Submerged hydrophytes ; These plants are completely immersed in water and rooted in the mud.

4. Amphibious Hydrophytes

These plants grow in shallow waters. Their roots, some part of stems and leaves are submerged in water. But some flowering shoots spring well above the water surface.

These plants are adapted to both aquatic and terrestrial modes of life. The aerial parts of these amphibious plants show mesophytic characters, while the submerged parts develop true hydrophytic characters. e.g. Sagittaria.

Mesophytes

Mesophytes are plants that are able to grow and thrive under typically average conditions. They require an average amount of water, and a consistent average temperature in order to survive. 'Meso-' means 'in the middle,' which might help you remember their middle or average requirements.

These plants have developed root systems, large leaves, and their stomatas are located on their lower surfaces for gas exchange. Most plants fit into the mesophyte category, so no matter how beautiful or fascinating a plant might be, most are decidedly average in terms of their adaptations.

Halophytes

A halophyte is a plant that grows in waters of high salinity, coming into contact with saline water through its roots or by salt spray, such as in saline semi-deserts, mangrove swamps, marshes and sloughs and sea shores.

Psammophytes

A psammophyte is a plant that thrives in shifting sands, primarily in deserts. Psammophytes are marked by a number of adaptations that enable them to exist on wind-blown sands. In such an environment, the plants are often covered with sand, or their root system is exposed.

Xerophytes

A xerophyte is a species of plant that has adaptations to survive in an environment with little liquid water, such as a desert or an ice- or snow-covered region in the Alps or the Arctic.

Qn. How are the following categories of plants adapted to living in their habitats?

(i) Hydrophytes
(ii) Halophytes
(iii) Psamophytes
(iv) Xerophytes.

MAN AND ENVIRONMENT
Man has greatly affected the modified natural environment through the activities like agriculture, settlement, industrialization, burning (fires), construction. This has led to exhaustion of resources, pollution e.t.c. extinction of some species, loss of habitat, etc
NATURAL RESOURCES
These are materials which can be provided by the environment naturally that are useful to man.
TYPES OF NATURAL RESOURCES
a) RESNEWABLE NATURAL RESOURCES
These are resources which grow and can be replaced e.g forests, wildlife, fish, etc.

b) NON-RENEWABLE NATURAL RESOURCES
These are exhaustible i.e they are not replaced as they are used e.g minerals and fossil fuels, e.t.c.

c) NON-EXHAUSTIBLE NATURAL RESOURCES
These cannot be depleted e.g light, oxygen and water.

IMPORTANCE OF NATURAL RESOURCES TO MAN

1. They are source of food to fish, wild life (animals), insects, etc which man feeds on.
2. They are sources of fuels e.g fossil fuels, trees etc.
3. They are habitats for useful species.
4. They are useful for biological scientific research.
5. Source of raw materials for industries.
6. Source of medicines.
7. For conservation of biodiversity and gene pools.
8. Some are water carriers and wind breakers e.g forests.
9. Trees absorb excess carbon dioxide.

ABUSE OF NATURAL RESOURCES

There are several human activities which directly destroy natural resources and the environment and these are:

1. **Deforestation;** This is the cutting down of trees thus destroying forests.

Forests have most species and diverse wild life communities. Their destruction will lead to extinction of numerous species and less of genetic variety and potential resources.
Forests protect the soil. Deforestation leads to soil erosion, clear water supply are destroyed and silting of reservoirs.
Forests catch large amounts of rain and release the water slowly into streams and rivers. Their destruction cause floods in areas down-hill.
Forests release large amounts of oxygen and absorb carbon dioxide (lock it up) during photosynthesis. Deforestation has led to increased global carbon dioxide hence causing global warming.
Forests influence the amount and frequency of rain fall received in an area. Their destruction may lead to prolonged droughts and/or desertification.

2. **Poor agricultural methods:**

These include Monoculture, shifting cultivation, use of artificial fertilizers and pesticides. Excess fertilizers and pesticides leads to eutrophication of water bodies giving rise to build up of toxic by-products by leaching and draining. Pesticides/herbicides/fungicides draining away from fields enter water ways are connected through the food chain. This leads to poisoning of top carnivores.

3. **Poor methods of mining;** such as open cast mining destroy habitats. Mineral elements mined cause destruction of the environment around the mine. Heavy metals like lead and mercury drain into water bodies causing severe destruction of aquatic fauna, poison water for human consumption; sulphides destroy vegetation altering the structure of plant and animal communities.
4. **Urbanization/human settlement;** e.g. aggregation of people, food and water supply, garbage disposal.
5. **Fires;** burning of fossil fuel
6. Cement manufacture

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 cause 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.

Categorisation of pollutants basing on their persistence in the environment

(a) Degradable (non-persistent) pollutants: Are the pollutants that are broken down completely or reduced to acceptable levels by natural physical, chemical and biological processes.

Biodegradation: is the breakdown of complex chemical pollutants into simpler chemicals by living organisms (usually specialised bacteria) e.g. sewage is a biodegradable pollutant.

(b) Slowly degradable (persistent pollutants): Are those that take a longer time to degrade e.g. DDT - an insecticide, and **plastics e.g. plastic bags.**

c) Non-degradable pollutants: these cannot be broken down by natural processes e.g. the toxic elements lead, mercury, arsenic, selenium.

TYPES OF POLLUTION

Pollution may take any of the three forms i.e air pollution, water pollution or soil pollution.

(a) AIR POLLUTION

Pollutant	**Source(s)**	**Effects/ consequences**	**Control measures**
(i) ***Carbonmonoxide***	**(i)**Motor vehicle exhausts**(ii)**Incomplete combustion of fossil fuels (iii) tobacco smoking	(i) Prevents oxygen usage by blood by forming carboxy-haemoglobin, which may cause death. (ii) Small concentrations cause dizziness and headache	(i)Efficient combustion of fuels in industry an homes (ii)Avoid smoking.(iii)Vehicle exhausts gas control.
(ii) ***Sulphurdioxide***	(i) Combustion of Sulphur containing fuels, oil, coal gas	(i) Causes lung diseases, irritation of eye surface, and asthma resulting into death if in high concentrations.(ii) Forms acid rain which increases soil PH.(iii) Reduces growth of plants and kills lichens. NB. *Lichens are indicator species for sulphurdioxide pollution.* *The presence of many lichen species indicates low level of sulphurdioxide pollution in that area.*	i) Use of Sulphur free fuel e.g. natural gas. (ii) Installation of Sulphurdioxide extraction units in industrial fluels and chimneys.
(iii) ***Ozone***	(i)Motor vehicle exhausts ii) combustion of fossil fuels to form nitrogen dioxide which decomposes to form oxygen atoms that combine with oxygen molecules to form ozone.	***Low level (tropospheric) ozone*** causes: (i) Internal damage to leaves hence reducing photosynthesis. (ii)Eye, throat and lung irritation which may result into death.(iii)Internal damage to leaves which severely reduces photosynthesis. (iv) Green house effect by absorbing and radiating heat which raises the temperature at the earth's surface. ***High level (stratospheric) ozone offers*** protection against excessive solar heat by absorbing solar ultraviolet radiation which would reach the earth's surface.	(i) Vehicle exhausts gas control e.g. in USA

(iv) Smoke	(i)House coal, smoke, soot ii)Motor vehicle exhausts iii) tobacco smocking iv)Incomplete combustion of refuse in incinerators and bonfires.	(i) Causes lung diseases when inhaled (ii) Sunlight barrier, hence reducing photosynthesis.(iii)Stunted growth of plants (iv) Stomatal blockage hence reducing photosynthesis	(i)Usage of smokeless fuels (ii)Efficient combustion iii)No smoking iv) Vehicle exhausts gas control
(v) *Dust*	(i) Solid fuel ash (ii) soil (iii) quarrying (iv) mining, etc	i)Lung diseases(ii) stomatal blockage iii) Stunted growth of plants.(iv) Smog – forms when temperature inversion occurs (layer of warm air traps cool air containing dust and smoke close to the earth' surface)	i)Installation of dust precipitators in industrial chimneys. ii) Efficient combustion. iii) Wearing of face masks by factory workers.
(vi) *Carbondioxide*	(i)Motor vehicle exhausts ii) combustion of fossil fuels	Increased carbon dioxide causes Green house effect – warming up of the earth's atmosphere as a result of the blanket of carbon dioxide, preventing escape of solar radiation higher into space.	(i)Planting more green plants, (ii0 reduction in combustion of fossil fuels by relying on alternative sources of energy e.g. solar energy.
(vii) *Nitrogen oxides* (*nitric oxide & nitrogen dioxide)*	(i) Car exhaust emissions (ii) industrial fuel gases	(i)Acid rain formation(ii) contribute to green house effect	(i) Car exhaust control
Viii)Chlorofluorocarbons CFCs	(i)Aerosol propellants, (ii) refrigerator (iii) air conditioner coolants (iv) expanded plastics. E.g. bubbles in plastic foam used for insulation and packaging **(polyurethane form)**	Enters stratosphere, the chlorine reacts with ozone hence reducing the ozone layer and permitting greater penetration of UV light to cause global warming.	Ban on the use of CFCs
(ix) *Noise*	(i) Discos (ii) road traffic,(iii) engines (iv) machines, (v) aeroplanes(vi) firearms	(i) Hearing impairment,(ii) total deafness (iii) nervous disorders	(i) Effect laws against excessive noise(ii)put on ear muffs and plugs while in industry
(x) *Radioactive*	(i) Nuclear weapons(ii)	Ionizing radiation causes cancer	Nuclear power controls

fallout from explosion	nuclear power fuels.		

GREENHOUSE EFFECT AND GLOBAL WARMING

Greenhouse effect

- This isthe condition which results when greenhouse gases i.e. gases in the troposphere like carbon dioxide, methane, chloroflorocarbons 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

This is the observed general global temperature rise as 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.
- Cultivation of rice in swamps and paddy 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^{2-} ions from sulphuric acid, causing formation of soft exoskeletons, which results into death of invertebrates.
- Aluminum ions are displaced from soil by SO_4^{2-} ions into water where it interferes with gill functioning in fish causing their death.
- Aluminum ions are displaced from soil by SO_4^{2-} 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 suchas 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 SO2 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.

Why high-altitude lakes quickly become acidic than low- altitude lakes?

Low- altitude lakes are richer than high-altitude lakes in limestone which buffers against the effects of acid rain, and also the surrounding soils to low-altitude lakes are deeper.

(b) **WATER POLLUTION**

Water is a habitat for aquatic life. Most aquatic life respires aerobically and so requires oxygen from their environment. Any change in the amount of oxygen in the water can severely/seriously affect the suitability of water as a habitat. **The main water pollutants are;**

- Untreated sewage
- Fertilizers (leach from near farm land)
- Pesticides/herbicides
- Heat from industries

EUTROPHICATION

This is the enrichment/addition of nutrients to water bodies which encourages excessive growth /blooming/ proliferation of algae, fungi and other aquatic plants. Massive death and decay of these organisms enriches the water body more with nutrients. At the same time aerobic decomposers(bacteria) use up oxygen leading to oxygen depletion which may lead to suffocation and death of other aquatic organisms e.g fish.

The human activities that cause eutrophication are;

- Discharge of untreated sewage into water bodies/industrial wastes
- Use of fertilizers which later wash into water bodies

Effects of eutrophication

(1) Species diversity decreases and the dominant biota change e.g Algal bloom reduces light penetration into the water body, so algae and other photosynthetic plants in the deeper regions of the water body are unable to photosynthesize leading to death of submerged aquatic plant species and animals.
(2) Plant, algal and animal biomass increase; due to excessive growth arising from abundant nutrients.
(3) Turbidity increases; due to increased amount of suspended particles from organic debris of dead plants and animals.
(4) Rate of sedimentation increases, shortening the lifespan of the lake
(5) Anoxic conditions may develop. The process of decomposition depletes the water of oxygen leading to increased biochemical oxygen demand (B.O.D).
(6) Due to anaerobic activity and decomposition the water becomes alkaline due to high concentration of ammonia.

Problems of eutrophication

(1) Treatment of drinking water may be difficult and the supply may have an unacceptable taste or odour
(2) The water may be injurious to health
(3) The amenity value of the water may decrease
(4) Increased vegetation may impede water flow and navigation
(5) Commercially important species (such as salmonids and coregonids) may disappear.

Monitoring eutrophication/indicators of eutrophication.

- Biochemical oxygen demand (BOD) is a useful **chemical indicator** of eutrophication. It is the measure of the rate of oxygen depletion by organisms.

- **Biological indicators** of eutrophication include changes in phytoplankton species present e.g blue-green bacterial blooms are common. Eutrophic waters characteristically show high abundance and low species diversity of phytoplankton.
- Other indicators may include **physical changes in water quality** e.g water colour, turbidity etc.

N.B:

- Eutrophication is greatly accelerated by thermal pollution because of heat increasing the rate of decomposition that bring about a higher oxygen demand in aquatic environment.

MAJOR CATEGORIES OF WATER POLLUTION

(A) ***SEWAGE DISCHARGE INTO RIVERS***

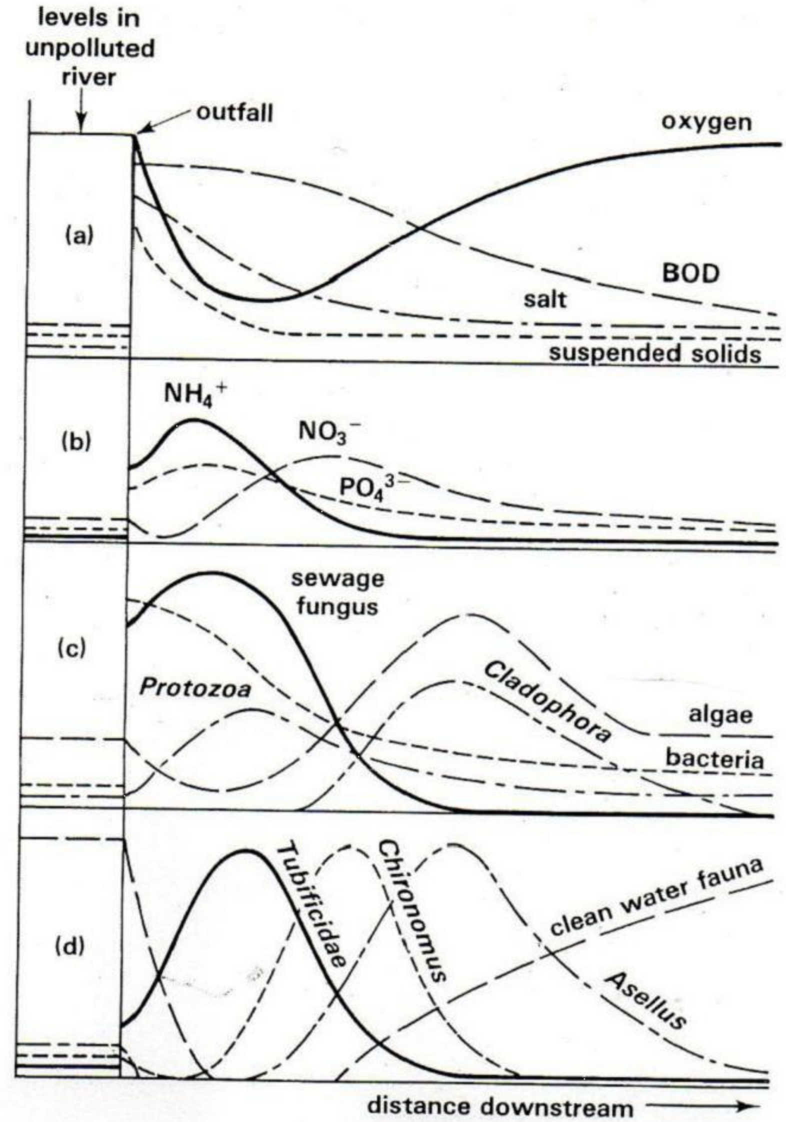
Sewage is liquid waste (composed of faeces, urine, water, detergents and other substances) from industries and/ or homes carried through pipes called **sewers**.

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



(a) What is meant by the term biochemical oxygen demand(BOD)?

b). Explain the changes in BOD shown in the diagram

(c.) (i) Explain the changes in nitrate level shown in the diagram.

(ii). Compare and comment on the curves for the sewage fungus and the algae in the diagram.

(d). Using evidence from the diagram, suggest a method by which an organism might be used as a pollution indicator.(Your answer should include practical details of your method)

(e) Suppose that the chemical works also discharged thermal pollution. Suggest one possible effect on the river's chemical content and one possible effect on its biological content.

Component(s)	Variation down stream	Explanation
(i) ***Dissolved oxygen and B.O.D (Biological or biochemical oxygen demand)*** NB. BOD is mass of oxygen consumed by microorganisms in a sample of water in a given time - usually measured as the mass (in mg) of oxygen used by 1dm3 of water stored in darkness at 20degrees Celsius 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).	-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.	-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 down stream.
(ii) ***suspended solids***	-Suspended solids are very few before outfall, increase rapidly at the sewage discharge but progressively decrease downstream.	-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.	-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.	-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.	-Sewage contains NH4+ ions. Putrefying (ammonifying) bacteria convert organic

	-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 (1) rapidly at discharge, (2) gradually just after outfall to a maximum, then decreases gradually to a very low level downstream.	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 (1) detergents and (2) decomposition of organic matter, yet the consumption by autotrophs is very low at outfall, accounting for the high PO_4^{3-} ion concentration. PO_4^{3-} ion gradual decline downstream is caused by (1) absorption by the progressively increasing populations of autotrophs (2) storage in sediments.
v) ***Clean water fauna (e.g. stonefly nymphs, mayfly 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) **NB-** organisms above are **indicator species** of un polluted, well oxygenated water.	-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.	-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 (i) relatively inactive to reduce oxygen demand and (ii) 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.

NB. (a) 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 (1) ***volume of incoming degradable wastes in sewage*** (2) ***flow rate of the river*** (3) ***temperature of the water*** (4) ***pH level of the water.(5)existing population of microorganisms.***
(b) 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.***

(B) ***ADDITION OF INORGANIC CHEMICALS, PLANT NUTRIENTS AND SEDIMENTS INTO LAKES.***

Pollutant	**Examples**	**Main human sources**	**Harmful effects**
(i) ***Plant nutrients***	(i)Nitrate (NO_3^-) (ii) phosphate (PO_4^{3-}) and (iii) ammonium (NH4+) 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.	(i)Rapid growth of algae and green protists (algal blooming/dramatic first growth of algae) (ii) reduces light penetration in water leading to (iii) Death and decay of algae, which depletes water of dissolved oxygen, killing fish and other aerobic animals. (iv) Excessive levels of NO3- if drank in water lowers the oxygen carrying capacity of blood and kill unborn children and infants **("blue baby syndrome").**
(ii) ***Sediment***	(i) soil (ii) silt	Land erosion	Can (i) cause turbidity / cloudiness in water; light penetration is reduced therefore reduce photosynthesis, (ii) settle and destroy feeding and spawning grounds of fish, (iii) clog and fill water bodies, shortening their lifespan (iv) disrupt aquatic ecosystems (v) carry pesticides, bacteria and other harmful substances into water.
(iii***)*** ***Inorganic chemicals***	(i) acids, (ii) compounds of toxic metals like lead (Pb), mercury (Hg), arsenic (As) and selenium (Se) and (iii) salts e.g. NaCl in ocean water	Surface runoff, industrial effluents and household cleaners	(i)Drinking water becomes unusable for drinking and irrigation (ii) Lead and Arsenic damage the nervous system, liver and kidneys (iii) they harm fish and other aquatic life (iv) they lower crop yields (v) they accelerate corrosion of metals exposed to such water.

C. ***HEAT (THERMAL) POLLUTION***

Main human sources

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

Harmful effects

1) Lowers dissolved oxygen levels since solubility of most gases reduces with temperature.
2) Make aquatic organisms more vulnerable to disease, parasites, and toxic chemicals.
3) 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**.
4) Some aquatic animals may migrate to water with favorable temperature.

Note:

Effects of eutrophication are more severe in water bodies where thermal pollution occurs because of;
1) Increased decomposition of organic matter and metabolism, which raise the demand for oxygen by higher organisms.
2) Reduced dissolved oxygen levels in water.

THERMAL STRATIFICATION

In lake ecosystems the problem of eutrophic oxygen depletion may be made worse by seasonal water stratification, when the water forms layers with different temperatures. In temperate regions, thermal stratification typically establishes in early summer. This occurs for two main reasons;

- The sun heats the surface water. Warmer water is less dense so it remains in the top layer of the lake(**epilimnion**). Heat transfer to deeper layers can only take place by conduction which is a slow process in water.
- Rivers and streams draining into the lake are shallow by comparison. This water will have become warmed throughout it depth. This warmer water, being also lighter and less dense, mixes only with the surface waters of the lake further raising its temperature by comparison with the deeper water(the **hypolimnion**).
- The transition region/interface between epilimnion and hypolimnion is the **thermocline**/**metalimnion**.

Thermo stratification particularly affects the supply of oxygen to the deep waters.

Oxygen supplies in lake waters come from three main sources. These are;

- Photosynthesis which requires light and is therefore most rapid in the surface waters;
- Diffusion from the atmosphere;
- Oxygen in the stream and river waters draining into the lake.

These sources all primarily enrich the surface waters. Oxygen in the deeper water will depend on effective diffusion from above or extreme turbulence linked with storm events. Storminess and good mixing of the water is more characteristic of the winter season. As cooler deeper waters freeze, the ice, being less dense floats to the top. Thus the warmer surface waters now richer in oxygen, being denser than ice and much cooler waters(temperature lower than 4^0c) will move to lower layers. The net result is higher temperatures, and relatively higher oxygen content deeper layers compared to summer levels.

Diagram showing thermo stratification in a mid-latitude lake

B.S PAGE 331

Questions

1.What are advantages and disadvantages of biological rather than chemical control of eutrophication?

Organisms live in their environment all the time; their presence (or absence) reflects the suitability of that environment for their living requirements at all times. A short-lived but severe pollution incident occurring at night would be reflected by the absence of sensitive organisms long after visible and chemical evidence of the pollution incident had disappeared. Biological indicators can therefore be a more sensitive and representative reflection of environmental conditions. Chemical monitoring all the time can only be done for small water courses e.g small rivers , streams and remote areas. It also requires much time-consuming and, in the long term, expensive laboratory analysis

Biological control requires reasonable expertise at identification and is also affected by seasonal factors.

2.(a) **State three ecological problems which arise from accumulation of domestic waste in urban communities.**

(b) Give two ways of reducing domestic waste in urban communities.

3. SOIL POLLUTION

Improper disposal of domestic solid wastes such as garbage, metals, cans, plastic containers and polythene materials cause soil pollution. Plastic and polythene materials are non biodegradable. The sewage we produce at home may also cause harmful effects to the soil such as bleaching solution that may change the PH level of the soil and it's toxic. Man's activities such as deforestation, bush burning, poor farming methods (zero grazing, monoculture) may lead to soil erosion, flooding etc.

INDICATOR SPECIES

An indicator species is an organism whose presence, absence or abundance reflects a specific environmental condition. Indicator species can signal a change in the biological condition of a particular ecosystem, and thus may be used as a proxy to diagnose the health of an ecosystem. For example, plants, or lichens sensitive to heavy metals or acids in precipitation may be indicators of air pollution.

FEASIBILITY STUDY:

It is an ecological study which is carried out in order to a certain suitability of a given area for a given project. E.g fish farming, poultry, cattle rearing, industry, etc.

The ecologist needs to find out the biotic and abiotic factors prevailing in the area that have got an influence on the project. These may include:

market availability, population and activities, peoples culture, vegetation, government policy, political stability, sources of raw materials, location of area, natural hazards, topography, water resources, soil, climate, infrastructure.