Instruction. *Copy the notes discuss and read them. Notes will be checked for at the beginning of the term. All drawings and illustrations should be complete. We'll do an ecology test in the first week. All in preparation for the ECOLOGY TRIP.*

ECOLOGY NOTES A'LEVEL

Competency: *The learner evaluates the interactions within ecosystems by analysing data and personal experiences to develop strategies for enhancing food security and promoting sustainable management of natural resources.*

Content breakdown

- Review of data analysis

- Population dynamics & factors affecting them in different ecosystems
  (i) Population characteristics.
  (ii) Population growth.
  (iii) Factors affecting population density.
  (iv) In groups, learners conduct field studies to estimate population density using quadrats and capture-recapture techniques in different ecosystems.

- Ecological succession and strategies for effective ecological restoration practices in diverse environments.
  (i) The role of primary and secondary succession in preserving biodiversity
  (ii) Techniques and benefits for restoring degraded ecosystems.
  (iii) Design and implement a small-scale restoration project on a degraded area within or around the school. Make a project report and present to the rest of the class.
  (iv) PROJECT; Small scale restoration project on a degraded area within or around the school

- Energy flow through ecosystems its role in maintaining ecosystem stability, and the impact of human activities on energy flow.
  (i) The concept of energy flow in the ecosystem.
  (ii) Effect of human activities on energy flow.
  (iii) Bio-accumulation, bio magnification, and feed conversion ratio, their importance and relationship to energy transfer/flow.
  (iv) Significance of bioaccumulation and bio magnification to the health of organisms and the environment in an ecosystem.
  (v) Applications of feed conversion ratios.

- Impact of invasive species on native biodiversity, ecosystems, and economies, as well as strategies for their management and control.
  (i) Characteristics of invasive species
  (ii) Their impacts on native biodiversity, ecosystems, and economies.

(iii) Strategies to manage and control the invasive species.
(iv) Using problem-based learning method, Learners examine a case study of a pest infestation controlled using biological agents.

- Analyse the concept of food security, focusing on its components and sustainable agricultural practices to address its challenges.
  (i) Components of food security; availability, access, utilization, and stability.
  (ii) Their roles in maintaining a stable food supply.
  (iii) Threats and solutions to food security.

  - Carbon footprint in relation to climate change, including its measurement, as well as the role of carbon sequestration in mitigating climate change.
  (i) The concept of carbon footprint and its measurement.
  (ii) Activities that contribute to carbon output and key sources of greenhouse gas emissions.
  (v) Feed conversion ratio in a small mammal (rat or rabbit) using different diets.

ECOLOGY

Ecology is the scientific study of the complex relationships between organisms and their environment.
These interactions determine the distribution and abundance of organisms within a particular environment.
An environment is the immediate surroundings of an organism.

Organisms live within a relatively narrow sphere (land, water and air) and the earth's surface and this is known as **Biosphere (ecosphere)**

The biosphere is divided into two major regions namely;

(a) **Aquatic regions;** These are made up of;
  (i) Fresh water (lakes, ponds, rivers, streams, and wetlands),
  (ii) Marine water (oceans, seas), and estuaries.

(b) **Terrestrial regions** covering a few meters deep in the soil and a few kilometers into the atmosphere.

On land, there are several biogeographical areas, each with specific conditions that support distinct species of plants and animals. Such areas include the present day continents.

Some of these areas may possess similar physical conditions, therefore supporting similar plants and animals; these areas are collectively called **Biomes**.

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

Biomes include;

(a) **Tropical rain forests**
(b) **Tundra regions** (where ground is frozen much of the year and vegetation is sparse)
(c) **Hot and dry desert regions** (where evaporation is high and there is too much heat)
(d) **Cold deserts** (where there is precipitation coming from colder water sources than rain, such as snow or ice)
(e) **Temperate region** (where there are winters and summers)

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

Biomes are further divided into zones, each with its unique properties.

For example;

(a) A forest biome is divided into
Ground zone consisting of millipedes & earthworms, and the
Canopy zone (aerial zone); consisting of birds & monkeys; with each of these zones supporting different animals that are adapted to the conditions within them.

(b) Aquatic biome is divided into **surface**, **intertidal**, & **benthic zones;** with the organisms in the intertidal zone withstanding wave action for example; snakes and snails. Those in the benthic zone are not able to withstand wave action for example sponges, while organisms requiring much air supply for example; photosynthetic algae inhabit the surface zone.

(c) Desert biome divide into **surface** and **subterranean zones**; with those in surface zone adapted to withstand extreme heat, while those in subterranean able to survive in low oxygen content.

NB. The zones in a biome are subdivided into **habitats.**
A habitat is specific locality where an organism normally lives within the environment with set physical conditions that support specific organisms

Examples of habitats include; leaf litter for earthworms, intestines of man for tapeworms, ponds for frogs, beside the water storage tanks for toads, kitchen for cockroaches, among others.

Ecological niche

An ecological niche is the role and position any species has within its habitat, and its interactions with living and non-living environment.

It describes how an organism meets its needs for food and shelter, how it survives, and how it reproduces.

Example;
Consider a forest habitat, with leaves scattered on the ground; an old rotting log sitting on a forest floor; earthworms may be seen under the soil feeding on decaying organic matter; with centipedes eating small beetles and other organisms; colony of ants working and feeding on dead insects; millipedes strolling around feeding on decaying leaves; therefore, all these organisms are filling an ecological niche looking at where they live, how they survive and how they reproduce.

Types of ecological niche.

Realized niche.
This occurs in the presence of predators, competitors, and parasites; limiting the habitat and roles performed by an organism. Its smaller in size.

Fundamental niche.
This occurs in the absence of predators, competitors, and parasites; allowing the organism experience a larger habitat and perform a variety of roles.

ECOSYSTEM

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

Ecosystems can be divided into;

(a) Water (aquatic) ecosystems which may be fresh water bodies for example; lakes, ponds, and rivers **or** marine water bodies, for example seas and oceans.

Organisms in water may be of large size (nektons). For example, fish, whales, turtles **or** very tiny (planktons), for example; phytoplanktons and zooplanktons.

(b) Land (terrestrial) ecosystems. These include; forests, deserts, savanna grasslands among others.

THE MAJOR COMPONENTS OF AN ECOSYSTEM

(a) Abiotic (non-living things). These are physical and chemical factors that influence living organisms in terrestrial and aquatic ecosystems.

Examples of abiotic components of an ecosystem

(a) **Climatic factors**, which include; Temperature, Light, Wind, Humidity, rainfall among others.
(b) **soil (edaphic) factors**; for example; Soil pH, Soil air, Inorganic particles, Soil water, Organic matter (dead organic matter and living organisms), Soil temperature among others.
(c) Topography
(d) Other physical factors for example fire and wave action.

Question. How do abiotic factors affect the distribution and abundance of organisms?

Climatic factors

Temperature

- It affects physiological processes like respiration, photosynthesis, and growth, in organisms which in turn influence their distribution.
- The ultimate heating and cooling of rocks cause them to break and crack into small pieces and finally form soil. Soil is required for many organisms like plants to survive well.
- Low temperatures inactivate enzymes while excessive temperatures denature enzymes.
- High temperature increases transpiration and sweating
- Low temperatures break dormancy of some plants.
- Exposure to low temperature (stratification) stimulates germination in some seeds after imbibition.

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,

- They have large body extremities for example; ear lobes; to increase surface area over which heat is lost.
- They are smaller in size 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
- They have little or no fur to reduce on insulation, and increase amount of heat lost
- They have a thin subcutaneous fat layer under the skin to increase heat loss from the body.
- They have tissues tolerant to extreme temperature changes, maintaining the body's main functions

Physiological adaptations

- Their enzymes work under a high optimum temperature range to maintain metabolism during day and night.

Behavioral adaptations

- Most are nocturnal. They are most active at night, when temperatures are relatively low
- Some undergo aestivation. **Aestivation** is a seasonal response by animals to drought or excessive heat during which they become dormant, and the metabolic rate lowers followed by body temperature fall to the minimum required for maintaining the vital activities of the body. This allows them to survive extremes of hot temperatures.
  For example; the African lungfish burrows into mud till the dry season ends. Earthworms, garden snails, desert rats, termites also aestivate
- Some show movement with some body parts raised to minimize direct contact with hot grounds. For example; desert snakes

- Some animals show salivation of the neck and legs, increasing heat loss by evaporation for example; in tortoise

Adaptations of animals for life in cold environments

Structural adaptations

- They have a thick layer of fat under the skin, to increase on insulation by avoiding heat loss
- They have small body extremities to reduce the surface area over which heat is lost
- They are larger in size, thus possess a small surface area to volume ratio hence reducing the amount of heat lost to the surrounding
- They have thick fur, to increase on insulation
- Their tissues are tolerant to extreme changes in temperature; maintaining their normal functions in the body

Physiological adaptations

- Their enzymes work under a low optimum temperature range to maintain metabolism during day and night

Behavioral adaptations

- Some animals undergo Hibernation. **Hibernation** is a is seasonal response by animals to cold temperature during which they become dormant, body temperature and metabolic rate fall to the minimum required for maintaining the vital activities of the body. The animal is said to be in 'deep sleep' to ably reduce energy needs to survive the winter when food is scarce allowing them survive extreme cold conditions. For example; in polar bears.
- Some animals gather in groups to warm themselves. For example; penguins

Rain fall

The amount of rainfall in a given area determines the abundance, distribution and types of plants in the area

Ecological significances of water (rainfall)

- Water is a habitat for many aquatic organisms. For example; frogs, fish among others
- Water is a raw material for photosynthesis
- Water has high thermal capacities, hence acts as a cooling agent for terrestrial organisms. For example; plants during transpiration and some animals during sweating.
- Water is an agent for fruit, seed, spore, larva and gamete dispersal
- Water is required for germination to take place.
- Water is highly transparent; therefore, allows light to reach aquatic organisms, for photosynthesis; and aquatic predators to locate their prey
- Water is an important factor in decay and decomposition; therefore increases in recycling of nutrients in an ecosystem.

Humidity

Humidity is the amount of water vapour in the atmosphere;

It affects the rate at which water evaporates from organisms. Low humidity results into 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 for example; in a kangaroo rat

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

- Humidity controls other activities of animals like feeding, hunting, and movements. For example; earth worms experience a larger ecological niche when the environment is humid.
- Humidity controls opening and closure of stomata; therefore, affecting rate of photosynthesis and transpiration.

Wind (air currents)

Wind or air currents influence the following,

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

Light (intensity, quality, and duration)

Light influences many physiological activities in organisms, which include;

- It is a source of energy for photolysis (breakdown of water during photosynthesis.)
- Absence of light causes etiolation (elongation of shoot inter nodes to expose plant leaves to light).
- It induces flowering in long-day plants for example; barley, but inhibits flowering in short day plants.
- It influences phototropism, by redistributing auxins on the darker sides of shoots and roots, with cells on darker side elongating more than those on illuminated side.

- It influences germination. Some seeds are positively photoblastic; germination in such seeds only occurs in presence of light while others do not require light to germinate. (are negatively photoblastic)
- It influences 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).
- It also influences predation. Hunting and killing of prey by predators require certain levels of illumination and visibility.
- It influences courtship; with some animals preferring light so as to carry out courtship while others prefer darkness.
- Light stimulates synthesis of vitamin D in mammals; where lipids(sterols) in the dermis are converted to vitamin D by ultra violet light
- 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. For example; sunlight polarized by water acts as a compass for migration of salmon fish.

Topography.;

- Topography refers to the nature of the landscape, which includes features like mountains, valleys, lakes among others.
- 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.
- Slope reduces water logging and there is a lot of soil erosion preventing proper plant establishment especially at steep slopes
- At low altitudes, average temperatures are high, high atmospheric pressure, partial pressures of oxygen are high, and in some places there is water logging.

Edaphic(soil) factors,

- 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)
- Also present in soil are; mineral salts, water, organic matter, and grasses.

Soil Ph.

- Soil Ph influences physical properties of soil and availability of certain minerals to plants, thus affecting their distribution in soil. For example; tea and coffee plants thrive well in acidic soils
- It affects the activities of decomposers. For example; in acidic medium, the rate of decomposition is reduced, subsequently recycling of matter in an ecosystem reduced.

Water content.

- The water content varies markedly in any well-defined soil,
- Any finely divided soil holding as 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.

- **Biotic content;**
    - Microorganisms like bacteria and fungi carry out decomposition of dead organic material, therefore recycling nutrients back to the soil.
    - Burrowing organisms, for example; earthworms improve drainage and aeration by forming air spaces in the soil.
    - Earthworms also improve soil fertility by mixing of soil, as they bring leached minerals from lower layers within reach of plant roots.
    - They also improve humus content, by pulling leaves into their burrows

- **Air content;**
    - Spaces between soil particles are filled with air from which plant roots obtain oxygen by diffusion for aerobic respiration,
    - Soil air is also essential for aerobic respiration by micro-organisms in the soil that decompose the humus.

Salinity;

- Salinity is the measure of salt concentration in aquatic bodies and soil-water.
- Salinity determines the osmotic pressure of water; therefore, the organisms have developed structural, behavioral, and physiological adaptations to osmoregulate in the respective salt concentration, **(read adaptations of fresh water fish, marine water fish and migratory fish to their osmoregulatory problems**).
- Mineral salts in water affect the distribution of plant species, which in turn affects the animals that depend on plants for food.
- Plants growing in soils deficient of certain salts, for example insectivorous plants in nitrogen deficient soils, obtain nitrogen feeding on insects.

- **Significances of mineral salts to plants**
- Mineral salts together with other solutes determine the osmotic pressure of cells and body fluids
- Na+ and Cl- are involved in transmission of nerve impulses
- They are constituents of certain pigments like hemoglobin, and chlorophyll containing iron and magnesium respectively.
- Some act as metabolic activators. Some ions activate enzymes, for example; chloride ions activate salivary amylase, magnesium activates enzymes in phosphate metabolism, and

phosphorus as phosphate is required in activation of sugars during Glycolysis in tissue respiration.

- Mineral salts like potassium are involved in formation of cell membrane and opening of stomata;
- They are required for proper development of stems and roots. For example; calcium pectate in formation of plant cell wall.

Fire

Types of fire

(a) Natural fires. These are set up by natural causes like lightening, volcanic eruptions among others.

(b) Artificial fires. These are set up by man either intentionally or carelessly

(c) Wild fires. These burn in the direction of wind

(d) Early fires. These are set up at beginning of dry season

(e) Prescribed fires. These are set up under ecological management where prevention measures are taken when setting up the fire.

Properties of fire

- Fire intensity; Is the heat content of the fire,

Depends on environmental factors such as wind, temperature as well as the amount and type of vegetation.

- Fire duration; Is the time taken by the fire to destroy a given area.
- Fire severity; is measured in terms of major vegetation destroyed by the fire.

Ecological effects of fire

Positive effects

- Fire removes old leaves and stimulates trees and grasses to produce new buds.
- Fire breaks dormancy (seed dormancy), incase seed coats are hard and impermeable.
- Fire causes release of mineral nutrients in form ash; on burning organic matter, releasing nitrate and phosphate compounds into soil, and subsequently improving on soil fertility.
- Fire improves on visibility of organisms such as predators, prey, mates allowing them easily carry out their activities.
- Fire improves on food productivity in terms of quality, quantity and productivity, because after burning new species with high protein content grows.
- Fire destroys pests
- Fire controls undesirable plant species and weeds

Negative effects

- Fire increases soil erosion; leading soil infertility
- Fire kills slow moving animals. For example; snails and earthworms
- Fire leads to destruction of habitats for most of the animal species leading to migration or extinction
- Fire increases fire resistant species.
- Fire leads to reduction in population density and biodiversity.

- Fire destroys food for animals like herbivores which may lead to starvation and eventually death.
- Fire leads to air pollution by products such as carbon monoxide and carbon dioxide.

Adaptations of plants to fire

- Possession of thick succulent shoot systems to reduce the effects of heat.
- Grasses grow in tussocks to protect the young growing buds.
- Some tree stems are succulent. They store water in parenchyma cells to reduce on the effects of fire heat.
- Many plants are annuals to avoid fire severity in form of seeds, which may be underground.
- Some trees have heat resistant tissues.

THE MAJOR BIOTIC (LIVING COMPONENTS) OF ECOSYSTEMS

(a) Producers.

These are autotrophs capable of synthesizing complex organic food materials from simple inorganic food raw materials, for example; carbon dioxide and water.
Examples include; large green terrestrial plants, for example; trees, shrubs and grass.
For aquatic ecosystem, the producers are microscopic algae and blue green bacteria.
Others are flagellates like euglena, volvox, chlamydomonas among others. 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. For example; Sulphur bacteria which are **chemosynthetic**.

(b) Consumers

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

(i) Primary consumers

These are consumers that feed on plants (herbivores). Examples include; insects, birds and 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

These are consumers that feed on other animals (carnivores). Examples include; birds of prey like eagle, kites, kingfishers; and lions, cheetahs, tigers, hyenas, snakes, big fish among others.

(iii) **Tertiary consumers**

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

NB. **Omnivore**s are consumers that feed on both plants and animals for example man and pigs.

(c) Decomposers

These are organisms that feed on dead organic matter.
They are classified into;

(i) Macro-decomposers (detritivores)

These are animals that feed on dead and waste matter not eaten by consumers (detritus).
Examples include; earth worms, rag worms, mites, maggots, wood lice, termites among others.

(ii) Micro-decomposers (Saprophytes)

These include; bacteria and fungi that feed on dead decaying matter.

Importance of decomposition:

- It enables dead bodies to be disposed off, which, if left would accumulate everywhere.
- Decomposition recycles nutrients to be used by other organisms. For example; Mineral salts are released from dead bodies into soil for plant growth.
- Decomposition unlocks trapped energy in the body of dead organisms.

FLOW OF ENERGY THROUGH AN ECOSYSTEM

The source of energy flowing into such ecosystems is the sun. The photosynthetic autotrophs, the producers absorb a small fraction of this light during photosynthesis.
About 0.2% of the solar radiation is fixed by the earth's green plants making organic food substances by the process of photosynthesis.
Some of the energy is passed on to higher trophic levels when the primary consumers eat the producers. About 5 to 20% is transferred from producers to the primary consumers. The energy loss in this transfer is because

- Some plants are not eaten,
- Not all plant parts are eaten, and
- Some energy is utilized by the producers for growth and sustainability.

Energy is passed on to higher trophic levels when consumers at higher trophic levels feed on those at lower trophic levels. About 5 -20% is passed on to the next higher trophic level.

Energy loss along transfer to the consumers at higher energy levels is due to the fact that;

- Some energy is utilized by the organism to maintain life processes
- Some energy is used for growth
- Not all consumers at lower energy levels are eaten by consumers at higher energy levels
- Some energy is lost in metabolic wastes and in egested food

However, decomposers and detritivores return some of the energy back into the ecosystem. These saprophytes decompose organic matter in metabolic wastes, egested food and dead organisms.

TROPHIC EFFICIENCY (ECOLOGICAL EFFICIENCY)
This is the percentage of energy at one trophic level that is converted into organic substances at the next trophic level.

Productivity in an ecosystem
This is the amount of organic material manufactured by organisms.

It can be measured using several methods. For example;
Harvest crop
Through oxygen production of the given area of the ecosystem.
Amount of carbon dioxide consumed during photosynthesis.
The rate of consumption or use of raw materials
Can be divided into;

(a) Gross productivity. This is the total amount of energy and organic matter stored in an organism over a period of time.
(b) Net productivity. This is the amount of energy and organic matter stored in an organism and passed onto the next trophic level.
(c) Primary productivity. This is the amount of energy and organic material stored in primary producers.
It is measured in **mass per unit area per unit time** (kilogram per unit area per year, Kg/M2/yr.)

The initial amount of energy incorporated into primary producers during photosynthesis is called **Gross primary productivity (G.P.P).**
The amount of energy transferred from primary producers to primary consumers is called **Net Primary Productivity (N.P.P).** It can as well be called dry mass of the harvest crop**.**

Therefore; GPP - assimilation (respiration & metabolism) = NPP

Secondary productivity is the amount of energy incorporated into the body of consumers. Also known as **Gross secondary productivity.**
Net secondary productivity is the amount of energy that can successfully be transferred from one consumer to another.

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

Net secondary productivity is higher in exotherms than in endotherms, because;

- Energy from absorbed food, is used in replace the lost heat to their surroundings, in order to maintain a constant body temperature, unlike exotherms that depend mostly on behavioral means to maintain their body temperature.

FOOD CHAINS AND FOOD WEBS.

FOOD CHAIN

A food chain is a linear sequence of energy flow from producers through a series of organisms in which there is repeated eating and being eaten.

Types of food chains

There are two types of food chains.

(i) Grazing food chain
(ii) Detritus food chain

Grazer food chain

This starts with autotrophs (producers) or green plants which convert carbon dioxide & water into chemical compounds.

These are then grazed upon by herbivores.

Energy is further transferred to carnivores.

This type of food chain can be in a grass land or water body (aquatic).

Examples;

Grass → millipedes → toads → snakes → hawks

Green algae → haplochromics → tilapia → kingfisher

Detritus food chain

This is a food chain where the consumers obtain energy from fragments of dead decaying organic matter.

It exists in both aquatic and terrestrial habitats.

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

Examples;

Tree log → wood lice → toad → python

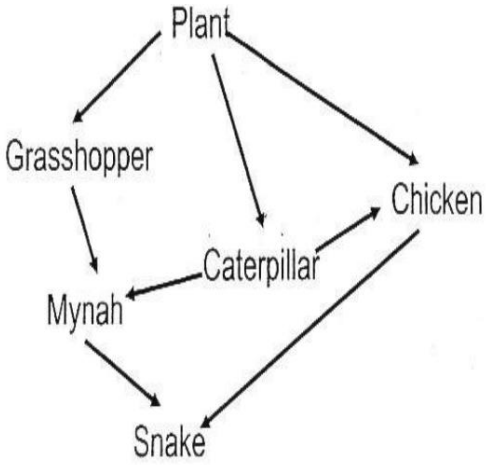
Dead animal → maggot → birds → python

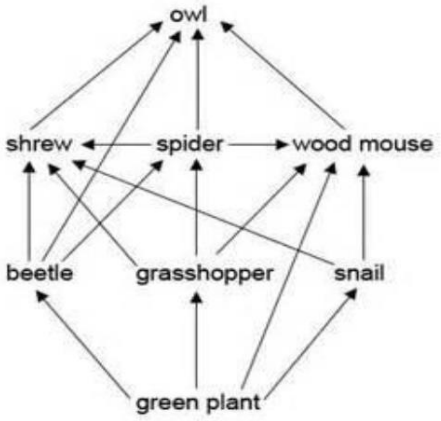
FOOD WEB

A food web is a complex nutritional interrelationship that illustrates alternative food sources and predator for each organism.

In a food web, there are several food chains.

Examples of food webs in a grassland ecosystem





Techniques used in constructing food webs and food chains

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

Assignment. **State the advantages and limitations of the above methods**

ECOLOGICAL PYRAMIDS

These are histograms that provide information about trophic levels (feeding levels) in ecosystems.

Types of ecological pyramids

There are three types of ecological pyramids namely;

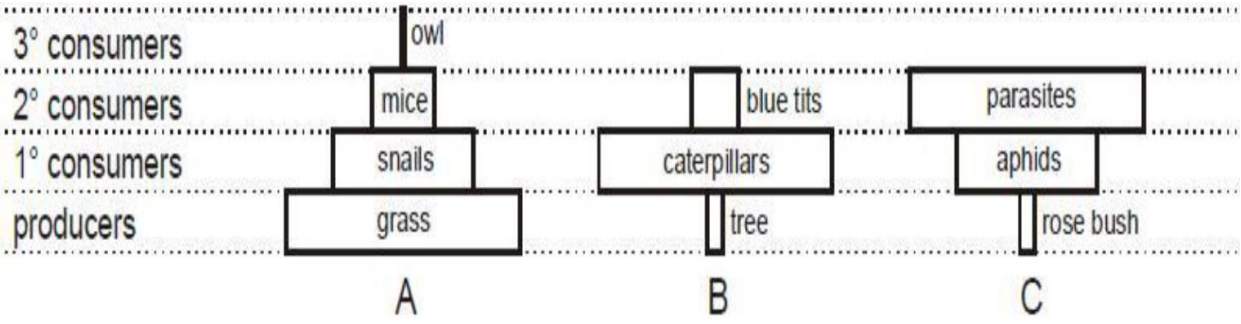
(a) Pyramid of numbers
(b) Pyramid of biomass
(c) Pyramid of energy

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

Pyramid of numbers.

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

Examples



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

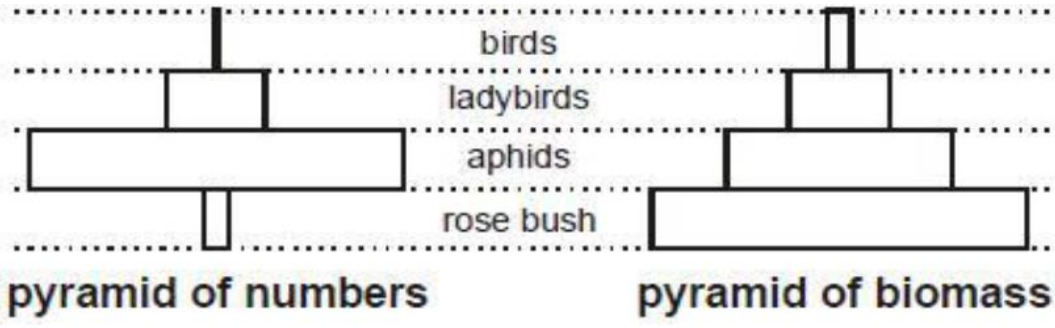
Limitations of a pyramid of numbers

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

Pyramid of biomass

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

Illustration



Advantages
It reduces the possibility of forming inverted pyramids because its construction depends on biomass of organisms

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

Disadvantages/limitations of pyramid of biomass

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

Pyramid of energy flow

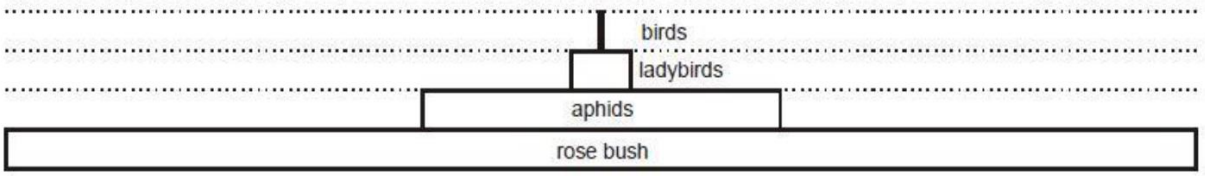
It is a histogram showing the total amount of energy present at each trophic level.

Because only a proportion of energy in a trophic level is transferred to the next, energy pyramids are never inverted nor do they have a central bulge.

They are more informative than pyramids of numbers and biomass because they show the amount of energy required to support each trophic level.

Energy values may be expressed variously as $kJ/m^2/yr.$ or $kCal /m^2/ yr.$

This explains why the earth can support more people if they eat at lower trophic level (by consuming grains, vegetables and fruits directly rather than passing such crops through another trophic level and eating grain eaters.



Advantages of a pyramid of energy flow

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

Disadvantage:

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

ECOLOGICAL SUCCESSION

This is a long- term directional change in the composition of a community from its origin to its climax through a number of stages brought about by the actions of the organisms themselves.

It is a process by which plants and animal communities in a given area change gradually over time, becoming replaced by different and usually more complex communities.

Pioneers are first sets of organisms to occupy the area, collectively such organisms constitute the pioneer community.

The process of succession continues through stages known as seral stages and there are a number of sere (complete succession) according to the environment being colonized. These include;

(i) Hydrosere (succession in aquatic environment)
(ii) Halosere (succession in salty environment)
(iii) Xerosere (succession dry environments) for example; deserts
(iv) Lithosere (succession on a rocky surface)

The first seral stage has pioneers and the final stage has a climax community, a final stable community at the end of succession, which a particular environment can sustain.

Characteristics of a Climax community.

- Diverse species
- Complex feeding relationships and
- Progressive increases in biomass.

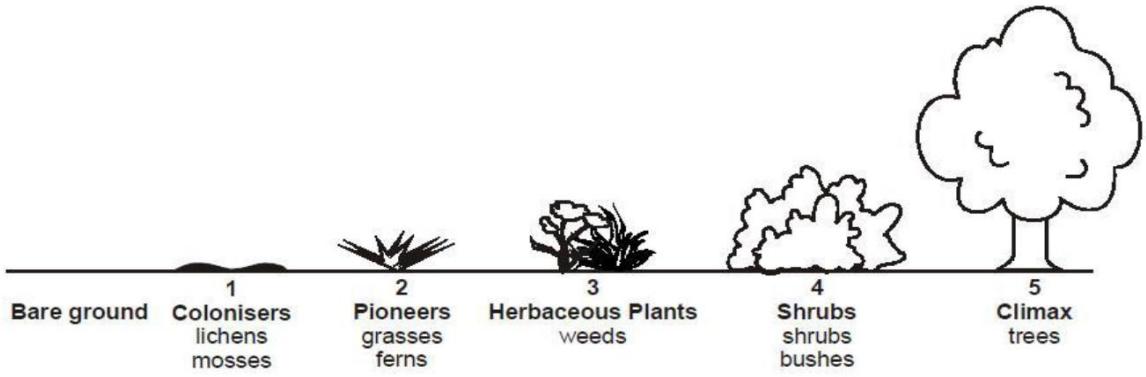
Types of succession

(a) Primary succession
(b) Secondary succession

Primary succession

This is the gradual change in species composition of an area that has never had any vegetation growing on it.
It occurs on Bare rocks exposed by erosion, newly cooled lava, newly created shallow ponds, Sand dunes, Abandoned highway or parking yard.

An example of primary succession on land



Description of Primary succession on land

The trend of succession on a bare rock is called primary succession. The process occurs in stages and these include;

The pioneer stage; this comprises of the first community to be established. It comprises mainly of lichens an association between algae and fungi.
The lichens secrete acids which break the rocks gradually forming little amount of soil. The lichens are adapted to survive on a minimum culture and can withstand extreme (harsh) environmental temperature conditions.

Moss stage; as more soil is formed as the bare rock breaks, mosses are established. This is observed as a green cover on the rock.
The mosses are photosynthetic and their establishment crowds out the lichens. Decomposition of the mosses by fungi leads to formation of more soil. At this stage, some soil invertebrates such as earth worms are established.

The weed stage; the moss are gradually replaced by herbaceous plants mainly grass. These plants are established due to increased soil formation, death and decomposition of the herbaceous plants forms more soil allowing more plant species to be established.
At this stage, associated animal community would comprise of soil invertebrates; small herbaceous and carnivorous insects, small amphibians and reptiles.
Short plants called shrubs are established scattered within the grassland. These will comprise of the next stage.

The shrub stage; the shrubs are gradually established to replace the grasses and the space between the shrubs is covered by herbaceous plants. Associated animal communities include invertebrates, birds, amphibians, reptiles, small mammals. Death and decomposition of organisms at this stage forms even deeper soil. This allows for establishment of trees; this initiates the **climax community.**
Several trees are established; interspacing the herbaceous plants and shrubs gradually. Many plant species are lost as larger plants gradually replace the smaller plants.

A climax community of a forest is finally established. If the trees form a canopy, the plant community is minimal due to decreased light penetration.
The climax community has an associated animal community including large reptiles, birds, amphibians, arthropods and mammals. Many decomposers and soil vertebrates are also established. The climax community normally has a dominant tree species.

Secondary succession.
This is the gradual change in species composition of an area where the natural community of organisms has been disturbed, removed or destroyed but some soil or bottom sediment remains. It occurs on abandoned farmlands, burnt or cut forests, heavily polluted streams, flooded land. Due to some soil or sediment present, vegetation usually begins to germinate within a few weeks.
Seeds and spores can be present in the soil and can be carried from nearby plants by wind, birds and insects.
The ground may even contain resistant plants/vegetative organs of the colonizing plants that survived the changes.

Characteristics of the stages of primary succession*;*

a) Early succession

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

b) Late succession

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

MATERIAL CYCLING/BIOGEOCHEMICAL CYCLING (NUTRIENT CYCLING)

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

THE CARBON CYCLE

The carbon cycle shows how carbon circulates in nature.
Carbon is always in constant circulation between the earth and water bodies. There is a lot of carbon dioxide in the atmosphere (0.36%) and some is dissolved in water bodies such as rivers, lakes and oceans.

Removal of carbon dioxide from the atmosphere:
Carbon dioxide is removed from the atmosphere by green plants in a process called photosynthesis. Plants use this carbon dioxide to make carbohydrates and fats. When animals feed on these plants, they gain the carbon.

Some of the carbon dioxide in the atmosphere dissolves in rain water to form carbonic acid. This acid reacts with soil mineral salts to form carbonates.
Addition of carbon dioxide in the atmosphere:

- **Combustion (burning):** When carbon containing fuels for example; petroleum, coal, natural gas and fire wood are burnt, carbon dioxide is released into the atmosphere. Formation of such fuels over millions of years is referred to as ***fossilization***.
- Carbon returns to the atmosphere in form of carbon dioxide during respiration in animals and plants
- Decomposition of organic matter by bacteria and fungi such as dead bodies of plants and animals. During this process, carbon dioxide is released into the atmosphere.

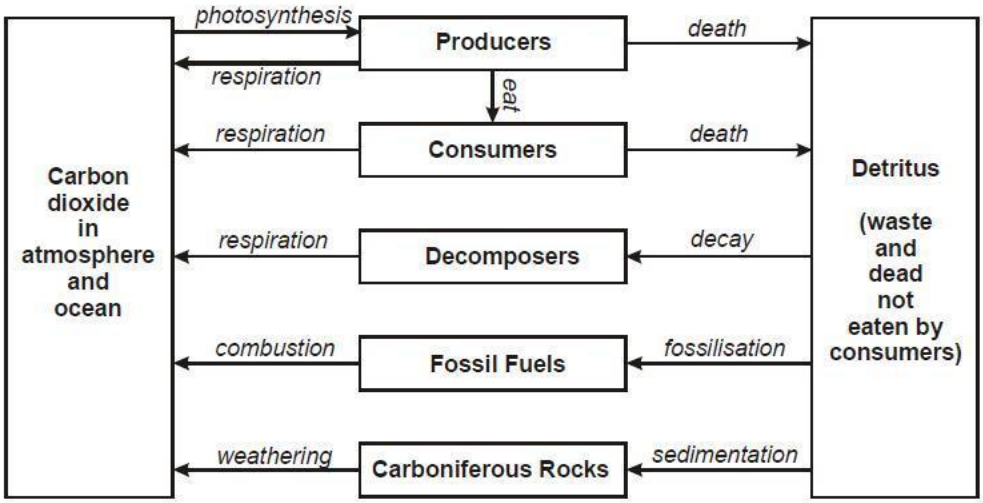
NB. Over millions of years, buried deposits of dead plant debris, animals and bacteria are compressed between layers of sediment to form the carbon-containing fossil fuels. For example coal, oil and natural gas, which when burnt release carbon dioxide into air.

In aquatic ecosystems, carbon dioxide may;
(i) Remain dissolved
(ii) Be utilized in photosynthesis
(iii) React with water to form carbonate ions and bicarbonate ions.
As water warms, more dissolved carbon dioxide returns to the atmosphere.

In marine ecosystems, some organisms take up dissolved carbon dioxide molecules, carbonate ions and bicarbonate ions and these ions react with calcium ions to form calcium carbonate ($CaCO_3$) used 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 carbon dioxide from limestone into the atmosphere.



How human activities affect the carbon cycle

Cutting trees and other plants that absorb CO_2 through photosynthesis increases carbon dioxide in the atmosphere.

Burning of fossil fuels like coal, petroleum oil among others and wood adds large amounts of CO_2 into the troposphere.

THE NITROGEN CYCLE

Nitrogen is the atmosphere's most abundant element, with chemically unreactive nitrogen gas making up 78% of the volume of the troposphere.

This refers to how nitrogen circulates in nature.

Gaseous nitrogen can be converted into forms usable to plants by two processes namely;

1. Nitrogen fixation
2. Nitrification

NITROGEN FIXATION

This is the process by which gaseous nitrogen is directly converted to nitrates. This is done through the following ways.

a) Nitrogen fixing bacteria. Some bacteria have ability to convert gaseous nitrogen into nitrates. Nitrogen-fixing bacteria may be free-living for example; **Azotabacter** and **Clostridium**. Others are **symbiotic bacteria** in the root nodules of leguminous plants for example; **Rhizobium.**

b) Haber process. This is an artificial process in which gaseous nitrogen is converted to nitrates.

c) **Lightening.** 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.

NITRIFICATION
This is the process by which ammonia/ammonium containing compounds are converted to nitrites and then to nitrates by bacteria.

This process results into formation of nitrates in the soil.
The conversion of ammonium compounds to nitrites is by bacteria such as **nitrosomonas** while the conversion of nitrites to nitrates is by bacteria such as **nitrococcus.**

The nitrates are then absorbed by plants which use them to manufacture proteins.

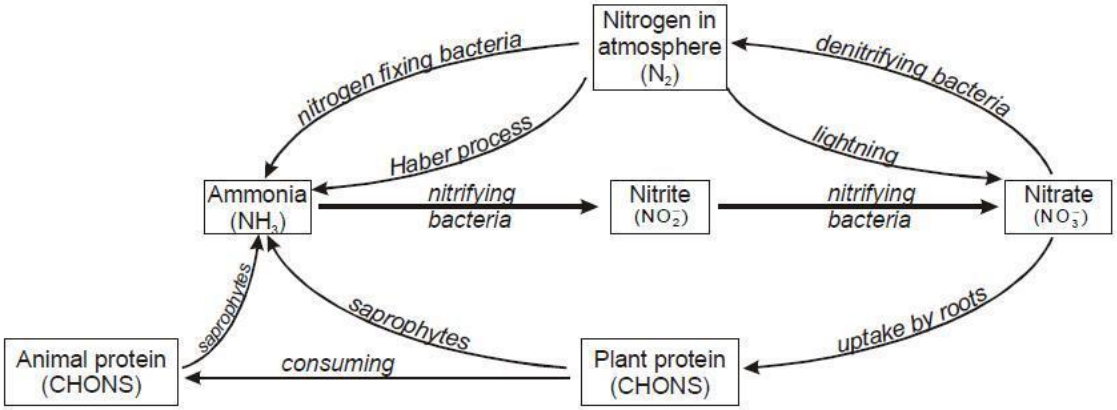
Assimilation occurs when inorganic ammonia, ammonium and nitrate ions are absorbed by plant roots to make nucleic acids, amino acids and protein.

When animals feed on these plants, they get the nitrogen contained in the proteins manufactured by the plants.

Animals release nitrogen from their bodies in form of ammonia/urea in a process called excretion. These wastes are converted to ammonium containing compounds by putrefying bacteria and fungi that also decompose the bodies of dead animals and plants in a process called **putrefication (ammonification)**

Nitrogen is lost from the soil through leaching. It also gets lost from the soil due to action of denitrifying bacteria that convert nitrates into gaseous nitrogen.

Denitrification occurs when mostly anaerobic bacteria. For example; ***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

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

Qn.

(a) Describe the flow of energy and the cycling of carbon and nitrogen in any named ecosystem.

(b). Suggest reasons why felling and removal of forest trees result in changes in the levels of nutrients in the soil.

WATER CYCLE/ HYDROLOGICAL CYCLE

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

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

- Runoff (down slope surface movement back to the sea to resume the cycle)

Assignment
Draw an illustration of the hydrological cycle.

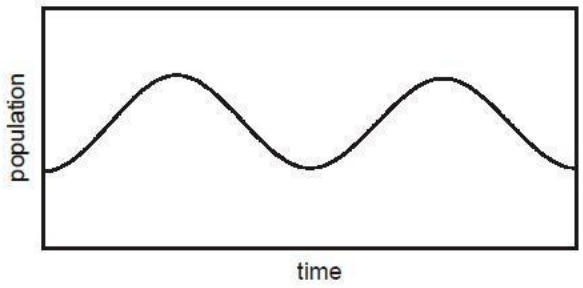
HOW BIOTIC FACTORS AFFECT THE DISTRIBUTION AND ABUNDANCY OF ORGANISMS

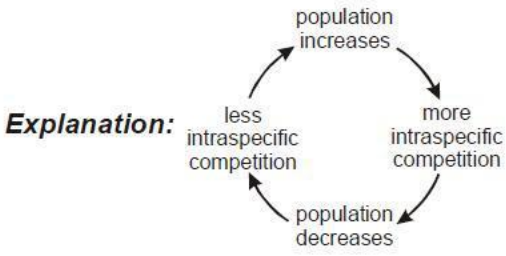
Biotic factors are those that arise in organisms interacting with each other.
Examples include; diseases; competition; parasitism; pollution; pollination &dispersal; anti biosis and mimicry.

(a) **Human influence**.
Of all living organisms, humans exert most influence on the distribution and survival of other species through a multitude of activities like pollution, deforestation, farming, construction among others.
Man is also a predator hunting down many animals to a point of extinction.

(b) **Competition**
This is a relationship whereby two individuals of the same species or different species struggle to obtain resources which are in limited supply.
For example; plants competing for light, carbon dioxide, water, minerals, pollinators, and sites for spores and seeds to germinate while animals compete for food, mates, breeding sites and shelter from predators.

(i) **Intraspecific competition**
This is the competition between members of the same species for the same resources.
Intraspecific competition tends to have a stabilizing influence on population size.
If the population gets too big, intraspecific population increases, so the population falls again.
If the population gets too small, intraspecific population decreases, so the population increases again.





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

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

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

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

For example;

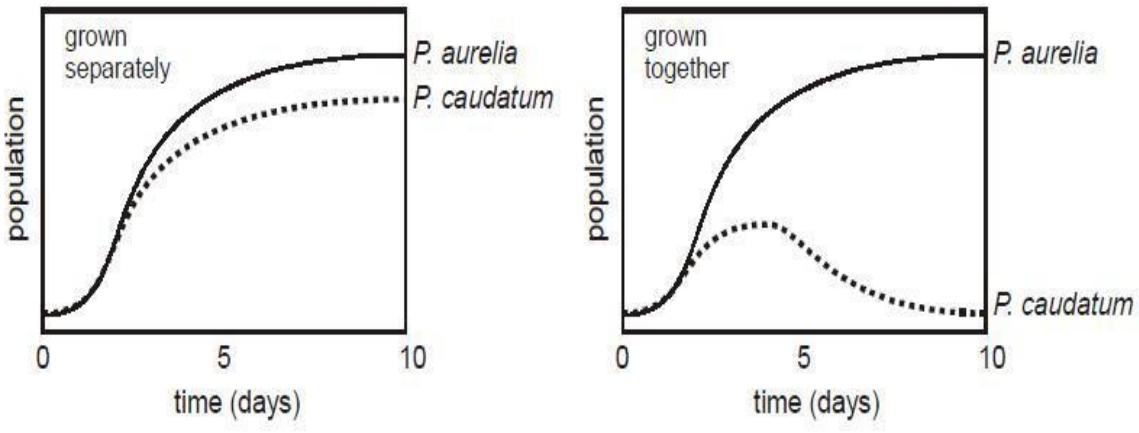
(i) Two species of flour beetles, *Tribolium castenum* and *T. confusum* were kept in the laboratory in bottles of flour acting as a habitat and providing food for them, under variable temperature conditions (24-34) and humid conditions (very humid, 70%RH & 30% RH).

Observations

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

Whatever the conditions, only one of the species eventually survived.

(ii) Two species of *Paramecium Aurelia* and *P. caudatum* were grown separately in the same culture, then later cultured together.



Observation;
(a) **When cultured separately;** each species has maximum population, only coming almost constant with time due to;

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

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

Competitive advantages of *P. aurelia* are;

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

HOW SPECIES REDUCE OR AVOID COMPETITION THROUGH RESOURCE PARTITIONING

Resource partitioning is the dividing up of scarce resources so that species with similar needs use them;

(i) At different times
(ii) In different ways or
(iii) In different places.

Some species that are in competition for the same limited 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:

(a) When living in the same area, lions prey mostly on larger animals while leopards on smaller ones.
(b) Hawks and owls feed on similar prey, but hawks hunt during the day and owls hunt at night.
(c) Each of the five species of common warblers (insect-eating birds) minimizes competition with the others by;
    (i) Spending at least half its feeding time in a different part of spruce tree branches for example; some hunt at the extreme top, others at the lower portion, some mid-way among others
    (ii) Consuming somewhat different insect species.

(d) Different species of eagles in a forest feed at different times of the day. For example; bald headed eagles are most active early mornings and evenings while the white-breasted eagles feed vigorously towards noon.

(e) 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.

(f) 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.

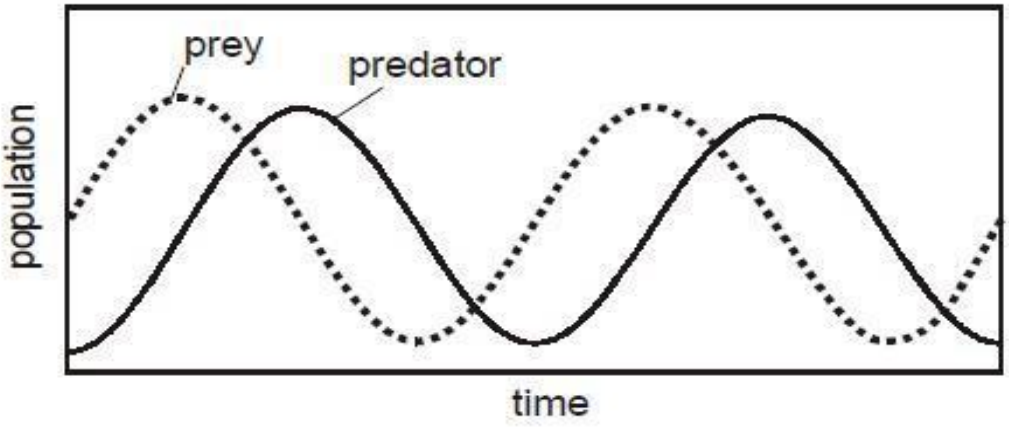
NB:

i) The more the two species in the same habitat differ in their use of resources, the more likely they can coexist.

ii) Two competing species also may coexist by sharing the same resource in different ways or at different times.

iii) The tendency for characteristics to be more divergent when populations belong to the same community than when they are isolated is termed **character displacement. For example;** Galapagos finches.

PREDATOR-PREY INTERACTIONS IN ECOSYSTEMS



Description of the changes in population numbers:

Initially, the population of the prey is higher that the population of the predator.
Within a short time, both populations of prey and predator increase rapidly.
The population of the prey reaches a maximum earlier than that of the predator.
As the prey population decreases rapidly, the predator population continues to increase gradually for a short than time to a maximum then also decreases rapidly.
As the predator population continues to decrease, the prey population starts to increase rapidly, followed by a rapid increase in predator population. The cycle is repeated.

Explanation for the observed changes in populations:
At the beginning, there are more prey than predator to provide food to the predators.
When the predator population is low, they get enough food and few preys are eaten so they both increase rapidly.
The large number of preys provides food to predators, so they reproduce fast and increase in numbers.
The increased predator population eats many preys and the prey population crashes.
The decrease in prey numbers causes the predators to starve and even their reproduction reduces, so the predator numbers decreases.
Finally, the very low number of predators allows the prey population to recover, causing the cycle to start again.

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

How are the predators suited for capturing prey?

A predator is an animal that feeds on another live organism.

- They have a keen eyesight to easily see their prey.
- They have strong jaw muscles to tear flesh of the prey.
- They have sharp claws to hold and kill their prey.
- They move very fast to enable them chase the prey.
- They have streamlined bodies to reduce air resistance during movement. For example, eagles
- Some have very sharp canines to tear flesh of their prey.
- They have colors, which enable them to camouflage so that they are not easily seen by their prey.
- Some snakes which have glands to secrete poison (venom) which the fangs inject into prey to immobilize it (prey).
- Web-spinning spiders use their silky cob webs to catch small sized ground walking or flying insects.
- Some have soft pads at the bottom of their feet so that they are not easily detected as they walk towards prey
- Some have stinging cells which paralyze their prey e.g. sea anemones
- Well-developed limbs which increase the speed of locomotion to chase and capture prey.

- African lions hunt in groups which increases chances of being able to kill their prey.
- Preying mantis and chameleons have cryptic coloration/camouflage that enables them to walk to prey unnoticed.
- Nocturnal predators for example; bats have a highly developed sense for detecting sound made by prey.
- Some use stinging cells which paralyze their prey for example; sea anemones

How are prey species suited to avoid predation?

A prey is the live organism that is fed on by the predator

- They perceive sound with high accuracy and are able to sense their predators at a distance.
- They are very fast in movement to escape from their predators.
- They have developed structures for defense such as horns. Possession of spines like in porcupines
- They normally move in groups to scare their predators.
- They prefer to stay in areas, which give them good visibility such as grasslands.
- They have colours, which enable them to camouflage so that they are not easily seen by their predators.
- Mimicry; this is where a palatable harmless organism attains colours of an unpalatable harmful organism and it is confused for a harmful organism by the predator.
- Possession of highly developed sense of sight or smell alerting the presence of predators.
- Possession of protective shells for example; in tortoise and snails for rolling into armor-plated ball.
- In some lizards' tails break off when attacked, giving the animal enough time to escape.
- Some preys secrete poisonous or repellant substances e.g. scorpions, caterpillars.
- Possession of highly developed sense of sight or smell alerting the presence of predators.
- Possession of protective shells for example; in tortoise and snails for rolling into armor-plated ball
- Possession of spines in porcupines or thorns in cacti and rose-bushes for pricking predators.
- Some prey **camouflage** by changing colour for example; chameleons have deceptive colours that blend with the background.

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***.

It exists in various forms;

(a) **Warning coloration.** Conspicuous coloring that warns a predator that an animal is unpalatable or poisonous for example; poisonous frogs, some snakes, monarch butterflies, and some grasshoppers

(b) **Disruptive coloration/patterning.** This works by breaking up the outlines of an animal with a strongly contrasting pattern, thus decreasing detectability. For example; a group of zebras
(c) **Cryptic coloration** allows an organism to match its background and hence become less vulnerable to predation. For example; in 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 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 for example; 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 for example; the five spot Burnet and related moths.
- Other preys gain some protection by living in large groups for example; schools of fish, herd of antelope, flocks of birds.
- Some prey scare predators by puffing up for example; blowfish, or spreading wings like in peacock.
- Some preys secrete poisonous or repellant substances for example; scorpions, caterpillars, and culex mosquito eggs
- The electric 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 for example; ants, various fish, small birds and mammals.
- Group defense, occurring among those that live and feed in herds for example buffalos.

NB Predation;
(a) 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.
(b) Leads to dispersal of animals which reduces competition, since it involves movement of animals from place to place.
(c) 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.

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

(a) 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

This is the secretion by organisms' chemical substances into their surrounding that may be repellant to members of the same species or different species.
For example; 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;

(a) **Intraspecific antibiosis.** This involves secretion by organisms, chemical substances into their surrounding that may be repellant to members of the same species. For example; 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.

(b) **Interspecific antibiosis.** This involves secretion by organisms, chemical substances into their surrounding that may be repellant to members of the different species. For example; penicillium (a fungus) secretes antibiotics that kill or prevent the bacterial growth.

Parasitism

This is a feeding relationship between two organisms of different species in which one organism, the parasite, benefits and feeds on the other called the host which is harmed in the process.

There are 2 types of parasites which include

a) Obligate parasites

b) Facultative/ partial parasites

Obligate parasites

These are organisms which can only live, survive and reproduce as parasites, throughout their lives because they cannot obtain nutrients by any other means. For example; Phytophthora which causes potato blight (cannot live independent of the host)

Partial or facultative parasite

These are organisms that can live parasitically at some times and can live freely at other times.

These do survive on the organic matter of their living and dead hosts body for food for example bacteria.

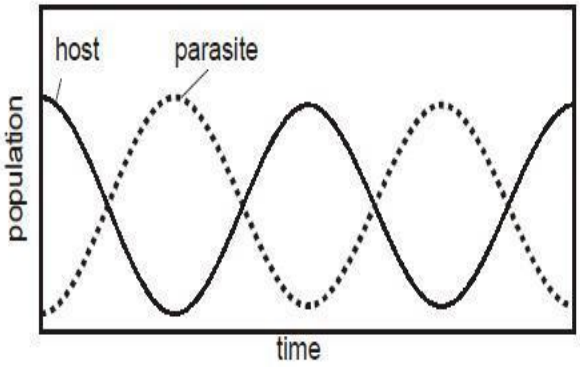
Or

These are organisms which partly survive as a parasite and partly as saprotrophs mainly when its host dies.

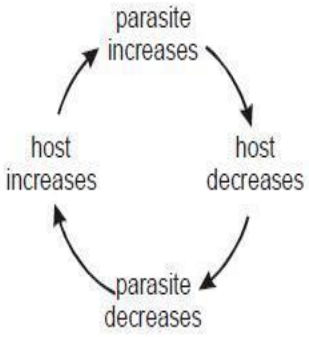
Parasites can also be categorized as;

(a) **Ecto-parasites.** These are parasites which live on the body surface of their host for example ticks, fleas, bedbugs among others

(b) **Endo-parasites.** These are parasites which exist inside the body of their host for example the gut parasites, Schistomsomes, plasmodia among others



Explanation:



MUTUALISM

Mutualism is a close association between two living organisms of different species which is beneficial to both partners, as in lichens, root nodules of legumes and in mycorrhizae.

The distribution and abundance of partners in a mutualistic association shows great interdependence and in many cases one partner cannot survive in the absence of the other.

Examples include lichens, mycorrhiza, cellulolytic bacteria (secrete cellulose enzyme) and herbivorous mammals among others.

LICHENS

A Lichen is a mutualistic association between a fungus and an alga which is beneficial to both partners whereby the alga obtains water, mineral salts, mechanical support and protection from high light intensity from the fungus. While the fungus benefits by obtaining oxygen and food from the photosynthetic alga.

Relationship between organisms in the lichen

Lichen is a mutualistic association between a fungus and a green alga or blue-green bacteria.

The fungus makes up most of the lichen body and cells of the green alga or blue-green bacteria are distributed within it.

The fungus provides anchorage of the lichen on the substratum, shelters the alga/bacterial cells in the mycelium, absorbs water and mineral salts, conserves water protects the alga/bacteria from drying out, and provides the alga/bacteria with carbon dioxide for photosynthesis from respiration.

The alga/bacteria contribute organic food from photosynthesis, provide the fungus with oxygen for respiration from photosynthesis and protect the fungus from high light intensity.

MYCORRHIZA

Mycorrhiza is a mutualistic association between a fungus and plant roots, whereby the **fungus benefits** by obtaining food from the plant roots.

The **plants benefits** by obtaining a large amount of water and mineral salts absorbed by the dense network of the rooting hyphae of the fungus from a large distant area which can't be absorbed by the root hairs. They also obtain protection from mechanical and microbial damages offered by the fungus. The fungus digests lignin, cellulose and pectin in soils and the products of their digestion are by the plant roots.

Cellulose digesting bacteria in gut of ruminants such as goats, cattle& sheep. Ruminants obtain sugars, amino acids while bacteria obtain shelter and food.

Leguminous plants for example; clover and nitrogen fixing bacteria(rhizobium). The plants obtain nitrates while bacteria obtain shelter, sugars, vitamins.

Mutualistic relationships that exist among marine organism and how they benefit

1. **Hermit crab and sea anemone**; the sea anemone lives attached onto the shell of a hermit crab. Sea anemone obtains scraps of food; and also obtains transport from the crab. In return the **hermit crab** obtains protection from its enemies by the sea anemone stinging cells

Commensalism

This is a close association between organisms of different species in which one member benefits while the other neither benefits nor is it harmed.
Examples are; Lichens on the bark of the tree, sea anemone and clown fish.

Commensalism is a close association between two living organisms of different species which is beneficial to one (the commensal) and does not affect the other (the host).

For example, the colonial hydrozoan Hydractinia attaches itself to *whole shells* inhabited by hermit crabs. Hydractinia obtains nourishment from the scraps of food left by the crab after it has eaten and the crab is totally unaffected by the association.

The distribution of the commensal depends on that of its host, while that of the host is totally unaffected by that of the commensal.

Other examples include; epiphytes and host plant.

Question.
Explain what is meant by the terms parasitism, mutualism and predation, indicating with the help of suitable examples how they differ from one another.

POPULATION DYNAMICS

Terms used in population studies.

- ***(a) Population size.*** This refers to the number of individuals in a population.
- ***(b) Population density.*** This refers to the total number of organisms of a species per unit area (land) or per unit volume (water)
- ***(c) Population growth.*** This refers to a change in the number of individuals (increase-positive or decrease-negative)
- ***(d) Population growth rate.*** This refers to a change in number of individuals per unit time
- ***(e) Birth rate (natality):*** This refers to the number of new individuals produced by one organism per unit time (Humans: per year). It is expressed as the number of individuals born in a given period for every 1000 individuals. For example; 36 births per 1000 people per year.
- ***(f) Death rate (mortality).*** This refers to the number of individuals dying per unit of time per unit of population (humans: number of deaths per 1000 per year. For example; 20 deaths per 1000 people per year)
- ***(g) Environmental resistance.*** This refers to all the environmental factors acting jointly to limit the growth of a population.
- ***(h) Carrying capacity.*** This refers to the maximum number of individuals of a given species that can be sustained indefinitely in a given area of land or volume of water.
- ***(i) Age structure/distribution*****. This 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

- ***(j) Biotic potential***. This is the maximum rate at which the members of a given population can reproduce given unlimited resources and favorable environmental conditions.
- ***(k)*** **Immigration.** This is the movement of individuals into a population from neighboring populations.
- ***(l)*** **Emigration.** This is the departure of individuals from a population.
- ***(m)*****Rare species.** These are species with small populations either restricted geographically with localized habitats or with widely scattered individuals.

(n) **Endangered species.** These are species with low population numbers that are in considerable danger of becoming extinct.

(o) **Extinct species.** These are species, which cannot be found in areas they previously inhabited nor in other likely habitats

Population distribution/dispersion (distribution of organisms in a habitat)

Three main types exist;

(i) Uniform distribution organisms are equidistantly placed due to severe struggle for resources in the environment.

(ii) Random distribution organisms are dispersed by chance with neither forces of attraction nor repulsion and the environment provides uniform factors.

(iii) Clumped distribution organisms aggregate into groups to gain better protection, feeding, reproduction among others. Clumped dispersion is the most common pattern of population distribution.

NB. Main characteristics of a population are; density; dispersion; age structure; natality; mortality; population size.

POPULATION GROWTH PATTERNS

Population grows when;

(a) Natality is greater than mortality

(b) Immigration is greater than emigration

Population growth may form a curve which is either;

(i) Exponential population growth curve (J-shaped)

(ii) Logistic population growth curve (Sigmoid/S-shaped)

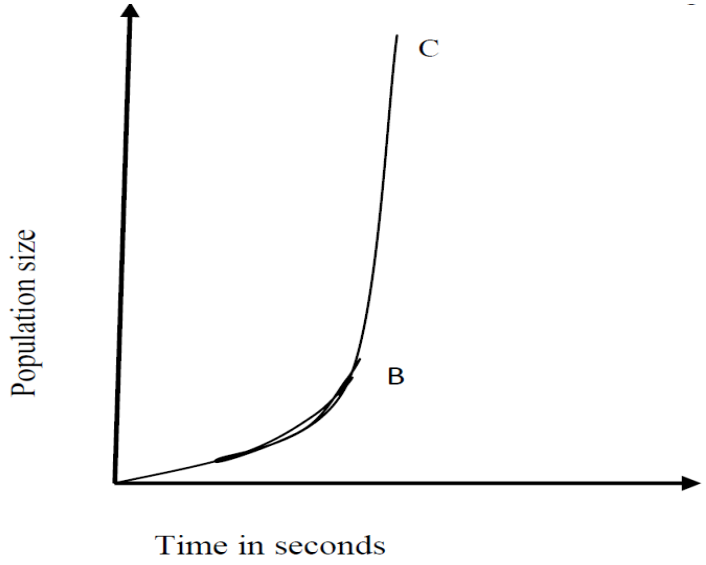
Exponential population growth (J-shaped curve)

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

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

It occurs when resources are unlimited and the population can grow at its intrinsic rate of growth. (rate at which a population would grow if it had unlimited resources)

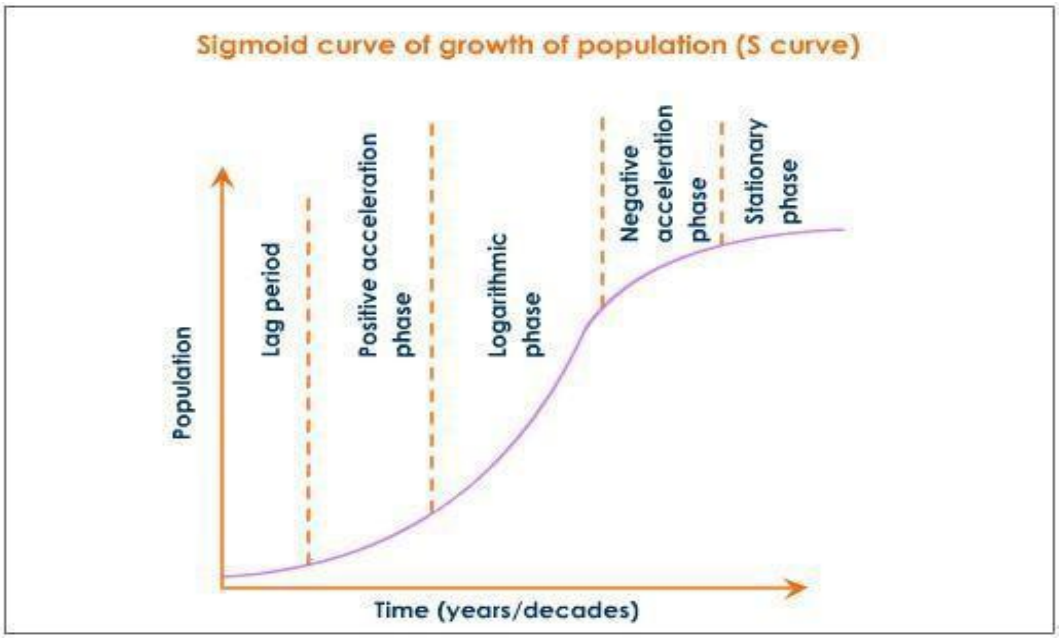
However, this is rare in nature because of limiting factors (environmental resistance).



Description
The number of individuals (population) is small initially. Their number increases gradually with time along AB. Later the population size increases rapidly with time along CB

Explanation
Initially, the number of individuals increases gradually with time because; the population size is small; thus few reproducing individuals; reproducing individuals are scattered within the environment; some may not have reached reproductive age; organisms are still getting used to their environment.
Later on, the number of individuals increases rapidly because; many individuals have now reached reproductive age; and the number of reproducing individuals now gets bigger.

Logistic population growth curve (sigmoid / s-shaped curve) .
Population growth starts out slowly and then proceeds faster to a maximum (carrying capacity) and then levels off.
Population then fluctuates slightly above and below the carrying capacity with time.
The population stabilizes at or near the carrying capacity (K) of its environment due to environmental resistance (any factors that may prevent a population from increasing as expected. For example; predation, parasitism, and accumulation of toxic substances)



The actual factors responsible for the shape of each phase depend on the ecosystem, and this can be illustrated by considering two contrasting examples: **yeast** in a flask (reproducing asexually), and **rabbits** in a field (reproducing sexually).

Lag phase
Little growth while yeast starts synthesizing appropriate enzymes for new conditions.
Little growth due to small population.
Individuals may rarely meet, so few mating.
Long gestation so few births.

Acceleration phase
Slow growth because cells are getting used to conditions in the environment
Slow growth because of few reproducing individuals

Log phase (Logarithmic phase)
Rapid exponential growth.
No limiting factors since relatively low density.
Rapid growth.
Few limiting factors since relatively low density.

Deceleration phase (Negative acceleration phase)
Slow growth due to accumulation of toxic waste products (for example; ethanol) or lack of sugar.
Slow growth due to intraspecific competition for food/territory, predation, etc.

Stationary phase
Population is stable (fluctuates slightly above and below the carrying capacity).

Cell death is equivalent to cells formation
Population is stable (fluctuates slightly above and below the carrying capacity).
Death rate is equivalent to the birth rate

How Population Density Affects Population Growth

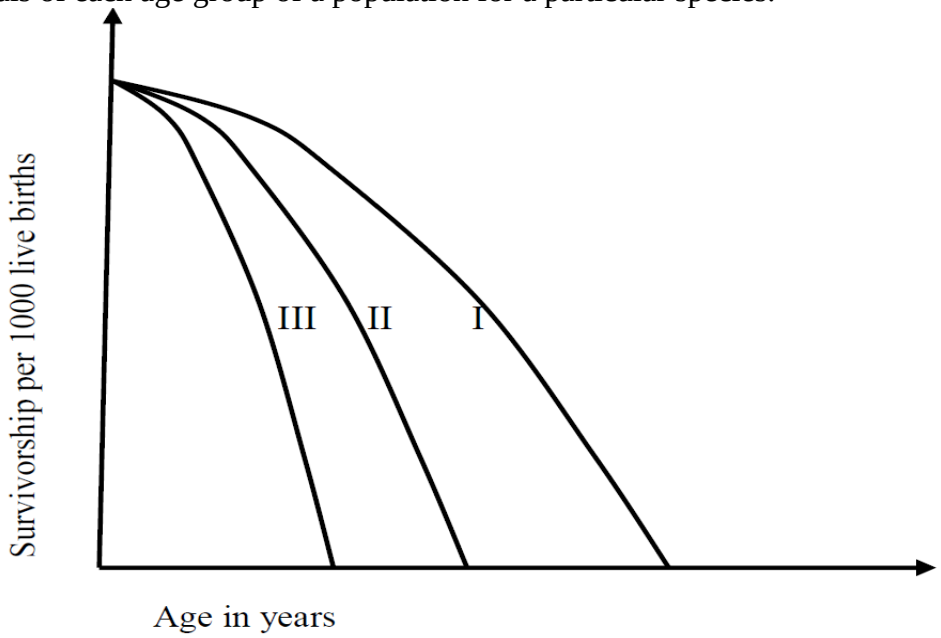
(a) ***Density dependent factors***. These are those factors whose effectiveness depends on number of individuals present in a unit space. The more individuals there are in the population, the greater the percentage of population that dies or fails to reproduce. These include; diseases, predation, competition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

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

SURVIVORSHIP

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

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



(I) **Late loss curves**
This occurs in Humans, elephants, rhinoceroses and mountain sheep
These are organisms with stable populations close to carrying capacity of the environment (K).

They produce few young ones which are cared for until reproductive age, thus reducing juvenile mortality and therefore enabling high survivorship to a certain age, then high mortality at later age in life.

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

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

Importance of plotting survivorship curves:
It enables determination of mortality rates of individuals of different ages and hence to determine at which age they are most vulnerable.
It enables identification of factors causing death at different ages so as to plan regulation of population size

DETERMINATION OF POPULATION SIZE OF ORGANISMS

Importance of estimating population size
It enables monitoring of population growth
It enables determination of habitat requirements of species.
It enables determination of carrying capacity in the area (determine whether existing population are likely to be sustainable)
It 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.
For example; determining the peak populations of organisms like 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 covers of the habitat.
Size of organisms under study.
Facilitation in terms of equipment to be used.
Behavior of the organism. For example; 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

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;

(a) **Direct counting method** (using a low flying aircraft)
(b) **Aerial photography**
(c) **Drive and count**
(d) **Strip census**
(e) **Removal method**

Direct counting method using a low flying aircraft
This is used to determine population of large animals.

Requirements
An air craft e.g. a helicopter; Survey map of the area; Stationary; binoculars among others.

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 for example; lions, buffalos among others.

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, for example under the trees.
It's greatly hampered by some weather conditions, for example fog, misty or cloudy weather.
It can only be used on large animals and those in open grass lands
It is not easy in very hilly areas.
The calculations involved may cause inaccuracy

Aerial photography.
Requirements
Low flying air craft and a Good camera

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

NB. A**dvantages and disadvantages are as seen above (direct counting**)

Drive and count method
Requirements
Man power; Stationary

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

Advantages
It is quick and more accurate especially for slow moving animals and those that live in herds for example; antelopes.
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 for example; lions and tigers
It is only limited to slow moving animals
It is restricted to animals moving in herds

Strip census
Requirements
Map of the area; 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.

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.

Capture mark Release recapture method (Lincoln Index).
This method is used on highly mobile animals like fish, small animals like mammals for example; rats, birds, arthropods like insects such as butterflies, moth and grass hoppers.

Requirements
Suitable traps; Suitable tags/label for example; 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 and they are recorded as **N1**.
They are all marked using a suitable label or tag. For example; 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; (those that have been recaptured). They are recorded 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 is the estimated total population of the area
N1- is the number of individuals captured on the first occasion.
N2- is the number of individuals captured on the second catch.
N3- is the 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?

$$P = \frac{N1 \times N2}{N3} = \frac{625 \times 873}{129} = \mathbf{4230\ Tilapia}$$

Use of quadrat
This is suitable for slow moving animals and grass.

Requirements
Metallic or plastic or wooden frame of a known area. For example; $1m^2$; 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 meter squared.
Total population is got by multiplying the average with the total area under investigation.

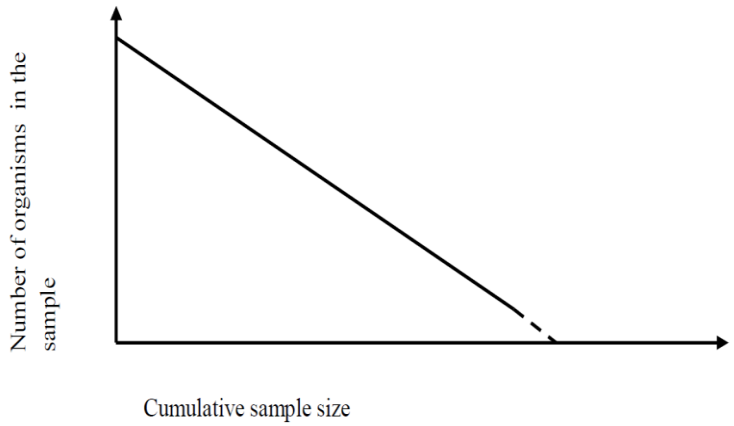
Advantages
It's accurate
It enables comparison of different areas and species.
It provides an absolute measure of abundance.

Disadvantages
Its time consuming.
It's not suitable for first moving animals.
It's not suitable for large sized animals.
some plants for example; grass species are indistinguishable and may disturb.

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.
Example.

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



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. For example; food, pests, diseases, predators among others.
The population itself initiates the control measure. 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. For example; predator –prey relationship.

Methods of population control

Biological control method
This is the eating or weakening of a pest species or weeds using other organisms called **control agents** for example; natural predator, parasite or pathogen.

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

Biological control method can be used to;

- Control of vector population
- Control of parasites
- Control of pathogens (bacteria& virus)
- Control of some plants. For example; weeds
- Control of pests.

Steps involved in biological pest control:
Identifying the pest and tracing its origins; (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 or release method for the control agent.

NB. Biological control of population is very specific; thus useful organisms are not affected.

Chemical method
This involves use of chemicals by humans to eradicate harmful organisms
These chemicals are named according to the target organisms. For example; herbicides kill weeds, insecticides kill insects, fungicides kill fungi.

Properties of an ideal pesticide:
It should be biodegradable or non-persistent so that toxic products are not left in or on crop plants.
It should be specific so that only pest species is killed.
It should not accumulate either in specific parts of an organism or as it passes along food chains.
It should effectively control the pest under field growing conditions
It should be easy to apply at the correct dosage

Problems of using insecticides

- Accidental misuse of toxic chemicals results into death of humans and domestic animals.
- Many are non-specific, killing non-target species, particularly natural predators of the pest species.

- Pest resistance sometimes occurs. Genetic variation enables a few individuals in the pest population to survive and may quickly reproduce.
- There is pest replacement since most crops 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. Non-specific pesticides may kill natural predators as well as pests, and so a small residual pest population may multiply quickly without being checked.
- **Bioaccumulation** (some molecules of the pesticide may be stored in specific organs or tissues at levels higher than would be expected) and **biological magnification** (the pesticide may get more concentrated as it passes along the food chains and webs) may occur.

Example

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, for example; birds of prey, the accumulation of DDT reaches a level which burns up and kills the final consumer.

NATURAL RESOURCES

A natural resource is anything not made by man obtained from the environment to meet human needs and wants

While some resources are directly available for use for example; solar energy, fresh air, wind, fresh surface water, fertile soil and wild edible plants;

Others become available after processing has been done for example; petroleum, metallic elements like iron, ground water, modern crops.

CLASSIFICATION OF NATURAL RESOURCES

(a) ***Perpetual resources***.

These are resources that are replaced (renewed) continuously on human time scale.

Examples include;

Solar energy; wind and tides.

(b) ***Renewable resources***

These are resources that are replenished (replaced) fairly rapidly (hours to decades) through natural processes as long as the usage is not faster than the replacement.

Examples include;

Fresh water; fresh air; fertile soil; animals and plants (Forests, grasslands)

(c) ***Nonrenewable resources***

These are resources that exist in a fixed quantity or stock in the earth's crust.

On the shorter human time scale, they are depleted much faster than they are formed

Examples include;

Fossil fuels for example coal, oil, natural gas;

Metallic minerals for example copper, iron, aluminium

Non-metallic minerals for example salt, clay, sand, phosphates

Further terms associated with natural resource

(a) *Sustainable yield*

This refers to the highest rate at which a renewable resource can be used indefinitely without reducing its availability supply.
In spite of the renewability, renewable resources can be depleted or degraded.

(b) *Environmental degradation*

This refers to when the resource's natural replacement rate is exceeded resulting into a decline in its availability.
This mainly occurs as a result of;
Urbanization of productive land, excessive soil erosion, deforestation, ground water depletion, over grazing of grass lands by livestock, reduction in the earth forms of wild life by elimination of habitats and species, pollution, water logging and salt build up in the soil

(c) *Recycling of resources*

This is the reprocessing of a resource into new products
Old aluminum saucepans and copper items can be recycled

(d) *Reusing of resources*

This refers to the using of resources over and over in the same form.
For example;
Glass bottles of alcoholic and soft drinks can be collected, washed and refilled many times

(e) Wild life

This includes plants and animals that occur in their natural environment
Examples include;
Forests and wild animals

POLLUTION

Pollution 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 the 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.

Categorization of pollutants basing on their persistence in the environment

(a) Degradable (non-persistent) pollutants. These are the pollutants that are broken down completely or reduced to acceptable levels by natural physical, chemical and biological processes.
Biodegradation. This is the breakdown of complex chemical pollutants into simpler chemicals by living organisms (usually specialized bacteria). For example; sewage is a biodegradable pollutant.

(b) Slowly degradable (persistent pollutants). These are pollutants hat take a longer time to degrade. For example; DDT - an insecticide, and **plastics such as plastic bags.**

(c) Non-degradable pollutants. These are pollutants that cannot be broken down by natural processes. For example; the toxic elements lead, mercury, arsenic and selenium

TYPES OF POLLUTION

AIR POLLUTION

Examples of air pollutants

Carbon monoxide
Sources. Motor vehicle exhausts; Incomplete combustion of fossil fuels; tobacco smoking

Effects/consequences
It prevents oxygen usage by blood by forming carboxy-haemoglobin, which may cause death.
Small concentrations cause dizziness and headache

Control measures
Efficient combustion of fuels in industry and homes
Avoid smoking
Vehicle exhausts gas control.

Sulphur dioxide
Sources.
Combustion of Sulphur containing fuels; oil and coal gas

Effects/consequences
It causes lung diseases; irritation of eye surface and asthma resulting into death if in high concentrations.
It forms acid rain which decreases soil PH.
It reduces growth of plants and kills lichens.
NB. *Lichens are indicator species for Sulphur dioxide pollution.*
The presence of many lichen species indicates low level of Sulphur dioxide pollution in that area.

Control measures
Use of Sulphur free fuel for example; natural gas.
Installation of Sulphur dioxide extraction units in industrial fuels and chimneys.

Ozone
Sources.
Motor vehicle exhausts.
Combustion of fossil fuels to form nitrogen dioxide which decomposes to form oxygen atoms that combine with oxygen molecules to form ozone.

Effects/consequences
Low level (tropospheric) ozone causes:
Internal damage to leaves hence reducing photosynthesis.
Eye, throat and lung irritation which may result into death.
Internal damage to leaves which severely reduces photosynthesis.
Greenhouse 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.

Control measures
Vehicle exhausts gas control for example; in USA

Smoke
Sources.
House coal, smoke, soot
Motor vehicle exhausts
Tobacco smoking
Incomplete combustion of refuse in incinerators and bonfires.

Effects/consequences
It causes lung diseases when inhaled
It is a sunlight barrier, hence reducing photosynthesis.
It causes stunted growth of plants
It causes stomatal blockage hence reducing photosynthesis

Control measures
Usage of smokeless fuels
Efficient combustion
No smoking
Vehicle exhausts gas control

Dust

Sources. Solid fuel ash; soil; quarrying; mining among others

Effects/consequences
Lung diseases; stomatal blockage; Stunted growth of plants; Smog forms when temperature inversion occurs (layer of warm air traps cool air containing dust and smoke close to the earth' surface)

Control measures
Installation of dust precipitators in industrial chimneys; Efficient combustion; Wearing of face masks by factory workers.

Carbon dioxide
Sources.
Motor vehicle exhausts
Combustion of fossil fuels
Effects/consequences
Increased carbon dioxide causes Greenhouse 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.

Control measures
Planting more green plants
Reduction in combustion of fossil fuels by relying on alternative sources of energy for example; solar energy.

Nitrogen oxides (***nitric oxide & nitrogen dioxide)***
Sources.
Car exhaust emissions; industrial fuel gases

Effects/consequences
Acid rain formation
Contribute to greenhouse effect

Control measures
Car exhaust control
Chlorofluorocarbons CFCs
Sources.
Aerosol propellants; refrigerator; air conditioner coolants; expanded plastics. For example; bubbles in plastic foam used for insulation and packaging

Effects/consequences
Enters stratosphere, the chlorine reacts with ozone hence reducing the ozone layer and permitting greater penetration of UV light to cause global warming.

Control measures
Ban on the use of CFCs

Noise
Sources.
Discos; road traffic; engines; machines; aero planes; firearms

Effects/consequences
Hearing impairment; total deafness; nervous disorders

Control measures
Effect laws against excessive noise; put on ear muffs and plugs while in industry

Radioactive *fallout from explosion*
Sources.
Nuclear weapons; nuclear power fuels.

Effects/consequences
Ionizing radiation causes cancer
Control measures
Nuclear power controls

GREENHOUSE EFFECT AND GLOBAL WARMING

Greenhouse effect
This is a description of the condition which results when greenhouse gases like carbon dioxide, water vapor, methane and nitrous oxide allow mostly visible light, some infrared radiation and ultraviolent radiation from the sun to pass through the troposphere to the earth, which transforms this solar energy to longer-wave lengths- radiations (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 average 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 that are 105 times worse than carbon dioxide as greenhouse gases

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 and 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 SO42- 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 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 human's respiratory diseases such as bronchitis and asthma.
It can leach toxic metals such as lead and copper from water pipes into drinking water.
It damages statues and buildings.
Decreases atmospheric visibility, mostly because of sulphate particles.
It promotes the growth of acid-loving mosses that can kill trees.
It leads to loss of fish population when the pH lowers below 4.5

Prevention
Installation of SO_2 extraction units 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.
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.

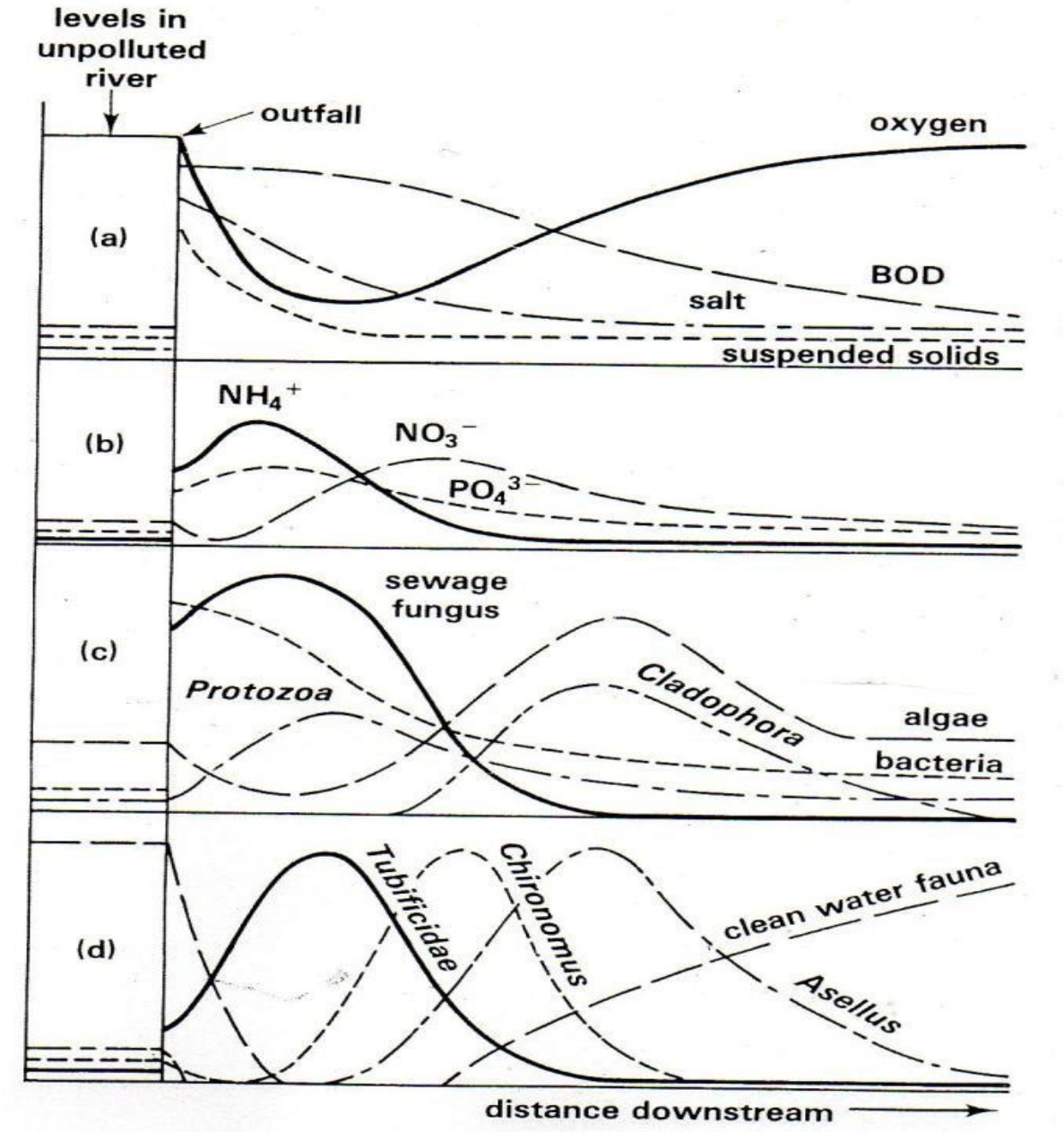
WATER POLLUTION

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 homes carried through pipes called **sewers**.

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

Dissolved oxygen and B.O.D (Biological or biochemical oxygen demand)
NB. BOD is the 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 $1dm^3$ of water stored in darkness at 20℃ for 5 days.

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

Variation down stream
Dissolved oxygen level is high in unpolluted water; decreases rapidly at sewage discharge to the minimum; and then increases gradually downstream, returning to a normal level further downstream.

B.O.D is very low in unpolluted water, increases rapidly at sewage discharge then decreases gradually downstream.

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

Component
Suspended solids

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

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

Component
Living organisms. For example; Aerobic bacteria, sewage fungus, algae and higher plants.

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

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

Explanation
Sewage contains aerobic bacteria that feed on organic substances, but population falls as availability of oxygen and nutrients diminishes.
Population increases at outfall because the sewage fungus thrives in anaerobic conditions and is very tolerant at high ammonia concentrations.

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

Component
Ammonium nitrate and phosphate ions.

Variation down stream
Ammonium, nitrate and phosphate ions concentration is very low before out fall.
NH_4^+ ions increase rapidly at discharge; more rapidly to a maximum just after outfall; then decreases rapidly and later gradually to a very low level downstream.
NO_3^- ions first decrease gradually to a minimum concentration after outfall, gradually increase to a maximum a short distance downstream, then decreases gradually further downstream.
PO_4^{3-} ion concentration increases rapidly at discharge; gradually just after outfall to a maximum then decreases gradually to a very low level downstream.

Explanation

Sewage contains NH_4^+ ions. Putrefying bacteria convert organic nitrogen-containing compounds in sewage to $NH4^+$ ions 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^- ions by nitrifying bacteria, then decrease gradually due to consumption by plants and algae.

Sewage contains PO_4^{3-} ions from; detergents and decomposition of organic matter, yet the consumption by autotrophs is very low at outfall, accounting for the high PO_4^{3-} ion concentration.
PO_4^{3-} ion gradual decline downstream is caused by; absorption by the progressively increasing populations of autotrophs and storage in sediments.

Component
Clean water fauna (stonefly nymphs, may fly larvae, Caddis fly
larvae) Asellus (fresh water louse), Chironomus(bloodworm), Tubifex and rat –tailed maggots (not indicated on the graph but it can be sketched basing on tolerance to pollution)

NB. Organisms above are indicator species of un polluted, well oxygenated water.

Variation down stream
The populations of clean water fauna are high before outfall, decrease rapidly to zero at outfall only appearing and increasing to normal with distance downstream.
Asellus population decreases rapidly to zero at outfall, only appearing and increasing rapidly to a maximum a short distance downstream after which it decreases rapidly.
Tubifex population increases rapidly to a maximum at outfall and then decreases rapidly downstream.
Chironomus population increases rapidly to a maximum at a slightly longer distance from outfall and then decreases rapidly downstream.

Explanation
Clean water species cannot tolerate anaerobic conditions at outfall, populations increase downstream because oxygen and food become available.

Asellus cannot tolerate anaerobic conditions at outfall and therefore dies and migrates to the relatively less polluted water downstream where it shrives.

The increase in population of Tubifex, and Chironomus is because they are; relatively inactive to reduce oxygen demand and 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;

volume of incoming degradable wastes in sewage; flow rate of the river; temperature of the water; pH level of the water and 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.
For example; they can be used in ecological investigations to find out about both the present and past conditions of soil and climate.

ADDITION OF INORGANIC CHEMICALS, PLANT NUTRIENTS AND SEDIMENTS INTO LAKES.

Pollutant
Plant nutrients

Examples
Nitrates (NO_3^-); phosphates (PO_4^{3-}) and ammonium ions (NH_4^+).
The nutrient enrichment of water bodies is termed eutrophication

Main human sources
Raw sewage discharge
Detergents and other chemical release from industries
Leaching of inorganic fertilizers for example; NPK from farmland.

Harmful effects
Rapid growth of algae and green protists (algal blooming/dramatic first growth of algae)
Reduces light penetration in water leading to; Death and decay of algae, which depletes water of dissolved oxygen, killing fish and other aerobic animals.
Excessive levels of NO_3^- if drank in water lowers the oxygen carrying capacity of blood and kill unborn children and infants **("blue baby syndrome").**

Pollutant
Sediments

Examples
Soil
Silt

Main human sources
Land erosion

Harmful effects
Can cause turbidity/cloudiness in water
Light penetration is reduced therefore reduce photosynthesis
Sediments settle and destroy feeding and spawning grounds of fish
They clog and fill water bodies, shortening their lifespan
They disrupt aquatic ecosystems; carry pesticides, bacteria and other harmful substances into water.

Pollutant
Inorganic chemicals

Examples; Acids; compounds of toxic metals like lead, mercury, arsenic (As) and selenium (Se); salts for example; NaCl in ocean water

Main human sources
Surface runoff, industrial effluents and household cleaners

Harmful effects
Drinking water becomes unusable for drinking and irrigation
Lead and Arsenic damage the nervous system, liver and kidneys
They harm fish and other aquatic life
They lower crop yields
They accelerate corrosion of metals exposed to such water.

HEAT (THERMAL) POLLUTION

Main human sources
Use of water as a coolant in industrial processes for example; electricity generating plants.

Harmful effects

- Lowers dissolved oxygen levels since solubility of most gases reduces with temperature.
- Make aquatic organisms more vulnerable to disease, parasites, and toxic chemicals.
- When a power plant shuts down for repair or opens, fish and other aquatic organisms adopted to a particular temperature range can be killed by the abrupt change in water temperature. This is known as thermal shock.
- Some aquatic animals may migrate to water with favorable temperature.

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

Assignment; Research and make a brief summary on

- Impact of invasive species on native biodiversity, ecosystems, and economies, as well as strategies for their management and control.
  (v) Characteristics of invasive species
  (vi) Their impacts on native biodiversity, ecosystems, and economies.
  (vii) Strategies to manage and control the invasive species.
  (viii) Using problem-based learning method, Learners examine a case study of a pest infestation controlled using biological agents.
- Analyse the concept of food security, focusing on its components and sustainable agricultural practices to address its challenges.
  (iv) Components of food security; availability, access, utilization, and stability.
  (v) Their roles in maintaining a stable food supply.
  (vi) Threats and solutions to food security.

END