S5 BIOLOGY

CYCLING OF NUTRIENTS OR MATTER (BIOGEOCHEMICAL CYCLES).

Although most ecosystems receive an abundant supply of solar energy, chemical elements are available only in limited amounts. Life on Earth therefore depends on the recycling of essential chemical elements. While an organism is alive, much of its chemical stock is replaced continuously as nutrients are assimilated and waste
products released. When the organism dies, the atoms in its complex molecules are returned in simpler compounds to the atmosphere, water, or soil *by* the action of decomposers.
Decomposition replenishes the pools of inorganic nutrients that
plants and other autotrophs use to build new organic matter.
Because nutrient cycles involve both biotic and abiotic components, they are called **biogeochemical cycles**.
Biogeochemical cycles containing nutrients essential to life of living organisms are referred to as nutrient cycles. Nutrient cycles existing in an ecosystem include,

- Nitrogen cycle.
- Carbon cycle.
- Hydrological or water cycle.

NITROGEN CYCLE.

Nitrogen comprises about 78% of all atmospheric gases. Atmospheric nitrogen is converted into nitrates by the following processes,

• ***Lightening.***

Lightening combines nitrogen and oxygen to form nitrates. Nitrates formed dissolve in rain water and fall down and enter the soil. The nitrates are absorbed by the plant roots and converted into nitrogen compounds in plants such as amino acids and proteins.

• ***Fixation of nitrogen/Nitrogen fixation.***

The aerobic nitrogen fixing bacteria such as *Rhizobium* and *Azotobacter* live in the root nodules of leguminous plants like peas, beans and clover. These aerobic nitrogen fixing bacteria in the root nodules fix or convert atmospheric nitrogen into nitrates which are then built up into amino acids and proteins in the plants. There fore ***nitrogen fixation*** is the process by which atmospheric nitrogen is converted into nitrogen compounds such as amino acids and nitrates.
The plant materials are consumed by the herbivores and other animals. In this way the nitrogen compounds become available in the herbivores. The herbivores are equally eaten by other animals called the heterotrophic organisms.
When the plants and animals become old, they die and their remains mix with the soil. In the soil, saprophytic organisms like putrefying bacteria and fungi cause the break down of proteins in dead decaying organisms to form ammonium compounds. Other ammonium compounds can be derived from any of the following sources,

• Animals excrete urine containing high concentration of the nitrogenous waste urea. Putrefying bacteria convert nitrogen compounds in the urea to ammonia.
• Industrial haber process produce ammonia that is released into the soil.

• Human activity which involves application of organic farm fertilizers like CAN, NPK releasing nitrogen compounds and urea into the soil. Putrefying activities cause release of ammonia.
• Sewage discharge on the land. Sewage contains ammonium compounds

In the soil, ammonia is converted into the ammonium compounds by chemical combinations. The ammonium compounds are converted into nitrites and nitrates in a process called Nitrification. Nitrification is the process by which ammonium compounds are converted to nitrites and nitrates in the soil by the activities of nitrifying bacteria.

In this process, aerobic nitrifying bacteria like *Nitrosomonas* and *Nitrococcus* oxidize ammonium compounds to nitrites. Then the Nitrobacter bacteria further oxidizes nitrites into nitrates. Nitrates are absorbed by the plants.

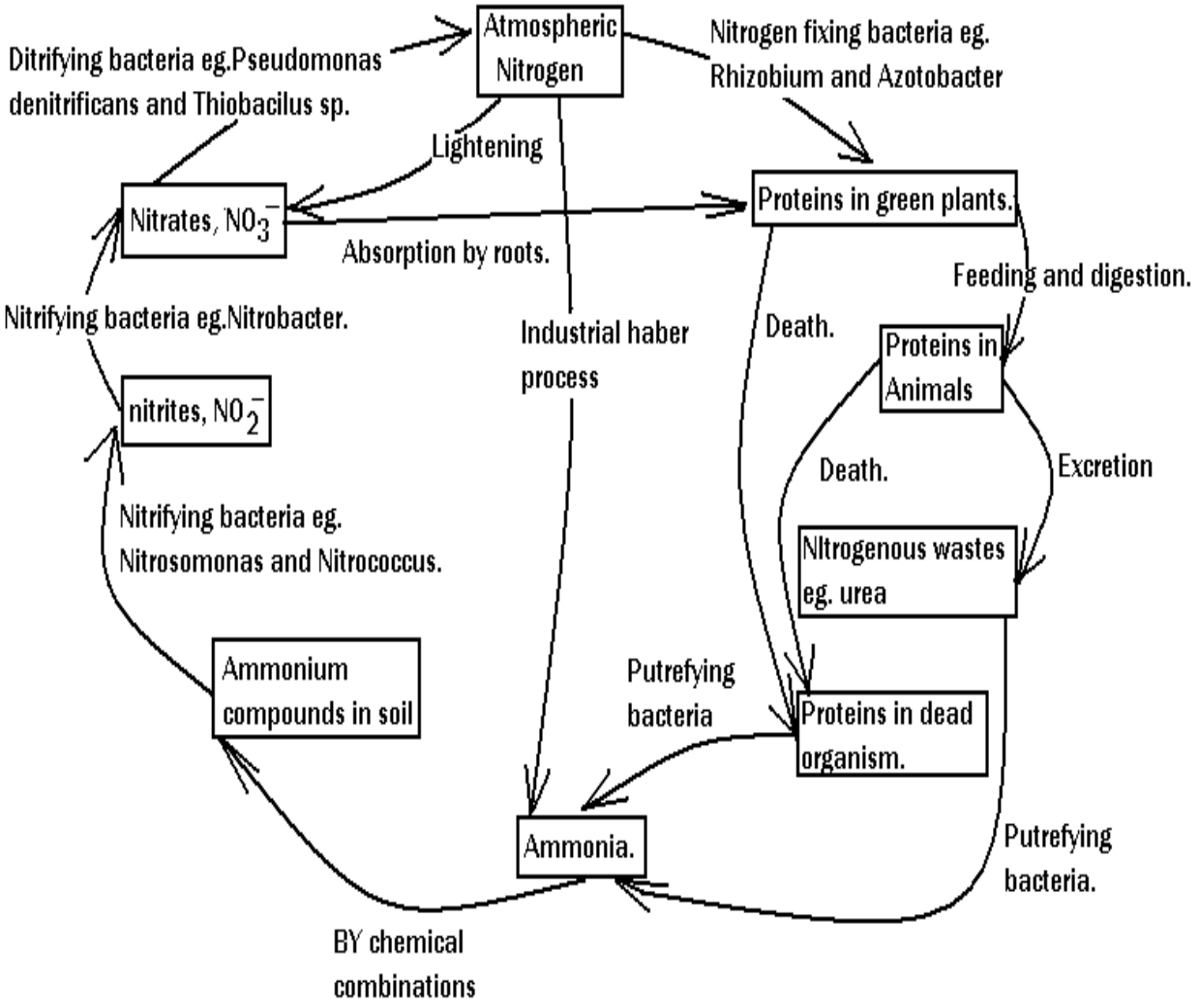
Some of the nitrates in the soil can be converted back into atmospheric nitrogen in a process called ***Denitrification.***

Denitrification is the process by which nitrates in the soil are converted into gaseous nitrogen which is given off into the atmosphere. It is carried out by anaerobic bacteria like Pseudomonas dinitrificans and Thiobacilus dinitrificans. The necessary anaerobic conditions are in water logged soils, where the denitrificans thrive and by converting nitrates to atmospheric nitrogen, they reduce soil fertility. This is why farmers plough and dig up their land in order to improve drainage and aeration so as to avoid anaerobic conditions but instead promote aerobic conditions for the activities of the nitrifying bacteria.

Note that, nitrogen enters the food chain in the following ways,
• Lightening. Includes electrical and photochemical fixation of atmospheric nitrogen to form nitrates.
• Nitrification process.
• Nitrogen fixation.
• Use of organic fertilizers.

Denitrification releases nitrogen into the atmosphere.

THE NITROGEN CYCLE IN AN ECOSYSTEM.



SIGNIFICANCE OF NITROGEN IN ECOSYSTEM

(i) Used for synthesis of amino acids and proteins in plants.

(ii) The amino acids and proteins are used for making structural and fibrous proteins eg. Muscles and cartilage in animals. The proteins are also used to form functional proteins like enzymes, antibodies and hormones.

(iii) Forms structure of vitamins needed for healthy body.

(iv) Used in synthesis of nucleotides which are subunits for nucleic acids, DNA and RNA.

(v) Utilized in synthesis of chlorophyll which traps sun energy for photosynthesis.

(vi) Components of plant hormones auxin, responsible for cell division, elongation resulting into growth. Also used in synthesis of insulin in animals, required for regulation of sugar levels in blood.

Deficiency of Nitrogen in plants causes,

- Stunted growth.
- Chlorosis (yellowing of leaves).

While in animals, it's deficiency is due to deficiency of proteins in the diet and causes,

- Kwashiokor.
- Stunted growth.
- General body weakneses.
- And oedema.

CARBON CYCLE.

The composition of carbondioxide in the atmosphere is about 0.03%. Despite this small proportion, carbondioxide is the major pool of carbon for plants and animals in an ecosystem.

Carbondioxide is removed from the atmosphere by the process of photosynthesis by photosynthetic organisms. In this case, green plants absorb carbondioxide from the atmosphere, phytoplanktons absorb dissolved carbondioxide from the water. The carbondioxide is utilized for the manufacture of carbohydrates, proteins and fats in a process of photosynthesis. The plants are eaten by herbivores which digest and assimilate the foods originally synthesized by the plants. The herbivores are in turn eaten by the carnivores which also acquire the assimilated carbon.

Carbondioxide is subsequently returned into the atmosphere through the following processes,

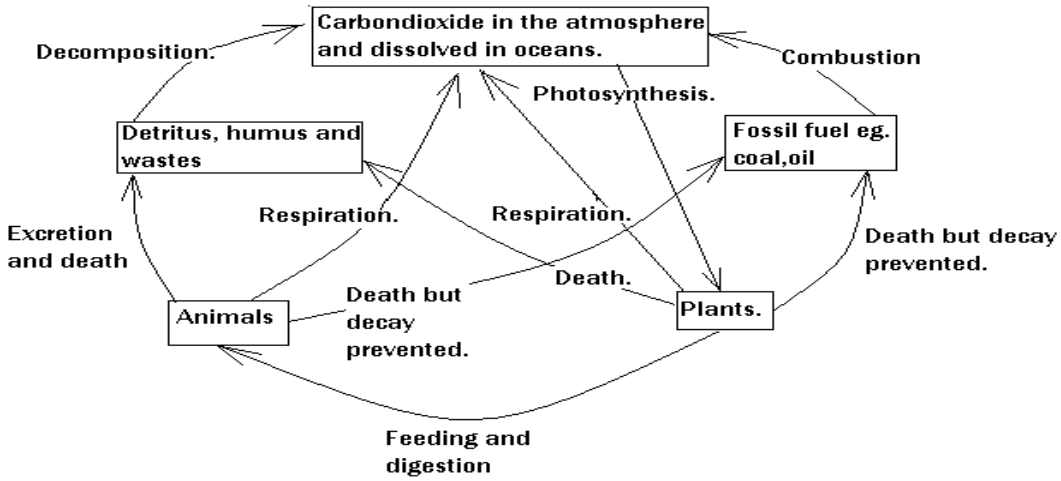
• Aerobic respiration by many living organisms produce carbondioxide.

• Death of plants and animals and rapid decomposition or decay of their remains by the activities of the saprophytes or putrefying bacteria, this releases carbondioxide.

• When large quantites of dead plants and animals accumulate in anaerobic conditions and prevented from decaying, they form coal, oil and other fossil fuels. Combustion of these fossil fuels produce large amounts of carbondioxide into the atmosphere.

The processes that absorb carbondioxide from the atmosphere and those returning it into the atmosphere function in such a way that the concentration of the carbondioxide is maintained fairly constant in the ecosystem/atmosphere.

THE CARBON CYCLE.



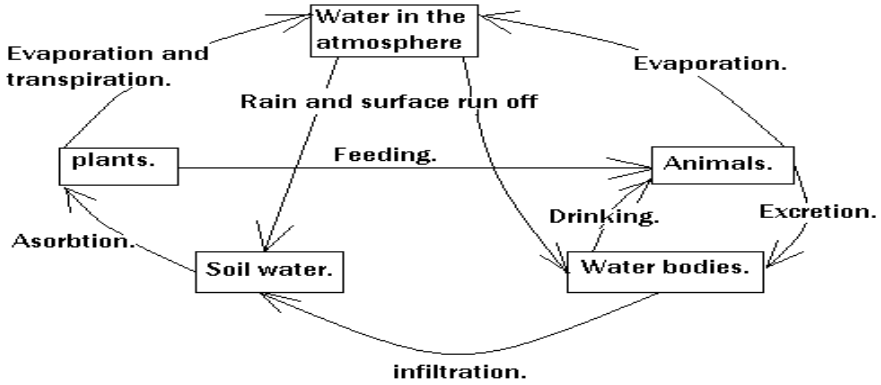
HYDROLOGICAL CYCLE (WATER CYCLE).

Water in the atmosphere exists as water vapour which form part of the cloud, subsequent condensation results into rain fall. Rain water is carried into water bodies and some rain water infiltrates the soil. Some water from various water bodies like rivers, lakes, seas also infiltrate into the soil to collect as soil water. Excretion of urine and faeces to a small extent add to the water bodies.

Plants absorb soil water by the root hairs. Animals drink water drawn from the water bodies. Animals can also obtain water when they feed on plant parts such as fruits, stem, roots which store high amounts of water.

Water is returned into the atmosphere when water evaporates from the surfaces of the skin of the animals, surfaces of the leaves, stem of plants through transpiration, and evaporation from water bodies.

DIAGRAM OF WATER CYCLE.



HUMAN ACTIVITIES THAT AFFECT WATER CYCLE.

(i) Dam construction which slows down the speed of water movements.

(ii) Swamp and land reclamation which drains water bodies and reduces the amount of water in the open water systems.

(iii) De-forestation which reduces the rate at which underground water is reabsorbed by the plants since the trees are cleared which absorb the under ground water.

(iv) Over utilization of the under ground water by excessive construction of bore holes and use of underground water pumping machines.

HUMAN ACTIVITIES THAT AFFECT NUTRIENT CYCLING AND ENERGY FLOW IN AN ECOSYSTEM.

(i) Deforestation.

This is cutting down or felling down of trees. It reduces amount of sunlight absorbed due to decrease in number of producers. Soil erosion occurs, resulting into lose of more nutrients since soil layer is removed in the process.

(ii) Air pollution.

This results from addition in excess of greenhouse gasses into the atmosphere, such gases include, carbon dioxide, chloroflorocarbon (CFC), and sulphur dioxide gas. Greenhouse gases results into depletion of ozone layer. While the rain water can dissolve sulphur dioxide gas to form acid rains. Ozone depletion results into global warming may cause death of many consumers. Global warming and acid rains cause destruction of producers, decreasing the number of producers, productivity is lowered which also lowers energy along the trophic levels.

(iii) Use of green houses and lighting of red and blue. Red and blue Wave lengths increase photosynthesis and number of producers, increasing light energy trapped.

(iv) Mulching reduces weed growth, thereby decreasing light energy absorbed by plants.

(v) Harvesting of crops. It involves removal of crops which reduces food energy available for herbivores. The herbivores (primary consumers) are eaten by humans.

(vi) Hunting. This removes energy available for carnivores and other organisms in food web.

(vii) Burning dead organisms including humans. Forest fires started by humans reduces energy available for decomposers and detritivores.

(viii) Use of pesticides and herbicides. This affect decomposers making recycling of materials slower.

ECOLOGICAL SUCCESSION / COMMUNITY CHANGES.

This refers to transitional changes over time where communities are replaced by more adapted ones until a climax community is reached.

A climax community is a stable self-perpetuating community which is in equilibrium with its environment. The change of community takes place in a series of succession stages called **seral stages**. The whole process or sum of all seral stages is called a **sere**. **There are three types of seres i.e.**

(i) **hydrosere**; succession in aquatic environment
(ii) **halosere**; succession in salty environment
(iii) **xerosere**; succession dry environments e.g. deserts

TYPES OF ECOLOGICAL SUCCESSION.

There are two types of succession. These are.

- *Primary succession.*
- *Secondary succession.*

PRIMARY SUCCESSION IN TERRESTRIAL ECOSYSTEM.

Is the sequence of change from the initial colonization of a new area which has never been inhabited before like bare rocks, sand or cooled lava flow, etc. To establishing a relatively stable community (climax community). Primary succession occurs in three stages, pioneer stage, spruce stage and climax community. The process proceeds quite slowly. It begins when the propagation structures like seeds, buds, rhizomes, stolons and bulbs are not readily available.

• ***Pioneer stage.***

During this stage, bare rock breaks down physically and chemically during the process of weathering. The acidic rains in tropics dissolve more minerals which cause further disintegration of the rocks. The existing conditions do not favour growth of most plant species but lichen which is an association between algae and fungi are the first to inhabit the rock. They are referred to as the pioneer organisms. Algae are a drought resistant and photosynthetic, providing food for the fungi. Some invertebrates exist and feed on the algae. Then the hyphae of the fungus penetrate tinny cracks, absorbing minerals and widening the cracks further, the hyphae also provide support. Some lichen die, decay and add onto the organic matter.

After the activity of the lichen has enlarged the cracks in the rocks and filled them with decomposing dead lichens, the conditions within the rock become favourable for the growth drought resistant and sun tolerant mosses as well as insects that feed on them. Mosses form a dense mat like net work which traps tiny particles of rocks, some organic debris and water. some thin soil layer begin to form and lichens gradually replaced by the mosses and liverworts.

• ***Spruce stage.***

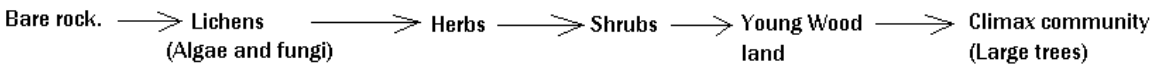
Death and decay of the moss plants adds nutrients to the rock particles. Thickness of soil increase and this favours the growth of herbs like the ferns, grasses and other angiosperms. Animals like amphibians, reptiles and birds also come in. Some herbs die off and add on the organic matter. The soil layer become thick enough.

• ***Climax stage.***

Soon large woody shrubs begin to grow in the newly formed soil. The mosses and the lichens may be shaded or covered by decaying leaves and other vegetation. Eventually as a thicker layer of soil develops, trees are able to take root in deeper rock crevices and the shrubs disappear. Larger animals may also come in. After a very long period of time, a mature forest community grows. This is the ***climax community***.

Climax community is defined as the relatively stable community which is in equilibrium with its environment. A single type of climax community is known as ***climatic climax***. A community where human interventions have led to a relatively stable community very different from the original climax is termed as ***a plagioclimax***. The succession is said to have been deflected. A climax community can have one ***dominant*** or ***several co-dominant*** species. Dominance in this case, refers to the species with the greatest collective biomass or productivity. Species with larger size can be referred to as being dominant.

DIAGRAM OF SUMMARY OF PRIMARY SUCCESSION.



PRIMARY SUCCESSION IN AQUATIC ECOSYSTEM.

In ponds and lakes, organic matter builds up from dead remains of plants and animals and sediments brought by the water run offs from the land. This causes the water in these water bodies to become shallower and richer in nutrients, allowing rooted plants to grow and crowd along the shores of the ponds, rivers and lakes.

The growth of these plants extends further into the pond, river and lake. More sediment is trapped in the process and the water become even shallower. The ponds, rivers and lakes develop into mashes, then into swamps which support growth of many herbs and shrubs. Given good climatic and ecological conditions, after a long time a wood land develops and eventually large trees forming climax community.

SECONDARY SUCCESSION.

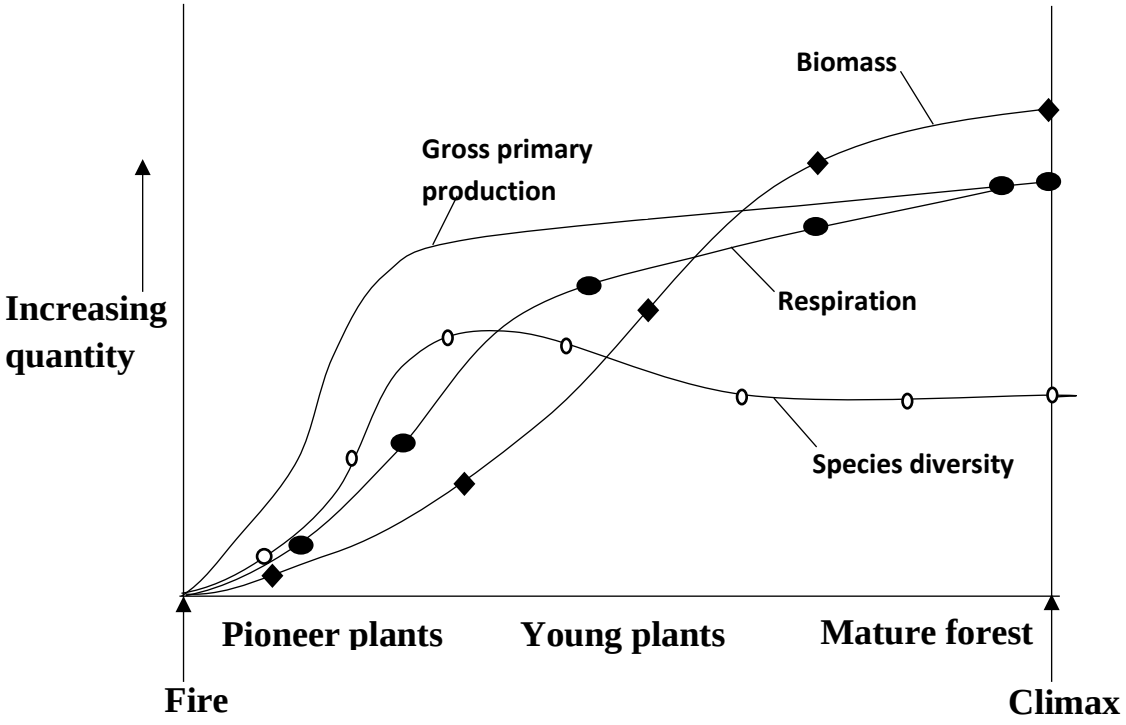
Is the sequence of change from the initial colonization of an area which has previously been inhabited by a particular community like cleared forest, abandoned field, burnt area to establishing a relatively stable community (climax community).

In secondary succession, the pioneer organisms are fast growing annual plants like *Bidens pilosa*, *commelina species*, they grow in an area which was previously inhabited by well established communities. The animals which become available at this stage include insects, detritivores such as earth worms and their predators. When some of the organisms die, they decompose and add organic matter into the soil.

After a few years, herbs such as *Lantana camara* begin to establish themselves in the area. After many years, the shrubs like Acacia and other small trees come in place, these shrubs gradually replace the herb community in the area. At this stage birds come in place. Due to favourable climatic conditions, accumulation of sufficient nutrients in the soil, a climax community comprising of large trees and larger animals develop. The animal communities keep changing with changing plant communities.

Sample question:

The figure below shows the changes in a number of ecological parameters describing a succession following a forest fire, which proceed over a period of more than 100 years



(a) (i) write an expression to describe the relationship between gross primary production and respiration (01 mark)
(ii) Suggest reasons for the relationship between gross primary production and respiration over the succession period (09 marks)

(b) Explain the changes in the following ecological parameters
(i) biomass (07 marks)
(ii) species diversity(08 marks)

(c) Using the information provided, state the characteristics of a climax community of the forest(04 marks)

(d) Explain why primary productivity of aquatic ecosystem is usually lower than that of terrestrial ecosystem(04 marks)

(e) Describe the effects fire would have on the fertility of the forest soil at start of succession. (07 marks)

Soln

(a) (i) net primary productivity = net primary productivity – respiration
(ii) During the early stages of succession, gross primary production is greater than total respiration; in young ecosystems not all net primary production is used for respiration; organic matter is still low; supporting a small number of organisms with lower respiration rates;
In climax ecosystem gross primary productivity is equal to total ecosystem respiration; ecosystem's net production accumulates as organic matter; which is both detritus and living organisms; increasing heterogeneity of the ecosystem; with surplus of organic matter empty niches arise; which are occupied by new species that fill up the empty niches; resulting in rapid increase in total ecosystem respiration that spends the whole gross primary production of the ecosystem;

(b) (i) increases gradually in early stages of succession; plant community is still dominated by herbs and shrubs; with a lower net primary productivity; accumulating less biomass per unit time;
Increases rapidly at later stages of succession; plant community is dominated by larger trees; whole growth is facilitated by increased soil depth and nutrient content; these have higher net primary production; thus accumulate more organic matter as biomass;
In a mature forest biomass remains almost constant; climax community has been reached; large number of organisms exist; with higher total ecosystem respiration that spend most if not all the gross primary production; limiting accumulation of biomass;
(ii) species diversity increases gradually and then rapidly in the early stages of succession; ecosystem is constituent of pioneer species herbs and shrubs; with a greater diversity; reaching maximum; at the time of invasion of the young forest trees; then decreases gradually in later stages; as pioneer species are eliminated; remains almost constant at climax community as large trees out compete the many plant communities that constitute the under growth; community is stabilizing and available species increase in size and number;

(c) Highest biomass
Highest gross primary production
Stable species diversity
High species diversity

(d) In aquatic ecosystems before light reaches the plants it is reflected by water; absorbed ; and nutrients content is very low; since the nutrients released by decay are not available in the surface waters; where plants grow; hence low plant diversity in aquatic ecosystem;

(e) Increased temporarily; due to nutrients released in the ash; and by the decay of those plants that have been destroyed by the fire; reduced transpiration improves soil moisture status;
Decrease due to volatilization of nitrogen; facilitation of leaching and soil erosion; as land is left bear; and also soil moisture decreases due to high evaporation rates resulting from high temperature generated by heat;

Driving forces of succession (initiatives of the succession process).

(i) Nudation.

This is exposure of a given locality to succession stages. For example clearing a given plant community to have an open land.

(ii) Arrival of propergules.

In this case, the propagation structures such as seeds, stolons, rhizomes and corms etc are dispersed to the locality or the already existing propergules begin to establish.

(iii) Germination (Ecesis): The established propergules together with the newly introduced ones germinate.

(iv) Competition: The germinated propergules begin to exhibit both interspecific and intraspecific competitions.

(v) Reaction: A better adapted and well-established individuals out compete those which are less adapted to the environment.

(vi) Establishment: A better competitor establish a climax community.

Changes that take place in a community during the succession process.

Succession is initiated by alteration of the physical environment by organisms such that those initially there make environment better for a new load which replaces the previous one. Apart from the physical environmental alteration, the following changes occur:

- Net primary production decreases with time because the first seral stages contain simple plants where by the food synthesized is not used in building up tissues like in trees.
- The standing biomass increases with time.
- The clear cut food chains emerge into food webs which become more and more complex with time.
- Nutrient cycles become established and more stable with time.
- Number of species increases with time.
- Stratification (different layers in space) of ecosystems becomes clear.
- Species composition changes and its more rapid in the pioneer or early Stages.
- Biomass and non-living organic matter increases.
- There is increased specialization in the trophic levels which become longer with up to five levels. Food webs become established from food chains.
- Primary productivity in the community reduce because of increased specialization.
- Total number of species represented in a community becomes fairly stable.
- Species diversity becomes high.
- The structure of the community change from simple to complex with many microhabitats and stratification.
- Niche specialization become narrow from being broad.
- The size of organisms become large.

r-SPECIES AND k- SPECIES.

The first species to colonise an area are known as r-species (opportunists) and the last species to colonise the land are known as the k-species (equilibrium species).

Examples of r-species.

Annual plants like the herbs, bacteria, paramecium, aphids, beetles etc.

Examples of the k-species.

Perenial plants, large birds, tropical butterflies, humans etc.

DIFFERENCES BETWEEN r-SPECIES AND k-SPECIES.

r-SPECIES.	***k- SPECIES***
➢ Reproduce rapidly. ➢ Reproductive rate not sensitive to population density to population density (i.e they do not stop producing when the number is large). ➢ Show significant population fluctuations. ➢ Are not very persistent in the environment. ➢ Are small in size. ➢ Disperse widely. ➢ Occupy short lived habitats e.g. Bacteria on rotting. ➢ Have shorter life cycle. ➢ Are poor competitors. ➢ Do not become dominant in an area.	➢ Reproduce slowly. ➢ Reproductive rate is sensitive to population density (they stop producing when the number is large) ➢ Population size is close to equilibrium. ➢ Are very persistent in the Environment. ➢ Larger in size. ➢ Do not disperse widely in an area. ➢ Occupy long lived habitats e.g. Trees in a forest. ➢ Have a longer life span. ➢ Are good competitors. ➢ They become dominant in an area.