Unit 3: Energy and the Environment

3.1 Modes of nutrition

Autotrophic and Heterotrophic nutrition

- *Understand the basic principles of Autotrophic and Heterotrophic modes of nutrition (no details of photosynthesis or digestion are required).*

Autotrophic nutrition: organisms prepare their own food.
Synthesise large complex organic molecules (glucose), using simple inorganic substances (CO_2 and H_2O) and energy(solar) from the environment.
Photosynthetic/ chemosynthetic.

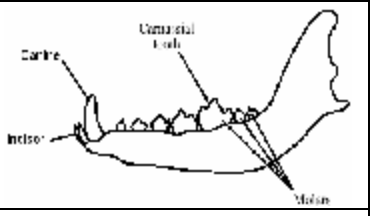
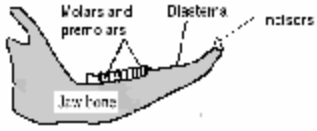
Heterotrophic: organisms cannot prepare their own food.
Obtain energy from the breakdown of complex readymade organic molecules, obtained from the environment. (holozoic, parasitic, saprobiontic)

Holozoic nutrition

- *Understand that holozoic nutrition involves the feeding on organic matter from the bodies of other organisms (no details of digestion are required)*

Holozoic nutrition is the feeding on organic matter from the bodies of other organisms. A complex digestive system is involved. It usually involves ingestion, digestion, absorption, assimilation and egestion. eg. humans.

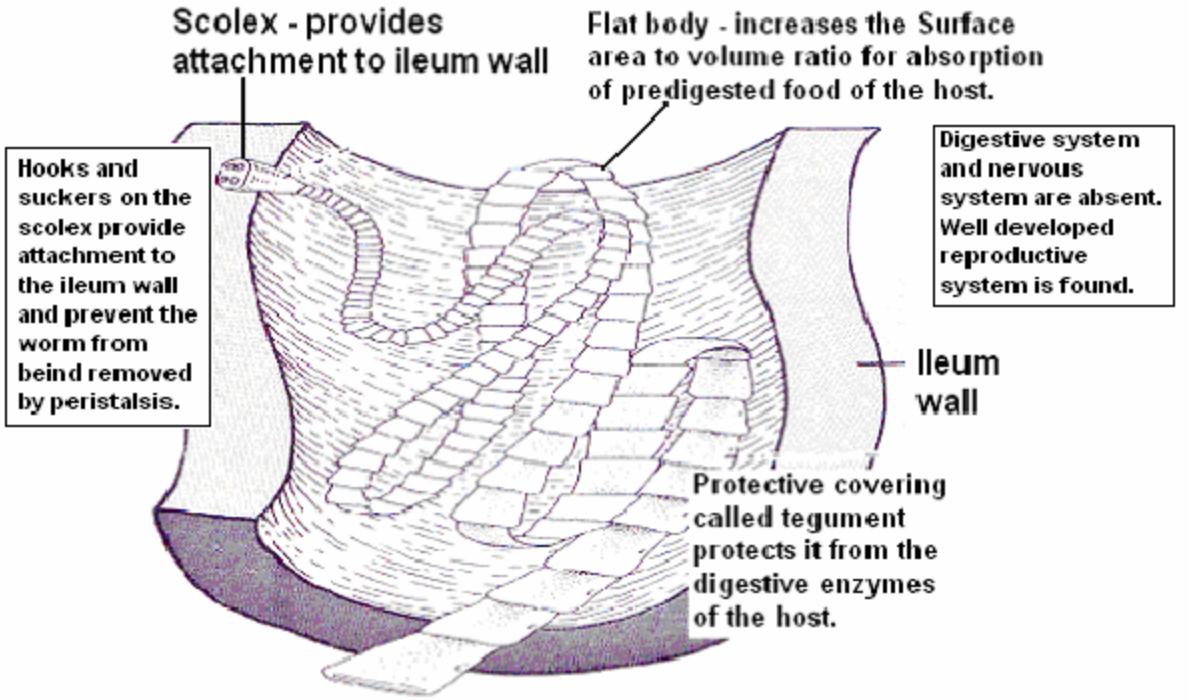
- *understand the adaptations of Herbivores and Carnivores to their diet, as illustrated by a named ruminant and a named carnivore.*

Herbivore/ Ruminant (sheep)	Carnivore/ Predators (dog)
Incisors and canines on lower jaw are used to crop leaves against a horny pad on upper jaw.	Sharp incisors to hold prey and remove flesh from bones.
Premolars and molars are broad and have raised cusps to grind leaves. 	Large pointed canines for holding prey and tearing flesh. 
Diastema (a gap between canines and premolars) is present to allow manipulation of the food bolus. 	Carnassial teeth (fourth premolar of upper jaw and first molar of lower jaw) are sharp to slice / cut flesh.
Loose jaw articulation allows sideways movement of lower jaw to enhance grinding of leaves.	Strong jaw muscles to hold and kill prey.
Rumen contains microorganisms to digest cellulose, which is a major component of the herbivore diet.	Sharp vision / claws make them efficient hunters.

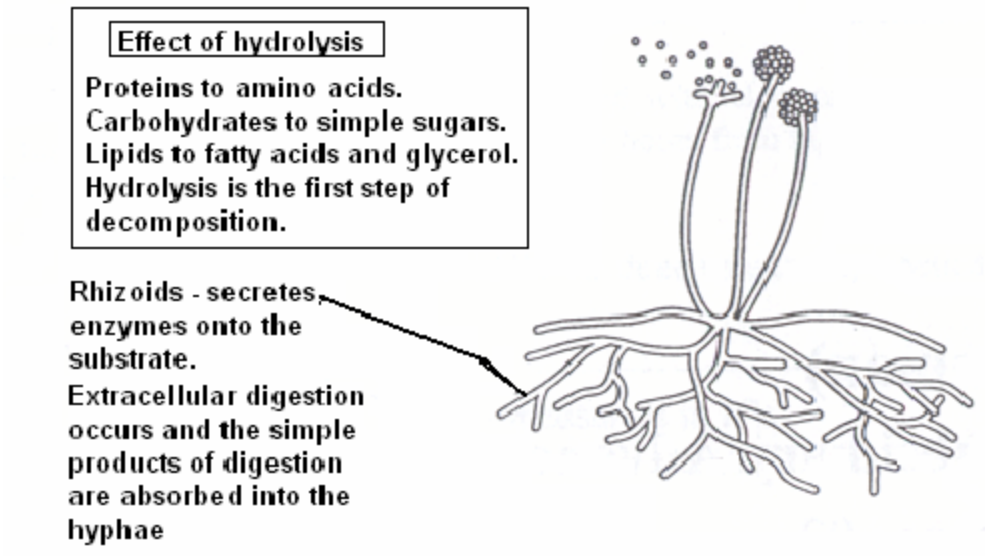
Saprobiontic and parasitic nutrition

? *Understand saprobiontic and parasitic modes of nutrition as illustrated by Rhizopus and Taenia (details of their life histories are not required)*

Parasitic mode of nutrition -obtains food from a living (human) host



Taenia – tapeworm, an endoparasite.

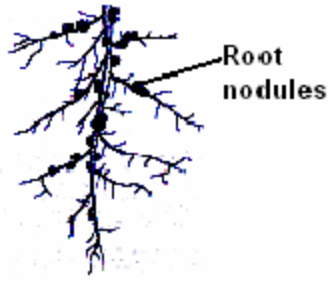


Saprobiontic mode of nutrition - obtains food from dead organic matter

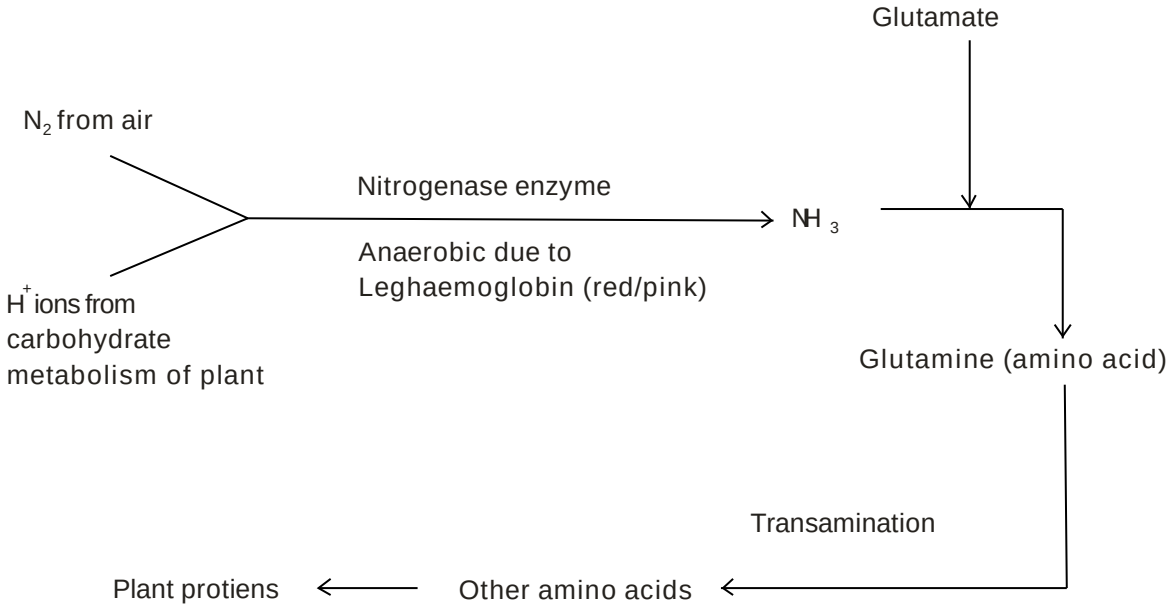
***Rhizopus* – a mould fungus**

Mutualism - nutrition

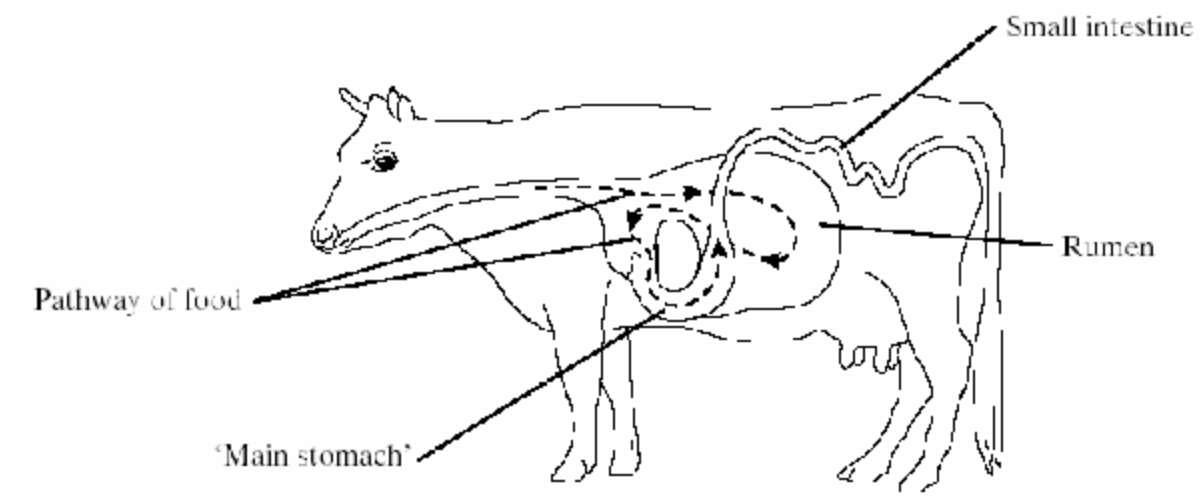
? *Understand mutualistic mode of nutrition as illustrated by Rhizobium with Papilionaceae and cellulose – digesting organisms in ruminant.*



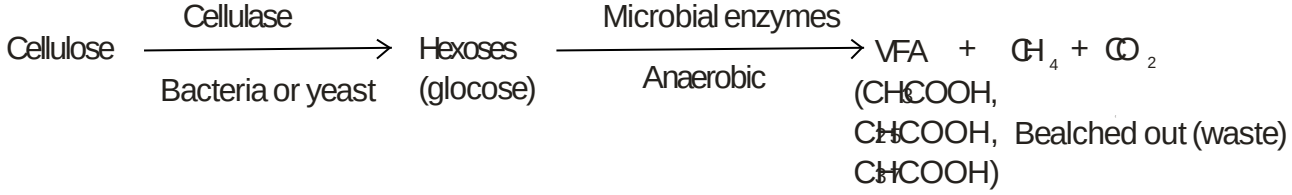
Rhizobium – Papilionaceae mutualism (both living together and benefiting each other)
Rhizobium (bacteria) lives in root nodules of Papilionaceae plants. Rhizobium benefits by getting carbohydrates from the plant. The plant benefits by obtaining ammonia produced by Rhizobium. Plant can survive in nitrogen deficient soil.



Cellulose digestion in ruminants (mutualism)



Bacteria and yeast present in rumen digest cellulose (a major component of the diet) for the herbivore



The VFA (Volatile Fatty Acids) are absorbed into the rumen and used by cow for carbohydrate and lipid metabolism. The microorganisms benefit by obtaining energy released from these reaction for their own metabolism.

3.2 Ecosystem

- *Recall the terms biosphere, ecosystem, habitat, producers, consumers and decomposers, trophic levels, food chains and food webs.*
- *Understand the role of producers, consumers and decomposers in food chains and food webs;*

Biosphere – part of the Earth and atmosphere where living organisms are found.

Ecosystem – the living world and its non-living environment. The biotic and abiotic factors interact with each other. Eg: Pond ecosystem, grassland ecosystem.

Habitat - a place where an organism lives. Eg: Pond, Grassland, Sea, Trees, etc.

Producers- prepare their own food by using solar energy and simple inorganic molecules like water and carbon dioxide from the environment. Convert solar energy into chemical energy/food. This food is the main source of energy for other trophic levels in food chains and food webs. Eg: all Green plants/algae.

Consumers- Organisms which obtain energy (and nutrients) from producers or other organisms. These organisms are found at the 2nd, 3rd or 4th trophic levels. Primary consumers are herbivores, secondary consumers are carnivores and feed upon primary consumers. Tertiary consumers feed upon secondary consumers. This ensures energy flow from one trophic level to another along the food chain.

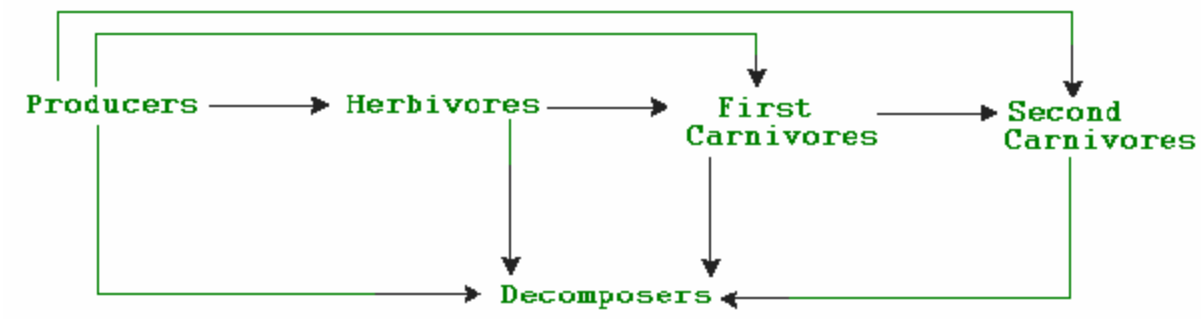
Decomposers- these are saprobiontic and break down large complex organic molecules, from the bodies of dead organisms, into simple inorganic molecules. This allows the *recycling of nutrients* (like C, N, P, S, etc) in nature. Eg: bacteria and fungi.

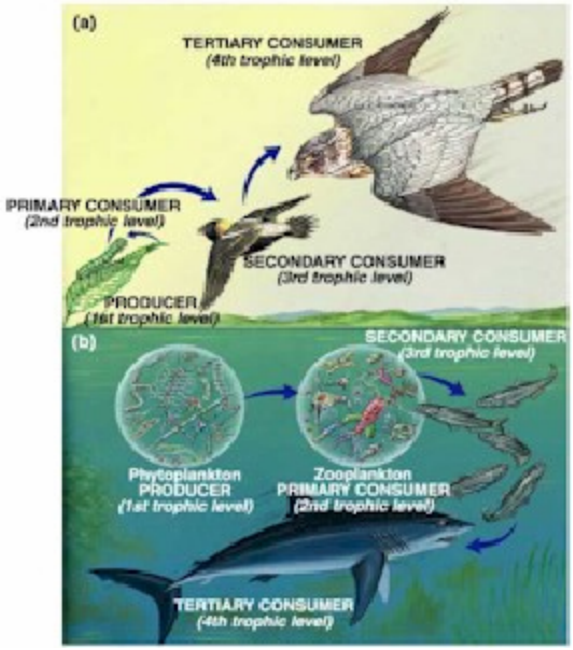
Trophic level- the feeding level of an organism in a food chain. Producers-1st trophic level, Herbivores- 2nd trophic level, Carnivores- 3rd trophic level.

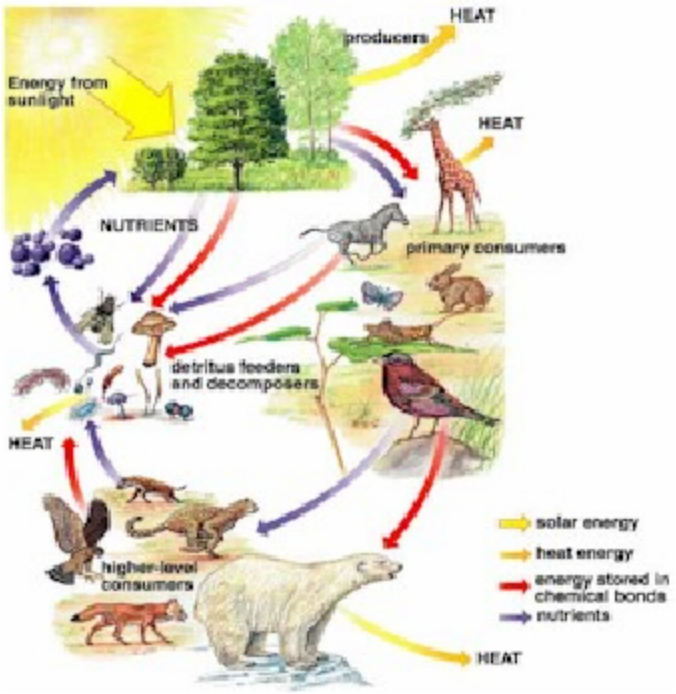
Food chain- shows the sequence of eating and being eaten. It represents the energy flow in an ecosystem. The generalized food chain is as below:

Producers → Primary consumers → Secondary consumers → Tertiary consumers

Food web- Many inter-linked food chains in an ecosystem.







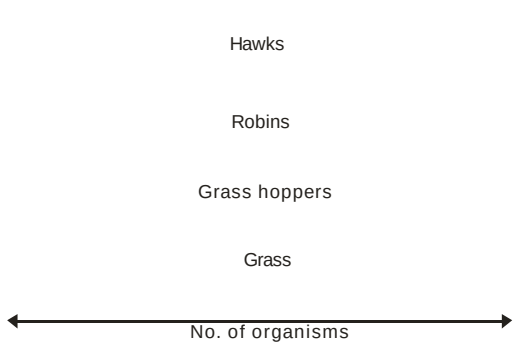
3.3 Energy flow

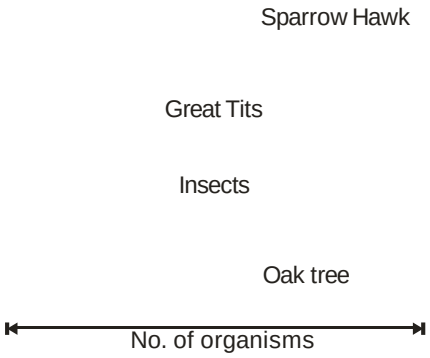
? *Recall that carbon dioxide and water are converted to Glucose and Oxygen, using energy from sunlight in photosynthesis and that light energy is absorbed by chlorophyll;*

$$\text{Carbon dioxide + Water} \xrightarrow[\text{Chlorophyll}]{\text{Solar energy}} \text{Glucose + Oxygen}$$

? *describe food chains quantitatively, using pyramids of numbers, biomass and energy.*

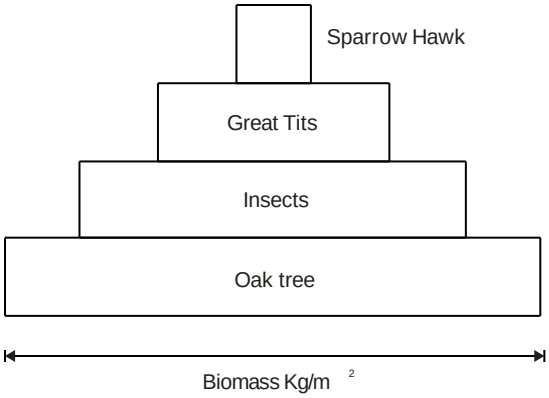
Pyramid of numbers- It is a graphical representation of the number of organisms at each trophic level. The number of producers are represented at the bottom and the numbers of organisms at higher trophic level are placed centrally above the lower trophic levels. The same scale must be used to represent each trophic level.

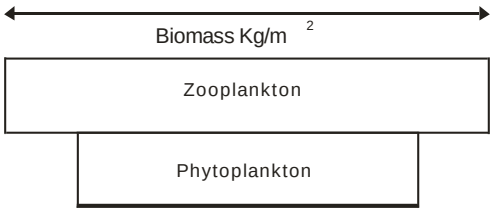




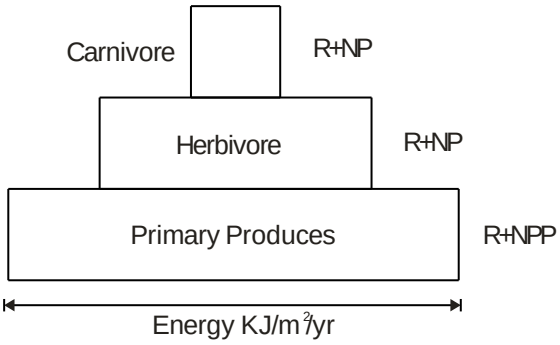
Pyramid of biomass- A graphical representation (drawn to scale) showing the biomass of each trophic level: Biomass is defined as the mass of organisms per unit area of ground (or water) at a given time, unit-tonnes/hectare or J/m^2 .

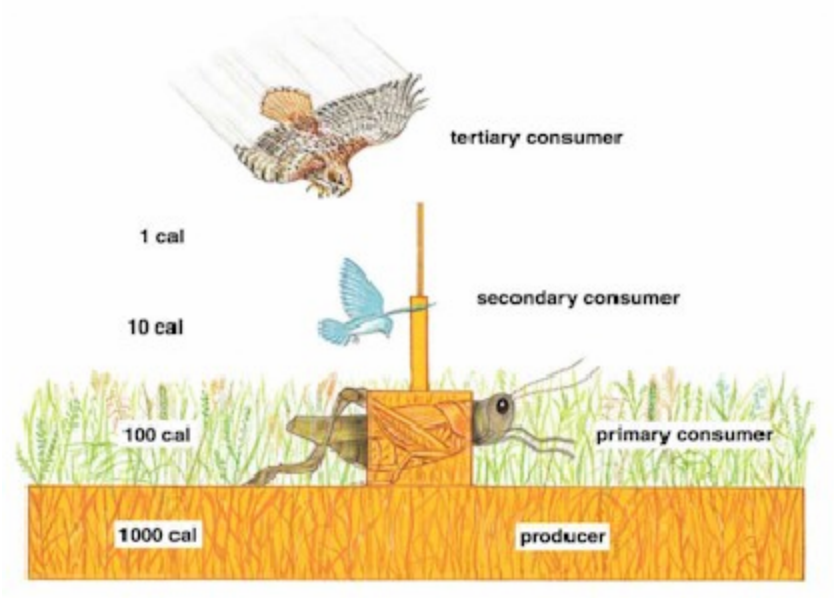
These pyramids are usually upright, but, sometimes they may be inverted, depending on the time of the year (inverted during winter, as primary productivity is low due to low temperature and light intensity), the continuous consumption by herbivores also contributes to the low biomass of producers. The high turnover rate (productivity) of phytoplankton prevents the population from being completely consumed by the larger herbivore population.





Pyramid of energy- A graphical representation (drawn to scale) showing the productivity for each trophic level in the ecosystem. Unit – KJ/m^2 yr. This is a true representation of the energy at each trophic level. It is *always upright*, unlike pyramid of numbers and biomass.





? *Understand how energy is transferred through food chains and food web and why energy is lost between trophic level*

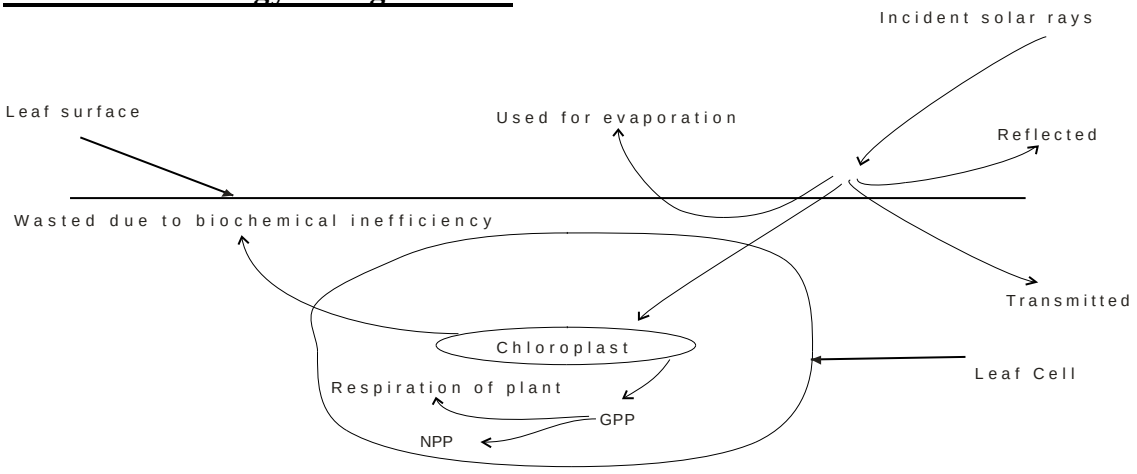
Energy flow from one trophic level to another and fate of energy within a trophic level.

The energy from plant biomass is transferred from one trophic level to the next in the form of organic compounds (food) along the food chains. There is a lot of energy lost between the trophic levels. The main reasons for energy loss are:

? Not all parts of the plants or animals are consumed by the next trophic level. Eg: roots bones, teeth, claws.
? All the consumed food is not assimilated in to the body. A large part remains undigested and is lost in faeces.
? A lot of the assimilated food is used up for respiration (R)
? Some energy is lost in urine.

- only about 10% of the food consumed is incorporated into biomass (NP). This is the energy which will be available for the next / higher trophic level.

Fate of solar energy falling on a leaf



Only about 1% of incident solar energy is utilised by plants

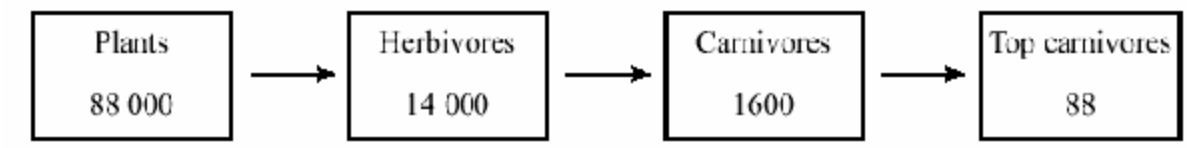
? *Understand the terms productivity, gross primary production and net primary production;*
? *Practical work to include the estimation of pyramids of numbers and of fresh biomass using simple techniques for the collection and determination of fresh mass.*

Gross primary production- the total amount of solar energy fixed by green plant during photosynthesis. Unit - KJ/m^2yr. This energy is used to make organic compounds. Some of these organic compounds get used up in respiration (R). The remaining organic compounds are used to produce plant biomass (NPP). This new plant biomass (NPP) is the energy available for consumption by the next trophic level (herbivores). (NPP - net primary productivity)

GPP = NPP + R

Primary productivity - It is the rate at which biomass is produced per unit area in an ecosystem. Unit – KJ/m^2yr.

Productivity (NP) - It is the measure of the energy content at each trophic level. It can be estimated from the biomass produced per year. Unit-KJ/m^2yr.

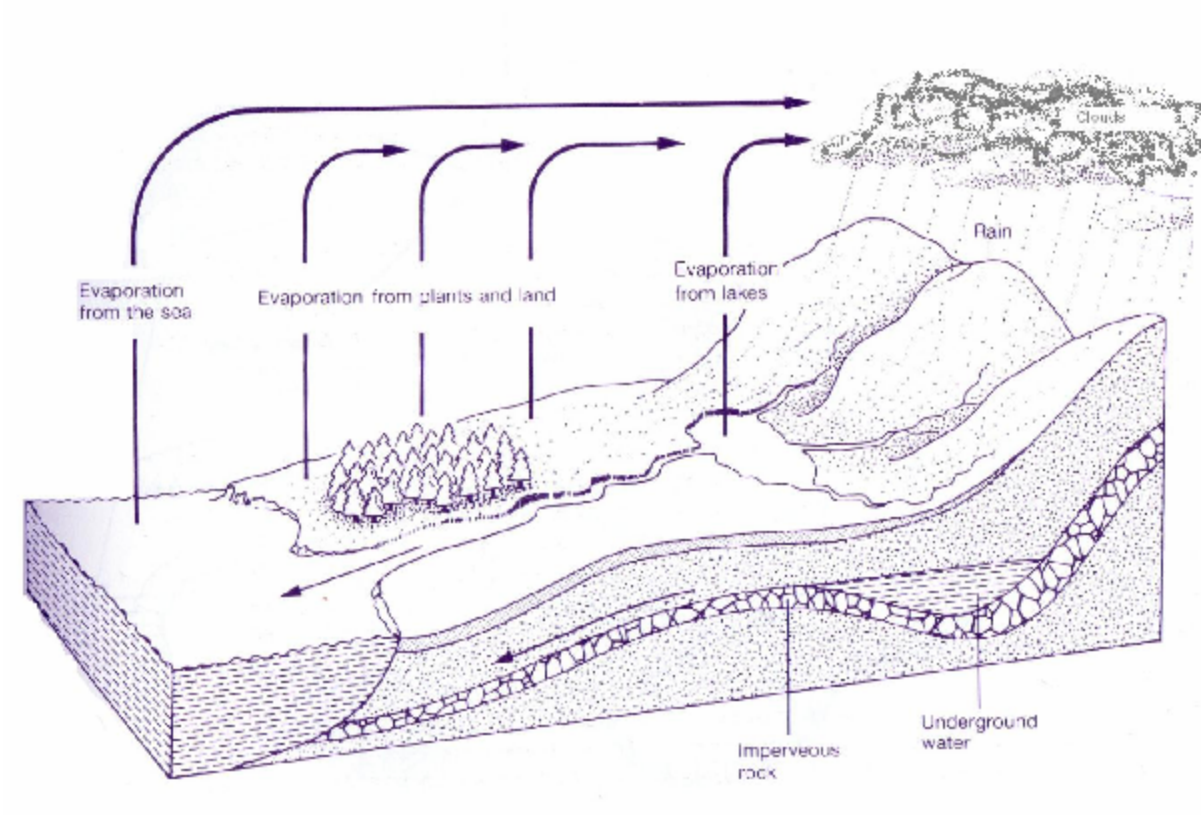


eg. the net primary productivity / NPP of the ecosystem above is 88,000 KJ/m^2yr. The productivity of the herbivores is 14,000 KJ/m^2yr and the productivity of the top carnivores is 88 KJ/m^2yr.

3.4 Recycling of nutrients

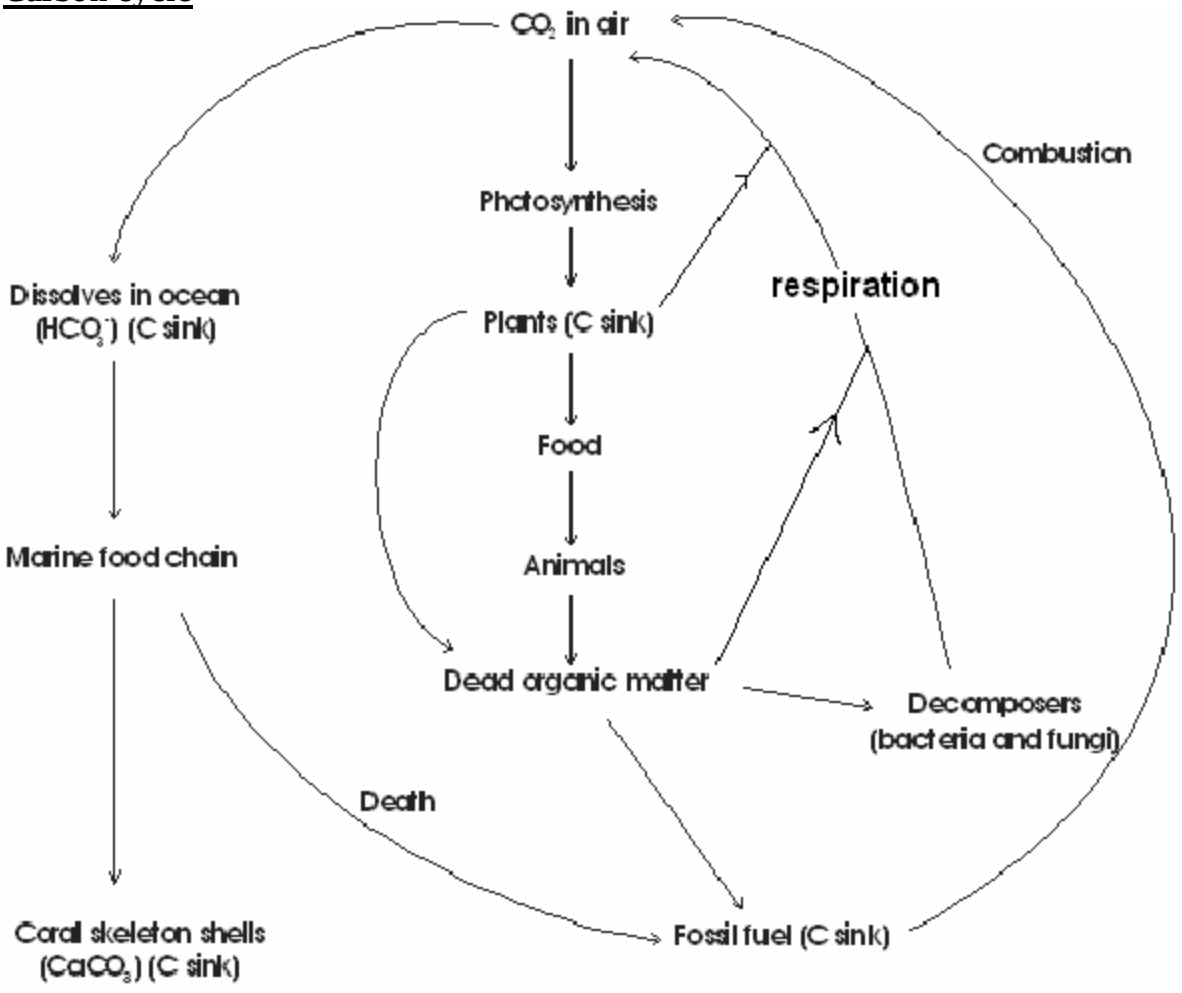
? *Recall the stages in the water cycle*;

Water cycle



? *Describe the stages in the carbon cycle and understand the role of microorganisms, carbon sinks and carbonates in the cycle;*
? *Understand how the carbon and nitrogen cycles are disrupted by human activities. Destruction of carbon sinks by combustion of fossil fuels or deforestation will increase carbon dioxide.*

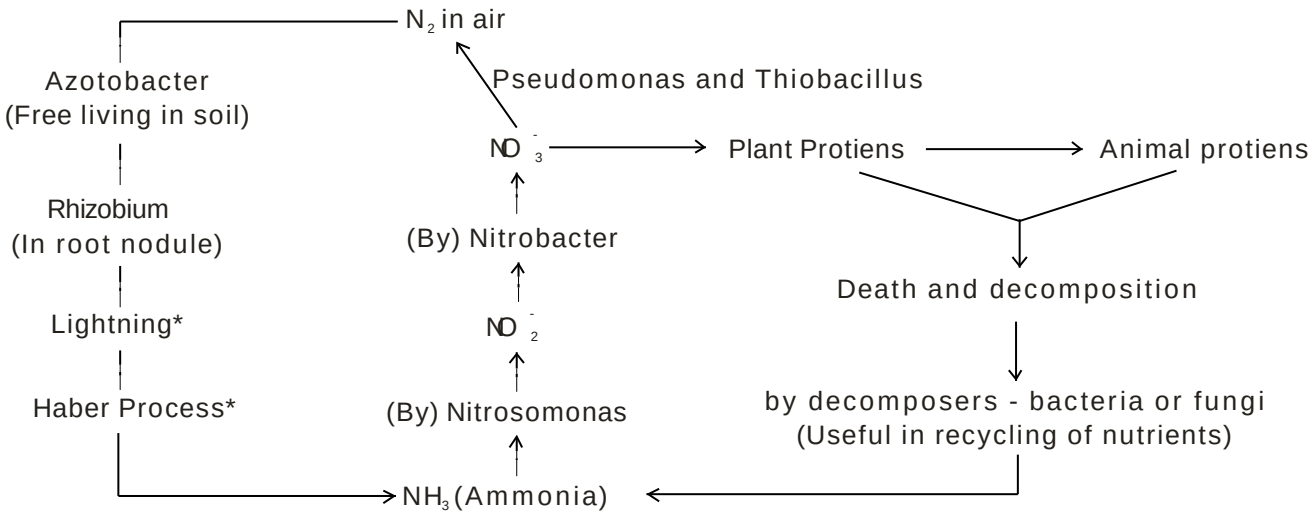
Carbon cycle



Carbon sinks remove Carbon dioxide from the atmosphere. This carbon remains trapped in the form of carbonates, wood of trees, fossil fuels and non biodegradable plastics for long periods of time. Destruction of carbon sinks by human activities (deforestation, burning of fossil fuels, burning of corals) has led to an increase in the level of carbon dioxide in the atmosphere. This is because carbon dioxide is released into the atmosphere faster than it can be removed.

? *Describe the stages in the nitrogen cycle and understand the role of microorganisms in the cycle as illustrated by decomposers, nitrifying bacteria (Nitrosomonas, Nitrobator), nitrogen-fixing bacteria (Rhizobium, Azotobacter), and denitrifying bacteria (Pseudomonas and Thiobacillus);*

Nitrogen cycle



Nitrogen fixation- Conversion of nitrogen gas into soluble Nitrogenous compounds like ammonia, which can be used by plants.

- **Nitrification**- Ammonia to nitrites and nitrates. This process is enhanced by the presence of oxygen in the soil - well aerated, well drained, loose soil.
- **Denitrification**- Nitrites/ Nitrates to nitrogen gas. Occurs in anaerobic conditions like water logged soil, clayey soil.
- Use of artificial fertilizers in the soil causes soil to lose it' s structure and water retaining capacity. This encourages leaching and subsequent eutrophication of water bodies. On the other hand, soil fertility enhanced by humus formation makes the soil retain more moisture and reduces leaching.

3.5 Energy resources

? *Understand how energy resources can be managed in a sustainable manner;*

Sustainability of fossil fuel

Sustainable management of energy resources.

- Increasing population / urbanization / industrial revolution has led to a great demand for energy. Most of the energy today is obtained from fossil fuels. Since fossil fuels are a non-renewable (exhaustible) source of energy, there is a need to take measures to make it last as long as possible (sustain it' s use).
- Sustainability can be brought about by **energy conservation** (increased used of public transport, switching off lights and fans when not in use), **more efficient use of energy** (developing fuel efficient engines) and by

the **use of renewable energy sources**. This also reduces the harmful environmental impact of fossil fuels (acid rain, global warming, oil spills).

? *describe the use of fossil fuels as illustrated by coal and oil;*

Use of coal & oil

Fossil fuels like coal and oil have been formed from biomass that was living million of year ago. Coal formed from vegetation which accumulated in peat beds in water-logged, anaerobic conditions. These get buried under sediments and slowly gets compressed into hard rock called coal (lithification). Petroleum has also formed from anaerobic decomposition of former organic matter, within sedimentary rocks of marine origin

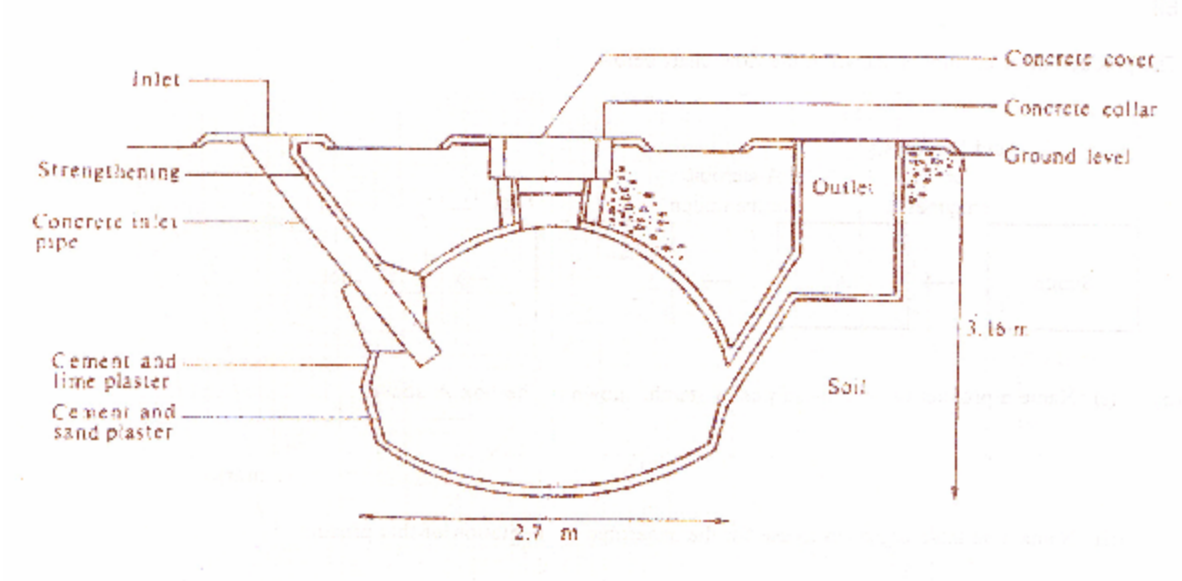
? The use of fossil fuels is preferred because they are relatively *cheap*, *easy to obtain, transport* and *store*. They also have a *high energy: mass ratio*.

? Disadvantages: exhaustible, non-renewable (cannot be formed / replaced quickly), cause air pollution (acid rain, global warming).

? *Describe the use of renewable energy sources, as illustrated by fast-growing biomass, gasohol from sugar, biogas from domestic and agricultural wastes.*

Biogas

Renewable energy resources occur naturally and can be replaced much faster than fossil fuels. This is mainly obtained from fresh fast-growing biomass.



Pig slurry/cow dung/kitchen waste (Proteins/lipids/carbohydrates) —Aerobic bacteria / (Hydrolysis)→ Sugars/amino acids/ fatty acids and glycerol

the digester tank should be air tight to maintain anaerobic condition & prevent escape of biogas. It is usually underground which provides thermal insulation and mechanical support.

Acetogenic bacteria | Anaerobic conditions

(Bio gas) Methane (CH_4) —Anaerobic conditions, low pH stimulate Methanogenic bacteria (obligate anaerobes)→ Acetic acid + CO_2 + H_2

$30^{\circ}C$ to $40^{\circ}C$

- **Advantages of biogas are**: It is a good way of producing cheap fuel (at the same time getting rid of organic waste). It is a renewable source of energy, which recycles carbon dioxide in a relatively short period of time.
- It does not contribute to acid rain as it produces only carbon dioxide & water vapour.
- It is a clean form of fuel. No soot/C dust is formed.

{Biomass is the total dry mass of organisms per unit area at a given time, Kg/m^2 or tonnes / hectare. The biomass is indication of energy available in the ecosystem at any given time KJ/m^2.}

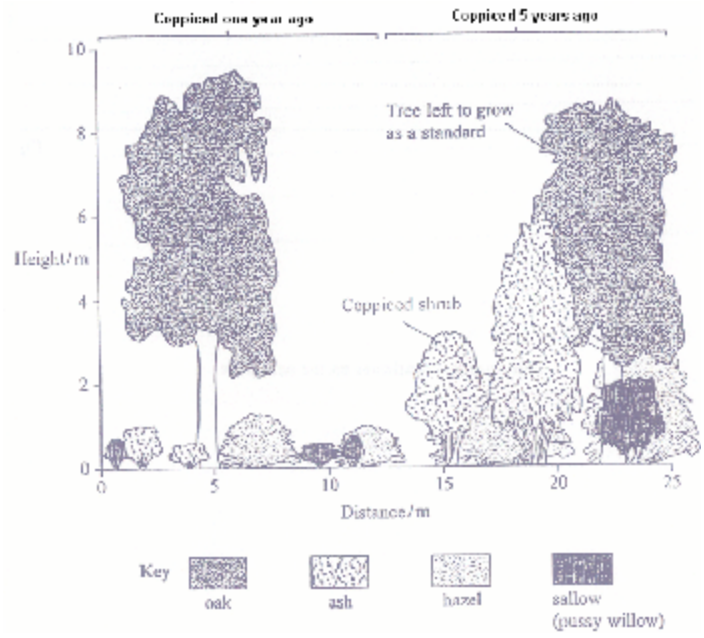
Straw/Hay/harvested stems of cereal crops.

Usually used for bedding and fodder for cattle. Excess can be burned in special boilers to generate electricity.

- Disadvantage: Difficult to collect, store & transport, as it is very bulky. Used to produce electricity in Denmark, USA and Britain.
- Advantage: low levels of sulphur.

NFFO (Non Fossil Fuel Obligation) – every powerhouse in UK has to produce some amount of electricity using a non fossil fuel source of energy. Most utilize wood from coppicing or straw.

Energy plantations (coppiced woodland)



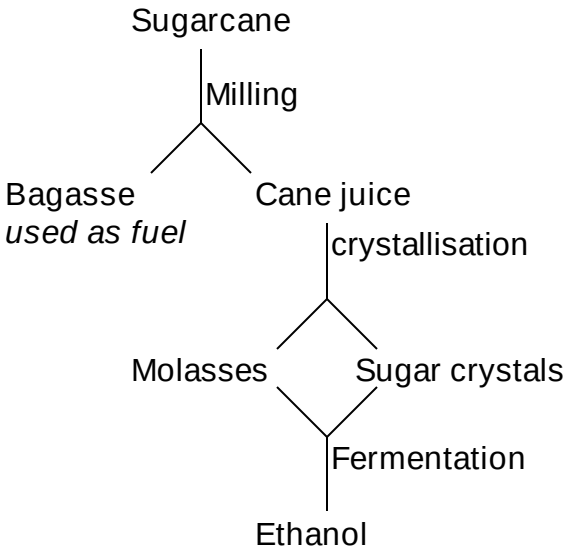
Wood can be an excellent source of renewable energy. Energy plantations provide a continuous supply of wood by *short – rotation coppicing*. Fast growing woody species, like willow and poplar, which are easy to propagate (grow from stem cuttings) and produce high yield, are planted closely and then cut off (coppiced) 2 to 3 feet above the ground, after 2 or 3 years. The stools (stumps) left behind in the ground produce many shoots (poles) which can be harvested every 2 to 5 years.

Miscanthus is a bamboo like grass which grows annually from Rhizomes, which can also be used as fuel.

- Energy plantations are useful as they recycle C, N, O, S in short periods – keeping levels constant, rather than releasing C removed from air long ago.
- Coppiced woodlands also increase biodiversity.

- Act as an alternative energy source, which helps to sustain the use of fossil fuels.

Gasohol - 80% unleaded petroleum spirit + 20% ethanol. Ethanol is mostly produced by fermentation of sugar by yeast (sacchoromyeces). Sugarcane, sugarbeat, maize, etc can be used to obtained ethanol.



- **Disadvantage:** Ethanol is uneconomic compared to petrol. Also a lot of land is needed to cultivate sugarcane. This land can be used for food crops.
- **Advantages**- it is a cleaner fuel (no S & N) so less pollution. Used extensively in Brazil when there was a petroleum crisis.
- Helps to sustain use of fossil fuels.

3.6 Human influences on the environment

- *Discus the causes and effects of deforestation and desertification with particular emphasis on communities, biodiversity and sustainable management;*

DEFORESTATION

Causes of deforestation: Deforestation is the permanent removal of trees and undergrowth. Some of the causes are:

- Removal of forests to obtain land for agriculture due to increase in human population.
- Supplying firewood as fuel.
- To obtain land for houses, industrial buildings, dams, roads (urbanisation).
- Removal of trees to obtain pulp for paper industries and wood for timber.
- Destruction of trees by atmospheric pollution (acid rain).

Effects of deforestation

- Increases soil erosion (as roots of plants bind soil / forests reduce wind speed / canopy prevents rain beating down on soil)

- ? Increases loss of nutrients from the soil through leaching (leading to eutrophication of fresh water bodies). Increases rate of surface run off causing rain water to run into streams or rivers rather than being held in soil).
- ? Loss/ reduction in biodiversity due to loss of habitats for many organisms.
- ? Some of the species that have become extinct might have proven to be useful to us.
- ? Reduction in biodiversity leads to a limited gene pool with less variation. This increases chance of extinction.

Sustainable management of forests (Balancing economic development and forest conservation)

- ? Forests need to be conserved rather than converted into agricultural and urbanised land. Moreover, barren land must be afforested (planting new forests). In places where forests are removed reafforestation (replanting forests) must be carried out.
- ? Forests are an important renewable resource. They provide building materials, fuel, paper, cocoa, palm oil, bananas, valuable drugs (like quinine – treatment of malaria, curare – an arrow poison, vincristine – a cancer treating drug, etc). Thus there is an important cause to conserve forests.

Some projects for sustainable management are:

- ➢ Discouraging deforestation.
- ➢ Encourage coppicing (Forest management and conservation technique).
- ➢ Promote agroforestry (interplanting of trees and crops)
- ➢ Promote ecotourism – attract visitors to natural forests to raise awareness for the need of conservation (awareness). This also provides local people a reason to preserve forests as tourism provide a source of income / livelihood.
- ➢ Promote afforestation and reafforestation

These activities allow people to reap the economic benefits of the forest and conserve the forests at the same time.

Biodiversity is a measure of the **species abundance** in an area

The index of diversity may be calculated from the formula

$$d = \frac{N(N-1)}{\Sigma n(n-1)}$$

where N = total number of organisms of all species
and n = total number of organisms of each species.

DESERTIFICATION: land degradation in arid and semi arid regions mainly due to human activities.

Causes

- ? Removal of vegetation (deforestation) for fuel, agriculture; by grazing of cattle. This causes soil erosion, leading to decreased soil fertility.

- Soil exposed to direct sunlight (vegetation is removed). Increased evaporation results in upward capillary movement of ground water and subsequent accumulation of salt in top layers of soil. This is called salination / salinisation. Excess salt is toxic to plants.
- Less vegetation causes decreased rainfall (decrease in transpiration) in an already semi arid / arid region to convert it into a desert (annual rainfall less than 250mm or 25 cm)

Effects: Desertification results from increased human population pressure on the semi arid Land. Degradation of land and drought causes starvation to people and their cattle, due to failure of crops and decreased rainfall.

Sustainable management: (Reversing desertification or preventing desertification of semi arid regions to sustain development of people and to maintain biodiversity)

- Terraced farming on slopes reduces the rate of surface run-off (reduces erosion).
- Planting Leguminous plants increase soil fertility and using stones to provide shade, reduce evaporation and trap moisture for seedlings (sub Saharan Africa).
- Digging furrows (trenches) in the ground traps wind blown seeds, moisture and provides shade for seedlings (in Australia)
- In Iran oil is sprayed on sand dunes to prevent blowing away of sand and seedlings. Drought resistant shrubs are then planted in narrow furrows.
- A thorough knowledge of plants suited to semi-arid conditions and the way they interact with soil has enable Kenya to plant more than 7 million tress in semi-arid regions.

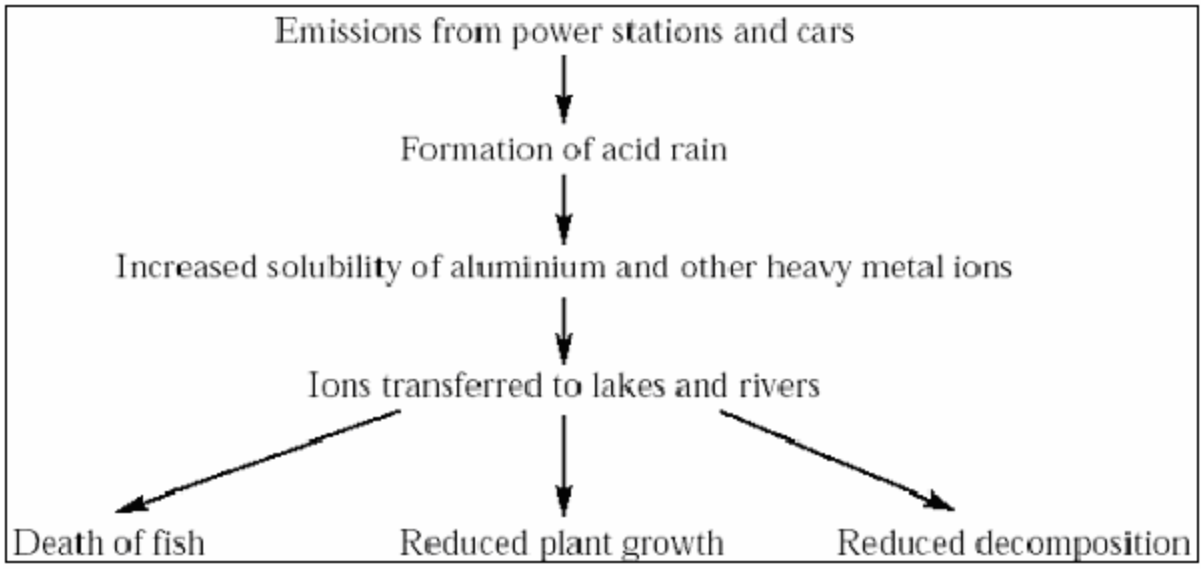
- *Describe the ecological impact of human activity on the environment, to include atmospheric pollution (acid rain and green house effect) and water pollution (effect of raw sewage and fertilizers on water quality oxygen content and biodiversity, eutrophication algal blooms);*

Atmospheric pollution: A change in the constitution of the atmosphere brought about by human (anthropogenic) activities, causing harm to humans or other living organisms in the environment.
The main impact of atmospheric pollution, due to human activity, takes place in the form of Acid rain and green house effect.

Acid rain pH below 5.0

Causes:

Burning fossil fuels releases nitrogen oxides / and sulphur dioxide. These gases dissolve in rain water in clouds to form Nitric acid, Nitrous acid, Sulphurous and Sulphuric acid. These acids are carried in clouds to long distances (eg: from UK to Norway) and the acid precipitation has harmful effects on plants, soil and animals.



Effects:

- Acid rain decreases pH of soil. Microorganism activity gets disturbed and recycling of nutrients decreases. This reduces nutrient content / fertility of soil. Plant growth decreases.
- Acid rain damages roots of plants, decreasing ion uptake. It also damage cuticle of leaves causing death of leaves (excess transpiration) (especially in conifers on mountain slopes . conifer become weak and susceptible to disease and drought)
- Acid rain causes leaking of Al^{3+} ions from soil into rivers and lakes. Al^{3+} ions excess secretion of mucous in gills of fishes, reducing gas and ions exchange, causing death.
- Acid rain inhibits the enzyme which causes hatching of fish and amphibian eggs. Reducing fish and amphibian population.
- Heavy metals in water cause diseases in humans. Mercury poisons the foetus, copper causes hair to turn greenish.

Green house effect

Short wave length solar radiation (400 to 700nm) penetrate atmosphere and are converted into longer wavelength radiation' s (4000 to 1000,000nm). These longer wavelength radiation' s are trapped by gases in atmosphere and radiated back to the earth. This prevents heat from escaping into space. This is called green house effect. The insulating gases are called green house gases. Eg: CO_2 , CH_4 , N_2O, CFCs, O_3 , H_2O. Green house effect is a natural phenomenon, necessary to maintain the earth' s atmosphere, Which would otherwise be about 30°C lower than today. However, human activities in recent years have led to an increase in release of green house gases. This may cause an increase in global temperatures. (Global warming)

Carbon dioxide

- ? Increase due to burning of fossil fuels
- ? Deforestation – less carbon dioxide absorbed
- ? Fluctuates in summer (more photosynthesis) and winter (less photosynthesis).

Has increase from 180ppm to 350ppm in least 160000years.

Methane: Produced in rumen of cattle, landfill sites and in marshes / swamps / bag by anaerobic fermentation of organic wastes, 21 times more effective than CO_2.

N_2O: By burning fossil fuels and decomposition of organic matter 206 times more effective than CO_2 as a green house gas.

CFCs: CF_2Cl_2 , $CFCl_3$ - synthetic aerosol used in refrigerators. 7000 times more effective than CO_2 lasts for 60 years in atmosphere. Use is banned by Montreal protocol of 1984.

O_3 (ozone) and H_2O vapor produced in internal combustion engines.

Effects: May cause sea level rise due to melting at polar ice caps and thermal expansion of ocean waters

- ? May increase primary productivity or can also increase the rate of evaporation of sea water.

Water pollution

The addition of substances which adversely affects the abiotic factors and biotic community of an aquatic ecosystem. The main source of water pollution are raw (untreated) sewage and fertilizers from agricultural lands.

Sewage: Domestic and industrial waste predominantly organic.

Composition and effect of sewage and fertilizers on water bodies

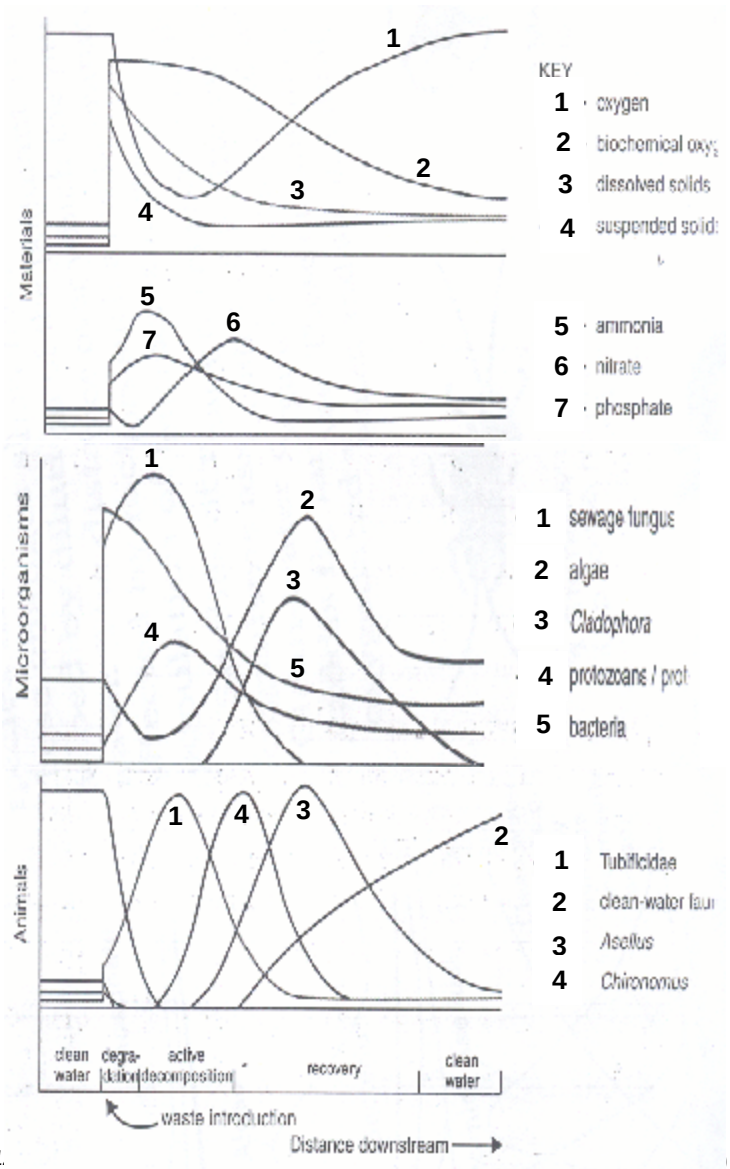
1. Organic solid/floating/ suspended: Reduces light penetration (No algae grow) less photosynthesis / less O_2 / more CO_2 / lower pH.
2. Phosphate – by decomposition of faeces and from fertilizers / soft detergents causes eutrophicaton by promoting algae blooms. Reach water bodies when fertilizers get leached into rivers.
3. Nitrogenous compounds / protein / amino acid / nucleic acids / NH_4^+ / NO_3^- in sewage and fertilizers.
4. Pathogens – Bacteria in drinking water causes diarrhoea, cholera, typhoid if water is taken from a river where untreated sewage is released.
5. Hard detergents (non-biodegradable) forms foams which reduces aeration & light penetration

Effects - proteins → NH_3/ NH_4^+ → NO_3^-

- NH_3/ NH_4^+ (toxic to fishes) ← Increase in pop^n of Microorganisms (decomposers)
- NH_3/ NH_4^+ → Nitrification → NO_3^-
- NO_3^- → absorbed by algae
- NO_3^- → increase in pop^n of decomposers, which use up dissolved O_2 (high BOD) → death of aquatic organisms due to lack of O_2 in water
- NO_3^- → Death of submerged plants and algae → less light penetration → algal blooms
- algal blooms → produces toxins which kill fishes.

Eutrophication: is the artificial nutrients enrichment of an aquatic ecosystem, NH_4^+, NO_3^- , PO_4^{3-} , K^+ causes growth of algae bloom

- ? At sewage outfall O_2 decreases as bacteria use up oxygen (high BOD). Downstream oxygen increases as there are less bacteria.
- ? Solid decreases as they are decomposed by bacteria into soluble compounds.
- ? Ammonia & Phosphates increase as they are products of decomposition.
- ? Ammonia converted to Nitrates (Nitrification) so NH_3 decreases & NO_3^- increases
- ? Nitrates & Phosphates are used up by algae for growth - algae blooms.
- ? Sewage fungus – tolerant to low O_2 & high NH_3 concentration
- ? Algal Population low as suspended solids block light. Downstream population increases as light penetration increases and concentration of NO_3^- and phosphates increase.
- ? Bacteria population is maximum where organic solids are high as they obtain food from these solids



Indicator species: Biological indicators of organic pollution. These species are arranged in order of the level of pollution they tolerate, where 1 lives in least polluted and 6 lives in the most polluted water. 4, 5 and 6 have special adaptations to survive in low oxygen concentrations. If a community of 4, 5 and 6 are found in an area then it is an indication that the oxygen concentration is low and the level of organic pollution is high. However it is more dependable to look for communities of indicators rather than populations.

1 Stonefly nymph
(up to 30 mm)

2 Mayfly larva
(up to 15 mm)

3 *Asellus*
(freshwater louse)
(up to about 12 mm)

4 Chironomid
(bloodworm; a midge larva)
(up to 20 mm)

5 Rat-tailed maggot larva
(up to 55 mm including
tube)

6 Tubifex
(sludge worm)
(up to 40 mm)

? *Be aware of European legislation to control air and water quality.*

European community (EC) directives of 1970s and EU in 1990s have defined and established objectives for air quality control to, '<u>avoid</u>, <u>prevent</u> or <u>reduce</u> harmful effects on human health and the environment as a whole' .Legislation aims at controlling level of pollutants in exhaust fumes and treatment of sewage and industrial wastes before emission into rivers and seas. Financial penalties offenders and incentives for good practice are implied.