ENVIRONMENTAL ISSUES

POLLUTION: It is an undesirable change in physical, chemical or biological characteristics of air, water, soil and land that has the potential to adversely affect human life, the lives of the desirable species, natural resources, industrial processes and cultural assets. Agents that bring about such an undesirable change are called as **pollutants.** In order to control environmental pollution, the Government of India has passed the **Environment (Protection) Act, 1986** to protect and improve the quality of our environment (air, water and soil).

CLASSIFICATION OF POLLUTANTS:

A). Based on the change or unchanged, pollutants can be of following types:

i) Primary Pollutants: Pollutants persisting in the environment in the form they are passed into it. e.g. DDT, CO_2, SO_2.

ii) Secondary Pollutants: Pollutants which are formed by reaction amongst the primary pollutants. e.g. O_3, PAN (Peroxy Acyl Nitrate). PAN are formed through reaction between nitrogen oxides and hydrocarbons in the presence of sunlight.

B). **Based on their degradability**, pollutants are of 2 types:

Biodegradable Pollutants	Non- Biodegradable pollutants
1. They are those pollutants which are decompose and degraded by microbes. 2. Biodegradable pollutants do not pile up. 3. They can be used to produce energy, manure, compost and biogas. e.g. Garbage, Sewage, Livestock waste.	1. The pollutants are not decomposed by microbes. 2. They often accumulate. 3. Some of them, if properly separated, can be recycled. Others are not manageable. e.g. DDT, BHC, Plastic, Glass, etc.

C. BASED ON THEIR NATURE OR QUANTITY:

i) Qualitative Pollutants: They are harmful products which function as pollutants due to their nature. They normally do not occur in the environment but are passed into it through human activity, e.g. DDT, Other pesticides.

ii) Quantitative Pollutants: They become pollutants only when their concentration reaches beyond a threshold value in the environment, e.g. CO, CO_2, Nitrogen oxides.

Q. *Which of the following is a quantitative pollutant?*

A) DDT B) Pesticides C) Fungicides D) CO_2

AIR POLLUTION: It is the addition of particles, gases and chemicals into the atmosphere that adversely affect human health, health of animals, vegetation, natural resources and human assets. Substances and factors which cause air pollution are called *air pollutants*.

Causes of Air Pollution:

1. Combustion of natural gas, petroleum, coal and wood.
2. Metallurgical processing (mineral dust, fumes containing fluorides, sulphides, etc)
3. Chemical industries including pesticides, fertilizers, weedicides, fungicides.
4. Welding, stone crushing, gem grinding, etc.
5. Processing industries like cotton textiles, wheat flour mills, asbestos.

AIR POLLUTION AND ITS CONTROL

i) Air pollutants cause injury to all living organisms. They reduce growth and yield of crops and cause premature death of plants.

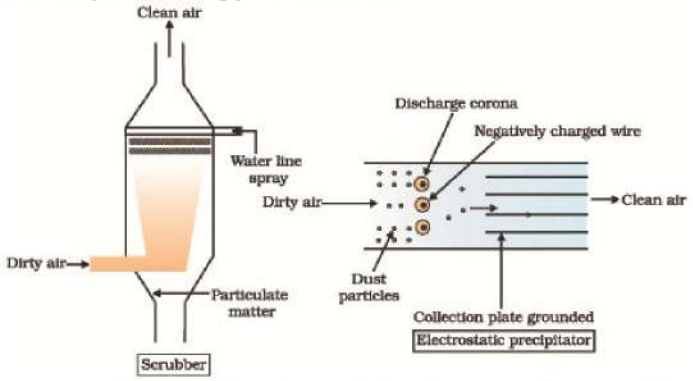
ii) Air pollutants also deleteriously affect the respiratory system of humans and of animals. Harmful effects depend on the concentration of pollutants, duration of exposure and the organism.

iii) Smokestacks of thermal power plants, smelters and other industries release particulate and gaseous air pollutants together with harmless gases, such as nitrogen, oxygen, etc.

These pollutants must be separated/filtered out before releasing the harmless gases into the atmosphere.

DEVICES FOR CONTROLLING AIR POLLUTION: There are several ways of removing particulate matter;

a) **Electrostatic precipitator:** The most widely used of which is the **electrostatic precipitator**, which can remove over 99 per cent particulate matter present in the exhaust from a thermal power plant. It has electrode wires that are maintained at several thousand volts, which produce a corona that releases electrons. These electrons attach to dust particles giving them a net negative charge. The collecting plates are grounded and attract the charged dust particles. The velocity of air between the plates must be low enough to allow the dust to fall.



b) **Scrubber**: A scrubber can remove gases like sulphur dioxide. In a scrubber, the exhaust is passed through a spray of water or lime. Recently we have realised the dangers of particulate matter that are very very small and are not removed by these precipitators. According to Central Pollution Control Board (CPCB), particulate size 2.5 micrometers or less in diameter (PM 2.5) are responsible for causing the greatest harm to human health. These fine particulates can be inhaled deep into the lungs and can cause breathing and respiratory symptoms, irritation, inflammations and damage to the lungs and premature deaths.

CATALYTIC CONVERTERS: Automobiles are a major cause for atmospheric pollution atleast in the metro cities. As the number of vehicles increase on the streets, this problem is now shifting to the other cities too. Proper maintenance of automobiles along with use of lead-free petrol or diesel can reduce the pollutants they emit. Catalytic converters, having expensive metals namely platinum-palladium and rhodium as the catalysts, are fitted into automobiles for reducing emission of poisonous gases. As the exhaust passes through the catalytic converter, unburnt hydrocarbons are converted into carbon dioxide and water, and carbon monoxide and nitric oxide are changed to carbon dioxide and nitrogen gas, respectively. Motor vehicles equipped with catalytic converter should use unleaded petrol because lead in the petrol inactivates the catalyst.

CONTROL OF VEHICULAR AIR POLLUTION:

(A) STEPS ADOPTED BY THE DELHI GOVERNMENT INCLUDE:

i) Switching over the entire fleet of public transport, i.e., buses, from diesel to **compressed natural gas (CNG)**. All the buses of Delhi were converted to run on CNG by the end of 2002.

ii) Phasing out of old vehicles,
iii) Use of unleaded petrol, use of low-sulphur petrol and diesel,
iv) Use of catalytic converters in vehicles,
v) Application of stringent pollution level norms (Euro – II norms) for vehicles, etc.

ACID RAIN: Acid rain is a rainfall with a pH of less than 5, generally 3 – 4.5. Acid rain is formed as

$2SO_2 + O_2 \longrightarrow 2SO_3$
$SO_3 + H_2O \longrightarrow H_2SO_4$
$2NO + [O] \longrightarrow N_2O_5$
$N_2O_5 + H_2O \longrightarrow 2HNO_3$

Sulphur dioxide and Nitrogen oxide are changed in the atmosphere into Sulphuric acid and nitric acid by combining with oxygen and water.

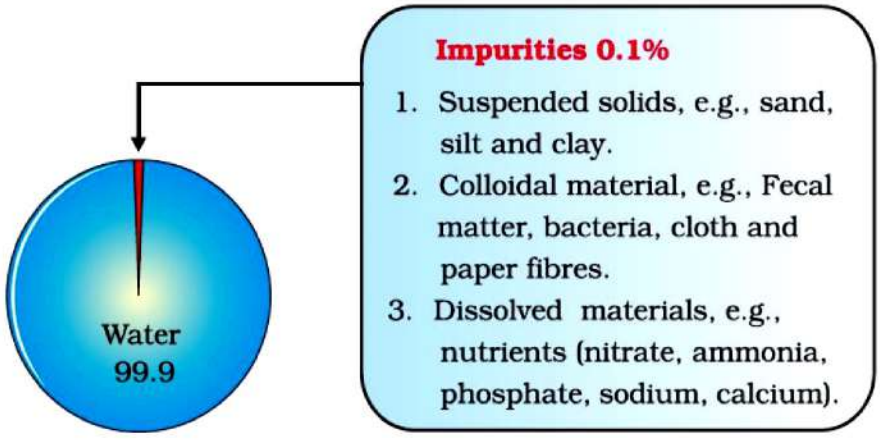
Effects of Acid Rain:
i) In plants, acid rain causes chlorosis, necrosis, defoliation, particularly at growing points.
ii) It causes leaching of essential minerals of soil.
iii) It kills many aquatic animals.
iv). Acid rain corrodes metals, marbles, painted surfaces, slate, stone, etc. The phenomenon is called stone leprosy.

(B) AUTO FUEL POLICY:
i) Through auto fuel policy, the Government of India has laid out a roadmap to cut down vehicular pollution in Indian cities.
ii) The goal is to reduce sulphur to 50 ppm in petrol and diesel and bring down the level to 35 per cent.
iii) According to Euro II norms, sulphur is to be controlled at 350 parts-per-million (ppm) in diesel and 150 ppm in petrol. Aromatic hydrocarbons are to be contained at 42 per cent of the concerned fuel.
iv) The Bharat Stage II (equivalent to Euro-II norms), which is currently in place in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra, will be applicable to all automobiles throughout the country from April 1, 2005.
v) All automobiles and fuel-petrol and diesel – were to have met the Euro III emission specifications in these 11 cities from April 1, 2005 and have to meet the Euro-IV norms by April 1, 2010. The rest of the country will have Euro-III emission norm compliant automobiles and fuels by 2010.

- As a result, the air quality of Delhi has significantly improved and there is a substantial fall in the level of sulphur dioxide and carbon dioxide.
- In India, the **Air (Prevention and Control of Pollution) Act** came into force in 1981, but was amended in 1987 to include noise as an air pollutant.

NOISE POLLUTION: **Noise** is undesired high level of sound. We have got used to associating loud sounds with pleasure and entertainment not realising that noise causes psychological and physiological disorders in humans. The bigger the city, the bigger the function, the greater the noise!! A brief exposure to extremely high sound level, 150 dB or more generated by take off of a jet plane or rocket, may damage ear drums thus permanently impairing hearing ability. Even chronic exposure to a relatively lower noise level of cities may permanently damage hearing abilities of humans. Noise also causes sleeplessness, increased heart beating, altered breathing pattern, thus considerably stressing humans.
Control: Reduction of noise in our industries can be affected by use of sound absorbent materials or by muffling noise. Stringent following of laws laid down in relation to noise like delimitation of horn-free zones around hospitals and schools, permissible sound-levels of crackers and of loudspeakers, timings after which loudspeakers cannot be played, etc., need to be enforced to protect ourselves from noise pollution.

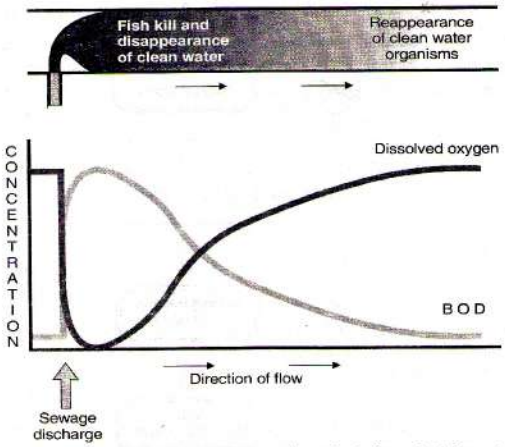
WATER POLLUTION: It is degradation of quality of water due to addition of substances, factors and deprivation that makes it health hazard, unfit for human use and growth of aquatic biota. A mere 0.1 per cent impurities make domestic sewage unfit for human use.



DOMESTIC SEWAGE AND INDUSTRIAL EFFLUENTS:
Domestic sewage primarily contains biodegradable organic matter, which are readily decomposed by –bacteria and other micro-organisms, which can multiply using these organic substances as substrates and hence utilise some of the components of sewage. It is possible to estimate the amount of organic matter in sewage water by measuring **Biochemical Oxygen Demand (BOD).**
Solids are relatively easy to remove, what is difficult to remove are dissolved salts such as nitrates, phosphates, and other nutrients, and toxic metal ions and organic compounds.

BIODEGRADATION: Decomposition of organic matter by microbes requires oxygen. Degree of impurity of water due to organic matter is measured in terms of B.O.D. **Biochemical oxygen Demand or B.O.D**. refers to the amount of dissolved oxygen needed by bacteria in decomposing the organic waste present in water. Micro-organisms involved in biodegradation of organic matter in the receiving water body consume a lot of oxygen, and as a result there is a sharp decline in dissolved oxygen downstream from the point of sewage discharge. This causes mortality of fish and other aquatic creatures.

Chemical Oxygen Demand or C.O.D. is the amount of oxygen required to oxidize all reducing substances present in water. Oxygen used up in B.O.D. or C.O.D. will reduce the amount dissolved oxygen (DO).



Effect of sewage discharge on some important characteristics of a river

B.O.D.	C.O.D.
1. It is amount of oxygen required for microbial decomposition of a unit mass of organic matter. 2. Only aerobic decomposer microbes are involved.	1. It is oxygen required for chemical oxidation of a unit mass of reduced organic and inorganic materials. 2. Chemical oxidants are involved.

EUTROPHICATION: Eutrophication is a nutrient enrichment of water body resulting in increased growth of algae, other plants and animals. Presence of large amounts of nutrients in waters (Eutrophication) also causes excessive growth of **planktonic** (free-floating) algae, called an **algal bloom** which imparts a distinct colour to the water bodies.

Algal blooms cause deterioration of the water quality and fish mortality. Some bloom-forming algae are extremely toxic to human beings and animals. (The excess growth of planktonic algae that causes colouration of water is called algal bloom). Algal bloom and floating plants cut off light from the submerged plant. The later dies. There is drastic decrease in O_2 replenishment inside water. Decrease O_2 level kills aquatic animals and further adding to organic loading.

In some cases, eutrophic water bodies support excessive growth of floating plants. Water hyacinth (*Eichhornia crassipes*) also called "***Terror of Bengal***" is one such plant that sometimes chokes ponds, lakes and rivers resulting in imbalance of ecosystem dynamics of water bodies.

Natural aging of a lake may span thousands of years. However, pollutants from man's activities like effluents from the industries and homes can radically accelerate the aging process. This phenomenon has been called **Cultural** or **Accelerated Eutrophication**.

Q. What is algal bloom? Give harmful effects of algal bloom in an aquatic body.

INDUSTRIAL EFFLUENTS: Waste waters from industries contain toxic heavy metals. Some of them and their effects are given below:

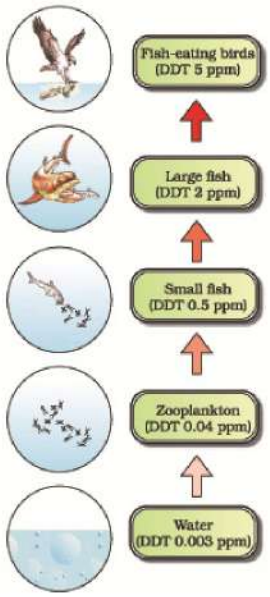
a) Mercury: It is changed to water soluble dimethyl mercury which undergoes biomagnifications. Eating poisoned animals causes deformity known as *minamata or minimata* disease which is characterized by diarrhea, haemolysis, impairment of various senses, numbness of lips, tongue, limbs, deafness, blurring of vision, mental dearrangement, meningitis and death.

b) Cadmium: It causes *itai-itai* (ouch-ouch) characterized by anaemia, hypertension, damaged to liver and kidney, diarrhea, etc.

c) Lead: It interferes with haem synthesis, oxygen and glucose metabolism. Harmful effects include anaemia, vomiting, loss of appetite, damage to liver and brain ,etc.

BIOMAGNIFICATION (BIOCONCENTRATION):

Biomagnification is increase in concentration of persistent pollutant (e.g. DDT) per unit weight of the organism with the rise in trophic level. It is caused by non-utilization of the substance in metabolism, accumulation of fat and non-breakdown by the decomposers. e.g. 0.003 ppm in water, 0.04 ppm in zooplankton, 0.5 ppm in small fish, 2 ppm in predator fish and 5 ppm in fish eating birds. Higher amounts of pesticide disturb calcium metabolism of birds resulting in thinning of egg shells and their premature breaking that kills the embryo.



Biomagnifications	Eutrophication
1. It is entry and increase in concentration of nonbiodegradable substances in food chains. 2. It is found in all types of ecosystems. 3. It does not result in organic loading. 4. There is no bloom formation. 5. It leads to toxicity in higher order consumers.	1. It is enrichment of the water body with plant nutrients. 2. It is found only in aquatic ecosystem. 3. It leads to organic loading. 4. Bloom formation occurs in eutrophic water. 5. It leads to death of most animals and plants.

Thermal Pollution: Heated (thermal) wastewaters flowing out of electricity-generating units, e.g., thermal power plants, constitute another important category of pollutants. Thermal wastewater eliminates or reduces the number of organisms sensitive to high temperature, and may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

A CASE STUDY OF INTEGRATED WASTE WATER TREATMENT:

Wastewater including sewage can be treated in an integrated manner, by utilising a mix of artificial and natural processes. The cleaning occurs in two stages –

(a) the conventional sedimentation, filtering and chlorine treatments are given. After this stage, lots of dangerous pollutants like dissolved heavy metals still remain. To combat this, an innovative approach was taken and

(b) the biologists developed a series of six connected marshes over 60 hectares of marshland. Appropriate plants, algae, fungi and bacteria were seeded into this area, which neutralise, absorb and assimilate the pollutants. Hence, as the water flows through the marshes, it gets purified naturally.

SOLID WASTES: Solid wastes refer to everything that goes out in trash. **Municipal solid wastes** are wastes from homes, offices, stores, schools, hospitals, etc., that are collected and disposed by the municipality. The municipal solid wastes generally comprise paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc.

Disposal of Solid Wastes:

i) Municipal solid wastes are burnt to reduce the volume of the wastes, but they are generally not burnt to completion and open dumps often serve as the breeding ground for rats and flies.

ii) **Sanitary landfills** were adopted as the substitute for open-burning dumps. In a sanitary landfill, wastes are dumped in a depression or trench after compaction, and covered with dirt everyday.

iii) Municipal wastes are incinerated and the heat emitted is used to generate electricity; they are also recycled for various components.

iv) e-wastes are buried as landfills or incinerated; they are also recycled. Recycling in an environment- friendly way is the only solution for e-wastes.

v) The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown. That leaves only the non-biodegradable to be disposed off.

AGROCHEMICALS: The two types of pollutant agrochemicals are pesticides and fertilizers. They not only change chemical properties of soil, but also affect soil organisms, surface water and ground water resources.

Pesticides: Most pesticides are broad spectrum, killing most of the organisms. They therefore, are called biocides. Many of them are also persistent.

Case Study of Organic Farming: Integrated organic farming is a cyclical, zero-waste procedure, where waste products from one process are cycled in as nutrients for other processes. This allows the maximum utilisation of resource and increases the efficiency of production. Ramesh Chandra Dagar, a farmer in Sonipat, Haryana, is doing just this. He includes bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes, which support each other and allow an extremely economical and sustainable venture. There is no need to use chemical fertilisers for crops, as cattle excreta (dung) are used as manure. Crop waste is used to create compost, which can be used as a natural fertiliser or can be used to generate natural gas for satisfying the energy needs of the farm. Enthusiastic about spreading information and help on the practice of integrated organic farming, Dagar has created the Haryana Kisan Welfare Club, with a current membership of 5000 farmers.

Case Study of Remedy for Plastic Waste: A plastic sack manufacturer in Bangalore has managed to find the ideal solution to the ever-increasing problem of accumulating plastic waste. Ahmed Khan, aged 57 years old, has been producing plastic sacks for 20 years. About 8 years ago, he realised that plastic waste was a real problem. Polyblend, a fine powder of recycled modified plastic, was developed then by his company. This mixture is mixed with the bitumen that is used to lay roads. In collaboration with R.V. College of Engineering and the Bangalore City Corporation, Ahmed Khan proved that blends of Polyblend and bitumen, when used to lay roads, enhanced the bitumen's water repellent properties, and helped to increase road life by a factor of three. The raw material for creating Polyblend is any plastic film waste. So, against the price of Rs. 0.40 per kg that rag pickers had been getting for plastic waste, Khan now offers Rs.6. Using Khan's technique, by the year 2002, more than 40 kms of road in Bangalore has already been laid. At this rate, Khan will soon be running short of plastic waste in Bangalore, to produce Polyblend.

Electronic Wastes: Irreparable computers and other electronic goods are known as **electronic wastes** (**e-wastes**). E-wastes are buried in landfills or incinerated. Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process. Unlike developed countries, which have specifically built facilities for recycling of e-wastes, recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-wastes. Eventually recycling is the only solution for the treatment of e-wastes provided it is carried out in an environment-friendly manner.

GLOBAL ENVIRONMENTAL CHANGES:

GREEN HOUSE EFFECT: It is warming effect found in green house by allowing solar radiations to pass in but preventing long wave heat radiations to pass out due to glass panes, water vapours and CO_2. The gases which are transparent to solar radiation but retain and partially reflect back long wave heat radiations are called green house gases (GHGs). Without greenhouse effect the average temperature at surface of Earth would have been a chilly -18^0C rather than the present average of 15^0 C.

Global warming is the rise in mean temperature of the lower atmosphere and surface of the earth.

Causes:

1) CO_2:– It contributes 60% to global warming. It is due to excess combustion of fossil fuel, biomass burning and deforestation.

2) CH_4:– It contributes 20% to global warming. The major sources are paddy fields, enteric fermentation in cattle and wetlands.

3) CFCs:- They are synthetic compounds of carbon and halogens used in aerosols, refrigeration, foaming, cleaning etc. It contributes 14% to global warming.

4) Nitrous Oxide:- It comes from burning of nitrogen rich fuel. It contributes 6% to global warming.

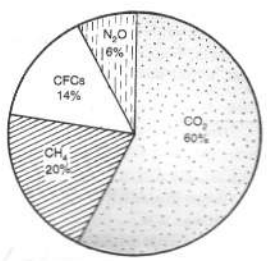


Fig: Contribution of different gases to green house effect

EFFECTS OF GLOBAL WARMING:-

1) Effects on atmosphere:- Warming of troposphere is accompanied by cooling of the upper strata of atmosphere. Cooling in the stratosphere will tend to increase the size of ozone holes.

2) Effect on weather and climate:- Moisture carrying capacity of air will increase. Pattern of air-mass movement will change. Precipitation will increase at higher latitudes. Frequency of droughts and floods will increase.
3) Changes in sea level:- Rise in temperature will raise sea level due to thermal expansion of sea water, melting of glaciers and Greenland ice sheets.
4) Food production:- Small temperature rise may increase crop productivity in temperate areas but higher temperature rise will be detrimental due to increase in respiration greater growth of weeds, eruption of diseases and pests. Therefore, despite increase in CO_2 fertilization, the overall crop productivity will be reduced.
5) Effects on range of species:- Rise in temperature of 2-5^0 C will push temperate range by some 250-600 Km pole wards. Many tree species and others which are sensitive to temperature will die out.
OZONE DEPLETION: The region of stratosphere where ozone is present is called as ozone layer. Ozone which is found in the lower atmosphere (troposphere) is called bad ozone that harms plants and animals. There is 'good' ozone also; this ozone is found in the upper part of the atmosphere called the **stratosphere**, and it acts as a shield absorbing ultraviolet radiation from the sun. UV rays are highly injurious to living organisms since DNA and proteins of living organisms preferentially absorb UV rays, and its high energy breaks the chemical bonds within these molecules. Thickness of ozone is measured in Dobson Unit (D.U.).
Ozone Hole: It is not an actual hole but an area of extreme reduction in ozone concentration in the ozone shield.
Certain substances react with ozone present in the stratosphere and destroy the same. They are called Ozone Depleting Substances (ODS). The major ODS are Chloroflurocarbons (CFCs), Halons, N_2O, CH_4, Chlorine, CCl_4, methyl bromide, etc.

A large amount of ODS like CFCs, Halons, N_2O, CH_4, Chlorine, CCl_4, Cl^- are released by advanced countries like USA, Japan, European countries. These are released in the stratosphere, drift towards poles and reach there before coming winter. During winter (temperature 8.5^{0}C) ice clouds are formed over Antarctica and no sunrise is received in polar areas. It catalyses release of Cl from CFCs. With the coming of spring season, Cl reacts with ozone in the presence of sunlight and converts O_3 causing ozone depletion/thinning of ozone shield in the stratosphere called ozone hole. This hole disappears in the summer due to free mixing of air Antarctica with the rest of global air.
Q. Why does ozone hole form over Antarctica? How will enhance Ultraviolet radiation affect?
EFFECTS OF OZONE DEPLETION:
1. Skin Cancer: UV-B radiation damage skin cells and cause ageing and skin cancer.
2. Blindness: Cornea absorbs UV-B radiations and become swollen. It is called Snow blindness cataract.
3. Immune System: It is partially suppressed. Incidence of herpes and other immune related diseases are likely to increase.
4. Phytoplankton: Both photosynthetic activity as well as function of phytoplankton are disturbed by UV-radiation.
5. Photosynthesis: Photosynthetic machinery is impaired. Photosynthesis decreases by 10-25%. There is a corresponding fall in crop yields.
6. Global Warming: Decrease photosynthetic activity will increase CO_2 concentration of the atmosphere resulting in global warming.

- Recognising the deleterious affects of ozone depletion, an international treaty, known as the **Montreal Protocol**, was signed at Montreal (Canada) in 1987 (effective in 1989) to control the emission of ozone depleting substances. Subsequently many more efforts have been made and protocols have laid down definite roadmaps, separately for developed and developing countries, for reducing the emission of CFCs and other ozone depleting chemicals.

RADIOACTIVE WASTES**:** Nuclear energy has two very serious problems -
i) The first is accidental leakage, as occurred in the Three Mile Island and Chernobyl incidents and
ii) the second is safe disposal of radioactive wastes.
a) Radiation from nuclear waste is extremely damaging to biological organisms, because it causes mutations to occur at a very high rate.
b) At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders, the most frequent of all being cancer. Therefore, nuclear waste is an extremely potent pollutant and has to be dealt with utmost caution.
DEGRADATION BY IMPROPER RESOURCE UTILISATION AND MAINTENANCE:
The degradation of natural resources can occur, not just by the action of pollutants but also by improper resource utilisation practices.
1) **Soil erosion and desertification**: The development of the fertile top-soil takes centuries. But, it can be removed very easily due to human activities like over-cultivation, unrestricted grazing, deforestation and poor irrigation practices, resulting in arid patches of land. When large barren patches extend and meet over time, a desert is created. Internationally, it has been recognised that desertification is a major problem nowadays, particularly due to increased urbanisation.
2) **Water-logging and soil salinity**: Irrigation without proper drainage of water leads to water-logging in the soil. Besides affecting the crops, water-logging draws salt to the surface of the soil. The salt then is deposited as a thin crust on the land surface or starts collecting at the roots of the plants. This increased salt content is inimical to the growth of crops and is extremely damaging to agriculture. Water-logging and soil salinity are some of the problems that have come in the wake of the Green Revolution.
DEFORESTATION: It is the conversion of forested areas to non-forested ones. It is estimated that almost 40 percent forests have been lost in tropics, compared to only 1 per cent in the temperate region.

Deforestation	Desertification
1. It is removal, decrease or deterioration of forest cover of an area.	1. It is conversion of former moist and fertile land into arid desert area.
2. Rainfall decreases to only minor extent.	2. Rainfall is less than the potential evaporation.
3. It leads to soil erosion.	3. Desertification is a product of soil erosion.

Causes of deforestation:
1) Shifting Cultivation: It is slash and burn agriculture and technically known as shifting cultivation. In India about 5 lakh hectares of land is cleared every year through lopping, burning the remainder, mixing the ash with soil and sowing the cleared land with crop seeds. This practice is called "*Jhum cultivation*" in north east. This destroys forests and causes soil erosion.
2) Hydroelectric Projects: Dams, reservoirs and hydroelectric projects submerge forest tracts, killing all plants and animals.
3) Human Establishments: There is an even increasing demand for agricultural land in order to grow more food crops for feeding growing human population which can be done only through clearing forest areas.
4) Mountain and Forest Roads: Construction of roads and railways in the hilly forested areas brings about a lot of deforestation, landslides and soil erosion.
Effects of Deforestation:
i) Climate: Deforestation results in reduced rainfall, increased drought, hotter summers and colder winters.
ii) Soil Erosion: Soil is exposed to insolation, dries up and gets.
iii) Loss of Biodiversity and Germplasm: In drier areas deforestation leads to desertification.
iv) Global Warming: Deforestation increases atmospheric CO_2 content by releasing carbon stored in organic matter and reduced primary productivity.

Afforestation	Agroforestry
1. It is planting of trees over bare area. 2. Afforestation completely covers the area. 3. All types of trees are grown during afforestation.	1. It is plantation of trees over agriculture land. 2. Woody plants cover the land partially as they are grown in combination of herbaceous crops either at the same time or in time sequence. 3. Mostly multipurpose trees are grown in agro-forestry.

30.Give three differences between afforestation and agroforestry. 3(2010, CoHSEM)

Reforestation is the process of restoring a forest that once existed but was removed at some point of time in the past. Reforestation may occur naturally in a deforested area. However, we can speed it up by planting trees with due consideration to biodiversity that earlier existed in that area.

PEOPLE'S PARTICIPATION IN CONSERVATION OF FOREST:

1). A Bishnoi woman of Khejari village, Rajasthan named Amrita Devi showed exemplary courage by hugging a tree and daring king's men to cut her first before cutting the tree. Nowhere in history do we find a commitment of this magnitude when human beings sacrificed their lives for the cause of the environment.

2) Chipko Movement: It is movement which was initially meant for protecting trees but not meant for preservation of environment including habitat and wildlife. Chipko movement was born in March 1974 in Gopeshwar in Chamoli district. The movement has two leaders, Chandi Prasad Bhatt of Gopeshwar and Sunder Lal Bahugana of Silyara in Tehri region. In 1974, local women showed enormous bravery in protecting trees from the axe of contractors by hugging them. People all over the world have acclaimed the Chipko movement.

3). Government of India in 1980s has introduced the concept of Joint Forest Management (JFM) so as to work closely with the local communities for protecting and managing forests. In return for their services to the forest, the communities get benefit of various forest products (e.g., fruits, gum, rubber, medicine, etc.), and thus the forest can be conserved in a sustainable manner.

El Nino is an abnormal weather pattern that is caused by the warming of the Pacific Ocean near the equator, off the coast of South America.

Consequences of El Nino:

i) In South America, there is a drastic increase in the risk of flooding on the western coast, while there is an increase in the risk of droughts on parts of the eastern coast.

ii) In eastern countries, like India and Indonesia, there is an increase in droughts.

iii) In general, El Nino causes vast amounts of rainfall in the eastern parts of the Pacific (the western coast of South America), and very dry weather on the western parts (India, Indonesia).

iv) With all the extra heat at the surface of the Pacific Ocean, energy is released into the atmosphere, causing an overall warming of the global climate temporarily. Years in which El Niño occurs tend to feature higher temperatures across the globe.

v) The effects of El Niño on the weather peak in December and can last for several months after that.

*****

Q.1. What are the various constituents of domestic sewage? Discuss the effects of sewage discharge on a river.

Q.2. List all the wastes that you generate, at home, school or during your trips to other places, could you very easily reduce? Which would be difficult or rather impossible to reduce?

Q.3. Discuss the causes and effects of global warming. What measures need to be taken to control global warming?

Q.4. Write critical notes on the following:

(a) Eutrophication (b) Biological magnification (c) Groundwater depletion and ways for its replenishment

Q.5. Why ozone hole forms over Antarctica? How will enhanced ultraviolet radiation affect us?

Q.6. Discuss the role of women and communities in protection and conservation of forests.

Q.7. What measures, as an individual, you would take to reduce environmental pollution?

Q.8. Discuss briefly the following: (a) Radioactive wastes (b) Defunct ships and e-wastes (c) Municipal solid wastes

Q.9. What initiatives were taken for reducing vehicular air pollution in Delhi? Has air quality improved in Delhi?

Q.10. Discuss briefly the following:

(a) Greenhouse gases (b) Catalytic converter (c) Ultraviolet B

Q.11 Suggest two measures to control noise pollution. (CBSE,2012) 2

Q.12. In an industrial area of fossil fuels, an old palace made of marble is getting damaged. What could be the possible cause for it?

Q.13."Air pollution can change climate". Give your comments by giving one points only. 1 (CoHSEM,2009)

Q.14.What will happen if ozone layer is totally depleted? Give one point. 1

Q.15.Explain three main steps to check global warming. 3

Q.16. If there was no CO_2 in the earth's atmosphere, the temperature of the earth's surface would be

(A) Higher than the present (B) Less than the present

(C) Same as the present (D) Dependent on the amount of other GHGs.

Q.17. Name one device for controlling Air-pollution. 1

Q.18. Write about the effect of Global warming on food-production. 3

Q.19. What is eutrophication? Explain its consequences on the life of plants and animals in such water bodies. 2

Q.20. What is the ozone shield and why is it important? Name the important gases that causes stratospheric ozone depletion. 3

Q.21. What is agroforestry? How do shifting cultivation and taungya system of cultivation contribute to it? What is the difference between these two systems?

Q.22. DDT content in the water of a lake that supplies drinking water to the nearby villages, is found to be 0.003 ppm. The Kingfishers of that area are reported to have 2 ppm of DDT. Why has the concentration increased in these birds? What harm will this cause to the bird population? Name the phenomenon. 2 (CBSE-2008)

Q. 23. A factory drains its waste water into the nearby lake. It has caused algal Bloom.

a) How was the algal bloom caused?

b) What would be the consequences?

c) Name the phenomenon that caused it?

Q.24. What is the relationship between dissolved oxygen and biochemical oxygen demand (BOD)? Mention their effect on aquatic life in river.

Q.25. Explain the cause of algal bloom in a water body. How does it affect an ecosystem?

Q. 26. Explain any three measures which will control vehicular air pollution in Indian cities.

Q.27. Ornithologists observed decline in the bird population in an area near a lake after the setting of an industrial unit in the same area. Explain the cause responsible for the decline observed.

Q.28. Mention the information that the health workers derive by measuring BOD of a water body.

Q.29. How is snow-blindness caused in humans? (CBSE-2010)

ORGANISM AND POPULATION

ECOLOGY: It is a branch of biology that deals with study of interactions and interrelationship between organisms and their environment. The term '*ecology*' was coined by German scientist Ernst Haeckel (1869).

ECOLOGY HAS TWO APPROACHES:

1) Autecology (Species ecology): It is the study of relationship of a single species or population with the environment for its various aspects like life history, population dynamic, adaptation etc.

2) Synecology (Community ecology): It is the study of biotic community in their various aspects like structure, development, distribution, adaptation, etc. in relation to their environment.

Q.5. Differentiate Autecology from Synecology. 1 (2004, CoHSEM).

Q.13. What is Synecology? 1 (2008, CoHSEM)

Ecological Organization: Ecology is basically concerned with four levels of biological organisation – organisms, populations, communities and biomes.

POPULATION: It is an aggregation or grouping of individuals of same species at the same time in a particular area or space. Population of an organism living in an area is called local population or deme. Local population of species occurring in different localities are called sister population.

Species: It is grouping of individuals which resemble one another in all important characters besides ability to interbreed freely.

Population	Species
1. It is grouping of individuals of the same species at the same time in a particular area. 2. A population belongs to a single ecotype.	1. It is the grouping of individuals which resemble one another in all important characters besides ability to interbreed freely. 2. A species may have several ecotypes.

Q.5. Differentiate between population and species by giving two points. 2 (2007, CoHSEM)

BIOLOGICAL COMMUNITY: It is an assemblage of population of different species present in an area which shows interdependence and interactions like competition, predation, host parasite interaction, commensalism and mutualism.

Population	Biological community
1. It is the grouping of individuals of same species found in a particular area. 2. The members do not have a relation of eating and being eaten. 3. Individuals of a population show interbreeding.	1. It is an assemblage of population of different species found in a particular area. 2. The members have a relation of eating and being eaten. 3. Interbreeding is absent amongst the members of different population.

ECOSYSTEM: It is a self sustained and self regulated segment of nature which is composed of biological community and physical environment. E.g . pond ecosystem

Landscape: It is a large area with natural boundary which usually possesses a number of different types of ecosystem occurring as a mosaic patches.

BIOMES: It is a major category of regional ecological organization which is delimited by a specific climatic zone. Biome is characterized by a major vegetation type and its associated fauna with unique climatic conditions.

ECOSYSTEM	BIOMES
1. It is a single self sustaining unit of ecological organization. 2. The size of the ecosystem is comparatively smaller. 3. The boundary of ecosystem is marked by different type surroundings. Example. Pond	1. It generally contains a member of ecosystem. 2. The size of biome is comparatively larger. 3. The boundary of biome is marked by different type of climate. Example. Tropical rain forest.

HABITAT: It is the locality along with sum total of abiotic and biotic factors of that specific place where an organism lives. Usually, it is a large area in which a number of species are found. Example*: pond, forest, desert, river.*

NICHE: It is a specific part of habitat utilized by an organism which represents a range of conditions. It can tolerate the resources it utilizes and functional role it plays in the ecological system.

HABITAT	NICHE
1. It is area or locality of residence of an organism which has a particular set of abiotic factors. 2. A number of species may occur in a habitat. 3. It is the address of an organism. 4. Habitat has several micro habitats.	1. It is the component of habitat which is governed by functioning of an organism. 2. A niche has only one species. 3. It is profession of an organism. 4. A niche has no sub-niches.

ORGANISMS & ITS ENVIRONMENT:

At the organismic level, ecology is essentially physiological ecology which tries to understand how different organisms are adapted to their environments in terms of not only survival but also reproduction. We know that the rotation of our planet around the Sun and the tilt of its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons. These variations together with annual variation in precipitation (remember precipitation includes both rain and snow) account for the formation of major biomes such as desert, rain forest and tundra.

Regional and local variations within each biome lead to the formation of a wide variety of habitats. Major biomes of India are - (a) Tropical rain forest; (b) Deciduous forest; (c) Desert; (d) Sea coast.

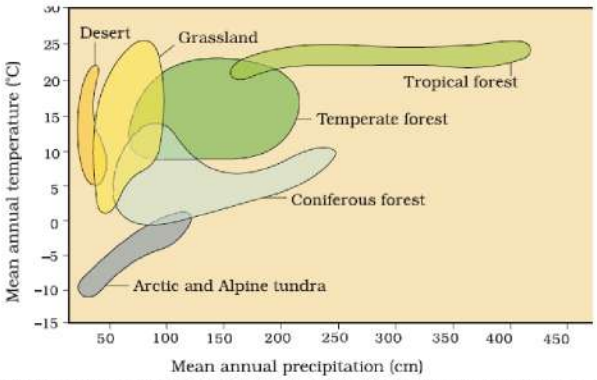


Fig: Biome distribution with respect to annual temperature and precipitation.

On planet Earth, life exists not just in a few favourable habitats but even in extreme and harsh habitats – scorching Rajasthan desert, perpetually rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost polar regions, high mountain tops, boiling thermal springs, and stinking compost pits, to name a few. Even our intestine is a unique habitat for hundreds of species of microbes.

Q. *What are the key elements that lead to so much variation in the physical and chemical conditions of different habitats*?

The most important ones are temperature, water, light and soil. The physico-chemical (abiotic) components alone do not characterise the habitat of an organism completely; the habitat includes biotic components also – pathogens, parasites, predators and competitors – of the organism with which they interact constantly. Over a period of time, the organism had through natural selection, evolved adaptations to optimise its survival and reproduction in its habitat.

Grassland	Savanna
1. It is a biome dominated by grasses and herbs. 2. All types of grasses occur in a grassland. 3. Rainfall is comparatively lower. 4. Trees and shrubs are nearly are absent.	1. It is a biome containing grasses with scattered woody plants. 2. It contains coarse grasses. 3. Rainfall is comparatively more. 4. Trees and shrubs occur scattered amongst the grasses.

ENVIRONMENTAL FACTORS: Components, conditions, forces of environment which have direct and indirect effect on the form, functioning, behavior and life history of an organism are called environment factors. They are of two types:- *abiotic* and *biotic.*

MAJOR ABIOTIC FACTORS:

i) **Temperature**: Temperature is the most ecologically relevant environmental factor. The average temperature on land varies seasonally, decreases progressively from the equator towards the poles and from plains to the mountain tops. It ranges from subzero levels in polar areas and high altitudes to $>50^0$C in tropical deserts in summer. There are, however, unique habitats such as thermal springs and deep-sea hydrothermal vents where average temperatures exceed 100^0 C. Mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forests and tuna fish are rarely caught beyond tropical latitudes in the ocean. A few organisms can tolerate and thrive in a wide range of temperatures (they are called *eurythermal*), but, a vast majority of them are restricted to a narrow range of temperatures (such organisms are called *stenothermal*). The levels of thermal tolerance of different species determine to a large extent their geographical distribution.

a) Eurythermal (*eurys*-wide, *thermos*-temperature) organisms are those organisms which can tolerate a wide range of temperature variations. e.g. most mammals ,birds, Cyclops, toad, wall lizard, etc.

b) *Stenothermal* (*stenos*-narrow, *thermos*-temperature) organisms are those organisms which live within narrow range of temperature because of their requirement of nearly constant temperature throughout the year. e.g. Polar Bear,fishes, plants, snails.

ECTOTHERMS: The body temperature of ectotherms tends to match with temperature of external environment in which the animal lives. Example- Invertebrates, fish, amphibians, reptiles.

ENDOTHERM (HOMEOTHERM): Despite fluctuations in outside temperature endotherm maintains a body temperature either constant or within tolerance limit.

ECTOTHERM	ENDOTHERM
1. They are unable to regulate their body temperature. 2. Body temperature changes with the temperature of environment. 3. The animal shows hibernation and aestivation. 4. They live only in those areas which have favourable environment temperature. 5. The animals are less active.	1. They are able to regulate their body temperature. 2. There is little effect of environment temperature on body temperature. 3. The two activities are rare. 4. They live in all places including the ones with highly unfavourable Environment temperature. 5. The animals are more active.

ii) **Water:** Next to temperature, water is the most important factor influencing the life of organisms. In fact, life on earth originated in water and is unsustainable without water. Its availability is so limited in deserts that only special adaptations make it possible to live there. The productivity and distribution of plants is also heavily dependent on water. For aquatic organisms the quality (chemical composition, pH) of water becomes important. The salt concentration (measured as salinity in parts per thousand), is less than 5 per cent in inland waters, 30-35 per cent the sea and > 100 per cent in some hypersaline lagoons. Some organisms are tolerant of a wide range of salinities (**euryhaline**) but others are restricted to a narrow range (**stenohaline**). Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems, they would face.

iii) **Light:** Since plants produce food through photosynthesis, a process which is only possible when sunlight is available as a source of energy. Many species of small plants (herbs and shrubs) growing in forests are adapted to photosynthesise optimally under very low light conditions because they are constantly overshadowed by tall, canopied trees. Many plants are also dependent on sunlight to meet their photoperiodic requirement for flowering. For many animals too, light is important in that they use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, reproductive and migratory activities. The availability of light on land is closely linked with that of temperature since the sun is the source for both. But, deep (>500m) in the oceans, the environment is perpetually dark and its inhabitants are not aware of the existence of a celestial source of energy called Sun.

iv) **Soil:** The nature and properties of soil in different places vary; it is dependent on the climate, the weathering process, whether soil is transported or sedimentary and how soil development occurred. Various characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils. These characteristics along with parameters such as pH, mineral composition and topography determine to a large extent the vegetation in any area. This is in turn dictates the type of animals that can be supported. Similarly, in the aquatic environment, the sediment-characteristics often determine the type of benthic animals that can thrive there.

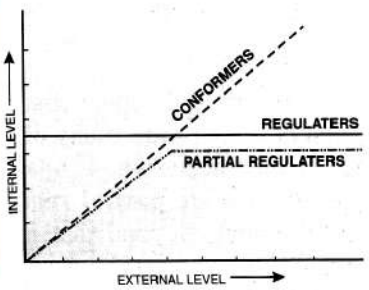
RESPONSE TO ABIOTIC FACTORS: Organisms show varied responses towards varied environmental conditions in different geological locations. The maintenance of equilibrium between organisms and external environment and a constant favourable internal environment in the body despite adverse changes is called **homeostasis**. However all organism are not able to spend so much of energy on maintaining homeostasis. For meeting stressful abiotic conditions, organisms regulate, conform, migrate, suspend their activities.

1. REGULATE:

Organisms are able to regulate body functions and maintain homeostasis through having a constant body temperature and constant osmotic concentration. They are called regulators. Example: Birds, mammals, a very few lower vertebrate and invertebrate species.

Plants, on the other hand, do not have such mechanisms to maintain internal temperatures.

A marine fish kept in fresh water will not be able to survive for long because water will enter its body due to endosmosis. Its water drinking habit also causes excess entry of water in the body. If it is able to excrete a large quantity of water in urine, it will be able to survive for sometimes. It does not have salt absorbing mechanisms of fresh water. Therefore, maintenance of osmolarity will not be possible.



2. CONFORMS: An overwhelming majority (99 per cent) of animals and nearly all plants cannot maintain a constant internal environment. Their body temperature changes with the ambient temperature. In aquatic animals, the osmotic concentration of the body fluids changes with that of the ambient water osmotic concentration. The organisms where body temperature and body fluid osmolarity change that of the ambient environment are called **conformer**. Thermoregulation is energetically expensive for many organisms. This is particularly true for small animals like shrews and humming birds. Heat loss or heat gain is directly related to surface area. Small animals (e.g. Shrew, humming bird) have large surface area relative to their volume. In colder environment, they tend to lose heat very fast. They have to spend more energy in maintaining their body temperature as compared to large sized animals. It is because of this reason small animals do not occur in polar regions.

OR, The smaller animals are at a disadvantage because they have a large surface area relative to their volume. They tend to lose body heat quickly if it is cold outside. It is because of this reason that small animals (e.g. humming bird) are rare in polar and alpine region.

Some are **partial regulators**. They have the ability to regulate body functions to a limited extent. Beyond that limit they become conformers.

Q.8. Why is the polar region not a suitable habitat for tiny humming birds? 1(2008, CBSE)

Regulators	Conformers
1. They possess a constant internal environment or homeostasis. 2. They maintain their body temperature. 3. The body fluids have a fixed osmotic concentration. 4. They consume large amount of energy. 5. They have a wide range of distribution. 6. Regulators are more active.	1. Homeostasis is little. 2. Their body temperature changes according to that of environment. 3. Osmotic concentration of body fluids varies according to that of external medium. 4. They consume lesser amount of energy. 5. They have a narrow range of distribution. 6. Regulators are more active.

3. MIGRATION: Migration is two way movement of whole population from a stressful habitat to a congenial area for food, shelter, favourable climate and other reasons. Every winter the famous Keolado National Park (Bharatpur) in Rajasthan host thousands of migratory birds coming from Siberia and other extremely cold northern regions.

4. SUSPEND:

In bacteria, fungi and lower plants, various kinds of thick walled spores are formed which help them to survive unfavourable conditions – these germinate on availability of suitable environment. In higher plants, seeds and some other vegetative reproductive structures serve as means to tide over periods of stress besides helping in dispersal – they germinate to form new plants under favourable moisture and temperature conditions. They do so by reducing their metabolic activity and going into a date of 'dormancy'.

In animals and other organisms which are unable to migrate, adopt the following methods –

Hibernation: It is the phenomenon in which animals arrest their metabolism during winter to escape from extreme cold, e.g. Polar bears.

Aestivation: It is the phenomenon in which animals arrest their metabolism to escape from extreme of heat during summer. e.g. Some snails and fish undergo *aestivation* to avoid summer-related problems – heat and desiccation.

Diapause: It is a state of suspended or arrested development. E.g. Under unfavourable conditions, many zooplankton species in lakes and ponds are known to enter *diapause*.

ADPTATION:-

Adaptation is any attribute of the organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat. [Changes occurring in structure, behavior, physiology and development which are useful to organism in adjusting themselves favourably to prevailing set of environmental condition are called adaptations].

Morphological Adaptation:

Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits to minimise water loss through transpiration. They also have a special photosynthetic pathway (CAM) that enables their stomata to remain closed during day time. Some desert plants like *Opuntia*, have no leaves – they are reduced to spines–and the photosynthetic function is taken over by the flattened stems.

Mammals from colder climates generally have shorter ears and limbs to minimise heat loss. (This is called the ***Allen's Rule.***) In the polar seas aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces loss of body heat.

Physiological adaptations are the changes in the physiology which helps an organism to respond quickly to a stressful environment. In the absence of an external source of water, the kangaroo rat in North American deserts is capable of meeting all its water requirements through its internal fat oxidation (in which water is a by product). It also has the ability to concentrate its urine so that minimal volume of water is used to remove excretory products.

In high altitudes, people face nausea, fatigue and heart palpitations. These are the symptoms of **altitude sickness.** This happens because higher altitudes have low atmospheric pressure which does not provide enough oxygen for our body. To cope up with this, our body shows physiological response called **acclimatization.** Acclimatization is a response to overcome altitude sickness. In this process, the body compensates low oxygen availability by increasing red blood cell production, decreasing the binding capacity of hemoglobin and by increasing breathing rate. This would result in high RBCs count and easy supply of more and more oxygen to different parts of body.

In most animals, the metabolic reactions and hence all the physiological functions proceed optimally in a narrow temperature range (in humans, it is 37^0C). But there are microbes (archaebacteria) that flourish in hot springs and deep sea hydrothermal vents where temperatures far exceed 100^0C. Similarly anti-freeze enzymes present in many fish helps them to thrive in Antarctic waters where temperature is always at subzero level. These enzymes prevent the body fluids from freezing. Several biochemical adaptations help a large variety of marine invertebrates and fish to live in deep trenches of oceans where pressure exceeds more than 100 times the normal pressure.

Behavioural adaptations: are the behavioural changes in response to the environmental variations. E.g. Desert lizards lack the physiological ability to cope up with the high temperatures of their habitat. Therefore, in order to maintain a constant internal body temperature they bask in the sun to absorb heat when their body temperature drops below the comfort zone, but move into shade (shady places) when the ambient temperature starts increasing. Some species are capable of burrowing into the soil to hide and escape from the above-ground heat.

POPULATION: It is an aggregation or grouping of individuals of same species at the same time in a particular area or space.

POPULATION ATTRIBUTES:

Birth Rates & Death Rates: A population has certain attributes that an individual organism does not. An individual may have births and deaths, but a population has *birth rates* and *death rates*. In a population these rates refer to *per capita* births and deaths, respectively. The rates, hence, are expressed is change in numbers (increase or decrease) with respect to members of the population. Here is an example. If in a pond there are 20 lotus plants last year and through reproduction 8 new plants are added, taking the current population to 28, we calculate the birth rate as 8/20 = 0.4 offspring per lotus per year. If 4 individuals in a laboratory population of 40 fruitflies died during a specified time interval, say a week, the death rate in the population during that period is 4/40 = 0.1 individuals per fruitfly per week.

Sex Ratio: Another attribute characteristic of a population is *sex ratio*. An individual is either a male or a female but a population has a sex ratio (e.g., 60 per cent of the population are females and 40 per cent males).

Age Pyramids: A population at any given time is composed of individuals of different ages. There are three ecological ages—pre-reproductive, reproductive and post-reproductive.

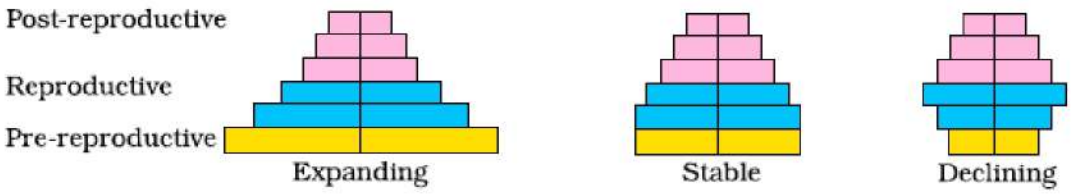


Diagram: Representation of age pyramids for human population

i) **Pre-reproductive individuals** are young individuals which will enter reproductive after some time. A very high proportion of pre-reproductive individuals occur in rapidly growing or expanding population. The number is small in declining population.
ii) **Reproductive individuals** are the ones which are actually adding new members to the population. Their number is almost equal to the pre-reproductive individuals in stable or mature population.
iii) **Post-reproductive individuals** are the older individuals which no longer take part in reproduction. Their small number indicates a growing population while a large number indicates a stable or declining population.

POPULATION GROWTH: A population has a number of characteristics like density, natality, mortality, dispersal, age distribution, biotic potential and growth forms. (Population size is also influenced by environmental resistance, carrying capacity, abiotic and biotic factors of the environment).

Population Density: It is the number of individuals of a population found in a unit area or space at a given time. It indicates the size of a population.

The density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes, two of which (natality and immigration) contribute an increase in population density and two (mortality and emigration) to a decrease.

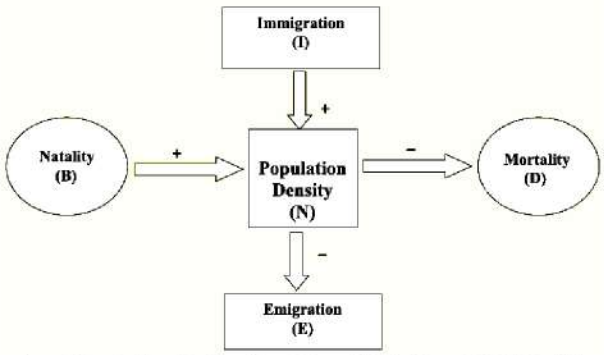
1) Natality or Birth Rate: It refers to the number of births during a given period in the population that are added to the initial density.
2) Mortality or Death Rate: It is the number of deaths in the population during a given period.

Natality	Mortality
1. It is the number of births per unit population per unit time.	1. It is the number of deaths per unit population per unit time.
2. Density of population increases.	2. Density of population decrease.
3. It maintains composition of population.	3. It maintains health of the population.

3) Immigration: It is permanent inward coming of individuals from outside into existing population.
4) Emigration: It is permanent outward movement of individuals from a population for settling into a new area.

Emigration	Immigration
1. It is outward movement of some individuals from a population.	1. It is inward movement of some individuals into a local population from an outside population.
2. It decreases the size of population.	2. It increases the size of population.

Q. 22. Describe two factors that control the population size in a given area. *2* (COHSEM-2000)



So, if N is the population density at time t, then its density at time **t +1 is $N_{t+1} = N_t + [(B + I) – (D + E)]$**

MIGRATION: It is two ways movement of the whole population from and into an area. Size of the population does not change.

Carrying Capacity: The maximum number of individuals of a population which can be provided with optimum resources for their healthy living is called Carrying capacity of the environment. Beyond carrying capacity the resources become deficient and the individuals are starved of the food and shelter.

Environmental Resistance: It is the sum total of all limiting factors that prevents a population to realize its full potential. It comprises limited food, disease, predation, adverse weather, competition, etc.

POPULATION GROWTH MODELS: The graphic pattern when a population growth is plotted against time is called population growth form. There are two types of growth forms, exponential or J-shaped and logistic or S-shaped.

(i) ***Exponential growth:***

When the resource availability is unlimited in the habitat, the population grows in an exponential or geometric fashion. If in a population of size N, the birth rates (not total number but *per capita* births) are represented as *b* and death rates (again, *per capita* death rates) as *d*, then the increase or decrease in N during a unit time period t (dN/dt) will be

$$dN/dt = (b - d) \times N$$

Let (b–d) = r, then

$$dN/dt = rN$$

The r in this equation is called the 'intrinsic rate of natural increase' and is a very important parameter chosen for assessing impacts of any biotic or abiotic factor on population growth.

When a population shows exponential growth, the curve plotted with N in relation to time assumes J shape.
$N_t = N_0 e^{rt}$, where
N_t = Population density after time t
N_0 = Population density at time zero
r = intrinsic rate of natural increase
e = the base of natural logarithms (2.71828)

Exponential or J-shaped Growth Curve: This type of growth curve is shown by small population like insect population in natural environment with plenty of food but no predators. There are 3 phases in this curve: lag phase, exponential phase and Crash phase.
a) Lag phase: There is slow rise in population as the initial population size is very small.
b) Exponential Phase or log phase: During this phase, the population size rises rapidly. The increase is so rapid that soon the population size grows much beyond the carrying capacity of the environment. The limited food and space available to the population are unable to support the same.
c) Crash Phase: A point is reached when population declines suddenly due to mass scale deaths. It is called crash phase.

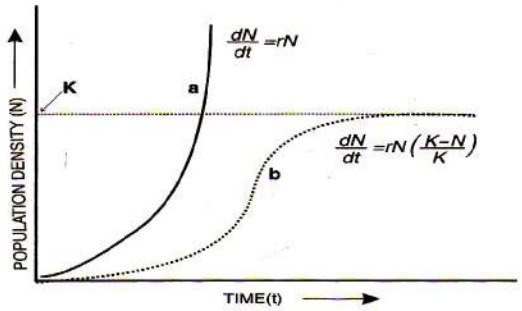


Fig: Population Growth Curves. *a*- exponential; *b*-logistic; K- *carrying capacity*.

B) S-shaped or Sigmoid Growth Curve: In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. Let us call this limit as nature's *carrying capacity* (K) for that species in that habitat. A population growing in a habitat with limited resources show initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote, when the population density reaches the carrying capacity. A plot of N in relation to time (t) results in a sigmoid curve. This type of population growth is called *Verhulst-Pearl Logistic Growth* and is described by the following equation:

$$dN/dt = rN\left(\frac{K-N}{K}\right)$$

Where N = Population density at time t
r = Intrinsic rate of natural increase
K = Carrying capacity

Since resources for growth for most animal populations are finite and become limiting sooner or later, the logistic growth model is considered a more realistic one.

S-shaped or Sigmoid Growth Curve: It is more common type of population growth form. It has 5 phases:
i) Lag Phase: There is slow increase in population size.
ii) Positive acceleration Phase: Increase in population starts and occurs at a slow rate in the beginning.
iii) Exponential Phase: Increase in population become rapid and soon attains its full potential rate. It continuous till environmental resistance comes to play.
iv) Negative acceleration (Deceleration) Phase: The growth rate finally slows down as environmental resistance increases. Environmental resistance is due to many factors such as more competition for food, space and greater mortality.
v) Equilibrium Phase: Finally, the population becomes stable when the population size reaches the point of carrying capacity of the area. Every population tends to reach a number at which it becomes stabilized with the resources of its environment.

J-shaped population Growth Form	S-shaped population Growth form
1. It occurs in irruptive type of population.	1. It is found in stable type of population.
2. An equilibrium is never reached in the population.	2. An equilibrium is reached when the size of the population approaches the carrying capacity of the area.
3. A phase of deceleration never occurs.	3. A phase of deceleration occurs before equilibrium is reached.
4. Population grows beyond the carrying capacity of the area.	4. Population seldom grows beyond the carrying capacity.
5. A crash phase occurs at the end of J-shaped growth.	5. A crash phase does not occur.

POPULATION INTERACTION: Three groups of interactions occur in biotic communities- neutral, negative (inhibition) and positive (beneficial).
I. Neutral Interactions:
II. Negative Interactions: Out of the two interacting species, one is harmed and the other may or may not be beneficial. Important types of negative interactions are-
1. Predation: It is an interaction between members of two species in which one species capture, kill and eat up members of other species. The organism which does the act of predation is called predator. The second organism which is killed and eaten is called prey. Predation can be illustrated by predator food chain.

(Herbivore → carnivore → carnivore).

Predation has three functions-
a) It acts as 'conduit' for energy transfer to higher trophic levels.
b) Predation keeps the prey population under control. It is called biological control.
c) It maintains the species diversity of a biotic community by reducing competition amongst the prey species.

2. Competition: It is interaction involving contest between individuals or groups of individuals for obtaining the same resource if it is in short supply. Competition is of two types- intraspecific and interspecific.

Intraspecific competition	Interspecific competition
1. It is competition among individuals of the same species. 2. The competition is for all the requirements. 3. The competing individuals have similar type of adaptation. 4. It is more severe due similar needs and adaptations.	1. The competition is amongst the members of different species. 2. The competition is for one or a few requirements. 3. The competing individuals have different types of adaptations. 4. It is less severe as the similar needs are a few and the adaptations are different.

Gause's '*Competitive Exclusion Principle'* states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This may be true if resources are limiting, but not otherwise. More recent studies do not support such gross generalisations about competition. While they do not rule out the occurrence of interspecific competition in nature, they point out that species facing competition might evolve mechanisms that promote co-existence rather than exclusion.

Resource Partitioning: Since competition also have a detrimental effect i.e. both competing species are harmed in term of either time, energy, survivability or reproductive success, competing species have evolved mechanism to avoid competition that would promote co-existence rather than exclusion. This mechanism is known as **resource partitioning** where competing species either utilize alternative resources or change their foraging time or pattern. Mac Athur showed resources partitioning between five closely related species of Wrables on a single tree where each species avoid competition by showing behavioural differences in foraging patterns.

3. Parasitism: It is a relationship between two living organisms of different species in which one organism called Parasite obtains its food directly from another living organism called host. Types of Parasite: There are 6 categories of parasites:

a) Ectoparasites and Endoparasites.

Ectoparasites	Endoparasites
1. Ectoparasites live on the surface of the host. 2. They can be temporary, intermittent or permanent. 3. They can be hemiparasites or holoparasites. 4. Respiration is aerobic. 5. Specialization has led to loss of fewer structures, e.g. Wings in fleas, bedbug and lice.	1. Endoparasites live in the body of the host. 2. They are generally permanent parasites. 3. They are usually holoparasites. 4. Respiration is often anaerobic. 5. Specialization has led the loss of several structures, e.g. digestive organs in *Taenia*.

b) Temporary and Permanent Parasites: Temporary parasites are the parasites which come in contact with host for a brief period. E.g. Bedbug, Leech, Sandfly, *Tse-tse fly*.

Permanent Parasites are the parasites remain in contact with the host throughout their life. E.g. *Entamoeba histolytica, Ascaris lumbricoides, Taenia solium*.

c) Holoparasites and Hemiparasites: Holoparasites are those parasites which are completely dependent on the host for all their requirements. e.g. *Raflesia, Cuscuta*

Hemi or semi-parasites are those parasites which receive only a part of nourishment from the host while the rest is manufactured by them. e.g. *Viscum, Loranthus, Santalum, Striga*.

d) Brood Parasitism: Brood parasitism in birds is an interesting example of parasitism in which the parasitic bird lays its eggs in the nest of its host and the host incubates them. During the course of evolution, the eggs of the parasite birds (e.g. Cuckoo) have evolved to resemble the host's egg (e.g. Crow) in size and colour to reduce the chances of the bird detecting the foreign eggs and ejecting them from the nest. E.g. Cuckoo lays her eggs in the crow's nest.

Predator	Parasite
1. It catches and kills the prey. 2. The predator is larger and stronger. 3. Predator feeds on killed prey.	1. It lives on or inside the body of host. 2. The parasite is smaller and weaker. 3. It feeds on living host.

4. Ammensalism: In **amensalism,** one species is harmed whereas the other is unaffected. (It is an interaction between two living individuals of different species in which an organism does not allow other organisms to grow or live near it). Inhibition is achieved through the secretion of chemicals called *allochemics*. e.g. *Penicillium* does not allow the growth *Staphylococcus* bacterium.

III. POSITIVE INTERACTIONS:

1. Commensalism: It is an interaction between the individuals of two different species in which one is benefitted while the other remains unaffected. E.g. a) Pilot fish follows Shark and feeds upon its left overs.

b) Sucker fish attaches itself under-surface of Shark with the help of its dorsal fin which is modified into holdfast. Sucker fish is dispersed by Shark to distant places having better food supply. Because of its association with Shark, Sucker fish is protected from its predators. It obtains food from fragments falling from Shark's mouth. Shark does not obtain any benefit from this association. It is also not harmed.

c) The relationship between Sea anemone (*Adamsia pallicata*) and Hermit Crab (*Eupagurus prideauxi*) is considered commensalism. Hermit crab resides inside an empty snail shell for protection.

d) Orchid growing as an epiphyte on the branch of a mango tree.

2. Proto-cooperation: It is an interaction between two living organisms of different species in which both are mutually benefitted but they can live without each other.

E.g. i) Red Billed Ox-pecker (*Buphagus erythrorhyncus*) and Yellow Billed Ox-pecker (*Buphagus africanus*) feeds upon ticks, leech and other ectoparasites found on the body of *Rhinoceros*.

ii) Leeches often enter the mouth of Crocodile, sucking blood. The bird Plover (*Pluvianus aegyptius*) enters the mouth of Crocodile and feeds upon the leech.

3. Mutualism or Symbiosis: It is an interaction between two organisms of different species where both the partners are benefitted with none of the two capable of living separately.

E.g. i) Lichens are formed of a photobiont (a blue green alga) and a mycobiont (fungus). The fungus helps in anchoring the lichen, absorption of water and minerals and providing a cover around the alga. The algal partner manufactures food not only for itself but also for the fungus. Because of this association the lichen is able to grow on such barren substrata as bare rocks.

ii) *Rhizobium* inside the root nodules of Legumes perform nitrogen fixation. The fixed nitrogen is shared by both.

*****

BIODIVERSITY

The occurrence of different types of genes, gene pools, species, habitats and ecosystem in a particular place and various parts of the earth is called biodiversity.

Levels of Biodiversity: It is of three inter-related hierarchical levels –

(i) ***Genetic diversity:*** A single species might show high diversity at the genetic level over its distributional range. The genetic variation shown by the medicinal plant *Rauwolfia vomitoria* growing in different Himalayan ranges might be in terms of the potency and concentration of the active chemical (reserpine) that the plant produces. India has more than 50,000 genetically different strains of rice, and 1,000 varieties of mango.

(ii) ***Species diversity:*** The diversity at the species level. For example, the Western Ghats have a greater amphibian species diversity than the Eastern Ghats.

Q.8. What does the term genetic diversity refer to? What is the significance of large genetic diversity in a population? 2 (CBSE-2007)

Q.1. India has more than 50,000 strains of rice. Mention the level of biodiversity it represents. 1 (CBSE-2010)

(iii) ***Ecological diversity:*** At the ecosystem level, India, for instance, with its deserts, rain forests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows has a greater ecosystem diversity than a Scandinavian country like Norway. It is of three types–

(i). Alpha Diversity:- It is species diversity in a given community or habitat. α – diversity is dependent upon species richness and evenness.

(ii) Beta Diversity:- It is biodiversity which appears in a range of communities due to replacement of species with the change in community/habitat due to presence of different microhabitats, niches and difference in environmental conditions.

(iii) Gamma Diversity:- It is diversity present in ranges of communities as represented by diversity of habitat/ecosystems over a total landscape or geographical area.

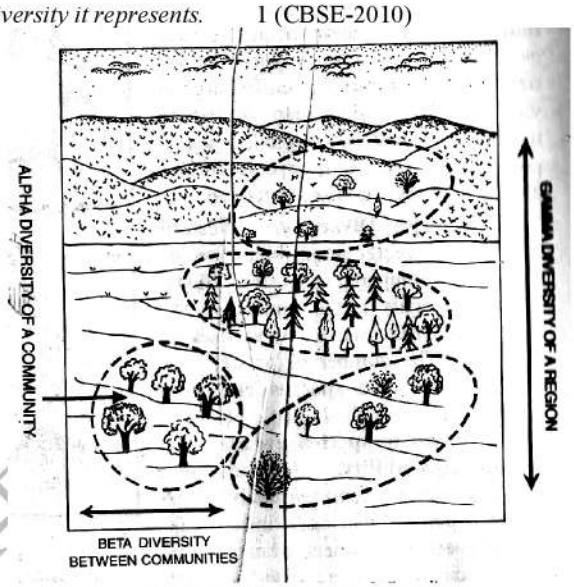


Fig: Three types of diversity

GLOBAL DIVERSITY: IUCN (2004) has put the total number of known plant and animal species to slightly more than 1.5 million.

Out of these the number of known species in India is 1,42,000 or roughly 8.1% of the total though India has only 2.4% land area. India, with about 45000 species of plants and twice as many species of animals is one of 12 megadiversity countries of the world.

More than 70 per cent of all the species recorded are animals, while plants (including algae, fungi, bryophytes, gymnosperms and angiosperms) comprise no more than 22 per cent of the total. Among animals, insects are the most species-rich taxonomic group, making up more than 70 per cent of the total. That means, out of every 10 animals on this planet, 7 are insects. The number of fungi species in the world is more than the combined total of the species of fishes, amphibians, reptiles and mammals.

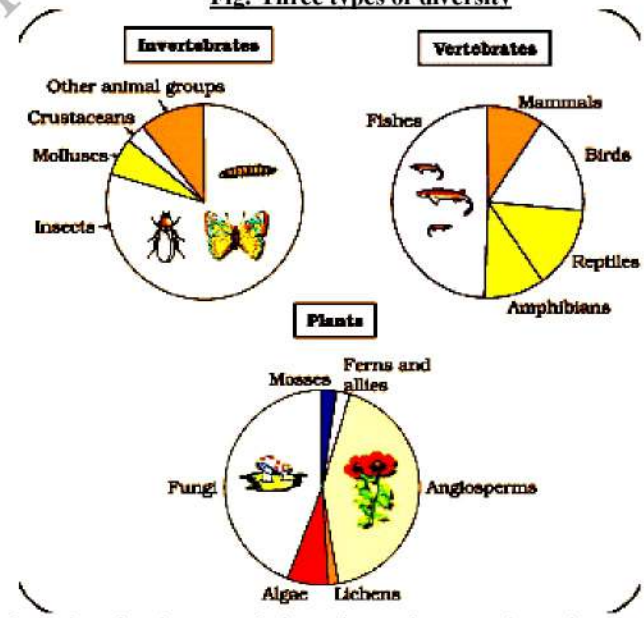


Figure : Representing global biodiversity: proportionate number of species of major taxa of plants, invertebrates and vertebrates

PATTERNS OF BIODIVERSITY:

Biodiversity is not uniform throughout the world but varies with change in latitude and altitude.

(i) ***Latitudinal gradients:*** The diversity of plants and animals is not uniform throughout the world but shows a rather uneven distribution. For many group of animals or plants, there are interesting patterns in diversity, the most well- known being the latitudinal gradient in diversity. In general, species diversity decreases as we move away from the equator towards the poles. With very few exceptions, tropics (latitudinal range of 23.5° N to 23.5° S) harbour more species than temperate or polar areas.

Colombia located near the equator has nearly 1,400 species of birds while New York at 41° N has 105 species and Greenland at 71° N only 56 species. India, with much of its land area in the tropical latitudes, has more than 1,200 species of birds. A forest in a tropical region like Equador has up to 10 times as many species of vascular plants as a forest of equal area in a

temperate region like the Midwest of the USA. The largely tropical Amazonian rain forest in South America has the greatest biodiversity on earth- it is home to more than 40,000 species of plants, 3,000 of fishes, 1,300 of birds, 427 of mammals, 427 of amphibians, 378 of reptiles and of more than 1,25,000 invertebrates. Scientists estimate that in these rain forests there might be at least two million insect species waiting to be discovered and named.

REASONS FOR GREATER BIODIVERSITY IN TROPICS: Greater biological diversity is observed in tropics because -

(a) Temperate regions were subjected to frequent glaciation in the past which had killed most of the species, but the tropics have remained undisturbed and hence, had evolved more species diversity.

(b) Tropical environments, unlike temperate ones, are less seasonal, relatively more constant and predictable. Such constant environments promote niche specialisation and lead to a greater species diversity and

(c) There is more solar energy available in the tropics, which contributes to higher productivity; this in turn might contribute indirectly to greater diversity.

Q. Explain giving three reasons why tropics show greatest levels of species diversity.

Q. What is so special about tropics that might account for their greater biological diversity?

(ii) ***Species-Area relationships***: Alexander von Humboldt has observed that within a region, species richness increased with increasing explored area, but only up to a limit. The relationship between species richness and area for a number of taxa (angiosperm plants, birds, bats, freshwater fishes) is found to be a rectangular hyperbola.

On a logarithmic scale, the relationship is a straight line and is described by the equation log S = log C + Z log A

Where, S= Species richness A= Area

Z = slope of the line (regression coefficient)

C = Y-intercept

Ecologists have discovered that the value of Z lies in the range of 0.1 to 0.2, regardless of the taxonomic group or the region (whether it is the plants in Britain, birds in California or molluscs in New York state, the slopes of the regression line are amazingly similar).

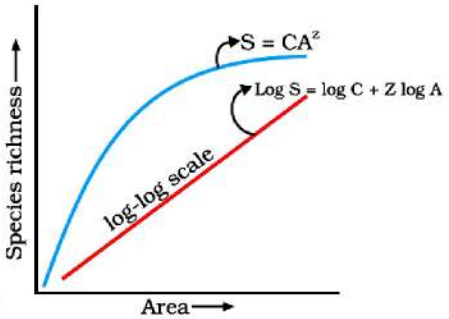


Fig: Showing species area relationship.

IMPORTANCE OF SPECIES DIVERSITY:

1. Stability: Biodiversity is essential for stability of an ecosystem. Communities with more species tend to be more stable than those with less species. It is able to resist occasional disturbance.

2. Productivity: Ecosystem with higher biodiversity (e.g., tropical forests) are more productive than ecosystem with lower biodiversity (e.g., temperate forests).

3. Ecosystem Health: Biodiversity is essential for maintenance and health of ecosystem through the occurrence of various checks, controls, negative and positive feed backs, critical link and keystone species. Killing or disappearance of even a few species may have a destabilizing effect.

Stanford ecologist, ***Paul Ehlrich*** *has proposed* ***'rivet popper hypothesis'*** *for the effect of decrease in biodiversity on the ecosystem.* In an airplane (ecosystem) all parts are joined together using thousands of rivets (species). If every passenger travelling in it starts popping a rivet to take home (causing a species to become extinct), it may not affect flight safety (proper functioning of the ecosystem) initially, but as more and more rivets are removed, the plane becomes dangerously weak over a period of time. Furthermore, which rivet is removed may also be critical. Loss of rivets on the wings (key species that drive major ecosystem functions) is obviously a more serious threat to flight safety than loss of a few rivets on the seats or windows inside the plane.

Loss of Biodiversity:

The biological wealth of our planet has been declining rapidly and the accusing finger is clearly pointing to human activities.

- The colonisation of tropical Pacific Islands by humans is said to have led to the extinction of more than 2,000 species of native birds.
- The IUCN Red List (2004) documents the extinction of 784 species (including 338 vertebrates, 359 invertebrates and 87 plants) in the last 500 years. Some examples of recent extinctions include the dodo (Mauritius), quagga (Africa), thylacine (Australia), Steller's Sea Cow (Russia) and three subspecies (Bali, Javan, Caspian) of tiger.
- The last 20 years alone have witnessed the disappearance of 27 species.
- Careful analysis of records shows that extinctions across taxa are not random; some groups like amphibians appear to be more vulnerable to extinction. Adding to the grim scenario of extinctions is the fact that more than 15,500 species world-wide are facing the threat of extinction.
- Presently, 12 per cent of all bird species, 23 per cent of all mammal species, 32 per cent of all amphibian species and 31per cent of all gymnosperm species in the world face the threat of extinction.
- There has been **5 episodes of mass extinction** of species and the **sixth extinction** is going on, but it is 100 – 1000 times faster than in the pre-human times and our activities are responsible for the faster rates. Ecologists warn that if the present trends continue, nearly half of all the species on earth might be wiped out within the next 100 years.

Loss of biodiversity in a region may lead to

(a) decline in plant production,

(b) lowered resistance to environmental perturbations such as drought and

(c) increased variability in certain ecosystem processes such as plant productivity, water use, and pest and disease cycles.

CAUSES OF BIODIVERSITY LOSSES: The accelerated rates of species extinctions that the world is facing now are largely due to human activities. There are four major causes (‘**The Evil Quartet’** is the sobriquet used to describe them).

1. Habitat loss and Fragmentation:

This is the most important cause driving animals and plants to extinction. The most dramatic examples of habitat loss come from tropical rain forests. Once covering more than 14 per cent of the earth’s land surface, these rain forests now cover no more than 6 per cent. They are being destroyed fast. By the time you finish reading this chapter, 1000 more hectares of rain forest would have been lost. The Amazon rain forest (it is so huge that it is called the ‘lungs of the planet’) harbouring probably millions of species is being cut and cleared for cultivating *soya beans* or for conversion to grasslands for raising beef cattle.

Besides total loss, the degradation of many habitats by pollution also threatens the survival of many species. When large habitats are broken up into small fragments due to various human activities, mammals and birds requiring large territories and certain animals with migratory habits are badly affected, leading to population declines.

2. Over Exploitation:

Humans have always depended on nature for food and shelter, but when ‘need’ turns to ‘greed’, it leads to over-exploitation of natural resources. Many species extinctions in the last 500 years (Steller’s sea cow, passenger pigeon) were due to overexploitation by humans. Presently many marine fish populations around the world are over harvested, endangering the continued existence of some commercially important species.

3. Alien (Exotic) Species Invasions: Introduction of non-native or alien species often become invasive and drive away the local species.

e.g. i) Invasive of alien species like carrot grass (*Parthenium*), *Lantana* and water hyacinth (*Eicchornia*) cause environmental damage and threat to our native species. Water hyacinth (*Eichhornia crassipes*) was introduced in Indian waters to reduce pollution. It has clogged water bodies resulting in death of several aquatic plants and animals.

ii) Nile Perch, a predator fish was introduced in the Lake Victoria of South Africa. It killed and eliminated over 200 native species.

iii) Africans Catfish, *Clarias gariepinus*, has been illegally introduced for aquaculture in India. It is threatening native Catfish (*Clarias batrachus*) of Indian river.

Q.23. Citing three examples, show how introduction of exotic species has threatened biodiversity. 3 (CoHSEM-2009)

Q.15. Alien species are a threat to native species. Justify taking examples of an animal and a plant alien species. 2 (CBSE-2010)

4. Coextinction: Certain obligatory mutualistic relationships exist in nature, e.g. *Yucca* and *Pronuba yuccaselles*. Extinction of one will automatically cause extinction of other.

---

5. Pollution: Excessive use of pesticide has polluted water and surface water bodies. Many sensitive species have disappeared.

6. Disturbance and Degradation: Manmade disturbance and degradation are more severe. They include felling of trees, use of fire for clearing, collection of litter and over exploitation for economically important products. These disturbances and degradation result in loss of biodiversity.

TYPES OF EXTINCTION:

Extinction is of three types – natural extinction, mass extinction and anthropogenic extinction.

(i) **Natural Extinction**: Natural or background extinction is a slow process of replacement of existing species with the better adapted species due to alternate evolution, changes in the environmental conditions, predators and diseases. A small population is more likely to become extinct sooner than the large population due to interbreeding depression and normal population fluctuations during unfavourable periods like drought, harsh winter or severe summer.

(ii) **Mass Extinction**: Earth has experienced five mass extinction due to environmental catastrophes. A mass extinction occurred about 225 million years ago in Permian when 90% of shallow marine invertebrates disappeared. Another mass extinction occurred between cretaceous and tertiary over 60 million years ago when Dinosaurs and a number of other organisms disappeared. It is also called **K-T boundary. K-T boundary** extinctions are connected with deposits of iridium which is otherwise rare on earth.

(iii) **Anthropogenic Extinctions**: They are extinctions abetted by human activities like settlements, hunting, overexploitation and habitat destruction. It seems that the earth is heading for ‘**Sixth Extinction’** but it would be anthropogenic. The difference between **sixth extinction** and previous one is in the rates; the current species extinction (**Sixth Extinction)** rates are estimated to be 100 to 1,000 times faster than in the pre-human times and our activities are responsible for the faster rates. Ecologists warn that if the present trends continue, nearly half of all the species on earth might be wiped out within the next 100 years.

Loss of Biodiversity is bound to cause:

i) Decline in ecosystem productivity,

ii) Reduced resistance to environmental perturbations like drought,

iii) Drastic changes in ecosystem processes like water use, pest and disease cycles.

30. How is ‘Sixth Extinction’ presently in progress different from the previous episodes of mass extinction of species? Give two points to overcome such disaster. 3 (CoHSEM,2020)

Ans:- **Sixth extinction** in Earth's history due to human activities (anthropogenic) is under way and is 100 – 1000 times faster than pre-human times and is more severe than previously feared. Mass extinction is the loss of species due to environmental catastrophes. A mass extinction occurred about 225 million years ago when 90% of shallow water marine invertebrates disappeared.

Two points to overcome such disaster:

(i) Use of pesticide should be checked because it has polluted water and surface water bodies and many sensitive species have disappeared.

(ii) Manmade disturbance and degradation are more severe. They include felling of trees, use of fire for clearing, collection of litter and over exploitation for economically important products. These disturbances and degradation result in loss of biodiversity. These activities should be stopped.

WCU or IUCN RED DATA: WCU (World Conservation Union) formerly known as IUCN (International Union of Conservation of Nature and Natural Resources) whose headquarters at Morges, Switzerland studies the threat to biodiversity in all parts of the world. It prepares a red list or red data book. Red list is a catalogue of species and subspecies facing various degree of extinction risk by using a set criteria relevant to all species all over the world. The various aims of preparing a red list are:

i) To provide information and develop awareness about the importance of threatened species.

ii) Identification and documentation of endangered species.

iii) Preparation of global index of decline of biodiversity.

iv) Imparting information about the urgency and scale of conservation problems to public and policy makers.

v) Preparing conservation priorities at local levels guiding conservation and restoration work.

vi) Giving information about various international agreement related to biodiversity like Convention on Biological Diversity and Conservation on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Red list has eight categories of species:

1. Extinct: A taxon is Extinct when there is no reasonable doubt that the last individual has died. e.g. Dodo.
2. Extinct in Wild: A taxon is Extinct in wild when exhaustive surveys in known and/or expected habitat, have failed to record an individual.
3. Critically Endangered: A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future. e.g. Pigmy Hog.
4. Endangered: A taxon is Endangered when it is not Critically endangered, but is facing a high risk of extinction in the wild in the near future. In India, their number is 54 animals and 113 plants. e.g. Red Panda, Blue Whale, Sangai (*Rucervus eldii eldii)*
5. Vulnerable: Presently the population is sufficient but is undergoing depletion due to some factors so that it is facing risk of extinction in medium future. e.g. Black buck.
6. Lower risk: They are threatened species which have lower risk of extinction and therefore, require only a small attention to become normal flourishing species.
7. Data Deficient: A taxon is Data deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction.
8. Not evaluated: The taxon has not been evaluated for risk of extinction.

- Rare species are the species with naturally small populations, either localized or thinly scattered, which are always at risk from pathogens/pests/exotic species.
- Indeterminate species are those species which are in danger of extinction but the reason is not known.

Q. Why should we conserve Biodiversity?

30. Which is the most endangered species of deer found in Manipur? Give one reason of it becoming endangered. 1+1=2 (CoHSEM-1997)

16. Give the name of an endangered animal in Manipur? 1(CoHSEM-1998)

23. Citing three examples show how introduction of exotic species has threatened biodiversity. 3(CoHSEM-2009)

24. What is endangered species? How many animals and plants are endangered in India? 2(CoHSEM-2012).

(A) CONSERVATION OF BIODIVERSITY FOR ECOSYSTEM SERVICES:

1. Preservation of Environments: It preserves environments having recreational, aesthetic, socio cultural and other importance.
2. Pollutants: It is involved in absorption and degradation of pollutants.
3. Gaseous Composition: Ecosystem maintains the gaseous composition of atmosphere through fixation of carbon dioxide and release of oxygen in photosynthesis. Amazon rain forest is estimated to contribute 20% of the total oxygen.
4. Water: Biodiversity maintains water cycle, conservation and purification of water by protecting water sheds, recharging ground water and water reservoirs.
5. Flood and erosion control: Rain does not go waste. It percolates into soil and reaches underground water level. Soil is protected from direct pounding by rain. Therefore, there is no soil erosion, nor there are floods.

(B) CONSERVATION OF BIODIVERSITY FOR NARROWLY UTILITARIAN REASONS:

(i) Humans derive countless direct economic benefits from nature food (cereals, pulses, fruits), firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and products of medicinal importance.

(ii) More than 25 per cent of the drugs currently sold in the market worldwide are derived from plants and 25,000 species of plants contribute to the traditional medicines used by native peoples around the world. Nobody knows how many more medicinally useful plants there are in tropical rain forests waiting to be explored.

(iii) With increasing resources put into 'bioprospecting' (exploring molecular, genetic and species-level diversity for products of economic importance), nations endowed with rich biodiversity can expect to reap enormous benefits.

(C) ETHICAL REASONS:

Every species has an intrinsic value, even if it may not be of current or any economic value to us. It is our moral duty to care for their well-being and pass on our biological legacy in good order to future generations.

STRATEGIES FOR CONSERVATION OF BIODIVERSITY:

There are two types of conservation strategies- *in situ* (on site) and *ex-situ* (offsite).

In situ Conservation Strategies:-

These conservation strategies involve protecting, preserving and restoring the threatened species and ecosystem in natural habitats. They are of two types, hot spots and protected areas.

1. HOT SPOTS: They are areas of high endemism and high level of species richness. Some 34 hot spots have been identified globally. These hotspots are also regions of accelerated habitat loss. Three of these hotspots – Western Ghats and Sri Lanka, Indo-

Burma and Himalaya – cover our country's (India) exceptionally high biodiversity regions. Ecologically hot spots are determined by four factors.

i) Number of species/ species diversity.
ii) Degree of endemism.
iii) Degree of threat to habitat due to its degradation and fragmentation.
iv) Degree of exploitation.

2. PROTECTED AREAS: They are biogeographical areas of land and/ or sea where biological diversity along with natural and associated cultural resources are protected, maintained and managed through legal and other effective measures. India now has 14 biosphere reserves, 90 national parks and 448 wildlife sanctuaries.

a) NATIONAL PARKS: They are areas maintained by government and reserved for betterment of wild life. Cultivation, forestry, and habitat manipulation are not allowed. India has 91 national parks (India, 2005). The first national park of India was Jim Corbett National Park. Manipur has 2 national parks-

i) Keibul Lamjao National Park (KLNP): This national Park was declared in 1977. The Park is situated in Bishnupur district along the south eastern corner of the Loktak lake among the floating vegetation or phumdi. The only floating National Park in the world is the natural habitat of *Rucervus eldii eldii* (Sangai). This species of deer has become an endangered due to Poaching.

Q.30. Which is the most endangered species of deer found in Manipur? Give one reason of its becoming endanger.
1+1=2 marks (CoHSEM, 1997).

Q.16. Give the name of an endangered animal in Manipur? 1 (CoHSEM-1998)

ii).Sirui National Park: This National Park is situated in Ukhrul district of Manipur. World famed Siroy Lily (*Lilium mackliniae*) and state flower of Manipur, which blooms only on the lofty heights of Shirui hill has become an endangered species.

b) SANCTUARIES: They are tracts of land with or without lake where wild animals/fauna can take refuge without being hunted. Other activities like collection of forest products, harvesting of timber, private ownership of land, tilling of land, etc are allowed. Manipur has one Wild life Sanctuary-

Yangoupokpi Lokchao Wild Life Sanctuary: It is situated in the Myanmar border in Chandel District (near Moreh).

Q.19. What is the difference between National Parks and Sanctuaries? Give the name of two National Parks located in Manipur.
2 (CoHSEM-2008)

34. Give five differences between a National park and a sanctuary. 5(CoHSEM-2012)

National Park	Sanctuary
1. It is meant for protection of both flora and fauna.	1. It is meant for protection of only fauna.
2. Cultivation of land is not allowed.	2. Cultivation of land is permitted.
3. Grazing is not allowed.	3. Grazing is allowed.
4. Forest products are not harvested.	4. Forest products are harvested.
5. Private ownership is not permitted.	5. Private ownership is permitted.
6. Boundary is well demarcated.	6. Boundary is not well demarcated.

c) BIOSPHERE RESERVES: They are multipurpose protected areas which are meant for preserving genetic diversity in representative ecosystem by protecting wildlife, traditional life styles of tribals and varied plant and animal genetic resources. Each biosphere reserve has

(i) Core and Natural Zone:-No human activity is allowed. The area is undisturbed and legally protected ecosystem.
(ii) Buffer Zone: It surrounds the core area. Limited human activity is allowed like resource use strategies, research and education.
(iii) Transition Zone (Manipulation Zone): It is the outermost or peripheral part of biosphere reserve where an active cooperation is present between reserve management and local people for activities like settlements, cropping, recreation, forestry and other economic uses without disturbing ecology.

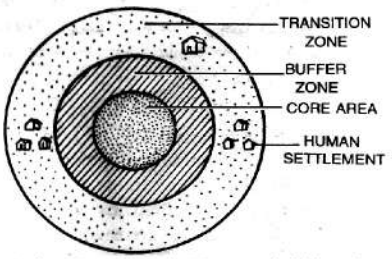


Fig: Zonation in Terrestrial biosphere

Functions of a Biosphere Reserve:

i) Conservation function: To contribute for conservation of species, ecosystems and landscapes.
ii) Development Function: To foster the human and economic development socio-culturally and ecologically.
iii) Logistic function: To support information exchange related to local, national and global issues of conservation through education and research.

d) SACRED FORESTS AND LAKES: Sacred forests (=sacred groves) are forest patches around places of worship which are held in high esteem by tribal communities. They are the most undisturbed forest patches (island of pristine forests) which are often surrounded by highly degraded landscapes. They are found in several parts of India, e.g.,

- Khasi and Jaintia Hills in Meghalaya
- Western Ghat regions of Karnataka and Maharastra,
- Aravali Hills of Rajasthan, (Aravalli),
- Sarguja, Chanda and Bastar of Madhya Pradesh
- Temples built by tribals are found surrounded by Deodar forests in Kumaon region.

Not a single branch is allowed to be cut from these forests. As a result, many endemic species which are rare or have become extinct elsewhere can be seen to flourish here.

- Bishnois of Rajasthan protect *Prosopis cineraria* and Black Buck religiously.
- Some water bodies are also held sacred in certain places, e.g., Khecheopalri in Sikkim. Their aquatic flora and fauna are naturally preserved.

e) Ramsar Sites: Ramsar sites are wetlands which are considered to be of international importance. Ramsar Convention (1971) is an international treaty for conservation and sustainable utilization of wetlands.
Ramsar convention works for
(i) conservation and use of wetlands,
(ii) recognition of fundamental ecological functions of wetlands and their cultural, economic, scientific and recreational value.

There are 26 Ramsar sites in India. Some of these are Ashtamudi wetland (Kerala), Sambhar lake, Rudrasagar lake, Chilka lake, Bhitakanika wetland (Odisha).

- Wetlands include marshes, lakes, coral reefs, etc.

MAB programme: Man and Biosphere programme is an international biological programme of UNESCO. MAB has studied human environment, impact of human interference and pollution on biotic and abiotic environments and conservation strategies for present as well as future.

Ex Situ Conservation: It is conservation of selected rare plants/animals in places outside their natural home. It includes-

1. Offside collection:- They are live collections of wild and domesticated species in botanical gardens, zoological parks, wildlife safari parks, arboreta, etc. currently, there are more than 1500 botanical gardens and arboreta having more than 80,000 species.
2. Gene Banks: They are institutes that maintain stocks of viable seeds, live growing plants (orchards), tissue culture and frozen germplasm with the whole range of genetic variability.

i) Seed Banks: Seeds are of two types, orthodox and recalcitrant. Orthodox seeds are those seeds which can tolerate reduction in moisture content (upto 5%), anaerobic condition and low temperature of -10^0 to -20^0 C or even lower for prolonged periods, e.g., cereals, legumes. At intervals the seeds are allowed to germinates, form plants and develops fresh seeds for storage.

Recalcitrant seeds are those which get killed on reduction of moisture and exposure to low temperature, e.g., Tea, Cocoa, Jackfruit, Coconut. They can be stored for shorter duration after treatment fungicides in rooms having humid air and normal oxygen.

ii) Orchards: Plants with recalcitrant seeds are grown in orchards where all possible strains and varieties are maintained, e.g., Litchi, Oil Palm, Rubber Tree, etc.

iii) Tissue culture: it is carried out trough callus formation, embryoids, pollen grain culture and shoot tip culture for those plants which are either seedless, have recalcitrant seeds, variable seeds progeny or where clone is to be maintained.

iv) Cryopreservation: Preservation at -196^0C (liquid N_2) can maintain tissue culture, embryos, animal cells/tissues, gametes indefinitely.

In situ conservation	Ex situ conservation
1. These conservation strategies involve protecting, preserving and restoring the threatened species and ecosystem in natural habitats. 2. These include protected areas like National Park, Biosphere reserves, Sanctuary etc.	1. They are conservation strategies in which the threatened species are reared and preserved outside their natural habitats. 2. These include botanical garden, Zoological gardens, DNA banks, etc.

CONVENTIONS ON BIODIVERSITY: Biodiversity knows no political boundaries and its conservation is therefore a collective responsibility of all nations.

- The historic Convention on Biological Diversity ('The Earth Summit') held in **Rio de Janeiro in 1992**, called upon all nations to take appropriate measures for conservation of biodiversity and sustainable utilisation of its benefits.
- In a follow-up, the World Summit on Sustainable Development held in **2002** in Johannesburg, South Africa, 190 countries pledged their commitment to achieve by **2010**, a significant reduction in the current rate of biodiversity loss at global, regional and local levels.

Q.15. Alien species are a threat to native species. Justify taking examples of an animal and a plant alien species. 2 (CBSE-2010)

Keystone species: A keystone species is a species that plays a critical role in maintaining the structure of an ecological community and whose impact on the community is greater than would be expected based on its relative abundance or total biomass. e.g. The carnivorous starfish *Pisaster ochracceus*, played a key role in maintaining the balance of all other species in the community.

Q.21. Alien species are highly invasive and are a threat to indigenous species. Substantiate this statement with any three examples. 3 (CBSE-2012)

Q. Give three points of difference between Genetic diversity and species diversity.

Genetic diversity	Species diversity
1. It is related to number of genes and their alleles found in organisms. 2. It is trait of species. 3. It influences adaptability and distribution of a species in diverse habitats.	1. It is related to number and distribution of species found in an area. 2. It is trait of the community. 3. It influences biotic interactions and stability of the community.

CITES: Convention on International Trade in Endangered Species.
CBD: Convention on Biological Diversity.
ITPGR: International Treaty on Plant Genetic Resources.

Q. What is meant by term "Hot spots" in biodiversity? List two criteria used for determining a Hot spot. Name two Hot spots of India.
Q. What is cryopreservation? Give its one use.
Q. Describe what are sacred forests.
Q. What is the new name for IUCN?
Q. What is Red Data List?
Q. Name the three components of biodiversity.

Q. Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem?
Q. What are sacred grooves? What is their role in conservation?
1. Name the three important components of biodiversity.
2. How do ecologists estimate the total number of species present in the world?
3. Give three hypotheses for explaining why tropics show greatest levels of species richness.
4. What is the significance of the slope of regression in a species – area relationship?
5. What are the major causes of species losses in a geographical region?
6. How is biodiversity important for ecosystem functioning?
7. What are sacred groves? What is their role in conservation?
8. Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem?
9. The species diversity of plants (22 per cent) is much less than that of animals (72 per cent). What could be the explanations to how animals achieved greater diversification?
10. Can you think of a situation where we deliberately want to make a species extinct? How would you justify it?

BIOLOGICAL CLSSIFICATION

Biological Classification: It is the scientific method of arranging organisms on the basis of resemblances and differences into hierarchy of categories.

Needs of classification: A proper system of classification is a must because of the following reasons:

1. It is not possible to study every organism. The study of one or two organisms gives sufficient information about the essential features of the group.
2. Classification helps in knowing the relationship among different groups of organisms.
3. On the basis of relationship and simplicity or complexity found in the members of various taxa evolutionary tendencies can be known.

Types of Classification: There are three main types of classification –

1. Artificial 2. Natural. 3. Phylogenetic

Artificial system of classification: It is a system of classification which was one or two morphological characters for grouping of organisms. Some artificial systems have used habit and habitat for this purpose.

Aristotle (father of zoology) divided animals into two categories – enaima (with red blood) and anaima (without red blood). Aristotle also classified animals on the basis of their habitat i.e. aquatic (e.g. fish, whale), terrestrial (e.g. Reptile, cattle) and aerial (e.g. birds, bat).

Natural system of classification: It is a system of classification which takes into consideration of a number of characters so as to bring out natural similarities and dissimilarities. The system employs those characters which are relatively constant. They include morphological characters, anatomical characters, Cytological characters, Physiology, ontogeny, reproduction, etc. The characteristics are helpful in bringing out maximum number of similarities in a group and comparable differences with other groups of organisms. E.g Mammals are characterized by the presence of mammary glands, hair, vivipary, four – chambered – heart, denucleated RBCs and warm blooded nature. Birds possess wings, feathers, pneumatic bones, ovipary, four – chambered heart, nucleated RBCs and warm blooded nature.

Phylogenetic system of Classification: (Classification based on Evolution)

Classification based on Evolutionary relationship of organisms is called phylogenetic system of classification.

Cytotaxonomy: It is a classification based on information provided by comparative cytological studies number of chromosomes, structures and meiotic behavior of chromosomes.

Chemotaxonomy: The system of classification is based on characteristic of various chemical constituents of organisms like amino acids, proteins, DNA, sequences, alkaloids, crystals, etc.

Numerical taxonomy: It evaluates resemblances and differences or primitiveness and advancement through statistical methods based on a large number of characters obtained from all disciplines of biology.

Two – Kingdom Classification: This system of classification in which all the organisms of the world have been divided into two kingdoms of animalia and plantae. This two kingdom system was founded by *Carolus Linnaeus*.

Kingdom Plantae: It includes all plants. They are distinguished by

(a) Presence of cell wall
(b) Presence of central vacuole in the cell
(c) Ability to manufacture food due to presence of chlorophyll
(d) Reserve food as starch.

Kingdom Animalia: This kingdom includes all the animals. They are characterized by:

(a) Absence of cell wall.
(b) Central vacuole is not found
(c) Ingestive mode of nutrition and absence of chlorophyll.
(d) Reserve food usually in the form of glycogen
(e) Excretory organs, sense organs, nervous system and muscular tissue are present.

Objections of two kingdom system:

i) Prokaryotes do not have sap vacuoles, membrane bound organelles, true nucleus and sexual reproduction. Prokaryotes cannot be related to plants which are eukaryotes.
ii) Fungi are included amongst the plants though they are quite different in structure, physiology, reproduction, food reserves and absence of chlorophyll.
iii) Organisms like *Euglena* have features of both plants and animals.
They performed photosynthesis in the presence of light. In dark, they lose chloroplast and become saprophytic or holozoic. Organisms like *Euglena* are studied by both botanist and zoologist.

Three Kingdom Classification: Ernst Haeckel (1866) divided living beings into three kingdom of Animalia, Plantae and Protista. He created new kingdom of Protista to include all those organisms which do not show differentiation of tissues i.e. algae, fungi and protozoa.

Defectives of three kingdom classification:

1. Keeping prokaryotes and eukaryotes together.
2. Mixing both unicellular and multicellular organisms together in protista.

Four Kingdom Classification: It was put forward by Copeland (1956). The four kingdoms are Monera, Protista, Plantae and Animalia. Protista came to have one eukaryotic unicellular. Fungi continue to remain with plants.

Five Kingdom Classification: In order to develop phylogenetic classification, R.H. Whittaker (1969), an American taxonomist, divided all the organisms into five kingdoms. Whittaker has used five criteria for delimiting the different kingdoms.

1. Complexity of cell structure, prokaryotic and Eukaryotic.
2. Complexity of body structure or structural organization, unicellular and multicellular.
3. Mode of Nutrition – photoautotrophy in plantae, absorptive heterotrophy in Fungi and ingestive heterotrophy in Animals.
4. Ecological life style like producers, decomposers and consumers.
5. Phylogenetic relationship.

Whittaker's Five Kingdoms are - 1) Monera 2) Protistae 3) Fungi 4) Plantae 5) Animalia

Characters	Five Kingdoms				
	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellular (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophyte/parasite)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

MONERA – Kingdom of Prokaryotes:

The kingdom includes all prokaryotes – eubacteria (true bacteria), Archaebacteria (ancient bacteria) and mycoplasm.

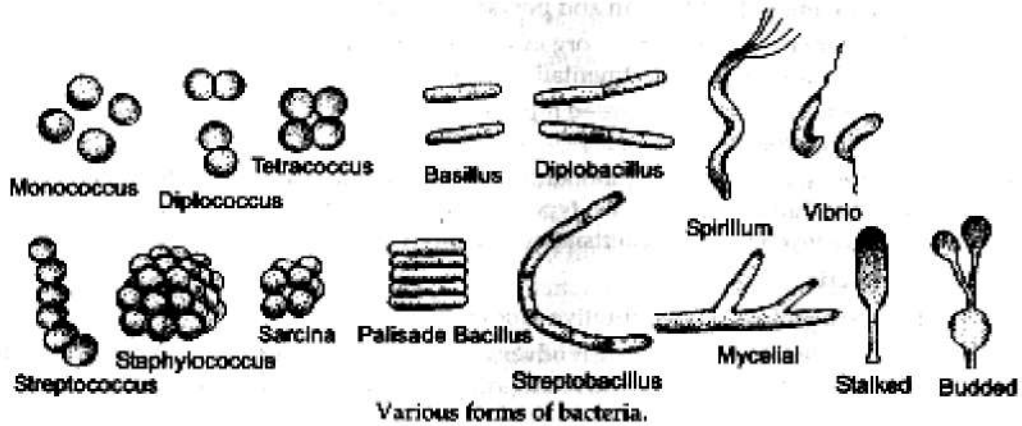
Eubacteria is further of two types – bacteria and Cyanobacteria (blue green algae).

Bacteria are the sole members of the Kingdom Monera. They are the most abundant micro-organisms. Bacteria occur almost everywhere. Hundreds of bacteria are present in a handful of soil. They also live in extreme habitats such as hot springs, deserts, snow and deep oceans where very few other life forms can survive. Many of them live in or on other organisms as parasites. Though the bacterial structure is very simple, they are very complex in behaviour. Compared to many other organisms, bacteria as a group show the most extensive metabolic diversity.

Bacteria are grouped under four categories based on their shape:

1. Coccus: Coccus bacteria are spherical or ovoid in outline. Depending upon their grouping, they are called

(i) Monococcus – occurring singling
(ii) Diplococcus – occurring in two
(iii) Tetracoccus – occurring in tetrads
(iv) Streptococcus – occurring in chain
(v) Staphylococcus – occurring in irregular grape like clusters
(vi) Sarcina – occurring in three dimensional geometric forms



Various forms of bacteria.

2. Bacillus: The bacterium is straight and cylindrical rod with ends being flat, rounded or cigar shaped. It has three special types:-

(i) Diplobacillus : occurring in two

(ii) Pallisade bacillus – occurring like stack
(iii) Streptobacillus – occurring in chains.

3. Spirillum: The bacterium is coiled like a cork screw, e.g. *Spirillum, Spirochaete.*

4. Vibrio: The body of the bacterium is like a comma e.g. *Vibrio cholerae*.

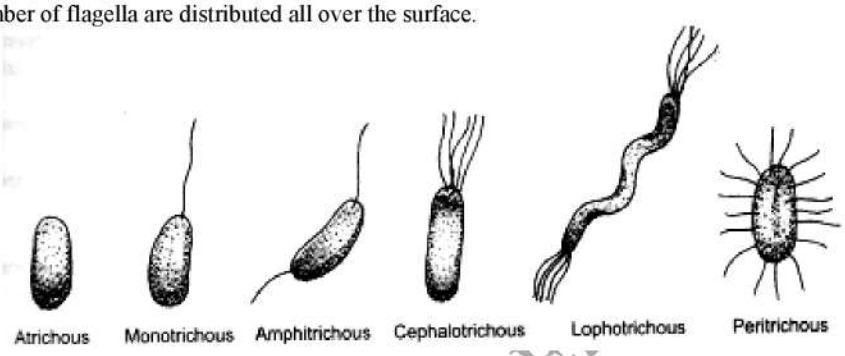
****

5. Stalked: The bacterium posses a stalked, e.g. *Caulobacter*.

6. Budding: The bacterium is swollen at places, e.g. *Rhodomicrobium*.

FLAGELLATION: Depending upon the presence or absence of flagella, bacteria are grouped into flagellate and non-flagellate type. The various forms of flagellation are as follows:

(a) Artichous :- Flagella absent
(b) Monotrichous : A single flagellum occurs at or near one end of bacterium
(c) Amphitrichous : A flagellum at each of the ends.
(d) Cephalotrichous : A group on tuft of flagella is found only at one end
(e) Lophotrichous – a group of flagella occurs at each of the two ends.
(f) Peritrichous – a number of flagella are distributed all over the surface.



Some of the bacteria are autotrophic, i.e., they synthesise their own food from inorganic substrates. They may be photosynthetic autotrophic or chemosynthetic autotrophic. The vast majority of bacteria are heterotrophs, i.e., they do not synthesise their own food but depend on other organisms or on dead organic matter for food.

Chemosynthetic autotrophic bacteria oxidise various inorganic substances such as nitrates, nitrites and ammonia and use the released energy for their ATP production. They play a great role in recycling nutrients like nitrogen, phosphorous, iron and sulphur.

Heterotrophic bacteria are the most abundant in nature. The majority are important decomposers. Many of them have a significant impact on human affairs. They are helpful in making curd from milk, production of antibiotics, fixing nitrogen in legume roots, etc. Some are pathogens causing damage to human beings, crops, farm animals and pets. Cholera, typhoid, tetanus, citrus canker are well known diseases caused by different bacteria.

Bacteria reproduce mainly by fission. Sometimes, under unfavourable conditions, they produce spores. They also reproduce by a sort of sexual reproduction by adopting a primitive type of DNA transfer from one bacterium to the other.

CYANOBACTERIA: The **cyanobacteria** (also referred to as blue-green algae) have chlorophyll *a* similar to green plants and are **photosynthetic autotrophs.** Cyanobacteria or Blue green algae are gram positive photosynthetic prokaryotes which performed oxygenic photosynthesis. They have chlorophyll *a* similar to green plants and are photosynthetic autotrophs. Cyanobacteria may be unicellular, colonial or filamentous, marine or terrestrial algae. The colonies are generally surrounded by gelatinous sheath. Each filament consists of a sheath of mucilage and one or more cellular strands called trichomes.

Cell Structure: Cyanobacteria are larger and more elaborate than bacteria. Cell structure is typically prokaryotic – one envelope organization with peptidoglycan wall, naked DNA, 70S ribosomes and absence of membrane bound cell organelles, thylakoids lie freely in the cytoplasm. Their membrane contains chlorophyll a, carotenes, xanthophylls. Many of them have the ability of nitrogen fixation.

Heterocyst: It is a large sized pale coloured thick walled cell which occurs in terminal, intercalary or lateral position in filamentous cyanobacteria. E.g. *Nostoc, Anabaena*. The thick wall is impermeable to oxygen but permeable to nitrogen. Mucilage sheath is absent. Photosystem II is absent. Thylakoids lack phycobilisomes. Therefore, photosynthesis is absent but cyclic photophosphorylation occurs. Heterocyst is dependent for its nourishment on adjacent vegetative cells. It has enzyme nitrogenase.

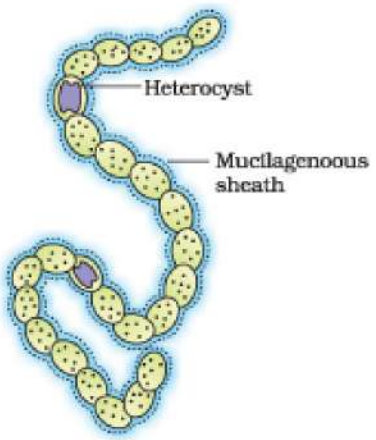


Figure :A filamentous blue-green algae-*Nostoc*

ARCHAEBACTERIA: They are a group of most primitive prokaryotes which are believed to have evolved immediately after the evolution of first life. Archaebacteria are characterized by the absence of peptidoglycan in their wall. Instead the wall contains protein and non-cellulosic polysachharides. Archaebacteria are also known as **living fossils** because they represent one of the earliest forms of life which experimented on the absorption of solar radiation for the first time, lived comfortably under anaerobic conditions and developed techniques to oxidize the chemicals present in the substratum on the availability of oxygen. Methanogens are present in the guts of several ruminant animals such as cows and buffaloes and they are responsible for the production of methane (biogas) from the dung of these animals.

USES: i) They are employed in production of gobar gas from dung and sewage.

ii) In ruminants, they cause fermentation of cellulose.

Q. Why are Archaebacteria known as living fossils?

MYCOPLASMA (PPLO): Mycoplasmas are the simplest and the smallest (0.1 – 0.5nm) of the free-living prokaryotes. They were discovered in the pleural fluid of cattle suffering from pleuropneumonia. They are often called MLOs (Mycoplasma like organisms) or PPLOs (Pleuropneumonia like organism). A cell wall is absent. Plasma membrane forms the boundary of the cell. They lack organized nuclease, endoplasmic reticulum, plastids, mitochondria, Golgi bodies, lysosomes, flagella, etc. Genetic material is single DNA duplex and is naked. Ribosomes are 70S. Enzymes lie freely in the cytoplasm and associated with plasma membrane.

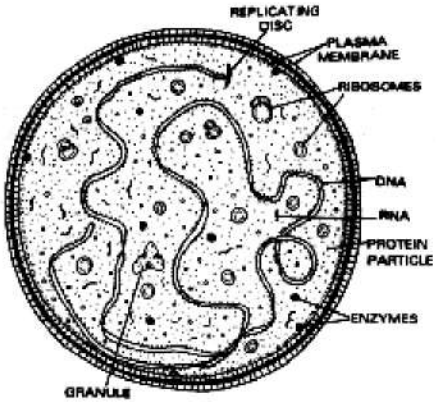


Fig. 2.18. Ultrastructure of PPLO.

KINGDOM - PROTISTA – Protista is the kingdom of all unicellular and colonial eukaryotes except some unicellular members of algae and fungi. The important characteristics are:

1. It includes all unicellular eukaryotes.
2. As mostly they are aquatic organisms forming plankton.
3. They have diverse modes of nutrition – photosynthetic, saprobic, parasitic, ingestive or holozoic.
4. Cellular organization is of two envelope type i.e. besides plasma membrane internal membranes occur around certain organelles.
5. Genetic materials is organized in the form of nucleus.
6. DNA is associated with histone proteins.
7. They reproduce asexually and sexually by a process involving cell fusion and zygote formation.

Locomotion: It is of five major types – i) Pseudopodial locomotion ii) Flagellar locomotion. iii) Ciliary Locomotion. iv) Wriggling locomotion. v) Locomotion by Mucilage propulsion.

The kingdom has been broadly divided into 3 groups:

A) Photosynthestic Protists of Protistian algae:

i) CHRYSOPHYTES:

- Includes diatoms and golden algae (desmids).
- Found in fresh water as well as marine environments.
- They are microscopic and float passively in water currents (plankton). Most of them are photosynthesis.
- Diatoms occur in all aquatic and moist terrestrial habitats.
- The common mode of multiplication is by binary fission.

Economic importance:

- The siliceous frustules of diatoms do not decay easily and they pile up at the bottom of water reservoir forming big heaps called diatomite or diatomaceous earth. Diatomite is employed as a cleaning agent in toothpaste and metal polishes.

ii) DINOFLAGELLATES:

-They are basically unicellular motile and biflagellate, golden brown photosynthetic protists; few are non-motile, non-flagellate.
-Cell wall has stiff cellulose plates on the outer surface.
-Toxins released by such large numbers may even kill other marine animals such as fishes.
E.g. *Glenodinium, Gonyalax* and *Noctiluca*.

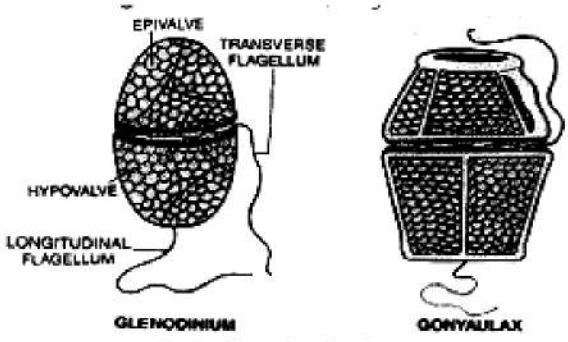


Fig. 2.4 Some dinoflagellates.

iii) EUGLENOID: They are a group of both chlorophyllous and non-chlorophyllous flagellate protists.

Characters:

i) They are unicellular flagellate protists, occur in fresh water habitat.
ii) Cell wall is absent.
iii) The unicells contains two flagella one long and one short.
iv) Nutrition is photoautotrophic, Saprobic or holozoic.
v) Photosynthetic pigments are chlorophyll a, chlorophyll b and Carotenoids.
vi) They store their carbohydrate as paramylon (Paramylum body). Paramylon is chemically different from starch and glycogen and doesn't stain with iodine.
e.g : *Euglena, Phacus, Eutreptia*

Euglena:

1. It is a free living solitary unicellular flagellate.
2. It is found in fresh water ponds and pools
3. Asexual reproduction occurs by longitudinal binary fission.

Structure:

1. Body is spindle like and it is covered by plasma membrane followed by pellicle.
2. Posterior end is pointed. The anterior end of the body is blunt and an eccentric cytostome (mouth)
3. Photosynthetic pigments are chlorophyll *a*, chlorophyll *b* and carotenoids. Reserved food material is paramylon.

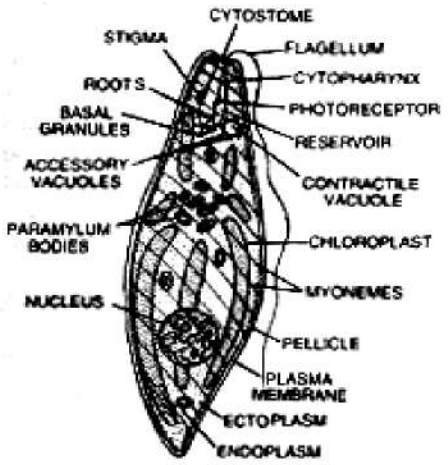


Fig. 2.5 *Euglena*

B) SLIME MOULDS: Slime moulds are simple organisms. They were included under mycetozoan or fungus animal.

E.g. *Physarum, Stemonites.*

Character:

1. They live usually among decaying vegetation
2. Chlorophyll is absent.
3. Body is surrounded by plasma membrane.
4. They are heterotrophic in nutrition. It is both saprotrophic and phagotrophic or holozoic.
5. Sexual and Asexual mode of reproduction are found.

C) PROTOZOAN PROTISTS: All protozoans are heterotrophs and live as predators or parasites. There are 4 major groups of protozoans.

1) Amoeboid protozoans: They live in fresh water, sea water or moist soil. Some of them are such as *Entamoeba* are parasites. *Entamoeba histolytica* resides in the upper part of large intestine and causes a disease known as amoebic dysentery or amoebiasis. The symptoms of the disease are abdominal pain, repeated motions with blood and mucus.

2) Flagellate Protozoans: They are either free living or parasitic. They have flagella. e.g. *Trypanosoma gambiense*: It is a parasite of sleeping sickness, transmitted by tse-tse-fly, *Glossina palpalis*. It causes African sleeping sickness.

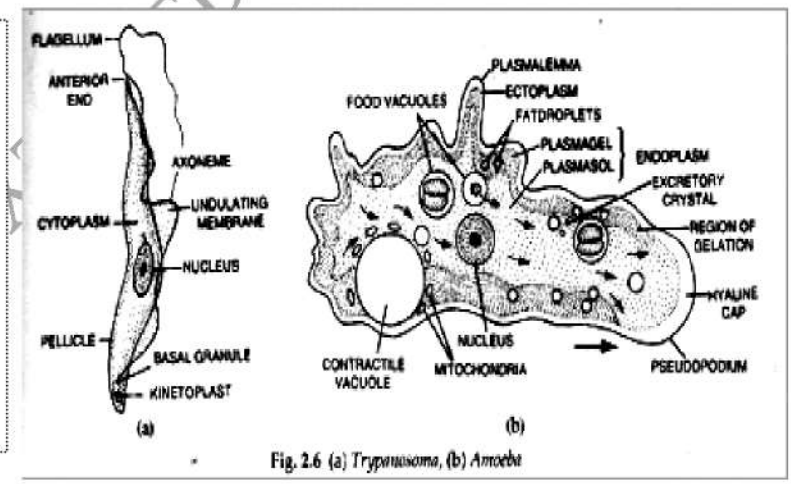


Fig. 2.6 (a) *Trypanosoma*, (b) *Amoeba*

3) Ciliated protozoans: They are protistan protozoans which possess cilia as organelles of locomotion and food capturing. They are mostly free living fresh water protista. e.g. *Paramecium, Vorticella, Opalina.*

Paramecium: It is free living ciliate which is found in fresh water pond, pools, ditches, etc. Nutrition is holozoic. *Paramecium* swims actively with the help of cilia. Exchange of gases takes place through body surface. Asexual and sexual reproductions are found.

4) *Sporozoans:* This includes diverse organisms that have an infectious spore-like stage in their life cycle. The most notorious is *Plasmodium* (malarial parasite) which causes malaria which has a staggering effect on human population.

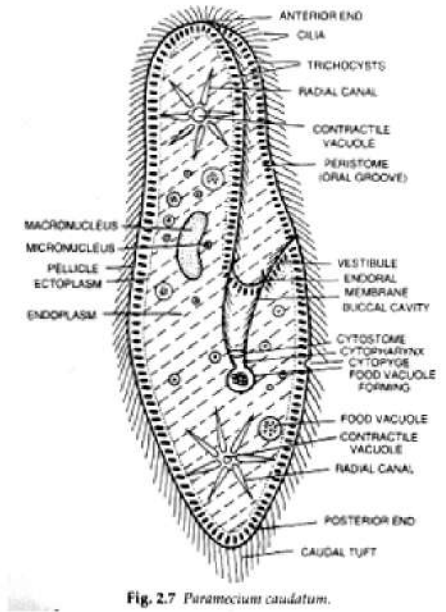


Fig. 2.7 *Paramecium caudatum.*

KINGDOM FUNGI (Kingdom of Mutlicellular decomposers)

The fungi constitute a unique kingdom of heterotrophic organisms. They show a great diversity in morphology and habitat. When your bread develops a mould or your orange rots it is because of fungi. The common mushroom are also fungi. White spots seen on mustard leaves are due to a parasitic fungus. Some unicellular fungi, e.g., yeasts are used to make bread and beer. Other fungi cause diseases in plants and animals; wheat rust-causing *Puccinia* is an important example. Some are the source of antibiotics, e.g., *Penicillium*. Fungi are cosmopolitan and occur in air, water, soil and on animals and plants. They prefer to grow in warm and humid places.

With the exception of yeasts which are unicellular, fungi are filamentous. Their bodies consist of long, slender thread-like structures called hyphae. The network of hyphae is known as mycelium. Some hyphae are continuous tubes filled with multinucleated cytoplasm – these are called coenocytic hyphae. Others have septae or cross walls in their hyphae. The cell walls of fungi are composed of chitin and polysaccharides.

Most fungi are heterotrophic and absorb soluble organic matter from dead substrates and hence are called **saprophytes**. Those that depend on living plants and animals are called **parasites**. They can also live as **symbionts** – in association with algae as **lichens** and with roots of higher plants as **mycorrhiza**.

Reproduction in fungi can take place by vegetative means – fragmentation, fission and budding. Asexual reproduction is by spores called conidia or sporangiospores or zoospores, and sexual reproduction is by oospores, ascospores and basidiospores. The various spores are produced in distinct structures called fruiting bodies. The sexual cycle involves the following three steps:

(i) Fusion of protoplasms between two motile or non-motile gametes called **plasmogamy.**

(ii) Fusion of two nuclei called **karyogamy.**

(iii) Meiosis in zygote resulting in haploid spores.

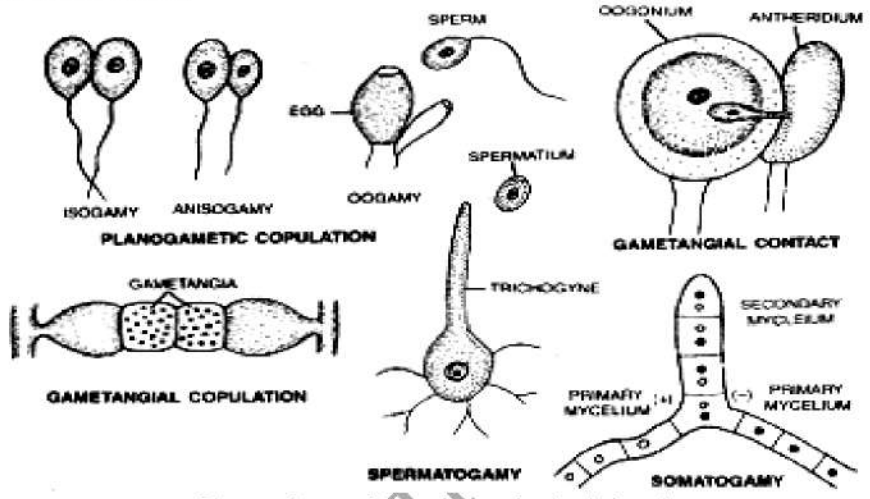


Diagram: Types of Sexual reproduction in Fungi.

When a fungus reproduces sexually, two haploid hyphae of compatible mating types come together and fuse. In some fungi the fusion of two haploid cells immediately results in diploid cells (2n). However, in other fungi (ascomycetes and basidiomycetes), an intervening dikaryotic stage (n + n i.e. two nuclei per cell) occurs; such a condition is called a **dikaryon** and the phase is called **dikaryophase** of fungus. Later, the parental nuclei fuse and the cells become diploid. The fungi form fruiting bodies in which reduction division occurs, leading to formation of haploid spores.

The morphology of the mycelium, mode of spore formation and fruiting bodies form the basis for the division of the kingdom into various classes -

PHYCOMYCETES:

Members of phycomycetes are found in aquatic habitats and on decaying wood in moist and damp places or as obligate parasites on plants. The mycelium is aseptate and coenocytic. Asexual reproduction takes place by zoospores (motile) or by aplanospores (non-motile). These spores are endogenously produced in sporangium. Zygospores are formed by fusion of two gametes. These gametes are similar in morphology (isogamous) or dissimilar (anisogamous or oogamous). Some common examples are *Mucor, Rhizopus* (the bread mould) and *Albugo* (the parasitic fungi on mustard).

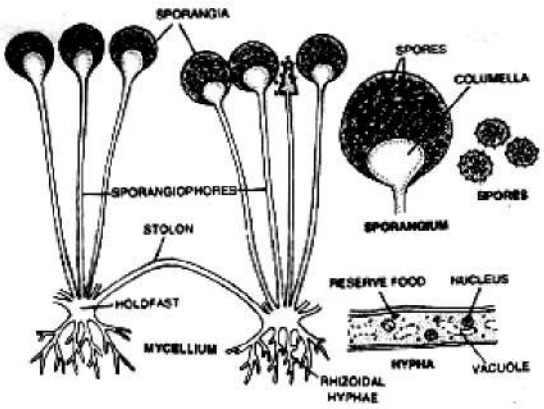
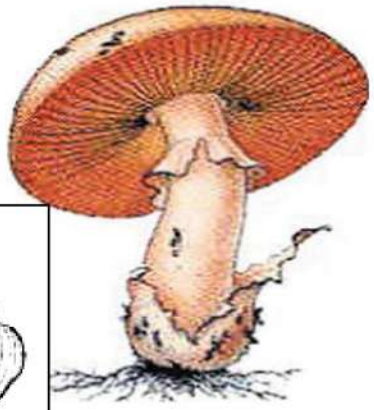


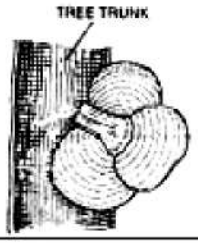
Fig. 2.11 Structure of Rhizopus.

ASCOMYCETES:

Commonly known as sac-fungi, the ascomycetes are unicellular, e.g., yeast (*Sacharomyces*) or multicellular, e.g., *Penicillium*. They are saprophytic, decomposers, parasitic or coprophilous (growing on dung). Mycelium is branched and septate. The asexual spores are conidia produced exogenously on the special mycelium called conidiophores. Conidia on germination produce mycelium. Sexual spores are called ascospores which are produced endogenously in sac like asci (singular ascus). These asci are arranged in different types of fruiting bodies called ascocarps. Some examples are *Aspergillus, Claviceps* and *Neurospora. Neurospora* is used extensively in biochemical and genetic work. Many members like morels and buffles are edible and are considered delicacies.

BASIDIOMYCETES: (Club fungi)
Commonly known forms of basidiomycetes are mushrooms, bracket fungi or puffballs. They grow in soil, on logs and tree stumps and in living plant bodies as parasites, e.g., rusts and smuts. The mycelium is branched and septate. The asexual spores are generally not found, but vegetative reproduction by fragmentation is common. The sex organs are absent, but plasmogamy is brought about by fusion of two vegetative or somatic cells of different strains or genotypes. The resultant structure is dikaryotic which ultimately gives rise to basidium. Karyogamy and meiosis take place in the basidium producing four basidiospores. The basidiospores are exogenously produced on the basidium (pl. basidia). The basidia are arranged in fruiting bodies called basidiocarps. Some common members are *Agaricus* (mushroom), *Ustilago* (smut) and *Puccinia* (rust fungus).





Bracket fungus

DEUTEROMYCETES: (fungi imperfecti)
Commonly known as *imperfect fungi* because only the asexual or vegetative phases of these fungi are known. When the sexual forms of these fungi were discovered they were moved into classes they rightly belong to. It is also possible that the asexual and vegetative stage have been given one name (and placed under deuteromycetes) and the sexual stage another. Later when the linkages were established, the fungi were correctly identified and moved out of deuteromycetes. Once perfect (sexual) stages of members of dueteromycetes were discovered they were often moved to ascomycetes and basidiomycetes. The deuteromycetes reproduce only by asexual spores known as conidia. The mycelium is septate and branched. Some members are saprophytes or parasites while a large number of them are decomposers of litter and help in mineral cycling. Some examples are *Alternaria, Colletotrichum* and *Trichoderma*.

Examples:

i. Red Rot : *Colletorichum falcatum* produces red rot of sugarcane which is conspicuous on leaf midribs as well as cane.
ii. Early Blight: *Alternaria solani* causes early blight of potato and tomato.
iii. Gibberellins: They were first discovered in the extracts of *Fusarium moniliformae*_ growing on rice. The perfect stage of fungus is *Gibberella fujikuroi*_ Gibberrellins are natural plant growth hormone.

KINGDOM PLANTAE:
Kingdom Plantae includes all eukaryotic chlorophyll-containing organisms commonly called plants. A few members are partially heterotrophic such as the insectivorous plants or parasites. Bladderwort and Venus fly trap are examples of insectivorous plants and *Cuscuta* is a parasite. The plant cells have an eukaryotic structure with prominent chloroplasts and cell wall mainly made of cellulose. Plantae includes algae, bryophytes, pteridophytes, gymnosperms and angiosperms. Life cycle of plants has two distinct phases – the diploid sporophytic and the haploid gametophytic – that alternate with each other. The lengths of the haploid and diploid phases, and whether these phases are free– living or dependent on others, vary among different groups in plants. This phenomenon is called *alternation of generation*.

KINGDOM ANIMALIA:
This kingdom is characterised by heterotrophic eukaryotic organisms that are multicellular and their cells lack cell walls. They directly or indirectly depend on plants for food. They digest their food in an internal cavity and store food reserves as glycogen or fat. Their mode of nutrition is holozoic – by ingestion of food. They follow a definite growth pattern and grow into adults that have a definite shape and size. Higher forms show elaborate sensory and neuromotor mechanism. Most of them are capable of locomotion.

The sexual reproduction is by copulation of male and female followed by embryological development.

ADVANTAGES OF 5 KINGDOM CLASSIFICATION:

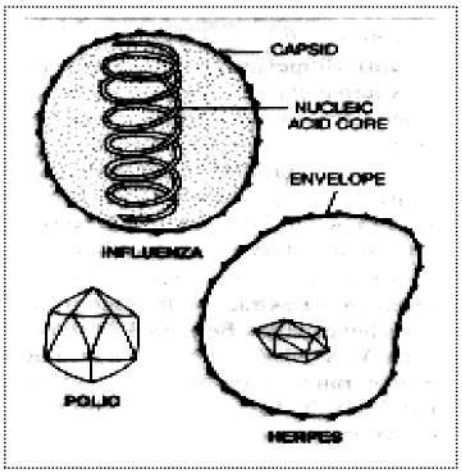
1. Separation of prokaryotes in a separate kingdom of monera is a wise step because prokaryotes differ from all other organisms in their genetic, cellular, reproductive and physiological organization.
2. Unicellular eukaryotes like *Euglena* was earlier included both in plants and animals. By grouping all unicellular eukaryotes in kingdom Protista, their anomaly has been removed.
3. Fungi have never been related to plants separation of fungi into a separate kingdom was long overdue.
4. Five kingdom system of classification succeeds in indicating the gradual evolution of early organisms into plants and animals to a good extend.
5. The five kingdom classification is based on levels of organization and nutrition which evolved very early and became established in later groups that are existing today.

Drawbacks of 5 kingdoms Classification:

1. Viruses have not been included in this system of classification.
2. Archaebacteria differ from other bacteria in structure, composition and physiology (achae – primitive).
3. Mycoplasmas are quite different from bacteria where they have been placed along with other prokaryotes.
4. Each group has so many diversities that it is difficult to keep them together. e.g. Monera and Protista contain both walled and wall less organisms, photosynthetic and non-photosynthetic organisms.
5. Red and brown algae are not related to other members of kingdom plantae.

VIRUSES, VIROIDS AND LICHENS:

In the five kingdom classification of Whittaker, there is no mention of some acellular organisms like viruses and viroids, and lichens. These are briefly introduced here.



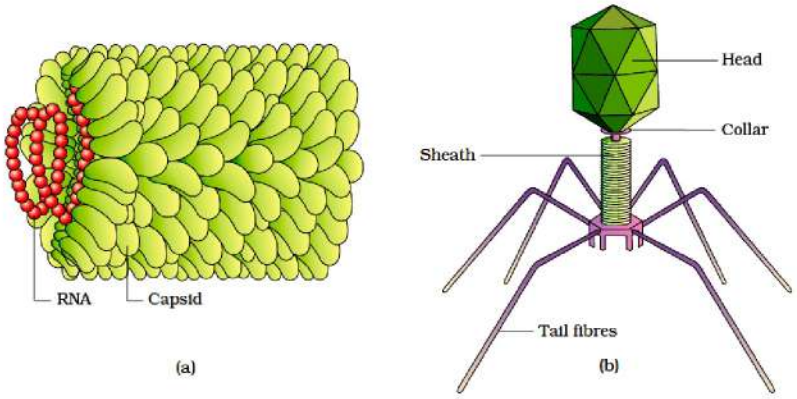


Figure: (a) Tobacco Mosaic Virus (TMV); (b) Bacteriophage

VIRUSES: A virus is a nucleoprotein and the genetic material is infectious. Virus becomes active only inside a living cell using the latter's machinery for multiplication through separate synthesis of its parts. The name virus that means venom or poisonous fluid was given by Pasteur. D.J. Ivanowsky (1892) recognised certain microbes as causal organism of the mosaic disease of tobacco. Viruses are obligate parasites.

In addition to proteins viruses also contain genetic material that could be either RNA or DNA. No virus contains both RNA and DNA. In general, viruses that infect plants have single stranded RNA and viruses that infect animals have either single or double stranded RNA or double stranded DNA.

Structurally, a virus has four parts:

i) Envelope – It is the other loose covering present in certain viruses (e.g. HIV) and made of protein of viral origin, lipid and carbohydrate of host. The virus without an envelope is called naked viruses.

ii) Capsid – It is the proteinaceous covering around the virus which protects the nuceloid from physical and chemical agent.

iii) Nucleoid – It represents the viral chromosome viral chromosome is made of single molecule of nucleic acid. The nucleic acid is either DNA or RNA

iv) Enzymes – Enzyme, Lysozyme is present in the region that comes in contact with the host cell in bacteriophages. Other enzymes are neuraminidase in influenza viruses, RNA polymerase, RNA transcriptase, reverse transcriptase in RNA viruses.

TYPES:

1. dsDNA Virus: It occurs in T_2, T_4 bacteriophages, coliphage Lambda, cauliflower Mosaic, pox virus, hepatitis – B, Simian virus – 40, Polyoma virus, Simian Virus-40 (SM40), Hepatitis B.
2. ssDNA Virus: It is found in coliphage ϕx174, coliphage MS-2, Coliphage *fd* (linear).
3. ssRNA Virus : It is found in poliomyelitis virus, foot and mouth disease virus, influenza virus, TMV (Tobacco Mosaic Virus)
4. dsRNA virus: It is found in Reovirus and Tumour Virus (both linear).

BACTERIOPHAGES: Bacterial viruses or bacteriophages (viruses that infect the bacteria) are usually double stranded DNA viruses. The protein coat called capsid made of small subunits called capsomeres, protects the nucleic acid. These capsomeres are arranged in helical or polyhedral geometric forms.

Viruses cause diseases like mumps, small pox, herpes and influenza. AIDS in humans is also caused by a virus. In plants, the symptoms can be mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.

VIROIDS: It was found to be a free RNA; it lacked the protein coat that is found in viruses, hence the name viroid. The RNA of the viroid was of low molecular weight. They are infectious RNA particles which are devoid of protein coat. They are obligate parasites. The RNA is tightly folded to form circular or linear structure. Viroids are known to cause diseases in plants only. e.g. Potato spindle tuber, Chrysanthemum stunt.

LICHENS: Lichens are symbiotic associations i.e. mutually useful associations, between algae and fungi. The algal component is known as **phycobiont** and fungal component as **mycobiont,** which are autotrophic and heterotrophic, respectively. Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner. Lichens are very good pollution indicators – they do not grow in polluted areas.

SOME PROBABLE QUESTIONS:

Q.1. Discuss how classification systems have undergone several changes over a period of time?

Answer: Scientific classification of living beings was first done by Aristotle. He used morphological characters as the basis of classification. He classified the living beings into plants and animals. He further classified the plant into trees, shrubs and herbs. He further classified the animals on the basis of presence of absence of red blood.

After that, Linnaeus proposed two kingdoms, i.e. Plant Kingdom and Animal Kingdom.

But there were certain organisms which could be kept in both of the kingdoms or could not be kept in either of the kingdoms. Hence, a need was felt for a better system of classification. At present, the Five Kingdom Classification is the most accepted one. This was proposed by Robert Whittaker in 1969. Whittaker used phylogenetic relationship to classify the living beings.

Q.2. State two economically important uses of:

(a) Heterotrophic bacteria

Ans:- Curd and antibiotic are made by using heterotrophic bacteria.

(b) Archaebacteria

Ans:- Methanogens are responsible for production of biogas which can be used as fuel. The archaebacteria which live in extreme conditions give us a clue about the beginning of life on earth.

Q. 3 - What is the nature of cell-walls in diatoms?

Answer: The cell walls in diatoms form two thin overlapping shells; which fit together as the two parts of a soapbox. The cell walls are embedded with silica and hence are indestructible.

Q. 4 – How are viroids different from viruses?

Answer: The free RNAs without the protein coat are called viroids, while viruses have a protein coat to protect the genetic material.

Q. 5 - Find out what do the terms 'algal bloom' and 'red-tides' signify.
Answer: A rapid increase in the population of microscopic algae in an aquatic habitat is called algal bloom. The algal bloom involving the dianoflagellates is called the 'red tide' because of its red hue. Red tide can be harmful for other aquatic life forms.

Q. 6 - Describe briefly the four major groups of Protozoa.
Answer: Four major groups of Protozoa are as follows:
Amoeboid protozoans: The amoeboid protozoans live in freshwater, sea water or in moist soil. They produce pseudopodia for locomotion and for capturing food. The marine forms have silica shells on their surface. Some of them are parasites, e.g. *Entamoeba histolytica*.
Flagellated protozoans: They are either free-living or parasitic. Flagella is present for locomotion. Many of them are parasites, e.g. *Trypanosoma*.
Ciliated protozoans: They are aquatic. Cilia are present for locomotion. A cavity (gullet) is present which opens to the outside of the cell surface. The coordinated movement of cilia facilitates the entry of food-laden water into the gullet. Example: *Paramaecium*.
Sporozoans: The sporozoans have an infectious spore-like stage in their life cycle. Example: *Plasmodium*.

Q. 7 - Plants are autotrophic. Can you think of some plants that are partially heterotrophic?
Answer: Pitcher plant, Venus fly trap and bladderwort are examples of partially heterotrophic plants.

Q.8 - What do the terms phycobiont and mycobiont signify?
Answer: Lichens are the symbiotic association of fungi and algae. The algal part of lichen is called phycobiont and the fungal part is called mycobiont. The mycobiont part provides minerals and support, while the phycobiont part provides nutrition.

Q. 9 - Give a comparative account of the classes of Kingdom Fungi under the following:
(a) Mode of nutrition
Answer: Phycomycetes are obligate parasites or saprophytes.
Ascomycetes are saprophytes or parasites or coprophilous.
Basidiomycetes are saprophytes or parasites.
Deuteromycetes are manly saprophytes, some are parasites.

(b) Mode of reproduction
Answer: In phycomycetes, asexual reproduction is by zoospores (motile) or by aplanospores.
In ascomycetes, asexual spores (conidia) and sexual spores (ascospores) are produced.
In basidiomycetes, vegetative reproduction takes place by fragmentation. Plasmogamy is also seen.
In deuteromycetes, only vegetative reproduction is seen.

Q. 10 - What are the characteristic features of Euglenoids?
Answer:- Most of them live in freshwater habitat in stagnant water. Cell wall is absent in them and instead there is a protein rich layer; called pellicle. The pellicle makes their body flexible. Two flagella; one short and another long; are present. They are photosynthetic; but behave as heterotrophs in the absence of sunlight.

Q. 11 - Give a brief account of viruses with respect to their structure and nature of genetic material. Also name four common viral diseases.
Ans:- Virus contains genetic material surrounded by a protein capsule. The protein coat on the virus is called capsid. It is made up of small subunits called capsomeres. The capsid protects the nucleic acid. The capsomeres are arranged in helical or polyhedral geometric forms.
The genetic material can be either RNA or DNA. Both RNA and DNA cannot be present in the same virus. Plant infecting viruses usually have single-stranded RNA and animal infecting viruses usually have double-stranded RNA or double-stranded DNA. Bacteriophages (bacterial viruses) usually have double-stranded DNA.

- Four common viral diseases are: Common cold, mumps, jaundice and influenza.

12. What are Lichens?
13. Mention three methods of locomotion seen among protists, with an example for each.

APPLICATION OF BIOTECHNOLOGY

Application of Biotechnology in health and agriculture:-Human insulin and vaccine production, gene therapy. Genetically modified organisms-*Bt* crops. Biosafety Issues, Biopiracy and patents.

Some of the terms used in biotechnology are:

1. **Red Biotechnology:** This term is used for medical processes like designing of organisms to produce antibiotics and to cure ailments by genetic engineering through manipulation.
2. **Green Biotechnology:** This term is used for agricultural processes like production of transgenic plants, to produce genetically engineered plants which do not require external application of pesticides, e.g. Bt cotton, Bt brinjal, etc.
3. **Blue Biotechnology:** This term is used to describe the marine and aquatic applications of biotechnology.
4. **White Biotechnology:** This term is used for industrial processes like designing of an organism to produce a useful chemical.

Transgenic Organisms/ GMOs: The organisms which contain functional foreign gene experimentally introduced into their genome by genetic engineering from another species are called transgenic organisms/GMOs.

Biotechnological Applications in Agriculture: There are three options to increase the food production.

i) Agrochemical based agriculture.
ii) Organic agriculture
iii) Genetically engineered crop-based agriculture.

Agrochemicals cause pollution of soil and water and are too expensive for the farmers.

Transgenic Plants: The plants produced through genetic engineering contain gene or genes usually from an unrelated organism. Such genes are transgenes and the plants having transgenes are called *transgenic plants.*

1. Bt Cotton: The soil bacterium *Bacillus thuringiensis* produces Crystal proteins called Cry proteins that are toxic to certain insects. Actually, the Bt toxin protein (Cry) exist as inactive *protoxins* but once an insect ingests the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilise the crystals. The activated toxin binds to the surface of midgut epithelial cells and creates pores. This causes swelling and lysis of cells leading to the death of the insects.

The toxin is coded by a gene named ***cry***. The choice of genes depends upon the crop and the targeted pest, as most Bt toxins are insect-group specific. Cotton is attacked by bollworms, *Earias vitella* and *E. insulana*. Bt toxin genes were isolated from *Bacillus thuringiensis* and incorporated into several crop plants such as cotton.

- *cry I AC* and *cryIIAb* control cotton bollworms.
- *cry I Ab* controls corn borer.
- *cry III Ab* controls colarado potato beetle.
- *cry III Bb* controls corn rootworm.

2. Pest Resistance in Transgenic Plants (Protection Against Nematodes):

A nematode, *Meloidegyne incognitia* infects the roots of tobacco plants and cause drastic reduction in yield. Transgenic tobacco plants were produced based on the process of *RNAi* (RNA interference). *RNAi* involves silencing of a specific mRNA by a complementary dsRNA that prevents the translation of the mRNA. RNAi takes place in all eukaryotic organisms as a method of cellular defence.

The specific genes in the form of cDNA from the parasite are introduced into the plant using *Agrobacterium tumefaciens* as the vector. The genes are introduced in such a way that both the sense RNA and antisense RNA (complementary to the coding or sense RNA) are produced. Since these two RNAs are complementary, they form a double stranded RNA (*dsRNA*). This neutralizes the specific RNA of the nematode, by a process called RNA interference (*RNAi*) and silenced the specific mRNA of the nematode.

As a result, the parasite cannot live in the transgenic host, which expresses the specific interfering RNA and thus the transgenic plant is protected from the nematode.

3. Mask expression of a native gene/Flavr-Savr Transgenic Tomatoes:

It prevents the expression of an existing native gene. In '*Flavr Savr'* variety of tomato, expression of a native gene for production of enzyme *polygalacturonase* has been blocked. This Enzyme *polygalacturonase* degrades pectin which promotes softening of fruit. In absence of enzyme, pectin degradation is stopped and the fruit fresh for long. It retains flavour, has superior taste and higher quantity of total soluble solid.

4. Production of Hirudin: The protein hirudin present in leech prevents blood clotting. Its gene was chemically synthesized and introduced in *Brassica napus* (Rapeseed). The protein accumulates in the seeds from where it is extracted purified and used as medicine.

5. Golden Rice: Golden Rice is a transgenic variety of rice (*Oryza sativa*) which contains good quantities of *β-carotene* (provitamin A), a principal source of vitamin A. Since the grains of rice are yellow in colour due to *β-carotene*, the rice is commonly known as golden rice.

6. Diagnostic and Therapeutic Plants: Transgenic plants can produce a variety of proteins used in diagnostic for detecting and curing human and animal diseases in large scale with low cost. The monoclonal antibodies, peptide hormones, cytokinins and blood plasma proteins are being produced in transgenic plants and their parts such as tobacco (in leaves), potato (in tubers), sugarcane (in stems) and maize (in seed endosperm).

Use Of Genetically Modified Plants:

i) Tolerance: Genetic modification has made the crops more tolerant to abiotic stresses like cold, heat, drought, salinity, etc.

ii) Pest Resistance Crops: It has reduced the dependence of crops on chemical pesticides as they are made pest-resistant. e.g. Bt cotton

iii) Reduction in Post-harvest losses: They have helped to reduce post harvest losses. E.g. Flavr Savr transgenic Tomato.

iv) Prevention of Early Exhaustion of Fertility of soil: As the plants have increased efficiency of mineral usage of plants, the early exhaustion of fertility of soil is prevented.

v) Increasing Nutritional Value of Food: Food produced from GM crops has enhanced nutritional value. E.g. golden rice is rich in vitamin A.

vi) Alternate Resources to Industries: GM plants have been used to create alternate resources to industries in the form of starches, fuels and pharmaceuticals. Researchers are working to develop edible vaccines, edible antibiotics and edible interferons.

vii) Phytoremediation: Plants such as popular trees have been genetically engineered to clean up heavy metal pollution from contaminated soil.

Disadvantages of Transgenic Plants (GM Plants):

A) Environmental Hazards:

1. Unintended Harm to other Organisms: If pollen from *Bt* corn is blown by the wind onto milkweed plants in neighbouring fields, the caterpillars can eat the pollen and die.
2. Reduced effectiveness of pesticides: Just as some populations of mosquito developed resistance to the pesticide DDT, many people are concerned that insects will become resistant to Bt or other crops that have been genetically modified to produce their own pesticides.
3. Gene Transfer to non-target Species: Another concern is that crop plants engineered for herbicide tolerance and weeds will cross breed, resulting in the transfer of the herbicide resistance gene from the crops into the weeds. These "*Superweeds*" would then be herbicide tolerant as well.

B) Human Health Risk:

1. Allergies: The transgenic may cause toxicity and produce allergies. The enzyme produced by the antibiotic resistance gene can cause allergies, because it is a foreign protein.
2. Effect on Bacteria of Alimentary Canal: The bacteria present in the human alimentary canal can take up the antibiotic resistance gene that is present in the GM food. These bacteria can become resistant to the concerned antibiotic and will be difficult to manage.

C) Economic concerns: Bringing a GM food to market is a lengthy and costly process, and of course agro-biotech companies wish to ensure a profitable return to their investment.

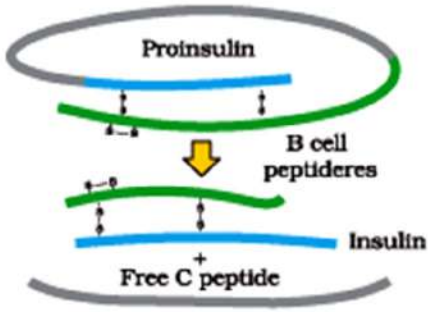
Transgenic plants	Useful application
1. Bt cotton	Pest resistance, herbicide tolerance and high yield. It is resistant to bollworm infestation.
2. Flavr Savr tomato	Increased shelf-life (delayed ripening) and better nutrient quality.
3. Golden rice	Vitamin A rich.
4. Potato	Higher protein content.
5. Corn, brinjal	Insect resistance
6. Soyabean, maize	Herbicides resistance.
7. *Brassica napus*	A gene encoding hirudin (an anticoagulant) is synthesized chemically and then transferred into *Brassica napus.*

BIOTECHNOLOGICAL APPLICATIONS IN MEDICINE

Genetically Engineered Insulin:

Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs. Insulin from an animal source, though caused some patients to develop allergy or other types of reactions to the foreign protein.

In mammals, including humans, insulin is synthesized as a pro-hormone (like a proenzyme, the pro-hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the C peptide. This C peptide is not present in the mature insulin and is removed during maturation into insulin. Human insulin is made up of 51 amino acids arranged in two polypeptide chains, A having 21 amino acids and B with 30 amino acids. The two polypeptide chains are interconnected by two disulphide bridges.



Maturation of pro-insulin into insulin after removal of C- peptide.

Genetically Engineered Insulin: In 1983, Eli Lilly an American company, first prepared two DNA sequences corresponding to A and B chains of human insulin. It involves following stages:

1. Preparation of DNA: Two DNA sequences for chains A and B of insulin were synthesized separately.
2. Formation of rDNA: The two DNA sequences, A and B, of insulin are separately inserted into two pBR322 plasmids by the side of β-galactosidase gene and are joined together by DNA ligase. It produces recombinant DNAs.
3. Introduction of rDNA into bacterial cell: The recombinant DNAs (plasmids) were separately transferred into plasmid free *E. coli* cells, through a process that a culture of plasmid free *E. coli* is now inoculated with recombinant plasmids in the presence of calcium chloride that increases the ability of bacterial cells in obtaining recombinant plasmids from outside.
4. Screening of the transformed cells: The genetically engineered bacteria are tested for the formation of polypeptide consisting of one insulin subunit and *β-galactosidase* sequence.
5. Multiplication of transformed bacteria: As the presence of both the insulin is ensured, the bacteria are first multiplied or cloned. They are then introduced in a sterilized bioreactor or fermenter having the growth medium.

When they increase in number, a part of population is harvested. The medium is replenished from time to time. Insulin is extracted from the harvested bacteria by first extracting and purifying the fusion polypeptides, treating them with cyanogen bromide for separating polypeptide of *β-galactosidase* and purifying insulin subunits. The purified chains A and B are then attached to each other by disulphide bonds *in vitro*. Insulin is spontaneously formed. Since it is exactly similar to human insulin, the same is also called ***Humulin*.**

Vaccines: Biotechnology may be used in the preparation of different vaccines which have been used to impart immunity in the body against diseases. In recent years, second generation vaccines have been prepared by genetic engineering against hepatitis-B, herpes virus, *Vibrio cholerae* (causing cholera), *Salmonella typhimurium* (causing typhoid), rabies virus, polio virus, etc. Even synthetic vaccines have been produced which are known as **third generation vaccines.** Antifertility vaccines have also been developed. Looking to the advancement in the field of biotechnology, it may now be possible to build vaccines into plants eaten as a part of the normal diet like banana, apple, orange, etc.

Transgenic Animals: The animals which carry foreign genes are called transgenic animals. Or They are animals which have been genetically modified by incorporating foreign and other specific genes through rDNA technology.

Transgenic animals are produced mainly for the following reasons:

a) Some transgenic animals are produced for economic benefits. E.g. Transgenic cattle are created to produce a particular type of milk containing specific human proteins which help in human emphysema treatment.

b) Some transgenic animals are produced as disease models. E.g. genetically modified mouses carry a gene that promotes the development of several types of cancers in human.

Many transgenic animals have been developed for commercial purposes to obtain leaner meat, fast growing to a marketable size, resistance to different diseases, to produce important recombinant proteins in their milk, blood, urine, meat, etc.

The first transgenic animal produced in 1982, was a mouse, known as '*supermouse*' due to its bigger size. Since then many types of transgenic animals have been produced for some specific purposes. Some of the important uses of transgenic animals are as follows:

1. Transgenic Pigs: Transgenic pigs having human genes possess human antigens. As a result their organs if transplanted do not produce any reaction. It will eliminate the requirement of human organs for transplantation, e.g. Pancreas, Kidney, Heart.
2. Vaccine safety: Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans. Transgenic mice are being used to test the safety of the polio vaccine. If successful and found to be reliable, they could replace the use of monkeys to test the safety of batches of the vaccine.
3. Chemical safety Testing: This is known as toxicity/safety testing. The procedure is the same as that used for testing toxicity of drugs. Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals. They are then exposed to the toxic substances and the effects studied. Toxicity testing in such animals will allow us to obtain results in less time.
4. Study of Disease: Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease. These are specially made to serve as models for human diseases so that investigation of new treatments for diseases is made possible. Today transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.
5. Normal physiology and development: Transgenic animals can be specifically designed to allow the study of how genes are regulated, and how they affect the normal functions of the body and its development, e.g., study of complex factors involved in growth such as insulin-like growth factor. By introducing genes from other species that alter the formation of this factor and studying the biological effects that result, information is obtained about the biological role of the factor in the body.
6. Biological products: Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make. Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (or genes) which codes for a particular product such as human protein (α-1-antitrypsin) used to treat emphysema. Similar attempts are being made for treatment of phenylketonuria (PKU) and cystic fibrosis. In 1997, the first transgenic cow, **Rosie**, produced human protein-enriched milk (2.4 grams per litre). The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow-milk.

Q. Why are these animals being produced? How can man benefit from such modifications?

Gene Therapy: It is therapeutic treatment of defective heredity by introduction of normal healthy and functional genes which also silence the defective genes of an individual.

Types:

1) Germ line gene therapy: In this therapy the functional genes are introduced into the germ cells for correction of genetic defects. [It is carried out in laboratory and formed animals. But it has not been attempted in humans due to technical and ethical problems].

2) Somatic Gene therapy: In this case, the functioning genes are introduced into body cells that lack them and the effects of the therapy are confined to the person undergoing treatment and are -not passed on the offspring.

Gene Therapy and SCID: SCID (Severe Combined Immuno Deficiency) is caused by a defect in the gene for the enzyme adenosine deaminase (ADA). These patients lack functional T-lymphocytes and therefore fail to fight in infective pathogens. In absence of enzyme ADA, purine metabolism is disturbed and T-Lymphocytes fail to function.

As a first step towards the gene therapy, lymphocytes are extracted from the patient's bone marrow and are grown in a culture outside the body. A functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes, which are reinjected to the patient's bone marrow. But as these cells do not always remain alive, it cannot be a permanent cure. The patient requires periodic infusion of such genetically engineered lymphocytes. However, if the isolated gene from bone marrow cells producing ADA is introduced into cells at early embryonic stages, it can be a permanent cure.

22. A four year old girl was introduced genetically engineered lymphocytes (collected from her own blood) for her treatment of ADA deficiency. What is the name of such therapy? What alternative technique can be taken for a permanent cure? 2 (CoHSEM-2012).

Q.29. a) What are plasmids? (CBSE-2008)

b) What is meant by ADA deficiency? How is gene therapy a solution of this problem? Why is it not a permanent cure?

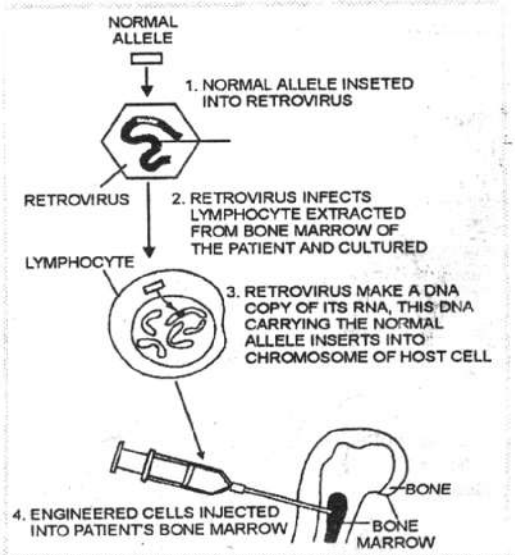


Fig: Gene Therapy SCID patient starts developing immune response after receiving a functional gene

ETHICAL ISSUES: Bioethics includes rules of conduct that may be used to regulate our activities in relation to biological world.

Biotechnology is producing newer GM organisms. Some of them can be extremely harmful due to intragenomic interaction and mutation. Therefore, Govt. of India has set up an organization called GEAC (Genetic Engineering Approval Committee) which will make decision regarding the validity of GM research and safety of introducing GM organisms for public services.

Under biosafety issues, main emphasis has been given to facilitate biosafety procedures for ensuring safety from the use of GMOs to the users as well as to the environment. Some biosafety issues related to biotechnology are as follows :

i) Violation of integration of species due to transfer of transgene from species to species.

ii) Effect on biodiversity due to various biotechnological experiments pose threat to the environment.

iii) Animals suffer greatly while performing experiments, on them.

BIOPATENT: Biopatent is an official right from a government granting an inventor or establishment the sole monopoly to use a particular biological material for certain period.

Biopatents are now being granted for the following purposes:

a) Genetically modified strains of plants and animals.
b) Proteins encoded by DNA sequences.
c) Cell lines.
d) New strains of micro-organisms.
e) Particular biotechnological procedures.
f) Biotechnological products.
g) Production processes, etc.

BIOPIRACY: **Biopiracy** is the term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

Research institutes, companies and other establishments of industrialized nations are doing exactly the same, collecting and exploiting bioresources of the developing nations.

i) The diversity of rice in India is one of the richest in the world. Basmati rice is distinct for its unique aroma and flavour and 27 documented varieties of Basmati are grown in India. In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.

ii) Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric neem. If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy and we may not be able to do anything about it.

BIOPIRACY: **Biopiracy** is the term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

Research institutes, companies and other establishments of industrialized nations are doing exactly the same, collecting and exploiting bioresources of the developing nations.

i) Basmati is a long-grained, aromatic variety of rice indigenous to the Indian subcontinent. In 1997 the US Patent and Trademark Office (USPTO) granted a patent (No. 5663484) to a Texas based American company Rice Tec Inc for "Basmati rice line and grains". The patent application was based on 20 very broad claims on having "invented" the said rice. Due to people's movement against rice Tec in March 2001 the UPSTO has rejected all but three of the claims.

Or, A patent in USA covers the entire Basmati rice germplasm which is indigenous to Indian subcontinent. The patent was obtained in 1997 by an American company by it as its own product – a new genetic variety of Basmati. It was actually developed by crossing Indian Basmati variety with a semi-dwarf variety.

ii) The people of India in a variety of ways have used neem, since time immemorial. Indians have shared the knowledge of the properties of the neem with the entire world. Pirating this knowledge, the USDA and an American MNC W.R. Grace in the early 90s sought a patent (No. 0426257 B) from the European Patent Office (EPO) on the "method for controlling on plants by the aid of hydrophobic extracted neem oil." The patenting of the fungicidal properties of Neem was an example of biopiracy.

iii) **Rice Biopiracy**

Syngenta is a biotech company that tried to grab the precious collections of 22,972 varieties of paddy, India's rice diversity, from India's rice bowl, Chattisgarh in India. Syngenta has signed a MoU with the Indira Gandhi Agricultural University (IGAU) for access to Dr. Richharia's priceless collection of rice diversity. Dr. Richharia is the ex-director of Central Rice Research Institute (CRRI), Cuttack and is known as the rice sage of India who has done pioneering work in this field.

****

1. Crystals of Bt toxin produced by some bacteria do not kill the bacteria themselves because –
(a) bacteria are resistant to the toxin (b) toxin is immature;
(c) toxin is inactive; (d) bacteria encloses toxin in a special sac.
2. What are transgenic bacteria? Illustrate using any one example.
3. Compare and contrast the advantages and disadvantages of production of genetically modified crops.
4. What are Cry proteins? Name an organism that produces it. How has man exploited this protein to his benefit?
5. What is gene therapy? Illustrate using the example of adenosine deaminase (ADA) deficiency.
6. Diagrammatically represent the experimental steps in cloning and expressing an human gene (say the gene for growth hormone) into a bacterium like *E. coli* ?
7. Can you suggest a method to remove oil (hydrocarbon) from seeds based on your understanding of rDNA technology and chemistry of oil?
8. What is golden rice?
9. Does our blood have proteases and nucleases?
10. Why does Bt toxin not kill the Bacillus?

The first transgenic animal produced in 1982, was a mouse, known as '*supermouse*' due to its bigger size. Since then many types of transgenic animals have been produced for some specific purposes. A few of them are:

1. **Transgenic Sheep:** This sheep contains bacterial genes which code for the enzymes needed for the synthesis of amino acid cysteine have been produced. They give higher wool yield. This amino acid also an important component of the protein keratin of wool. Sheep with gene for growth hormone which is responsible to yield more meat.
2. **Transgenic Goat:** This type of goat contains a human gene that codes for a blood clot dissolving protein. This protein is secreted in the milk which is used to treat coronary thrombosis.
3. **Transgenic Cow:** This type of cow produces **lactoferrin** due to the presence of cDNA coding. It is an antibacterial human iron-binding protein.
4. **Transgenic Pig:** These pigs have been given human genes so that their organs carry human antigens. Pig organs like kidney, heart and pancreas can be transplanted into humans. Due to the presence of human antigens, these organs are not rejected by the human body.
5. **Transgenic Fish**: Some of the transgenic fish like common carp, catfish, salmon, goldfish contain human growth hormone (hGH) gene. They also grow double in size to that of non-transgenic fish.

****

BIOTECHNOLOGY: PRINCIPLES AND PROCESSES

Biotechnology can be defined as technological controlled use of biological agents such as micro-organisms or cellular components, for beneficial use. The term biotechnology was coined by Karl Ereky (1917).

TWO PHASES:

1) Traditional (Old) Biotechnology: It is the use of natural strains of micro-organisms and cell lines for obtaining products. Curd, vinegar, ghee, wine, beer and alcoholic beverages, paneer and some other foods have been produced using traditional technology.
2) Modern Biotechnology:- When highly new and useful traits in crop varieties and animal breeds are created with the help of genetic engineering, it is called modern biotechnology.

PRINCIPLES OF BIOTECHNOLOGY:-

Two main techniques that gave birth to modern biotechnology are-

i) Genetic Engineering: The techniques which change the chemistry of genetic material (DNA and RNA) to introduce those into host organisms and thus alter the phenotype of the host organisms are called genetic engineering or recombinant DNA technology.
ii) Chemical Engineering:- Maintenance of sterile (microbial contamination-free) ambience in chemical engineering processes to enable growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc.

Three Basic Steps in Creating Genetically Modified Organism (GMO) or Transgenic Organism: These are as follows:

i) Identification of DNA with desirable genes.
ii) Introduction of the identified DNA into host.
iii) Maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

Tools of Recombinant DNA technology:

Three types of biological tools are used in the formation rDNA. These are as follows:

A) Enzymes
B) Cloning Vectors
C) Competent host (for transformation with recombinant DNA).

A) ENZYMES:

1) Lysing Enzymes:- These enzymes are used to open up the cells to get DNA for genetic experiments. Lysozyme is used to dissolve the bacterial cell wall, cellulase for plant cell wall and chitinase for fungal cell wall (Chitin).
2) Cleaving Enzymes: These enzymes are used to break DNA molecules. They belong to a larger group of enzymes called "nucleases". These enzymes are of following types – exonucleases, endonucleases and Restriction endonucleases.

i) Exonucleases	ii) Endonucleases
i) These nucleases cleave base pairs of DNA at their terminal ends. ii) They act on single strand of DNA or gaps in double stranded DNA. iii) They do not cut RNA.	i) They cleave DNA at any point except the terminal ends. ii) They cleave one strand or both strands of double stranded DNA. iii) They may cut RNA.

iii) Restriction endonucleases:- These endonucleases were found by Arber in 1962 in bacteria. They act as molecular scissors or chemical scalpels. They recognize the base sequence at palindrome sites in DNA duplex and cut its strands.

Palindromes are groups of letters that form the same words when read in both directions forward and backward.

e.g. AND MADAM DNA, MALAYALAM, SEX AT NOON TAXES.

Restriction endonuclease EcoRI found in the bacteria *E. coli*, recognizes the base sequence G A A T T C in DNA duplex and cuts its strands between G and A as shown below:

```
                ↓
5′---------- G A A T T C ----------3′   Palindromic sequence.
3′---------- C T T A A G----------5′
                ↑
```

Types of Restriction Endonucleases:- Three main types of restriction endonucleases are type I, type II and type III.

Type I	Type II	Type III
1. Enzyme structure consists of 3 different subunits. 2. They require ATP, Mg^{2+} and S-adenosyl-methionine for restriction. 3. They recognize specific sites within DNA but do not cut these sites. 4. They are not used in rDNA technology.	1. Enzyme structure is simple. 2. They require Mg^{2+} ions for restriction. 3. They recognize specific sites within the DNA and cut these sites. 4. They are used in rDNA technology.	1. Enzyme structure consists of two different sub units. 2. They require ATP, Mg^{2+} and S-adenosyl-methionine for restriction. 3. They recognize specific sites within the DNA but do not cut these sites. 4. They are not used in recombinant DNA technology.

Q. Why are restriction endonucleases called as 'molecular scissors' or 'Chemical scalpels'?

3) DNA ligase:- These enzymes called "genetic gum" form phosphodiester bonds between adjacent nucleotides and covalently link two individual fragments of double stranded DNA. The action of ligase enzyme requires a phosphate group at the 5′ carbon of one nucleotide and a hydroxyl (-OH) group at the 3′ carbon of the adjacent nucleotide to form the phosphodiester bond between these two nucleotides.
4) Alkaline Phosphatase (AP):- Ligation absolutely requires the presence of 5′ phosphate group at the DNA site to be ligated. If this phosphate group is removed, this DNA cannot be ligated. The enzyme alkaline phosphatase is used to remove the phosphate from the 5′ end of a DNA molecule, leaving a free 5′ hydroxyl group.
5) Synthesizing Enzyme:- These enzymes play a role in the synthesis of DNA strands on suitable templates. These are of two types: Reverse transcriptase and DNA polymerase.

a) Reverse Transcriptase: This enzyme is used to synthesize the copy of DNA or complementary DNA (cDNA) by using mRNA as a template. It is very useful in the synthesis of cDNA and construction of cDNA clone bank.
b) DNA polymerase: This enzyme polymerizes the DNA synthesis on the DNA template or complementary DNA (cDNA). It also catalyses a 5′ → 3′and 3′→ 5′ *exonucleolytic* degradation of DNA.

Some common examples of restriction enzymes type II, their source, recognition sequence and site of cleavage

Restriction Enzyme	Source	Recognition Sequence and Site of Cleavage	Product
1. *Alu* I	*Arthrobacter luteus*	5′-A-G↓C-T-3′ 3′-T-C↑G-A-5′	A-G / T-C C-T / G-A blunt ends
2. *Bam* H I	*Bacillus amyloliquefaciens H*	5′-G↓G-A-T-C-C-3′ 3′-C-C-T-A-G↑G-5′	G / C-C-T-A-G G-A-T-C-C / G Sticky ends
3. *Eco* R I	*Escherichia coli* RY13	5′-G↓A-A-T-T-C-3′ 3′-C-T-T-A-A↑G-5′	G / C-T-T-A-A A-A-T-T-C / G sticky ends
4. *Eco* R II	*Escherichia coli* R245	5′-C↓C-T-G-G-3′ 3′-G-G-A-C-C↑5′	5′ C-C-T-G-G-3′ / 3′G-G-A-C-C 5′ blunt ends
5. *Hae III*	*Haemophilus aegyptius*	5′-G-G↓C-C-3′ 3′-C-C↑G-G-5′	G-G / C-C C-C / G-G blunt ends
6. *Hin* d III	*Haemophilus influenzae* Rd	5′-A↓A-G-C-T-T-3′ 3′-T-T-C-G-A↑A-5′	A / T-T-C-G-A A-G-C-T-T / A sticky ends
7. *Hin* d II (first discovered Restriction endonuclease)	*Haemophilus influenzae* Rd	5′-G-T-C↓G-A-C-3′ 3′-C-A-G↑C-T-G-5′	G-T-C / C-A-G G-A-C / C-T-G blunt ends
8. *Sal* I	*Streptomyces albus*	5′-G↓T-C-G-A-C-3′ 3′-C-A-G-C-T↑G-5′	G / C-A-G-C-T T-C-G-A-C / G sticky ends
9. Sca I	*Streptomyces caespitosus*	5′-A-G-T↓A-C-T-3′ T-C-A-T↑G-A	A-G-T / T-C-A A-C-T / T-G-A blunt ends
10. Sma I	*Serratia marcescens*	5′-C-C-C↓G-G-G-3′ 3′-G-G-G↑C-C-C-5′	C-C-C / G-G-G G-G-G / C-C-C blunt ends

B) Cloning Vectors (Vehicle DNA) for Recombinant DNA: The vectors are DNA molecules that can carry a foreign DNA segment and replicate inside the host Cell. Vectors may be plasmids, a bacteriophage, cosmids, phagemids, Yeast Artificial Chromosomes (YACs), Bacterial Artificial Chromosomes (BACs), transposons and viruses. Out of these vectors, plasmid vectors and bacteriophage vectors are commonly used.

1) Plasmid Vectors: Plasmids are extra – chromosomal, self replicating, usually circular, double stranded DNA molecules, found naturally in many bacteria and also in some yeasts. The most widely used, versatile, easily manipulated vector pBR 322 is a plasmid vector.

pBR322 Vector: This was the first artificial cloning vector constructed in 1977 by Boliver and Rodriguez. It is widely used in gene cloning experiments.

Nomenclature: In pBR322 plasmid
p- denotes that is a plasmid
BR- stands for Boliver and Rodriguez who constructed this plasmid;
322 – is a number given to distinguish this plasmid from others developed in the same laboratory. e.g. there are pBR325, pBR327, pBR328, pBR345 etc.

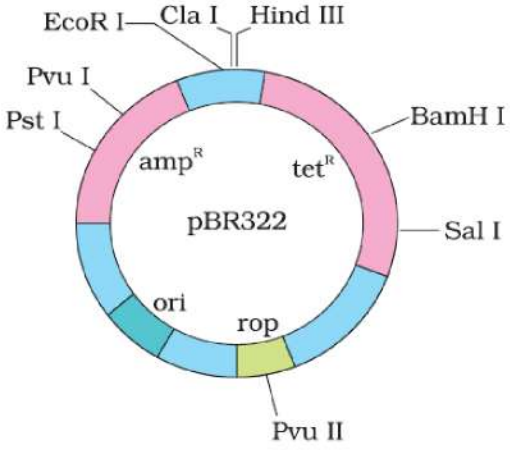


Diagram showing essential features of Plasmid pBR 322

The following are the features that are required to facilitate cloning into a vector.

(i) *Origin of replication (ori):* This is a sequence from where replication starts and any piece of DNA when linked to this sequence can be made to replicate within the host cells. This sequence is also responsible for controlling the copy number of the linked DNA. So, if one wants to recover many copies of the target DNA it should be cloned in a vector whose origin support high copy number.
(ii) *Selectable marker:* In addition to 'ori', the vector also requires a selectable marker, which helps in identifying and eliminating nontransformants and selectively permitting the growth of the transformants. Transformation is a procedure through which a piece of DNA is introduced in a host bacterium. Normally, the genes encoding resistance to antibiotics such as ampicillin, chloramphenicol, tetracycline or kanamycin, etc., are considered useful selectable markers for *E. coli*. The normal *E. coli* cells do not carry resistance against any of these antibiotics.
(iii) *Cloning sites:* In order to link the alien DNA, the vector needs to have very few, preferably single, recognition sites for the commonly used restriction enzymes. Presence of more than one recognition sites within the vector will generate several fragments, which will complicate the gene cloning. The ligation of alien DNA is carried out at a restriction site present in one of the two antibiotic resistance genes. For example, a foreign DNA can be ligated at the Bam H I site of tetracycline resistance gene in the vector pBR322. The recombinant plasmids will lose tetracycline resistance due to insertion of foreign DNA but can still be selected out from non-recombinant ones by plating the transformants on ampicillin containing medium. The transformants growing on ampicillin containing medium are then transferred on a medium containing tetracycline. The recombinants will grow in ampicillin containing medium but not on that containing tetracycline. But, non-recombinants will grow on the medium containing both the antibiotics. In this case, one antibiotic resistance gene helps in selecting the transformants, whereas the other antibiotic resistance gene gets 'inactivated due to insertion' of alien DNA, and helps in selection of recombinants.
2. Bacteriophage Vectors: Bacteriophages are viruses that infect bacterial cells by injecting their DNA into these cells. The injected DNA is selectively replicated and expressed in host bacterial cell resulting in a number of phages which bursts out of the cell (lytic pathway) and reinfect neighbouring cells. This ability to transfer DNA from the phage genome to specific bacterial hosts during the process of bacterial infection gave scientists the idea that specially designed phage vectors would be useful tools for gene cloning experiments. Two phages that have been extensively modified for development of cloning vectors are lambda phage and M13 phage.
3. Vector for cloning Genes in Plants: A soil inhabiting, plant pathogenic bacterium, *Agrobacterium tumefaciens*, infects broad leaved crops including tomato, soyabean, sunflower and cotton, but not cereals. It causes tumours called crown galls. Tumour formation is induced by its plasmid, which is therefore, called **Ti** plasmid (*Ti* for tumour inducing). The *Ti* plasmid integrates a segment of its DNA, termed T-DNA, into the chromosomal DNA of its host plant cells. The *T-DNA* causes tumours. As the gene transfer occurs without human effort, the bacterium is known as "*natural genetic engineer*" of the plants.

Plant molecular biologists have started using *Ti* plasmid as vectors to transfer foreign genes of interest into the target plant cells. The tumor inducing (Ti) plasmid has now been modified into cloning vector which is no more pathogenic to the plants but is still able to use the mechanisms to deliver genes of our interest into a variety of plants. The transformed bacteria do not cause disease.

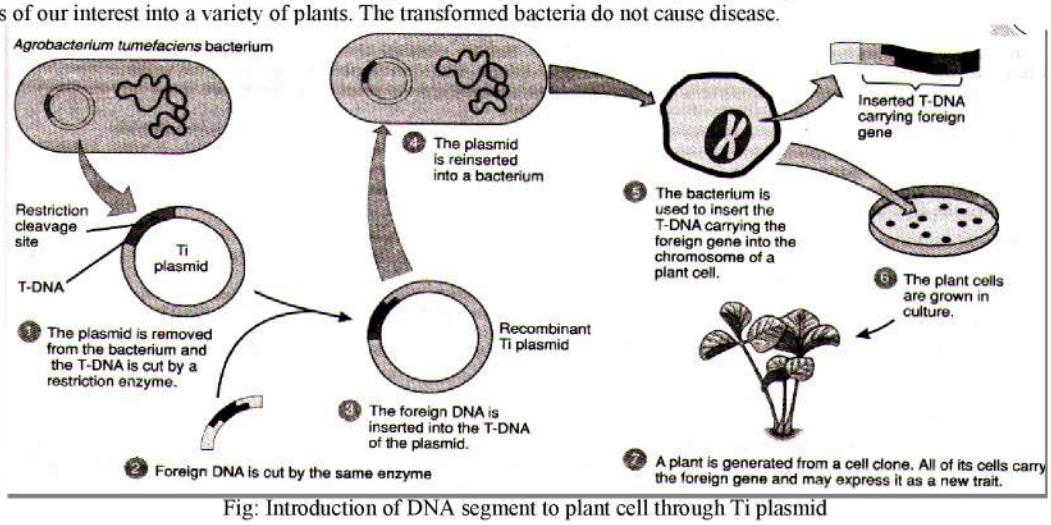


Fig: Introduction of DNA segment to plant cell through Ti plasmid

4. Vector for cloning Genes in Animals: Retroviruses in animals have the capability to transform normal cells into cancerous cells. Retroviruses have been disarmed and are being utilized to transfer genes of interest to animal cells.
PASSENGER DNA: It is the DNA which is transferred from one organism into another by combining it with the vehicle (vector) DNA.

Three types of DNA are used as passengers:
i) Complementary or copy DNA (cDNA): It is synthesized on RNA template with the help of reverse transcriptase enzyme and necessary nucleotides. (It is a copy or complementary DNA which is synthesized *in vitro* on an template by reverse transcriptase enzyme). The cDNA duplex so formed can be joined to vehicle DNA for introduction into a host cell.
ii) Synthetic DNA (sDNA): It is synthesized with the help of DNA polymerase on DNA template or from free deoxyribonucleotides without a template.
Artificial synthesis of DNA on Template:
In 1961, Kornberg and his coworkers synthesized DNA from a mixture of deoxyribonucleoside triphosphates, DNA polymerase enzyme, metal ions and a segment of viral DNA to act as a primer. When introduced into bacteria, this DNA coded for the formation of virus particles similar to the one from which primer DNA was taken.
Artificial Synthesis of DNA without a Template:
Hargobind Khorana and his colleagues produced the first synthetic DNA in 1965 by purely chemical means. They synthesized the gene coding for yeast alanine – tRNA which needed only 77 pairs. Unfortunately, this gene did not function. Khorana and his associates, in 1979, synthesized the gene coding for tyrosine – tRNA of *E. coli*. The gene had 207 nucleotide pairs.
iii) Random DNA: It refers to small fragments formed by breaking a chromosome of an organism with the help of restriction endonucleases.

CHARACTERISTICS OF A CLONING VECTOR:
1. Origin of Replication (Ori): This is a sequence from where replication starts and any piece of foreign DNA is linked to this sequence. The replication occurs inside the host cells.

2. Selectable Marker: (A selectable marker is a gene which helps in selecting those host cells which contain the vector (transformant) and eliminating the non-transformants.)

The vector also requires a selectable marker (antibiotic resistance gene) to identify and eliminate non-transformants and selectively permit the growth of the transformants. Transformation is a process through which a piece of DNA is introduced in a host bacterium. Generally, the genes encoding resistance to antibiotics such as tetracycline, ampicillin, kanamycin or chlorampenicol etc. are useful as selectable marker for *E. coli.*

3. Recognition Sites (Cloning Sites): The vector must also have one unique restriction endonuclease recognition site to enable foreign DNA to be inserted into the vector during the generation of a recombinant DNA molecule. Presence of a unique restriction site allows the particular enzyme to cut the vector only once.

Q. What are the essential properties of cloning vectors?

Ans:- An ideal cloning vector must possess the following features:

a. It should contain an origin of replication (Ori).
b. It should incorporate a selectable marker, which helps in identifying and eliminate non-transformants.
c. The vector must also have atleast one unique restriction endonuclease recognition site.
d. It should be relatively small.

COLOUR REACTION: It is another method to differentiate between recombinants and non-recombinants on the basis of their ability to produce colour. The common recognition or cloning site is lac gene z that codes enzyme *β –galactosidase*. Insertion of alien DNA into it inactivates the gene and prevents the synthesis of *β – galactosidase*. Chromogenic substrate, Xgal produces blue coloured if the plasmids do not have inserts, but those with an insert or recombinant, do not produce any colour.

C) Competent Host: Competence is the ability to pick up genes and plasmids from outside. Since DNA is a hydrophilic molecule, it can't pass through the cell membranes, so the bacterial cells must be made capable to take up DNA.

This is done by treating them with a specific concentration of divalent cation, such as calcium, which increases the efficiency with which DNA enters the bacterium through pores in its cell wall.

Recombinant DNA can then be forced into such cells by incubating the cells with rDNA on ice, followed by placing them briefly at 42^0 C (Heat shock), and then putting them back on ice. This enables the bacteria to take up the rDNA.

DIRECT OR VECTORLESS TRANSFER:

1) Microinjection: In this method foreign DNA is directly injected into the nucleus of animal cell or plant cell by using micro needles or micropipettes. It is used in oocytes, eggs and embryo.

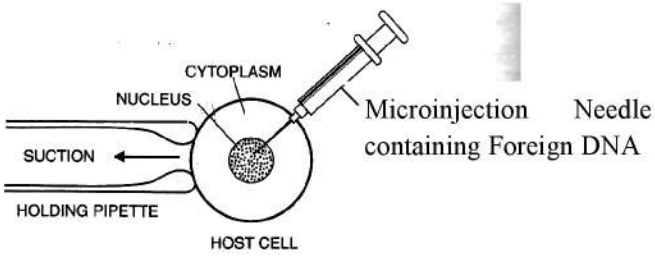


Fig: Microinjection

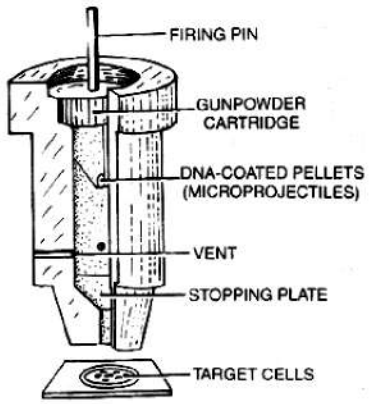


Fig: Gene Gun

2. Electroporation: In this method the electrical impulses induce transient (temporary) pores in the plant cell membrane through which, the DNA molecules are incorporated into the plant cells.

3. Direct DNA injection: Direct injection of DNA into skeletal muscle led to the possibility of using gene as vaccines. This method gave birth to the concept of DNA vaccine or genetic immunization.

4. Gene Gun or Biolistic: Gene gun where tungsten or gold particles coated with desired genes are shot with high velocity into target cells, suitable for plants.

GEL ELECTROPHORESIS: (SEPARATION AND ISOLATION OF DNA FRAGMENTS)

Electrophoresis is a technique used for the separation of substances of different ionic properties. Treatment of DNA with restriction endonuclease produces a number of DNA fragments of variable lengths. They are separated through gel electrophoresis. Gel electrophoresis has an electric field with a cathode (−) and anode (+) and an agarose medium. DNA fragments are negatively charged. They move towards the positively charged anode end. [Agarose has a sieving effect. Larger fragments move slowly while smaller fragments move fast]. The separated DNA fragments can be seen only after staining the DNA with a compound known as ethidium bromide, followed by exposure to UV- radiation and stained DNAs become visible as orange coloured bands. The separated bands of DNA are cut out from the agarose gel and extracted from the gel piece. This step is called as *elution.*

PROCESS OF RECOMBINANT DNA TECHNOLOGY: Recombinant DNA (rDNA) technology involves the following steps:

1. Isolation of the Genetic material (DNA): Because the DNA is covered by the membranes, it has to break the cell open to release DNA and other macromolecules like RNA, polysaccharides and lipids. Pure DNA can be obtained by treating the bacterial cells/plant or animal cells with enzymes such as lysozyme (bacteria), cellulase (plant cells), chitinase (fungus). RNA, proteins like histones can be removed by treating with ribonuclease and proteases respectively. The purified DNA finally precipitates out after addition of chilled ethanol.

Q. How is DNA isolated in purified form from a bacterial cell?

Ans:- The bacterial cells are treated with enzymes, lysozymes to break the cells and open to release DNA along with RNA and proteins. RNAs are removed by treatment with ribonucleases and proteins are removed with by treatment with proteases, thus, the DNA is obtained in a pure form.

Q. How can DNA segments, separated by gel electrophoresis, be visualized and isolated?

Ans:- The separated DNA segments are stained with ethidium bromide. Then by exposure to UV-radiation, the separated and stained DNAs become visible as orange coloured bands. The separated bands are cut out from the agarose gel and then extracted from the gel piece, this process is called as elution.

2. Cutting of DNA at specific Location: The purified DNA is cut by the restriction enzyme. Agarose gel is used to check the progress of a restriction enzyme digestion. Since DNA is negatively charged molecule, it moves towards the positively charged electrode (anode). This process is also repeated with the vector.

Both the source DNA and vector DNA are treated separately with the same restriction endonuclease. It produces complementary sticky ends. Self ligation is prevented by alkaline phosphatase. The two types of DNAs are joined together with the help of DNA ligase. The union of plasmid (vector) DNA and desired DNA fragment produce a rDNA.

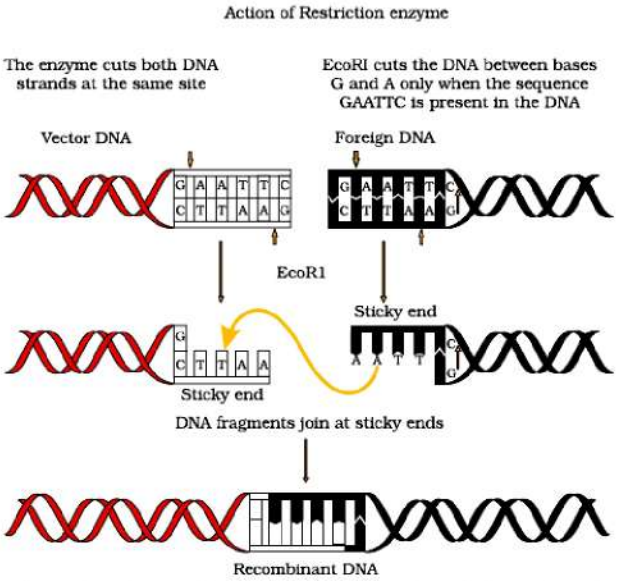


Fig: Steps in the formation of recombinant DNA by action of restriction endonuclease enzyme – EcoRI.

3. Amplification of Gene of Interest using PCR:

The Polymerase Chain Reaction (PCR) is in vitro synthesis of multiple copies of a gene or DNA segment. It was invented by *Kary Mullis* in 1985. *Kary Mullis* shared the Nobel Prize with *Michael Smith* in Chemistry in 1993.

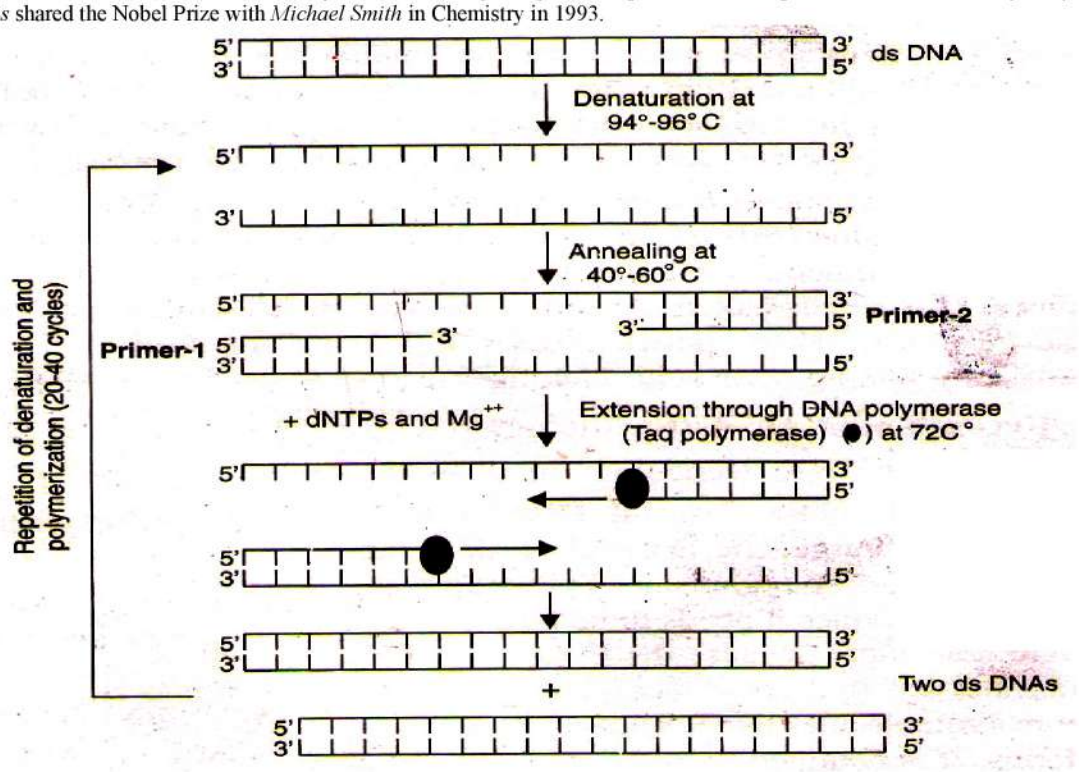


Fig: A Schematic representation of Polymerase Chain Reaction (PCR)

Basic Requirements of PCR:

i) DNA Template: This contains the DNA sequence to be amplified.

ii) Primers: Primers, usually 10-18 nucleotides long are used to hybridize target DNA region. Two primers are required.

iii) DNA polymerase: DNA polymerase which is stable at high temperature is used. *Taq polymerase* (a DNA Polymerase isolated from a bacterium, *Thermus aquaticus*) is generally used.

iv) Deoxyribonucleotide triphosphates (dNTPs): Each PCR requires 4 types of dNTPs (dATP,dGTP, cCTP, dTTP).

WORKING MECHANISM OF PCR: A single PCR amplification cycle involves three basis steps:

a) Denaturation: In denaturation step, the target DNA is heated to a high temperature (usually 94° to 96°C), resulting in the separation of the two strands. Each target DNA then acts as a template for DNA synthesis.
b) Primer Annealing: (Anneal= joining) In this step, the two oligo-nucleotide primers anneal (hybridize) to each of the single stranded template DNA since the primer is complementary to the 3′ ends of the template DNA. This step is carried out at a lower temperature (usually 40° to 60°C) depending on the length and sequence of the primers.
c) Primer extension (Polymerisation): The final step is extension, wherein Taq DNA polymerase synthesizes the DNA region between the primers, using deoxyribonucleotides and Mg^{2+}. It means the primers are extended towards each other so that DNA segment lying between the two primers is copied. The optimum temperature for this step is 72° C.

To begin the second cycle, the DNA is again heated to convert all the newly synthesized DNAs into single strands, each of which can now serve as template for synthesis of more new DNA. Thus the extension product of one cycle can serve as a template for subsequent cycles and each cycle essentially doubles the amount of DNA from the previous cycle. As a result, from a single template molecule, it is possible to generate 2^n molecules after n number of cycles.

APPLICATION OF PCR:

i). Diagnosis of Pathogens: To detect pathogens, pathologists used techniques based on detecting specific enzymes or antibodies against disease related proteins. But these techniques can not used for detecting infectious agents that are difficult to culture or that persist at very low levels in infected cells. To overcome these problems, PCR-based assay have been developed that detect the presence of gene sequences of the infectious agents.

In recent times, PCR is being used in the detection of HIV at early stage when the infant is 18 months old.

ii). DNA Fingerprinting: PCR is of immense value in generating abundant amount of DNA for analysis in the DNA fingerprinting technique used in forensic science to link a suspect's DNA recovered at a crime scene.

iii). In Prenatal Diagnosis: It is useful to detect genetic disease in the foetus before birth. If the disease is not curable, abortion is recommended.

iv). Gene Therapy: PCR proves to be of immense help in monitoring a gene in gene therapy experiments.

v). Detection of Specific Microorganisms: In recent years, PCR has also found use for detecting specific microorganisms from the environment samples of soil, sediments and water.

vi). In Paleontology: PCR is used clone the DNA fragments from the mummified remains of humans and extinct animals like wooly mammoth and dinosaurs.

vii). Diagnosis of plant pathogens: Many diseases of plants can be detected by using PCR.

viii). Diagnosis of specific Mutation: Mutations are related to genetic diseases. The tests are rapid, offer greater sensitivity and specificity. PCR is also a valuable tool in locating mutation that is responsible for causing a particular genetic disease.

e.g. By using PCR phenylketonuria, muscular dystrophy and sickle cell anaemia can be diagnosed.

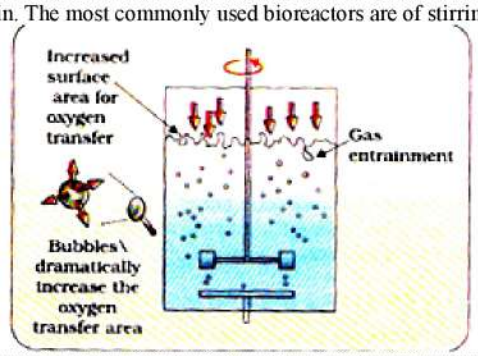
4. Preparation and Insertion of Recombinant DNA into the Host Cell/Organism: There are several methods of introducing the ligated DNA into recipient cells. Recipient cells after making them 'competent' to receive, take up DNA present in its surrounding. So, if a recombinant DNA bearing gene for resistance to an antibiotic (e.g., ampicillin) is transferred into *E. coli* cells, the host cells become transformed into ampicillin-resistant cells. If we spread the transformed cells on agar plates containing ampicillin, only transformants will grow, untransformed recipient cells will die. Since, due to ampicillin resistance gene, one is able to select a transformed cell in the presence of ampicillin. The ampicillin resistance gene in this case is called a **selectable marker**.

5. Obtaining of desirable/foreign Gene Product: The major aim of recombinant biotechnology is to produce a desired biochemical or proteins useful to humans. As it is produced through recombinant DNA technology inside heterologous host cells, the product is called recombinant proteins or biochemical. The cells harbouring cloned genes of interest may be grown on a small scale in the laboratory. The cultures may be used for extracting the desired protein and then purifying it by using different separation techniques.

6. Bioreactors (Fermenters): Small volume cultures cannot yield appreciable quantities of products. To produce in large quantities, the development of bioreactors, where large volumes (100-1000 litres) of culture can be processed, was required. **Bioreactor/fermenter** is the container in which the biochemical process is carried out by using living cells and their growth medium. A bioreactor provides the optimal conditions for obtaining the desired product by providing optimum growth conditions such as temperature, pH, substrate, vitamins, oxygen and salts.

The cells can also be multiplied in a continuous culture system wherein the used medium is drained out from one side while fresh medium is added from the other to maintain the cells in their physiologically most active log/exponential phase. This type of culturing method produces a larger biomass leading to higher yields of desired protein. The most commonly used bioreactors are of stirring type.

a) Simple stirred –tank bioreactor



b) Sparged stirred – tank bioreactor which sterile air bubbles are sparged.

A stirred-tank reactor is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents. The stirrer facilitates even mixing and oxygen availability throughout the bioreactor. Alternatively, air can be bubbled through the reactor. If you look at the figure closely you will see that the bioreactor has an agitator system, an oxygen delivery system and a foam control system, a temperature control system, pH control system and sampling ports so that small volumes of the culture can be withdrawn periodically.

7. Downstream processing: Downstream processing is the recovery of the product from the fully grown genetically modified cells, its purification and preservation. After fermentation of the product in the bioreactors, it undergoes through some processes before a finished product to be ready for marketing. The processes include separation and purification of products which are collectively called the *downstream processing*. The product is subjected to quality control testing and kept in suitable preservatives. The downstream process and quality control test are different from product to product.

*****

EVOLUTION

Origin of Universe:

Big –bang theory: The **Big Bang** theory attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms. The universe expanded and hence, the temperature came down. Hydrogen and Helium formed sometime later. The gases condensed under gravitation and formed the galaxies of the present day universe. In the solar system of the milkyway galaxy, earth was supposed to have been formed about 4.5 billion years back. There was no atmosphere on early earth. Water vapour, methane, carbondioxide and ammonia released from molten mass covered the surface. The UV rays from the sun broke-up water into Hydrogen and Oxygen and the lighter H_2 escaped. Oxygen combined with ammonia and methane to form water, CO_2 and others. The ozone layer was formed. As it cooled, the water vapour fell as rain, to fill all the depressions and form oceans. Life appeared 500 million years after the formation of earth, i.e., almost four billion years back.

ORIGIN OF LIFE: The earth formed about 4.6 billion years ago. Many theories have been put forward to explain the origin of life.

Modern theory or Oparin-Haldane Theory of Origin of Life:

Oparin of Russia and Haldane of England proposed that the first form of life could have come from pre-existing non-living organic molecules (e.g. RNA, protein, etc.) and that formation of life was preceded by chemical evolution, i.e., formation of diverse organic molecules from inorganic constituents. The conditions on earth were – high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, etc.

Conditions For The origin of Life: There are four basic requirements for the life to arise:

1. primitive atmosphere with little or no oxygen.
2. right chemicals, including water, various inorganic ions and organic molecules.
3. an energy source and
4. infinite time.

All these conditions were available on primitive earth.

Conditions of the earth's primitive atmosphere proposed by Oparin and Haldane -

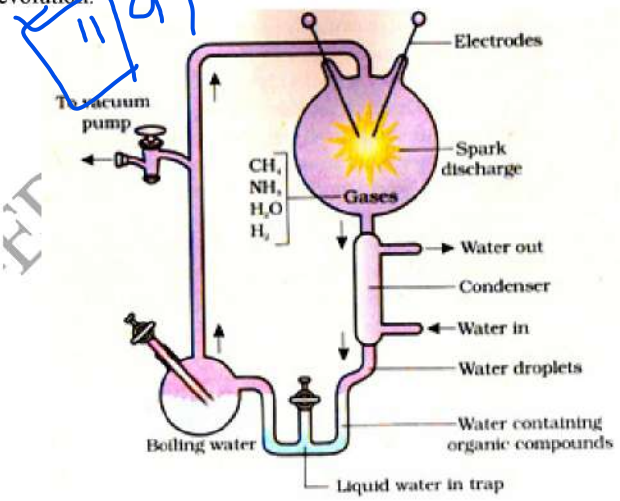
I. The temperature was very hot.
II. It was strongly reducing.
III. Sources of energy were from lightning, cosmic rays, UV-radiation etc.
IV. Presence of methane, ammonia, hydrogen and water vapour.

Modern views regarding the origin of life include chemical evolution and biological evolution.

EXPERIMENTAL EVIDENCE FOR ABIOGENIC MOLECULAR EVOLUTION OF LIFE:

Stanley Miller in 1953, who was then a graduate student of Harold Urey at the University of Chicago, demonstrated it clearly that ultra-violet radiation or electrical discharges or heat or a combination of these can produce complex organic compounds from a mixture of methane, ammonia, water (steam of water), and hydrogen.

Miller circulated four gases – methane, ammonia, hydrogen and water vapour in an air tight apparatus and passed electrical discharges from electrodes at 800^0 C (simulation of lightening). He passed the mixture through a condenser. He circulated these gases continuously in this way for one week and then analysed the chemical composition of the liquid inside the apparatus. He found a large number of simple organic compounds including some amino acids such as alanine, glycine and aspartic acid. Miller proved that organic compounds were the basis of life.



Some external sources must have been acting on the mixture for reactions. These external sources might be

i) Solar radiations such as ultra-violet light, X-rays, etc.

ii) energy from electrical discharges like lightening.

iii) high energy radiations are other sources of energies.

There was no ozone layer in the atmosphere. The oceanic water rich in mixture of organic compounds was termed as '*Hot dilute soup*' (termed by J.B.S. Haldane) of organic substances'. The 'hot dilute soup' is also called '*Prebiotic soup*'. Once formed, the organic molecules accumulated in water because their degradation was extremely slow in the absence of any life or enzyme catalysts.

FORMATION OF EARLIEST CELLS i) The first living organisms originated among organic molecules and in oxygen free atmosphere. They presumably obtained energy by the fermentation of some of these organic molecules. They were anaerobes, capable of respiration in absence of oxygen. They depended on the existing organic molecules for their nutrition and thus they were *heterotrophs*.

ii) When the supply of existing organic molecules was exhausted, some of the heterotrophs might have evolved into autotrophs. These organisms were capable of producing their own organic molecules by chemosynthesis or photosynthesis.

Formation of Ozone Layer: As oxygen accumulated in the atmosphere, the ultraviolet light changed some of oxygen into ozone.

$$2O_2 + O_2 \longrightarrow 2\,O_3$$

The ozone formed a layer in the atmosphere, blocking the ultraviolet light and leaving the visible light as the main source of energy.

Early (Primitive) atmosphere: Earth originated about 4.5 – 5.0 billion years ago. The temperature was 4000 – 8000^0 C. Volcanoes were abundant which continued to emit materials from inside over the surface. Chemically, it was reducing in nature. The gaseous mixture mainly consisted H_2, CH_4 and NH_3. An ozone layer was absent. All types of high energy radiations like cosmic rays and UV-rays reach the earth. It was hot. It favoured reactions that could form organic molecules.

Primitive Atmosphere	Modern Atmosphere
1. Chemically, it was reducing in nature.	1. Chemically, it is oxidizing in nature.
2. The gaseous mixture mainly consisted of H_2, CH_4 and NH_3.	2. The gaseous mixture mainly consists of N_2 and O_2.
3. An ozone layer was absent.	3. An ozone layer is present.
4. All types of high energy like cosmic rays and UV radiations could reach the earth.	4. High energy radiations are mostly filtered out ozone layer.
5. It was very hot.	5. It has cooled down in the middle strata and moderately warm near the earth.
6. It favoured reactions that could form organic molecules.	6. It does not favour formation of organic molecules.

EVOLUTION: Organic evolution is a process of cumulative change of living populations and in the descendant populations of organisms. The term evolution was used by **Herbert Spencer.** In other words, it is **"*descent with modification*"** (defined by Charles Darwin).

Fossilisation (Formation of Fossils): Fossils are remained of hard parts of life-forms found in rocks. The animals or plants preserved and fossilized when they are buried in the lava of volcano, in the ice, in an oil rich soil, in swamps, in desiccated deserts, in rocks, or under water, etc. Of all the media mentioned above the most common is water. Dead remains of aquatic animals and plants settle down at the bottom. Remains of terrestrial organisms are also brought to seas and big lakes by rivers and streams. Mud and sand settle down continuously at the bottom. Sedimentation (deposition of layers) of mud and sand occurs. The sedimented mud and sand harden with time to form rocks.

Determination of the Age of Fossils: The age of the fossils is determined by the three methods:

1. Clock of the rock method or Radioactive Clock: This method is based on the conversion of unstable radioactive nuclei into stable over a fixed period. It has been estimated that one million gram of uranium produce 17,600 gram of lead in one year. Therefore, by calculating the amount of lead in the rock, one can approximately estimate the age of the rock and thus the age of the fossil present in it can be calculated.
2. Radioactive Carbon Method: In every 5568 years half of C^{14} will decay back to N^{14}.
3. Potassium Argon Method: It has recently been used to determine the age of hominid fossils in East Africa. This method is useful because potassium is a common element found in rocks. Half life of potassium is 1.3×10^9 years.

MASS EXTINCTION: When plants and animals become extinct on a large scale over relatively short span of time, such episodes are called mass extinctions. Mass extinctions of dinosaurs took place about sixty million years ago. Many factors are responsible such mass extinction. Metal iridium is rare on earth. This metal is present in meteorites in large quantities. The time during which such iridium – rich soils deposited in the earth is around 60 million years ago. It is now obvious that a comet or meteorite hit the earth at that time. Such impact could have resulted in mass extinction of organisms present at that time. It has also been suggested that mass extinction of organisms might occurred due to 'global cooling'. These are all hypotheses. Definite answers to all these problems have yet to be found.

EVIDENCES OF ORGANIC EVOLUTION: In support of organic evolution some important evidences are as follows:

A) PALAEONTOLOGICAL EVIDENCES (Evidences From Fossil Record)**:** From the fossil records it has been concluded that evolution has taken place from simple to complex in a gradual manner. In support of it, some evidences are given below.

I. Number and Nature of Fossils in Early Rocks: The rocks of early era contain less number of fossils than the rocks of later era and only fossils of simple marine invertebrates are in these rocks. It is due the fact that the life first originated in sea as a simple form. So fossils were not in plenty in the beginning as they were in later stage.
II. Distribution of Fossils in the successive Strata: The distribution of fossils indicates that early fossils present in the bottom rocks are simple, however the recent fossils found in the upper layer of rocks are more complex. It shows that fossils forms become more and more complex as we proceed from earliest to the recent rocks.
III. Disparity between the Past and Present Forms of Life: On the basis of fossil study, it has been shown that the early organisms were very different from their modern forms, viz., the early man lived in the caves without any social life and spent their life their life like beasts, but man progressed and the modern man has become civilized, and leads a vigorous social life. Thus, the organisms have been changing since their appearance, which supports that evolution has been taking place.
IV. Missing Links (Transitional Forms) : The fossil organisms which show characters of two different groups are called missing links.
e.g. *Archaeopteryx,* a fossil which displays the characters of both the reptiles and birds.

Reptilian Characters of *Archaeopteryx*:

a) The body axis is more or less lizard like.
b) A long tail is present.
c) The bones are not pneumatic.
d) The jaws are provided with similar teeth.
e) The hand bears a typical reptilian plan and each finger terminates in a claw.
f) Presence of a weak sternum.
g) Presence of free caudal vertebrae as found in lizard.

Avian Characters of *Archaeopteryx*:

a) Presence of feathers on the body.
b) The jaws are modified into a beak.
c) The fore limbs are modified into wings.
d) The hind limbs are built on the typical avian plan.
e) An intimate fusion of the skull bones as seen in the birds.

From the above facts, it is clear that the birds have been evolved from reptilian ancestors. Thus *Huxley* justified in calling ***'birds are the glorified reptiles'***.

B) EVIDENCES FROM COMPARATIVE ANATOMY AND MORPHOLOGY:

There are similarities and differences among organisms of today and those existed years ago. These evidences are as follows.

i) Organ Systems: The different systems of animal body are similar in many groups of organisms, e.g. nervous system, blood vascular system, excretory system, etc.

ii) Homologous Organs: The organs which have the same fundamental structure but are different in functions are called *homologous organs*. These organs follow the same basic plan of organization during their development. But in the adult condition, these organs are modified to perform different functions as an adaptation to different environments. The homologous structures are a result of divergent evolution. Homology indicates common ancestry.

e.g. Tendrils of *Passiflora, Cucurbita* or Grape vine, thorns of *Bougainvillea*, phyloclades of *Opuntia* or cladodes of *Ruscus* are all stem structures.

Forelimbs of man, Chetah, Whale and bat have the same basic structural plan. [In each case the forelimb consists of humerus, radio-ulna, carpals, metacarpals and digits. The skeletal parts of the forelimbs of all these vertebrates are similar in structure and arrangement.] But the forelimbs of these animals have different shapes and functions. In man they are used for grasping, in Chetah for running, in Whale for swimming and in bat for flying.

iii) Analogous Organs: The organs which have similar functions but are different in their structural details and origin are called analogous organs. The analogous structures are the result of **convergent evolution**.

e.g. a) The wings of an insects are analogous to wings of a bird. It is due to the fact that the basic structure of the wings of insects is different from the wings of bird. However their function is similar.

b) Fins of fishes and flippers of whales are analogous organs. Fins of fishes are pentadactyle. The flippers of whales are pentadactyle. Thus basic structure of fins of fishes and flippers of whales is different but both are useful in swimming.

c) The function of leaves is taken over by other organs like stipules (e.g. *Lathyrus aphaca*), petiole (e.g. *Acacia auriculoformis*) and stem branches (e.g. *Ruscus, Asparagus*). They are analogous amongst them as well as to the leaves.

d) Plant tendrils are meant for climbing. They can be derived from stem branches (e.g. *Passiflora*), leaves (*e.g. Lathyrus aphaca, Pisum sativum*).

Homologous Organs	Analogous Organs
1. They differ morphologically. 2. They have similar internal structure.	1. They show superficial resemblance. 2. Their internal structure is quite different.

3. They develop in related organisms. 4. Stages in the development are similar. 5. They have similar developmental pattern. 6. They perform different functions. 7. Homologous organs show adaptive radiation (divergent evolution).	3. They develop in unrelated organisms. 4. Stages in the development are different. 5. They have dissimilar developmental pattern. 6. They have similar functions. 7. Analogous organs show convergent evolution.

iv) Vestigial Organs: The organs which are present in reduced form and do not perform any function in the body but correspond to the fully developed functional organs of related animals are called vestigial organs.

e.g. nictitating (plica semilunaris) membrane, muscles of pinna (auricular muscles), Vermiform appendix, caudal vertebrae (also called coccyx or tail bone), third molars (wisdom teeth), hair on the body, nipples in male.

In the ray florets of sunflower, the stamens are absent while the pistil is rudimentary with small functionless stigma and ovule-less ovary.

Leaves are reduced to scales in *Cuscuta, Orobanche, Asparagus, Ruscus* and a number of other plants.

V) Connecting Links: The organisms which possess the characters of two different groups are called Connecting Links.

e.g. a) *Euglena* is a chlorophyll containing protozoan that forms connecting link between the animals and plants.

b) The lung fishes, e.g. *Protopterus* (African lung fish), *Lepidosiren* (South American lung fish) and *Neoceratodus* (Australian lung fish) may be considered the connecting link between the fishes and amphibians.

[The lung fishes have all the characters of a typical fish, but they are capable of respiring through lungs and possess a three chambered heart].

Connecting Links	Missing Links
1. The living organisms which have the characters of two different groups are called connecting links. 2. They are living organisms. e.g. *Peripatus, Neopilina, Protopterus, Ornithorhyncus*, etc.	1. The fossil organisms which show characters of two different groups are called missing links. 2. They are fossil organisms. e.g. *Ichthyostega, Seymouria, Cyanognathus, Basillosaurs*, etc.

VI) Atavism: It is the reappearance of certain ancestral characters which had either disappeared or were reduced. There are present some examples of atavism in human beings, viz., the power of moving pinna in some persons, greatly developed canine teeth, exceptionally long dense hairs, short tail in some babies and presence of additional mammae in some individuals.

C) EMBRYOLOGICAL EVIDENCES (EVIDENCES FROM EMBRYOLOGY):

These evidences are based on the comparative study of the embryos of various animals.

i) Similarity in early Development: In all multicellular animals the fertilized egg (zygote) undergoes segmentation (cleavage) to produce a solid structure, the morula. The morula develops into a single layered hollow blastula. The later changes into either two or three layered gastrula. Such a similar early development establishes a close relationship among all multicellular animals.

ii) Resemblances among Vertebrates Embryos: If a comparative study of embryos of the same age of vertebrates, such as a fish, a salamander, tortoise, a chick and a man is made, it is observed that they resemble one another closely. They have more or less the same form and structures like gill clefts, tail, etc. Although the embryos of all vertebrates resemble, more closely related groups resemble more than the embryos of the distant groups. This is another evidence for establishing close relationship among these divergent vertebrates.

iii) Temporary Embryonic Structures: Embryos often possess structures which do not occur in the adults. e.g. bird embryo has tooth buds and gill clefts which are not found in the adult animal. Presence of tooth buds has no relevance to the embryo as food is obtained from the yolk through special blood vessels. The presence of tooth buds in the embryos can be explained only on the assumption that –

a) birds have developed from toothed ancestors;
b) birds have lost teeth during evolution;
c) The bird embryo possesses some ancestral characters due to the persistence of some genes that express their effect during developmental stages.

iv) Development of Vertebrate Organs: Development of many vertebrate organs (e.g. heart, brain, kidney) indicate the possible path of evolution as well as the common ancestry of vertebrates. e.g. during its development the heart of a mammal or bird is initially two – chambered (as in fishes), then three – chambered (as in amphibians and some reptiles) and ultimately four – chambered. It clearly shows that birds and mammals have originated from fishes through amphibians and reptiles.

V) Recapitulation theory/ Biogenetic Law: In 1828, Von Baer, the father of modern embryology, proposed Baer's law which stated that during embryonic development, the generalized features (such as brain, spinal cord, axial skeleton, aortic arches, etc. are common to all vertebrates) appeared earlier than the special features (like hair in mammals only, feathers in birds only, limbs in quadrupeds only) which distinguish the various members of the group. Later on this law was modified as the biogenetic law by Ernst Haeckel in 1866. Haeckel's biogenetic law states that "Ontogeny repeats phylogeny". Ontogeny is the life history of an organism while phylogeny is the evolutionary history of the race of that organism. In other words an organism repeats its ancestral history during its development.

e.g. In the development of the frog a fish like tailed larva (tadpole) is formed, which swims with the tail and respires by the gills. This indicates that the frog has been evolved from the fish like ancestor.

VI) Retrogressive Metamorphosis: It refers to metamorphic changes in an organism from highly complex to a less complex or simplified form. Ascidian tadpole is free swimming larva which possesses all three chordate characters but due to metamorphosis it losses all chrodate characters and gets transformed into sedentary adult.

VII) Resemblances among Invertebrates Larvae: Annelids and molluscs possess a similar type of larva called trochophore. Echinoderms and Hemichordates also have similar larva called trochophore. Echinoderms and hemichordates also have similar larvae. Larval resemblance points to a common ancestry.

ADAPTIVE RADIATION (DIVERGENT EVOLUTION): During his journey Darwin went to Galapagos Islands. There he observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him. He realised that there were many varieties of finches in the same island. All the varieties, he conjectured, evolved on the island itself. From the original seed-eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches. ***This process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called adaptive radiation.*** (Development of different functional structures from a common ancestral form is called **adaptive radiation**). Darwin's finches represent one of the best examples of this phenomenon.

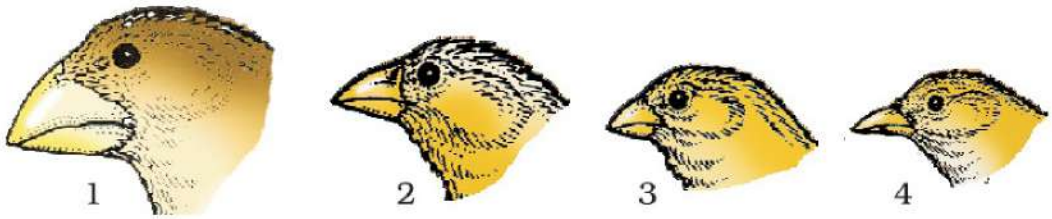


Figure: Variety of beaks of finches that Darwin found in Galapagos Island

Another example is Australian marsupials. A number of marsupials, each different from the other evolved from an ancestral stock, but all within the Australian island continent.

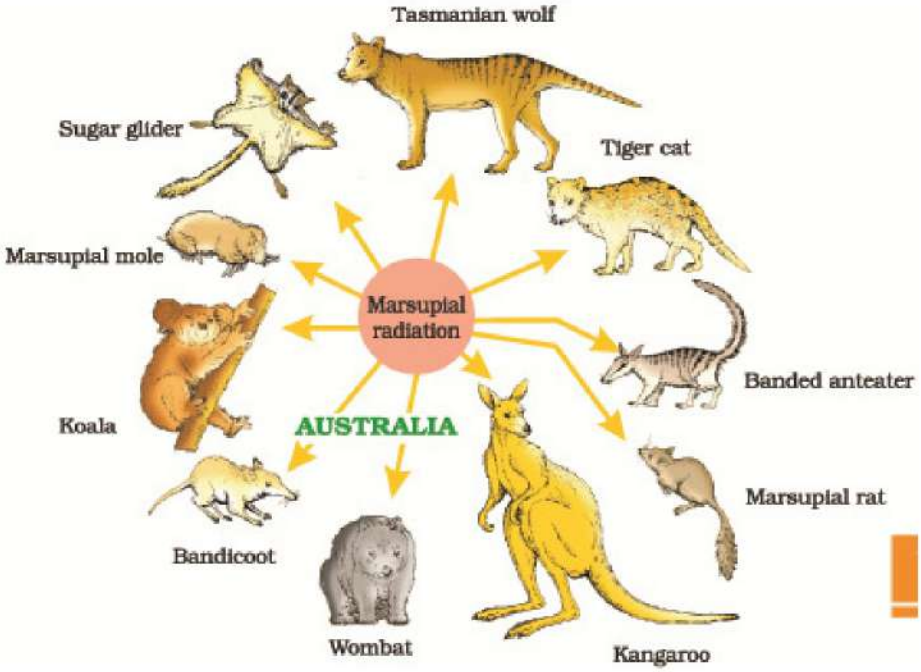


Figure: Adaptive radiation of marsupials of Australia

ii) Australian Marsupials: Darwin explained that adaptive radiation gave rise to a variety of marsupials (pouched mammals) in Australia. A number of marsupial, each different from the other evolved from an ancestral stock, but all within the Australian island continent.

When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing different habitats), one can call this convergent evolution.

5. Convergent Evolution (Adaptive Convergence): Development of similar adaptive functional structures in unrelated groups of organism is called adaptive convergent or convergent evolution.

E.g i) Wings of insect, bird and bat show marked convergent evolution.

ii) Various aquatic vertebrates, not closely related show a marked convergent evolution.

Divergent Evolution	Convergent Evolution
1. Development of different functional structures from a common ancestral form is called divergent evolution. 2. Homologous organs show divergent evolution. E.g. Darwin's Finches, Australian Marsupials, Locomotion in mammals.	1. Development of similar adaptive functional structures in unrelated groups of organisms is called convergent evolution. 2. Analogous organs show convergent evolution. E.g. Australian Marsupials and placental mammals, various aquatic vertebrate and wings of insect, bird and bat.

THEORIES OF EVOLUTION: Three theories have been put forward to explain the mode of evolution, i.e. origin of species.

1) Darwinism or Darwin's theory of natural selection.
2) Hugo de Vries' mutation theory
3) Modern concept of evolution.

NATURAL SELECTION: Darwin formulated the theory of Natural selection. The main features of the theory of natural selection are as follow –

1. Overproduction: All organisms possess enormous fertility. They multiply in geometric ratio. e.g. Insects lay hundreds of eggs.
2. Limited Food and Space: Despite of rapid multiplication of all species, food and space and other resources remain limited. They are not liable to increase.
3. Struggle for Existence: Individuals multiply in geometric ratio whereas space and food remain almost constant. There is an intense competition and three fold of struggle to ensure living to obtain maximum amount of food and suitable land. The struggle can be of three types –
   a) Intraspecific struggle: It is the competition among the individuals of the same species because their requirements like food, shelter, breeding places etc. are similar.
   b) Interspecific struggle: It is the struggle between the members of different species, normally for the food and shelter.
   c) Struggle with Environment: It is the struggle of living organisms against environmental factors such as extreme heat or cold, heavy rains, earthquake, disease, etc.
4. Appearance of Variation: Except the identical twins, no two individuals are similar and their requirements are also not exactly the same. It means there are differences among the individuals. These differences are called variations. Due to variations, some individuals would be better adjusted towards the surroundings than others.
5. Natural selection or Survival of the Fittest: During the struggle for existence only those individuals could survive which exhibit such variations that are proved to be more beneficial in facing the hardships and rigorous of environment or which change to adapt them to the changing conditions.
6. Inheritance of Useful Variations: The organisms after getting fitted to the surroundings, transmit their useful variations to the next generation, while the non-useful variations are eliminated.
7. Speciation (Formation of new Species): As a result of struggle for existence, variability and inheritance, the successive generations tend to become better adapted to their environment. These adaptations are better preserved and accumulated in the individuals of the species, ultimately lead to the origin of new species from the old ones.

HUGO DE VRIES' MUTATION THEORY: According to mutation theory, evolution is a jerky and discontinuous process which is caused by the appearance of sudden discontinuous inheritable genetic variations or mutations that attain full constancy at once and give rise to new elementary species. Mutations are thus the raw material of evolution.

In the first decade of twentieeth century, Hugo deVries based on his work on evening primrose (*Oenothera lamarckiana*) brought forth the idea of mutations – large difference arising suddenly in a population. He believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about. Mutations are random and directionless while Darwinian variations are small and directional. Evolution for Darwin was gradual while Hugo deVries believed mutation caused speciation and hence called it **saltation** (single step large mutation). Studies in population genetics, later, brought out some clarity.

MODERN CONCEPT OF EVOLUTION: The present concept of evolution is a modified form of the Darwin's theory of natural selection and often called **Neo – Darwinism**. According to it only genetic variations (mutations) are inherited and not all variations as held by Darwin.

The synthetic theory of evolution is the result of the work of a number of scientists namely T. Dobzhansky, R.A. Fisher, J.B.S. Haldane, Sewall Wright, Ernst Mayr and G.L. Stebbins. It includes the following factors:

1. GENETIC VARIATION IN POPULATION: It is the population that evolves and not its individual members. The individual's role in the evolutionary process is to pass its genetic variation to its offspring. Evolution occurs through the accumulation of genetic variations in the population over long periods of time. The change in the genes occurs through the following ways –

i) Mutation: It is defined as the change in chemical composition of a gene. Mutation is the basic raw material for evolution that can produce alternative alleles at given locus and alternate phenotype of the individuals in a population.

ii) Genetic Drift (Sewall Wright Effect): The random changes in gene frequencies in a population occurring by chance alone rather than by natural selection are called **genetic drift.** [The term genetic drift refers to the elimination of certain genes of certain traits when a section of population migrates or dies of natural calamity]. It changes the gene frequency of the remaining population. Although it occurs in all small populations, its effects are most marked in very small population. Two important examples of genetic drift are

a) Founder Effect: When a few individuals or a small group of individuals from some large population invades a new or isolated geographical region, these become the founders or founder members. And formation of a different genotype in new settlement is called the founder effect.

b) Bottleneck Effect: Sometimes a population is subjected to near extinction because of a natural disaster (catastrophe) or overharvesting and habitat loss. Then only a few individuals are left to form the progenitors for the future generation of the population which may multiply sporadically in the next generation and may decline after one or two generations.

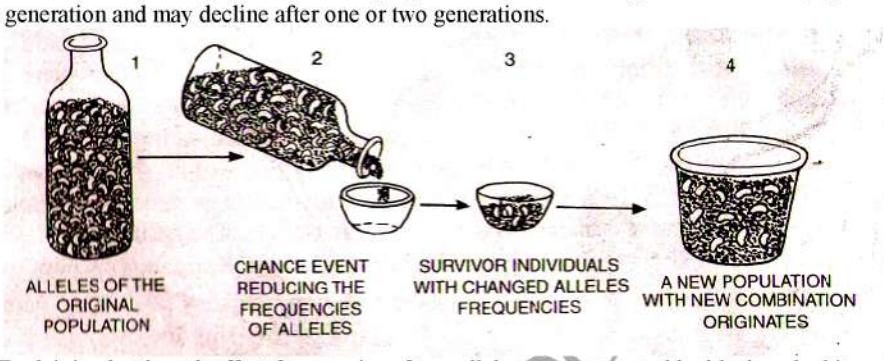


Fig: Explaining bottleneck effect frequencies of two alleles are represented by black and white colours

This yearly or seasonal phenomenon of cyclic fluctuation in population density causing periodic squeezing of the genes in a gene pool in random fashion is called bottleneck phenomenon.

iii) Migration: Migration of individuals from one population to another is also a factor for evolution.

iv) Non-random Mating: It also contributes to the genetic variation.

v) Gene Recombination: Genetic variation also arises by crossing over of chromosomes, independent assortment of chromosomes during meiosis and random coming together of maternal and paternal chromosomes at fertilization.

vi) Hybridization: It is also a method of mixing the genes of two populations.

2. ISOLATION: Isolation is the prevention of mating amongst interbreeding groups due to physical (geographical, ecological) and biotic (e.g. physiological, behavioural, mechanical, genetic) barriers.

i) Geographical Isolation: It is the separation of groups of related organisms by geographical barriers like mountains, valleys, deserts, glaciers, water bodies, etc.

ii). Reproductive Isolation: The population with different genotype appearing in them must be isolated so that differences may accumulate to form a new species.

4. HERIDITY: The transmission of characteristics or variations from parent to the offspring is called heredity which is an important mechanism of evolution. Organisms possessing hereditary characteristics that are helpful, either in the animal's native environment or in some other environment, are favoured in the struggle for existence. Thus the offspring are able to benefit from the advantageous characteristics of their parents.

5. NATURAL SELECTION: It is differential reproduction which means some members of a population have traits (genes) that enable them to grow up and reproduce at a higher rate and leave more surviving offspring in the next generation than others. If differential reproduction continues for many generations, genes of the individuals which produce more offspring will become predominant in the gene pool of the population.

6. SPECIATION (Origin of new Species): The population of a species present in their environments and separated by geographical and physiological barriers, accumulate different genetic differences (variations) due to mutations, recombinations, hybridization, genetic drifts and natural selection. These populations, therefore, become different from each other morphologically and genetically, and they become reproductively isolated, forming new species.

EXAMPLES OF EVOLUTION BY NATURAL SELECTION:

1. Industrial Melanism: This phenomenon was studied by *Barnard Kettlewell.*

Before industrial revolution, white winged forms peppered moths – *Biston betularia* were dominant; the dark-winged moths (Black) were rare because it was susceptible to predation by birds. The reason was that it was conspicuously visible while resting on tree trunks.

The industrial revolution resulted in large scale smoke which got deposited on the tree trunks turning them black. Under such condition, the white winged moths did not survive due to predation and dark winged moths survived. Therefore black winged moths that were hidden in the background survived. This industrial melanism supports evolution by natural selection.

2. Sickle Cell Anaemia and Malaria: Normal individuals, $Hb^A Hb^A$ die of malaria. $Hb^S Hb^S$ die of haemolytic anaemia. Heterozygote $Hb^A Hb^S$ do not suffer from anaemia under normal conditions. They do not catch malaria because malaria parasite is unable to penetrate RBCs having $Hb^A Hb^S$ haemoglobin. Therefore, the heterozygotes $Hb^A Hb^S$ have selective advantage in malaria prone regions. It is only under conditions of stress or oxygen deficiency that their RBCs become sickle-shaped and undergo haemolysis.

3. Resistance of Insects to Pesticides: The DDT was thought to be an effective insecticide against household pests, such as mosquitoes, houseflies, body lice, etc. But within two to three years of introduction of insecticide, new DDT resistant mosquitoes appeared in the population. These mutant strains, which are resistant to DDT, soon became well established in the population, and to a great extent, replaced the original DDT-sensitive mosquitoes.

5. Antibiotic Resistance in Bacteria: We use antibiotics or drugs against disease causing bacteria. When a bacterial population encounters a particular antibiotic, those sensitive to it die. But some bacteria having mutations become resistant to the antibiotic. Such resistant bacteria survive and multiply quickly as the competing bacteria have died. Soon the resistance providing genes become widespread and entire population becomes resistant.

TYPES OF NATURAL SELECTION:

1. Stabilising Selection (Balancing Selection): It occurs when an intermediate phenotype is favoured. The extreme individuals (phenotypes) are eliminated from the population and the individuals near the average are favoured. The shape of the curve tends to narrow through continual elimination of the less adapted individuals. Thus stabilizing selection reduces variation and favours the average or near normal phenotypes. If we draw a graphical curve of population, it is bell-shaped.

e.g. Mortality in babies: The optimum birth weight favoured by stabilising selection is 7.3 pounds. New borne infants less than 5 pounds and more than 10 pounds have the highest mortality rate. (7 lb = 3.2 Kg).

2. Directional Selection: It occurs when an extreme phenotype is favoured and the distribution curve shifts in that direction. Such a shift can occur when a population is adapting to a changing environment and become best adapted to new environmental condition.

e.g. Evolution of DDT resistant mosquitoes, Industrial melanism in peppered moth and evolution of giraffe.

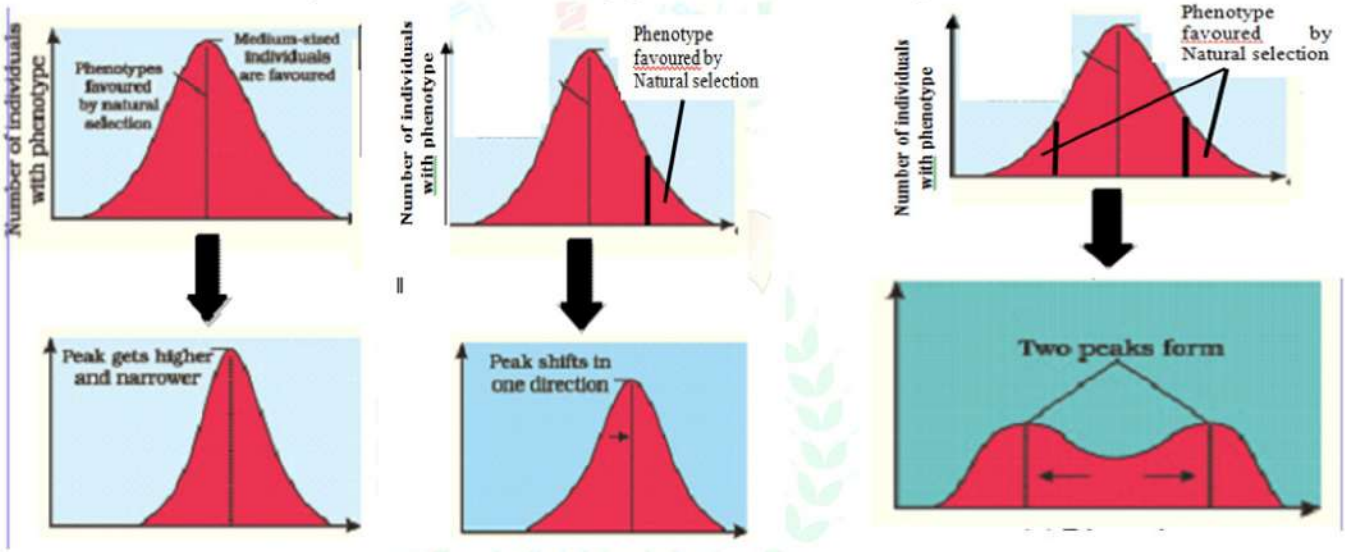


Fig: Types of Natural Selection on the basis of variants of traits selected (a) Stabilising (b) Directional and (c) Disruptive

3. Disruptive Selection (Diversifying Selection): This type of selection favours both small-sized and large sized individuals (extreme phenotypes). It eliminates most of members with mean expression, so produces two peaks in the distribution of the trait that may lead to development of two different populations. It is opposite of stabilizing selection. e.g. Black billed seed cracker, *Pyrenestes ostrinus* (West African finch) reveals disruptive selection. Some birds have small bills and some have large bills to feed on seeds of Sedges, a marsh plant. The young birds with bills different from those two extreme sizes, do not survive because their bills do not help them to feed on any other available food source.

SPECIATION: It is the evolution/formation of one or more new species from an existing species.

Types of Speciation: It is of following types:

1. Allopatric Speciation: (*allo*-other; *patria*- native land)

In this type of species formation, a part of the population becomes geographically isolated from the main population. The population becomes entirely separated and finally constitutes a new species. Thus geographic isolation brings about allopatric speciation. e.g. formation of Darwin's finches that formed separate species in the Galapagos islands.

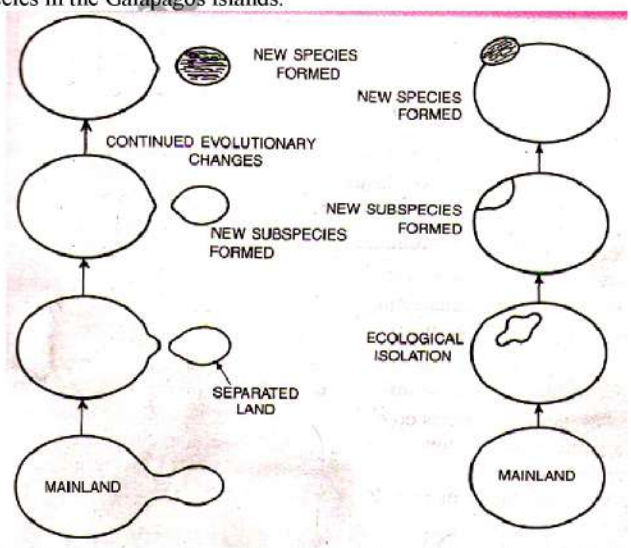


Diagram – (A) – Allopatric speciation; (B) - Sympatric speciation (hypothetical representation)

2. Sympatric Speciation: In this type of species formation, a small segment of the original population becomes isolated reproductively. As the isolating mechanism comes into force, a new subspecies emerges. In due course of time a new species is formed. Thus sympatric speciation is the formation of species within a single population without geographical isolation. The reproductive isolation brings about sympatric speciation.

Allopatric speciation	Sympatric speciation
1. It occurs in a spatially, isolated population.	1. It occurs from a segment of within a population.
2. The barrier is physical.	2. The barriers is ecological and genetic.
3. There are chances of breakdown of isolating mechanism.	3. Chances of breakdown of isolating mechanism are rare.
4. Speciation is slow.	4. Speciation is rapid.
5. Barriers to interspecific crossings are fewer.	5. Barriers to interspecific crossings are more pronounced

Polyploidy: Increase in number of chromosomes or chromosome sets is called polyploidy. Polyploidy does not occur commonly in animals. The additional chromosomes in animals are mostly lethal. However, polyploidy occurs commonly in plants. Polyploidy has played an important role in plant evolution.

Hardy –Weinberg Equilibrium Principle: It states that allelic frequencies in a population are stable and remain constant generation after generation. The gene pool remains constant. This is called genetic equilibrium.

Essential Conditions of Hardy –Weinberg Equilibrium Principle:

1. No Mutation: It is defined as the change in chemical composition of a gene. Mutation is the basic raw material for evolution that can produce alternative alleles at given locus and alternate phenotype of the individuals in a population. There should not be either gene or chromosomal variations.
2. No Gene Flow (Gene Migration): Within the gene pool of a breeding population there is a continual interchange of alleles between organisms. Gene flow refers to the movement of alleles from one population to another as a result of interbreeding members of two populations. The removal of alleles from one population or addition of alleles into another population is called gene flow or gene migration. There must not be gene flow between the populations.
3. No Genetic Drift: It is random changes in gene frequency. It occurs only by chance. It is non directional. It can cause elimination of certain alleles or fixation of the other alleles in the population. So it must not occur.
4. No Genetic Recombination: The alleles of parental linkage groups separate and new associations of alleles are formed in the gamete cells, this process is known as genetic recombination. Thus crossing over during meiosis is a major source of genetic variation within population. Offspring formed from these gametes showing 'new' combination of characteristics are called recombinants. There must not be recombination.
5. No Natural selection Pressure: Natural selection is the primary factor that controls the evolutionary process. The variations brought in by mutation and recombination may be useful or harmful in nature. Natural selection favours those genes that assure highest level of adaptive efficiency between the environment and the population. Harmful genes are eliminated from the gene pool by natural selection. Natural selection incorporates heritable variations which increases the reproductive success and over generations would result in **speciation.** There must be no natural selection pressure with respect to the alleles.

According to Hardy-Weinberg Principle, *gene frequencies will remain constant if the above five conditions are met.*

Constant gene frequencies over several generations indicate that evolution is not taking place. Changing gene frequencies would indicate that evolution is in progress. In other words, *evolution occurs when the genetic equilibrium is upset*.

In a diploid p and q represent the frequency of allele A and allele *a*. The frequency of AA individuals in a population is p^2. This can be stated in another way, i.e. the probability that an allele A with a frequency of p appears on both the chromosomes of a diploid individual is the product of probabilities, i.e. p^2. Similar of *aa* is q^2, of *Aa* is 2pq. Thus $p^2 + 2pq + q^2 = 1$. p= dominant allele frequency, q = recessive allele frequency, p^2 = homozygous dominant genotype, 2pq = heterozygous genotype, q^2 = homozygous recessive genotype, 1 = sum total of all the alleles frequencies.

It is possible to calculate all allele and genotype frequencies using the expression allele frequency $p + q = 1$, and genotype frequency $p^2 + 2pq + q^2 = 1$.

If q is the frequency of the allele *a*, then Hardy-Weinberg equation states q^2 = percentage individuals homozygous for allele *a* say 16%.

$q^2 = 0.16$, $q = 0.4$

Factors affecting Hardy-Weinberg's Principle:

1. Mutation: It is defined as the change in chemical composition of a gene. Mutation is the basic raw material for evolution that can produce alternative alleles at given locus and alternate phenotype of the individuals in a population.
2. Gene Flow (Gene Migration): Within the gene pool of a breeding population there is a continual interchange of alleles between organisms. Gene flow refers to the movement of alleles from one population to another as a result of interbreeding members of two populations. The removal of alleles from one population or addition of alleles into another population is called gene flow or gene migration.
3. Genetic Drift: It is random changes in gene frequency. It occurs only by chance. It is non directional. It can cause elimination of certain alleles or fixation of the other alleles in the population.
4. Genetic Recombination: The alleles of parental linkage groups separate and new associations of alleles are formed in the gamete cells, this process is known as genetic recombination. Thus crossing over during meiosis is a major source of genetic variation within population. Offspring formed from these gametes showing 'new' combination of characteristics are called recombinants.
5. Natural selection Pressure: It is the primary factor that controls the evolutionary process. The variations brought in by mutation and recombination may be useful or harmful in nature. Natural selection favours those genes that assure highest level of adaptive efficiency between the environment and the population. Harmful genes are eliminated from the gene pool by natural selection. Natural selection incorporates heritable variations which increases the reproductive success and over generations would result in **speciation.**

Q.33. Explain the five factors that affect the Hardy-Weinberg Principle. 5(CoHSEM, 2017)

Agents of Evolutionary change:

1. Mutation
2. Migration
3. Genetic drift
4. Recombination
5. Natural selection.

Q. For the MN-blood group system, the frequencies of M and N alleles are 0.7 and 0.3, respectively. The expected frequency of MN-blood group bearing organisms is likely to be

a. 42% b. 49% c. 9% d. 58%

Ans:- a. 42%

Q.45. In certain population, the frequency of three genotypes is as follows –

Genotypes	BB	Bb	bb
Frequency	22%	62%	16%

What is the frequency of B and b alleles?

Ans:- Frequency of B alleles = All BB + ½ Bb
= 22 + 31
= 53%

Frequency of b alleles = All bb + ½ Bb
= 16 + 31 = 47%

Q. Cystic fibrosis is a recessive condition that affects about 1 in 2500 babies. Calculate the following:

(a) The frequency of the recessive allele in the population.

(b) The frequency of the dominant allele in the population.

(c) The percentage of heterozygous individuals (carriers) in the population.

Ans:- (a) It is given that q^2 is 1/2500 or 0.0004. Therefore, q is the square root, or 0.02. Hence the frequency of the cystic fibrosis (recessive) allele in the population is 0.02 (or 2).

(b) The frequency of dominant (normal) allele in the population (p) is simply 1 – 0.02 is 0.98 (or 98%).
(c) The percentage of heterozygous or carriers, then the equation will be as follows: 2pq = 2 (0.98) (0.02) = 0.04 or 1 in 25 are carriers.
Q. At a particular locus, frequency of '*A*' allele is 0.6 and that of '*a*' is 0.4. What would be the frequency of heterozygotes in a random mating population at equilibrium?
a) 0.36 b) 0.48 c) 0.16 d) 0.24.
Ans:- b) 0.48
Q. Frequency of an autosomal lethal gene is 0.4. The frequency of carrier in a population of 200 individual is:
a) 72 b) 96 c) 104 d) 36
Ans:- b) 96

A BRIEF ACCOUNT OF EVOLUTION:

About 2000 million years ago (mya) the first cellular forms of life appeared on earth. The mechanism of how non-cellular aggregates of giant macromolecules could evolve into cells with membranous envelop is not known. Some of these cells had the ability to release O_2. The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelized by appropriate light harvesting pigments. Slowly single-celled organisms became multi-cellular life forms.

A) HISTORY OF EVOLUTION OF ANIMALS:-

i) By the time of 500 mya, invertebrates were formed and active.
ii) Jawless fish probably evolved around 350 mya.
iii) Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In 1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct. These animals called lobefins evolved into the first amphibians that lived on both land and water. There are no specimens of these left with us.
iv) The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. In the next 200 millions years or so, reptiles of different shapes and sizes dominated on earth.
v) Some of these land reptiles went back into water to evolve into fish like reptiles probably 200 mya (e.g. *Ichthyosaurs*). The land reptiles were, of course, the dinosaurs. The biggest of them, i.e., *Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth. About 65 mya, the dinosaurs suddenly disappeared from the earth.
vi) Small sized reptiles of that era still exist today. The first mammals were like shrews (Mammals evolved from reptiles). Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least. When reptiles came down mammals took over this earth. There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.

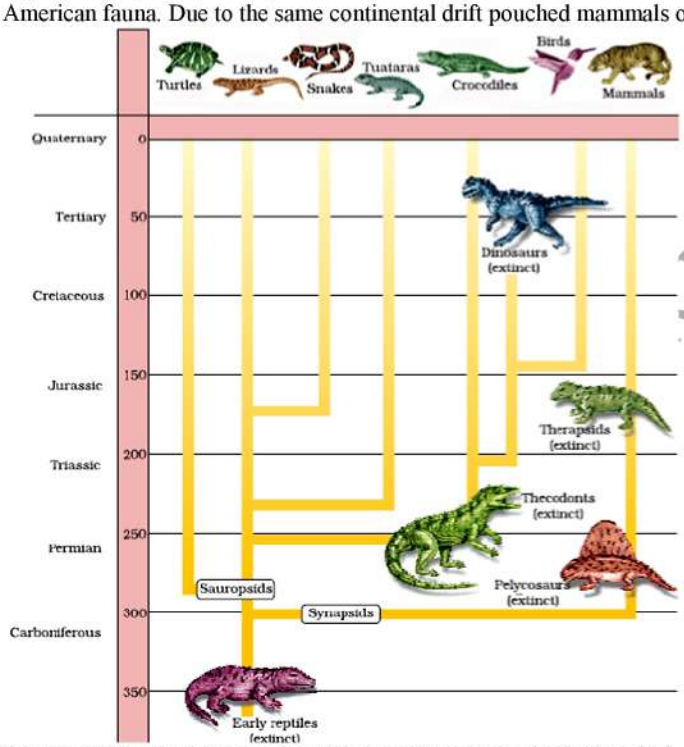


Fig: Evolutionary history of vertebrates through geological period

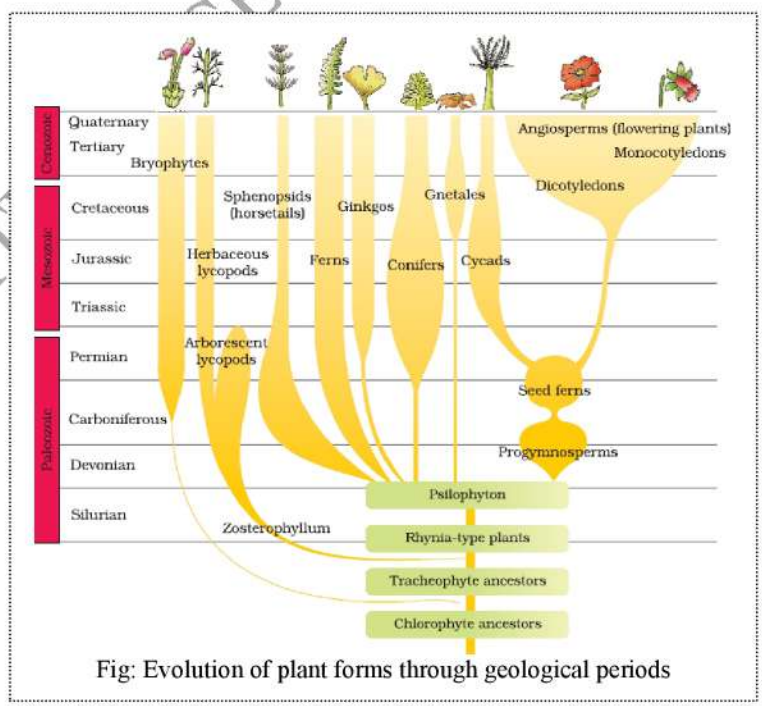


Fig: Evolution of plant forms through geological periods

B) HISTORY OF EVOLUTION OF PLANTS:

- Sea weeds and some plants existed around 320 mya.
- Bryophytes were the first plants to colonise lands. (Plants colonized land much before animals).
- *Psilophyton* is the common ancestor for horsetails, ferns, gymnosperms and angiosperms.

Q. State the significance of Coelocanth in evolution.
Or, Coelocanth was caught in 1938 in South Africa. Why is it very significant in the evolutionary history of vertebrates?
Ans:- The discovery of Coelocanth (lobe fins), the first amphibians is significant as they prove that amphibians have evolved from fish-like organisms. Lobe fins were the ancestors of modern day frog and salamanders.

EVOLUTION OF MAN

The fossil evidence clearly indicates the origin of man occurred in Central Asia, China, Java and India (Shivalik Hills). It has been established that *Dryopithecus* is the oldest fossil, which in turn evolved into apes and men. The origin and evolution of man can be studied in the following three major headings:

I. Prior to Ape men:

- Dryopithecus: The fossil of *Dryopithecus africanus* was discovered from Meiocene rocks of Africa and Europe. It lived about 20 – 25 million years ago.
  It was more ape – like but had arms and legs of the same length. Heels in its feet indicate its semi-erect posture. It is regarded a common ancestor of man and apes (gibbons, orangutan, chimpanzee and gorilla).
- Ramapithecus: It has been established that in late Miocene epoch *Dryopithecus* gave rise to *Ramapithecus.*

Perhaps it walked erect on its hind feet. It was more man-like and lived on the tree tops but also walked on the ground. Its jaws and teeth were like those of humans. Its small canines and large molars suggest that *Ramapithecus* ate hard nuts and seeds like modern man.

II. Ape Men including Prehistoric Men

i) Australopithecus (First ape man): The early human stock gave rise to *Australopithecus*.

Raymond Dart discovered the fossil of *Australopithecus africanus* (African Ape man) from Pliocene rocks near Tuang in Africa and it was about 1.5 metres high and had human as well as ape characters. It was with bipedal locomotion, omnivorous diet and had erect posture. It had human like teeth but it had more of an ape brain than a human brain. Its brain capacity was about 500 c.c., similar to that of an ape. Australopithecus Africans existed until about 1.5 million years ago and gave rise to *Homo habilis* about two million years ago. He lived in caves. It did not have chin.

ii) *Homo habilis* (Able or Skillful man): It was about 1.2 to 1.5 metres tall. It bipedal locomotion, moved erect and was omnivorous. The brain capacities were between 650-800cc. The teeth were like that of modern man. *Homo habilis* was the first tool maker and used tools of chipped stones extensively. He also led community life in caves and greatly cared for the young ones. They probably did not eat meat.

iii) *Homo erectus* (Erect man): *Homo erectus* appeared about 1.7 million years ago in middle Pleistocene. *H. erectus* evolved from *Homo habilis*. He was about 1.5-1.8 metres tall. *Homo erectus* males were probably larger than females. He had erect posture. His skull was flatter than that of modern man. *Homo erectus* had a large brain around 900cc. *Homo erectus* probably ate meat. He made more elaborate tools of stones and bones, hunted big game and perhaps knew use of fire.

Homo erectus includes three fossils: Java Ape-man, Peking man and Heidelberg man.

III. True men including the Living Modern Man

i) Neanderthal Man (*Homo sapiens neanderthalensis*): Fossils of Neanderthal man were first obtained from Neander Valley in Germany from the late Pleistocene epoch. He had slightly prognathous face. Neanderthals walked upright, as we do, and had low brows, receding jaws, and high domed heads. The Neanderthal man with a brain size of 1400 cc lived in near east and central Asia between 1,00,000 - 40,000 years back. They used hides to protect their body and buried their dead. They were the legendary cave dwellers. They were adapted to a cold environment. They were cannibals. They wore cloths of animal skin.

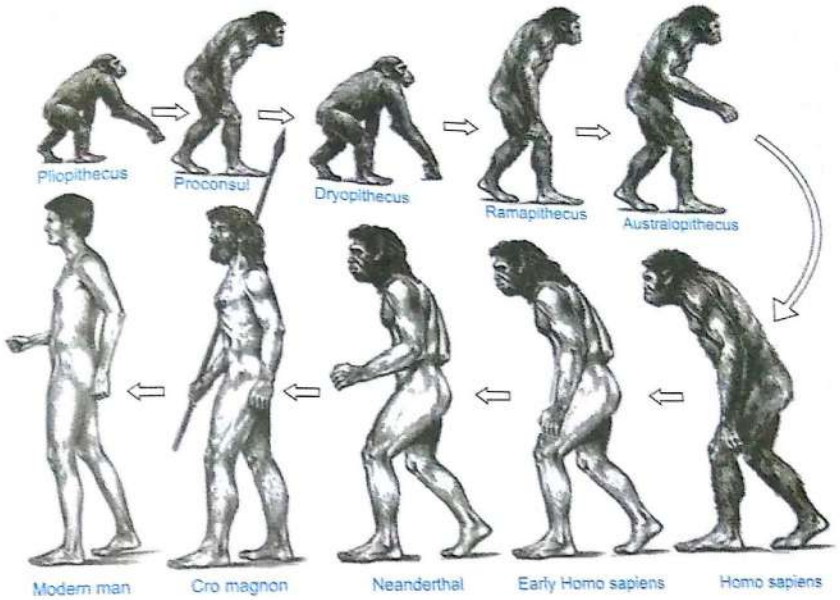


Figure: Progressive evolution of modern man: through primitive apes, apes, ape man and prehistoric man

ii) Cro-Magnon man (*Homo sapien fossilis*).

It has been known as Cro-Magnon man because its fossils were first discovered in 1868 from Cro-Magnon rocks of France by Mac Gregor. Cro-Magnon man emerged about 34000 years ago in Holocene epoch. Thus, it is regarded as most recent ancestor of today's man. The Cro-Magnon man had, like us, about 1.8 metres tall, well-built body. Its cranial capacity was 1650 cc. (maximum). It could walk and run faster and lived in families in caves and also painted beautiful painting on cave walls. They made excellent tools and even ornaments, not only of stones and bones, but also of elephant tusks. They were omnivorous and used skin clothes. They became extinct about 10,000-11,000 years ago.

iii) The Living Modern Man (*Homo sapiens sapiens*):

Homo sapiens sapiens appeared about 25000 years ago, in Holocene epoch and started spreading all over the world about 10,000 years ago. Morphologically, the transition is marked merely by a slightly raising of skull cap, thinning of skull bones, a slight reduction in cranial capacity 1450 cc (average), and formation of four curves in the vertebral column. It is believed that the man of today first appeared about 11,000 or 10,000 years ago in the region around Caspean and Mediterrranean Seas. From there, its members migrated westwards, eastwards and southwards, respectively changing into the present day white or Caucasoid, Mongoloid and black or Negroid races.

Q. What is saltation according to Hugo de Vries?

Ans:- According to Hugo de vries, saltation means single step large mutation that means mutation causes species formation.

Q. Mention how is mutation theory of Hugo de Vries different from Darwin's theory of natural selection?

Ans:- Hugo de Vries theory: It states that evolution occurs due to single step large mutation called saltation, whereas Darwin's theory states that the speciation occurs gradually through a number of generations, with accumulation of minor variations.

Q. What does Hardy – Weinberg's equation $p^2 + 2pq + q^2 = 1$, convey?

Ans:- It indicates genetic equilibrium which means the allele frequencies in a population are stable and remain constant from generation to generation.

Q. When does a species become founders to cause founder effect?

Ans:- When the change in allele frequency is very different in the original drifted population. It becomes founder effect.

Q. Branching descent and natural selection are the two key concepts of Darwinian theory of evolution. Explain each concept with the help of a suitable example.

Ans:- Branching Descent:

i) Members of a population vary in characteristics, even though they look superficially similar. Most of these variations are heritable.

ii) Accumulation of variation over a period of a time through a number of generations lead to change in population characteristics.

Example: Evolution of marsupials of Australia from common ancestor.

Natural Selection: Nature selects those individuals who are fit in the environment. Fitness according to Darwin is reproductive fitness. Those who adapt better to the habitat will reproduce more and progeny consists of more fit individuals who are selected by nature.

Example: Industrial melanism.

MICROBES IN HUMAN WELFARE

MICROBES: Microbes are micro organisms which being small (0.1mm or less) are not visible with naked eye and can only be seen only with help of microscope. E.g. Bacteria, protista, fungi.

MICROBES IN HOUSEHOLD PRODUCTS:

A. DAIRY PRODUCTS: Micro-organisms such as *Lactobacillus* and others commonly called **lactic acid bacteria (LAB)** grow in milk and convert it to curd. During growth, the LAB produces acids that coagulate and partially digest the milk proteins. A small amount of curd added to the fresh milk as inoculum or starter contain millions of LAB, which at suitable temperatures multiply, thus converting milk to curd, which also improves its nutritional quality by increasing vitamin B_{12}. In our stomach too, the LAB play very beneficial role in checking disease causing microbes. They convert lactose sugar of milk into lactic acid. Lactic acid causes coagulation of milk protein casein. Milk is changed into curd, yoghurt and cheese.

I. Curd: It is prepared by inoculating cream and skimmed with *Lactobacillus acidophilus* at a temperature of about 40° C or less.

II. Cheese: It is pressed and flavoured milk curd which became component of human diet very early.
   - **'Swiss cheese'** has large holes due to production of large amount of CO_2 by a bacterium named *Propionibacterium sharmanii*.

III. Yoghurt: It is produced by curdling milk with the help of *Streptococcus thermophilus* and *Lactobacilus bulgaricus*. The temperature is maintained at 45°C (40°-46°C) for four hours.

B. BREAD: Selected strains of *Saccharomyces cerevisiae* (Yeast) grown on molasses are used for Baker's yeast.

MICROBES IN INDUSTRIAL PRODUCTS: Fermentative activity of microbes is used industrially to obtain a number of products. The two common ones are alcoholic fermentation and antibiotics.

1. Alcoholic Fermentation:

Microbes especially yeasts have been used from time immemorial for the production of beverages like wine, beer, whisky, brandy or rum. For this purpose, the same yeast *Saccharomyces cerevisiae* used for bread-making and commonly called **brewer's yeast**, is used for fermenting malted cereals and fruit juices, to produce ethanol.

Depending on the type of the raw material used for fermentation and the type of processing (with or without distillation) different types of alcoholic drinks are obtained. Wine and beer are produced without distillation whereas whisky, brandy and rum are produced by distillation of the fermented broth.

2. Antibiotics: Antibiotics are drugs produced by micro-organisms which in low concentration kill pathogenic microbes by inhibiting their growth and metabolism without harming the host. (An antibiotic is a substance produced by a micro-organism, which inhibits the growth and metabolic activity of pathogenic organism without harming the host).

First antibiotic is generally associated with the name of Alexander Fleming (1928), when he discovered penicillin from *Penicillium notatum* (did not allow growth of *Staphylococcus aureus*). Alexander Fleming while working on *Staphylococci* bacteria, once observed a mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He found out that it was due to a chemical produced by the mould and he named it Penicillin after the mould *Penicillium notatum*. However, its full potential as an effective antibiotic was established much later by Ernest Chain and Howard Florey. This antibiotic was extensively used to treat American soldiers wounded in World War II. Fleming, Chain and Florey were awarded the Nobel Prize in 1945, for this discovery.

Chemicals: Microbes are also used for commercial and industrial production of certain chemicals like organic acids, alcohols and enzymes. Examples of acid producers are *Aspergillus niger* (a fungus) of citric acid, *Acetobacter aceti* (a bacterium) of acetic acid; *Clostridium butylicum* (a bacterium) of butyric acid and *Lactobacillus* (a bacterium) of lactic acid.

ENZYMES: A wide range of enzymes extracted from micro-organisms are greatly contributed towards human welfare.

a) Enzyme **lipase (**obtained from *Candida lipolytica* and *Geotrichum candidum*) is added in detergents for removing oil stains from clothes.

b) Enzymes **pectinase** and **proteases** are used as clarifying agents in bottled fruit juices. This is the reason why marketed bottled fruit juices appear clearer than homemade juices.

c) Enzyme **streptokinase** produced by a bacteria *Streptococcus*, is modified genetically to be useful in human beings. It is used as '**clot buster**'. Clot busters remove blood clots in the blood vessels of patients suffering from myocardial infarction that lead to heart attack.

BIOACTIVE MOLECULES:

a) **Cyclosporin A**: It is an eleven membered cyclic oligopeptide obtained through fermentative of activity fungus *Trichoderma polysporum*. It has **antifungal**, **anti-inflammatory** and **immunosuppressive** properties. It inhibits activation of T-cells and therefore, prevents rejection reaction in organ transplantation.

b) **Statins** produced by *Monascus purpureus*, a yeast are commercial used as blood cholesterol lowering agents. Statin resemble mevalonate and are competitive inhibitors of enzyme *β-hydroxy – β – methylglutaryl* or HMG CoA reductase. This inhibits cholesterol synthesis. Statins are therefore used in lowering blood cholesterol, e.g. lovastatin, pravastatin, simvastatin.

MICROBES AS BIOCONTROL AGENTS: Instead of trying to eradicate pests and pathogens through chemicals, which is also a toxic and biocide, it is better to use biological agents for controlling them. The natural method of pest and pathogen control involving use of viruses, bacteria and other insects (which are their natural predators and pests) is called biocontrol and biological control.

BIOPESTICIDES: They are biological agents and their products which are used to control pests like weeds, insects and pathogens. Biopesticides are divisible into two categories- bioherbicides and bioinsecticides.

a) Bioherbicides- They are organisms and their extracts which destroy weeds without harming crop plants. They are of three types-

1. Predator herbivores: They are herbivore insects which feed over particular plants. E.g. *Cactoblastis cactorum* has controlled the spread of *Opuntia*.

2. Smoother Crops: These are those crops which do not allow the weeds to grow.

3. Mycoherbicides: are fungi which parasite specific plants.

E.g. *Phytophthora palmivora* does not allow Milkweed Vine to grow in citrus orchards.

b) Bioinsecticides: They are living organisms or their products which are able to kill or repel specific insects.

An example of microbial bicontrol agents that can be introduced in order to control butterfly caterpillars is the bacteria *Bacillus thuringiensis*.

- *Trichoderma* species are free-living fungi that are very common in the root ecosystems. They are effective biocontrol agents of several plant pathogens.
- Baculoviruses are pathogens that attack insects and other arthropods. The majority of baculoviruses used as biological control agents are in the genus *Nucleopolyhedrovirus*. These viruses are excellent candidates for species-specific, narrow spectrum insecticidal applications. They have been shown to have no negative impacts on plants, mammals, birds, fish or even on non-target insects. This is especially desirable when beneficial insects are being conserved to aid in an overall integrated pest management (IPM) programme, or when an ecologically sensitive area is being treated.

MICROBES AS BIOFERTILISERS: Biofertilizers are micro-organisms, which bring about nutrient enrichment of soil by enhancing the availability of nutrients like nitrogen and phosphorus to crops.

The important biofertilizers are-

I. Free Living Nitrogen Fixing Bacteria: They live freely in the soil and perform nitrogen fixation.
e.g. *Azotobacter, Bacillus, Polymixa, Clostridium, Beijerinckia.*

II. Symbiotic Nitrogen fixing Bacteria: They form a mutually beneficial association with the plants. The bacteria obtain food and shelter from plants and in return, they give a part of their fixed nitrogen to the plants.
E.g. *Rhizobium leguminosarum* live in symbiotic relationship in the root nodules of legumes.
Frankia forms root nodules in *Casuarina* and *Alnus.*

III. Free Living Nitrogen Fixing Cyanobacteria: A number of freeliving cyanobacteria or blue green algae are capable of nitrogen fixation.
E.g. *Anabaena, Nostoc, Aulosira, Tolypothorix.*

IV. Symbiotic Nitrogen Fixing Cyanobacteria: Nitrogen fixing cyanobacteria (Blue-green algae) form symbiotic association with several plants. E.g. Cycad roots, lichens, *Azolla* (Fern).
Out of these, *Azolla-Anabaena* association is of great importance to agriculture.

V. Mycorrhiza: It is symbiotic association between fungi with the roots of higher plants. The fungal symbiont in these associations absorbs phosphorus from soil and passes it to the plant. Plants having such associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development.

There are two kinds of mycorrhizae:

a) Ectomicorrhiza: In this form of association, the fungal mycelium completely encloses the root. The hyphae penetrate the intercellular spaces of the root cortex to form a network. e.g. *Pinus*, *Quercus*(Oak), *Alnus, Betula*.

b) Endomicorrhiza: In this form of association, the fungus mostly lives in the intercellular spaces as well as intracellularly in the cortical cells of roots. Only a small portion of fungus lives outside the root. One of the important type of endomicorrhizae is Vesicular arbuscular mycorrhiza (VAM). Some of the hyphal branches enter root cortical cells and form vesicles or arbuscles for obtaining nourishment.

15. A farmer adds *Azotobacter* culture to soil before sowing maize seeds. How does it increase the yield of maize? 1(CoHSEM,2005)

19. "Legumes fertilize the soil but cereals do not". Discuss. 2(CoHSEM,2012)

ADVANTAGES OF USING BIOFERTILISERS:

i) Biofertilisers do not cause pollutions.

ii) Biofertilisers are cheap and economical. They can be used even by poor farmers.

iii) Biofertilisers improve physical and chemical properties of soil (such as water holding capacity, buffer capacity etc.).

iv) Besides fixing atmospheric nitrogen, Cyanobacteria synthesize and excrete several growth hormones (auxin and ascorbic acid) and vitamins (B_{12}) which enhance seed germination and growth of crop plants.

v) *Azotobacter* and microbe biofertilisers increase 15-35 percent additional yield in most of the vegetables crops.

Cyclosporin A: It is an eleven membered cyclic oligopeptide obtained through fermentative activity fungus *Trichoderma polysporum*. It has antifungal, anti-inflammatory and immunosuppressive properties. It inhibits activation of T-cells and therefore, prevents rejection reaction in organ transplantation.

MICROORGANISMS IN SEWAGE TREATMENT

Primary or Physical Treatment: It is the process of removal of small and large, floating and suspended solid from sewage through **two processes of filtration and sedimentation.** These treatment steps basically involve physical removal of particles – large and small – from the sewage through filtration and sedimentation. These are removed in stages: initially, floating debris is removed by sequential filtration. Then the grit (soil and small pebbles) are removed by sedimentation. All solids that settle form the ***primary sludge***, and the supernatant forms the *effluent*. The effluent from the primary settling tank is taken for secondary treatment.

Secondary treatment or Biological treatment: The primary effluent is passed into large aeration tanks where it is constantly agitated mechanically and air is pumped into it. This allows vigorous growth of useful aerobic microbes into ***flocs*** (masses of bacteria associated with fungal filaments to form mesh like structures). While growing, these microbes consume the major part of the organic matter in the effluent. This significantly reduces the ***BOD (biochemical oxygen demand)*** of the effluent. BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidised by bacteria. The sewage water is treated till the BOD is reduced. The BOD test measures the rate of uptake of oxygen by micro-organisms in a sample of water and thus, indirectly, BOD is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.

Once the BOD of sewage or waste water is reduced significantly, the effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment. This sediment is called **activated sludge**. A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum. The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters**. Here, other kinds of bacteria, which grow anaerobically, digest the bacteria and the fungi in the sludge. During this digestion, bacteria produce a mixture of gases such as methane, hydrogen sulphide and carbon dioxide. These gases form **biogas** and can be used as source of energy as it is inflammable.

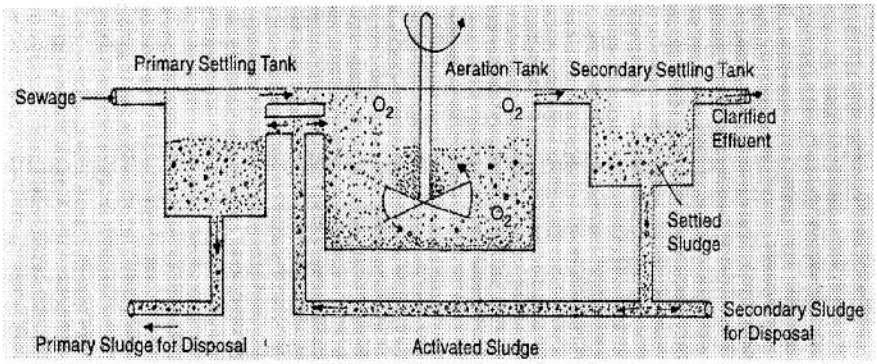


Fig: Activated sludge method of sewage treatment

Primary sludge	Activated Sludge
1. It is the sludge formed during primary sewage treatment.	1. It is sludge formed during secondary sewage treatment.
2. It does not possess flocs of decomposers microbes.	2. It possesses flocs of decomposer microbes.
3. It does not require aeration.	3. Formation of activated sludge requires aeration.

Primary Treatment	Secondary Treatment
1. It is a physical process. 2. It involves both grit and large pieces of organic matter. 3. It does not require aeration. 4. It involves shredding, churning, filtration and sedimentation.	1. It is a biological process. 2. It removes small sized organic materials. 3. Aeration is required. 4. It involves microbial digestion of organic matter, formation of flocs, sludge and sludge digestion.

MICROBES IN PRODUCTION OF BIOGAS: Biogas is a mixture of gases (containing predominantly methane) produced by the microbial activity and which may be used as fuel. Microbes produce different types of gaseous end-products during growth and metabolism. The type of the gas produced depends upon the microbes and the organic substrates they utilise. However, certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with CO_2 and H_2. These bacteria are collectively called **methanogens**, and one such common bacterium is *Methanobacterium*. These bacteria are commonly found in the anaerobic sludge during sewage treatment. These bacteria are also present in the rumen (a part of stomach) of cattle. A lot of cellulosic material present in the food of cattle is also present in the rumen. In rumen, these bacteria help in the breakdown of cellulose and play an important role in the nutrition of cattle. Thus, the excreta (dung) of cattle, commonly called *gobar*, is rich in these bacteria. Dung can be used for generation of biogas, commonly called *gobar gas*.

The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed. A floating cover is placed over the slurry, which keeps on rising as the gas is produced in the tank due to the microbial activity. The biogas plant has an outlet, which is connected to a pipe to supply biogas to nearby houses. The spent slurry is removed through another outlet and may be used as fertiliser.

Cattle dung is available in large quantities in rural areas where cattle are used for a variety of purposes. So biogas plants are more built in rural areas. The biogas thus produced is used for cooking and lighting. The technology of biogas production was developed in India mainly due to the efforts of Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC).

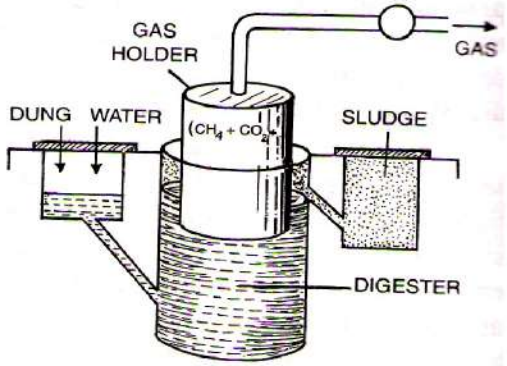


Figure: A typical biogas plant

Biogas (Gobar Gas):

Biogas is a methane rich fuel gas produced by anaerobic breakdown or digestion of biomass with the help of methanogenic bacteria. Biogas is made up of methane (50-70%), CO_2 (30-40%) with traces of nitrogen, hydrogen sulphide and hydrogen. The energy released from biogas depends upon the proportion of methane gas. The calorific value of biogas is 23 – 28 MJ/m^3.

******

1. Bacteria cannot be seen with the naked eyes, but these can be seen with the help of a microscope. If you have to carry a sample from your home to your biology laboratory to demonstrate the presence of microbes under a microscope, which sample would you carry and why?
2. Give examples to prove that microbes release gases during metabolism.
3. In which food would you find lactic acid bacteria? Mention some of their useful applications.
4. Name some traditional Indian foods made of wheat, rice and Bengal gram (or their products) which involve use of microbes.
5. In which way have microbes played a major role in controlling diseases caused by harmful bacteria?
6. Name any two species of fungus, which are used in the production of the antibiotics.
7. What is sewage? In which way can sewage be harmful to us?
8. What is the key difference between primary and secondary sewage treatment?
9. Do you think microbes can also be used as source of energy? If yes, how?
10. Microbes can be used to decrease the use of chemical fertilisers and pesticides. Explain how this can be accomplished.
11. Three water samples namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant were subjected to BOD test. The samples were labelled A, B and C; but the laboratory attendant did not note which was which. The BOD values of the three samples A, B and C were recorded as 20mg/L, 8mg/L and 400mg/L, respectively. Which sample of the water is most polluted? Can you assign the correct label to each assuming the river water is relatively clean?

1. Nitrogen fixer bacteria present in the root nodules of legumes is 1(CoHSEM,2011)
(A) *Mycobacter* (B) *Clostridium* (C) *Salmonella* (D) *Rhizobium*

Q. What is statin?

Ans:- Statin is a bioactive molecule procured from *Monoscus purpureus* that is used commercially as blood cholesterol lowering agent. This inhibits cholesterol synthesis.

Q. What is floc?

Q. What are baculoviruses?

Q. What is Biochemical Oxygen Demand?

Q. How do streptokinases act as 'clot buster'?

12. Why bio gas plants are more available in rural areas than urban areas? Give one point. 1(CoHSEM-2017)

25. What are Baculoviruses? Write down two uses of these viruses as Biocontrol agents? 3 (CoHSEM-2017)

REPRODUCTION IN ORGANISMS

LIFE SPAN: The period from birth to the natural death of an organism is called its life span.

The appropriate life span of some organisms is as follows:

Organisms	Maximum life-span		Organisms	Maximum life-span
1.Fruit fly	30 days		6. Dog	20 – 30 years
2. Butterfly	1 – 2 weeks		7. Crocodile	60 years
3. Rice plant	3 – 4 months		8. Tortoise	100 – 150 years
4. Crow	15 years		9. Elephant	60 – 90 years
5. Cow	20 – 25 years		10. Banyan tree	300 – 500 years

REPRODUCTION: It is a biological process in which an organism gives rise to young ones (offspring) similar to itself.

Functions of Reproduction:

1. Continuity of species: Reproduction maintains the continuity of the species indefinitely.
2. Replacement: It replaces individuals dying out due to senescence or ageing, predation and disease.
3. Population Organization: Reproduction maintains population organization of young, adult and the aged.
4. Life: Life can exist on the earth only if there is reproduction of living organisms.
5. Variation: Reproduction introduces variations in structure, function and behavior. They produce individuality of living organisms.

Q. Why do organisms reproduce? Give three points. ***3 marks.***

TYPES OF REPRODUCTION: Reproduction is of two types: *asexual* and *sexual*.

ASEXUAL REPRODUCTION: It is a mode of multiplication in which new individuals develop from a single parent without involving the production and fusion of sex cells. In Protists and Monerans, the organism or the parent cell divides into two to give rise to new individuals. Thus, in these organisms **cell division** is itself a mode of reproduction.

All divisions are mitotic. All the individuals formed through asexual reproduction from a parent are genetically similar to one another as well as their parent. They are *clone* of their parent as well as of one another. The term *ramets* is used for members of a clone.

Characteristics of Asexual Reproduction:

i) A single parent is involved (uniparental condition).
ii) Gametes are not formed.
iii) No fertilization.
iv) There is only mitotic cell division.
v) Daughter organisms are genetically identical to parent.
vi) Multiplication occurs rapidly.

Q.12. *Write two characteristic features of asexual reproduction.* ½ + ½ = 1 (CoHSEM,1997)

Types of Asexual Reproduction: Asexual reproduction takes place in the following ways:

A) FISSION: It is a mode of asexual reproduction in which body of a mature individual divides into two or more similar and equal sized daughters. It can occur by *binary fission, multiple fission and plasmotomy*.

1. Binary Fission: In this process of asexual reproduction, the parent organism divides into two halves, each half forming an independent daughter organism. It involves mitosis. The resultant offspring are genetically identical to the parent and to each other. Depending upon the plane of division, binary fission is of the following types.

i) Simple Binary Fission: It can occur through any plane, e.g. *Amoeba*.
ii) Longitudinal Binary Fission: The plane of division passes along the longitudinal axis of the animal. e.g. *Euglena, Vorticella*.
iii) Transverse Binary Fission: The plane of division runs along the transverse axis of the individual, e.g. *Paramecium, Planaria, diatoms* and *bacteria*.

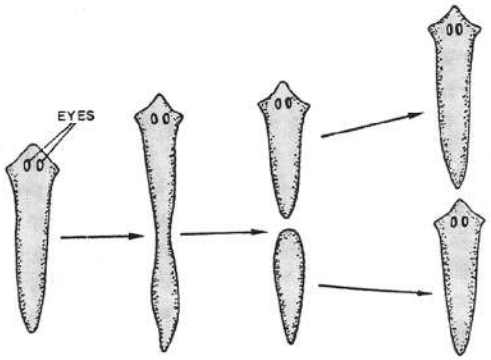


Fig: Transverse Binary Fission

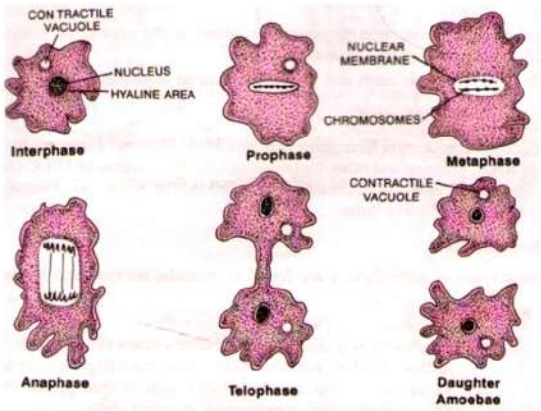


Fig: Irregular Binary Fission in *Amoeba*.

2. Multiple Fission: In this process the parent body divides into many daughter organisms. e.g. *Amoeba, Plasmodium, Monocystis*. Multiple fission in *Amoeba* occurs in unfavourable condition, i.e. in drought condition when water dries up in a pond.

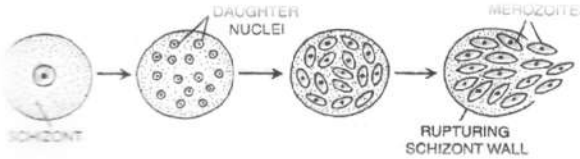


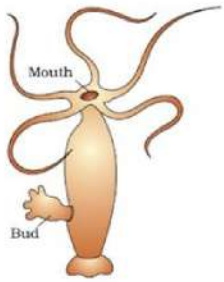
Fig: Multiple Fission

Binary Fission	Multiple Fission
1. It forms two daughter individuals.	1. It produces a number of daughter individuals.
2. The nucleus of the parent body divides only once.	2. The nucleus of the parent body divides repeatedly.
3. It occurs during favourable condition.	3. It can take place under favourable conditions (e.g. *Plasmodium*) as well as unfavourable conditions (e.g. *Amoeba*)
E.g. *Bacteria, Amoeba, Euglena, Paramecium, Planaria.*	E.g. *Amoeba, Plasmodium, Monocystis*.

3. Plasmotomy: It is a modification of multiple fission. Plasmotomy occurs in multinucleate or syncytial organisms. During reproductive phase, the cytoplasm cleaves with or without simultaneous division of nuclei. Nuclear division occurs later on to maintain normal number of nuclei. As a result, a number of daughters are formed each with one to a few nuclei. e.g. *Opalina, Pelomyxa*

B). BUDDING (TORULATION): In this, a daughter organism is formed from a small projection, the bud, arising from the parent body. It is of 2 types:

a) Exogenous/External Budding: In this type of budding, an outgrowth or bud grows externally on the surface of the body. The bud may split away from the parent and take up an independent existence. E.g. *Hydra, Sycon, Salpa, Yeast.*



Buds in *Hydra*


Gemmules in sponge

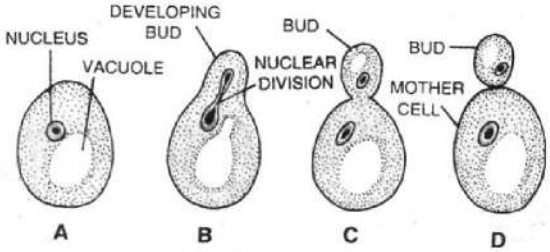


Fig : Budding in *Yeast*

b) Internal Budding (Endogenous): Specialized structures capable of forming new individuals develop inside the body of the parent. They are internal buds. Internal buds of sponges are called *gemmules*.

Binary Fission	Budding
1. The parent body divides into equal and similar halves, each half forms a new individual. 2. A protuberance is not formed. 3. Division is equal. 4. Parent's body disappears. e.g. *Bacteria, Amoeba, Euglena, Paramecium, Planaria.*	1. The parent produces a small bud that gradually grows in size and then separates from the parent body. 2. A protuberance (bud) is formed. 3. Division is unequal. 4. Parent's body remains intact. e.g. *Yeast, Sycon, Hydra.*

C) FRAGMENTATION: It is the breaking of an organism into two more parts. Each part grows to form a new individual. It is found in sponges, flatworm, algae (e.g. *Spirogyra*).
This method is also a form of regeneration.

REGENERATION: It is formation of the whole body of an organism from a small fragment (morpholaxis) or the replacement of the lost part (epimorphosis). The morpholaxis, is a type of asexual reproduction. (or, Regeneration is the capacity of some organisms by virtue of which if cut across into two, three, or more parts, each part regenerate into a complete and normal individual). It is found in *Amoeba*, Sponge, *Hydra, Planaria, etc.*

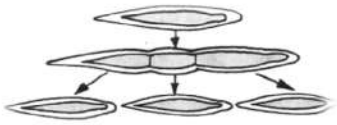


Fig: Fragmentation in Flatworm

Regeneration is of 2 types:

i) Epimorphosis: It is the regeneration of a part of an organism by proliferation on the missing surface.
ii) Morphollaxis: It is the regeneration of a part of organisms from a fragment by reorganization with cell proliferation.

- Axial gradient theory was put forwarded by M.C. Child. According to this theory, "metabolic activity is highest in the head and gradually decreases towards the tail end."

D) SPORULATION (SPORE FORMATION): It is the method of formation of small unicellular bodies called spores. Spores are minute, single celled, thin walled *propagules*. The spores after maturation detach from the parent and grow into new organisms when the conditions are favourable. Spores may be **zoospores, aplanospores, hypnospores,** etc.

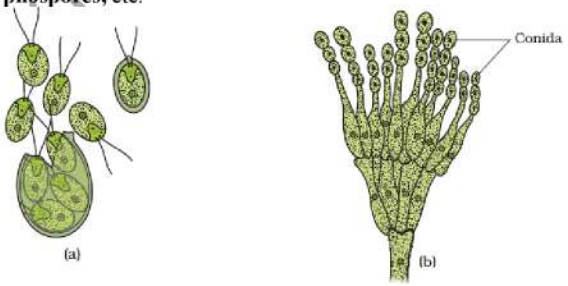


Diagram - (a) Zoospores of *chlamydomonas*; (b) Conidia of *Penicillium*

ZOOSPORES: These spores are special kind of motile and flagellated spores produced inside the *zoosporangia*. They are generally naked (without cell wall). The reproduction by zoospores occurs in some lower fungi phycomycetes (e.g. *Achlya, Saprolegnia, Albugo, Phytophthora, etc.*) and some algae (e.g. *Chlamydomonas, Ulothrix*).

Q.6. Mention a characteristic feature and a function of zoospores in some algae. 1 (CBSE-2010)

Ans:- Zoospores have flagella and help in movement, so motile.

ADVANTAGES OF ASEXUAL REPRODUCTION:

i) It is uniparental reproduction. Therefore, a mate is not required.
ii) It involves simple processes of division, amitosis and mitosis.
iii) It is rapid/quick mode of reproduction.
iv) A single parent may produce a large number of offspring.
v) The young ones are genetically similar to their parent.
vi) Consumption of resources is lower.

DISADVANTAGES OF ASEXUAL REPRODUCTION:

i) There is no mixing of genetic material, therefore, no variation takes place.
ii) Since variations do not occur asexual reproduction has no role in evolution.
iii) Adaptability to change in environment is low due to absence of new variations.
iv) Due to rapid multiplication, it causes overcrowding.

VEGETATIVE PROPAGATION: Vegetative propagation (vegetative reproduction) is the formation of new plants from (somatic parts) vegetative units such as roots, stem, leaf or bud. These vegetative units are called *vegetative propagules*. It is a method of asexual reproduction as it is uniparental in nature and does not involve formation of sex cells. It may be described under two main headings: Natural methods of vegetative propagation and artificial vegetative propagation.

Natural Methods of Vegetative Propagation: They are methods of plant multiplication occurring naturally in which a somatic part of the plant detaches from the body of the mother and develops into a new independent plant under suitable environmental conditions. It is done by following means:

1) Roots: Both tap roots and adventitious roots take part in vegetative propagation. Tap roots of some plants develop adventitious buds to form new plants, e.g. *Dalbergia sissoo* (Sheesham), Guava.

Fleshy roots (root tubers) which develop adventitious buds also take part in vegetative propagation, e.g. Sweet potato, Tapioca, *Dahlia, Asparagus*.

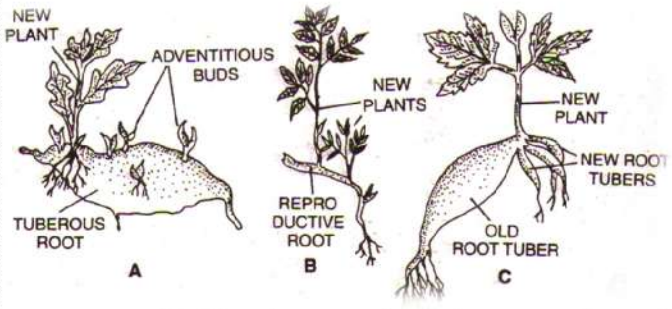


Fig: Vegetative propagation A- Sweet potato, B) root of *Dalbergia*, C) Old root tuber of *Dahlia*

2) Underground Stems: Different types of underground stem structures can take part in vegetative propagation.

i) Tubers: They possess buds over their nodes or eyes. The buds produce new plantlets when a stem tuber or a part of it having an eye is placed in the soil. e.g. Potato.

ii) Bulbs: Bulbs are underground condensed shoots which have one or more buds. When sown in soil, buds present inside the bulbs sprout to form new plants. e.g. Garlic, Onion.

iii) Corms: These are unbranched swollen underground stems having circular nodes that have buds for growth of daughter plants. e.g. *Colocasia, Amorphophallus* (Zamikand), *Crocus, Fressia*.

iv) Rhizomes: Rhizomes are main underground stems which store food for perennation during unfavourable conditions. These form buds for formation of new aerial shoots during favourable conditions. Rhizomes take part in propagation due to these buds. e.g. Banana, Ginger (*Zingiber officinale*), Turmeric, *Aspidium, Adiantum.*

v) Suckers: These are slender underground branches that develop from base of aerial shoot, grow for some distance and form new aerial shoots or crowns. Breaking of suckers forms new plants. e.g. Mint (*Mentha spicata*), *Chrysanthemum*.

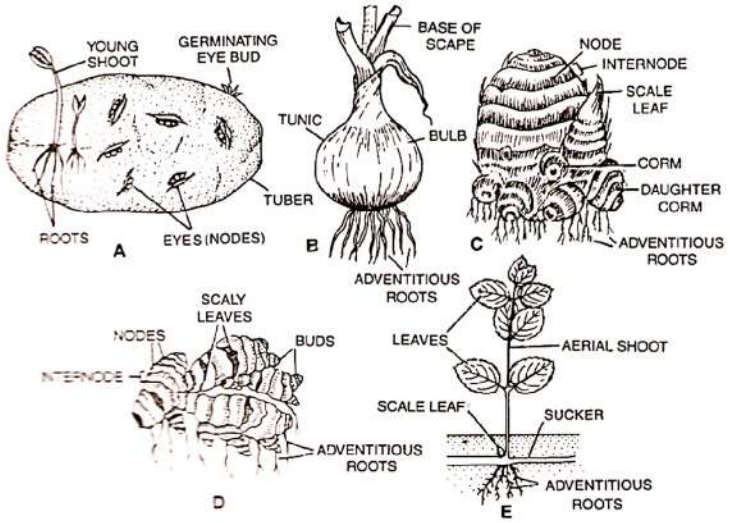
3) Subaerial or Creeping Stems: These are of three types which take part in vegetative propagation –

i) Runners: These are narrow, green, horizontal branches which develop at the base of crown and root at intervals where new crowns are also formed. Breaking of runners helps in vegetative propagation, e.g. Lawn Grass, *Centella*.

ii) Stolons: These are arched horizontal branches which develop at the base of crown and helps in vegetative propagation like runners. e.g. Strawberry, *Vallisneria*.

iii) Offsets: These are one internode long runners that occur in some aquatic plants. Breaking of offsets helps in propagation. e.g. *Eichhornia* (Water Hyacinth), *Pistia* (Water Lettuce).

4) Aerial Stems (Aerial Shoots): Fleshy phylloclades occur in *Opuntia* and some other plants. Each segment of such stems can form a new plant. Sugarcane is propagated by planting segments of stems having at least one node.

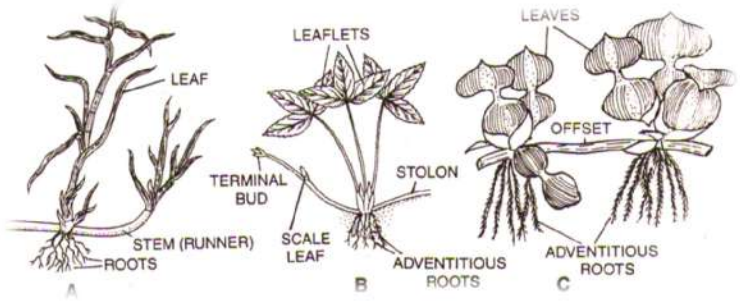


A- Young shoot arising from buds in the region of nodes in stem tuber of potato,
B- Tunicated bulb of Onion, C- Corm of *Colocasia,* Rhizome of Ginger, E- Sucker of Mint

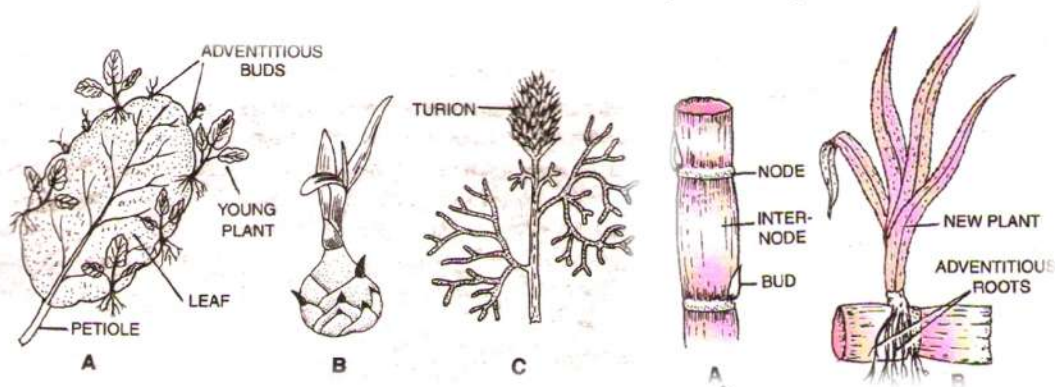
5) Leaves: Leaves of many plants have adventitious buds and help in vegetative propagation. e.g. *Begonia, Bryophyllum, Streptocarpus. Adiantum caudatum* is also called *Walking fern* because its leaf tips form new plants when they come in contact with soil.

6) Bulbils: These are multicellular fleshy buds that take part in vegetative propagation. e.g. *Agave,* Pineapple (*Ananas*), *Dioscorea* (Yam). In *Agave*, bulbils are modified floral buds that develop on the flowering axis. They remain attached to floral axis and germinate (Vivipary). Thus *Agave* (Century plant) shows vegetative reproduction from reproductive organ like floral buds.

7) Turions: A turion is a swollen bud, which contains much stored food. It is detached from the parent plant and remains inactive through the winter and gives rise to new plant in the following spring. Turions are found in a number of water plants (e.g. *Potamageton, Utricularia, etc*).



A- Runner of Grass, B- Stolon of Wild strawberry, Offset of Hyacinth.



A- Leaf buds in *Bryophyllum,* B- Bulbil in *Agave, C- Utricularia showing* turion.

Fig: A- portion of Sugarcane stem having buds, B- a bud growing into new plant.

HORTICULTURAL OR ARTIFICIAL METHODS OF VEGETATIVE PROPAGATION:

These are manmade special techniques in which part of somatic body of a plant is made to develop into new independent plant. The various methods are as follows-

1. Cutting: Cuttings are pieces of root, stem and leaves which are planted in nurseries. For this, root promoting chemicals are used, e.g. IBA (Indole –butyric acid), NAA (Naphthaline acetic acid).

i) Root Cuttings: These are long pieces of roots which are used to artificially propagate new plants. Root cuttings are used in propagation of Lemon, Orange, Blackberry, Raspberry, Boysenberry, etc.

ii) Stem Cuttings: 20 – 30 cm long pieces of one year old stems (including nodes) are cut. Their lower ends are dipped in root promoting hormones for several minutes before planting in the soil. The lower ends develop adventitious roots. e.g. Sugarcane, Rose, *Citrus,* Grape, China rose *(Hibiscus rosa sinensis)*, etc.

iii) Leaf Cuttings: Snake plant *(Sansevieria*) can be propagated by leaf cuttings. Leaves are cut transversely into two or three parts and planted in vertical positions in the soil. e.g. *Sanservieria* (Snake plant), *Begonia, Bryophyllum.*

Q. Why do internodal segments of Sugarcane fail to propagate vegetatively even when they are in contact with damp soil?

Ans:- A growing point or bud is required for vegetative propagation which is absent in internodal segment.

2. (A) Layering (Soil Layering): Layering is carried out on one year old basal shoot branches commonly during early spring or early rainy season. A soft basal branch is defoliated in the middle where a small injury or cut is also given – tongueing (oblique cut), notching (V-shaped cut), ringing (removal of a bark). The injured part is pegged in the soil to develop adventitious roots. The pegged down branch of the plant is called layer.

2. B) Mound (Stool) Layering: The shoot is pruned and lower part is covered by the soil, when a number of new shoots develop. Soil and saw dust pare poured over the base to form a mound. Each shoot develops roots. Rooted shoots are separated and planted. e.g. Apple, Pear, Gooseberry, Jasmine, Raspberry, Cherry, etc.

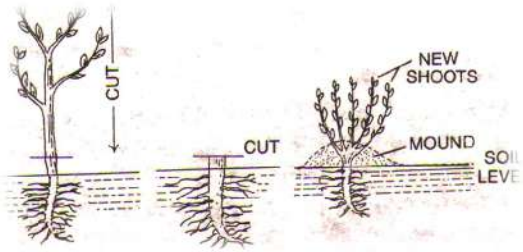


Fig: Stages in Mound Layering

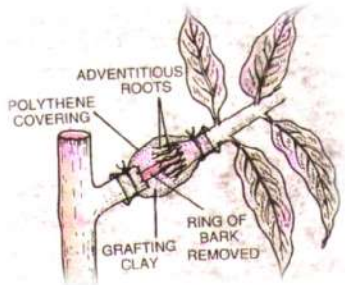


Fig: Gootee (Air Layering)

2. C) Gootee or Air Layering: During early monsoon rains, 3 – 5 cm long ring of bark is removed from basal region of a healthy and woody branch. It is covered by a thick plaster of grafting clay. Grafting clay is composed of 1 part cowdung, 1 part finely cut hay or moss and two parts clay. To it water is added along with a small quantity of root promoting hormones like IAA, IBA or NAA. It is then wrapped in polythene. After 2 – 3 months, roots appear. The shoot is now cut below the bandage and used for planting. E.g. Litchi, Pomegranate, China Rose, Guava, Orange, Lemon.

2. D) Simple Layering: In this layering, soft basal partly injured branch is pegged at one place, e.g. Cherry, Jasmine, Grape vine.

2. E) Serpentine Layering: Branch is pegged at several places so as to form many plants. e.g. *Clematis.*

2. D) Trench Layering: The branch is pegged in a horizontal position in a trench. It develops a number of vertical shoots, e.g. Walnut, Mulberry.

2. F) Drop Layering: A plant capable of forming several branches (e.g. Dwarf *Rhododendron*) is grown in a deep soil. Adventitious roots develop at the base of branch shoots. They are separated and planted.

2. G) Tip Layering: A shoot is bent in the soil in such a way that basal end is slanting while the upper region is upright. Soil is pressed. It induces root formation and later growth of shoot tip, e.g. Blackberry, Dewberry, Raspberry.

3. Grafting: Grafting is a technique of connecting two parts, usually a root system and a shoot system of two different plants in such a way that they unite and later develop as a composite plant. It is used only in cambium containing woody eustelic plants. A small shoot of plant with superior character is employed. It is called *graft* or *scion*. The root system of the other plant is allowed to remain intact. It is called *stock*. Grafting is practiced in Mango, Apple, Pear, *Citrus,* Guava, Rubber plant, Plum, Peach, etc. the various techniques of grafting are as follows:

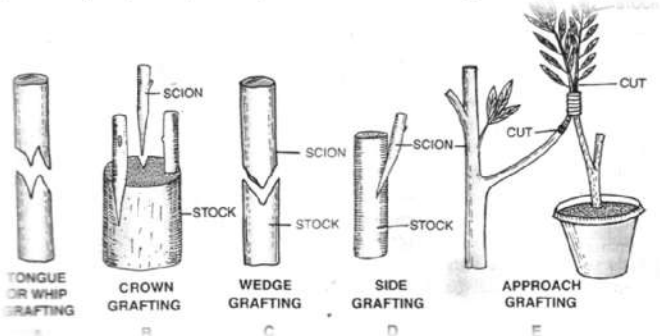


Fig: A- Tongue or Whip grafting; B- Crown Grafting; D- side Grafting; E- Approach Grafting.

i) Tongue Grafting: Oblique sloping cut or notch is given to both stock and scion. The two perfectly fit upon one another. They are tied together. Stock and scion are of same diameter.

ii) Crown Grafting: Many scion are selected and shaped at the base to form wedge. Many slits are formed on the sides of stock. Scions are inserted in the slits and bandaged. Stock has large diameter than scion.

iv) Wedge Grafting: V-shaped notch is given to stock while wedge like cut is given to scion. Both are also of same diameter.

v) Side Grafting: V-shaped notch is given to stock at one side. One end of scion is sharpened. It is inserted in the stock. Stock also has larger diameter than scion.

vi) Approach Grafting: Two independently growing plants are brought together. The shoots of the two are given cuts at the same level for a distance of 2.5 – 5.0 cm. The cuts are in the form of removing smooth slices of bark (spliced approach grafting), tongue shaped cuts for interlocking and deeper vertical cuts if the stock is thicker than the scion.

Q. If a branch of 'dasheri mango' is grafted on a tree producing 'deshi mangoes', what type of mangoes will be borne on grafted branch and other branches of the plant?

4. Bud Grafting: Scion is a bud with small piece of bark and cambium. Bark is lifted to expose cambium. Bud is inserted and the bark is allowed to come back to its original position. The joint is treated with grafting wax and bandaged. Bud develops after 3 – 5 weeks.. Bud grafting is practiced in Apple, Peach and Rose.

5. Micropropagation (Propagation by Plant Tissue Culture): This method includes propagation of plants by culturing the cells, tissues and organs which is called *tissue culture*.

Advantages of Vegetative Propagation:

i) It is the only method of multiplication in seedless plants, e.g. Sugarcane, Banana, seedless Grape, seedless orange, etc.

ii) Plants with reduced power of sexual power reproduction are commonly multiplied vegetatively, e.g. *Cynodon dactylon* (Lawn grass).

iii) Plants with long seed dormancy or poor seed viability are multiplied easily through this method.

iv) It is a quicker method of multiplication requiring far less time than the one taken through sexual reproduction. Potato crop requires more than one year with the help of seeds, however, it takes only 3 to 4 months with the help of tubers.

v) Grafting helps in combining good traits of two or more varieties into a single composite plant.

vi) Flowers of scion are much superior in quality.

vii) Superior varieties with poor root system can be propagated through grafting.

Q.14. "Nowadays gardeners have employed the various methods of vegetative propagation". Justify the statement by giving one reason.

1 (CoHSEM-2011)

Disadvantages of Vegetative Propagation:

1. Vegetative propagules cannot be stored for long.
2. Vegetative propagules are prone to infections, desiccation and decay as they are not protected and dehydrated like seeds.
3. Variability and adaptability are absent.
4. A disease present in the parent plant spreads to all the daughters.
5. There is no mechanism to introduce good traits or eliminate bad traits.
6. There is no dispersal of vegetative propagules. Therefore, it causes over-crowding.

Q.29. Give four points each of –a) advantages and b) disadvantages of vegetative propagation in plants. Name two of the artificial means of vegetative propagation in plants. 4+2=6 (CoHSEM-2002)

SEXUAL REPRODUCTION: It is the process of development of new individuals through the formation and fusion of male and female gametes. It is also called *amphimixis* or *syngenesis* or *amphigony*.

Sexual reproduction involves four processes:

1. Formation of gametes (haploid cells) by gametogenesis.
2. Fusion of the two gametes forming diploid cells, the zygotes (fertilization).
3. Repeated mitotic divisions of the zygotes to form embryos (embryogenesis) and
4. Growth of embryos into new individuals (development).

Characteristics of Sexual Reproduction:

1. It is usually biparental.
2. Gametes are always formed.
3. Fertilization takes place.
4. It involves both meiosis and mitosis.
5. Daughter organisms genetically differ from the parents.
6. Multiplication is not so rapid as in asexual reproduction.

Advantages of Sexual Reproduction: (***Why is sexual reproduction better than asexual reproduction?***)

1. Variations: Since fusion of gametes from different parents occur during sexual reproduction, hence genetic recombination takes place causing variations.
2. Evolution: Variation being a major factor of natural selection, therefore, it plays an important role in evolution.
3. Adaptation: The offspring produced due to sexual reproduction adapt better to the changing environment conditions.

4. Vigour and Vitality: Genetic recombination, interaction, etc. during sexual reproduction provide vigour and vitality to the offspring.
5. Uniformity of Population: There is flow of genes amongst individuals of a population during sexual reproduction. New mutations or variations do not remain restricted to a few individuals. They ultimately pass into the whole population through sexual reproduction.

Disadvantages of Sexual Reproduction:

1. Sexual reproduction is commonly biparental.
2. It is a slow process and requires a lot of time.
3. Fertilization has a chance factor.
4. A large number of young ones die due to poor genetic makeup in face of high level of competition.

Asexual Reproduction	Sexual Reproduction
1. It is uniparental.	1. It is generally biparental but can be uniparental.
2. Sex organs do not form.	2. Sex organs differentiate during this type of reproduction.
3. It does not involve formation and fusion of gametes.	3. There is formation and fusion of gametes.
4. It does not introduce variability.	4. It introduces variability.
5. It involves only mitosis.	5. It involves both meiosis and mitosis.
6. It produces a large number of daughters.	6. Comparatively fewer offspring are formed.
7. Adaptability and evolutionary significance are absent.	7. It is important both for adaptability and evolution.

Q.16. Give four differences between the asexual and sexual reproduction. 2 (CoHSEM,1998)

Q.8. What is the major difference you observe in the offspring produced by asexual reproduction and in the progeny produced by sexual reproduction? 1 (CBSE-2010)

PHASES IN LIFE CYCLE: Life cycle of an individual is divisible into 3 phases – juvenile, reproductive and senescent.

1. Juvenile phase: It is pre-reproductive period in the life cycle of an individual. The period is characterized by rapid growth. All the resources are used up in growth and development of the body. The juvenile phase is called vegetative phase in plants. the duration of juvenile phase varies from organism to organism.

2. Reproductive Phase: It is the phase of life cycle wherein individuals have the potential to reproduce. The early period of reproductive phase is called puberty. Sex organs develop and mature during puberty. Growth is slowed down. In higher plants, appearance of flowers is indication of sexual maturity. Sexually, there are two types of flowering, monocarpic and polycarpic.

Monocarpic plants	Polycarpic plants
1. These plants flower only once in their life.	1. These plants flower every year in particular season.
2. The plants are generally annual or biennial.	2. These plants are perennial.
3. They die after flowering and fruiting.	3. They do not die after flowering and fruiting.
e.g. Rice, Wheat, Radish, Carrot, Bamboo, etc.	e.g. Apple, Mango, Orange, etc.

In females of placental mammals, there are cyclic changes in ovaries, accessory reproductive ducts and hormones during the reproductive phase. These are of two types.

Menstrual Cycle	Oestrous Cycle
1. It occurs in primates (monkeys, apes and human beings) only.	1. It occurs in nonprimates such as cows, dogs, etc.
2. It consists of menstrual phase, proliferative phase and secretory phase.	2. It consists of short period of oestrous or heat (e.g. 12 – 24 hours in cow) followed by anoestrous or passive period.
3. Blood flows in the last few days of this cycle.	3. Blood does not flow in this cycle.
4. The broken endometrium is passed out during menstruation.	4. The broken endometrium is reabsorbed.
5. Sex urge is not increased during menstruation.	5. Sex urge is increased during oestrous period.
6. Female does not permit copulation during menstrual phase of the cycle.	6. Female permits copulation only during oestrous period.

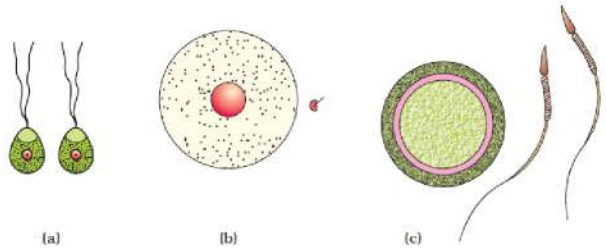
3. Senescent Phase: It begins from the end of the reproductive phase. The terminal irreversible stage of ageing is called senescence. This is the last phase of life span, senescence ultimately leads to death.

EVENTS OF SEXUAL REPRODUCTION:

These events of sexual reproduction are grouped into three stages: *pre-fertilization, fertilization* and *post-fertilization* events.

1. Pre-fertilization Events: These include
a) Gametogenesis (formation of gametes), and
b) Transfer of gametes.

a) Gametogenesis: **Gametogenesis** refers to the process of formation of the two types of gametes – male and female. Gametes are haploid cells. In some algae the two gametes are so similar in appearance that it is not possible to categorise them into male and female gametes.



Types of gametes: (a) Isogametes of *Cladophora* (an alga); Heterogametes (b) *Fucus* (an alga); (c) Human beings

---

They are hence, are called **homogametes** (**isogametes**). However, in a majority of sexually reproducing organisms the gametes produced are of two morphologically distinct types (**heterogametes).** In such organisms the male gamete is called the **antherozoid** or **sperm** and the female gamete is called the **egg** or **ovum**.

b) Gamete Transfer: After their formation, male and female gametes must be physically brought together to facilitate fusion (fertilisation). In a majority of organisms, male gamete is motile and the female gamete is stationary. Exceptions are a few fungi and algae in which both types of gametes are motile. There is a need for a medium through which the male gametes move. In several simple plants like algae, bryophytes and pteridophytes, water is the medium through which this gamete transfer takes place. A large number of the male gametes, however, fail to reach the female gametes. To compensate this loss of male gametes during transport, the number of male gametes produced is several thousand times the number of female gametes produced.

In seed plants, pollen grains are the carriers of male gametes and ovules have the egg. Pollen grains produced in anthers therefore, have to be transferred to the stigma before it can lead to fertilisation. **Pollination** facilitates transfer of pollen grains to the stigma.

2. FERTILIZATION: The fusion of two compatible male and female gametes to form a diploid zygote is called fertilization. It is also called *syngamy*. Depending upon the place of fertilization, fertilization is of two types – External and internal:

External Fertilization	Internal Fertilization
1. It is fertilization that occurs outside the body of the female. 2. A large number of gametes are released in the surrounding medium (e.g. water) where fertilization takes place. e.g. Bony fish, Amphibians (e.g. Frogs) , most of Algae, etc.	1. It is fertilization that occurs inside the body of the female. 2. The number of gametes produced is less. The male gametes are deposited in the body of the female with the help of copulatory organ. e.g. Reptiles, Birds, Mammals, Bryophytes and Trachophytes (Pteridophytes, Gymnosperms, Angiosperms), etc.

Q.7. Mention the site where syngamy occurs in amphibians and reptiles respectively. ***1 (CBSE-2010)***

3. POST FERTILIZATION EVENTS: Events in sexual reproduction after the fertilization (formation of zygote) are called post fertilization events. These events may be described under two headings: zygote and embryogenesis.

Zygote*:* Formation of the diploid zygote is universal in all sexually reproducing organisms. In organisms with external fertilisation, zygote is formed in the external medium (usually water), whereas in those exhibiting internal fertilisation, zygote is formed inside the body of the organism.

Embryogenesis: **It** refers to the process of development of **embryo** from the zygote. During embryogenesis, zygote undergoes **cell division** (mitosis) and **cell differentiation**. While cell divisions increase the number of cells in the developing embryo; cell differentiation helps groups of cells to undergo certain modifications to form specialised tissues and organs to form an organism.

Animals are categorised into **oviparous** and **viviparous** based on whether the development of the zygote take place outside the body of the female parent or inside, i.e., whether they lay fertilised/unfertilised eggs or give birth to young ones. In oviparous animals like reptiles and birds, the fertilised eggs covered by hard **calcareous shell** are laid in a safe place in the **environment;** after a period of incubation young ones hatch out. On the other hand, in viviparous animals (majority of mammals including human beings), the zygote develops into a young one inside the body of the female organism. After attaining a certain stage of growth, the young ones are delivered out of the body of the female organism. Because of proper embryonic care and protection, the chance of survival of young ones is greater in viviparous organisms.

Oviparous	Viviparous
1. Oviparous animals lay eggs. 2. Yolk of the egg supplies food for the developing embryo. 3. Complete development of embryo takes place within the egg.	1. Viviparous organisms give birth to young ones. 2. Developing embryo receives nourishment from the mother's blood through placenta. 3. Development of embryo takes place within the uterus of female parent.

In flowering plants, the zygote is formed inside the ovule. After fertilisation the sepals, petals and stamens of the flower wither and fall off. The pistil however, remains attached to the plant. The zygote develops into the embryo and the ovules develop into the seed. The **ovary** develops into the **fruit** which develops a thick wall called **pericarp** that is protective in function. After dispersal, seeds germinate under favourable conditions to produce new plants.

PARTHENOGENESIS: (out of syllabus)

Development of an egg (ovum) into a complete individual without fertilization is known as parthenogenesis.

Parthenogenesis is of two types: natural and artificial.

1. Natural Parthenogenesis: It occurs regularly in the life cycle of certain animals. It may be complete, incomplete or paedogenetic.

a) Complete (obligatory) Parthenogenosis: It occurs in those animals which breed exclusively by parthenogenesis. There are no males, and therefore, such individuals are represented by females only.

e.g. *Lacerta saxicola armaniaca* (Caucassian Rock Lizard) – lizard from Armania (name of a country).

Typhlina brahmina perhaps the smallest snake of India (15.2 cm), *Cnemidophorus* species (Whiptail lizards of America)

b) Incomplete (Cyclic) Parthenogenesis: It is found in those animals in which both sexual reproduction and partheneogenesis occur.

Examples: i) In honey bees, fertilized eggs (zygotes) give rise to queens and workers (both are females) and unfertilized eggs (ova) develop into drones (males).

ii) Some species of wasps produce alternately a parthenogenetic generation and one which develops from fertilized eggs.

c) Paedogenetic Parthenogenesis (Paedogenesis): When larva produces a new generation of larva by parthenogenesis, it is called paedogenesis. e.g. It is found in life cycle of the Liver fluke.

Based on the sex of offspring, there are following three types of parthenogenesis:

i) Arrhenotoky: (*Gk. arren* – male, *tekos – birth*)

In this type of parthenogenesis, only males are produced by parthenogenesis. It occurs in rotifers, bees (honey bees), wasps, ticks, mites and certain spiders.

ii) Thelytoky: (Gk. *thelys* – female)

In this type of parthenogensis, only females are produced by parthenogenesis. It occurs in *Solenobia* of Lepidoptera, *Lacerta saxicola armaniaca*, *Typhlina brahmina, etc.*

iii) Amphitoky: In this type of parthenogenesis, parthenogenetic egg may develop into individual of any sex (i.e. male or female). It occurs in *Aphis* (Aphid).

Q. In Whiptail lizards only females are born generation after generation. There are no males. How is this possible?

Ans:- In Whiptail lizards (*Cnemidophorus* species), the young ones develop parthenogenetically from egg.

2. Artificial Parthenogenesis:

In this type of parthenogenesis, the egg (ovum) is induced to develop into a complete individual by artificial stimuli. Artificial parthenogenesis may be induced by physical as well as chemical stimuli.

i) Physical Stimuli: These include changes in temperature and pH, electric shock, ultra-violet light, and mechanical stimulus (e.g. prick by a needle).

ii) Chemical Stimuli: These include changes in the salt concentration of the surrounding water, application of chloroform, ether, alcohol, urea, fatty acids, etc.

e.g. Eggs (ova) of annelids, molluscs, echinoderms (sea urchin, star fish), frogs, salamanders, birds (turkeys, hen) and even mammals (rabbit) may be induced by physical or chemical stimuli to develop parthenogenetically into complete individuals.

Parthenocarpy	Parthenogenesis
1. It is the production and development of seedless fruits without pollination and fertilization. 2. Parthenocarpic fruits are normal. 3. It occurs in plants only. 4. It has no role in reproduction. e.g. Apple, Tomato, Papaya, Banana, etc.	1. It is the development of unfertilized egg into a complete individual without fertilization. 2. Young ones produced by parthenogenesis are generally weak. 3. It occurs in both plants and animals. 4. It takes part in reproduction. e.g. Plants such as *Solanum nigrum, Nicotiana, Datura* and animals like *Drones, Lacerta saxicola armaniaca, etc.*

Embryogenesis	Blastogenesis
1. The process of development of embryo from a diploid zygote is known as embryogenesis. 2. The offsprings are quite different from the parents in their genetic makeup. 3. The involvement of both the parents is required.	1. Development of offspring from the reproductive units like buds (bulbil) or fragments in asexual reproduction is called blastogenesis. 2. The offsprings are genetically similar to their parents. 3. A single parent can give rise to a number of offsprings.

Monoecious	Dioecious
1. Organisms bear both male and female reproductive structures. 2. Single organisms may give rise to a new generation. 3. Both male and female gametes are produced by the single organisms.	1. Organisms bear either male reproductive structures or female reproductive structures, i.e. sexes are separate. 2. Both sexes play a significant role in giving rise to a new generation. 3. Male and female gametes are produced separately by the male and female parents.

1. Cut-pieces of *Bryophyllum* leaf when put into wet soil produce new plants. How? 1(CBSE-2011)

1. A monocarpic plant 1(COHSEM,2013)

(A) flowers twice in every year
(B) bears only one type of flower
(C) flower once in every year
(D) dies after flowering once in its life cycle.

1. Why is reproduction essential for organisms?
2. Which is a better mode of reproduction sexual or asexual? Why?
3. Why is the offspring formed by asexual reproduction referred to as clone?
4. Offspring formed due to sexual reproduction have better chances of survival. Why? Is this statement always true?
5. How does the progeny formed from asexual reproduction differ from those formed by sexual reproduction?
6. Distinguish between asexual and sexual reproduction. Why is vegetative reproduction also considered as a type of asexual reproduction?
7. What is vegetative propagation? Give two suitable examples.
8. Define
(a) Juvenile phase, (b) Reproductive phase, (c) Senescent phase.
9. Higher organisms have resorted to sexual reproduction in spite of its complexity. Why?
10. Explain why meiosis and gametogenesis are always interlinked?
12. Define external fertilisation. Mention its disadvantages.
13. Differentiate between a zoospore and a zygote.
14. Differentiate between gametogenesis from embryogenesis.
15. Describe the post-fertilisation changes in a flower.
16. What is a bisexual flower?
17. Why are offspring of oviparous animals at a greater risk as compared to offspring of viviparous animals?

*****