CPA COLLEGE OF GLOBAL STUDIES, PUTHANATHANI
5th SEMESTER BOTANY CORE COURSE
GYMNOSPERMS, PALAEOBOTANY, PHYTOGEOGRAPHY AND EVOLUTION

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Syllabus

GYMNOSPERMS

1. Introduction, General characters and classification of Gymnosperms (Sporne, 1965)
2. Distribution, morphology, anatomy, reproduction, life cycle and affinities of the following types (Developmental details not required): *Cycas, Pinus* and *Gnetum*
3. Evolutionary trends in Gymnosperms; Affinities of Gymnosperms with Pteridophytes and Angiosperms
4. Economic importance of Gymnosperms.

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Gymnosperm

Introduction

The word Gymnosperm,*"Gymnos"=neckedand*"*Sperma"meansseeds* was first used by Theophrastus, a pupil of Aristotle in his famous book *"Enquiryinto Plants*". He used this term in all those plants having unprotected (withoutcovering) seeds. On the basis of their seeds with or without covering are grouped into two major categories namely Angiosperms and Gymnosperms. Thus the plants or Spermatophyta is divided into two subgroups Angiosperms and Gymnosperms. The ovules of gymnosperms have freely exposed before and after fertilization while in case of angiosperms where *(Angios=Vessels and Sperma =Seeds*) the ovules are enclosed within the carpel. Thus due to this, the angiosperms are considered as the most advanced type of organisms in plant kingdom.

Diversity and Origin

- There are between 700 and 900 extant* or currently living species of Gymnosperms.
- It is widely accepted that the gymnosperms originated in the late Carboniferous Period. Early characteristics of seed plants were evident in fossil progymnosperms of the late Devonian period around 380 million years ago.

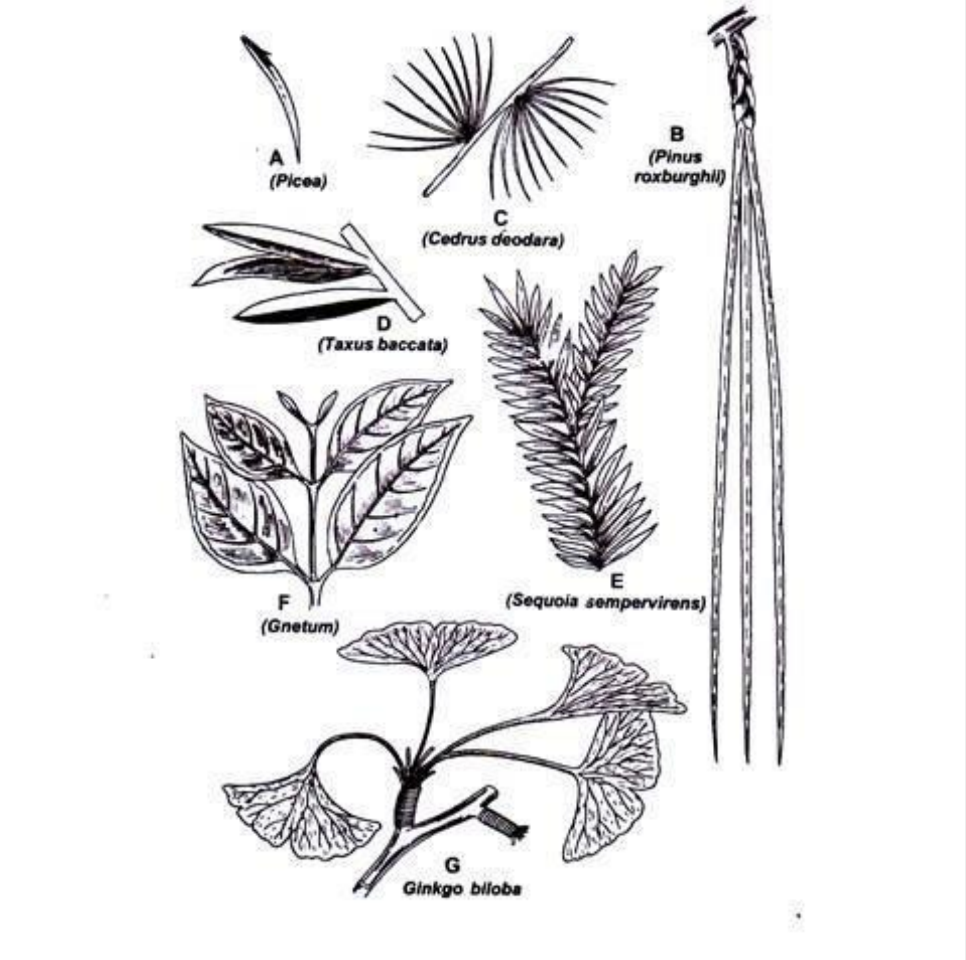
General characters of Gymnosperms

- Most of the gymnosperms are trees
- All Gymnosperms have exposed seeds
- Some are evergreen, i.e. pine
- They are slow growers and lacks vegetative means of reproduction such as by cuttings, layering etc.
- They are unable to grow under varied habitats means they are able to grow on some specific habitats and conditions.
- They have limited means of dispersal of seeds and can be dispersed only by wind, animals or by human beings.
- Most of the gymnosperms are terrestrial or land loving and unable to grow in aquatic habitats except a few.
- They lack vessels in xylem (with few exceptions) and companion cells in phloem.
- Most of the gymnosperms are unisexual, thus due to absence of bisexuality, chances of self-pollination reduces.
- As wind is the main source of pollination hence maximum amount of pollen grains are wasted.

Morphology of vegetative organs

- The living gymnosperms including, tall trees, shrubs and climbers includes approximately 70 genera and 725 species.
- There are complete absence of herbs and climbers. Vegetative propagation is not reported in this group but only bulbils are known in some ***Cycas*** as means of vegetative propagation. Generally they possess tap root but sometimes mycorrhizal and corolloid roots (*Pinus* and *Cycas* respectively) are present in some genera.
- **Stem:** The stem may be aerial, erect, unbranched (e.g. *Cycas, Zamia*) or aerial, erect branched (e.g. *Pinus*, *Cedrus* etc.). In gymnosperms the branches may be of two types on the basis of their branching system.
- They may be either- two types as in *Pinus*- i) the long shoots and ii) the dwarf shoots at their apices and collectively known as spurs.
- **Leaf:** Gymnosperms bears both microphyllous and megaphyllous leaves. The microphyllous leaves are large and well- developed and their vascular supply always leaves a leaf- gap in the stem stele is another characteristic feature of gymnosperms. The leaves may be simple or compound and vary in shape, size and form, as a minute scale leaf to several feet long megaphylls (e.g. in *Cycas*). Gymnosperms show great diversity in leaf venation, it may be parallel (*Welwitschia*), reticulate *(Gnetum*) or even dichotomous (*Ginkgo*). The leaves are always evergreen and mostly possess resin canals as in *Pinus*, *Cedrus* and *Abies*. The leaves of Gnetales lack resin passages but *Gnetum* possess latex tubes.
- **Leaf Arrangements:** The arrangement of leaves may be whorled (*Cedrus*), opposite or decussate ***(****Gnetum*, *Ephedra* ***e****tc.*) or spirally arranged ***(****Taxus*, *Podocarpus* etc.). Conifers usually have sunken stomata. The shape of leaves may also vary from triangular *(Pinus roxburghii***)**, semi-circular (Pinus sylvestris), bifid or circular ***(****Pinus microphylla*), and bifacial leaflet of *Cycas*, *Zamia*, and *Gnetum* leaves). Likewise leaves the system and arrangement of vascular bundles also shows great variations in gymnosperms. In a young stem the ring of discrete vascular bundles. The leaf base remains permanently merismatic while the tip drying off.
- Due to secondary growth gymnosperms possess primary and secondary wood. The secondary wood is the characteristic feature of cycadophyta. The wood is porous, soft and more parenchymatous in nature, while pycnoxylic wood is the characteristic feature

of coniferophyta; the wood is compact and narrow medullary rays, xylem lacks wood vessels except in *Ephedra*, *Gnetum* etc. The xylem is usually endarch or mesarch in stem while it may be exarch in roots. The vascular bundles are conjoint, collateral, endarch and open in gymnosperms.



Distribution

- Certain groups of gymnosperms are entirely extinct, while others are present in living as well as in fossil forms with primitive features. Still there are some groups chiefly within living gymnosperms that extend throughout the temperate, tropical and even in arctic zones. Most of the gymnosperms are evergreen xerophytes. The total number of living gymnosperms in the world is approximately number seventy genera and 725 species. A total of 16 genera and 53 species were reported from India (M. B. Raizada and K. C. Sahni, 1960).
- Maheshwari listed only 14 genera. This lesser number of representatives is mainly due to their habitat as gymnosperms are mainly dwellers of temperate regions in India and such climate was afforded only by the Himalayas, They form extensive forests and

grow luxuriantly in the various Himalayan ranges that is why most of the gymnosperms are distributed in eastern and western Himalayas besides in some other regions of India.

- There are six living orders of gymnosperms and out of them four are represented in India. These include- Cycadales, Coniferales, Ephedrales and Gnetales. The Cycadales are represented by 4 species of *Cycas* in India. Gymnosperms are very poorly represented in the Indian flora. In the vast peninsular India they are represented by a few species of *Cycas, Podocarpus,* and *Gnetum.* However, in the extra peninsular Himalayas and in some extent in the connected ranges of Kashmir, Assam, and Arunachal Pradesh gymnosperms represented only by conifers and covering extensive tract of forest land.
- Among gymnosperms, different groups of this category i.e. Cycads, Conifers, Ginkgoales, and Gnetales the most frequently and densely populated group is the Coniferales. This group as we know is represented by *Pinus, Cedrus, Abies, Larix, Picea, Cupressus, Tsuga, Juniperous, Taxus, Araucaria, Thuja, Podocarpus, Cephalotaxus* are common. Conifers are found predominantly in the Himalayas and are particularly rich in the north-west Himalayas (Uttarakhand, Kashmir, Himachal Pradesh etc.). Their distribution is generally governed by altitude and generally ranges from 1800- 3300 meters asl. While some species of *Pinus* (P. *insularis* 700- 1,850 m asl and *P. merkusii* (150- 600 m asl.) are reported from Khasya region of Assam and on the hillocks in East Bengal respectively). Among Cycads only Cycas occurs in India and the genus is represented by four species *viz. C. circinalis, c. beddomei, C. pectinata* and *C. rumphii*, beside this another species *C. revolute*, which is a native of Japan is commonly cultivated in Indian gardens. Species *of Zamia, Macrozamia, Encephalortos* and *Stangeria* are exotics and occasionally cultivated in Indian gardens. Similarly a few plants *of Ginkgo biloba*, a native of China, occur in Indian under cultivation in gardens. Gnetales are represented in India by a number of species of *Ephedra* and *Gnetum*. Out of seven species of *Ephedra* only one *(E. foliate*) occurs in the plains of Rajasthan and Punjab while rest six are confined to the north- west Himalayan regions.

<u>Classification</u>

- The group Gymnosperms is a very large class which includes both living and fossil forms. Due to ample records of fossil forms the classification has become somewhat complicated. Several workers have classified Gymnosperms differently from time to time. K. R. Sporne in 1965 classified Gymnosperms in his book namely "***The Morphology of Gymnosperms"*** based on Pilger and Melchior (1954) classification.

- Gymnosperms- divided into three divisions

1.Cycadopsida 2. Coniferopsida and 3. Gnetopsida

1. Division Cycadopsida-

Order 1. Pteridospermales- Families-(7)-1. Lyginopteridaceae-(Lyginopteris)

2- Medulosaceae (Medulosa)

3- Calamopteridaceae (Calamopitys)

4- Glossopteridaceae (Glossopteris)

5- Peltospermaceae (Xylopteris)

6- Corystospermaceae (Xylopteris)

7-Caytoniaceae (Caytonia)

Order 2. Bennettitales - Families (3) 1- Williamsoniaceae (Williamsonia)

2. Wielandiellaceae (Wielandiella)

3. Cycadeoideaceae (Cycadeidea)

Order 3. Pentoxylaes -Family(1) 1. Pentoxylaceae (Pentoxylon), Sahnia)

Order 4. Cycadales-Family(2) 1. Cycadaceae (Cycas, Zamia etc.)

2. Nilssoniaceae (Nilssonia)

2. Division Coniferopsida

Order 1. Cordaitales –Families (3) 1. Ertophytaceae (Eristophyton)

2. Cordaitaceae (Cordaites)

3. Poroxylaceae (Poroxylon)

Order 2. Coniferales –Families (9) 1. Lebachiaceae (Lebachia)

2. Votziaceae (Voltziopsis)

3. Palissyaceae (Palissya)

4. Pinaceae (Pinus, Abies, Picea)

5. Taxodiaceae (Taxodium)

6. Cupressaceae (Cupressus)

7. Podocarpaceae (Podocarpus)

8. Cephalotaxaceae (Cephalotaxus)

9. Araucariaceae (Araucaria, Agathis)

Order 3. Taxales- Family (1) Taxaceae (Taxus, Torreya)

Order 4. Ginkgoales.-Families (2) 1. Trichoptyaceae (Trichopitys)

2. Ginkgoaceae (Ginkgo)

3.Division Gnetopsida

Order 1. Gnetales.- Families (3) 1. Gnetaceae (Gnetum)

2. Welwitschiaceae (Welwitschia)

3. Ephedraceae (Ephedra)

Reproduction

- Gymnosperms possess two different types of spores and hence refers as hetrosporous. The microspores are smaller while another spore larger in size called megaspore. These two kinds of spores on germination produce two different kinds of gametophytes. The microspore or pollen grains produce male gametophyte, while the larger megaspore produces female gametophyte, bears two or more archegonia or female sex organs. These spores are produced within the leafy structures or sporangia that borne on sporophylls, spirally arranged along an axis to form compact strobili or cones.
- The microsporangiate or male strobili bearing microsporophyll and microsporangia while the megasporangiate or female strobili bear megasporophylls with ovules or microsporangia. The two types of cones or strobili may be borne on same tree as in *Pinus* or on different trees like in *Cycas* and *Ginkgo*. The microsporangium contains numerous small microspores whereas the megasporangium contains only one larger megaspore. Both the spores i.e. microspore and megaspores are haploid and develop as a result of meiosis or reduction division in the respective spore mother cells. They are the primary structures of the male and female gametophytes respectively.
- In gymnosperms the gametophytes are endosporic i.e. they develop within or inside the respective spore wall. In general the strobili or cones are of varying shapes and sizes in different species. Their position also varies from plant to plant. Among gymnosperms, the microsporangiate or male cones are largest and arise singly at the apex of male plant.

- **Female gametophyte or ovule:** As per discoveries the ovules of gymnosperms are without any covering or naked and are borne on usually spirally arranged megasporophylls around a central axis. The ovules are generally sessile. Among gymnosperms, ovules of *Cycas* are the largest among the plant kingdom. In a ovule there is a megasporangium or nuecllus encloses in a parenchymatous mass of cells. The nuecllus encloses a single diploid megaspore mother cell that undergoes meiosis and formed 4 haploid mother cells arranged in linear tetrad form. Out of these 4 only one, usually the lower one remains functional and the rest ones degenerates. The functional megaspore enlarges and undergoes free nuclear division and resulted into large number of free nuclei. This transforms into young gametophyte that has developed within the megaspore.
- The nucellus now covered by a single massive layer or integument grow around and leaving a small pore at one end known as micropylar end. Thus the new megasporangium integumented is called ovule. Now around each free nuclei a centripetal wall formation starts and it continues till the whole female gametophyte becomes cellular.
- In gymnosperms, a single ovule consists of one middle stony layer covered by inner and outer fleshy layer. The apical region of the nucellus forms a pollen chamber by degeneration consisting the semi- germinated pollen grains or microspores. These megaspores remain in the chamber till further growth, towards the micropylar end the female prothallus develops two or more archegonia. Depending upon species the archegonia have a short or long neck made up of 2, 4, and 8 cells, in *Cycas*, *Taxus* and *Biota* respectively. This develops into megaspore mother cell which further undergoes free nuclear divisions.
- Afterwards nuclear divisions the cell wall formation starts as a result of which the female gametophyte becomes a cellular structure. The female gametophyte or prothallus get differentiated into upper reproductive region, middle storage region and the lower basal haustorial region.
- Ultimately most of the cells abort and only one remain and matures. Generally in gymnosperms the female gametophyte has cellular tissue at its lower end while on its upper end a few free nuclei remains without wall formation and acts as eggs. After fertilization this apex end however, becomes cellular (exceptional in *Welwitschia)*.

- **Microspores:** In gymnosperms the pollen grains or microspores are unicellular and haploid structures. They differ in shape and sizes in different groups of gymnosperms. They may be tetrahedral with a definite polarity due to the thicker exine towards the base (e.g. *Cycas)* and uniapertuate, may be almost spherical and uniapertuate (Ginkgo), may be winged (saccate), uniaperturate with reticulate exine (*Abies pindrow, Cedrus deodara, Pinus roxburghii* and *P. wallichiana, Picea smithiana* etc.) whereas in Ephedra the pollen grains are inapertulate elongate with palcate exine surface. *E. foliate* showing parallel ridges along the long axis of grains the pollen grains possess two tiny (sac like) structures the extremities however, in other species sacs are almost absent. (Figs. ovules of gymnosperms, archegonia of gymnosperms). Based on studies it is suggested there is a gradual reduction in the wings or sacs and ultimately resulted in non-winged pollen grains as reported in Ephedra.
- **Male Gametophyte:** The male gametophytes in gymnosperms are endosporic in nature and show variations regarding their release from sporangia, the number of male prothallial cells (they complete their development partly in the microsporangium and partly in the pollen chamber of the ovule), size and motility of male gametes and their time of formation and discharge. In different groups of gymnosperms differs in their morphology. In lower gymnosperms- cycadaceous micro gametophytes there is one male prothallus cell that divides into a large sterile cell or stalk cell and a body cell or a spermatogenous cell and a tube nucleus. They are arranged in a linear row. The body cell again divides into two multiciliate male gametes. In all Cycads the pollen tube is formed and is more haustorial in nature than a sperm carrier. While in *Microcycas* the stalk cell divides into 10 or 11 body cells or spermatogenous cells. These all cells divide to produce 20 or 22 spermatozoids. Contrary to this in *Ceratozamia* there are 4 spermatozoids. Generally in Gymnosperms the generative cell divides into stalk cell and body cell except in *Cycas revolute*, where it is divided anticlinally.In case of Coniferales, different families of this group show slight variations in the sequence of micro-gametophyte development, although the major event shows similarities.
- In Pinaceae family the nucleus of microspore divide twice by periclinal walls and cut off three cells- two male prothallus cells and one antheridial cell. The latter divides periclinally and forms a tube cell and a generative cell. The grains are liberated at this four celled stage (two prothallus cells, one tube cell and one generative cell). Again the generative cell undergoes periclinal division and forms a stalk cell and a body cell. All

these cells lie in an axial row. The semi germinated pollen grains may germinate immediately or after a month. The pollen tube may start branching on entering the nuecllus, then the tube nucleus migrates into one of the branches of pollen grain and moves to the tip, while the generative cell remain within the spore wall and divides into stalk cell and body cell between the pollination period of the year or in the following spring, these two moves into the pollen tube. Simultaneously about a week before fertilization, the body cell divides into two non- motile, unequal size male gametes. There is difference in opinion regarding the male gamete. According to some workers the two male gametes are as two nuclei of binucleate sperm cells, whereas others regard them as two sperm cells. Sometimes the generative cell divides before pollination, in some genera *e.g. Abies, Cedrus, Picea,* and *Larix* etc. In Abies the cell sometimes divides into two male gametes before pollination or shortly after pollination.

Pollination and Fertilization

- In gymnosperms the medium of pollination is wind; it results in the transfer of semi-germinated pollen grains on the micropyle of the ovule. In most of the gymnosperms, the pollen grains are caught into a pollination drop selected by micropylar end of the ovule. After drying of pollination drop the microspores in semi- germinated stage are drown into the ovule. Just after the drawing of the microspores in the micro gametophyte the micropyle closes. A distinct pollen chamber is formed at the apex of the nuecllus and receives the micro- gametophytes on pollination as in some gymnosperms *(Cycas, Ginkgo, Ephedra* etc.)
- While in Conifers and other gymnosperms the semi- germinated pollen grains come in direct contact with the nuecllus beak. Contrary to this in the palaeozoic gymnosperms now extinct the pollen chambers contained liquid filled cavities in which the motile sperms were liberated due to the dehiscence of the microspore wall. In general in all the living gymnosperms, the microspores by division produce pollen tube as a tubular outgrowth that grows through the nucellar tissue. In Cycads and *Ginkgo* the pollen tubes mainly acts as the haustorial organs and grows for long time (several months) into the nucellar tissue and absorb food and supply it to the micro gametophyte at the grain end or at the lower end of the pollen tube. The pollen tube bursts during fertilization and liberation of multiciliate male gametes along with some liquid in the cavity above the mega gametophyte. At that time the sperms swims to the archegonial neck and enters into the archegonia and only one of them fuses with the egg or oosphere and form the

diploid zygote or oospore.In the conifers the pollen tube plays an important role of sperm carrier. The male gamete along with stalk and tube nucleus migrate to tip of the pollen tube. The tube grows through the nucellar tissue, reaches to the archegonial tube enters through it and after bursting liberates the male gametes. Among them, one fuses with the egg to form a diploid zygote. This specific process of fertilization is termed as Siponogamous.

- However, in Cycadofilicales, Bennettitales and Cordaitales, the extinct orders of gymnosperms did not produce pollen tubes and sperms were liberated directly into the pollen chamber. This process is known as **Zooidogamous.**
- In case of *Welwitschia* the female gametophyte gives out tubular prolongation that meets the pollen tips fertilization takes place after the intervening wall dissolves. In *Welwitschia* and *Gnetum t*here are no archegonia.

EMBRYOLOGY:

- In different groups of gymnosperms embryogeny differs in different stages. It also differs in living and fossil forms. In living or present day gymnosperms the first phase in embryo development is the free nuclear divisions except in *Gnetum*, *Welwitschia* and *Sequoia semipervirens*. While it is completely absent in angiosperms and other tracheophyta.
- Just after free nuclear division, wall formation begins and the embryo transformed into cellular form. Later it differentiated into a suspensor, radicle, hypocotyl, plumule and cotyledons. When the shoot end of the embryo is directed away from the micropylar end of the ovule, that type of embryo development or embryogeny is called **"Endosporic**".
- Polyembryony is the characteristic and significant feature of gymnosperms. This is possible as more than one archgonia are fertilized and so more than one zygote are formed. These zygotes later developed into embryos, but one of them succeeded in developing into a complete embryo. Comparatively to Cycades, in Conifers there is a ***"Cleavage Polyembryony***". As reported earlier that in conifers only four nuclei formed, so in this case all the four cells of the young embryo separates after wall formation and develop into 4 embryos, but only one completes further development while others abort.
- In *Thuja* no cleavage Polyembryony reported and only one embryonial initial develops into an embryo. No free nuclear division is reported in *Sequoia*

semipervirens and the zygote divided first by a transverse wall and forming two cells which divided further by other longitudinal walls to form four cells. All these cells may function as embryo initial and give rise to filamentous embryo.

- In majority of conifers the zygote develops four free nuclei and later because of further divisions and wall formation results in forming a ***"Proembryo***" with a four celled distal embryonal tier, middle suspensor tier and upper rosette tier *(Pinus, Cycas, Tsuga* etc.)
- While in other gymnosperms as in *Abies, Picea* and *Larix* the rosette tier disappears at a later stage. In further developmental stages the lower embryo tier develops into all the organs at a later stage. The suspensor tier develops into additional embryos. While the upper most tier ends are in open contact with the egg cytoplasm. This end is apparently active in transmission of nutrients to the growing embryos.The number of cotyledons varies in different species end even in the same species. It is 10 in *Pinus roxburghii, P. banksiana*- 3-6, *P. contorta*- 2-8, *P. sabiniana*-7-8. Cleavage Polyembryony is not reported in *Araucaria angustifolia* the member of Araucariaceae. In this species 32-45 free nuclei are formed. Later by polar elongation wall formation is accompanied. The cells at the distal end develop into enlarged cap cells. The central cells develop into embryo and those situated towards the micropylar end give rise to suspensor. There is complete absence of ***"Cleavage Polyembryony***".

SEED FORMATION:

- After fertilization, the structure developing from fertilized ovule and its consequent enlargement is known as seed. The zygote develops into an embryo while the endosperm persist as an nutritive tissue, whereas the nuecllus becomes disorganize (or serves as nurse cells for developing embryo) or it may remain in the form of dry tissue at the micropylar end of the seed known as nucellar cup.
- In gymnosperms the inner fleshy layer called the tegmen, may persist as a thin layer of seed coat. The middle stony layer later changes into a hard layer called the testa, which mechanically protected the female gametophyte and the embryo. Development of seed may vary in different species of gymnosperms. In *Cycas and Taxus* the outer fleshy layer develops into scarlet red and fleshy outermost seed coat.
- In *Gnetum* the seed develops before the embryo complete its development. In *Taxus* a fleshy aril develops from the basal cup- shaped structure. Except *Cycas* and *Ginkgo,*

the seeds of all gymnosperms remain dormant for some time. While in these two genera the seeds germinate immediately, they lose their viability when fall on moist substratum.

- In gymnosperms the seed represents two sporophytic and one gametophytic generation. Different parts of a seed of gymnosperms represents different generations.
- The young embryo represents the new sporophytic generation.
- The seed coat represents the old sporophytic generation and
- The endosperm represents the gametophytic generation
- In most of the genera of gymnosperm the germination of seed is epigeal means the cotyledons come above ground except in *Ginkgo* where the cotyledons remain embedded in the endosperms. While in *Ephedra trifurcate* ***Vivipary*** **h**as been reported. All the gymnosperms represent ***heterogenous alternation of generation***

<u>ECONOMIC INPORTANCE OF GYMNOSPERMS</u>

- Gymnosperms are of great economic importance in nature and have many economic importance for human beings. It gives valuable wood, resin, essential oils, gums, paper, turpentine, medicines, food, ornamentals and miscellaneous items.Gymnosperms are frequently used in parks, gardens because of their evergreen habit and symmetrical appearance. The trees are used for timber, building construction, resin, paper manufacturing etc. They are also used in medicines, perfumes, varnishes, paints and essential oils. While roasted seeds of *Ginkgo* are eaten at feast in China and Japan, to promote digestion and diminishes the effect of drinking wine. Seeds *of Pinus gerardiana* (chilgoja) used as dry fruit. Seed kernels of *Gnetum ula* yield an oil for illumination and massage in rheumatism. Bark of *Taxus baccata* is used as main ingredient of famous *Bhati*a *tea*.
- **FOOD:** In some parts of India, Malaya, Philippines and Indonesia, young succulent leaves of various species of *Cycas* are cooked and eaten as vegetable. The famous ***"Sago"*** starch is obtained from the stem / seeds of *Cycas* and used as food. This stem starch obtained from *Macrozamia spiratis* is an important source of food for poultry, dairy animals and pigs. The seeds of *Cycas* are used as paste and eaten as cakes in Nicobar Island.
- **GREEN MANURE:** Leaves of *Cycas* are rich in nitrogen and used as green manure for rice, sweet potato and sugarcane.
- **MEDICINE:** Leaf extract of *Ginkgo biloba* is useful in the treatment of cerebral

insufficiency and vertigo.

- **ORNAMENTAL:** *Ginkgo biloba* and *Cycas* species are grown as an avenue tree and in gardens also for beautification. These trees are preferred especially due to their slow growth, evergreen nature and beautiful symmetry.
- **TIMBER:** Conifers and Taxales are most important genera of gymnosperms significantly important to produce high quality, straight grained, light colored, high weight and strong wood in comparison to their weight. They are suitable for making cabinets and furniture due to their strength and durability. The wood of *Abies is* light and termite free. It also has pleasant scent smell and used for packing cases, match wood, wood wool, aircraft work, plywood, light camp furniture and also used as household materials. *Juniperus* wood is fragrant, reddish brown and rarely damaged by insects. *Cedrus* wood is also durable, oily, fragrant, insect repellant and rot resistant. The wood of *Taxus* is strong, oily, elastic, close- grained, fragrant and very durable with smooth glossy surface. Beside this, wood of *Araucaria canninghana* used for plywood manufacture.
- **RESIN:** Conifers exudated resins, this help the wood resistant to decay. Conifers are the major resin yielders of the world. These resins evaporate their oil and became harder which makes them invaluable in paints, varnishes, paper sizing, medicines and liquors industries.
- **CANADA BALSAM:** A resin obtained from *Abies balsamea* which has a very high refractory index approximately that of glass. Due to this property it is extremely suitable as amounting medium for microscopic objects and as cements for uses in optical work.
- **ESSENTIAL OILS:** All conifers young branches and adherent leaves provide essential oils. ***Himalayan Cedar oil*** (*Cedrus deodara*) and ***Red Cedar Wood*** *(Juniperus virginiana*) are used cleaning tissues in histological work and also use with the oil immersion lens of the microscope. The oil obtained from *Cedrus atlantica* possess medicinal properties and used against bronchitis, tuberculosis, skin diseases and gonorrhea. The essential oils are used extensively in preparation of deodorants, room sprays, disinfectants, perfumery and medicine etc.
- **FATTY OILS**: Many conifer seeds are rich in fatty oils. The oil from the seeds of *Pinus cembra* and *Torreya nucifera* is edible and also used for paints. The Tail Oil obtained as a by product from sulphate process of cooking conifer wood for making

Kraft paper is used in paints, soaps, linoleum, emulsifiers etc.

- **PHARMACEUTICALS:** The leaves of *Taxus baccata* are used in asthma, bronchitis, hiccough, epilepsy and for indigestion. ***Taxol*** (from *Taxus brevifolia*) is found effective against ovarian cancer, breast cancer, and melanoma and colon cancer. *Ephedra* is the source of a valuable drug ***Ephedrine*** obtained from *E. equisetina, E. gerardiana, E. major, E. sinica, E. intermedia* and *E. nebrodensis*. It is used against cold, respiratory disorder and hay fever. An aromatic beverage, known as ***Mormon tea*** is also brewed from the species of *Ephedra* in south western United State.
- **AMBER:** It is a fossil, water insoluble tree resin which was secreted by the now extinct pine, (*P. succinifera)*. It is yellow, brown to black, hard and brittle with an aromatic odor.

CYCADALES: CYCAS

- The members of this order are commonly known as cycads.
- They originated from the seed ferns. i.e., Cycadofilicales, towards the end of Carboniferous periods and formed a dominant vegetation during the Triassic periods of Mesozoic era.
- The order includes eleven living genera and about 100 species.
- They are usually woody trees except *Zamia pygmaea.*
- The stem is mostly unbranched and is covered by persistent leaf bases.
- The leaves are arranged in whorls at the apex of the stem; they are pinnately compound.
- The wood is monoxylic. The micro-and megasporophylls usually from male and female strobili.

CYCAS

Systematic Position

Division - Cycadophyta

Class - Cycadopsida

Order - Cycadales

Family- Cycadaceae

- *Cycas* is the most widely distributed genus of the order Cycadales.
- There are about 20 species which occurs in wild state in China, Japan, Australia, Africa, Burma and India.
- Four species of *Cycas* – *C. circinalis* , *C. pectinata, C. rumphii* and *C. beddomei* – occurs in natural state in India, Chiefly in Assam, Orissa, Meghalya, Andaman and Nicobar Islands, karnataka and Tamil Nadu. *C. revoluta* and *C. siamensis* are widely grown in gardens.

Cycas pectinata:

- It is mainly distributed in Nepal, Sikkim, hills in Bihar Assam and Chittagong.
- The plant is 2- 3.5m in height with a crown of leaves at the top of the unbranched stem.
- The leaves are 1.5 – 2 m long with flat and linear leaflets.
- The male cones are cylindric- ovoid and about 40 cm long.
- Each megasporophyll has 4-6 ovules.

C. revoluta:

- It is a native of China and Southern Japan and is widely cultivated as an ornamental plant in India.
- The plant is 1.5- 2 m in height and has revolute leaflets.
- The male cones are cylindrical or ovoid- oblong.
- The tomentose megasporophyll bears 2- 4 ovules.

***C. beddomei*:**

- It occurs in wild state in Cuddapah district of Andhra Pradesh.
- It has a dwarf trunk, only up to 40 cm high, and strongly revolute leaflets.
- The rachis is without spines, but the basal part of the rachis is covered with tufted hairs.
- The male cones are oblong- ovoid, and the megasporophylls are ovate- lanceolate with linear teeth.

C. circinalis:

- It is common in the western parts of Peninsular India, Western Ghats and Orissa hills.
- It is 1.5- 3 m in height. The leaf has more than 160 pairs of flat and acuminate leaflets.

- The male cones are cylindric- ovoid and the to mentose megasporophyll bears up to 12 ovules.

***C. rumphii*:**

- This species occurs in Andaman and Nicobar Islands.
- The plant is 1.5- 4 m high with 1-2 m long leaves, each with 50-100 pairs of leaflets.
- The male cones are ellipsoidal and stalked, and the megasporophyll is linearovate and 6-10 ovulate.

***C. siamensis*:**

- It is widely distributed in Burma, China, Thailand and Yunnan.
- In India, It is grown as an ornamental plant.
- The plant is about 3 m tall with nearly a meter long leaves.
- The male cones are ovoid- oblong, and the megasporophyll has two ovules.

SPOROPHYTE

- Plants are low and palm-like, height 4-8 feet.
- Tallest species, *C. media* – up to 20 feet high
- Stem unbranched , columnar and covered with persistent leaf bases.
- Leaf segment remains circinnately involute within the bud–leaves dimorphic.
- Female reproductive structures–the megasporophylls are not aggregated in cones.
- Ovules (2 or more) borne on the lower margins in ascending order

External Morphology

- Stem- Cycas plant shows tuberous stem when young , becoming columnar and unbranched later.
- Leaf– Shoot apex is protected by a rosette of brown scale leaves.
- Plant grows very slowly adding a new crown of leaves every 1 or 2 years , alternating with crown of scale leaves.
- The pinnately compound megaphyllous leaves have 80-100 pairs of leaflets arranged on the rachis
- Leaf base is rhomboidal in shape and attaches the leaf transversely to the stem
- The leaflets are thick , leathery in texture, ovate or lanceolate in shape & photosynthetic in function.
- Scale leaves are very small , rough and dry , triangular in shape and brown in colour , thickly coated.

- Root is of two types – normal and coralloid.
- Normal tap-roots grow from the radicle deep inside the soil giving out lateral branches
- Some of the lateral roots grow apogeotropically towards the surface of soil and branch dichotomously
- These roots are short , thick and swollen at the tips.
- The much branched mass appears like a coral on the soil surface hence called coralloid roots
- Do not bear root caps
- The cluster has lenticel like apertures
- Become infested by N2 fixed blue-green algae (cyanobacteria); bacteria & diatoms eg. *Nostoc punctiforme*, *Anabaena cycadacaerum*
- Symbiotic relationship thus established

<u>Anatomy Root</u>

- Young root shows typical structure like that of a dicotyledonous root
- Outer most layer , epiblema , encloses the parenchymatous cortex interspersed with tannin cells and mucilage canals
- Endodermis with casparian thickenings
- Pericycle is multilayered with thin cells having starch grains
- Vascular tissue within is typically radial
- Roots usually diarch to tetraarch , rarely polyarch
- Vessels absent in vascular tissue
- Pith reduced or absent

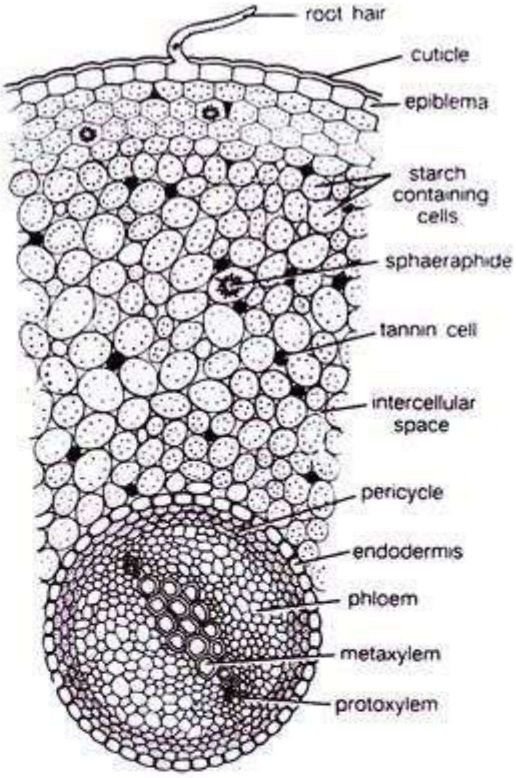


Fig. 8.16. *Cycas revoluta* T.S. normal root (*Young*)

- Older roots show secondary growth
- Cambial ring is initiated between xylem & phloem and completed by differentiation in inner layer of pericycle adjacent to protoxylem elements
- These cambial cells are meristematic and add secondary xylem on the inside and secondary phloem towards cortex
- Along side phellogen (cork cambuim) develops in outer most layer of cortex below the epidermis
- This produces dead cork cells (phellem) towards outer side and living secondary cortex cells (phelloderm) on the inside.
- Lenticels are developed in old roots

Coralloid Roots

- Has additional algal zone in the cortex
- Cells of algal zone palisade like and form the middle cortex

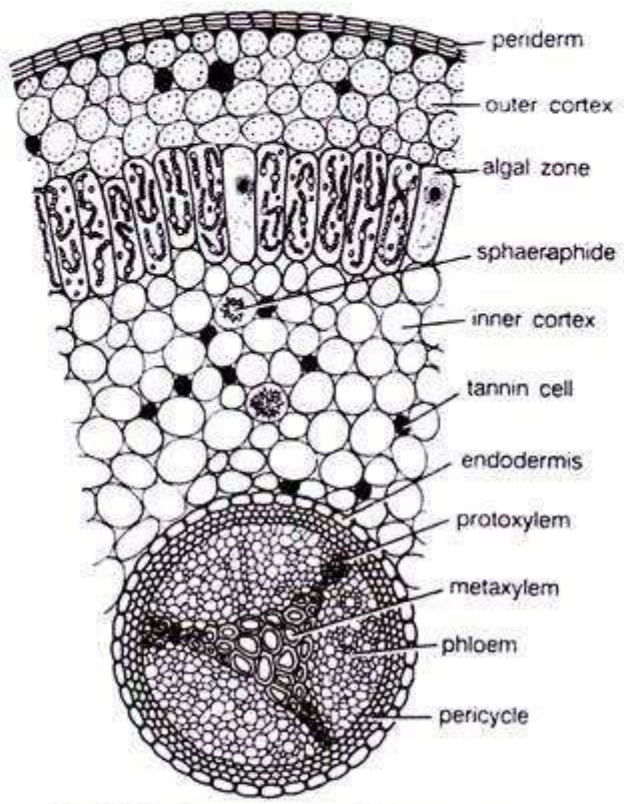
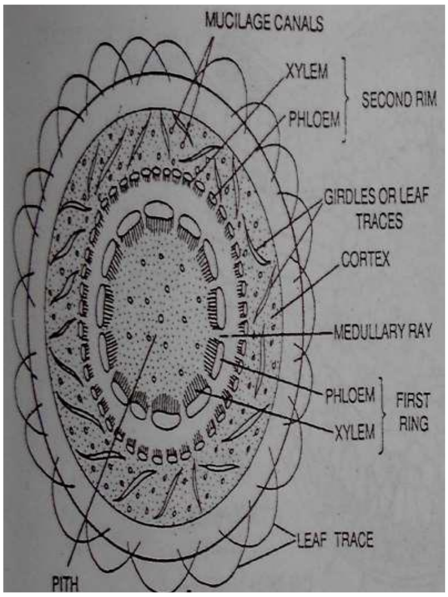


Fig. 8.18. *Cycas revoluta* T S coralloid root

Stem

- Show irregular outline due to the presence of leaf bases , therefore epidermis is not a continuous layer
- Broad cortex is traversed by simple and girdle leaf traces
- Numerous mucilage canals, starch grains also present
- Narrow zone of vascular tissue having open, endarch vascular bundles arranged in a ring and separated from each other by wide medullary rays
- Pith is large, parenchymatous having mucilage canals and starch grains
- Old stem of *Cycas* shows secondary growth
- Wood manoxylic type with scanty xylem and wide medullary rays



Rachis of Cycas

- Woody and thick
- Hypodermis sclerenchymatous
- Characteristic feature is omega shaped (Ω) outline of the numerous vascular bundles
- Each bundle has sclerenchymatous bundle sheath and is open , collateral.

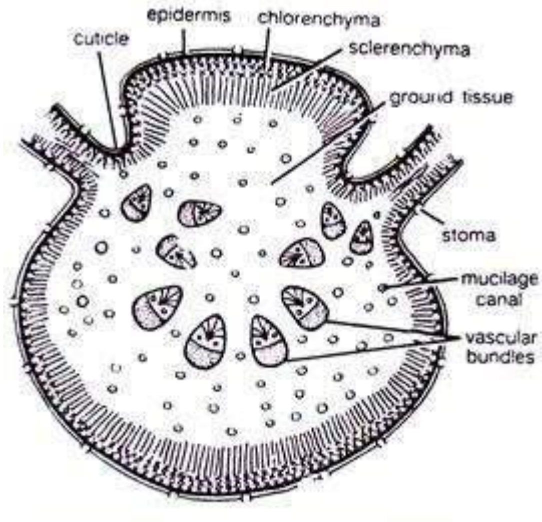
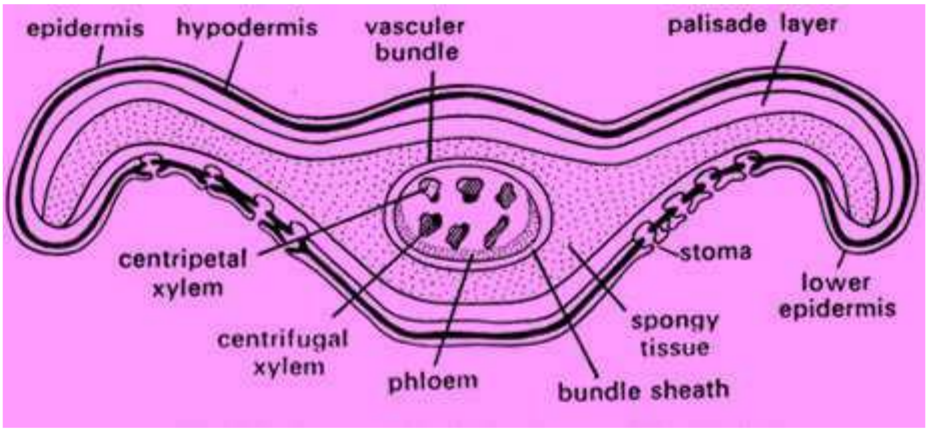


Fig. 8.25. *Cycas*. T.S. rachis (diagrammatic).

***Cycas* Leaflet**

- Leaflet is thickly cutinized and leathery
- Possesses all xerophytic characters
- Sunken stomata and thickened hypodermis present
- Well developed palisade layer in mesophyll

- Between the palisade and lower mesophyll layers , there are transversely running long colourless cells in 3-4 layers extending from mid- rib to near leaf margin
- These constitute the transfusion tissue
- Mid-rib bundle consists of abroad triangular centripetal xylem and two small patches of centrifugal xylem–thus dipoxylic
- Phloem abaxially placed



Reproduction –Vegetative

- Vegetative reproduction is by means of bulbils
- Develop in crevices of scale leaves and leaf bases at the basal part of an old stem
- Produces new plant on Detachment

Reproduction –Sexual

- Strictly dioecious plant
- Male plants are rare
- Male strobilus or cone borne singly at the apex of the trunk
- Apical shoot apex utilized in the development of male cone, hence branching sympodial
- Cone shortly stalked & large (upto 50 cm length or more)
- Numerous micro- sporophylls spirally arranged around the central axis
- Each micro- sporophyll is narrow below and broad above terminating into projection–the apoplysis
- Microsporangia confined to abaxial (lower) surface
- Usually present in sori– each with 2- 6 sporangia
- They contain a large number of haploid microspores (pollen grains)

Male Cone

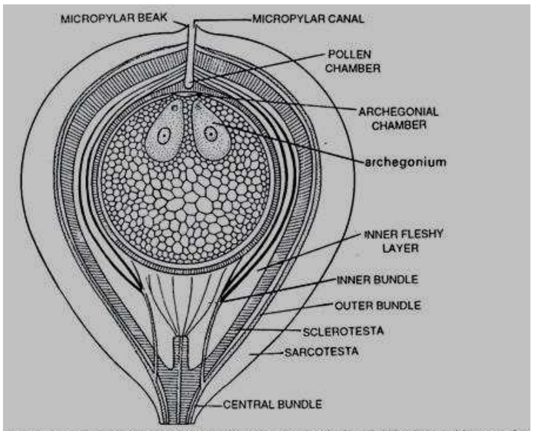
Female Cone

Female Reproductive Structures

- Female plant do not produce definite cones
- A whorl of spirally arranged megasporophylls arise around the short apex
- Each megasporophyll resembles the foliage leaf and approximately 10-23 cms. Long
- Lower petiolar part bears the naked ovules on the margins

Ovule Structure

- Largest ovule (6 cms. X 4 cms.) seen in *C. circinalis*
- Ovules are orthotropous, sessile , ovoid or spherical in shape and unitegmic.
- The thick integument is differentiated in three layers outer and inner fleshy layers , middle stony.
- The integument remains fused in side with nucellar tissue except at the position where it forms the micropylar opening.
- Ovule is well supplied with vascular bundles.



Cycas revoluta. V.S. of ovule showing internal structure before fertilization and its vascular supply.

Megasporangium

- The megaspore develops in the nucellus by meiotic division and goes on to form female gametophyte tissue.
- 2- 3 archegonia are formed in this haploid tissue which is food laden.
- Egg cell in the venter of archegonia undergoes fertilization by the motile spermatozoid forming diploid zygote.

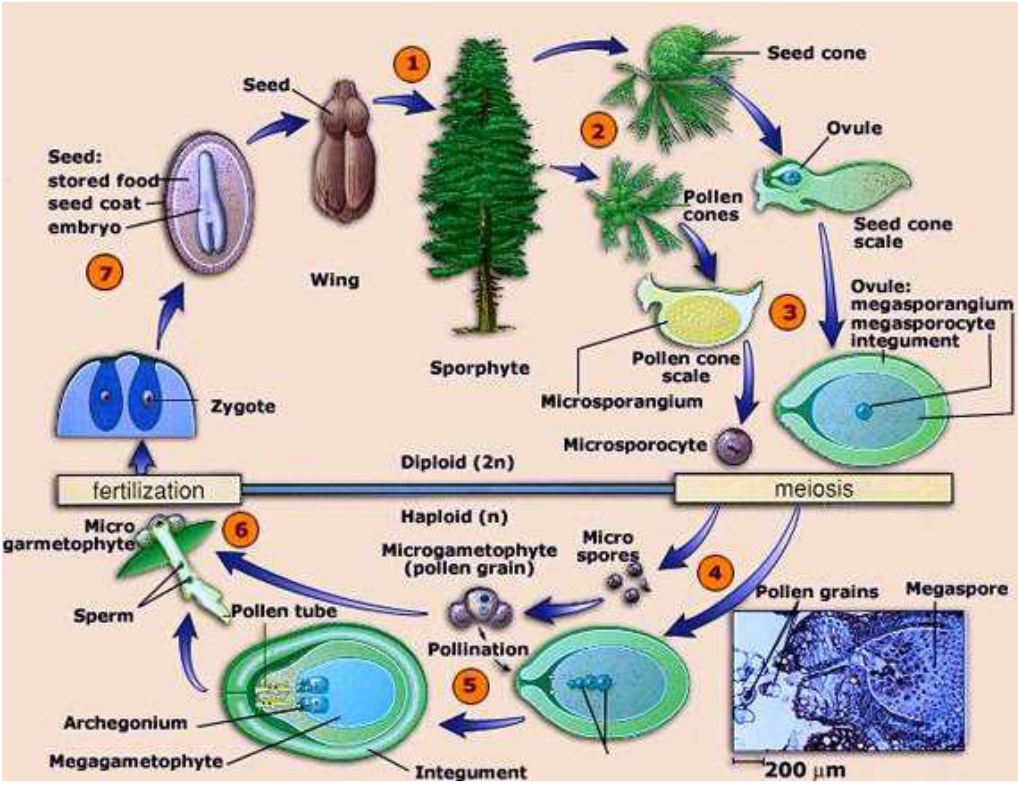
Pollination -Development of male gametophyte after pollination

- The pollen grains are carried by wind (Anemophily) and caught by pollination drop secreted by ovule. Pollination is direct.
- The pollination drop is dehydrated and the pollen grains are sucked in to the pollen chamber.
- Pollen grains take rest for sometime in the pollen chamber.
- During the germination of pollen grain the exine is ruptured and the inner intine comes out in the form a tube like structure known as pollen tube.
- At this time the generative cell divides and forms a larger, upper body cell and smaller , lower stalk cell.
- The pollen tube acts as haustorium to absorb food materials from the nucellus besides as sperm carrier.
- The body cell divides and forms two naked, top shaped, motile, multiciliated antherozoids.
- The cilia are in 4–5 spirals.
- The male gametes of *Cycas* are 180–210 µ in size and largest in the plant kingdom.

- The pollen tube apex is ruptured and the male gametes are released into the archegonial chamber.
- Presence of multiciliated male gametes is the fern character shown by *Cycas* male gametophyte

Young Sporophyte–Embryo

- Embryo development is meroblastic.
- Pro embryo shows upper haustorial part, middle elongating suspensors and the basal meristematic embryonal region.



Life cycle

CONIFEROPHYTA: PINUS

- This is the largest division of gymnosperms, which includes Pines, Yews, Spruces, Junipers, Cedars and many more plants
- With approximately 588 living species, this is the most diverse and by far the most ecologically and economically important gymnosperm group
- They are usually long, branched and evergreen trees.
- The branches usually dimorphic and bear needle like, linear or lanceolate leaves.
- The wood is pycnoxylic, characterised by the presence of resin canals.

- The micro and megasporophylls form compact cones.
- The male gametes are non- motile and the fertilization is siphonogamous.

PINUS

Systematic Position

Division - Coniferophyta

Class- Coniferopsida

Order- Coniferales

Family- Pinaceae

Genus- *Pinus*

- Pinus is one of the most important taxon of the order conoiferals, is represented by about 105 species, distributed throughout the northern hemisphere.
- Five species of Pinus occurs in the Indian sub continent of these four species are confined to the north east and north west Himalayan regions.

1. ***Pinus roxburghii*:**
   Pinus roxburghii (known as chir pine) is a species of pine. *Pinus roxburghii* is a large tree reaching 30–50 m (98–164 ft) with a trunk diameter of up to 2 m (6.6 ft), exceptionally 3 m (10 ft). The bark is red-brown, thick and deeply fissured at the base of the trunk, thinner and flaky in the upper crown. The leaves are needle-like, in fascicles of three, very slender, 20–35 cm (7.9–13.8 in) long, and distinctly yellowish green.

2. ***Pinus wallichiana*:**
   The leaves ("needles") are in fascicles (bundles) of five and are 12–18 cm long. They are noted for being flexible along their length, and often droop gracefully. The cones are long and slender, 16–32 cm, yellow-buff when mature, with thin scales; the seeds are 5–6 mm long with a 20–30 mm wing.

3. ***Pinus gerardiana*:**
   This species common in Kashmir and Kinnaur district. The trees are 10-20 m tall with usually deep, wide and open crowns with long, erect branches. However, crowns are narrower and shallower in dense forests. The leaves are needle-like, in fascicles of

3, 6–10 cm long, spreading stiffly, glossy green on the outer surface, with blue-green stomatal lines on the inner face; the sheaths falling in the first year.

4. ***Pinus merkusii:***

   This species occurs on the hillock in East Bengal at an altitude of 150- 600 meter . The plant is only 3-4 meters high. There are two needles in each foliar spur.

5. ***Pinus insularis*:**

   This species is widely distributed in khasya regions of Assam at an altitude of 700-1850 meters. The plant attain a height of about 30 meters and the foliar spurs are trifoliate.

Sporophytic Plant Body

- Adult plants are tall trees up to 200 feet in height
- Perennial, xerophytic plants appearing pyramidal or conical due to radial branching
- Branches are dimorphic – long shoots and dwarf shoots (spurs)
- Leaves are dimorphic – Scale leaves and green acicular leaves
- Male and female cones present on the same plant, hence monoecious

External Morphology – Stem

- Erect, tall, cylindrical, woody and branched
- Branching monopodial and excurrent
- Lower branches longer and horizontal giving the conical shape to the plant
- Branches of unlimited growth are the long shoots
- Arranged spirally around the main trunk
- Bear scale leaves and dwarf shoots in axils of scale leaves
- Branches of limited growth or dwarf shoot lacks apical bud
- Possess 8-10 spirally arranged scale leaves terminating into 1-5 needle like foliage leaves at apex

External Morphology – Leaves

- Scale leaves thin, brown and small
- Main function is to protect young buds & conserve water around the branches
- Foliage leaves are long & acicular (needle like)
- Remains green for a number of years (3-10 yrs) hence plants are evergreen
- No. of needles per spur varies from 1-5 with species (monofoliar to pentafoliar)

External Morphology – Root

- Plant possesses tap root
- Elongated structure with strong lateral branches
- Root-hairs scanty; function taken up by ectotrophic mycorrhiza (fungus roots)
- It is symbiotic association of fungal mycelium on the root's surface
- Helps in absorption of nutrients & protection from pathogens
- Fungal species identified are Rhizopogon, Amanita, Boletus, Entoloma, etc. – mostly members of Basidiomycetes

Anatomy – Root

- Resembles typical dicotyledonous root.
- Pili ferous epiblema bear unicellular root hair (seen only in young roots)
- Broad parenchymatous cortex
- Endodermis and pericycle layers
- Vascular tissue is radially arranged in 2-6 groups of xylem and phloem
- This tissue lacks true vessels and companion cells
- Resin canals present in xylem patch making it Y-shaped
- Old roots show secondary growth

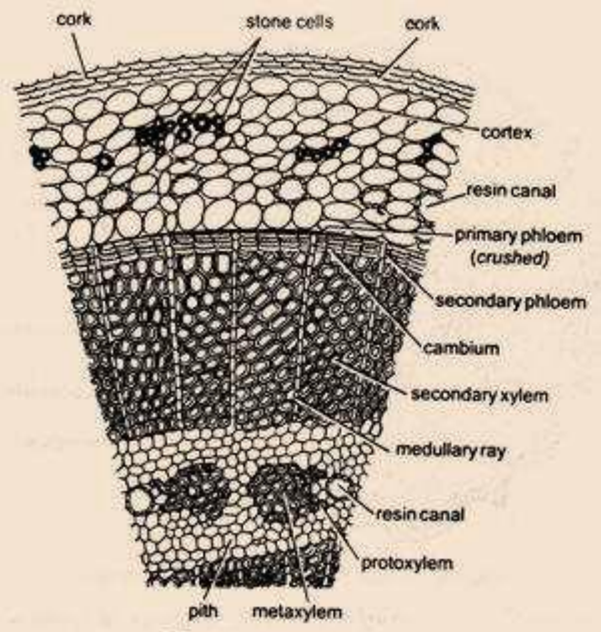
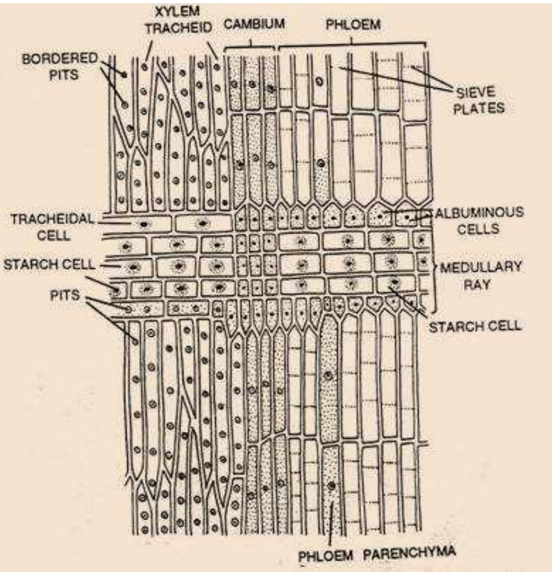


Fig. 30. Pinus. T.S. old root.

Anatomy – Stem

- Typically dicotyledonous stem

- Cuticularized epidermis encloses the lignified sclerechymatous hypodermal layer below
- Inner cortex is thin walled parenchyma containing chloroplasts and resincanals
- Vascular bundles are conjoint, collateral, endarch , open and form a ring
- Medullary rays are narrow
- Vessels in xylem and companion cells inphloemare absent



4.22. *Pinus roxburghii*. Anatomy of stem; T.L.S. of secondary wood and phloem, and the structure of secondary medullary ray.

Secondary growth in stem

- Ring of vascular cambium develops
- Remains active each year forming spring wood & autumn wood – annual rings
- Important in dendrology for estimation of the age of the plant
- Secondary medullary rays usually uniseriate
- Pinus wood is dense and massive with few parenchyma cells – pycnoxylic
- Cork cambium (phellogen) formed in outer cortical layer
- Forms secondary cortical cells (phelloderm) towards inner side and cork (phellem) on outer side

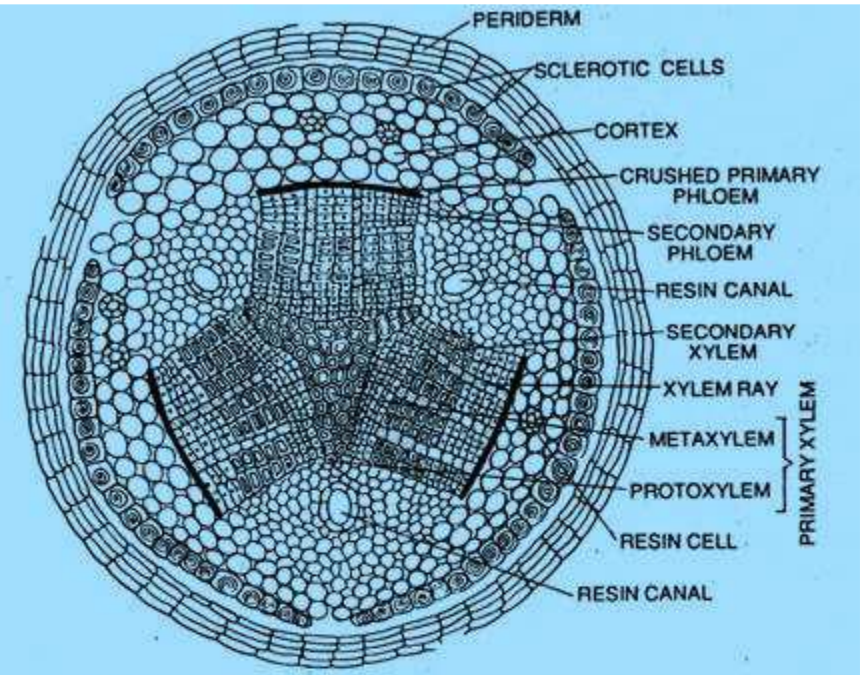
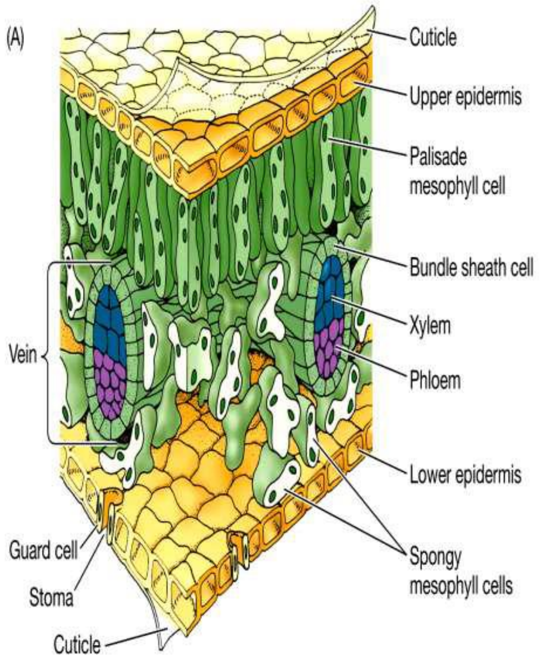


Fig. 4.16. *Pinus.* Tranverse section of an old triarch root with secondary growth.

<u>Anatomy – Leaf</u>

- Xeromorphic
- *P. longifolia* is trifoliar; so the needle shows triangular outline
- Outermost epidermal layer has thick-walled cells which are cuticularized
- Stomata are sunken
- Hypodermisissclerenchymatous



- Mesophyll not differentiated further
- These cells have peg-like in foldings of cellulose projecting in their cavities
- Have a large number of chloroplasts & starch grains
- Resin canals with secretory tissue present
- Two vascular bundles with conjoint
- Tissue present in the middle

Reproduction

- Takes place by means of spores – microspores (male) and megaspores (female).
- The plants are therefore heterosporous
- The male and female cones occur on the same plant, but different branches i.e. monoecious

Male cones (Staminate cones)

- Borne on the lower branches in the axils of scale leaves.
- Appear in the month of January (in plains) and March (in hills) reaching maturity within 2-3 months.
- Can be seen in clusters just behind the shoot – apex.

Male cones (Staminate cones)

- Each cone has 60-100 spirally arranged microsporophylls
- Two microsporangia are present on the underside of each microsporophyll
- Development of microsporangium is eusporangiate type
- Within the microsporangium, the microspore mother cells undergo meiotic divisions to form haploid microspores

Microspore (Pollen grain)

- It is surrounded by a 3-layered wall
- Exine heavily cuticularized on one side of the microspore
- Middle layer (exo-intine) projected outwards into two large balloon-like air sacs or wings
- Inner layer (intine) is very thin
- On maturation the spores germinate in situ.
- Hence, early gametophytic development is precocious
- At the time of dehiscence, huge quantities of microspores form yellow clouds around the pine forests.

- It’s called the “Shower of sulphur dust”

Female cone (Ovulate cone)

- Borne on the upper branches of the tree, in axils of scale leaves either singly or in groups of 2-4.
- Female cones are seen in February and get pollinated within 3-4 months
- Complete maturation and seed dispersal takes place in the 3^{rd} year of development
- Each cone consists of central axis bearing spirally arranged ovuliferous scales (60-70)
- On young cones a small thin & leathery bract scale can be below the ovuliferous scale
- Each ovuliferous scale has two ovules on its upper surface
- Cone on maturity is usually cylindrical and 15-20cms in length

Megasporophyll

- The ovuliferous scale is thick, large, woody & brownish structure
- More or less triangular in outline – broad, terminal portion is apophysis with its centrally projected area – the umbo
- Basal portion is narrow and bears two naked, sessile anatropous ovules on its upper surface

Ovule Structure

- Micropyle of the ovule faces the central axis of the cone
- The single integument is fused to the nucleus except for a short distance near the micropyle
- Embedded in the nucellus ,the archesporial cell divides meiotically to form four megaspores

Male Gametophyte

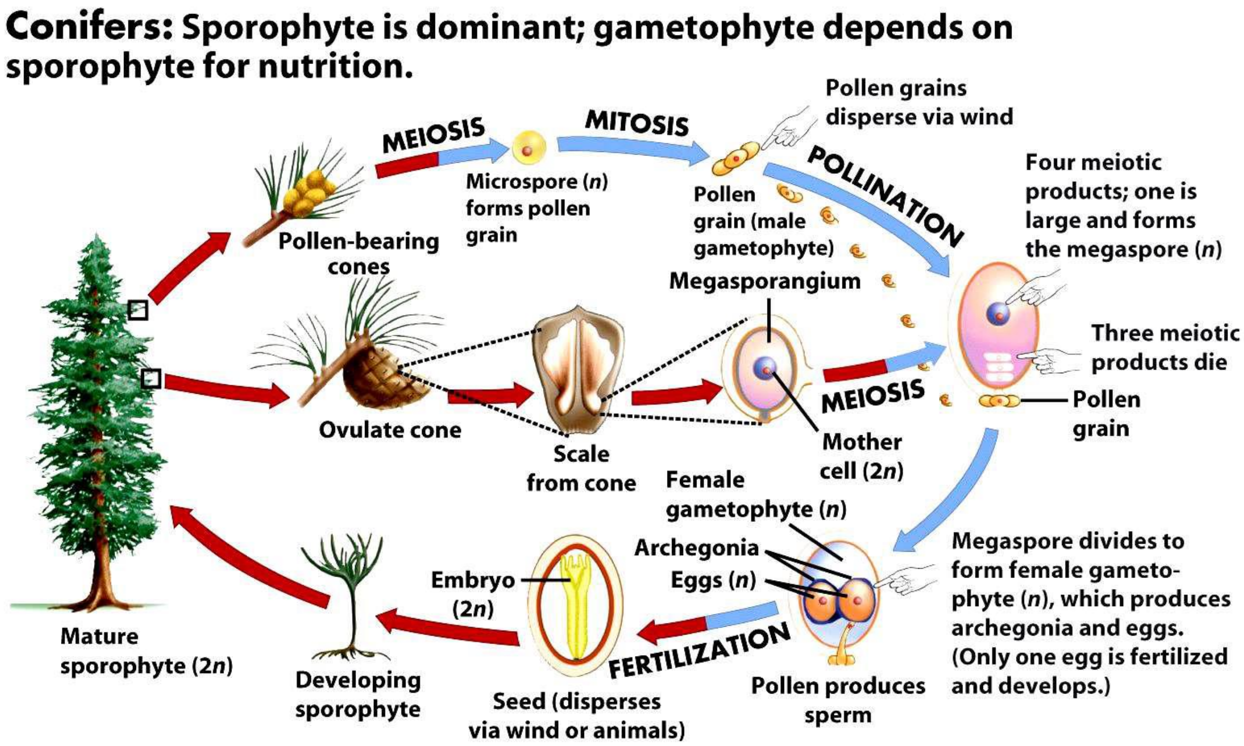
- Early development takes place inside the microsporangium
- Pollen grains are released at the 4- celled stage (2 prothalial, a generative cell and tube cell)
- Pollination is anemophilous and pollen reach the pollen chamber of the ovule through micropyle
- Further development here, results in the formation of pollen tube which carries the two unequal male gametes to the neck of the archegonium
- The released male gametes will fertilize the egg cell resulting in zygote formation
- Time gap of 12-14 months is seen between pollination and Fertilization

Female Gametophyte

- The inner most functional megaspore further gives rise to the haploid female gametophyte tissue wherein the archegonia develop.
- The venter of the archegonia contains the upper ventral canal cell and the larger egg cell.

Young Sporophyte

- Embryo development is meroblastic
- In early stages the embryonal tier of the pre-embryo splits apart forming 4 apical segments each with its suspensor
- Each of these terminal embryonal cell give rise to a mature embryo , thus Cleavage polyembryony is observed



Gnetum

- Characteristic Features of Gnetum
- Most Species are climbers except few being shrubs & trees
- Branches 2 types: Branches of limited growth Branches of unlimited growth
- Climbing Species have branches of limited growth (short shoots) and unbranched with foliage leaves.

- Leaves: Dicot like large & oval with entire margins 9-10 in pairs arranged in decussate fashion with reticulate venation.

Leaf Anatomy

- Internally, Gnetum leaves also resemble with a dicot leaf. It is bounded by a layer of thickly circularized epidermis on both the surfaces. Stomata are distributed all over the lower surface except on the veins. The mesophyll is differentiated generally into a single-layered palisade and a well-developed spongy parenchyma. The latter consists of many loosely packed cells. Many stellately branched sclereids are present near the lower epidermis in the spongy parenchyma. Many stone cells and latex tubes are present in the midrib region of the leaf.
- Several vascular bundles in the form of an arch or curve are present in the prominent midrib region. A ring of thick-walled stone cells is present just outside the phloem. Each vascular bundle is conjoint and collateral. The xylem of each vascular bundle faces towards the upper surface while the phloem faces towards the lower surface. The xylem consists of tracheids, vessels and xylem parenchyma while the phloem consists of sieve cells and phloem parenchyma.

Male Cone and Male Flower

- The male flowers are arranged in definite rings above each collar on the nodes of the axis of male cone. The number of rings varies between 3-6. The male flowers in the rings are arranged alternately. There is a ring of abortive ovules or imperfect female flowers above the rings of male flowers. Each male flower contains two coherent bracts which form the perianth. Two unilocular anthers remain attached on a short stalk enclosed within the perianth. At maturity, when the anthers are ready for dehiscence, the stalk elongates, and the anthers come out of the perianth sheath. In Gnetum gnemon a few (2-3) flowers are sometimes seen fusing each other.

Female Cone

- The female cones resemble with the male cones except in some definite aspects. A single ring of 4-10 female flowers or ovules is present just above each collar. Only a few of the ovules develop into mature seeds. In the young condition, there is hardly any external difference between female and male cones. All the ovules are of the same size when young but later on a few of them enlarge and develop into mature seeds. All the ovules never mature into seeds. Ovule or Female Flower Each ovule consists of a nucellus surrounded of three envelopes. The nucellus consists of central mass of cells. The inner envelope elongates beyond the middle envelope to form the micropylar tube or style. The nucellus contains the female gametophyte. There is no nucellar beak in the ovule of Gnetum.

- Stomata, sclereids and laticiferous cells are present in the two outer envelopes. Madhulata (1960) observed the formation of a circular rim from the outer epidermis of the inner integument in G. gnemon. Thoday (1921), however, observed the formation of a second such rim at a higher level. The ovules in G. ula are stalked.
- Relationships of Gnetum and Other Gymnosperms: Gnetum shows several resemblances with gymnosperms and has, therefore, been finally included under this group. Some of the characteristics common in both Gnetum and other gymnosperms are under mentioned:

  1. Wood having tracheids with bordered pits.
  2. No sieve tubes and companion cells are present.
  3. Presence of naked ovules.
  4. Absence of fruit formation because of the absence of ovary.
  5. Anemophilous type of pollination.
  6. Development of prothallial cell.
  7. Cleavage polyembryony.
  8. Resemblance of the vascular supply of the peduncle of the cone of Cycadeoidea wielandii with that of a single flower of Gnetum.
  9. Resemblance of the structure of basal part of the ovule in Gnetum and Bennettites.

<u>Gnetum and Angiosperms:</u>

- A key position to Gnetum has been assigned by scientists while discussing the origin of angiosperms. Both Gnetales and angiosperms originated from a common stalk called “Hemiangiosperm”. Thompson (1916) opined that the ancestors of both Gnetum and angiosperms were close relatives. Some other workers have gone up to the extent in stating that Gnetum actually belongs to angiosperms. Hagerup (1934) has shown a close relationship between Gnetales and Piperaceae. In a beautiful monograph on Gnetum, Maheshwari and Vasil (1961) have stated that “Gnetum remains largely a phylogenetic puzzle.
- It is gymnospermous but possesses some strong angiospermic features”.
- Some of the resemblances between Gnetum and angiosperms are under mentioned:

  1. The general habit of the sporophyte of many species of Gnetum resembles with angiosperms.
  2. Reticulate venation in the leaves of Gnetum is an angiospermic character.

3. Presence of vessels in xylem is again an angiospermic character.

4. Clear tunica and corpus configuration of shoot apices is a character of both Gnetum and angiosperms.

5. Strobili of Gnetum resemble much more with angiosperms than any of the gymnosperms

6. Micropylar tube of Gnetales can be compared with the style of the angiosperms because both perform more or less similar functions.

7. Tetrasporic development of the female gametophyte is again a character which brings Gnetum close to angiosperms.

8. Absence of archegonia again brings Gnetum and angiosperms much closer.

9. Dicotyledonous nature of the embryo of Gnetum brings it quite close to the dicotyledons.

- Resemblances Between Gnetum, Ephedra and Welwitschia: All the three genera of Gnetales show following resemblances:

(1) Opposite leaves;

(2) Vessels in their secondary wood,

(3) Similar structure and development of perforation plates in their vessels;

(4) Similar Gnetalean mode of development of their vessels i.e. by the dissolution of torus and middle lamella of the bordered pits;

(5) Almost similar structure of their sieve cells and phloem parenchyma;

(6) Spiral or annular elements in their protoxylem;

(7) Arrangement of their flowers in compound strobili;

(8) Unisexual flowers;

(9) Dioecious plants;

(10) Stalked male flowers bearing synangia made of 1-6 or more sporangia;

(11) Almost consistent structure of the wall of their microsporangia;

(12) Wingless pollen grains;

(13) Orthotropous ovules;

(14) Ovules surrounded by several envelopes which are interpreted variously as integuments or perianth;

(15) Extremely elongated micropylar tube;

(16) Formation of unicellular primary suspensors;

(17) Dicotyledonous embryo; (18) Simple type of polyembryony

PALEOBOTANY

WHAT IS PALEOBOTANY?

- Humans are by nature curious, and we are all interested in the Earth on which we live and how various aspects have changed through geologic time.
- It is natural to wonder about prehistoric life—how these organisms lived, what their patterns of behavior were, and even why they became extinct.
- The paleobotanist is a plant historian who attempts to piece together the intricate and complicated picture of the history of the plant kingdom.
- Fossil plants and floras from one period of geologic time are different in size and shape, level of complexity, and abundance from those of other time periods.
- The most logical explanation for these differences is that the types of plants **changed**, or **evolved**, through geologic time.
- By studying the record of fossil plants, it is possible to assess the time at which various major groups originated, the time each reached its maximum diversity, and, in the case of certain groups, when they became extinct

Objectives of Paleobotany

- One of the aspects of paleobotany, which makes it unusual and interesting, is that it is and can be approached from inherently interdisciplinary either a biological or a more geological perspective—or both together.
- Each perspective presents a variety of questions that are unique to that discipline.

Fossils

- Fossils are perserved remains or traces of living things.
- Fossils normally form in sedimentary rock.
- Hard parts are the only parts of an organism that leaves a fossil.
- Examples: Bones, shells, teeth, seeds, and woody stems.

FIVE types of Fossils Found in Rock are:

- 1. Molds
- 2. Casts
- 3. Petrified Fossils
- 4. Carbon Films
- 5. Trace Fossils

Environments for Fossil Formation

- Other fossils may be found in tar, amber, or ice.
- Large beds of sedimentary rocks indicate a former marine or aquatic/semi-aquatic environment
- Sedimentary rocks form when sediments (sand, silt, mud) are hardened into stone as the environment changed in response to changes in climate or geography.
- The presence of fossils in sedimentary rocks indicate that the past environment supported life.

Types of fossils

Chemical Fossils

- These are the remnants of organic compounds p reserved in sediments or in parts of fossilised structures without undergoing any or minimal change. These include amino acids, hydrocarbons, fatty acids, lipids, carbohydrates and the derivatives of other organic compounds.
- The chemical composition of Pre-Cambrian rocks is an important criterion to establish the biogenicity of putative unicellular or multicellular organisms present in Pre- Cambrian rocks. The existence of insoluble kerogen is used as proof of biogenicity. Similarly, the occurrence of pristane and phytane, degradable products of chlorophyll molecule, may be used as proof of photosynthesis.

Trace Fossils or Ichnofossils:

- Sometimes, indications of prior existence of organisms in the sediments of earth may be regarded as trace fossils or Ichnofossils. These include animal tracks or foot print preserved in rocks, burrows of invertebrates, coprolites (fossil excretes), gastroliths (polished stones in the abdomen of dinosaurs), gnawed bones, etc.

Microfossils:

- Microscopic organisms like bacteria, spores and pollen grains, fungal and algal spores, foraminifera, diatoms, epidermal and wood fragments of plants etc. preserved in the sedimentary deposits are referred to as microfossils. Microfossils are visible only after maceration of sediments.

Megafossils:

- Large parts of plants like leaf, stem, root, flower, seed, etc. and animal remains as whole organism or in parts, preserved in the sedimentary deposits are called megafossils. These are visible to naked eyes and are the better source of morphological as well as anatomical studies.

- The megafossils may be categorised into the following **types** on the basis of the nature of fossilisation:

Compressions:

- These are plant parts, compressed by the vertical pressure of the sediments. The plant fragments like leaves, stem, seeds get flattened and are retained as thin carbonaceous films with outline of external features.
- Generally, internal structure is not preserved, however, in rare instances cuticles, stomate, etc. are retained.

Impressions:

- Impression may be defined as the negative of a compression. These are just impression of plant parts which do not contain organic matters as in compression. The sediments containing the flattened plant parts become hardened and when split open shows the negative imprint i.e. impression.

Petrifactions:

- These are the best, but rarest types of fossil which preserve the external form as well as the internal structures. The cellular details are preserved due to the infiltration of minerals like SiO_2, $CaCO_3$, $MgCO_3$, FeS, etc. into the tissue. The petrified fossils can be cut into small pieces and series of section can be made for anatomical studies.

Casts or Incrustations and Molds:

- In these types, the deposition of iron and carbonate minerals occurs in the form of a hard cast around the plant parts. The internal structure is degraded to form a cavity which is completely filled up by the surrounding sediments. Thus, the external preserved surface of the plant part is called a mold (Fig. 1.86), while the replaced internal structure of the plant part is called a cast.
- Stigmarian root system is an example of mold, while the pith cast of a Catamites stem is a common example of incrustation. In these types, only external forms are preserved, while internal cellular details are not preserved.

Sub-Fossils:

- A certain time period is required for the formation of a fossil. If the plant or animal parts are excavated before they completed their fossilisation process, they are called sub-fossils. Coal is a compressed fossil, while peat, an early stage of coalification is referred to as sub-fossil.

Pseudofossils:

- Sometimes inorganic rocks that appear to be fossils are actually mineral deposition. These fake structures are mistaken for plant or animal remains. These are known as pseudofossils.

Derived Fossils:

- The fossilised organisms that held in a stratum younger or older than the fossil themselves are called derived fossils. These are results of tectonic movement of earth or other geological upheaval.

Coal Balls:

- The petrified spherical balls containing plant parts are commonly termed coal balls. These spherical balls are formed as a result of infiltration of plant debris in swamps by carbonates of calcium or magnesium, thus restricting the conversion of the debris into coal. Coal balls occur in localised regions and they range in few centimeters to several meters and weigh from a few to several pounds. Coal balls are specifically significant in palaeobotanical studies.

Paper Coal:

- It consists of thin dead leaves, dispersed in organic matrix. The inner tissues of leaves are destroyed, thus the paper coal consists of layer after layer of cuticles, often with decomposed stems. The carbonaceous lime stone horizon at Tovarkovo, in Toula in Russia, is an example of paper coal.

Amber:

- The fossilised resin of extinct coniferous trees, Pinus succinifera in particular, is called Amber. The resinous exude flowed due to injury caused by boring insects which eventually accumulated on the forest floor and got hardened forming amber. Insects and flowers are often found preserved in amber. Amber has high economic value and used in jewelllery.

Index Fossils:

- The organisms that help in dating other fossils found in the same sedimentary layer are called index fossils. Such fossils are found widely distributed geographically, and limited in time span having very distinct characteristic features. Monograptus is an index fossil of Lower Devonian, while Myrepollenites is a marker of Eocene. Foraminifera, pollen grains, spores etc. are also used as index fossils.

Nomenclature of Fossils:

- The whole plant is not preserved, but only detached plant parts like stem, root, cone, leaf, etc. are preserved as fossils. These detached plant parts are being discovered in different times by different authors. Thus, these detached plant parts or organs are given a bionomial (generic and specific name) by the same set of rules under the International Rules of Botanical Nomenclature which have been framed for living plants.
- The first valid description of Lepidodendron came into existence from the publication of Sternberg in 1820. Thus, this date has been considered as the starting point of palaeobotanical nomenclature like that of Linnaeus's 'Species Plantarum' in 1753 for the nomenclature of modern vascular plants.
- Each detached organs or fragments is given a different name. Each of these names acquires the status of a genus. The generic name in fossils is applicable for only a plant part like root, stem, leaf, cone or other organ, without indicating to what plant it belongs. Thus, the genus is termed form genus or artificial genus in contrast to natural genus for living plants.
- A form genus cannot reliably be assigned to a single family, however, it may be assigned to an order or other higher taxonomic rank. For example, Stigmaria is a form genus of the order Lepidodendrales which cannot be assigned to any one of the three families: Lepidodendraceae, Sigillariaceae or Bothrodendraceae.
- When the relationships among different organs like stem, root, leaf and reproductive structures are established and can be assigned to the same family, then the genera can be called organ genera. For example, stem genus Bucklandia, leaf genus Ptilophyllum, male fructification Weltrichia and female fructification Williamsonia are genetically related and assigned to the same family Williamsoniaceae. Thus, all are considered to be organ genera. However, there is no provision in the International Rules of Botanical Nomenclature for the use of organ genera.
- During reconstruction, the palaeobotanists should select the earliest (after 1820) validly published generic name applied to any one of its parts as per Rule of Priority. He or she will use any one of the form genera as the generic name for the whole organism. Say, for example, the validly published female fructification, Williamsonia has been used for naming the whole plant.
- Rules for naming form genera: A particular suffix is used for naming a form genus which signifies the organ it belongs.

Suffix	Applied to organ	Examples
Dendron	Stem	*Lepidodendron, Lyginodendron.*
Xylon	Woody part	*Dadoxylon, Cordaixylon, Mesoxylon.*
Phyllum	Leaf	*Ptilophyllum, Nipaniophyllum, Brachyphyllum*
Pteris	Fern-like stem or frond	*Sphenopteris, Lyginopteris, Etapteris, Archaeopteris*
Spermum	Seed	*Corystospermum, Mitrospermum*
Carpon	Seed or seed like	*Lepidocarpon, Mazocarpon, Calamocarpon*
Carpus	seed	*Trigonocarpus, Cardiocarpus*
Stoma	seed	*Lagenostoma, Stamnostoma*
Theca	Microsporangia	*Codonotheca, Aulacotheca, Crossotheca*
Strobus	Cone	*Lepidostrobus, Androstrobus*

Phytogeography

Phytogeography (from Greek *phytón* = "plant" and *geographía* = "geography" meaning also distribution) or **botanical geography** is the branch of biogeography that is concerned with the geographic distribution of plant species and their influence on the earth's surface. Phytogeography is concerned with all aspects of plant distribution, from the controls on the distribution of individual species ranges (at both large and small scales, see species distribution) to the factors that govern the composition of entire communities and floras.

Phytogeography, Climate, Vegetation and Botanical Zones of India

According to Campbell (1926), the main theme of plant geography is to discover the similarities and diversities in the plants and floras of the present and past found in widely separated parts of the earth.

Wulff (1943) states that Phytogeography is the study of distribution of plant species in their habitats and elucidation of origin and history of development of floras.

According to Croizat (1952), Phytogeography is the study of migration and evolution of plants in time and space.

Distribution:
On the basis of area of the earth surface occupied by the plants, the various taxa are categorized as under:
1. Wides.

2. Endemics.

3. Discontinuous species.

1. Wides:
Plants widely distributed over the earth in definite climatic zones and the different continents are referred to as wides. Cosmopolitan is applied for wides but, in fact, no plant is cosmopolitan in real sense of the term. Taraxacum officinale and Chaenopodium album are the common examples of the wides. Plants of tropical regions are called Pantropical. The plants of very cold climate may not only be found in the arctic regions but also in alpine zone of mountains in tropical and subtropical regions. These are called arctic-alpine plants.

2. Endemics:
A taxon whose distribution is confined to a given area is said to be endemic to that area. The taxon may be of any rank, although it is usually at a family level or below, and its range of distribution may be wide, spanning an entire continent, or very narrow covering only a few square metres. The concept of endemism is important because in the past the formulation of biogeographic regions was based on it.

The limits of a region are determined by mapping the distributions of taxa; where the outer boundaries of many taxa occur, a line delimiting? a biogeographic region is drawn. Major regions are still determined as those that have the most endemics or stated another way, those that share the fewest taxa with other regions. As regions are further broken down into subdivisions, they will contain fewer unique taxa.

This has been criticized because it assumes that species ranges are stable, which they are not. An alternative method of determining biogeographic regions involves calculating degrees of similarity between geographic regions. The concept of endemic distribution of plants was put forth by A.P. de Candolle (1813). Engler (1882) suggested two categories of endemic forms; Palaeo-endemics which are survivors of ancient forms and indigenous or native forms which are confined to a particular ocahty. According to area of distribution, the species may be continental endemics (restricted to a continent, endemic to a country, provincial, regional or local endemics (restricted to valley, hills, islands, etc.).

Now the endemic species have been grouped into the following categories:
(i) Relics or Palaeoendemics:
They are the survivors of once widely distributed ancestral forms, for example, Ginkgo biloba (restricted to China and Japan), Sequoia sempervirens (confined to coastal valleys of California, U.S.A.). Agathis australis, Metasequoia (Confined to Single valley in China). These species are called Palaeoendemics or epibionts. A great majority of the endemic species belonging to this type have many fossil relatives. They are also called living fossils. Because of little variability the endemics are adapted only to a particular environment and even if they reach new areas, they fail to establish themselves in new environment.

(ii) Neoendemics:
The other endemics may be modem species which have had not enough time for occupying a large area through migration. They are called neoendemics. There are several such genera which are widely endemic or few species of which are endemic. Neoendemics show good variability and have many biotypes, grow in diverse habitats and have wide tolerance for habitats.

Some of the well known endemic genera in Indian flora are Mecanopsis (Papaveraceae) Chloroxylon swietenia (Flindersiaceae, formerly Rutaceae). Catenaria and Butea (Papilionaceae) Caesulia (Compositae), Petalidium (Acanthaceae), etc. Eletteria repens (Zingiberaceae) Piper longum (Piperaceae), Piper nigrum (Piperaceae), Ficus religiosa (Moraceae), Shorea robusta (Dipterocarpaceae), Venda caerulea (Orchidaceae), Salmalia malabarica (Bombacaceae) Eleusine coracana (Grammeae) are the well known endemic species of Indian flora.

There are some special terms to designate the quality of these endemics, viz. Local endemics which are found in small land features, progressive endemics which tend to spread with time retrogressive endemics in which case the area of distribution is contracting and micro-endemics (i.e., the endemics of lower groups).

Pseudo endemics:
These endemics arise due to mutation in existing population at a particular place. These pseudo endemics or mutants may or may not persist for long in the particular area where they originate. Endemism results from the failure on the part of species to disseminate its seeds fruits spores or propagules because of existence of great barriers like mountains, oceans and large deserts. The oceanic islands which are isolated from rest of the world by large expanses of water abound in endemic species and water barrier checks the migration of those species outside their original habitat.

3. Discontinuous Distribution:
When plants occur at two or more distant places of the world which are separated by overland's or oceans hundreds or thousands of kilometres apart. Such a distribution is called discontinuous or disjunct distribution. Three genera Nothofagus, Jovellona and a for example are found in parts of South America, South Africa and Australia which are
-paraded by vast oceans.

The significant phytogeographical causes for discontinuous distribution are as follows:
(i) The species might have evolved at more than one place and they failed to migrate outside their original habitats because of barriers.

(ii) The species which were once widely distributed in the past disappeared from certain areas and are now surviving in some distant pockets.

(iii) The climate may also be a factor for discontinuity in distribution of species. Plants having specific climatic requirements are found in widely separated areas with similar environmental conditions, as for example, plants of arctic regions are also found in alpine zone of high mountains in tropics and subtropics. Salix and Silen species show discontinuous distribution in arctic-alpine regions.

Theories of Discontinuous Distribution:

1. Theory of Land Bridge:

According to this theory, land bridges occurring in between the separated continents are believed to have helped in the migration of various taxa from one continent to the other. Uniform distribution of plants and animals in different parts of the world during Palaeozoic era is believed to have been due to those land bridges. With the passage of time the land bridges became submerged in sea and the connections between the various continents snapped beyond the dispersal capacity of organisms resulting thereby the discontinuity in the distribution.

2. Theory of Continental drift:

The theory of continental drift was propounded by Wegner (1912 1924) According to him the whole land- mass of the world was a single super continent during Palaeozoic era. He named it as Pangaea. That super continent was surrounded by sea on all the sides which was named Panthalassa. During Mesozoic, Pangaea split up into two large landmasses; Laurasia in the north and Gondwanaland in south.

The two landmasses were separated by Tethys Sea. Du Toit (1937), however, suggested that Laurasia and Gondwanaland existed from the very beginning. The two large landmasses having characteristic flora and fauna broke up into new landmasses called continents. Laurasia gave rise to Eurasia, Greenland and North America and similarly Gondwanaland gave rise to South America, Africa, India, and Polynesia, Australia Antarctica etc.

About 135 million years ago reorientation of continents began. The continents were drifted apart by the oceans. This is called Continental Drift. The occurrence of Dinosaurs and many fossil plants lend support to the existence of Laurasia and Gondwanaland. With the separation of continents the distribution areas of several plant and animal species got separated and gave rise to discontinuous distribution areas.

Factors Affecting Distribution of Species:

Several factors are known to affect the geographical distribution of plant species, some of which are as follows:

1. Geological history and distribution,

2. Migration, and

3. Ecological amplitude.

1. Geological history and distribution:

The place where a species first originated is called its centre of origin. Evolution of species is a slow but continuous process. Some of the species in present day flora are quite old while a great majority of them are recent in origin.

The process of species differentiation involves:

(i) Hybridization between the related species as well as mutation and

(ii) The natural selection of the hybrid and mutant populations.

In the selection process not all the hybrids and mutants are selected by nature and only the fittest individuals which find the habitat conditions within their ecological amplitudes are selected and the individuals least fit are eliminated. Changing climate has also played important role in the origin of new species. In the course of evolution several old species became extinct, some of which can be found even today as fossils. The fossils provide direct evidence for the existence of various taxa in the past.

Age and Area Hypothesis:

This hypothesis was proposed by J. W. Willis (1915) on the basis of his extensive studies of geographical distribution of certain plant species in tropics. On the basis of his findings Willis postulated that the species which evolved earlier occupy greater areas than those which appeared later in the evolutionary sequence. According to this hypothesis, the frequency of a species over an area is directly proportional to its age in scale of evolution and age of species is directly related with the area of its distribution.

Thus a small area of distribution of a species will indicate its relative young age. Willis has quoted several examples such as Impatiens, Primula, Gentiana, Rhododendron in support of his hypothesis. Genus Coleus may be quoted here as an example in support of this hypothesis. There are two species of Coleus namely C. elongatus and C. barbatus.

The former species is endemic while the latter is widely distributed. On the basis of areas under distribution of these species Willis considered C. elongatus less evolved and derived from C barbalins. Willis has also pointed out that the majority of endemics are found to be members of large and successful genera. The age and area hypothesis, however, is not universal and it has been criticized by many.

2. Migration:

The newly evolved species starts migration to new areas and side by side it undergoes further evolutionary changes. The dispersal of germules and propagules is brought about by several agencies like wind, water, glaciers, insects, animals, even man. The dispersal is followed by ecasis. Migration may be adversely affected and sometimes even totally stopped by some factors called migration barriers. Barriers in the dispersal of species may be classified as ecological or environmental and geographical.

The climate, an ecological barrier, plays important role in distribution and establishment of species. Unsuitable climatic condition or change of climate in particular area forces the species to migrate from one place to another and the failure of some species to migration leads them to gradual extinction. Besides climate, there are geographical barriers, as for example, high mountains, vast oceans or deserts.

The fresh water plants, for example, cannot be dispersed across oceans if their propagules are suitable only for fresh water dispersal and similarly germules or propagules of land plants from one country cannot reach other country separated by vast oceans and mountains. Species are called natives of the place of occurrence if they originated there. Outside the area of its origin, the species is referred to as exotic. Exotic species reach new area through migration. If any species is introduced intentionally in new area by man then it is called introduced species.

3. Ecological amplitudes and distribution:

Environmental conditions not only influence the life and development of plants but also determine the presence or absence, vigour or weakness and relative success or failure of various plants in a particular habitat. Each plant species of a community has a definite range of tolerance towards physical and biological environment of the habitat. This is referred to as ecological amplitude. The presence of species at a particular place, no doubt, indicates that the environmental conditions of that habitat are within its ecological amplitude but the absence of a species from one place does not necessarily indicate that the environment is not suitable for that species.

The ecological amplitude is governed by genetic set up of the species concerned and thus different species have different ecological amplitudes which may sometimes overlap only in certain respects. Further, some species may occur at different geographical regions as and when the conditions fall within their ecological amplitudes. As for example, some plants of temperate region say conifers, may also be found in alpine zone of high mountains in tropical and subtropical regions.

The other consideration in ecological amplitude as a factor in plant distribution is its change with time. In sexually reproducing plants the hybridization between related species results in offspring's with new genetic composition. With the change of environment the plant species also make adjustments with new environment by shifts in their ecological amplitudes facilitated by changes in the genotype. Within a species there may occur several genetically different groups of individuals (populations) which are adjusted to particular set of ecological conditions.

These populations are called ecotypes or ecological races or ecological populations. In Euphorbia thymifolia, for example, there are two major populations-one is calcium loving or calcicole and the other type is calcium hating or calcifuge. Similarly ecological races of Xanthium strumarium and Ageratum conyzoides differ in the photoperiodic requirements. The existence of ecotypes within the species widens the area of its geographical distribution.

Botanical Zones of India

Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors.

The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.

India has been divided into the following botanical zones by D. Chatterjee (1962) Fig. 11.4:

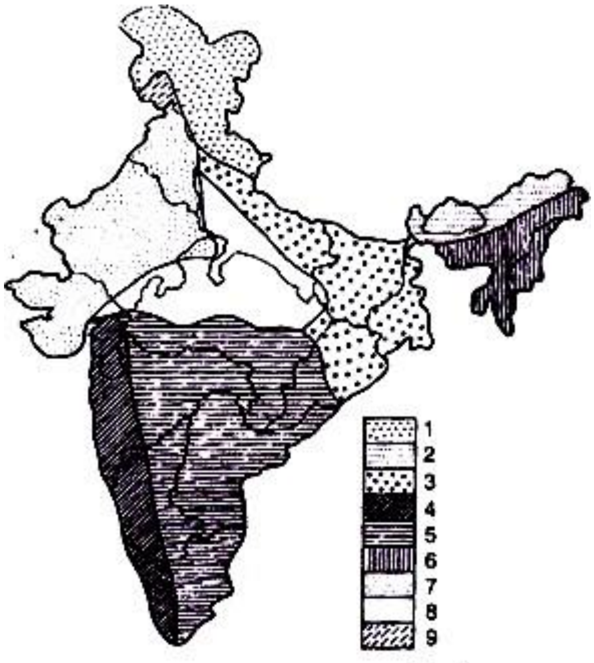


Fig. 11.4. Botanical zones of India.

(1) Western Himalayas,

(2) Eastern Himalayas,

(3) Indus plain,

(4) Gangetic plain,

(5) Central India,

(6) Deccan,

(7) Western coasts of Malabar,

(8) Assam, and

(9) Bay Islands of Andaman and Nicobar.

1. Western Himalayas:
The northern part of our country is bounded by highest ranges of Himalayas and is one of the important botanical regions of the world with climate and vegetation ranging from truly tropical near the low altitudes to temperate arctic types at the high altitudes. The northern mountain division can phytogeographically be divided into western, central and eastern zones.

Western Himalayas consist of north Kashmir, south Kashmir, a part of Punjab, H.P., Garhwal and Kumaon. This zone is wet in outer southern ranges and slightly dry in inner northern zone. The average annual rainfall in this region is from 100 to 200 cm. Snowfall occurs in this region during winter season. The region may be divided into three subzones (Fig. 11.5).

(i) Submontane zone or lower region or tropical and subtropical belts (up to about 1500 metres altitude from the sea level).

(ii) Temperate zone (from 1500 metres to 3500 metres altitude),

(iii) Alpine zone (above 3500 metres and up to the line of perpetual snow).

(i) Submontane or lower region or tropical and subtropical belts:
It includes outer Himalayas, particularlyregion of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 and 1500 metres above sea level. In this zone, forests dominated by timber trees of Shorea robusta are common. Other important tree species are Salmalia malabaricum, Butea monosperma. Acacia catachu and Zizyphus species.

In the swampy areas, Dalbergia sisso (Shisham), Ficus glomerata, Eugenia jambolana are of common occurrence. In west dry regions sal trees are replaced by xeric plants particularly Zizyphus, Carissa, Acacia, and thorny Euphorbias. At higher elevation, around 1000 to 1500 metre altitude, cheer (pine) forests are also found at certain places. The common species of pine are Pinus longifolia and Pinus roxburghii. Ground vegetation is scanty.

(ii) Temperate zone:
It commonly ranges at the altitudes from 1500 to 3500 metres above the sea level. Oaks are dominant along with Populus, Rhododendron, Betula and Pyrus. Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus and Taxus baccata are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are Ranunculus hirtila, Polygonum, Pedicularia, Potentilla argyrophylla. Primula, Delphinium, Clematis, crucifers and many members of asteraceae.

In cultivated drylands of Punjab, wheat and barley are main crops. In Kashmir, Betula (birch), Salix (cane), Populus (poplar) are of common occurrence. Besides these, Quercus semicarpifolia, Q. dilatata, Aesculus indica (chestnut) and many conifers are commonly met within this region. In west Kashmir rice cultivation is common Sar or saffron (Crocus sativus), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

(iii) Alpine zone:
Above the altitude of 3500 metres and up to snowline (about 5000 m) is alpine zone. The vegetation consists of evergreen conifers and some low and broad leaved trees. The vegetation of this region is characterized by cushion habit, dwarf nature and gregarious habit. In lower alpine region, shrubby forests are common which may be (a) Birch—fir forest which is fairly dense and is mixed with evergreen shrubby Rhododendron at higher level and (b) Birch— Rhododendron forests in which silver fir, Betula, Rhododendron and Juniperus are common. In the upper alpine region, prominent herbaceous plants are the species of Primula, Polygonum, Gentiana, Cassiope, Meconopsis, Saxifraga, Potentilla, Geranium, Aster, Astragalus etc. which form alpine meadows. At about 5000 metre altitude and above snow perpetuates round the year and plant growth is almost nil. This altitude is called snow line or ice line.

Populations of Draba, Braya, Cortia, Leontopodium go on increasing with the increase in altitude. Species of Ephedra, Juniperus, Berberis are also found scattered. Poa, Stipa and Fectuca are common grasses of alpine zone.

2. Eastern Himalayas:
Eastern Himalayas extend from Sikkim to upper Assam, Darjeeling and NEFA. Vegetation of this region differs from that of western Himalayas. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humidity.

This region can also be divided into:
(i) Tropical submontane zone

(ii) Temperate or Montane zone, and

(iii) Alpine zone

(i) Tropical or Submontane Zone:
The tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of about 1800 m. In this zone mostly sal forests, and mixed deciduous forests consisting of important plants, such as Sterculia, Terminalia Anthocephalus cadamba and Bauhinia are common. In the savannah forests, common plants are Albezzia procera, Bischofia, Salmelia, Dendrocalamus. Evergreen forests of Dillenia indica, Michelia champaca, Echinocarpus, Cinnamon, etc. are common.

(ii) Temperate or Montane Zone:
It may be further divided into upper and lower zones Lower temperate zone is the region between 1800 and 3000 metre altitudes. In the lower temperate zone, Oaks (Quercus). Michelia, Pyrus, Cedrela, Eugenia, Echinocarpus are common plants. In upper temperate zone (3000-4000 metre altitude), conifers and Rhododendrons are common. Important conifers of this region are Picea spinulosa, Abies, Larix, Juniperus, Tsuga griffithi, Tsuga brunoniana, etc.

(iii) Alpine Zone (from 4000 metres up to snow line):
Climate is humid and extremely cold. The vegetation in the alpine zone is characterised by complete absence of trees and predominance of shrubs and meadows. Important plants of this zone are Rhododendron and Juniperus. Eastern Himalayan vegetation is considered to be one of the richest vegetational units in the world and consists of several species of plants

which are native of foreign countries, such as, China, Japan, Burma, Malaya and European countries.

3. Indus Plains:

It includes part of Punjab, Rajasthan, Cutch, Delhi, a part of Gujarat. Some part of this plain is now in Pakistan. The climate of this zone is characterised by dry hot summer, and dry cold winter. Rainfall is usually less than 70 cms, but in certain regions it is as low as 10-15 cms. The soil of a wide area except cultivated land, is saline. Much of the land has become desert due to excessive dryness.

Vegetation is mainly bushy and thorny Acacia arabica, Prosopis spicigera, Salvadora Capparis decidua are very common plants of this region. Salsola phoetida and Lunakh grass are found mostly in saline soils. Other plants of this botanic province are Anageissus, Eugenia, Mango, Dalbergia sisso, Albizzia lebbek, Zizyphus nummularia, etc.

Historical evidences indicate that the area was covered by dense forest some 2000 years ago, but gradual destruction of vegetation cover either by biotic agencies or by any other agency led to the development of desert in this plain. Saccharum munja, Cenchrus ciliaris, Prosopis spicigera. Acacia leucophloea, A. Senegal are the important plant species which are grown for checking the spread of desert.

4. Gangetic Plains:

This is one of the richest vegetational zones in India. This zone covers flat land of a part of Delhi, whole of U.P., Bihar, and West Bengal and also a part of Orissa. Rainfall in this zone is from 50 cm to 150 cm. A great part of the land is under cultivation. The common crop plants are wheat, barley maize. Sorghum (jowar), Bajra, urad, Moong (Phaseolus mungo), Cajanus cajan, til (Sesamum indicum), sugarcane. Pea (Pisum sp.), gram (Cicer arietinum), potato, Brassica, rice.

In western part of U.P. annual rainfall is from 50 cm to 110 cm. Dry deciduous and shrubby forests are common in this part. Important plants of south-western part of U.P. are Capparis, Saccharum munja, Acacia arabica. In the north-western part of U.P. near Himalayas foothills Dalbergia sisso. Acacia arabica are most common plants.

In eastern gangetic plain, the conditions are cold and wet (annual rainfall, 150 cm in West Bengal). In this part evergreen forests are common. In central part, the annual rainfall is about 100 cm to 150 cm. The vegetation consists mainly of deciduous trees. Sal trees are dominant. Other common trees are Terminalia tomentosa, T. belerica. Acacia species, Bauhinia, Diospiros (Biri Ka patta or tendu) Eugenia sp., neem trees (margosa), Madhuca indica (Mahua), Cordia myxa (Lasora), Tamarindus, Mango (Mangifera indica). Ficus etc.

In Bihar and Orissa hills, Rubus, Potentilla, Fragaria (Rosaceae), Pyrus etc. are common. Mangrove vegetation is common in tidal regions in West Bengal near Sunder-ban, and Orissa. Rhizophora mucronata, R. conjugata,

Sonneratia, Ceriops roxburghiana and Acanthus ilicifolius, Kandelia rheedii, Bruguiera gymnorhiza are common mangrove plants in those regions.

5. Central India:

Central India covers Madhya Pradesh, part of Orissa (now Odisha), Gujarat and Vindhya. The areas are hilly. The average rainfall per annum may be 100-170 cm. Some places are at the altitudes of 500-700 m from the sea level. Biotic disturbances are very common in this botanical province which have led to the development of the thorny vegetation in open areas. In this region teak (Tectona grandis) and sal (shorea robusta) forests are very common. Other trees are Terminalia tomentosa, Bauhinia, Mango, Phyllanthus, Ficus glomerata, etc. Among common shrubs are Mimosa rubricaulis, Desmodium, Acacia sp., Zizyphus rotundifolia and other.

Entire forest vegetation of central India may be divided into:
(i) Sal forests

(ii) Mixed deciduous forests

(iii) Thorny forests.

At Sarguja (M.P.) many species have been reported to occur. Some of them are Pyrus, Barberis asiatica, Rubus, elipticus, etc.

6. Deccan:
This region comprises whole of the southern peninsular India including Satpura and southern part of Godawari River. Average annual rainfall in this region is about 100 cm.

It may be divided into the following two subdivisions:
(i) Deccan plateau

(ii) Coromandel coast.

In Deccan plateau teak forests containing Diospiros, Acacia, Prosopis spicigera. Santalum a hum (chandan tree) and Cedrda toona are common. On rocks, Capparis, Euphorbias, Phyllunthus are common. Teak, Pterocarpus, Borassus, Foenix silvestris are also common in this area In Chhota Nagpur plateau, important species are Clematis natans, Barberis, Thallictrum and also many members of Annonaceae, Rosaceae, Compositae, Araliaceae, Apocynaceae, Lauraceae, Amaranthaceae, Orchidaceae. Some ferns also common.

In Coromandel coast vegetation consists largely of some halophytic species.

7. Western Coast of Malabar:
This is small botanical province covering Cape Comorin to Gujarat and Western Ghats .This is a region of heavy rainfall.

In this zone, four types of forests are common:
(i) Tropical forests (occur at 700 m altitude).

(ii) Mixed deciduous forests (found at the altitude up to 1600 m).

(iii) Temperate evergreen forests (occur above 1200 m altitude), and

(iv) Mangrove vegetation.

In tropical evergreen forest the trees are tall and they have root buttresses. Important species are Cedrela toona Dipterocarpus. Mangifera indica, Sterculia alata, Artocarpus hirsuta. In the mixed deciduous forests, important plants are Terminalia tomentosa, Terminalia peniculata Tectona grandis, Dalbergia, Lagerstroemia lanceolata and bamboo species, particularly Dendrocalamus and Bamboosa arundinacea. On the Nilgiri hills sub-tropic and temperate conditions exist. Important plants of Nilgiri vegetation are Rubus, Rhododendron arboreum, Barberis, Thallictrum Ranunculus, Fragaria, Potentilla. Many other herbs along with many grasses are also common.

Temperate forests commonly called as “sholas” contain Gardenia obtusa, Michelia nilgirica Eugenia species are also common. In Malabar, plants belonging to family Dipterocarpaceae' Tihaceae, Anacardiaceae, Meliaceae, Myrtaceae, Piperaceae, Orchidaceae and many ferns are common. The west coast of Malabar region receives very high rainfall. In the coastal region mangrove plants grow luxuriantly.

8. Assam:

This botanical province is very rich in vegetation and covers valley of Brahmaputra, Naga hills and Manipur. This is the region of heaviest rainfall. Cherapunji is one of the rainiest place in the world where annual rainfall often exceeds 1000 cm. Excessive wetness and high temperature in this zone are responsible for the development of dense forests. Broad leaved, tall evergreen angiosperms and some conifers are very common in the forests.

Common plants occurring in this region are Ficus, Artocarpus, Michelia champaca, Sterculia alata. Morus species. Besides these bamboos canes, climbers, and green bushes are also common. Prominent plants in the northern forests of this zone are Alnus nepalensis, Betula. Rhododendron arboreum. Magnolia, Michelia and Prunus. Sal also occurs at Garo hills. Orchids and fern species are very rich in this zone.

9. Bay Islands of Andaman and Nicobar (India):

Islands:

These are represented by the Andaman and Nicobar islands in the east and Lakshadweep islands in the west. The Andaman and Nicobar islands are a group of more than 300 islands, which support many characteristic plants and animals. The forests range from tropical evergreen to moist deciduous and even mangroves. The Lakshadweep group of islands comprise 36 major Islands, which together from an area of 32 sq km. Many varied marine fauna are present here that include turtles, crabs, molluscs and fishes. Beautiful coral reefs are also present in this part of India.

These bay islands represent elevated portions of submarine mountains. Climate is humid in the coastal region. In Andaman, beech forests, evergreen forests, semi-evergreen forests deciduous forests and mangrove vegetation are of common occurrence. Rhizophora Mimusops, Calophyllum, etc. are common plants in mangrove vegetation. In the interior evergreen forests tall trees are common. Important species of trees are Calophyllum, Dipterocarpus, Lagerstroermia and Terminalia etc. Some part is under cultivation. The important crops are paddy and sugarcane.

EVOLUTION

ORIGIN OF LIFE

The term 'evolution' can be defined as "the changes in the genetic composition of a population with the passage of each generation." The outcome of the evolutionary process is an adaptation of an organism to its environment. The evolution is the property of population and not of individuals. Natural selection is the evolutionary force.

In our solar system, there are seven major planets besides Earth. Neptune, Uranus, Saturn and Jupiter are said to be having clouds like surface bur Mercury and Venus lack water and atmosphere. The Mars which distance from earth is about 35,000,000 miles possibly has oxygen, CO_2 and water but with temperature ranging between 10^oC to freezing point. Some life has been reported to be present on Mars but still, it is a matter of debate. The life cannot exist all the time on earth because the high temperature and dry climate of the early time of earth would have made life impossible to exist. The world has its own account of the origin of life.

The earth was cast off from some molten and hot gaseous material. This mass later condensed and gradually cooled and decreased in volume. The earth acquired in the course of time a gaseous atmosphere with sufficient pressure to retain water on the surface. The water filled the deep area, which made sea and oceans. The life could appear only after the water and lands had cooled.

Ancient theories related to Origin of Life:

Special Creation Theory:-

The biblical story of the creation of world within six days was put forward by Spanish monk father Suarez. He described that the earth and heaven were created on the first day and sky on the second day. The third day the earth surface was dried and ancestors of plant and animals originated. The sun, the moon, and the stars were created on the fourth day. The birds and fishes are created on the fifth day and finally, man and beast were created on the sixth day of creation. In the end of the seventh day, a woman was constructed from the 12^{th} ribbed of the man.

Theories of spontaneous generation:-

This theory is also known as the theory of a-biogenesis. According to this theory, life has originated from the non-living organic material. Anaximander and Anaxagoras believed that life appeared in the small seed which came to earth along with rain water. Aristotle suggested that a number of animals originated in the way discussed above. A number of worms, larvae of bees, larvae of wasps, ticks, flies and many other insects develop from the morning dew or from decaying slime manure, from dry wood, hair, sweat and meat while tapeworms are born in the rotting portion of the body and excreta. Mosquitoes, flies, moths, beetles, fleas, bed-bugs and bees are generated in the slime of well, rivers or sea, in the humus of the fields, in manure, in decaying trees or fruits etc. crab and mollusks were brought to come from the moist soil and decaying slime. Some higher animals have similar origin though in the case of latter his first appearance is in the form of a worm. In fifteen century, it was thought that leaves falling from trees turned into fish if they fell in the water and turned into a bird if they fell on land.

Experimental studies

Redi’s experiments

Francesco Redi (1626-1698) was the first to put forth the experimental evidence of the concept of spontaneous generation. He placed the meat or fish in three large jars. One jar was left open, one was covered with gauze and one was covered with a muslin cloth. The meat or fish decayed in all jars and flies were attracted to all. He showed that the white maggots in the meat of the first jar were the larvae of flies and nothing else. He notices that in the second jar, worms did not appear in the meat. However, he noticed the eggs and some developing stages on the wire gauze. He, therefore, concluded that the decaying substance or soil or mud was only a place or nest for the development of the insects and that the necessary prerequisite for the appearance of the worms was laying of eggs.

Lazzaro Spallanzani disproved the theory of spontaneous generation in 1765. He boiled the meat in the sealed long-necked flask. The broth remained clear for months. No sign of life was recorded. Needham claimed that by boiling, the vital forces necessary for a spontaneous generation had driven out. Then the seal was broken and the broth was exposed to fresh air. On testing the broth, the presence of microbes proved the origin of life from preexisting life.

Louis Pasteur disproved the theory of spontaneous generation in the nineteenth century. He boiled a solution of sugar and yeast for several hours in a swan neck flask and the flask was left unsealed. The solution remained free of microbes because the swan neck flask was shaped so to trap viable microbial particles and to allow only air to enter the flask. After breaking the neck of the flask, he reported the micro-organism in the solution, thus he disproved the concept of spontaneous generation.

9.3.3- Cosmozoic Theory:-

The cosmozoic theory is also known as Panspermia theory. According to this theory, the life is distributed throughout the cosmos in the form of the resistant spores of living forms, the cosmozoa. These reached the earth accidentally from some other planet, and on getting favorable conditions for life these developed into organisms. The cosmozoic theory was proposed by Richter. According to this theory, life came from another planet in the form of celestial bodies and small particles carrying viable germs or spores, which upon reaching on earth accidently, could develop and initiate panoply of living organisms. Life only changes its form but is never created from dead substances. It has no origin and has always existed. Preyer assumed that life must have existed even at that time when the earth was a mass of molten liquid. According to him, life comes from life and never from dead material.

9.1 Modern concept of origin of life:-

A.I Oparin, published a book named "**The Origin of Life**" in 1939. In addition, several realistic theories have also been offered to explain the origin of the earth and life, but the most widely accepted theory today is known as the Big Bong theory, proposed in 1951. Before twenty billion years the universe was one big ball of neutrons or neutral particles. The movement of these particles becomes greater until the big ball generated the nearly unbelievable amount of heat. The increase in temperature caused a parallel increase in pressure. Finally, the big ball exploded and created the biggest bang ever known. Neutrons were flung everywhere. As the neutrons moved farther from their point of origin, they began to cool and produce negative charges or electron. The production of electron left behind protons and the attraction of electron to proton created hydrogen. This process continued until the newly formed particles began to aggregate into small balls. Each ball becomes a galaxy; our galaxy is the Milky Way. Within each galaxy, the process continued to form smaller balls, creating the solar system. This ball can be best thought of as clouds of gases, which astronomers call dust clouds. As time passes each dust cloud became cooler. Many dust clouds developed extremely cold temperature that hovered near absolute zero. However, as the particle of the dust cloud showed down and moved closer, heat once again was generated. The heat becomes too intense so as to cause the fusion of hydrogen, forming helium and releasing energy in the form of light and heat. The acceleration of this process caused dust clouds to throw off groups of particles, creating eddies of smaller clouds. The hot and illuminated central masses became the stars of the universe, the less hot eddies of dust radiating around them became a planet. Today these processes continued. Stars and planets are constantly being born throughout the universe while other explode and disappear into oblivion.

Our earth came into existence in five billion years ago. Earth was like other planets. It was at first a very hot molten mass of materials. However, as the mass cooled, hydrogen became the basic building block from which all other elements were made. The core of earth today is still a hot molten ball, volcanic eruptions not only demonstrate the existence of a molten core but also provide a glimpse of what the earth was like much earlier when volcanoes that dotted its surface were continually erupting.

9.1.1 Chemical Evolution:-

From monomers to polymers

First, the amino acids began to accumulate in the oceans and smaller bodies of water and they embedded into proteins and other macromolecules. Sidney Fox of the University of Miami found that heating a dry mixture of amino acids causes the formation of long proteinoids polymers having a molecular weight of more than 10,000. Fox has suggested that such polymerizations took place in volcanic cinder cones and that the proteins formed were then washed into the sea. J.B.S. Haldane and other considered it more likely that the first macromolecules were formed in sea water or pond water rather than formed dried mixtures of monomers. This too has been shown to be possible, for solutions of amino acids will form polypeptides in the presence of hydrogen cyanide even at the suitably low temperatures.

On other hand polymerizing monomers of various types and to wet and dry them, alternately, on the surface of the clay. The historical operation of this mechanism is particularly plausible from geological points of view. According to Miller, in which simple molecules were formed, many different conditions have been shown to be compatible with the formation of proteins and other polymers.

Microspheres

This is the accumulation of the biological polymers and other compounds into isolated droplets of increasing complexity. There are, in fact, several ways in which such accumulation can be accomplished in the laboratory.

Example: Fox found that his proteinoids have a remarkable tendency to form microspores approximately 2µm in diameter when hot, concentrated solution of the proteinoids is slowly cooled. These microspheres show a double layered boundary resembling a membrane and they swell and shrink as the salt concentrations in the solution is changed. If allowed to stand for several weeks, the microspores absorb more proteinoid material from the solution produce buds and sometimes divide to produce second generation microspheres. Cleavage or division can also be induced by changing pH or adding magnesium chloride. These microspheres should not be taken to be the ancestors of life.

One method for the accumulation of chemical substance into partially organized structures was proposed by the Irish physicist J.D. Bernal. This method involves some clay particles, such particles have electrical charges that attract and bind substances such as protein. Methane, ammonia and water vapour can be subjected to electrical discharge and among the products are spheres, one-quarter of a micrometer in diameter, consisting of mixtures of biological molecules bound to clay-like particles eroded from the glass of the reaction chamber.

Theory of chemical evolution

It is possible that the immediate precursors of the living organism were capsules of chemical reaction similar to coacervate droplets. Some coacervates would enclose reactions that led to the early breakup of the droplets; other would enclose reaction that made them stable. The more stable coacervates would survive longer and could possibly grow at the expense or their surroundings by absorbing chemical substances derived from the remains of the less stable droplets.

If wave action of other chemical forces broke a large coacervate into many small droplets, each of these might be able to absorb the material and grow on its own. This stage of evolution would be purely a matter of chemical competition. Any non-biological catalysts that accelerated the rate of favorable reactions in a given type of coacervate would give it a great advantage over more slowly reaction droplets. Chemical selection, therefore, would favor catalyzed reactions. It is not hard to imagine more and more efficient catalyst would be developed and retained by chemical selection until finally, the evolving system stumbled on to the ultimate improvement of protein like catalysts enzymes.

Oparin postulated the existence of organized metabolizing but non-reproducing systems that he called protobionts. According to this reasoning, the breakthrough that led to truly living organism was the development of reproduction, the ability of a successful chemical system to ensure its survival by duplicating itself. The molecules in which the instructions for duplication are stored in modern living creatures of DNA or RNA. Yet the living unit of life is not just the nucleic acid as a computer without a program, but the DNA or RNA alone can be more live than a program without a computer can also do the calculation. Any simple biological molecules released into today's environment are quickly consumed by already living things. For another, such molecules are no longer accumulating through the mechanism. Earth atmosphere has changed. Oxygen too can oxidize biological molecules. In addition, it gives rise to the ozone that filter ultraviolet from the sunlight falling on the planet. In doing so, it blocks one of the sources of energy once available for promoting chemical reactions. In sum, spontaneous generation is a thing of the past.

Meteorites and extraterrestrial life

The most primitive Precambrian bacteria were probably compared with non-living matter. Their discovery sheds no light on the central question of chemical evolution. Earth is steadily bombarded with showers of meteors presumably the debris the shattered asteroids, and some of this material contains organic molecules also found in living systems. Most meteorites are metallic, but a relatively small number are soft and crumbly, with high carbon content. These soft meteorites are called carbonaceous chondrites, and the meteorites that fell in a shower around Orgueil belong to this category. A variety of hydrocarbons have been found and some of the organic compounds are optical isomers, which are usually associated with synthesis carried out by living organism. Some amino acids found in meteorites are ones not found in organisms on this planet and, hence, cannot be contaminants introduced after the meteorites fell. Spheroids and other organized bodies of some complexity have been reported, but a continuation of the meteorites samples by airborne spores and pollen has confused the issue. In at least on the instance, the organized bodies turned out to be ragweed pollen. Most of the complex organized bodies have proved to be terrestrial contaminants and those that are definitely meteoric in origin are sufficiently simple that they may be natural mineral formation rather than artifacts of life.

The presence of hydrocarbons and other biochemical compounds in the meteorites indicates that at least the first step in molecular evolution for the formation of complex organic compounds can occur spontaneously even in space. These meteorites are not evidenced for life on some shattered planet; they may be evidence for the universality of the organic chemical-rich environment in which life could develop.

Origin of primitive living organism

The coacervates showed some chemical reactions which produced special proteins and enzymes. This led to self-replication of compounds; those processing this property might be regarded as a free gene. Such a structure is comparable with the free-living virus and is supposed to be, formed of nucleoproteins. Self-replication and mutation of a gene could lead to the formation of gene aggregates. Such gene aggregates may be regarded as independently existing chromosomes. It is believed that some of the smallest bacteria represent such a stage in the evolution. The mutation might be led to the accumulation of metabolites around the chromosomes. The complex so formed represents the exposed nucleus. Some of the bacteria showed this kind of structure. The cytoplasm has been acquired but not separated from the nuclear material as in blue-green algae and in some large bacteria.

Miller's Experiment

Stanley L. Miller proved the important evidence in support of chemical synthesis of life. A mixture of some gasses like ammonia, methane, and hydrocarbon was taken in a special flask. A high-frequency spark by tungsten electrodes was discharged in a constantly circulating mixture of gases for about a week. During the period of the experiment, steam is supplied from the boiling water which mixes with the other gases. The steam thus formed condenses to water through the condenser and flows back to the boiling water flask. After the experiment is completed, the resulting fluid collected in the U-shaped tube and analyzed. The mixture consisted of various acid and amino acids e.g. glycine, alanine, B-alanine and aspartic acid, important for protein synthesis.

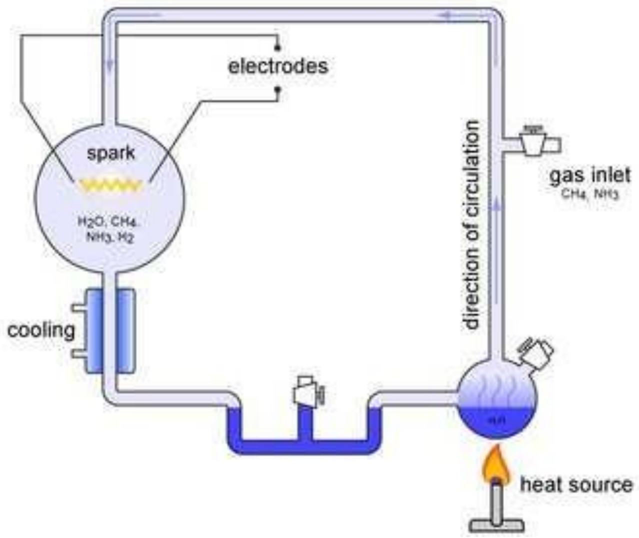


Fig.9.1 Miller–Urey experiment

Origin of primary organism

Oparin's coacervates had common properties and still definite individualism ties and structures. These could grow in size as a result of absorbing substances dissolved in the surrounding water thus, became more complex and created diversity among them, Due to the presence of some substances like iron, copper, and calcium etc. first rudiments of future enzymes were formed. The primitive organisms were successful coacervates. Blum states that the source of free energy available for the first living thing was the absorption of ultraviolet rays. According to others thought, coacervates utilized energy during fermentation of organic substances absorbed from seawater. The production of energy was done through anaerobic respiration. The sea water provided the necessary raw material for the duplication of nucleoprotein and thus, the amount of it was increased. From nucleoprotein virus-like organisms developed.

Cellular life

Horowitz in 1945 and Orgel in 1976 stated that life originated in its simplest form in the sea. The genes along with proteins developed long chains of nucleoproteins that can be compared with chromosomes. The molecules of nucleoproteins along with organic compounds of sea developed a membranous covering and thus, the cells similar to prokaryotic cell were evolved. This cell has protein and some other organic substance in the colloidal state around DNA molecules but devoid of the nucleus, mitochondria, chloroplast, Golgi apparatus, lysosome and other organelles. These cells were holozoic as far as their nourishment is a concern. They can use the dissolved organic material present in marine water. They used solar energy and synthesized their own food. Now, for the first time, free oxygen was liberated out in the atmosphere

CONCEPT OF ORGANIC EVOLUTION

Introduction:-

When evolution was busy to seek a plausible explanation for evolution at that time some worker and researcher were trying to collect facts about the evolutionary process. The evidence is physiology, taxonomy, morphology and embryology of living forms and the fossils of previously existing forms. The recent techniques have been helpful in demonstrating the evolution taking place in the laboratory within a short period of only a few years. If an organism with very short life cycles such as fruit fly or bacteria is reared for several generations in the laboratory, new kind of individuals is observed in the progeny. Initially, these individuals differ slightly from their parents, but as they increase in number, differences keep on accumulating and a stage reached when these become so markedly different from their parents that they fail to interbreed with their parents and thus form new species.

Bio-evolution or organic evolution is continuity of life with constant modifications. It means that the living being modifies and adapt according to the ever-changing environmental needs. These modifications keep accumulating in the organism generation, resulting in more complex and better adapted new species.

Principles of organic evolution

1. The new species are always better adapted than their ancestors.

2. Life is capable of changing with the changing environmental conditions. This is called adaptability.

3. The environmental conditions are ever changing.

4. Evolution is a continuous process.

5. All present species had common ancestors at some time of their evolution.

6. Individuals migrate from their place of origin to varied geographical areas and gradually adapt to different sets of environmental conditions.

7. Evolution is a very complex and extremely slow process.

8. Formation of several new species from one individual species is known as divergent evolution.

The name of Charles Darwin is closely associated with the concept of evolution and for many people, Darwinism in itself evolution. Several theories of historical important were described by Greek philosophers before the birth of Jesus Christ.

According to Thales (624-528 B.C.) propounded the theory of the aquatic or marine origin of life. He considered sea water to be a mother from which all living creatures were originated.

According to Xenophanes (576-480 B.C.), the existence of fossils of marine animals on dry land indicated that the dry land was once under the sea. He suggests that the earth was once under the sea and life has originated in the sea.

Francis Bacon (1561-1626 B.C.) emphasized on variations as being the cause for the origin of new species from old one. He suggested that flying fishes are intermediate between fishes and birds and the bats between birds and quadrupeds. His work influenced the thinking of the successors.

Concept of organic evolution:-

The contributions made by Lamarck, Darwin, Cuvier, Weisman and Huxley etc. are of great importance, since these provoked real scientific thinking of evolutionary process and their theories are still being helpful.

1. Lamarck theory of inheritance of acquired characters (1744-1829). Lamarck theory emphasizes the influence of environment on the living being. The changes introduced by the environment are acquired by the living being and are inherited to the next generation.

2. Darwin's theory of natural selection (1809-1882) Darwin formulated the theory of "Origin of species by natural selection."

3. Weismann's theory of the continuity of germplasm- the germplasm produces gametes which transmit the characteristics of the parent into offspring.

The modern synthetic theory of evolution has evolved during the last century through an accumulation of facts, which are theoretical conclusions from a number of scientists: Dobzhansky (1937) in his book "Genetics and the origin of species" has emphasized the role of genetic changes in population in the process of evolution.

At present, the synthetic theory of evolution recognizes five basic processes namely gene mutation, changes in chromosomes numbers, genetic recombination, natural selection and reproductive isolation. The three accessory processes also affect the working of the process. These are migration, hybridization, and chance in small populations.

Evidence from Paleontology:-

The paleontology is the study of the ancient life of past geologic ages and it is based on the remains of extinct animals and plant including traces of their existence such as footprints and impressions. Such remains have been found in rocks, mud and snow or in soft sediments are called as fossils. The fossils are the direct evidence of descendants leading stepwise from an ancestor to a descendant species. The evidences in support of evolution so far are of circumstantial nature, but the direct evidence comes from the study of fossils. The fossil means something dug out. Any imprint left by some previous organism in the soft mud, which subsequently hardened or the moulds and cast of entire organisms of the soft animal preserved in some other way manner. Mostly fossils are found in the sedimentary rocks which are formed by the deposition of sand or debris in the bottom of rivers, ponds, lakes and sea. Entire bodies or part of the dead organism become covered by sand deposits. After their burial, most animals rot away without leaving any sign of their existence. Slowly over the centuries, the material of the hard part is replaced molecules by molecules with mineral matter from the surrounding mud. The replacement is sometimes so accurate that even the cellular details can be studied accurately. Within thousand and million years, these layers of mud shrink and harden into rocks.

Definition of fossils

Fossils are only animals and plant which have been dead rather longer than those which dead yesterday (T.H. Huxley).

Significance of fossils

The study of fossils reveals the existence of life in past and illustrate the course of evolution of plants and animals. The fossils records establish the following facts:

1. Fossils are remains of an organism that lived in past. Fossils from different geological strata belong to different genera.
2. The fossils from bottom layers of rock have the simplest organization and become more or more complex in strata lying above them. The simpler forms could match with the unspecialized member of the living phylum.
3. The transitional fossils forms are known between different existing groups from fishes to amphibians, from amphibian to reptiles and from reptiles to birds and mammals.
4. The dominant groups of fossils arose near the close of existing period when great climatic changes were taking place. The groups enjoyed dominance in the next period because of the favorable environmental condition and finally perished by the end of the

period on account of alteration on the climate. These become replaced by some new forms more suited to the changed conditions.

5. The mammals among animals and angiosperms among plants are the most recent products of evolution. Geologist has prepared a time- table which helps in depicting the distribution of animals and plants to geological time. It has been divided into five eras, which are further differentiated into periods. The study of these eras and period depicts the story of the evolution of living beings on earth. It has been estimated that life appeared on this earth about 2700 million years ago. Some names of the era are as: Archeozoic era, Proterozoic era, Palaeozoic era, Mesozoic era and Coenozoic era.

The Mesozoic era is described as the age of reptiles. Mammals and birds diverged from reptiles in Triassic and Jurassic periods respectively. The coenozoic era is the age of mammals.

Types of Fossils

The different types of fossils are can be arranged under the following heads.

1. Actual remains

The recently extinct animals and plants which have been buried by some sort of preserving material constitute the first type under consideration. Such remains have undergone little or no change of the original organic matter into inorganic. Thus we find the complete bodies of great hairy mammoths frozen in the arctic ice. These are so well preserved that dogs have fed upon their flesh. Nearly a thousand species of extinct insects, including many ants, have been obtained practically intact from amber, a form of petrified resin. Innumerable mollusc shells, teeth of sharks, pieces of buried logs, bones of animals buried in asphalt lakes and bogs, have been found in a well-preserved condition.

2. Petrified fossils

The process of petrification involves the replacement, particle for particle, of the organic matter of a dead animals or plant by mineral matter. So, the finer structure is completely preserved that microscopic sections of preserved tissue, especially of the plant, have practically the same appearance as section made from living organisms. Various minerals have been employed in petrification, such as quartz, limestone or iron pyrites.

3. Cast, Moulds and Impression

When the animals and plants are embedded in the hard material, their entire body material may be decayed and dissolved away by the water current under the strata and sometimes percolate by sand or something which become accumulated in that rock moulds. Such moulds and casts have been reported in the rocks of Cambrian age. Only external appearance has been preserved, as would be the case in making plaster of paris casts. Sometimes traceries of soft- bodied animals have been left upon forming slate or coal that is almost as accurate in detail as a lithograph.

Most remarkable fossils are those found by Professor Charles D. Walcott in the marine oily shale's of British Columbia. A large number of soft-bodied invertebrates of Cambrian age have been found so wonderfully preserved that not only are the external features revealed but sometimes even the details of the internal organ may be seen through the transparent integument.

4. Trails and footprints

Sometimes animals that passed over sand or mud left their foot- print in the sediments and after that when preserved became the fossils in the form of the footprint. Sometimes animals and worm, mollusk left their movement line and formed their trails.

5. Coprolites

When the food particles in the food tract or excretory material become fossilized and are named as coprolites.

Most paleontologists have been able to reconstruct the appearance of extinct animals and also able to from the history of the development of the earth and its life in the form of geological record. They believe that many fossils are quite different from the forms found today and indicate that evolution has taken place. It is also possible, in many cases, to arrange the fossils in a serial order which proves that evolution has taken place through the series. The fossil series of the horse is quite an example of this type. Also, the paleontological history of camel, elephant, and Man are regarded as evidence of evolution.

Determination of Age of Rock and Fossils:-

The fossils can be dated in several ways. Carbon 14 method is the most popular method. The stable form of carbon and therefore, the carbon that is most frequently cycled through food chains and webs, is carbon 12. However, part of the carbon that is cycled is carbon14; an unsuitable isotope gives off beta particles which make it radioactive because of its instability, Carbon 14is slowly converted, that is decayed to the next possible stable form, which is nitrogen 14.

The rate of change for Carbon 14 is precisely known as it is exactly 5730 years for half of a specific amount of Carbon 14 to be converted to N. thus the half-life for Carbon 14 is 5730 years. For example, if you only 2 micrograms of carbon 14 in 5730 years you would have only one microgram, in 11460 years you would have 0.5 micrograms.. The ratio of C^{12} to C^{14}in a specific tissue, such as bone, is known for animals alive today. By biochemical assay, the ratio of

C^{12} to C^{14} is measured in fossils as the amount of beta particle emission; the result can be converted into years of age. However, when the specimen being dated in much more 50,000 years old, the technique loses its accuracy of the original C^{14} is left.

The fission backdating is a new method, like uranium 238 in reverse. If Uranium-238 is placed in an atomic reactor, the explosions that accompany its decay, a series of the etching in the glass can be observed with a microscope. The same process happens naturally in inactive volcanoes. Glass specimens took from the volcanic sediments show fission tracks that can be counted. The specimen is then placed in an atomic reactor so that the remaining Uranium 238 is used. During its decay a new set of etching is created. The total number of etch line is proportional to the original amount of Uranium 238 and therefore proportional to the age.

Above mentioned methods of fossil dating is used singly or in any combination, allows paleontologist to determine the age of fossils remains and rocks with reasonable accuracy. Of course, these methods are not perfect, and degree of error is expected. However, an error in a few thousand years or even tens of thousands of years is negligible when considering fossils that are several million years old.

Taxonomy:-

One of the tenets of the theory of evolution is that all the diverse plant and animal varieties that we observe today have evolved from common ancestral stock. The theory of organic evolution appears most plausible explanation for the occurrence of varied forms of plants and animals on this earth. But the absolute proof in this connection is lacking. If we go through the classification of the organism, we find there is a strong connection (family tree) among the animals as well as plants evolution.

Comparative Anatomy

Morphological studies of various organ systems of vertebrates indicate that these are constructed on the same basic plan. The minor differences seen in some forms are the adaptive modifications to the diverse mode of living. These similarities are known as homology.

I.) Homology and homologous organs

Homology is the similarity between organs of different animals based on common ancestry. Therefore, the homologous organs have a common origin and are built on the same fundamental pattern, but perform varied functions and have a different appearance. Homology is seen in every organ system from fish to man.

1. Homology in limb structure of vertebrates.

The flipper of a seal, wing of a bat, forelimb of a mole, front leg of the horse and the arm of a man look very different and perform different functions, but exhibit the same structural plan. The modification includes shortening or lengthening of bones, variation in shape, reduction in the number of bones or fusion of bones in accordance with the function.

Forelimbs of various animals become evidence that these vertebrates must have had a common ancestor with a prototype of the forelimb.

2. Homology in brain structure

Ranging from fishes to mammals, the brain consists of similar series of parts as olfactory lobes, cerebral hemispheres, optic lobes, cerebellum, and medulla oblongata.

As we progress through the series from fishes to mammals some lobes present gradual enlargement. In fishes, the cerebral hemispheres are even smaller than the optic lobes, but in mammals, there are so much enlarged that they hide the olfactory lobes in front and the optic lobes behind.

3. Homology in the structure of heart

The heart is two-chambered in fishes, consisting of one auricle and one ventricle. The auricle receives blood from entire body and ventricle pumps it to the gills. In amphibians and lower reptiles, the heart is three chambered. There are two auricles and one ventricle. The oxygenated blood from lungs is collected in the left auricle and deoxygenated blood from rest of the body in the right auricle. Thus the oxygenated and deoxygenated blood is stored separately. But it gets mixed in the ventricle while being pumped to the body organs. In higher reptiles, birds and mammals heart are four chambered and the oxygenated and deoxygenated blood is completely separated. This represents a gradual modification in the heart of vertebrate series while the fundamental structure of heart remains same in all the groups.

II.) Serial homology

Several homologies have been observed among invertebrates. All the arthropods have segmented body with an exoskeleton of chitin. The exoskeleton is constructed on the same basic pattern of classes of phylum arthropods. In crustaceans, all the segments of body carry paired jointed appendages. All of them are constructed on a common structural plan, consisting of a basal two segmented portion, the protopodite (coxa and basis), which bears two lateral outgrowths, the exopodite and endopodite. The appendages of various body segments perform different functions and in correlation with that exhibit modification of the basic structural plan. This phenomenon of similarity has been described as serial homology.

III.) Analogy and analogous structure

The analogous organ has the almost similar appearance and performs the same function but these develop in totally different groups on the totally different pattern. For example, the wing of a butterfly, bird, pterodactyls and bat serve the same purpose of uplifting the body in the air, but their basic structure is totally different. The wing of insect is formed of a thin flap of chitin and stiffened by a series of veins. It is operated by muscles attached to its base. In pterodactyl, the wing is an enormous fold of skin supported by an enormously enlarged fourth finger of the forelimb. In the bird, the flight surface is formed by feather attached to the bones of the forelimb. In bat, the wing is formed by a fold of integument (patagium), supported by the elongated and outspread phalanges of last four digits. Similarly, the fins of fishes and Ichthyosaur and the flippers of whale have similar appearance and function but their structure details are totally different. These functional similarities between analogous organ support occurrence of organic evolution.

IV.) Adaptive radiation

The concept of adaptive radiation also provides strong evidence in support of the theory of organic evolution. The adaptive radiation is exhibited by the limb structure in mammals. The limbs in mammals are variously adapted for climbing, flying, running, swimming or burrowing etc. Naturally, these exhibit structural modifications correlated with their mode of working. In the arboreal or tree dwelling forms like sloths and monkeys, limbs are modified for having a powerful grip of the branches. Mammals adapted for flight have their forelimb modified into wings. In aquatic mammals, the limbs get modified into flippers. The size of limb bones is much reduced. The forelimbs of fossorial mammals are modified for digging burrows with short and strong limb bones. In cursorial forms like horses, the limbs are suited for fast running over hard ground.

All the aforesaid limb structures are constructed on the same fundamental pattern and can be derived from the prototype, pentadactyl limb structure. In other words, it could be said that all of them represent evolutionary lines radiating out in various directions from the prototype limb structure. This is known as adaptive radiation which represents the evolution of new forms in several directions from the common ancestral type.

V.) Convergent Evolution or adaptive convergence or parallel evolution

The whale and their relatives, the extinct reptiles and Ichthyosaurs attained fish-like body with their limbs modified into fins or flippers. The similarities are so marked that whale is understood as a fish by laymen. This similar body shape between animals of distantly related groups represents the phenomenon of convergent evolution

VI.) Vestigial organs or Vestiges

The vestigial or rudimentary organs are the useless remnants of structure or organ which might have been large and functional in the ancestors. These are undersized, degenerate and nonfunctional.

1. Vestigial organs in man:

a.) Vermiform appendix in man b.)

Muscles of external ear

c.) Nictitating membrane d.)

Vestigial tail vertebrae e.)

Wisdom teeth

2. Vestigial organ in other animals

a.) Both whales and pythons have vestiges of bones of hind limbs and pelvic girdle embedded in the flesh of abdomen.

b.) `Kiwi possesses vestiges of wing supported by tiny replicas of usual bones of bird's wing.

c.) in horse leg, the splint bones represent the metacarpals of second and fourth digits.

d.) In the animals living permanently in deep caves, the eyes are rudimentary.

VII.) Evidence from atavism or reversion

Atavism is the reappearance of those ancestral characteristics in an organism of a group; that do not occur normally by the individuals of that group. Such abnormal structure is known as atavistic characters of reversion or atavism. In such cases, abnormal characters appear in the embryo or in adult, which were not present either in the parent or grandparents but in some remote ancestors.

Comparative Embryology:-

Ontogeny is the life history of the individual starting from ovum and phylogeny is the series of adult ancestors of the individual which must have incurred in the evolution of the group of this individual. It means that an individual during its development briefs its ancestral history.

1. Homology in early development

The entire multicellular organism exhibits a common pattern of development. Their development starts from unicellular fertilized egg or zygote. The fertilized egg after repeated cell divisions forms blastula, which finally develops into a two layered gastrula. The outer layer of gastrula represents future ectoderm and inner one future endoderm. The cavity lined by endoderm forms the archenteron, the future digestive tract. The development after gastrula stage becomes modified in different groups of animals.

2. Recapitulation in Human Embryo

The development of man can be taken as an example to illustrate the theory of recapitulation. The fertilized egg may be compared to the single-celled ancestor of all the animals and the blastula to a colonial protozoan of some spherical multicellular from which might have been the ancestor of all the metazoan. Gastrula represents the coelenterate ancestor and the embryo with the development of mesoderm represents triploblastic stage like a flatworm.

3. Homology in the Embryo

The early embryo in all the vertebrates exhibit remarkable similarity and it is not easy to differentiate a human embryo from the embryo of chick, lizard, frog or fish in early stages. It has also observed that the early embryos of all the individuals are much alike, later those of different classes become recognizable and still later family and species characters become evident i.e. the embryos during their development become progressively more and more different from those of the other animals.

4. Retrogressive metamorphosis

The ascidians tadpole is free swimming and possesses all their chordate characters. On metamorphosis, it changes into sedentary degenerated adult. During metamorphosis, it loses all the chordate features, like notochord, nerve cord and myotomes. This is called retrogressive metamorphosis; it has helped in determining its chordate nature.

5. Neoteny

In some animals, the larva fails to undergo metamorphosis. It develops gonads; attain sexual maturity and starts reproduction. This is called neoteny or paedogenesis e.g. axolotl larva of *Ambystoma*.

Physiology:-

When the physiological processes and the chemical composition of various cells and tissues are considered it is found that there are at least some similarities in different animals showing the relationship between them. This indicates that they have descended from a common ancestor. The physiology of heart, kidney and gonads also show similarities among most of the vertebrates. These similarities explain the idea to common ancestry.

Biochemistry:-

The protoplasm of different organisms is considered it prove to be basically the same. The nucleic acid found in the cells is also similar in all organisms. In the same way, very similar enzymes and hormones are found in many animals. The parts of the central nervous system perform, so far they have been tested approximately the same functions. The chemical reactions involved in the process of respiration are essentially similar in most diverse organisms. Most animals can readily oxidize uric acid to allantoin which is more soluble and as eliminated from the body along with urine, man is unable to do so and, as result, is liable to gout. Serological evidence also proves the remarkable kinship between different animals as shown by Dr. Nuttal. Animals, which on other grounds are closely related, have been found to possess similar blood. Thus it has been experimentally proved that the blood of a horse and ass is similar, so is that of rabbit, hare, man and the anthropoid apes. Serological tests provide a method of measuring the degree of relationship among different animals, and are helpful in establishing their affinities. Chromosomes: it is an essential component of the nucleus in every living cell.. The chromosomes have a fairly constant chemical composition in the living animals being composed of DNA and proteins. The basic unit of DNA is a nucleotide consisting of a molecule of phosphoric acid, one molecule of pentose sugar is deoxyribose and a purine or a pyrimidine as a nitrogenous base. The chemical composition of DNA is basically the same in all living beings except for differences in the sequences of nitrogenous bases. How can such diverse organisms have the same basic fundamental composition? It means all have gradually evolved from some common ancestor.

The hemoglobin is conjugated protein. It is formed of two identical alpha chains and two identical beta chains. Each alpha chain has 141 amino acids and each beta chain has 146 amino acids. B chain of hemoglobin of human and gorilla differ in one amino acid, of human and pig in ten amino acids and of human and horse in 26 amino acids.

The cytochrome is present in all eukaryotic cells. It forms a part of the electron transport system and in all eukaryotes accepts an electron from H^+ ions. It is formed of 104 amino acids.

Insulin: beef insulin is so similar to human insulin that it has been used for the treatment of human diabetes. Even human immune system fails to detect the difference.

Cytology:-

The strong evidence in favor of organic evolution comes from genetics. Source of such cases are hybridization and domestication etc. for example, the mule is hybrid. Mule is the offspring of a jackass (*Equus caballus*). This is an evolutionary dead end and with very rare exceptions, the mule is sterile. But the mule is very strong and hardy. The mule has a different chromosome number and normal gamete formation is prevented. It is clear that these animals can be traced back to a common ancestry and their genetic material are still sufficiently similar but during the course of evolution their chromosomes and genes have diverged so much that they are no longer so similar to allow normal gamete formation.

On the basis of chromosome material, the animals show the relationship among themselves. The chromosomes are chemically composed of nucleoprotein, a combination of protein and nucleic acid. Two kinds of nucleic acid have been found in all species, they are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). DNA is found to be in the nucleus of cells, while RNA may be found in nucleus and cytoplasm both. In all the cases, except for plant viruses, DNA is the hereditary material while RNA mediates the protein synthesis. Human DNA differs in only 1.8% of its base pairs from chimpanzee DNA and there are no differences between the two in the amino acid sequences for the protein cytochrome C.

THEORY OF ORGANIC EVOLUTION

Lamarckism:-

Lamarckian theory of evolution can be most specifically explained in the following factors which he considered important in evolution.

1. Favorable changes in the environment, soil, food and temperature etc. influence directly the life of plants while indirectly in the case of animals and human being.

2. According to needs new organs originate or modify thus, leading to the appearance of new organs during the life of individuals subjected to the environmental changes.

3. Use and disuse: the proper use of an organ establishes it while no use makes its eventually lost. For example, anterior limbs of birds became capable of sustained flight through use, while hind limbs of whales are lost due to their disuse.

4. Competition: Nature itself balances the number of living things avoiding overcrowding by competition among animals, stronger destroy the weaker. So the smaller multiply rapidly, while larger less rapidly.

5. Acquired characters are transmitted: The advantageous changes resulting from use and disuse and needs are handed down to descending generation thus transmitting the acquired characters attained by parents to offspring.

6. Cross-breeding: The individuals acquiring any peculiar character or defect, on pairing, produce the same character in the offspring. But perpetual crosses between individuals, which have not the same peculiarities of form, result in the disappearance of all the peculiarities acquired in the particular circumstances.

7. Isolation: Animals diversified due to separation by distance. Lamarck expressed this thought in his account of the origin of man from ape and is not applicable to the living thing in general.

Analysis of Lamarck's theory

1st law: Lamarckian first law simply emphasizes on the growth and progress of organisms and the size increases truly due to metabolic activities, though controlled by vital factors. So the first law is accepted.

2nd law: this law is not acceptable because one cannot develop any organ if he or she needs it. It is unbelievable that if we want our eyes on the back of our head just or see behind of us, they can be developed. So, need of any organ does not develop that organ.

3rd law: the third law says that development of organs depends on the use or disuse of that organ. He suggested that variations appear among animals mainly through use or disuse of parts brought about as a result of conscious effort on the part of animals in response to various external stimuli. Such variations according to Lamarck are heritable, being passed on to the offspring during sexual reproduction. A repetition of such efforts by successive generations of offspring under similar, environment conditions will result in the production of new characteristic and thus new species.

According to Lamarck, animals and plants and affected by the environment in which they are living. This can be illustrated by the example of a plant- *Ranunculus aquatilis* commonly called water crowfoot. This plant grows partly immersed water on banks of the streaming water. The part of plant submerged develops filamentous prickles in place of leaves, and the other above water develops rounded and lobed leaves. When this plant grew away from water, it develops leaves on the part that was submerged, but when returned to the water it again develops prickles.

Lamarck gives a number of examples, the most famous amongst them are those of the giraffe and snake.

(i) Giraffe: according to Lamarck the ancestral giraffe was a short-necked form browsing on ground vegetation. When falling in grass or herbage came and they were forced to depend upon the foliage of trees, they had to stretch their neck to reach the higher vegetation. This resulted in a short increase in the neck length and it was transmitted to the next generation. Thus, repeated conscious effort by successive generations to feed on the leaves of trees which grew progressively taller and taller resulted in a continuous increase in the length of the neck eventually leading to the modern long-necked giraffe.

(ii) Snakes: the snakes have been evolved from lizard-like ancestors which were having two pairs of limbs. These ancestors of snakes felt insecure from mammals of that time because the latter were more powerful and enormous in number. To escape from the mammals, the ancestors of the snakes started living in narrow holes or crevices and in thick jungles. To accommodate their body in narrow spaces they could not use their limb that is why the limbs were reduced and finally disappeared, while their body became longer and cylindrical.

(iii) Aquatic birds: Aquatic birds like ducks have been evolved from the terrestrial ancestors. Since they had to go to water due to lack of food. Some structures like a web between the toes developed in them, so that they could live in water easily. The wings were not used for the flying as they were not needed, and later they got reduced.

(iv) Flat fishes. They are flat and bear both the eyes on one side and live at the bottom of the water. During the embryonic stage, their eyes are present laterally, one eye on either side. The body of these fishes is not flat at this stage but later on, both the eyes are shifted to one side and the body becomes flat to withstand the pressure of water.

(v) Flightless birds. The ancestor of these birds was capable to flying,, but due to some environmental factors they had plenty of food and were well protected. So they did not use their wings and that is why the latter become vestigial.

(vi) Deer. The ancestor of deer did not have so much speed in running, but as they needed protection from other animals so they started running due to which present speed was achieved by the deer and consequently their limbs got developed and the body became streamlined.

(vii) Claws of carnivorous mammals. The lions, cats and dogs are well adapted to their carnivorous habits. The claws of these mammals are retractile because they run very fast.

(viii) Skin of man. The use and disuse of organs are best illustrated during the development of man. The skin of the palm and the sole of the feet are generally smooth and velvety in touch at the time of birth, due to constant use the skin gradually becomes thick and rough in the course of time. The presence of vestigial organs in various animals is also explainable on the basis of the use and disuse theory.

The fourth law of Lamarckism doctrine is of many controversies. According to Lamarck, the characters attained during the lifetime of an animal are heritable, which gradually led to evolutionary changes. In other words, the environment acted as the motivating force, which brought about changes in the organism constituting the first step in evolution. This was considered by Lamarck, as “principle of inheritance of acquired characters.” Herbert-Spencer also supported this theory with the example of fish- *Gasterosteus*. These fishes inhabit freshwater, brackish water, and sea. The marine fishes possess 20-30 bony plates on the mid- dorsal line of the trunk, the brackish water forms 3-15 and freshwater possess none of these plates. If a marine species is transferred to fresh water, it gradually tends to lose all the plates and this acquired character is inherited by its offspring. Similarly, if a freshwater form is transferred to a marine environment, in due course of time, it tends to develop the bony plates and this acquired character is transmitted to its progeny. However, many objections were given against Lamarckism. The greatest blow to Lamarckism came from August Weismann.

According to Weismann, the body of an organism consists of somatic cells and the germinal cells. Any change affecting the soma is not heritable and it disappears with the death of the individual. Weismann showed that if we cut the tail of white mice during its lifetime, then the offspring of these rats do possess tail and do not show the absence of the tail indicating that the character is not transmitted. He explained for 22 generation, every time cutting the tails of parental generation and recording the presence of the tail in the progeny. He found not even a single mice developed even a reduce tail.

Pavlov, during the experiments, trained the dog to takes its food on hearing the bell. But this character was not transmitted to the offspring. Instead every dog, in order to develop this character, was needed to be trained similarly. So, this clarifies that the acquired character are not inherited.

Darwinism:-

Charles Darwin was a methodical painstaking English naturalist and he was the first who founded the theory of organic evolution. He was born on February 12, 1809, at Shrewsbury. He was educated at Shrewsbury. The career of Charles Darwin began with his voyage of H.M.S Beagle (December 27, 1831, to October 2, 1836) as the ship’s naturalist. He visited Cape Verde and other Atlantic Islands, New Zealand, Australia, Tasmania, Mauritius and Brazil. He spent about five weeks among the Galapagos Islands and about five years in the voyage. He was very much impressed by the remote animal life.

Charles Darwin married his cousin Emma Wedgwood in 1839. He was blessed with two daughters and five sons. He was very kind to his family, friends and fellow scientists. He was acknowledged as Great before his death. He died on April 19, 1882 and buried in Westminister Abbey next to Sir Issac Newton.

Evolution before Darwin

The French scientist Georges-Louis Leclerc Comte de Buffon (1707-1788) was among the first to suggest that species undergo changes within the course of time. Buffon believed that these changes took place by the process of degeneration. He suggested that, in addition to the numerous creatures produced by divine creation at the beginning of the world, "there are lesser families conceived by Nature and produced by Time." Buffon's hypothesis, although vague as to the way in which changes might occur, did attempt to explain the bewildering variety of creatures in the modern world.

Another early doubter of fixed unchanging species was Erasmus Darwin (1731- 1802), Charles Darwin's grandfather. Erasmus Darwin was a physician, a gentleman naturalist, and a prolific writer, often in verse, on both botany and zoology. He suggested, largely in asides and footnotes, that species have historical connections with one another, that animals may change in response to their environment, and that their offspring may inherit these changes. He maintained, for instance, that a polar bear is an "ordinary" bear that, by living in the Arctic, became modified and passed the modifications along to its cubs. These ideas were never clearly formulated but are interesting because of their possible effects on Charles Darwin, although the latter, born after his grandfather died, did not profess to hold his grandfather's view in high esteem.

The Earth has a History:-

The person who most influenced Darwin as Charles Lyell (1797-1875), a geologist who was Darwin's senior by 12 years. One of the books Darwin took with him on his voyage as the first volume of Lyell's newly published Principles of Geology and the second volume was sent to him when he was on the Beagle. On the basis of his own observations and those of his predecessors, Lyell opposed the theory of catastrophes. Instead, he produced new evidence in support of Hulton's early theory of uniformitarianism. According to Lyell, the slow, steady and cumulative effect of natural forces had produced a continuous change in the course of the earth's history. Since this process is demonstrably slow, its result being barely visible in a single lifetime, it must have been going on for a long time. If the earth had a long continuous history and if no forces other than well known, natural forced were needed to explain the events as they were recorded in the geologic record, might not living organisms have a similar history?

The voyage of the Beagle:-

This was the intellectual equipment with which Charles Darwin set sail from England. As the beagle moved down the Atlantic coast of South America, through the Straits of Magellan, and up the Pacific coast, Darwin traveled the interior, fished, hunted and rode horseback. He explored the rich fossil beds of South America and collected specimens of the many new kinds of plants and animal life he encountered. He was impressed mostly during his long, slow trip down the coast and up again by the constantly changing varieties of organisms he saw. The birds and animals on the west, for example, were very different than those on the east coast, and even as he moved slowly up the western coast, one species would give way to another.

Most interesting to Darwin were the animals and plants that inhabited a small, barren group of islands, the Galapagos, which lie some 950km off the Eastern coast of Ecuador. The Galapagos were named after the islands most striking inhabitants, the tortoises, some of which weigh 100kg or more. Each island has its own type of tortoise; sailors who took tortoises on board as a conventional source of fresh meat on their sea voyages could readily tell which island any particular tortoise had come from. Then there was a group of finch-like birds, 13 species in all that differed from one another in sizes and shape of their bodies and beaks, and particularly in the type of food they ate. In fact, although clearly finches, they had many characteristics seen only in completely different types of birds on the mainland. One finch, for example, feeds by routing insects out of the bark of a tree. It is not fully equipped for this, however, lacking the long tongue with which the woodpecker flicks out insects from under the bark. Instead, the woodpecker finch uses a small stick or cactus spine to pry out the insect loose.

From his knowledge of geology, Darwin knew that these islands, clearly of volcanic origin were much younger than the mainland. Yet the animals and plants of the island were different from those of mainland, and in fact, the inhabitants of different islands in the archipelago differed from one another. Were the living things on each island the product of a separate special creation? “One might really fancy”, Darwin mused at a later date, “that from an original paucity of birds in this archipelago one species had been taken and modified for different ends.” After his return, this problem continued to, in his own words, “haunt” him.

In 1858 Charles Darwin and Alfred Wallace had a paper presented to the Linnaean Society of London in which they used the term evolution to describe the progressive changes in successive generations of living organisms. The theory of evolution is an attractive one for it helps explain two things.

a) The similarities between related organisms, as being due to their descent from a common ancestor and

b) The differences between them as being the result of variation inherited from one generation to next.

The theory of evolution by natural selection announced jointly by Darwin and Wallace in 1858, made little impact on the world of science until the publications of Darwin's books "The Origin of Species by Natural Selection" in 1859 in which Darwin expounded the theory. The entire edition was sold out on the day of publication, November 24, 1859. He prevented possible mode of transformation of species natural causes as opposed to the doctrine of the special creation of all the species.

The Data Suggestion Evolution:-

Darwin had a little scientific training when he joined the beagle. The trip itself was his education. It provides him with the facts and experiences that eventually led to the formulation of his theory of evolution. In later years, Darwin recalled those observations that made him question the contemporary theological view that each and every species had been created by the divine power. It is of considerable importance for us to review the data which led to such a view, for evolution is a most abstract idea; one does not look at nature and suspect that evolution has occurred.

These were the observations that made Darwin wonder:

1. The relation of fossil to living species:-

While he was in South America, Darwin collected the remains of stone giant fossil mammals that were covered with armor similar to that of a living armadillo. There are two important features of this observation: First, the living armadillos that Darwin observed on the pampas were obviously different from members of the fossil species. In spite of these differences, the two were clearly of the same general animal type that is both were 'armadillos'. Second, the living and the fossil armadillos occur only in the Western Hemisphere.

The question that ran through Darwin's mind was something probably like this, "Where the two forms, the extinct and the living, created separately, or could the extinct species have been a progenitor of the living? If on the other hand, the two represented separate and independent creations, was it not surprising that two such similar forms should have been created in precisely the same part of the world? He concludes, 'The wonderful relationship in the same continent between the dead and the living will, I do not doubt, hereafter throw more light on the appearance of the organic beings on our earth, and their disappearance from it, than any other class of facts'.

2. Geographical succession of allied species:-

The Beagle made frequent stops along the east coast of South America between central Brazil and southern Argentina. Darwin noticed that in any one locality the individuals of a given species would be identical or nearly so. At the next stopping place of the Beagle, which might be several hundred miles distant, the individuals of this same species would appear homogenous among themselves, yet differ slightly from those in the first locality. With increasing distance between the localities, the divergence in character might be considerable. Darwin observed this type of phenomenon in enough species to be convinced that it was a general rule. Should one conclude that not only was each species created separately but that many slight versions were created, one for each locality?

3. Geographical variation of animals and plants in the "Galapagos Islands":-

The Galapagos Islands are situated in the Pacific Ocean about 600 miles west of Ecuador. They are volcanic in origin, and in Darwin's opinion, they were not of great antiquity. For years, the principal visitors were buccaneers and Whalers who came to fill their casks with fresh water and their larders with the giant tortoises. Somewhat more than a dozen islands comprise the archipelago. The main islands of the group are close to one another, each being separated by not more than 30 miles from its nearest neighbor. From these islands, Darwin collected both animals and plants, and when these were studied a number of interesting facts emerged. First, the majority of species that he collected were new to science. Second, most of the species are found only in the Galapagos Islands. Third, although the majority of the species are peculiar to the islands, they are obviously similar to forms inhabiting the American mainland. Fourth, in many instances, a species would be restricted to one island.

To these facts should be added the fifth and most surprising observation of all: namely, Darwin noticed that frequently each island would have its own species of an animal or plant type. Thus, the giant tortoise was found on all the islands, but each island had its own tortoise population that differed slightly from that of every other island. One of the local officials told Darwin 'that the tortoise differed from the different islands and that he could with certainty tell from which island any one was brought'. Apropos of this, Darwin wrote: I never dreamed that islands, about fifty or sixty miles apart, and most of them in one sight of each other, formed of precisely the same rocks, placed under a climate, rising to a nearly equal height, would be differently tenanted; Not only was this true for tortoises, but for many other animals, and plants also. Thus the plant genus *Scalesia* is restricted to the Galapagos. Six species were found and each was restricted to a single island.

Most Galapagos Islands finches eat seeds they gather from the ground. During times of food shortage, there is severe competition for seeds and many birds die. Birds with different sized bills are most efficient at husking different sized seeds and birds with small bills cannot crack large, hard seeds. The suggestion that competition for food has influenced the evolution of

bill size is supported by differences in bill sizes between populations of finches with and without potential competitors (a) *Geospiza fuliginosa* and *G. fortis* are both small ground feeding finches.
(b) When either one is the only finch present on the island, it has a bill size similar to that of the other species (c) When they occur together, however *G. fortis* has larger, and *G. fuliginosa* has smaller bills than either has when it lives alone.

Individuals of *G. fortis* have average or even larger bills on an island lacking the more robust ground finch, *G. magnirostris*.

Some of these differences are probably caused by differences in the kinds of seeds available on the various islands, but competition clearly contributes to the sizes of the bills of these finches. The work of Darwin can be summarized under the following heads:

1. Tendency to rapid increase in number

Organisms produce far more offsprings than those whomever reach maturity. This is the tendency of all living organisms to multiply their number rapidly. For example, one pair of common house flies breeding in April would have by August, if all eggs hatched and all resulting individual lived to reproduce in their turn, 191,010,000,000,000,000,000 descendants. In the case of Drosophila, each female lays`200 eggs and the fly completes the life cycle in 10-14 days. Therefore, if the production goes as such, in 40 days there will be about 200,000,000 flies. Another example is taken from *Paramecium*. It multiplies at the rate of 3000 generations in five years, if all the descendants existed, their protoplasm would approximately equal to 10 times the volume of the earth. Similarly, one mosquito may have two hundred billion descendants in one summer. An oyster lays about 1, 14,000,000 eggs in a single spawning. A single *Ascaris* lays about 27 million of eggs in her life span. Among the lower vertebrates where no parental care is given to the young, the potential productivity is necessarily enormous. In Herrings the number of eggs varied from 20,000 to 47,000, in a Cod there may be as many as, 6,000,000 eggs, in Turbot, 9,000,000 and in a Ling, 28,000,000 eggs in a season. One female toad may lay as many as 12,000 eggs. The elephant is the slowest breeder; the one pair normally produces only six off springs in one hundred years. If they are allowed to reproduce, and if all the off springs survive then in a span of 750 years, a single pair will produce 19 million descendants.

2. Survivor’s number constant

Although the animals and plants produce great numbers of descendants, yet the number always remains constant, this is because otherwise the food and land will be much less for over population. Similarly to keep the number within reasonable limits curbs and checks are operating. These may be either due to limited food supply, predatory animals, as diseases, as space restriction, as the inanimate environment that includes climate, seasonal changes, drought, flood etc. Thus the numbers of individuals in a species remain more as less the same.

3. Struggle for existence

Struggle for existence is most important check for keeping the numbers constant. Due to the excessive rate of production of organisms, there is an everlasting competition or struggle between the various individuals for food, space and other requirements. Therefore, the population of most species tends to remain more or less constant because of various limitations such as lack of food, living space and breeding spaces etc. For all these requirements, a competition for existence takes place among the individuals of the species and this is what is called as a struggle for existence. There are three types of the struggle for existence, which are as follows:

(a) Intra-specific

This is the struggle among the organisms of single and same species i.e. within the same species because of their' requirements like food, shelter, breeding places etc. are similar. Cannibalism (eating the individuals of own species) is the example of intraspecific struggle. Many human wars are also included in this category.

(b) Inter-specific

This is the struggle among organisms of different species i.e. between the different species. For example, the rabbit is preyed upon by a fox, fox by tiger on its turn. ln this way a struggle continues between aggressor and a victim.

(c) Extra- specific or Environmental struggle

The environmental factors like extreme cold, heat, heavy rains and earthquakes also play an important role in determining the number of individuals and causing population control.

4. Variation and heredity transmission

Due to everlasting competition, there is a variation of living beings. With the changing conditions, all individuals show at least some and very few changes from each other, and this is the variation. Due to the variations, some individuals would be better adjusted towards the surroundings than the others. Adaptive modifications are caused by the struggle for existence. Darwin considered these variations to be hereditary. Only those variations which are helpful and most suited are transmitted to the next generation while unsuited variations are eliminated.

5. Survival of the fittest or Natural Selection

Darwin suggested that in the struggle for existence only those individuals survive and propagate which adopt the changing variations. This process was named as the “survival of the fittest”. The individuals who lacked favorable variations will not be able to face the condition of life and will perish or fail to reproduce and hence will be eliminated from the population.

According to Darwin, the process would continue to operate in succeeding generations, gradually adapting the animals to their respective environments. When there is a change in the environmental conditions there would also be corresponding changes in the sort of characters that could survive under natural selection.

Darwin's finches: A species in a changing environment or a species migrating to a new environment would in course of time be suitably changed in the new conditions. This is clearly shown by birds known as Darwin finches. There are 13 species of this bird having special adaptations suitable to a particular environment. For example, the birds which fed on insects had long slender beaks by which they could pick small insects from small crevices or pierce them. On the other hand, plant eaters had strong beaks which were helpful in breaking hard nuts. The birds which lived on islands covered with volcanic eruptions had black feathers matching with the surroundings. The birds living in green vegetation have green feathers and those finches inhabiting probably beaches had speckled grey plumage. Darwin, therefore, argued that if a group of individuals of same species survives the conditions of life in a particular area through continued variations along different lines under natural selection, then after many generations each individual will be so different from its ancestors that it will be classified as a new species.

'Darwin also cited the example of tiger, leopard, lion and cat that all these animals possess a number of similarities but are different so that they are classified separately. This might be due to the fact that all of them might have diverged from a common ancestor but through variations, competitions and natural selections. They possessed their present position on the taxonomic calendar. Therefore, in the words of Darwin, “it is the nature which decides on the selection or otherwise of particular individuals for continued existence.”

6. Origin of New Species

According to Darwin adaptation of survivors to new environments may lead to the formation of new structures and modes of behaviors. Thus, organisms, generation after generation, will show new forms and thus latest forms will be regarded as new species. Thus, modifications in relation to changes of environment will lead to the origin of new species.

Darwin thought that possible new species might have arisen from the old ones with the difference of lines of descent, which produced varieties, incipient species and then species themselves.

Evidence In Favor Of Darwinism:-

There are number of evidences which go in favour of Darwinism. Some of them are given below:

1. Size. In olden days there existed large sized animals which later on faced the scarcity of food, space and the changes in the climate. They are now replaced by the small size and more suited animals.

2. Pedigree. Pedigree of horse, camel, elephant and other animals also support the theory of Darwin

3. Struggle for Existence. Competition or struggle for existence is seen in all organisms.

4. The abundance of Variations. Variations are so abundant in nature that no two individuals of a species are similar, not even the monozygotic twins (they possess some dissimilarity due to their environment).

5. Production of New Varieties of Plants and Animals by Sexual Selection. When a man can produce various new varieties of plants and animals in a short period, nature with its vast resources and a long time at its disposal can easily produce new species by selection.

6. Mimicry and Protective Coloration. They are found in certain animals and are products of natural selection.

7. Correlation between Nectaries of Flowers and Proboscis of insects (Entomophily). The position of nectar in a flower and the length of proboscis in pollinating insects are wonderfully correlated.

8. Pedigrees of some Animals. Pedigrees of horses, camels and elephants also support the Natural Selection Theory.

9. The rate of reproduction. The rate of reproduction is many times higher than the rate of survival in all organisms.

Objectives to Darwinism

In spite of the fact that Darwinism is universally accepted as the factor of evolution, there are many objections to the theory and they are as follows:

1. *Inheritance of small variations*. According to natural selection theory, only useful variations are transmitted to the next generation, but sometimes small variations which are not useful to the possessor, are also inherited. It is beyond understanding that if the appearance of small wings in birds could help them in flying.

2. *Over-Specialization of some organs*. Some organs like tusks of elephants, antlers of deer have developed so much that instead of providing usefulness to the possessor, they often give hindrance to them. This theory cannot explain these facts.

3. *Vestigial organs*. Theory of natural selection does not satisfactorily explain the occurrence of vestigial organs, which are useless and if they were not of any use, they should not have been preserved and further developed by natural selection.

4. *Duration* The geologic time has been too short to give selection opportunity to do its work.

5. *The arrival of the Fittest*. Darwin left us with a very fundamental and important problem, which was not solved by him that "upon what material does natural selection act in the formation of species". It is true that fittest survive, but what is the origin of fittest?

6. *Discontinuous Variations*. The theory fails to explain the cause of sudden changes in the body. The main drawback of Darwin was a lack of the knowledge of heredity and that is why he could not explain, how the variations are caused.

7. *Selection*. Selection depends on the organisms having a sum total of good and bad characters and not a single character.

8. *Darwinism* does not include the traditional stages in the formation of new species.

9. It is difficult to imagine a reason why variations tending in an infinitesimal degree in any special direction should be preserved.

10. No one has ever observed new species developing from another - this ought to be possible if evolution by natural selection is not in progress.

These are some of the reasons which, on purely rational grounds, appear amply to justify those who decline to pledge their faith in Darwinism in spite of the popularity it enjoys.

Modern Synthetic Theory or Neo-Darwinism:-

Darwinism was generally accepted by biologists in the latter part of the last century. But about 1890, doubts began to be thrown upon it and around 1910, some critics proclaimed the death of Darwinism due to following facts. Darwinism became purely speculative involving selection to explain anything and everything without requiring proof and without providing any explanations. With the discovery of mutations, it is said that hereditary change proceeds by large jumps.

Mendel contributed the force necessary to establish Darwin's concept and its general acceptance. Darwin's natural selection theory contained a number of defects which cannot explain the entire process of evolution. For example, it failed to differentiate acquired characters and inheritable variations. Secondly, natural selection is a limiting and not an initiating force. In the light of modern developments, Huxley, Haldane, Goldschmidt, Dobzhansky, Fischer and others put forth the theory which supported Darwinism and this is named as Neo- Darwinism.

According to Darwin, evolutionary change in animals is small variations and suitable variations under the force of natural selection survived. This is something true and several important pieces of evidence of natural selection have come to light. For example, if an area of mosquitoes is sprayed with DDT to kill them, mutant forms have been found to have evolved which showed great tolerance to DDT. Thus, Neo-Darwinism has a genetic basis and it lays special emphasis on the occurrence of mutations. Neo-Darwinism only involves the germinal mutations.

Although the genes are highly stable units but undergo mutation which may be caused by physical or chemical changes in the makeup of genes. If a single gene undergoes mutation while the corresponding gene in the other chromosome remains unchanged, the resulting organism will become a hybrid for that particular trait. It has been found that gene mutations can be induced by various extrinsic factors such as X- rays, chemicals etc in every generation by sexual recombination or by mutations inheritable variations may arise.

If the organisms exhibiting such variations survive and reproduce, their genetic make-up will be perpetuated so that ultimately it will spread to many or all the members of the population. Whether such a spreading will take place or not depends on natural selection Natural selection is, therefore, synonymous with differential reproduction and it means that those individuals of a population which leave more offspring than others are more successful.

By various experiments and statistical analysis it has been shown that the gene frequencies in a population will remain constant from generation to generation if (a) mating is a random process,
(b) if gene mutations are balanced and (c) if the population is large. This is known as Hardy-Weinberg law (HWL) which states that when a population is in genetic equilibrium, the rate of evolution is zero. When two individuals with mutually stable traits mate the gene, which controls such traits will increase in number through the offspring and spread through populations. Individuals with mutually undesirable traits are not likely to mate and so their genes do not spread through populations. Thus non-random mating in a population means natural selection. As a result, some genes spread more rapidly than others in a population, the gene frequencies will become altered upsetting the HWL equilibrium. This represents evolutionary change, natural selection operating for or against given genes.

Darwin's theory of Natural Selection was accepted to the account of its direct approach and practical nature. The staunch supporter of Darwinism was Wallace, Thomas Henry, Huxley, Ernst Heinrich Haeckel, August Weismann and Mendel etc. But in 1880 doubts started creeping up about its validity and applicability. Many biologists carried out experiments to provide support to Darwinism. These supporters of Darwinism are known as Neo-Darwinians. These have introduced a number of new facts to make the idea of natural selection more conceivable. Some of the experiments conducted in this series are as follows.

1. Whedon's experiments with the shore-crabs of Plymouth sound: Weldon in the experiments with shore-crabs placed a large breakwater near the mouth of Plymouth sound. This slowed the rate of flow of river water and china-clay deposition was increased. This caused the death of numerous crabs. The survivor had slightly narrow frontum and there was a progressive narrowing of the frontum in succeeding generations. This showed that under the changed environmental conditions natural selection operates upon minute fluctuating variations.

2. Cesnola's experiments with mantis: the role of natural selection was illustrated by Cesnola in *Mantis religiosa* by fixing them on plants. Those having color marking harmonious with the plants survived, whereas all others were eaten up by the birds.

3. Polution's and Sander's experiments with butterfly pupae: The survival value of protective coloration was also exhibited by Polution's experiments. The numerous pupae of butterflies with different colors were placed under conditions which favored protective colouration. Some of them were also kept in the non-harmonious background. The protective colouration was found to have a survival value.

4. Davenport's experiment with chicken: Chicken with black, white, barred and checkered color pattern was left in the field. It was found that the chickens with plain colors were killed by hawks while those with barred and checkered color pattern were spared because these were inconspicuous from the surroundings.

In last 25 years, a number of new facts have been added to the knowledge of evolution and the theory of Natural selection has been re-analysed.

The modern theory of Origin of Species or evolution is known as Modern Synthetic Theory of Evolution or Neo-Darwinism. Theodosius Dobzhansky reviewed the Darwinian concept of evolution by Natural Selection in Mendelian populations. In his book 'Genetics and origin of species' (1937), he presented the chromosomal studies of *Drosophila* populations and interrelation among its different species. E.B. Babcock provided botanical support to the 'Neo- Darwinian theory' by studying plant genus *Crepis*. Stebbins (1950) provided an account of 'Variation and Evolution in plants'. It presents a combination of mutation, variations, heredity, isolation and natural selection.

1. Mutation: Any alteration in the chemistry of gene or DNA molecule, which is able to change its effect, is known as gene mutation. Mutation can produce drastic change or may remain insignificant.

2. Variation and heredity: During Darwin's time little was known about the nature of genetic variations caused by reshuffling of genes during sexual reproduction. The phenomenon of meiosis caused a random assortment of genes during synapsis and rearrangement maternal and paternal chromosomes in both kinds of gametes. Such a reassortment of genes, especially in a large population with the large gene pool is one of the basis of appearance of a new organism.

Crossing over of genes during meiosis also adds to the variations and chromosomal variations like inversion and translocation and moreover in the chromosome number (polyploidy) also result in the origin of new species.

4. Natural selection: Natural selection includes all those kinetic forces introduced by physical and biotic factors, which determine how and in what direction an organism is going to change. Natural selection plays no favoritism, but it is obvious that the organism which is more suited for the environmental condition will survive overpowering the force of competition. Thus the natural selection of a creative process which uses the variations and mutations of the raw materials from which better survivals having combinations of better survival value are obtained. How natural selection acts in nature can be exemplified as follows:-

In any physical environment at a given moment, a certain proportion of individuals in the population carry normal genes while others represent the mutants, which have mutant genes combined in such a manner that the individuals carrying them differ from normal parents. If the gene pool of that population achieves stability i.e. there are no more changes in the genotype of individuals of the population, it will exhibit following conditions:-

i) Mutational equilibrium

ii) Random Mating

iii) Equal chances for all genotype to live and reproduce.

But a population is never stable and constant, and changes in its genetic code, chromosomal rearrangement and recombination of genes. Due to the unequal opportunity of mating and inadequate chances of survival in every case, the individuals with changes of survival value survive and perpetuate, while others die off. Thus natural selection due to environmental or biotic factors always exerts a selective influence as a result of which certain mutational changes or variations establish themselves in the line. The process is known as non-random reproduction or differential reproduction.

4. Isolation: Isolation or segregation of individuals of a species into several populations or groups under psychic, physiological or geographical factors is considered to be one of the most important factors responsible for evolution.

Geographical isolation includes physical barriers like mountains, rivers, oceans and long distance, which prevents interbreeding between related forms. Physiological barriers help in maintaining the individuality of the species because these isolations do not permit the interbreeding among the individuals of different species. All these lead to reproductive isolation.

Origin of new species: The population of a species, when representing in different environments, and are separated by some above-mentioned barrier, accumulate different mutations independently and become morphologically and genetically so different that they become reproductively isolated and form new species.

Difficulties of Neo-Darwinism

Goldschmidt believed that the Neo-Darwinian type of evolution, by the accumulation of micro mutations under the influence of natural selection, is largely restricted to subspecific differentiation within species and that the decisive step in the formation of new species must involve an altogether different genetic process, the systematic mutation. Only a few of the reasons which led him to this conclusion can be indicated here, briefly. If Neo-Darwinian evolution gives rise to new species, then new species should come only if the terminal members of a Rassenkreis and the Rassenkreie of closely related species should blend into one another. But actually, this does not happen. He believed that good species are always separated from their nearest relatives by a bridgeless gap. Controversial cases he believed depend in part upon purely morphological definitions of species which do not take the genetic facts into account. Goldschmidt believed that interbreeding or potentially interbreeding, populations should be treated as a single genetic unit, a species, from an evolutionary point of view, even of other factors may make it advisable for taxonomists to break it up into several species. On this basis, many difficult cases can be resolved in accordance with his ideas.

Mutation Theory:-

Mutation theory is somewhat recent and convincing up to some expectation. It was put forward in 1901 by a Dutch botanist -Hugo De Vries (1848-1935). He was the director of the Botanical Gardens at Amsterdam. His conclusions were based upon careful observations on evening primrose – *Oenothera Iamarckiana*. According to his theory, new species arise from pre-existing ones in a single generation by the sudden appearance of marked differences called mutations. Evolution is, thus, a discontinuous and jerky process, rather than a continuous and gradual one as held by Lamarck and Darwin. In other words, there is a jump from one species to another.

The Raw Materials of Evolution

The Dutch botanist Hugo De Vries, one of the three rediscoveries of Mendel’s laws, experimented with a number of plants, especially the evening primrose, which grew wild in Holland when he transplanted these into his garden and bred them, he found that unusual forms; differing markedly from the original wild plant, appeared and bred true thereafter. For these sudden changes in the characters of an organism, he coined the name “mutation".

Darwin had referred to such changes but believed that they occurred too rarely to be important in evolution. Countless breeding experiments with plants and animals since 1900 have shown that such mutations occur constantly and that their effects may be of adaptive value with the development of the gene theory, the term mutation has came to refer to sudden, discontinuous, random changes in the genes and chromosomes, although it is still used to some extent to refer to the new type of plant or animals.

In the plants and animals most widely used in breeding experiments, corn and fruit fly several mutations have been observed in the past fifty years. The fruit fly mutations are tremendously varied, including all shades of body color from yellow through brown and gray to black; red, white brown or purple eyes, peculiarly shaped ‘wings and a complete absence of wings, oddly shaped legs and bristles and such extraordinary arrangements as a pair of legs growing from the forehead in place of the antennae. Among domestic animals, mutations are no less common, the six-toed cats of Cape Cod and the short-legged breed of Ancon sheep are two of many examples of the persistence of a single mutation.

Early in the present century, a heated discussion arose as to whether evolution is the result of natural selection or of mutations. As more was learned about heredity, it became clear that natural selection can operate only when there is something to be selected in another word, when mutations present alternate ways of coping with the environment. The evolution of new species, then, involves both mutation and natural selection by differential reproduction.

A similar argument has continued to the present day between the Neo-Darwinists who believe that new species evolve by the gradual accumulation of small mutation, and another group, who believe that new species and genera arise in one step by a macromutation or major change in the genetic system. Such a macromutation producing a major change early in development would result in an adult from, considerably different from its parents into the new species or genus. \.

Many major changes result only in monster which dies almost immediately, though some give rise to what Rich and Goldschmidt of the University of California called “hopeful monsters” forms enabled by their mutation to occupy some new environment. He suggested that the evolution of the extinct ancestral type of bird. Archaeopteryx, into the modern bird, may have occurred in fashion. The archaeopteryx had a long, reptile-like tail. If by a single mutation that tail was greatly shortened, a hopeful monster with the fan-shaped arrangement of feathers might have been the result. The new tail better suited for flying than the old, long one would give its possessors a selection advantage in subsequent evolution. There is, of course, no proof that this is how present birds evolved.

Analogous major skeleton changes to occur as the result of a single mutation. The Manx cat, for example, owes its stubby tail to a mutation in some ancestor, which caused the shortening and fusing of the tail vertebrae. Goldschmidt did not deny the role of the accumulation of small mutations in evolution, geographic races and not to species, genera and the higher taxonomic divisions.

DE VRIES'S EXPERIMENT:-

De-Vries' experimental plant - *evening primrose (Oenothera lamarckiana)* is a plant native of America. It is a biennial plant of about 5-6 feet height. It bears bright yellow flowers at the tips of the branches. The flowers blossom in the evening, hence named evening primrose. During his work in the gardens, De Vries observed not only the original *Oenothera lamarckiana* but also two other varieties which he named as *Oenothera brerisfylis* characterized by short-styled flowers and *Oenothera lamarckiana* characterized by smooth leaves. Out of curiosity, he cultivated the three different plants in his garden and collected 54,343 plants, out of which 837 were different from the original wild parental variety. The markedly different forms were found to breed true. They gave rise to a few still more different plants in each generation. From this, De Vries held that the new types were appearing in evening primrose and that he was actually seeing evolution going on. He called the marked difference 'mutations' or spots' and the plants bearing them "mutants". He found that the mutations appeared suddenly and were inherited by the offspring.

As De Vries has pointed out, each mutation may be different from the parent form in only a slight degree for each point although all the points may be different. A unique feature of these mutations is the constancy with which the new form is inherited. It is this fact, not previously fully appreciated, that De Vries work has brought prominently into the foreground. There is another point of great interest in this connection many of these groups that Darwin recognized as varieties correspond to the elementary species of De Vries. These varieties, Darwin thought, 'are the first stages in the formation of species, -and, in fact, cannot be separated from species in most cases. The main difference between the selection theory and the mutation theory is that the one supposes these varieties to arise through a selection of individual variations, the other supposes that they have arisen spontaneously and at once from the original form. The development of these varieties into new species is again supposed, on the Darwinian Theory, to be the result of further selection, on the mutation theory, the result of the appearance of new mutations.

In consequences of this difference in the two theories, it will not be difficult to show that the mutation theory escapes some of the gravest difficulties that the Darwinian theory has encountered. Some of the advantages of the mutation theory may be briefly mentioned here:

1. Since the mutations appear fully formed from the beginning, there is no difficulty in accounting for the incipient stages in the development of an organ, and since the organ may persist, even when it has no value to the race, it may become further developed by later mutations and may come to have finally an important relation to the life of the individual.

2. The new mutations may appear in large numbers, and of the different kinds, those will persist that can get a foothold. On account of the large number of the times that the same mutation appears, the danger of becoming swamped through crossing with the original form will be lessened in proportion to the number of new individuals that arise.

3. lf the time of reaching maturity in the new form is different from that in the parent forms, then the new species will be kept from crossing with parent form, and since this new character will be present from the beginning, the new form will have much better chances of surviving than if a difference in time of reaching maturity had to be gradually acquired.

4. The new species that appear may be in some cases already adapted to live in a different environment from that occupied by the parent form, and if so, it will be isolated from the beginning, which will be an advantage in avoiding the bad effects of intercrossing.

5. It is well known that the difference between related species consists largely in differences of unimportant organs, and this is in harmony with the mutation theory but one of the real difficulties of the selection theory.

6. Useless or even slightly injurious characters may appear as mutations, and if they do not seriously affect the perpetuation of the race, they may persist.

Later Investigation or Mutations:-

Since the publication of De Veris's classic investigations a large amount of attention has been paid both by botanists and by zoologists to the subject of mutations. Some of the investigators, notably B.M. Davis, went far toward discrediting the whole of the exceptionally careful work of De Vries by claiming that *Oenothera Lamarckiana* is of hybrid origin. It was pointed out that the form Worked with is a domestic type escaped from cultivation and that there is nowhere in the known world any wild species comparable with it. It is supposed to have been brought to Europe from America many years ago, but there are no such species in America today. Davis claims that he has succeeded in producing, by crossing two American wild species, a hybrid from distinctly resembling *Oenothera Lamarkiana*, and that when inbred this hybrid produces offspring showing various combinations of the two parent species that are not unlike some of the mutants observed by De Vries has also pointed out that the pollen grains of *Oenothera Lamarkiana* exhibit a high percentage of sterility, which he believes to be a stigma of hybridity. The general terms of this type of destructive criticism are to invalidate the whole mutation theory as developed by De Vries and to reduce his mutants to the level of mere mendelian recombination of characters once introduced from two or more parental species.

A large amount of work on the cytology of Oenothera by Gates and others has, however, served to show that the mutants of De Vries are more than hybrid segregates. Moreover, the beautiful work of Blakeslee on the Jimson weed (Datura) and the work of many other botanists, whose findings are reported by Gates in a contribution quoted below, serve to indicate that the type of evolutionary behavior first observed in *Oenothera* is by no means exceptional, but is probably a common thing at least among plants and may be commoner that we at present know of animals. It may be said by way of anticipation of Gates detailed account that nearly all of the mutations observed in various species of plants may be definitely correlated with observable changes in the chromosomes of the germ cells, involving changes in number or changes in the arrangement of these nuclear elements.

While botanists buried themselves with their type of mutations, the zoologists, especially T.H Morgan and his able collaborators, were making discoveries of the equal moment in connection with their studies of the mechanism of mendelian heredity in Drosophila.

Hundreds of new hereditary types arose, apparently spontaneously, in pure pedigreed stock. Each new type is designated a mutant, and the cause of the changed hereditary condition is not a gross chromosomal change, but an invisible change of a definite point in a definite chromosome, whose cause is unknown but whose location can be exactly determined. Such mutations are known as gene mutations. Like the mutants of Oenothera, these Drosophila mutants do not differ from the parent species is just one or two characters but in several or many characters. Usually, some one or two characters in any given mutant are especially characteristic, and these serve to give a name to each mutant and make it easier to identify them. Both morphological and physiological characters are involved in these mutants, and every part of the body may be involved. Sometimes the change is so slight as to require an eye sensitized by much training to detect them. It may happen, for example, that two mutants of the eye are so much alike that the human eye is not sufficiently been to tell them apart, but they may be distinguished by differences in their hereditary behavior. A large percentage of the mutants discovered in Drosophila are lethal which means that the change is decidedly for the worse under the prevailing conditions of life and that they render the individual unfit to live.

De Vries regarded the main plants as elementary species and classified them as following:

(a) Progressive species

In this case, one or more new characters are observed which are quite different from the original plants. *O. gigas* is more vigorous than the parent plant and much stouter. With large leaves and flowers.

(b) Retrogressive species

When in mutant there is a loss of one or more characters of the parental nature, the variety is called as retrogressive species. *O. nanella* is a dwarf plant having only one-fourth of the height of the parental plant. A

(c) Degressive species

In this case, one or more, essential characters are lost and due to this, their survival becomes limited. In

Oalbida, the chlorophyll becomes defective hence could not survive.

(d) lnconstant species

These are the mutants which behave just like the parents and occasionally give rise to mutants. *O.lata* bears only pistils in the flowers and hence self-pollination is not possible.

On the observations recorded by De Vries, he suggested that new species arose as a result of large, conspicuous, discontinuous mutations (variations).

Objections to Mutation Theory:-

As per our recent knowledge, it is established that mutations are rare and non-predictable. Therefore, it is doubtful that animals and plant species could appear by mutations.

Moreover, the cases of amazing resemblance of the mimics with their models, harmonization of animal colours with their surroundings and relationship between position of nectaries in flowers and length of proboscis in their insect pollinators cannot be imagined to have developed all of a sudden by mutations because some of the characters are attained during lifetime only by, adaptations.

However, De Vries' mutation theory contributes a lot in the field of gene studies. Evidences

Supporting Mutation Theory

Besides objections, there are certain sure points which go in favor of mutation theory. There are definite examples of mutations giving specific characteristics. Some of them are:

(a) Ancon sheep (a short legged variety) was produced by an ordinary sheep in a single generation in 1891. This mutant is highly beneficial for farmers.

(b) Hornless cattle from normal were produced in l889.

(c) Hairless cats, dogs, and mice were produced from normal parents.

The discovery of mutations in *O. lamarckiana* by Hugo De Vries gave ample ideas to scientists to investigate the nature and behavior of genes.