Biyani's Think Tank

A concept based exclusive material

Pteridophytes, Gymnosperms & Palaeobotany

[B.Sc. Part-I]

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Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the "Teach Yourself" style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, *Chairman* & Dr. Sanjay Biyani, *Director* (*Acad.*) Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this Endeavour. They played an active role in coordinating the various stages of this Endeavour and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

Author

Syllabus

Unit I

General characters of pteridophytes, classification by Smith, Bold: & Sporne. Important characteristics of Psilopsida, Lycopsida, Sphenopsida and Pteropsida. Stelar system in Pteridophytes. Alternation of Generations. Distribution, structure and life history of *Lycopodium*, *Equisetum*.

Unit II

Distribution, structure and life history of *Seloginella*, *Marsilea*. Heterospory and seed habit.

Characteristics of seed plants. Differences between Gymnosperms and Angiosperms, General characters classification of (Andrews, Sporne & Bierhorst) and Economic importance of Gymnosperms.

Unit III

Systematic position, distribution, Morphology of Vegetative and reproductive parts, anatomy, reproduction and life cycle of following genera,—*Cycas*, *Pinus* and *Ephedra*.

Unit IV

Fossilization types of fossils, techniques of study of fossils. Geological time scale.

Applied aspects of palaeobotany-use in coal and petroleum exploration. Primitive land plants : *Rhynia*.

Fossil Pteridophytes, *Lepidodendron*, *Calamites*.

Fossil Gymnosperms - *Williamsonia*.

Unit-I

Pteridophytes

Q1 Stelar system in Pteridophytes?

Ans. The entire vascular cylinder of the primary axis of pteridophytes is usually referred to as stele. Besides xylem and phloem, it includes pith (if present) and is delimited from the cortex by the pericycle. The concept that stele is the fundamental unit of vascular system was put forward by Van Tieghem and Douliot (1886). They proposed the stellar theory, according to which the root and stem have the same basic structure consisting of two fundamental units- the cortex and the central cylinder.

Types of steles in pteridophytes:

Schmidt recognized the two principal types of steles in pteridophytes.

(1) Protostele (2) Siphonostele.

(I) Protostele:

It is a non-medullated stele consisting of a central core of xylem, surrounded by a band of phloem. There is a single or multiple layer of pericycle outside the phloem which is delimited externally by a continuous sheath of endodermis e.g. Fossil pteridophytes (e.g. Rhynia, Horneophyton) as well as many living primitive vascular plants (e.g. Psilotum) show this type of stele.

The following four types of protosteles are recognized in pteridophytes:-

(a) Haplostele:

It is the simplest and most primitive type of protostele. It consists of a solid xylem core with smooth circular outline, which is surrounded by a ring of phloem.

Haplostele is found in fossil (i.g. Rhynia, Cooksonia) as well as in many living pteridophytes (e.g. Psilotum. Selaginella, Lycopodium).

1. Actinostele:

In this type of protostele, xylem is star-shaped with many radiating arms. The phloem instead of forming a continuous ring is present in small patches in between the radiating arms of the xylem. Actinostele is characteristic of many living (e.g. Psilotum, Lycopodium serratum) and fossil forms e.g. Asteroxylon, Sphenophyllum).

2. **Plectostele:**

A protostele in which the central xylem core breaks into more or less parallel plates is known as plectostele. Each xylem plate is surrounded by phloem.

e.g. Lycopodium clavatum
Lycopodium volubile

3. **Mixed protostele:**

Sometimes, the solid xylem core of the protostele is broken into small groups of tracheids, which remain embedded in the phloem. Such a protostele is known as mixed protostele e.g. Lycopodium cernuum.

(II) Siphonostele:

A protostele having definite parenchymatous pith or medulla in the centre is called as siphonostele, i.e. a modified protostele with a central pith is known as siphonostele or medullated stele.

Jeffery (1910) on the basis of their association with leaf and branch traces recognized two types of siphonosteles – cladosiphonic and phyllosiphonic

(1) A cladosiphonic stele is characterized by the absence of leaf traces, e.g. Microphyllous lycopsids

(2) Phyllosiphonic stele has both the leaf and branch traces and is found in the members of order Filicales.

→ **Ectophloic siphonostele:**

A siphonostele having a single phloem ring external to the xylem is called as ectophloic siphonostele.

e.g. Equisetum, Osmunda.

→ **Amphiphloic** siphonostele:

A siphonostele having a ring of phloem each external and internal to the xylem is called as amphiphloic siphonostele.

e.g. Adiantum, Dryopteris, Marsilea.

(2) **Modifications of Siphonostele:**

Depending on the presence of non-overlapping or overlapping gaps, the following three types of siphonosteles are recognized.

Solenostele A siphonostele with non-overlapping leaf gaps is known as solenostele. The solenostele may be ectophloic or amphiphloic .

(b)Dictyostele:

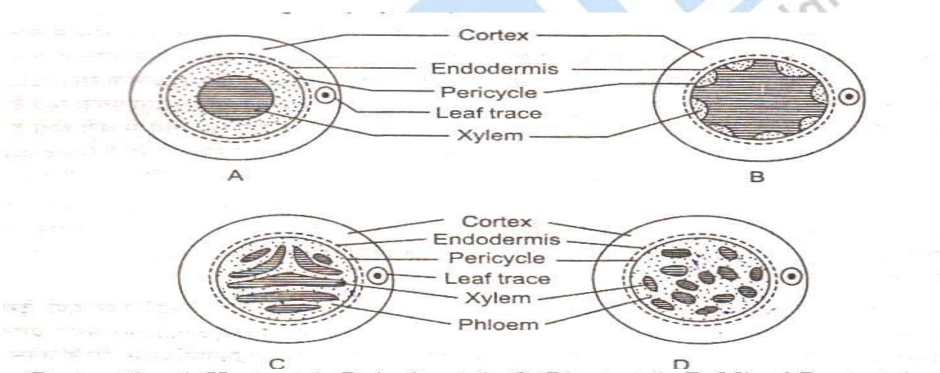
A siphonostele with overlapping leaf gaps is known as dictyostele. A dictyostele has many scattered vascular strands, each of these strands is called a meristele. e.g. Pteris, Ophioglossum. Dryopteris.

(c)Polycylic stele:

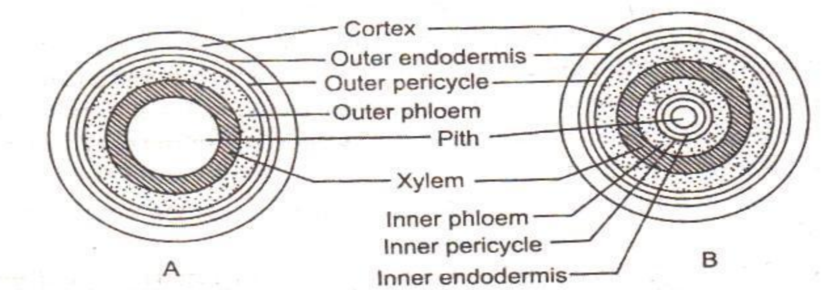
Stelar structure of certain pteridophytes is more complex. They possess two or more concentric rings of vascular tissue and are called polycylic, e.g. there are two rings of vascular tissue in Pteridium aquilinum , three in Montania pectinata.

If in a polycyclic stele , the outer cylinder is solenostelic, it is called polycyclic solenostele.

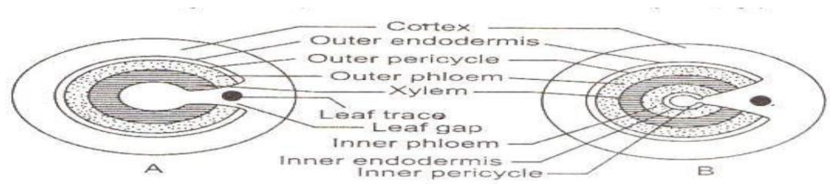
If the outer cylinder is dictyostelic, it is known as polycylic dictyostele.



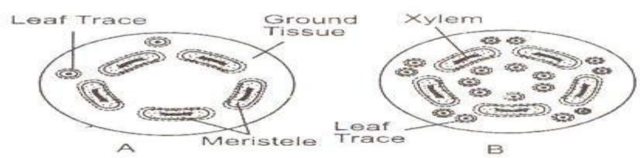
Protostele : A-Haptostele B-Actinostele C- Plectostele D-Mixed Protostele



Siphonostele : A-Ectophloic Siphonostele B- Amphiphloic Siphonostele



Solenostele : A-Ectophloic Solenostele B-Amphiphloic Solenostele



Modified Siphonostele : A - Dictyostele B - Polycyclic Stele

Q2 Write about the salient features of the Pteridophytes.

Ans. The Pteridophytes are the spore - bearing vascular plants and are distinguished from the other cryptogams by the possession of vascular tissues- xylem and phloem. They are commonly called **"<u>Vascular cryptogams</u>".**

<u>The Salient Features</u>:

<u>Occurrence</u>:

(A) The pteridophytes grow in a variety of habitats. Most pteridophytes are terrestrial plants and thrive well in abundant moisture and shade while some flourish well in open, dry situations especially in xeric conditions. A few pteridophytes are aquatic while still others are epiphytes.

(B) **<u>The plant body (the adult sporophyte)</u>:**
The sporophyte is the recognized plant body of all pteridophytes. The sporophyte develops from the zygote , a diploid cell which results from the fertilization of the egg by a sperm.

(C) The sporophytic plant body is differentiated into true roots, stem and leaves. Some primitive members of the group may lack true roots and well developed leaves, e.g. orders psilophytales and psilotales.

(D) In some members, the branching of the stem is of dichotomous type, while in others it is monopodial.

(E) The sporophytic plant presents a great range in form. Two main categories may be distinguished. One category comprises megaphyllous types in which the leaves are large in relation to the stem and is represented by the ferns. The second category consists of microphyllous types, in which the leaves are small in relation to the stem and is represented by the lycopods and the horsetails.

(F) All the vegetative organs of the sporophyte possess vascular supply. The vascular system of pteridophytes varies in different groups. It may be a simple protostele, siphonostele or a dictyostele. Phloem lacks companion cells. In some members e.g. Selaginella and Equisetum, the primitive vessels are present.

(G) Secondary growth does not take place in majority of the living pteridophytes, Isoetes being an exception.

(H) The sporophytic plant reproduces asexually by means of spores which are produced in small capsules called sporangia.

(I) The position of the sporangia differs among the groups, but they are always found on the sporophyte. In some pteridophytes, the sporangia are borne on stems i.e. they are cauline in original. In others, the sporangia are borne either on the leaves (foliar) or in their axils (between the leaves and the stem). Leaves bearing the sporangia are called sporophylls.

(J) The sporophylls may be widely scattered on a plant or may clustered in definite areas and structures called cones or strobili (Selaginella and Equisetum).

(K) In some pteridophytes, the sporangia are produced within the specialized structures called the sporocarps. (Marsilea, Salvinia and Azolla).

(L) According to other mode of development, the sporangia are of two fundamental types, the eusporangium and leptosporangium.
The eusporangium is found in most cases and develops from several sporangial initials.

(M) Within the sporangia are developed the diploid spore mother cells or sporocytes. These spore mother cells undergo meioses or reduction division to form spores. If all the spores are of same size the plant is said to be homosporous (Lycopodium and Dryopteris) and if they are of different sizes, the plant is called heterosporous (Selaginella, Isoetes, and Marsilea). The smaller spores are called microspores or males spores and are developed in microsporangia while the larger spores which are generally produced in smaller numbers and termed as megaspores and are formed in megasporangia.

The Gametophyte:-

(N) The spores on germination give rise to the haploid gametophytes or prothalli which are usually small and insignificant structures. The gametophytes are inconspicuous as compared to the sporophytes.

(O) The gametophytes are of two general types-

(a) Gametophytes that develop from homospores grow upon the soil and form independent plants. Such gametophytes are known as exosporic gametophytes (Psilotum, Lycopodium spp and Ophioglossum).

(b) Gametophytes, that develop from heterospores are for the most part, retained within the original spore case and are called endosporic gametophytes (Selaginella, Isoetes and Marsilea).

(P) Exosporic gametophyte is typically a delicate, thin thallus and is commonly called the prothallus. In most of the vascular cryptogams the exosporic gametophytes grow exposed to light and remain attached to the ground by numerous rhizoids. In such cases they manufacture the food by means of their chloroplasts and live an independent life. The rhizoids are meant for the fixation and absorption of water.

In some vascular cryptogams, the exosporic gametophytes are devoid of chlorophyll and are subterranean in habit. In such cases , they obtain their food by symbiosis through the agency of mycorrhiza which occurs within the tissue of the prothallus or gametophyte. E.g. Psilotum.

(Q) Endosporic gametophytes, that develop from heterospores are greatly reduced structures. They develop largely or entirely within the spore wall and live on food deposited in the spores.

Sex organs:-

(R) The gametophyte or prothallus bears the sex-organs, the antheridia and archegonia. Typically, the gametophytes formed from the homospores are monoecious, that is both antheridia and archegonia are borne in large numbers on the same gametophyte or prothallus. The gametophytes formed from the heterospores are dioecious.

(S) The antheridia:-

The antheridia may be embedded either wholly or in part in the tissue of gametophyte or they may project from it. The former are the embedded antheridia which are found in Lycopodium, Selaginella and Equisetum while the latter are the projecting antheridia which are usually found in the leptosporangiate ferns.

The archegonia:

(T) The archegonia in pteridophytes resemble closely with those of the bryophytes. Each arch gonium is a flask-shaped structure, consisting of a basal swollen, embedded portion, the venter and a short neck. The wall of the venter develops from the tissue of the prothallus and hence the venter lies embedded in the tissue of the prothallus.

The venter encloses the egg and ventral canal cell. Inside the neck are found the neck canal cells.

Fertilization:-

(U) Fertilization in all cases is accomplished by the agency of water. The fusion of a male gamete and an egg restores the diploid chromosome number and results in the formation of the zygote.

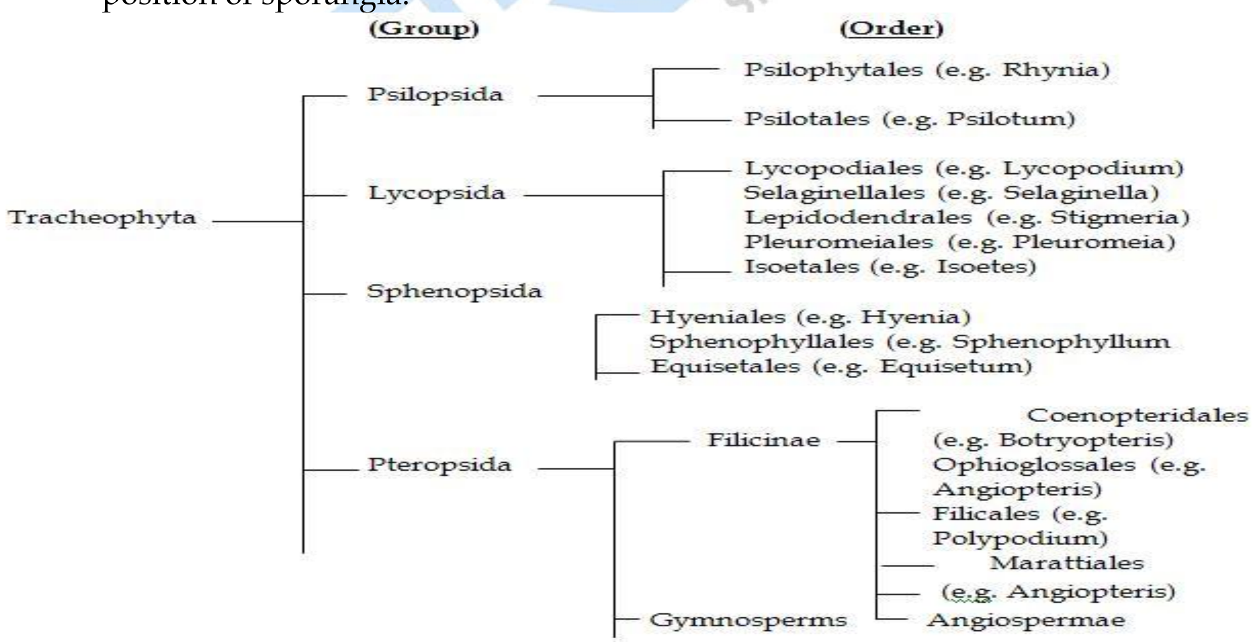
The embryo (The new sporophyte):

(22) The zygote undergoes repeated divisions to form a new sporophyte. The young sporophyte remains attached to the gametophyte by means of a foot and draws nourishment from the prothallus (gametophyte) until it develops its own stem, roots and leaves. The sporophyte is dependent on the gametophyte only during its early stages.

Q3 Describe the classification of Pteridophytes.

Ans. The vascular plants have been divided into two groups- Pteridophyta and Spermatophyta. Pteridophyta include vascular cryptogams (e.g. Psilotum, Lycopodium, Equisetum, ferns etc) which lack seeds and reproduce by spores.

Arthur J. Eames opined that classification of vascular plants should be based upon several fundamental characters of the plant body, instead of a single character. He classified Tracheophyta into the following four groups on the basis of (i) the nature and relation of leaf and stem (ii), the vascular anatomy (iii) the position of sporangia.



Tippo gave Tracheophyta the status of a phylum and divided it into the following four subphyla (equivalent to sub- division)

Phylum – Tracheophyta

Sub Phylum Psilopsida	Lycopsida	Sphenopsida	Pteropsida
Class: Psilophytinae	Class: Lycopodinae	Class: Equisetinae	Class: 1 Filicinae
Order 1 Psilophytales	Order 1 Lycopodiales	Order 1 Hyeniales	Order 1 Coenopteridales
2 Psilotales	2 Selaginellales	2 Sphenophyllales	2 Ophioglossales
	3 Lepidodendrales	3 Equisetales	3 Marattiales
	4 Pleuromeiales		4 Filicales
	5 Isoetales		Class 2 Gymnospermae
			Class 3 Angiospermae

Smith was of the view that it is inappropriate to treat Psilopsida, Lycopsida, Sphenopsida and Pteropsida as subdivisions of a single division Tracheophyta as it minimizes their marked divergence from one another.
Therefore he divided vascular cryptogams (pteridophytes) into the following four divisions.

Vascular Cryptogams

Divisions Psilophyta	Lepidophyta	Calamophyta	Pterophyta
Class: Psilophytinae	Class: Lycopodinae	Class: Equisetinae	Class: Filicinae
Order 1. Psilophytales	**Order:** 1 Lycopodiales	**Order 1.** Hyeniales	Subclass 1 Primofilicales
2 Psilotales	2 Selaginellales	2 Sphenophyllales	**Order 1** Protopteridales
	3 Lepidodendrales	3 Equisetales	2 Coenopteridales
	4 Isoetales		3 Archaeopteridales
			Subclass 2 Eusporangiate
			Order 1 Ophioglossales
			2 Marattiales
			Subclass 3 Leptosporangiate
			Order 1 Filicales
			2 Marsileales
			3 Salviniales

Bold followed the classification of Smith . He divided Pteridophytes into 4 divisions and divided each division into one or more classes. The outline of Bold Classification is as follows-

Pteridophyta

Division I	-	Psilophyta
Class 1	-	Psilopsida
Division II	-	Microphyllophyta
Class 1	-	Aglossopsida
Order 1	-	Lycopodiales
Class 2	-	Glossopsida
Order 1	-	Selaginellales
Order 1	-	Isoetales
Division III	-	Arthrophyta
Order 1	-	Equisetales
Division IV	-	Pterophyta
Class 1	-	Eusporangiosida
Order 1	-	Ophioglossales
Order 2	-	Marattiales
Class 2	-	Leptosporagiopsida
Order	-	Filicales

Riemers proposed a classification of pteridophyta which was published in 1954 edition of Engler's Syllabus der Pflanzenfamilien .Sporne (1966) also followed the same classification. Following is an outline of Riemers classification

Division	-	**Pteridophytes**
(I) **Sub division**		:**Psilophytopsida**
Order	:	Psilophytales
Families	:	Rhyniaceae
		Asteroxylaceae, Psilophytaceae
(II) Sub division	**:**	**Psilotopsida**
Order	:	Psilotales
Families	:	Psilotaceae, Tmesipteridaceae
(III) Sub division	**:**	**Lycopsida**
Order 1	:	Protolepidodendrales
Families	:	Drepanophyceae, Protolepidodendraceae
Order 2	:	Lycopodiales
Family	:	Lycopodiaceae
Order 3	:	Lepidodendrales
Families	:	Lepidodendraceae, Sigillariaceae
Order 4	:	Isoetales
Family	:	Isoetaceae
Order 5	:	Selaginellales
Family	:	Selaginellaceae
(IV) **Sub-division**	**:**	Sphenopsida
Order 1	:	Hyeniales

Families	:	Sphenophyllaceae Cheirostrobaceae
Order 3	:	Calamitales
Families	:	Asterocalamitaceae Calamitaceae
Order 4	:	Equisetales
Family	:	Equisetaceae
(V) **Sub division**	**:**	Pteropsida
(1) **Class**	**:**	**PRIMOFILICES**
Order 1	:	**Cladoxylales**
Families	:	Cladoxylaceae Pseudosporochnaceae
Order 2	:	Coenopteridales
Families	:	Zygopteridaceae
(2) **Class**	**:**	**EUSPORANGIATAE**
Order 1	:	Marattiales
Families	:	Angiopteridaceae, Asterotheaceae Danaeaceae
Order 2	:	Ophioglossales
Family	:	Ophioglossaceae
(3) **Class**	**:**	**OSMUNDIDAE**
Order	:	Osmundales
Family	:	Osmundaceae
(4) **Class**	**:**	**LEPTOSPORANGIATAE**
Order 1	:	Filicales
Families	:	Schizaceae, Gleicheniaceae, Hymenophyllaceae Cyatheaceae, Adiantaceae, Polypodiaceae
Order 2	:	Marsileales
Families	:	Marsileaceae Pilulariaceae
Order	:	Salviniales
Families	:	Salviniaceae Azollaceae.

Q4 Discuss about the life cycle of Psilotum.

Ans

Reproduction:-

The sporophytic plant of Psilotum , reproduces asexually by means of spores. The plant also reproduces vegetatively.

Vegetative reproduction:-
In P. nudum , new plants are formed by means of gemmae or brood bodies, which develop on the rhizomes. When detached from the rhizome , these gemmae germinate into new plants.

Reproduction by spores:-

When the plant becomes mature, many of its aerial shoots become fertile and produce tri-lobed sporangia in the axils of the bilobed leaf like appendages. Each lobe of the sporangium has a spore sac with numerous spores. Such a sporangium , formed by a group of two or more spore sacs (three in this case) is called synangium.

Development of sporangium:-
The development of sporangium is of eusporangiate type. The primordium of the synangium differentiates quite early in the ontogeny of the fertile appendage. Each of the three sporangia develops from a single or a group of superficial cells of the sporangiophore.

Each sporangial initial divides periclinally into an outer primary jacket initial and an inner primary archesporial cell.
The primary jacket initial undergoes periclinal and anticlinal divisions to form a jacket layer 4to 5 cells in thickness. The primary sporogenous cells or archesporial cell divides repeatedly to form a large number of sporogenous cells.

The entire sporogenous mass does not become converted into spore mother cells , but a few sporogenous cells disintegrate and serve as a nourishing fluid for the developing spore mother cells and spores. Each spore mother cell divides meiotically to form four haploid spores. After the spores have been formed , the cell walls in the epidermal layer of the jacket start becoming thickened in a small vertical row which is the future line of longitudinal dehiscence of the sporangium. All spores are of the same type. (homosporous).

The Gametophyte:

The spores of the Psilotum are all of one kind and vary in size from 0.065-0.032 mm. The spores are of the bilateral type but tetrahedral spores may also occur. The spores are colorless and bean shaped. A narrow ridge connects the two curved ends of the spore. Each spore has got a median slit which is bounded throughout its length by a smooth but thick lip. Each spore has a wall made up of 2 layers. The outer thin and reticulated layer is called exine and the inner thin layer the intine.

Germination of Spore and Development of Gametophyte:-

The stages in the germination of spore in Psilotum were studied by Darnell – Smith. The spores are slow to germinate and it takes three to five months for a spore to germinate. The wall of the spore opens along the cleft and the contents of the spore protrude out as a conical mound.

A wall is laid down in a transverse plane which separates the extruded portion from the basal one that remains within the spore wall. At this stage , the young prothallus consists of a large basal cell, remaining within the spore wall and the upper cell. An apical cell is established by the oblique divisions in the upper cell. By the further divisions of the apical cell, a mass of thin walled cells is formed. This cellular body is invaded by the hyphae of soil fungi.

Structure of Mature Prothallus:-

The mature prothallus is non- green and subterranean. It grows beneath the soil surface. It is brownish in colour, cylindrical , elongated and imperfectly dichotomously branched. Long unicellular rhizoids grow from the surface which penetrate the surrounding soil. They grow as saprophytes with an associated fungus. The large prothalli sometimes possess a strand of conducting tissue consisting of a few tracheids. Psilotum is the only known plant in which the vascular tissue normally develops in the gametophytic generation.

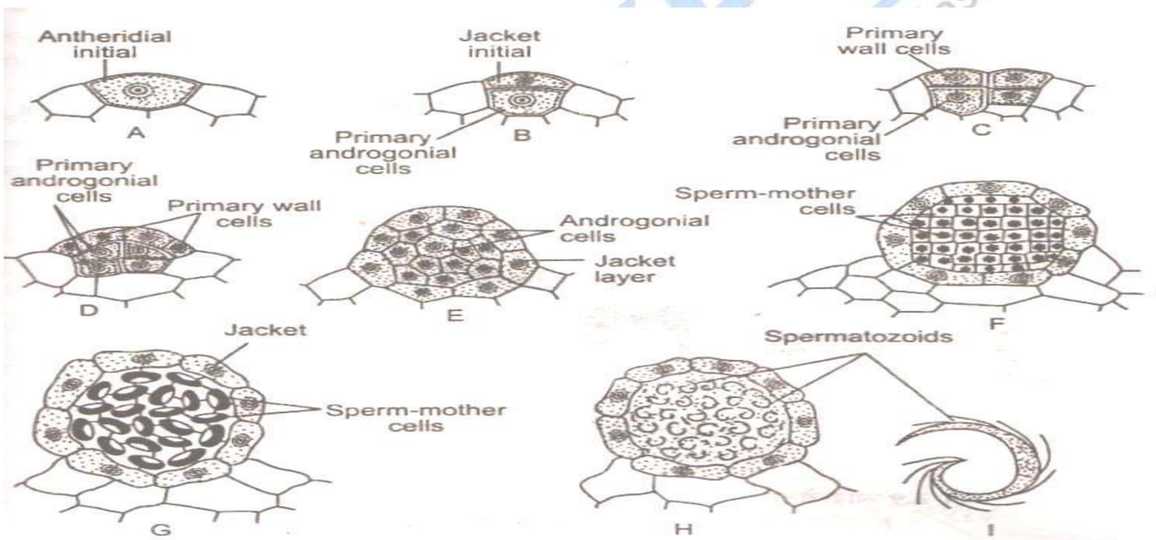
Sex Organs:-

The gametophytes of Psilotum are monoecious. The antheridia and archegonia are borne over the entire surface of the prothallus and are intermingled . The antheridia develop in more numbers and prior to archegonia.

Development of Antheridium:-

A single surface cell behaves as an antheridial initial. It undergoes a periclianal division, which sets aside an outer jacket initial and an inner primary androgonial cell. The jacket initial divides by repeated anticlinal divisions to form a single layered wall of the antheridium.

The primary androgonial cell first divides by an anticlinal division to form two cells. Both of these cells continue to divide and produce a large no. of androgonial cells, the last cell generation of which are the androcytes. At this stage, the antheridium bulges above the surface as a minute protuberance. Each androcyte or antherozoid mother cell metamorphoses into a spirally coiled and multiflagellate antherozoid.



Psilotum : A-G Stages of the development of Antheridium H - Mature Antheridium I - Antherozoid

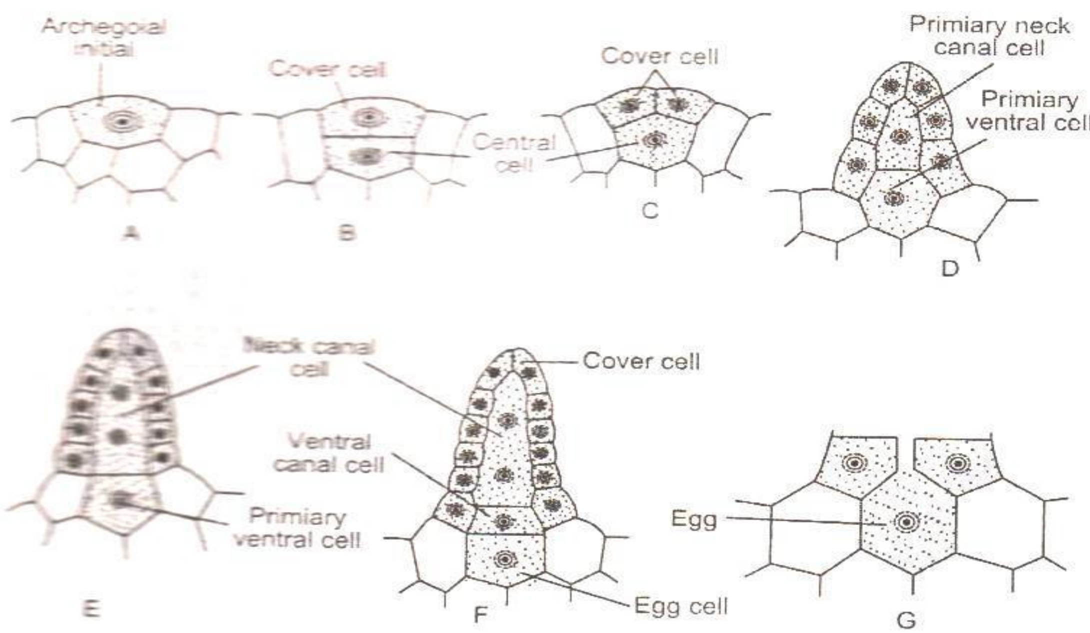
Structure of Mature Antheridium:-

The mature antheridium is a globular structure and projects from the surface of the prothallus. The wall of the antheridium is single layered at the centre of which is a triangular opercular cell, the eventual disintegration of which helps in the liberation of antherozoids. Inside the wall of antheridium are present many antherozoids. Each antherozoid is spirally coiled and multiflagellate.

Development of Archegonium:-

Any superficial cell of the prothallus behaves as an archegonial initial. It undergoes periclinal division to form an outer primary cover cell and an inner central cell. The primary cover cell is divided by two anticlinal walls at right angles to one another so that four neck initials are formed. The four neck initials divide transversely to form a neck, 4 to 7 cells in height and consisting of 4 vertical rows of cells.

The central cell divides by transverse division to form an upper primary canal cell and a lower primary ventral cell. The primary canal cell may divide to form two neck canal cells ; although in most cases walls separating the two nuclei have not been observed. The primary ventral cell divides transversely to produce the egg and a ventral canal cell.



Psilotum : A-E Stages of the development of Archegonium F-Mature Archegonium G - Archegonium at the time of Fertilization

Structure of mature archegonium:-

As the archegonium attains maturity, the cell walls between certain tiers of neck cells become cutinized and the upper part of the archegonium is sloughed off. With this break of the upper part of the neck and further disintegration of the canal cells a pathway is created for the entrance of antherozoids in the venter of the archegonium. Earlier botanists were of the view that the sloughing off of the neck happened before the fertilization , but according to Bierhorst (1904) , this decapitation takes place after the fertilization.

Fertilization:

Fertilization is accomplished by the union of a sperm and egg, resulting in the formation of an outer epibasal cell and an inner hypobasal cell. The epibasal cell develops into the foot of the embryo. The embryo of Psilotum is peculiar in that no suspensor, root or leaf is present.

Q.5 Describe the life history of Lycopodium.

Ans

Reproduction;-

Lycopodium reproduces vegetatively and by spores.

1. Vegetative reproduction:-

Propagation of sporophyte by vegetative methods is quite frequent in Lycopodium and takes place by the following methods.

1. By Bulbils or gemmae.
2. By adventitious buds.
3. By fragmentation and decay.
4. By root tubers.

5. Reproduction by Spores:-

Spore producing organs :-

Spores are formed within sporangia which originate singly on the adaxial (upper) side of specialized leaves , called sporophylls or fertile leaves.

The sporophyll forms a protective covering around the sporangium. The mature sporangium is abaxial and protected in L. cernuum, subfoliar and exposed in L. squarrosum.

The sporangium is unilocular , sub-spherical or reniform at maturity. The sporangia are homosporous and yellow or orange at maturity.

Development of Sporangium:-

The development of sporangium is of eusporangiate type. A group of 2-5 surface cells becomes differentiated as sporangial initials on the adaxial side of the sporophyll close to the axil. These cells divide periclinally and differentiate into an outer and an inner layer. The cells of the outer layer, called primary wall cells , undergo periclinal and anticlinal divisions and form three or more layered jacket of the sporangium. The cells of the inner layer, which function as primary sporogenous cells, undergo repeated mitotic divisions and ultimately give rise to spore mother cells.

As the sporangium develops , the innermost wall layer adjacent to the sporogenous mass , differentiates into a nutritive layer , called tapetum. The cells of the tapetum stain deeply indicating their high protein contents. These cells provide nutrition to the developing spores. The tapetum disintegrates completely by the time meiosis starts.

As the sporangium matures , the spore mother cells separate from each other and become almost spherical. Each spore mother cells forms a spore tetrad by meiosis.

Dehiscence of Sporangium:-

With the maturation of the sporangium , all jacket layers, except the outermost disintegrate. The cells of the outer layer elongate anticlinally and become thin-walled. But a narrow transverse strip of cells across the apical portion of the sporangium fails to elongate and forms a line of dehiscence, called stomium. The cells of the jacket shrink on drying and the sporangium ruptures along the stomium due to the nature of wall thickenings in this region.

Gametophyte:-

In some (L. cernuum) , spores may germinate immediately after they are shed, but in others (L. clavatum) , it takes place only after one or two or more years.

Development of the Gametophyte:

The spore begins to divide even before the outer wall is ruptured. The first division which is horizontal or oblique divides it into two cells of equal size One of these , the basal cell, besides cutting off a small rhizoidal cell does not divide further . Sometimes even this division may be absent (L. cernuum). The other cell by two oblique walls produces an apical cell with two cutting faces. The development of the gametophyte beyond the five- celled stage is dependent on the entry of the fungus , the apical cell cuts off 10- 12 segments , from both sides. Then it will be replaced by an apical cell which divides periclinally into an inner cell and a peripheral cell. All the peripheral cells formed from these segments also become infected with the symbiotic fungus.(mycorrhiza). The group of meristematic cells at the apex produce the major part of the prothallus.

Types of Gametophytes:-

The gametophytes of several species of Lycopodium are known and can be mainly recognized into three types on the basis of habit and nutrition. They are monoecious.

First type:-

In L. cernuum and L. inundatum , the gametophytes develop early from the spores which germinate within a few days after their liberation. These gametophytes are short lived and are usually inconspicuous measuring a few millimeters and the biggest of them measures about 2-3 millimetres in diameter. The lower cylindrical part is buried in the soil and it is colourless with endophytic mycorrhiza. It is also provided with rhizoids which absorb the necessary nutrients from the soil. The upper part is having several green , irregular , aerial , leaf like lobes and hence the prothallus is more or less independent.

The meristem which is above the cylindrical zone, contributes to the growth of the upper green part, as well as the lower colorless portion. The antheridia and archegonia are intermingled. They occur between the lobes of the crown. The archegonia have a short neck with 1 or two (2) neck canal cells.

Second type:-

In L. annotinum , L. clavatum and L. complanatum , the germination of spore takes place only after 2-5 years of their liberation. These gametophytes are brownish or even colourless and they are much larger than those of the first type. These prothalli measure 1-2 centimetres in diameter and accumulate food materials. The gametophytes of these species are completely subterranean and they are top- shaped as in L. clavatum or bottle –like as in L. complantum. The rhizoids are present in the lower region.

The endophytic fungus present in the massive conical portion helps in the saprophytic nutrition . In L. clavatum, the sex organs are towards the crown , with the antheridia occurring at the centre. In L. complanatum, the sex organs are in the lobes present at the top of the cylindrical portion. The antheridia and archegonia occur in close groups , but they are not intermingled. The archegonia have a long neck unlike those of green gametophytes. In the neck, 6 or more neck canal cells are present. The meristematic zone is present between the lobes and cylindric part. Thus , these gametophytes are strictly subterranean saprophytes.

Third Type:-

In epiphytic species (L. plegmaria) , the prothallus is repeatedly branched and the colorless branches are attached to the bark by hairs. The gametophyte is saprophytic and the endophytic fungus helps in nutrition. The sex organs are on the upper side of the branches.

Sex Organs:-

The gametophytes of Lycopodium are monoecious. The archegonia and antheridia are numerous and they occur at the base of the lobes of the crown. In some subterranean gametophytes which live for several years , sex organs are present all through the year. In the gametophytes , where the upper part of the thallus is aerial and green, the two types of sex organs are intermingled , but in subterranean gametophytes , sex organs occur in different groups. A sex organ is formed from a single dorsal superficial cell.

Development of Antheridium:-

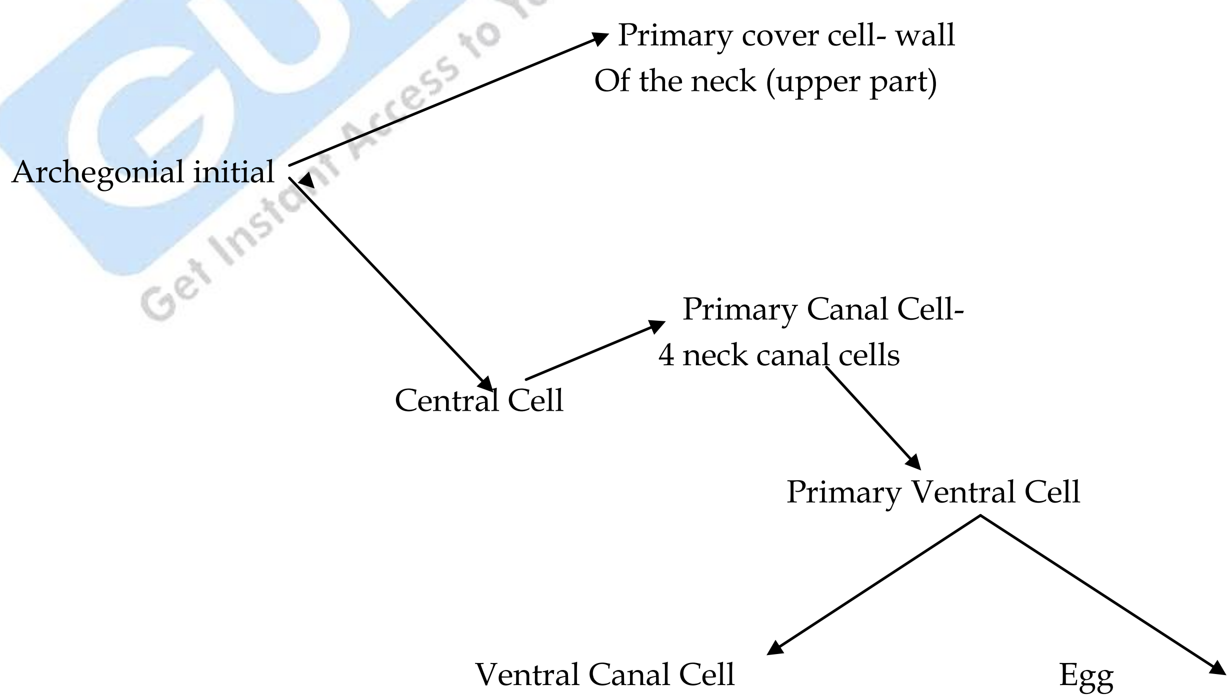
The antheridial initial divides transversely into an outer jacket initial and an inner primary androgonial cell. The former produces by anticlinal divisions , the one- celled thick wall- layer in which an opercular cell is distinguished.

The inner primary androgonial cell divides repeatedly forming a mass of sperm mother cells or androcytes. These are embedded within the prothallus. The sperm mother cells or androcytes give rise to the antherozoids which have two flagella at the narrow anterior end . Rarely, there may be three flagella. The sperms are liberated by breaking down of the opercular cell.

Development of the archegonium:-

The archegonial initial divides into an upper primary cover cell and an inner central cell. The central cell divides perclinally into a lower primary venter cell and an upper primary canal cell . The primary venter cell may directly function as the egg or may divide into the egg and venter or ventral canal cell. The primary canal cell divides to form neck canal cells. In the archegonia of green gametophytes (L. cernuum) , only 1-2 neck canal cells are present. But in subterranean gametophytes , they will be 6-8 and in Lycopodium complanatum they are even more.

By this time , the primary cover cell , by two divisions at right angles to each other , forms four neck initials. Each neck initial may divide transversely into 3 to 4 cells. Hence , the neck will have a wall composed of four vertical rows of cells, in which each row is only 3-4 cells in height.
The whole archegonium is embedded within the prothallus and only the neck projects above the general surface. The cells lining the egg and the lower neck canal cells are prothallial cells and they are not derived from the archegonial initial.



At the time of fertilization , all the cells of axial row , except the egg , degenerate and a passage will be formed into it by the disintegration of the tip of the wall of the neck.

Q.6 Describe the life cycle of Equisetum in detail.
Ans

Reproduction:
Equisetum reproduces by vegetative and sexual methods.

Vegetative propagation:-
In some species , as Equisetum arvense , vegetative propagation occurs by means of tubers which are swollen internodes.
Sporangiophores and Sporangia:-
The sporangia , in the genus Equisetum are borne in cones or strobili terminating many of the main axis sometimes also the lateral branches. The cone or strobilus consists of a fairly stout axis bearing crowded alternating whorls of T- shaped peltate scales called the sporangiophores , projecting at right angles from the axis.
Each sporangiophore has a short cylindrical stalk and expands at its distal end into a flat disc on the undersurface of which five to ten sporangia are borne. The peltate heads of the sporangiophores arise in such close contact that, as a result of mutual pressure, they become hexagonal in outline. The sporangia are elongate – sac like structures , attached in a sort of a whorl , on the underside of the disc of the sporangiophore , near the edge , projecting horizontally towards the cone axis. They vary considerably in size and the number per sporangiophore ranging from 5- 10. The sporangium when ripe , consists of a wall two- layered and contain spores inside.
Development of Sporangium:-
The development of sporangium is eusporangiate i.e. the sporangium develops from a group of initials. The first division of the sporangial initial is periclinal , establishing an outer and an inner daughter cell. The inner daughter cell forms sporogenous tissue by repeated divisions in all possible planes. Outer daughter cell divides both anticlinally and periclinally and forms 2 – 7 layered sporangial wall. The innermost layer of the sporangial wall functions as tapetum. The cells of the tapetum are irregular , thick walled and nutritive in function.
As the sporangium matures , all but the two outermost wall layers disintegrate and form a periplasmodial liquid. At this stage, the sporogenous cells separate from each other and function as spore mother cells. Before meiosis about 30% spore mother cells also disintegrate and form periplasmodial fluid. Each spore mother cell undergoes a reduction division and forms four spores . The spores soon become spherical.

Dehiscence of the Sporangium:-

As the spores are ripe , the sporangiophores shrink and pull apart. The sporangium dehisces longitudinally by a slit facing inwards towards the stalk. As a result , the spores become liberated from the sporangium.

Gametophyte:-

The spores of Equisetum generally germinate readily in 10 to 12 hours after they are sown, into gametophytes. The gametophytes are green , thallose , branched structures which grow on wet soil in shaded places. They are not generally found wild in nature because they are small in size and inconspicuous , being usually only 1 – 10 nm , in diameter and dull brown in colour.

Development of the Gametophyte:-

Mature spores of Equisetum are relatively large and are green and contain numerous chloroplasts.

The first division in the spore , during germination , is transverse and results in two cells of unequal size. The smaller cell develops into the first rhizoid and the larger cell gives rise to the remainder of the thallus. Division and redivision of the larger cell is irregular in sequence and produces a small cushion – like tissue, several cells in thickness , which bears numerous rhizoids on its lower surface. The cells in the upper portion contain Chloroplasts and those in the lower portion are colourless. The entire margin of the cushion is meristematic in nature and develops the several lobes of the prothallus.

Sex Organs:-

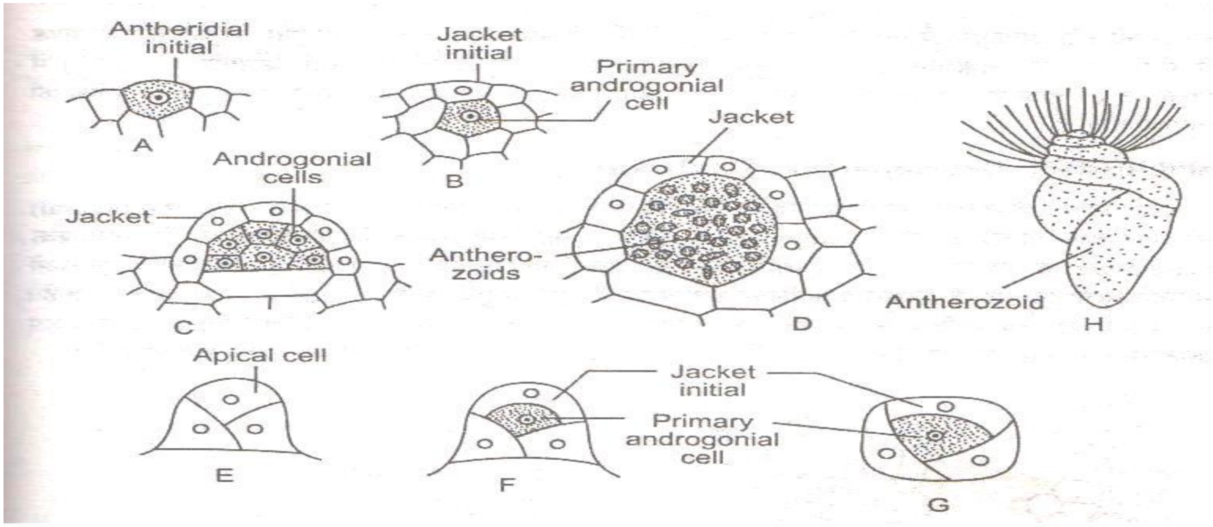
The prothallus or the gametophyte reproduces sexually and bears the sex organs, the antheridia and archegonia , generally when the gametophytes are 30 to 40 days old. They are developed in the meristematic region of the cushion.

(a) Development of antheridium:-

In monoecious species , antheridia develop after archegonia. There are usually two types of antheridia : (i) projecting antheridia and (ii) embedded antheridia.

The antheridium develops from a single superficial cell. The superficial antheridial initial divides periclinally into an outer jacket initial and an inner androgonial cell. The jacket initial divides only anticlinally and gives rise to a single layered antheridial jacket . One of the cells of the jacket layer forms a triangular cover cell or opercular cell.

The inner cell , the primary androgonial cell, by division and redivision , forms a considerable number of androgonial cells. At the androcyte mother cell stage , two blepharoplasts become visible and one goes to each to each of the two androcytes formed by a mother cell. The androcytes metamorphose into multiflagellate spirally coiled spermatozoids or antherozoids. . The anterior part of the antherozoid is spirally coiled and has numerous flagella , whereas the posterior part is somewhat expanded. When the antheridium is matured, it opens by the opercular cell in the wall and the spermatozoids become liberated.



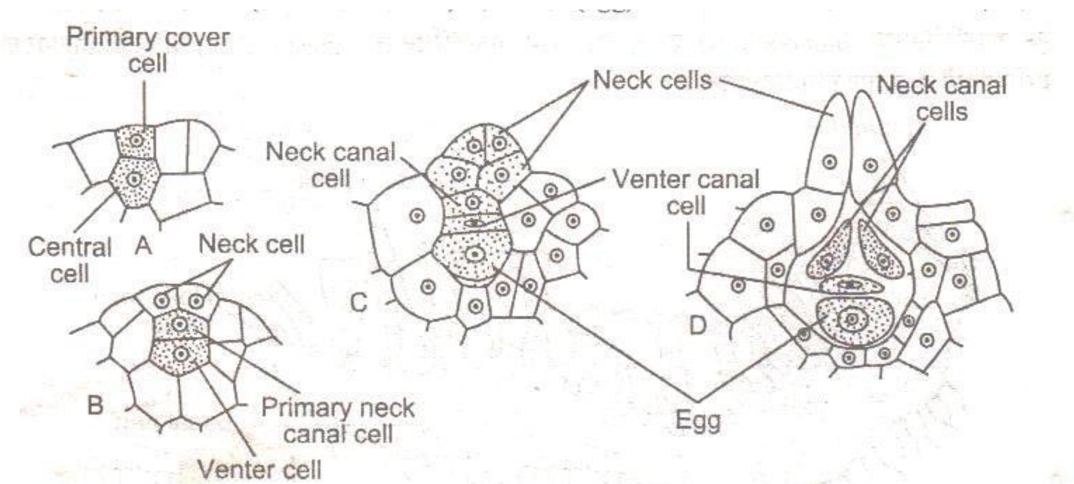
Equisetum A-D

Development of archegonium :

The archegonium develops from a single superficial cell of the marginal meristem at the bases of the lobes. The superficial cell may function as archegonial

Initial . It divides periclinally into an outer primary cover cell and a central cell. The primary cover cell divides by two vertical divisions at right angles to each other, forming 4 primary neck cells. These cells divide further and form 3-4 celled high neck of the archegonium.

The central cell divides transversely into a primary neck canal cell and a venter cell. The primary neck canal cell divides once to form two neck canal cells. When there are two neck canal cells , the division of the primary canal cell may be transverse so that the neck canal cells may lie one above the other as in E. telemateia or the division wall may be oblique and they lie obliquely as in E. **scirpoides** . But more usually , the primary neck canal cell divides by a vertical wall into two ' Boot shaped' cells as in E. arvense , E. hyemale and E. debile etc. The venter cell divides transversely to form two unequal cells; the larger basal cell forms egg and the smaller upper cell functions as venter canal cell.



Equisetum : Stages of the development of Archegonium

Fertilization:

Before fertilization, the neck canal cells and venter canal cell disintegrate and form a passage for the entry of the antherozoids. The disintegrated mass of these cells contains malic acid ; which attracts freely swimming antherozoids towards the neck of the archegonium.

Frequently many antherozoids may enter the archegonium but only one of them fuses with the egg and fertilizes it . The zygote is formed which is diploid.(2n)

Unit – II

Pteridophytes and Heterospory

Q1 Discuss about the life cycle of Selaginella.

Ans. The sporophyte of Selaginella reproduces vegetatively and by spores.

(I) <u>Vegetative reproduction</u>:

In Selaginella, vegetative propagation takes place by tubers, bulbils, dormant buds and by fragmentation.

(II) <u>Reproduction by spores</u>:

Selaginella is a heterosporous pteridophyte, it produces two types of spores- megaspores and microspores. The megaspores form female gametophytes on germination and the microspores give rise to male gametophytes.

The sporangia bearing microspores are called microsporangia and those bearing microspores are called as megasporangia.

The sporangia are borne singly in the axils of sprophylls.

(1) <u>Strobilus or cone</u>:

In most of the species of Selaginella, sporophylls are aggregated at the apex of the main stem and its branches in definite loose or compact cones, called strobili. (singular = strobilus.)

(2) <u>Development of sporangium</u>:-

The early development is same in both kinds of sporangia. The sporangium may develop from a single initial (S. apus) or a row of initials (S. spinulosa). In either case, the first periclinal division results in an upper jacket or primary wall cell and lower archesporial cell or primary sporogenous cell.

The archesporial cell produces the sporogenous tissue by divisions in all planes. The sterile jacket or the wall of the sporangium is formed from the jacket initial or initials. This sterile wall is two-layered in which the outer one is thick walled and the inner one is thin walled.

The outermost layer of the sporogenous tissue differentiates into a tapetum, except above the stalk. The tapetum remains intact until the spores are mature.

The development of megosporangium and microsporangium differ from this stage onwards. In the microsporangium, many sporogenous cells undergo meiosis and form several tetrads of spores and only a few degenerate. But in the megasporangium only one sporogenous cell undergoes meiosis and forms a tetrad of spores and the others degenerate and nourish the spores.

Gametophyte:-

The spore is the mother cell of the gametophyte generation.

(a) Development of male gametophyte:-

The microspores germinate inside the microsporangium and are shed at 13 celled stage. The first division of the microspore is asymmetrical. As a result of which a small lenticular prothallial cell and a large antheridial cell is formed. The prothallial cell does not divide further.

The first division of the antheridial initial is nearly at right angles to the prothallial cell. It results in the formation of two antheridial cells of almost equal size. Both these cells divide by a vertical wall, at right angles to the first division, to produce a group of 4 cells.

Thus, at this stage, the gametophyte consists of five cells (four cells derived from the antheridial initial and a prothallial cell). The two basal cells, derived from the antheridial initial, do not divide further, whereas the upper two daughter cells divide repeatedly and form 10 cells.

At this stage, the gametophyte has 13 cells (10 cells derived from the upper daughter cells of the antheridial initial, 2 basal daughter cells and 1 prothallial cell).

Of these 4 central cells function as primary androgonial cells and 8 peripheral ones as jacket cells.

The four primary androgonial cells of the male gametophyte divide repeatedly forming a mass of 128-256 antherozoid mother cells or androcytes. Each androcyte metamorphoses into a spindle-shaped biflagellate antherozoid.

With the formation of antherozoids, the jacket cells decompose and form a mucilaginous substance. The antherozoids float in the substance. Until this stage, the male gametophyte is completely enclosed within the wall of the microspore. Thus, it is entirely endosporic and extremely reduced structure.

(b) Development of female gametophyte:-

The development of female gametophyte of Selaginella also begins while it is still within the megasporangium.

Immediately before the development of female gametophyte initiates, a large vacuole appears in the centre of the megaspore and as a result the cytoplasm is pushed along the spore wall in the form of a thin membrane.

The outer spore wall (exospore) grows more rapidly than the mesospore and the endospore. As a result of which, a large gap is formed in between the exospore and mesospore. At this stage the exospore is attached to the mesospore only at one point .The space between the exospore and mesospore is filled with a homogeneous liquid.

The haploid nucleus of the megaspore divides repeatedly without any wall formation. The free nuclei are unequally distributed in the peripheral cytoplasm. They are clustered beneath the triradiate ridge of the spore.

Now, wall formation begins in the apical region and a lens shaped pad of small cells is formed at the apical end. It is separated from the rest of the female gametophyte by a distinct diaphragm.

The cytoplasmic layer becomes thicker gradually and pushes the mesospore outward. As a result the mesospore again comes in contact with the exospores. With the increase in the amount of cytoplasm, the central vacuole diminishes and eventually disappears.

The part of the gametophyte below the diaphragm is multinucleate in early stages but becomes multi cellular as wall formation proceeds inward. At this stage, the spore wall ruptures along the triradiate ridge exposing the apical cellular pad.

The exposed part of the female gametophyte may develop chloroplasts but the photosynthetic ability of this part is of limited importance. Many rhizoids develop from the exposed part of the gametophyte.

Development of archegonium:-

Archegonia develop from the apical tissue of the gametophyte. All superficial cells of this tissue have the potential of forming archegonia.

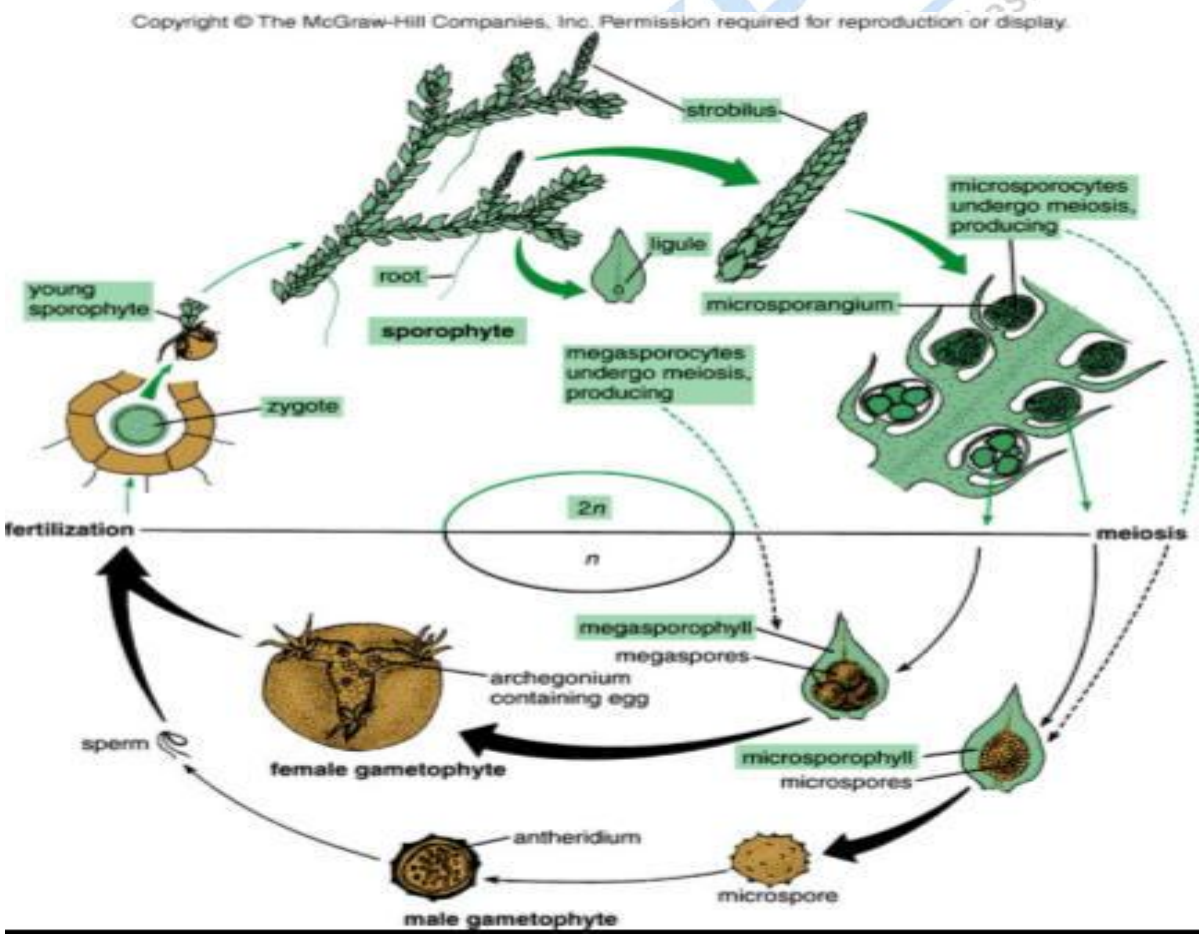
The archegonial initial divides periclinally into a primary cover cell and a central cell.

The primary cover cell divides by two vertical divisions at right angles to each other and forms 4 neck initials.

The neck initials divide transversely so as to form 8 neck cells, arranged in two tiers of four each. In the meantime, the central cell divides by a periclinal wall and an outer primary neck cell and an inner primary venter cell is established.

The former does not divide further and directly functions as neck canal cell, whereas the latter divides transversely into a venter canal cell and an egg.

The mature archegonium of Selaginella has two cells long neck (consisting of 8 cells in two tiers of four each), a neck canal cell, a venter canal cell and an egg. The four terminal cells of the neck project beyond the surface of the gametophyte as asymmetric nipples. Rest of archegonium remains embedded in the tissue of the gametophyte.



(Life Cycle of Selaginella)

(c) **Fertilization:**

Fertilization usually takes place after the megasporangium has fallen on the soil, but in some species it may occur while the female gametophyte is still within the sporangium.

Just before fertililzation, the neck cells of the archegonium separate from each other and form a passage for the entry of antherozoids. After liberation from the male gameltophyte, antherozoids swim in rain or dew water and reach the archegonia .Usually only one antherozoid enters into an archegonium and fuses with the egg to form a diploid zygote.

Q2 Describe the gametophyte of Marsilea or give an illustrated account of the development of male and female gametophytes in Marsilea.

Ans

Gametophyte:

Marsilea is a heterosporous fern, producing two types of spores - microspores and megaspores. Microspores give rise to the male gametophyte and the megaspores give rise to the female gametophyte.

(I) Micropores and development of male gametophyte:

Microspores are minute, spherical structures, ranging from 0.060-0.075 mm in diameter. The spore wall is differentiated into an outer exine and an inner intine. The exine is covered by a thin layer, called perispore. The microspore has a haploid nucleus and its cytoplasm is rich in starch grains.

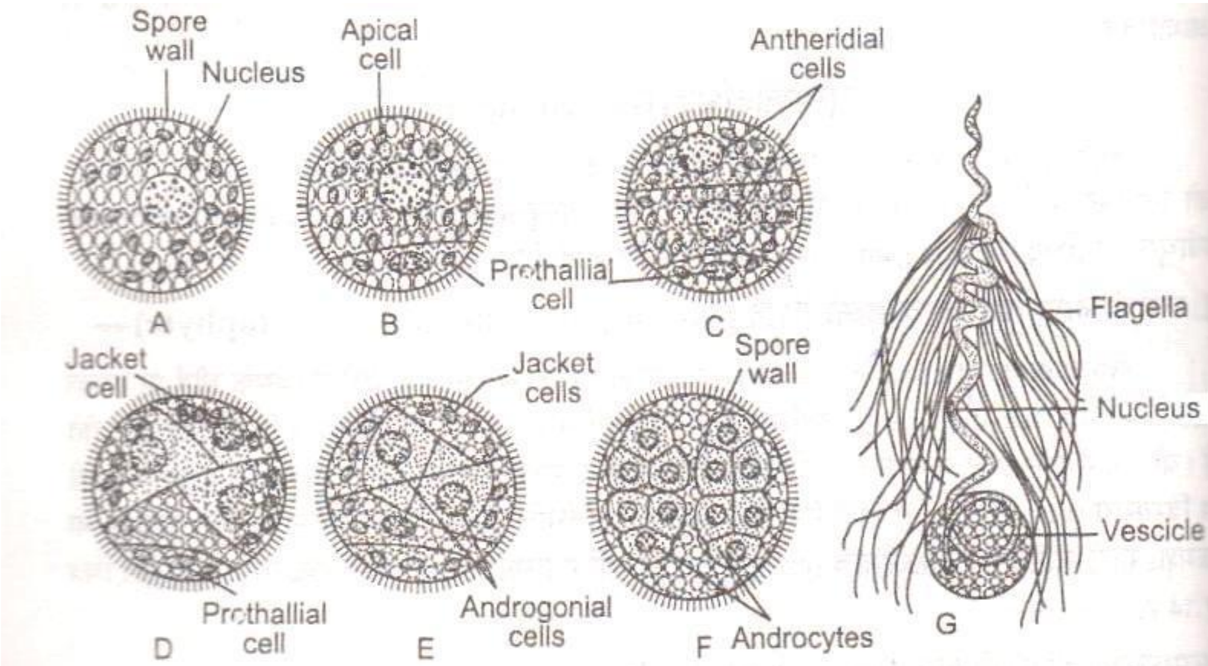
The microspore germinates immediately on shedding. The first division is asymmetrical and as a result, the spore is divided into a small biconvex prothallial cell and a large apical cell. The apical cell undergoes a transverse division to form two nearly equal antheridial initial cells.

Each antheridial initial cell divides periclinally forming an outer first jacket cell and a larger wedge shaped cell. The latter divides further by a periclinal wall and thus a small jacket cell and an outer large cell are distinguished.

The outer cell again divides periclinally forming an outer third jacket cell and an inner primary androgonial cell.

Each primary androgonial dcell, divides repeatedly forming a group of 16 antherozoid mother cells or androcytes.

During the development of androcytes, the prothallial cell and the jacket cells of both the antheridia degenerate and as such the two groups of androcytes lie free within the spore wall (or male gametophyte). Each androcyte metamorphoses into a cork screw-shaped multiflagellate antherozoid, characterized by the presence of a prominent terminal vesicle. The wall of the male gametophyte breaks when antherozoids mature and thus setting them free. The development of male gametophyte is extremely rapid.



Marsilea : A-FStages of the Development of Male Gametophyte G : One Male Gamete

(II) <u>Megaspore and development of female gametophyte</u>:

The megaspore is ellipsoidal and it has a dark-coloured hemispherical protuberance or papillant at the anterior end. This portion has a thin wall with triradiate markings. The outer thick gelatinous wall expands when the spore is in contact with water.

The protuberance contains granular cytoplasm and a small nucleus. The protoplast of the remaining portion consists of numerous starch grains and watery cytoplasm.

The development of the female gametophyte is slower than that of the male gametophyte.

Before germination, the nucleus of the megaspore along with the cytoplasm moves into the apical papilla. The first division is transverse, forming a small nipple-shaped apical cell and a large basal prothallial or nutritive cell. The apical cell forms the female gametophyte and the prothallial cell is sterile and provides nutrition to the developing female gametophyte.

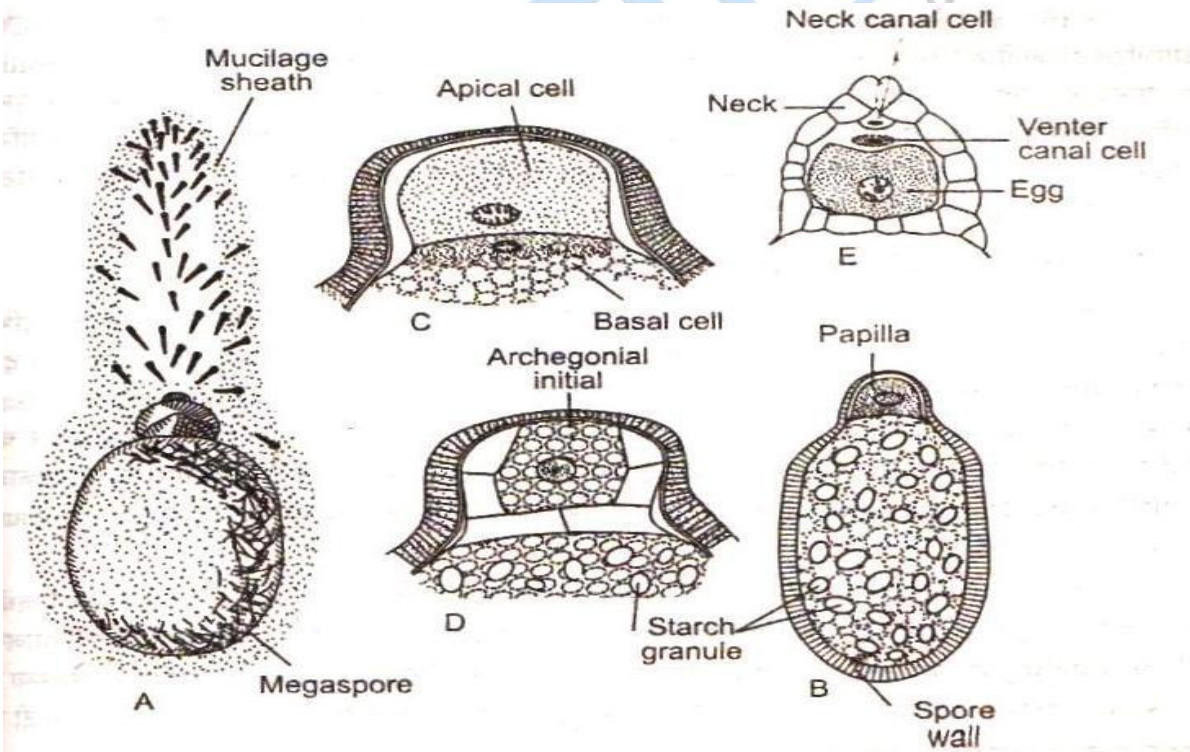
The apical cell divides by three intersecting vertical divisions, establishing an axial cell surrounded by three lateral cells. The axial cell functions as archegonial initial.

The archegonial initial divides periclinally into an outer primary cover cell and an inner central cell. The primary cover cell divides into four quadrately arranged cells by two successive anticlinal divisions, at right angles to each other. These 4 cells are the neck initials and each one obliquely divides into two, resulting in a short neck, formed of two superimposed tiers of 4 cells each.

The central cell divides transversely, thus forming an upper primary canal cell and a lower primary venter cell. The former does not divide further and functions as neck canal cell, whereas the latter divides again by a transverse wall forming a venter canal cell and an egg.

Thus the mature archegonium has an 8 celled neck with a single neck canal cell, a small venter canal cell and a large egg.

The female gametophyte is surrounded by a gelatinous sheath. The sheath extends to the apex of the spore as thin, cone-shaped mass, leaving a small opening.



Marsilea : A . Female Gametophyte -B Megaspore C-E Development of Female Gametophyte & Archegoniol

Q.3 Describe heterospory in detail and the seed habit in Pteridophytes.
Ans

Heterospory and seed habit

Heterospory:

The phenomenon where two types of spores differing in size, structure and function are formed on the same plant is known as heterospory.

The smaller spores are called microspores and the larger spores are known as megaspores.

(a) Palaeobotanical evidences of heterospory:

Many fossils of the late Devonion and early Carboniferous period (e.g. Lepidocarpon, Lepidostrobus, Calamocarpon and Calamostachys) were heterosporous.

In C. casheana, two distinct types of sporangia-micro and megasporangium occurred. There were some aborted spores in the megasporangia indicating that megaspores were formed at the cost of abortion of some of the spores in the sporangium. A similar abortion of spores was also observed in certain species of Lepidocarpon , Calamocarpon and Stauropteris.

e.g. a mature megasporangium of Lepidocarpon and Calamo-carpon had only a single functional megaspore as other spores aborted during the development. In Stauropteris, a megasporangium had two functional megaspores and two aborted spores.

The above examples indicate that-

1. Heterospory has not evolved in living forms but was also present in fossil plants, and
2. It originated due to disintegration of some spores in a sporangium

(b) Evidences from developmental studies:

Development studies in pteridophytes, particularly the events that take place during the formation of sporocytes, meiosis and maturation of spores, provide a real insight in the understanding of heterospory.

1. In Selaginella, the development of the micro-and megasporangium is similar till the differentiation of sporocytes.

   All the sporocytes in the microsporangium, undergo meiosis, with the result that a large number of microspores are formed. On the other hand, all sporocytes in the megasporangium, except one abort and the surviving sporocyte undergoes meiosis forming 4 large functional megaspores.
2. In Isoetes, the microsporangia and megasporangia are identical till the differentiation of sporogenous tissue. In the microsporangium , almost

entire sporogenous tissue forms sporocytes, which after meiosis, give rise to a very large number (1,50,000-1,000,000) of microspores.

In the megasporangium, a part of the sporogenous tissue and so also many sporocytes degenerate and they provide nutrition to the growing sporocytes (megaspores). There are only 50-300 megaspores in a megasporangium.

3. In Marsilea, differences in the development of microsporangium and megasporangium do not become evident until after meiosis.

   In a microsporangium all the 64 microspores formed after reduction division are functional, but in the megasporangium also though 64 spores are formed, only one is functional and the rest disintegrate. A similar condition also exists in Salvinia and Azolla.

   Thus , Developmental studies have shown that determining process of heterospory becomes operative either before (e.g. Selaginella, Isoetes) or after meiosis (e.g. Marsilea, Salvinia, Azolla).

(c) Evidences from experimental studies:

Experimental studies on Selaginella and Marsilea have shown that heterospory originated due to nutritional factors. It was observed that if photosynthetic activity of Selaginella was slowed down by keeping it in low light intensity, then only microsporangia, developed. Due to low photosynthetic activity, nutrition becomes limiting factor and spores could not grow in size. Thus under such conditions only microspores were produced. Similar results were obtained in the experiments done on Marsilea.

Importance of heterospory:

(I) Heterospory expresses sex determining capability of the plant e.g. a microspore always gives rise to male gametophyte and a megaspore to female gametophyte.

(II) In heterosporous forms development of gametophyte is endosporic and the nutrition for the developing gametophyte is derived from the sporophyte. So the development of gametophyte is not affected by ecological factors as in case of independently growing gametophytes.

(III) Megaspore is retained by the parent even after fertilization. This ensures nutrition for the developing embryo,

Seed Habit:

The requirements for the formation seed are as follows-

(I) Formation of two types of spores microspores and megaspores (heterospory)

(II) Reduction in the number of functional megaspores to one per megasporangium.

(III) Retention of megaspore in the megasporangium until embryo development.

(IV) Elaboration of the apical part of megasporangium to receive microspores or pollen grains.

In Selaginella, the most common genus of the heterosporous pteridophytes, provides the best examples.
Most of the species of Selaginella are heterosporous and they have only one functional megaspore mother cell which gives rise to 4 megaspores after meiosis. Only a single functional megaspore in a sporangium is present in Selaginella rupestris, S. monospora and S. erythropus. The development of female gametophyte, fertilization and embryo development takes places within the megasporangium. Thus, evolution of seed habit took place in such species of Selaginella.
However the seeds developed in these species cannot be called true seeds because (i) the megasporangium is not covered with integuments and (ii) there is not resting stage after embryo development ; the development of embryo is accompanied with the development of shoot and rhizophore.

Q-4 **Write about embryo development in Equisetum and Selaginella.**
Ans

<u>Embryo development in Selaginella</u>

The diploid zygote is the mother cell of the sporophytic generation. It divides transversely, establishing an epibasal (upper) suspensor cell and a hypobasal (lower) embryonic cell. As development proceeds, the suspensor cell repeatedly divides to form a suspensor which pushes the developing embryo deep into the female gametophyte. The rest of the embryo develops from the embryonic cell. It divides by two vertical walls at right angles to each other and thus a four-celled embryo is formed. One of the four cells of the embryo divides by an oblique vertical wall and thus an apical cell with three cutting faces is established. This eventually functions as the apical cell of the embryonic shoot.

The remaining three cells of the 4-celled embryo and the sister cell of the apical cell (i.e. total 4 cells) divide transversely to form two tiers of four cells each.

The cells of both the tiers divide irregularly forming a multicellular embryo. Usually, the cells of the lower tier divide more rapidly than the upper tier and due to this differential growth, the entire embryo apex rotates at 180^{o} and emerges through the apical pad of the gametophyte.

The derivatives of the lower tier form the foot. At first the foot grows on one side but eventually comes to lie opposite the suspensor. The foot acts as a haustorial organ. Its main function is to absorb nutrition for the developing sporophyte from the female gametophyte.

At this stage, a superficial cell in each of the two diagonally opposed quadrants of the upper tier differentiates as the apical cell of a foliar appendage, which eventually forms a cotyledon. In the axil of each cotyledon, a ligule develops.

The part of the embryo immediately posterior to cotyledons develops into hypo -cotyledonary part of the stem. The stem grows with the help of the apical cell of the embryo.

After the formation of cotyledons and stem, the apical cell of the root differentiates on the lateral surface of the foot. The derivatives of this cell develop into a root like structure. .

Embryo development in Equisetum

The diploid zygote is the mother cell of the next sporophytic generation. It develops into an embryo, which forms a new sporophyte.

In most species, the first division of the zygote is transverse (i.e. at right angles to the neck of the archegonium) establishing an epibasal and a hypobasal cell. Both of these cells contribute to the embryo. No suspensor is formed.

The second division of the zygote is vertical. Thus, a four-celled embryo is established. In E. arvense, the 4 celled embryo divides by a second vertical division at right angles to the first one, thus forming 8 cells arranged in two tiers of four each.

The largest of the four epibasal cells differentiates as apical cell of the shoot and the remaining three cells form leaf initials. The largest of the hypobasal cells functions as root initial and the remaining three cells give rise to the foot.

Active divisions in the apical cell of the shoot and the root initial results in the establishment of the shoot and root. The embryonic root penetrates the prothallus and enters the soil. The first-shoot, called primary stem, bursts through the neck of the archegonium and grows upright. It is differentiated into nodes and internodes. Each node of the primary stem has only three leaves.

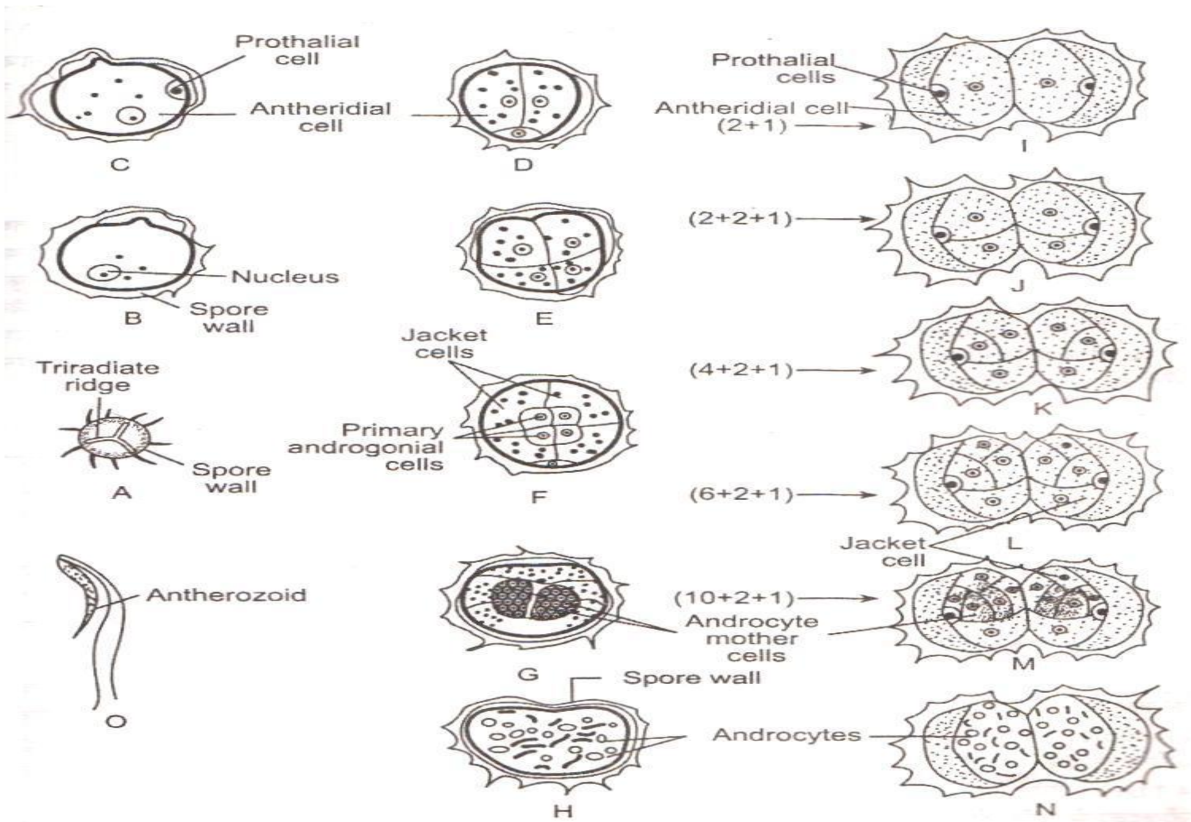
The primary stem shows only limited growth. Its apical growth ceases after 10-15 internodes have been formed. Thus, a secondary branch develops at the base of the primary stem from a bud. It has 1-5 leaves at each node. The secondary branch also has limited growth and is replaced by another upright branch arising from its base. This process may be repeated until 3-4 shoots have appeared and finally, a shoot, instead of growing in usual upright position, grows horizontally and penetrates the ground forming the first underground rhizome. It is perennial and gives out new aerial shoot regularly called rhizophore. Roots develop at the apex of the rhizophore. In early stages of development, the young sporophyte is attached to the megaspore and derives its food from the female gametophyte with the help of its foot. But after the establishment of root and stem, the sporophyte becomes independent.

Q-5 Describe the development of Male and Female Gametophyte of Selaginella .

Ans

(I) <u>Development of male gametophyte</u>:-

The contents of the microspore divide into two cells of very unequal size. This is accomplished before the spores are shed. The smaller cell is called the prothallial cell and takes no further part in the development. It represents the vegetative part of the prothallus.

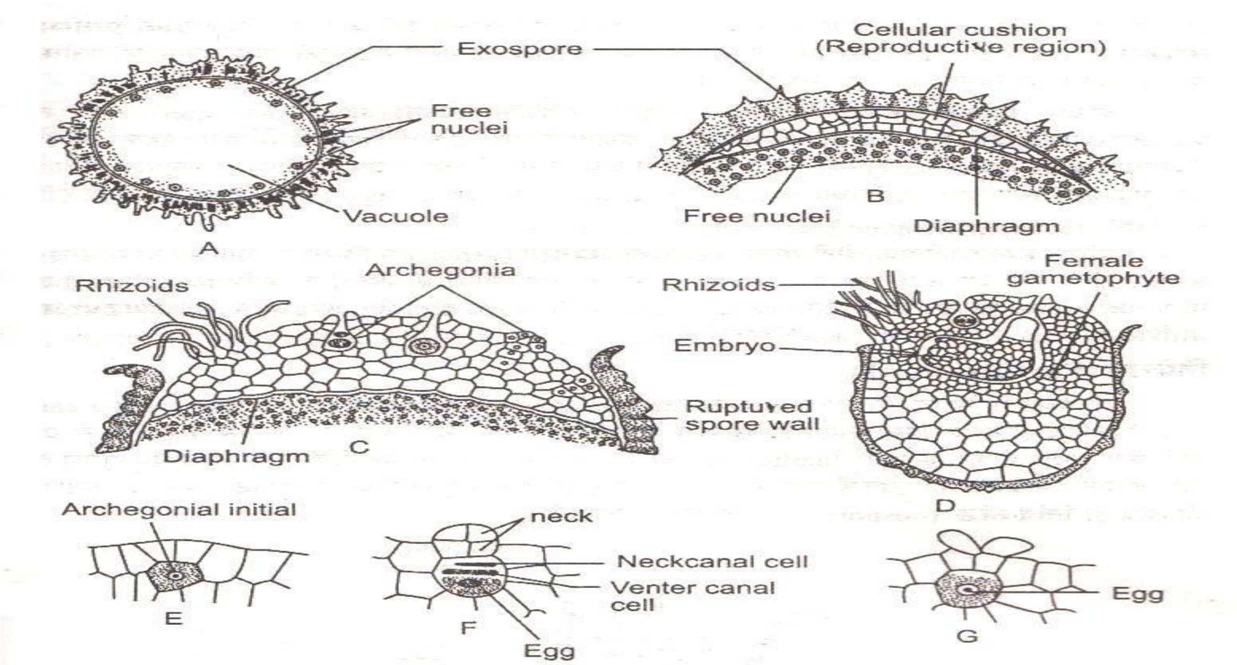


Selaginella : Stages of the development of Male Gametophyte

The larger cell, which is called the antheridial cell, continues to divide until a group of 12 cells is formed .Of these 8 form a wall enclosing a group of 4 central cells.

Whilst these changes have been going on within the spore, ridge, its outer wall bursts at the triradiate ridge , so that the outer end of the developing tissue is only covered by a thin cellulose wall. The central cells now undergo a number of divisions, forming a mass of 128 tiny cells lying freely in a space formed by the breakdown of the outer cells. This structure is regarded as antheridium, the 8 outer cells forming its wall, and the central cells representing the antherozoid mother cells, from each of which at maturity an antherozoid develops. The antherozoid is an elongated body, at the end of which two long flagella are produced. The antherozoids escape by the bursting of the thin cell wall at the upper end of the microspore and swim away in the film of water which normally covers the damp soil in which these plants live. The development of the male prothallus often begins before the spores are shed and is completed on the ground.

The female Gametophyte:-



Selaginella : A-C Development of Female Gametophyte D Mature Gametophyte with Embryo E-G development of Archegonium

Meanwhile, the megaspores have also germinated. In fact their development also has already begun before the megaspores have been shed from the megasporangium.

At an early stage of development, the protoplast contracts to a small sac and its wall rapidly expands, so that a wide space separates them. At the same time, the spore wall separates into two thick layers, the exospores and the mesospore, separated by a space containing a gelatinous membrane. At this stage, there is only one monoploid nucleus, but this soon begins to divide repeatedly until large no. of nuclear are distributed round the protoplasmic layer. Now the protoplast rapidly increases both in size and thickness, pressing the two spore coats into contact once more and gradually filling up all the central vacuole with cytoplasm.

At the apex of the spore, that is towards the centre of the triradiate ridge, delicate walls begin to appear in the cytoplasm, diving it into cells, which form a lens-shaped layer, three cells thick in the middle but only one cell thick at the sides. This is the female prothallus.

Below the prothallus some rather vague walls extend downwards into the rest of the protoplasm, but without dividing it completely into closed walls. The bottom of the prothallus itself becomes thickened, and is thus clearly separated from the material below. The thickened layer is called the diaphragm.

Certain cells, now begin to enlarge to form archegonia and at this stage the spore opens along the ridge, exposing the prothallus. Three little protrusions are formed on its surface, which develop rhizoids, but they are purely vestigial, as the prothallus is never independent. Numerous archegonia are formed.

They are of simple type, the initial cell dividing only into two, not three as in Lycopodium. The upper cell forms a short neck, two cells high and the lower cell divides into the oosphere, the ventral canal cell and a single neck-canal cell which penetrates into the neck.

Fertililzation:-
It is effected by the passage of the antherozoids down the neck of the archegonium, and the fusion of one male nucleus with that of the oosphere. Prior to this, the neck canal cells and the ventral canal have disorganized.

Q 6 Comment on the Morphological nature of the sporocarp of Marsilea.

Ans. The Morphological nature of the sporocarp of Marislea is debated and several interpretations have been put forward from time to time by different workers. These views can be grouped into the following three categories:-

(a) Leaf-segment or laminar hypothesis
(b) Petioles or whole leaf hypothesis
(c) A phylogenetically synthesized new organ.

(i) Leaf segment or laminar hypothesis:

According to the laminar hypothesis, the sporocarp is the lateral fertile part of a leaf. This view was supported by Russow, Campbell, Bower (1926), Goebel (1930), Eames (1936), Smith (1938), Puri and Garg (1953) and Gupta (1957).

According to Russow and Busgen sporocarp is made up of two leaflets with their ventral surfaces facing each other.

Campbell (1892) interpreted the sporocarp as a modification of a pinnately compound leaf, in which leaflets (pinnae) fuse to form the sporocarp. Bower (1926) considered the sporocarp as modified unipinnately compound leaf, with rachis bearing two rows of pinnae. The lateral fusion of these pinnae have given rise to sporocarps of Marsilea. This interpretation receives support from the vascular supply of the sporocarp.

Eames states that the sporocarp is morphologically comparable to the tip of the leaf with its four leaflets. The two distal leaflets form the body of the sporocarp and the two proximal are represented by two tubercles, present on the raphe on the dorsal surface of sporocarp. Evidences in support of this interpretation are derived from (i) the course of vascular bundles in the sporocarp and their similarity with the vasculature of the leaf and (ii) the structure of abnormal leaves. In their color and texture some abnormal leaves were found to be intermediate between normal leaves and sporocarps. Besides in many cases, the proximal leaflets are very small, whereas the distal ones are large and valve like. Smith considers that the sporocarp is formed by the enfolding of a single pinna of cyatheaceae type. The sori are borne ventrally on either side of the midrib and were protected by indusial flaps. But during development, the inner one elongated and grew towards the margin and the outer one was suppressed. The two halves were brought together by ventrally folding down enclosing the sori within.

According to Puri and Garg, the sporocarp is a modified leaflet in which the no. of fertile pinnules corresponds to the number of commissural (lateral) bundles. The commissural bundles fuse to form the midrib of the pinnule. Each pinna splits into two up to half of its length and each lobe receives a branch of the commissural bundle. The sori are restricted to the inner fertile margins of the pinnules. This hypothesis is based on the anatomical and ontogenetic studies of the sporocarp. The vascular supply of the sporocarp is similar to that of the leaflets and this provides support to the laminar nature of the sporocarp.

(ii) <u>Petiolar or whole leaf hypothesis</u>:

This hypothesis, propounded by Johnson (1898) postulates that the sporocarp of Marsilea is homologous to a sterile leaf where the marginal cells of the leaf develop into sporangia instead of leaflets. Thus, according to this hypothesis, sporocarp is the modification of the whole leaf and not just of a pinna.

(iii) A <u>phylogenetically synthesized new organ</u>:

According to Bierhorst (1971), the early ontogeny of sporocarps of Marsilea polycarpa contradicts the leaf segment interpretation. Here a number of sporocarps are borne on one side of the petiole but the ontogeny shows that the entire group of sporocarps originates after the vegetative pinnae are formed and they cannot be traced through the marginal meristems of the vegetative pinnae.

Instead, each sporocarp initiates from a single cell with three cutting faces, a condition unknown for any fern pinna.

The marginal series of sporocarp initials in Marsilea are comparable to those of the filicalean sporangial stalk initials. Thus Bierhorst (1971) states that "these are organs which truly changed their morphological nature in mid - ontogeny"

Q-7 Discuss about the life cycle in Pteridium.

Ans Pteridium reproduces vegetatively and by spores.

(I) Vegetative propagation:-

Death and decay of the underground rhizome is the common method of vegetative propagation. When the death and decay of rhizome reaches up to the point of dichotomy , both the branches separate and each grows into a new plant.

(II) Reproduction by Spores :-

Pteridium is a homosporous fern. The sporangia develop in large numbers on the adaxial side of the pinnules. Thus , the fronds also function as sporophylls. The sporangia form a continuous linear sorus along the margins. Such a sorus is known coenosorus. Thus, in Pteridium individuality of sori is lost .

Development of Sporangium:-

Development of sporangium is strictly leptosporangiate i.e. it develops from a single initial cell. A marginal cell which functions as sporangial initial slightly projects above the receptacular surface in the form of a papilla. It divides periclinally into an outer and an inner cell . The inner cell may or may not divide and does not participate in further development of the sporangium.

The outer cell divides by three intersecting diagonal divisions as a result of which a pyramidal apical cell is distinguished. The pyramidal apical cell divides periclinally into a flat outer cell , the jacket initial and an inner tetrahedral archesporial cell. The archesporial cell functions as internal apical cell and cuts off

Tubular tapetal initials from each of its four cutting faces , leaving a central tetrahedral primary sporogenous cell. The tapetal initials divide anticlinally as well as periclinally and form a double layered tapetum.

The primary sporogenous cell undergoes four successive divisions forming 16 spore mother cells. Meanwhile, the tapetal cells break down and form a nutritive fluid in which the spore mother cells float. Each spore mother cell undergoes meiosis and forms 4 haploid spores.

The distal part of the sporangial jacket is formed by repeated anticlinal division of the jacket initial. It is always single layered. As the jacket develops, a vertical row of 13 strongly thickened cells, the annulus becomes differentiated. A thin area of tubular cells present between the annulus and stalk is known as stomium.

Dehiscence of Sporangium:-

Dehiscence of sporangium takes place due to changes in the cells of the annulus. In dry weather , water evaporates from the thin outer walls of the cells of the annulus and there is loss of turgidity. Consequently, the outer wall being thin , bends inwards and due to this structural change , the annulus tears the sporangial wall from the stomium and turns backward. Some of the spores are blown away by wind through the ruptured capsule, The cells of the annulus become still drier due to further loss of water, there is sudden release of tension and the annulus snaps back to it original position ejecting the spores forcibly.

Gametophyte:-

(I) Development of prothallus:-

Haploid spore is the mother cell of the gametophytic generation. It germinates immediately after dispersal if moisture and suitable temperature is available. The exine ruptures at the triradiate mark and the intine protrudes out in the form of a germ tube. The germ tube usually grows into a short , multicellular chlorophyllous filament. The basal cell of the filament gives rise to colourless rhizoids which attach the developing prothallus to the soil. The cells of the filamentous prothallus divide repeatedly and eventually form a green cordate (heart shaped) prothallus.

Sex Organs:-

Both male (antheridia) and female (archegonia) sex organs are borne on the same prothalus.

Antheridium:-

An antheridium develops from a superficial cell on the ventral surface of the prothallus. The antheridial initial divides transversely into a lower first ring cell and an upper daughter cell. Due to high turgor pressure in the upper daughter cell , the wall between these two cells is is pressed downward and as a result the upper cell becomes dome- shaped.

The upper cell divides by an arched periclinal wall into an outer dome cell and an inner primary androgonial cell. Dome cell now divides transversely into a cover cell and a second ring cell.

The cover cell and the first and second ring cells eventually form a single layered jacket of the antheridium by anticlinal divisions. The primary androgonial cell divides repeatedly and give rise to 30 – 40 androcytes. Each androcyte metamorphoses into a multiflagellate antherozoid.

(II) Archegonium:-

Archegonium develops on the ventral surface of the prothallus near the apical notch. The archegonial initial divides transversely into an upper primary cover cell and a lower central cell. The primary cover cell divides by two vertical walls at right angles to each other, as a result four neck initials are formed.

The neck initials ,by repeated transverse divisions give rise to 5 – 7 celled high neck of the archegonium. The central cell divides transversely and eventually forms three cells – a neck canal cell , a venter canal cell and an egg. The nucleus of the neck canal cell may divide further but it is not accompanied by wall formation.

Thus, a mature archegonium is differentiated into a 5- 7 cells high neck composed of 4 vertical rows of cells and a venter. The neck is occupied by a venter canal cell. The venter contains a single large egg. The neck of the archegonium is curved towards the posterior side of the prothallus as the two anterior neck canal cells grow faster than the posterior cells. The neck projects above the surface of the prothallus, whereas , the Venter remains embedded in it .

Fertilization:-

Water is essential for fertilization. At maturity , the antheridium absorbs water and as such there is an increase in the pressure within the the antheridium. Consequently, the cover cell of the antheridium splits apart and the antherozoids swim freelyin a thin film of water present on the surface of the prothallus.

Almost at the same time , the neck canal cell and venter canal cell of the arch gonium disintegrate and form a viscous mucilaginous mass. The mucilage swells due to absorption of water and as a result the neck opens. The mucilaginous mass contains chemical substances like malic acid which attracts antherozoids to the neck of the arch gonium chemo tactically. Although , many antherozoids may enter the neck , only one of them fuses with the egg and forms zygote.

Unit-III

Gymnosperms

Q.1 Discuss about the development of male and female gametophyte in Ephedra.

Ans. The microspores and megaspores develop into male and female gametophytes respectively.

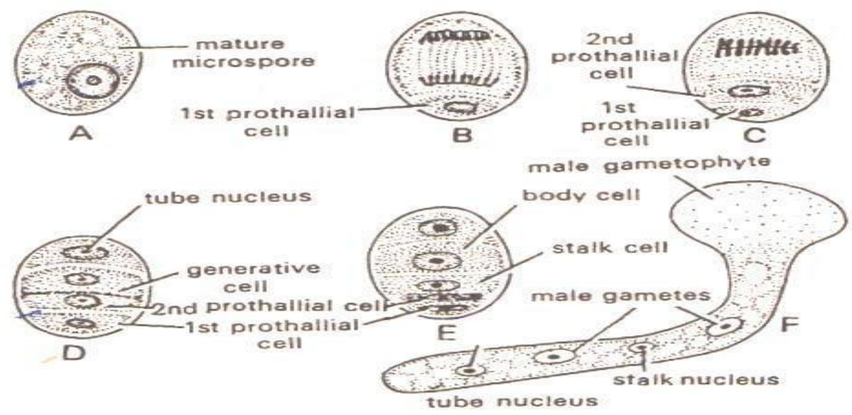
Development of male gametophyte:-

The microspore (Pollen grain) represents the earliest stage of the male gametophyte. Germination of the microspore starts within the microsporangium itself. Hence, partial development of the male gametophyte occurs inside the sporangium before pollination.

The microspore first divides by a transverse wall into a small prothallial cell and larger outer cell. The outer cell divides again by a transverse wall and forms a second prothallial cell and an antheridial cell. Both prothallial cells soon degenerate. The nucleus of the antheridial cell divides to form a small generative cell and a comparatively large tube cell. The generative cell does not possess a distinct cell wall. It divides by a perclinal wall into a stalk cell and a body cell. At this stage, the male gametophyte consists of five cells , - two prothallial cells, a stalk cell & a body cell and a tube nucleus. The sporangium dehisces at this stage and microspores (male gametophytes) are now ready for pollination.

In Ephedra, pollination is anemophilous and the microspores are carried by the wind to the ovulate strobilus. They are deposited on the micropylar canal and then sucked inside by the pollination drop. They come to lie in a deep pollen chamber in direct contact with the neck of the archegonium. Further development of the male gametophyte takes place in the pollen chamber.

In the pollen chamber, the microspore germinates, the exine bursts and the intine comes out in the form of a pollen tube. At this stage, the body cell divides to form two male gametes. The gametes are non-motile. The pollen tube grows through the tissue of the long neck carrying the two male nuclei, a tube nucleus and a stalk nucleus.



A-F. *Ephedra* : Stages in the development ot male gametophyte.

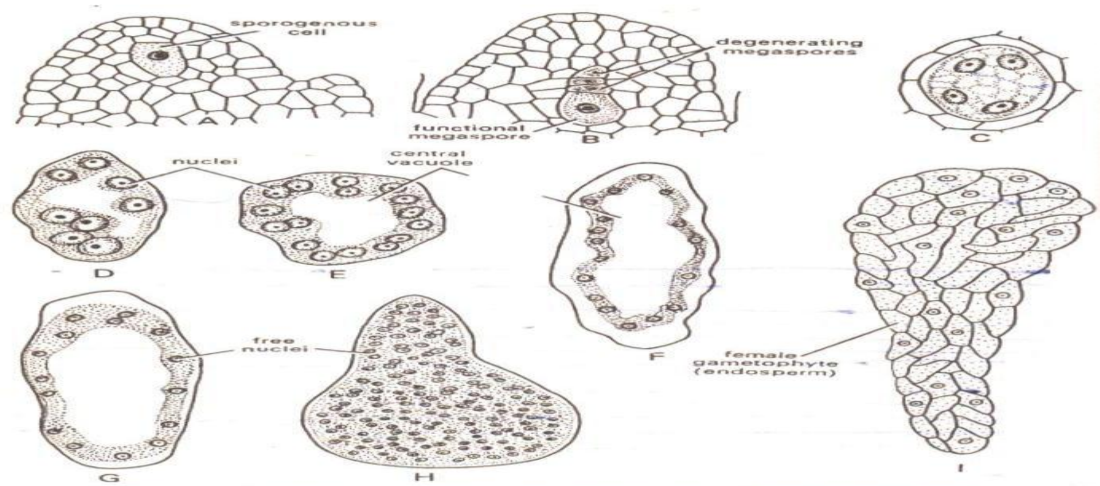


Fig. 12 A-I. *Ephedra* : Stages in the development of female gametophyte.

Development of female gametophyte:-

The functional megaspore represents the first stage of the female gametophyte. The nucleus of the megaspore divides mitotically and forms two daughter nuclei which occupy the two opposite poles of the megaspore due to the development of a large central vacuole. Both nuclei divide again and the four nuclei thus formed are arranged in equidistant positions on the periphery of the sac. These nuclei continue to divide till about 256 free nuclei are formed. At this stage, the central vacuole disappears and wall formation starts from the periphery towards the centre. Thus, a mass of tissue, known as female gametophyte or endosperm is formed. Later the gametophyte is differentiated into two regions, the lower chalazal region is the food storage tissue and in the food storage tissue and in the upper micropylar region normally 1-3 archegonia develop.

Any superficial cell of the female gametophyte may function as archegonial initial. The archegonial initial divides by a periclinal wall and forms outer primary neck cell and inner central cell. The primary neck cell by several divisions form a long neck of 30-40 cells. During this process in the beginning, the division is regular but later it becomes irregular. Archegonial neck in Ephedra is the largest among those of living Gymnosperms. (Land – 1904). The central cell divides to form a venter canal nucleus and an egg nucleus. There is no wall formation between the two. Venter canal nucleus soon degenerates. In the meantime, the cell adjacent to the central cell divides and form 1 or 2 layered archegonial jacket. Thus in Ephedra a mature archegonium not only lacks neck cell but also distinct venter canal cell.

With the development of the archegonium, the nucellar tissue above the gametophyte disintegrates and a deep pollen chamber is formed.

Q2 Describe the development of male and female gametophyte of Pinus.

Ans. (I) <u>Development of male gametophyte</u>:

The microspore is a uninucleate structure with an outer cuticularised exine and an inner thin intine. The exine expands on the lateral sides to form two balloons like structures, known as wings.

The germination of microspore starts in situ, i.e. they germinate while still inside the microsporangium.

(a) Development of male gametophyte within the microsporangium before pollination:

The microspore divides asymmetrically into a small lenticular cell and a larger cell. The former known as first prothallial cell does not divide further. The larger cell, known as apical cell divides asymmetrically and forms a lenticular second prothallial cell and a large antheridial cell.

The second prothallial all does not divide further and remains attached to the first prothallial cell. The antheridial cell divides to form a generative cell (adjacent to the second prothallial cell) and a large tube cell. At this stage, the male gametophyte has 4 cells- first and second prothallial cells, a generative cell and a tube cell. The microspores are released from the microsporangium at 4 celled stage. They are disseminated by wind.

(b) <u>Development of male gametophyte after pollination</u>:

After pollination, the 4 celled male gametophyte reaches the pollen chamber and there it remains inactive for about 11 months. Further development of the male gametophyte starts in the next spring. The exine bursts and the intine comes out in the form of a pollen tube. The pollen tube gradually progresses towards the archegonium, penetrating the nuclear tissue. It is rich in starch grains and it may be branched or unbranched. It acts only as a sperm carrier.

The generative cell of the 4 celled gametophyte divides to form a body cell and a stalk cell. The stalk cell is larger and body cell remains attached at its free end. The nucleus of the body cell divides to form two nuclei just before fertilization. These two daughter nuclei are known as male nuclei and they swim in the cytoplasm of the body cell.

The wall of the body cell gradually disappears and both male nuclei pass into the cytoplasm of the pollen tube. At maturity four nuclei (a tube nucleus, a stalk nucleus and two male nuclei) are present at the tip of the pollen tube.

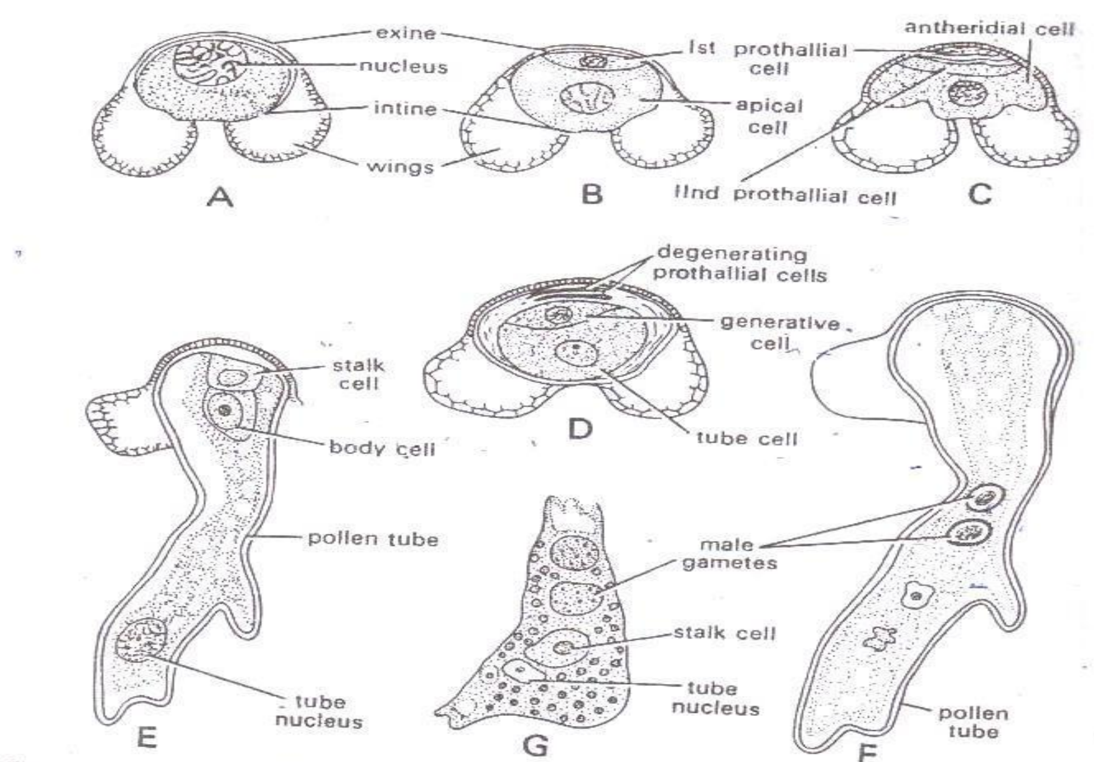


Fig. 21 A-G. *Pinus* : Development of male gametophyte; A-D. Stages before pollination; E-G. Stages after pollination.

The male nuclei function as sperms, which are microscopic, non-flagellate and ephemeral structures.

Microspore divides asymmetrically

(a) First prothallial cell → Does not divide further

(b) Apical cell divides asymmetrically

(i) Second prothallial cell → Does not divide further

(b) large antheridial cell divides

(I) Generative cell

large tube cell.

(i) Body cell (ii) stalk cell

Nucleus Divides → Two male Nuclei

Function as → Sperms (non-flagellate)

(II) **Development of Female Gametophyte in Pinus**

.

The megaspore is the mother cell of the female gametophyte. During the development of female gametophyte, the functional megaspore enlarges in size and its haploid nucleus divides repeatedly to form 2,000-2,500 daughter nuclei. A vacuole develops in the centre of the megaspore and the multinucleate cytoplasm forms a thin layer near the periphery.

Thereafter, wall formation starts from the periphery towards the centre. Thus numerous radially elongated multinucleate tube-like cells are formed, which are known as alveoli. Later reach alveolus divides to form many uninucleate cells. They represent endosperm or female prothallus. The nucellar cells surrounding the multinucleate endosperm form a 2-3 layered nutritive layer. This layer is also known as spongy layer or endosperm jacket.

Development of archegonium:

Though all the superficial cells at the top of the female gametophyte are potential archegonial initials but only 2-8 superficial cells at the micropylar end become slightly enlarged and prominent functioning as archegonial initials.
The nucleus of the archegonial initial moves towards the periphery and then divides by a transverse wall into an upper smaller primary neck cell and a lower larger central cell.

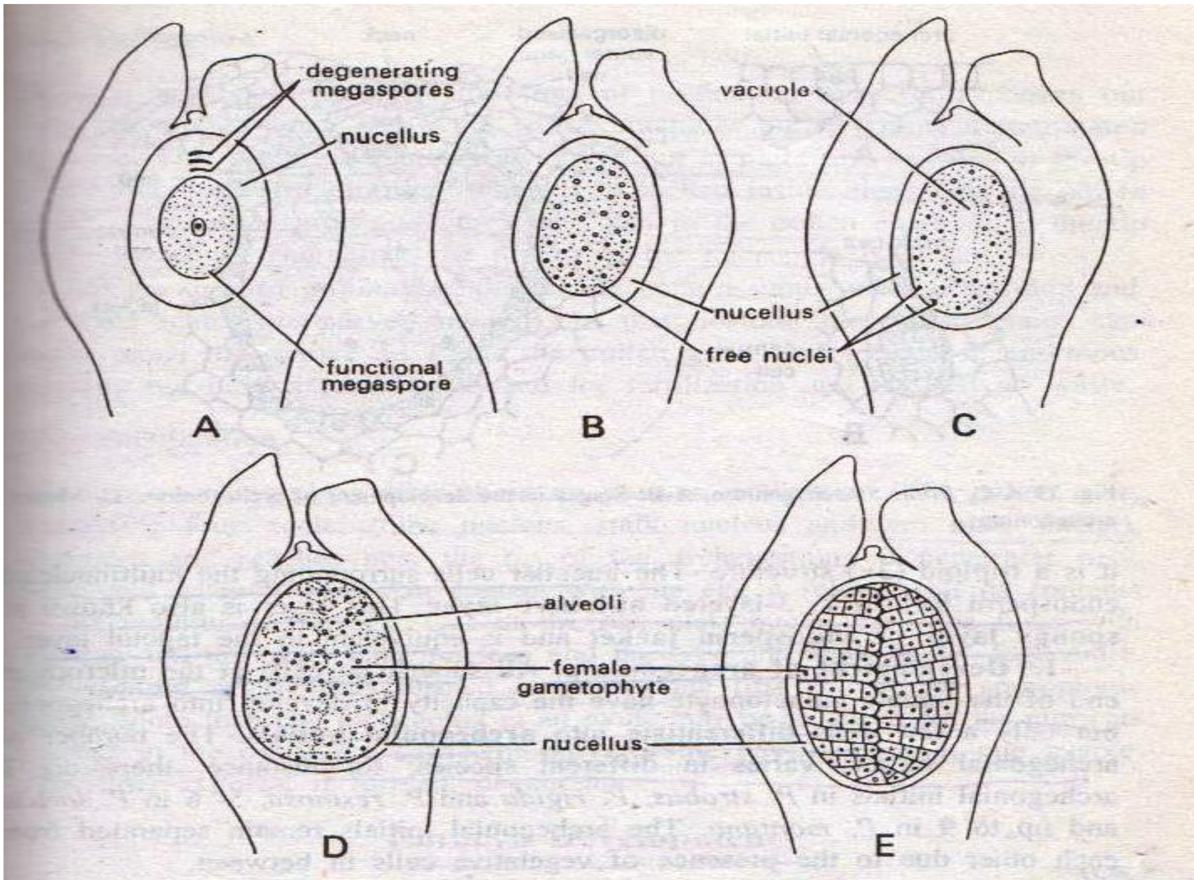


Fig. 22 A-E. *Pinus* : Development of female gametophyte.

The primary neck cell divides by two vertical walls into a tier of 4 cells that constitute the neck of the archegonium. The central cell undergoes rapid enlargement and its cytoplasm shows conspicuous vacuoles, which later disappear and the cytoplasm becomes dense.
Proteid vacuoles or para nuclei make their appearance in the cytoplasm. By this time , a distinct jacket layer of cells surrounds the central cell. These cells have large nuclei and can be easily made out from the surrounding female/gametophyte cells. The nucleus of the central cell divides into two

daughter nuclei and a wall is laid down between them to form a small lenticular venter canal cell and a large egg cell.

The former soon degenerates. The egg nucleus migrates towards the centre and enlarges considerably. At maturity, the cytoplasm of the egg becomes fibrillar with fibrils radiating from the nucleus to the periphery. Proteid vacuoles are also present.

The mature female gametophyte is a small ovoid thallus. During its growth, the megaspore crushes and consumes most of the surrounding nucellar tissue reducing it eventually to a thin membrane and a cone of tissue at the end towards the micropyle. It is the nucellar beak. Its cells contain abundant starch.

The megaspore with its contained female prothallus corresponds to the embryo sac of the angiosperms.

Q3 Describe the classification and distribution of Gymnosperms.

Ans Robert Brown for the first time recognized Gymnosperms as a group distinct from angiosperms, due to the presence of naked ovules. Bentham and Hooker (1862-83) considered them equivalent to dicotyledons and monocotyledons, and placed them between these two groups of angiosperms. They recognized three classes of gymnosperms Cycadaceae, Coniferae and Gnetaceae.

The fossil record of gymnosperms includes many distinctive taxa that do not belong to the four modern groups, including seed-bearing trees that have a somewhat fern-like vegetative morphology (the so called seed ferns or pteridosperms).

Engler created another group Ginkgoales to accommodate the genus Ginkgo. Van Tieghem treated gymnosperms as one of the two sub divisions of spermatophyta.

To accommodate the fossil members, subsequently three more classes- Pteridospermae, Cordaitales and Bennettitales were created. Coulter and Chamberlain (1910), Engler and Prantl (1926), Rendle (1926) and others considered gymnosperms as a division of Spermatophyta ,Phanerogamia or Embryophyta and they further divided them into 7 orders (1) Cycadofilicales, (2) Cycadales, (3) Bennettitales, (4) Ginkgoales, (5) Coniferales, (6) Cordaitales and (7) Gnetales.

On the bases of wood structure Steward (1919) divided gymnosperms into two classes.

Class-1 Manoxylic: Wood is not compact due to the presence of well developed pith and cortex and broad medullary rays.

Class-2 Pycnoxylic: Wood is compact as pith and cortex are reduced and medullary rays are narrow. Three orders (Cycadales, Cycadeoidales and

Cycadofilicales) were recognized in Manoxylic and four (Cordaitales, Ginkgoales, Coniferales and Gnetales) in Pycnoxylic.

On the basis of morphological nature of ovule bearing organs, Sahni (1920) recognized two sub-divisions in gymnosperms- Phyllospermae and Stachyospermae.

Gymnosperms

Sub Division

Phyllospermae
(seeds borne on leaves)
Orders 1 Cycadofilicales (Pteridospermae)
2 Cycadales
3 Bennettitales
(i) Gnetales

Stachyospermae
(seeds borne on stems)
1. Cordaitales
2. Coniferales
3. Ginkgoales

The classification of Chamberlain was more or less on the lines of Sahni, but he raised the sub-divisions to the rank of divisions.

Gymnosperms Divisions

Cycadophyta
(wood manoxylic, sporophylls simple)

Orders 1 Cycadofilicales
2 Cycadeoidales
3 Cycadales

Coniferophyta
(wood pycnoxylic
sporophylls complex)
1. Cordaitales
2. Ginkgoales
3. Coniferales
4. Gnetales

Tippo (1942) considered gymnosperms as a class of the sub-phylum Pteropsida and divided them into sub-classes.

Gymnospermae

↓

Sub-classes

Cycadophytae	**Coniferophytae**
Order 1 Cycadofilicales	1. Ginkgoales
Order (2) Cycadales	2. Cordaitales
Orders(3) Bennettitales	3. Coniferales
	4. Gnetales.

Pant (1957) recognized three division's, nine classes and 17 orders in gymnosperms.

Division-1 Cycadophyta (Manoxylic wood, unbranched or poorly branched trunks, leaves, large and pinnate).

Class-1 Pteridospermopsida	Orders (1) Lyginopteridales
	Order (2) Medullosales
	Order (3) Glossopteridales
	Order (4) Corystospermales
Class-2 Cycadopsida	Order (5) Caytoniales
Class-3 Pentoxylopsida	Order (6) Cycadales
Class-4 Cycadeoidopsida	Order (7) Pentoxylales
(Bennettiopsida)	Order (8) Cycadeoidales or Bennettitales

Division-II

Chlamydospermophyta (Peculiar angiosperm like forms)

Class-1 Gnetopsida	Orders (1) Gnetales
	Order (2) Welwitschiales

Division-III

Coniferophyta (Pycnoxylic wood, large sized trees with profusely branched stems, simple leaves).

Classes	**Orders**
1 Coniferopsida	i. Cordaitales
2 Ephedropsida	ii. Coniferales
3 Czekanowskiopsida	iii. Ginkgoales
4. Taxopsida	iv. Ephedrales
	v. Czekanowskiales
	vi. Taxales

Sporne (1965) divided gymnosperms into three classes and nine orders.

Class-1 Cycadopsida	Orders (1) Pteridospermales
	(2) Bennettitales

(3) Pentoxylales
(4) Cycadales

Class-2 Coniferopsida — Orders (1) Cordaitales
(2) Coniferales
(3) Taxales
(4) Ginkgoales

Class-3 Gnetopsida — Order (1) Gnetales

Cronquist, Takhtajan and Zimmermann (1966) placed gymnosperms in the division Pinophyta of the sub-kingdom Embryophyta. Pinophyta was divided into three sub-divisions and six classes.

Division Pinophyta

<u>Sub-division 1</u> <u>Cycadicae</u> (= Cycadophyta)

Class
1. Lyginopteridatae = (cycadofilicales)
2. Cycadatae (=cycadales)
3. Bennettitatae (=Bennettitales)

<u>Sub- division II</u> <u>Pinicae</u> (=Coniferophyta)

Class
1. Ginkgoatae (=Ginkgoales)
2. Pinatae

Sub-Class (i) Cordaitadae (=Cordaitales)

4. Pinidae (=Coniferales)

Sub-division III Gneticae (Gnetales)

Class 1. Gnetaitae

Sub-Class (i) Ephedridae (=Ephedrales)
(ii) Welwitschidae (=Welwitschiales)
(iii) Gnetidae (=Gnetales)

Bierhorst (1971) recognized three classes and 11 orders in gymnosperms.

Gymnosperms

Class

Cycadopsida	**Coniferopsida**	**Gnetopsida**
Orders 1. Pteridospermales	1. Cordaitales	1. Ephedrales
2. Cycadales	2. Coniferales	2. Gnetales
3. Cycadeoidales	3. Taxales	3. Welwitschiales
4. Caytoniales	4. Ginkgoales	

Taylor (1981) was of the opinion that classification of gymnosperms is still a subjective exercise .He proposed the following classification where gymnosperms were divided into 6 divisions.

Division-I Progymnospermophyta
Division-II Pteridospermophyta
Orders:- 1. Lyginopteridales
2. Medullosales

3. Callistophytales
4. Caytoniales
5. Corystospermales
6. Calamopityales
7. Peltaspermales
8. Glossopteridales

Q 4 Describe the general characters of Gymnosperms in Detail.

Ans General Characters of Gymnosperms

Gymnosperms (Gymnos = Naked + Spermos = Seed) commonly called 'naked seeded plants ' form a distinct sub- division of the Spermatophyta (seed plants) . These have been referred by Goebel as "Phanerogams without ovary ''. The plants of this group are regarded as most primitive of all the seed plants.

General characters:-

(a) Distribution and habitat:-

The living Gymnosperms are distributed throughout the temperate and tropical zones and even in the arctic regions of the world. The greatest development among the living Gymnosperms has been attained by the coniferous forms in the temperate climate of both the hemispheres. In general, they are found in physical or physiologically dry situations.

(b) Gymnosperms are predominantly woody, evergreen , perennial trees or shrubs. A few members are climbers e.g. (Gnetum ula , Ephedra foliata). Stem is branched except in Cycas. They are xerophytic in habit and thus possess xerophytic adaptations in different forms. The height of the plant varies from 3-5 cm (Zamia pygmaea) to 40 cm.(the tallest tree is Sequoia wellingtonia). The growth of the stem varies from few mm (Ephedra) to about 15 metres. (Sequoia sempervirens).

(c) Leaves:-

The leaves present on the Gymnospermous plants may be of only one kind or of two kinds. (dimorphic).

(d) The foliage leaves are green, simple, needle shaped or pinnately compound.

(e) The scaly leaves are usually minute and deciduous. In some taxa like Ephedra only scaly leaves are present.

(d)**Anatomy:-**

(i) The vascular cylinder of the stem of Gymnosperms is made up of conjoint, collateral , endarch and open vascular bundles.

(ii) Xylem is composed of only tracheids and xylem parenchyma . Vessels are absent, with the exception of the members of the Gnetales.

(f) The phloem consists of sieve tubes and phloem parenchyma , companion cells are absent.

(g) The stem shows secondary growth and conspicuous annual rings are present in the wood. However, in some Gymnosperms like Cycas primary cambium is short lived and is replaced by successive rings of cambia formed outside the secondary phloem.

(h) In Coniferales and Ginkgoales , pith and Cortex are much reduced, consequently, the wood in such cases is dense and is known as pycnoxylic.

In members of Cycadales , the pith is large , cortex is thick and the primary cambium is either short –lived or functions slowly, as such in Cycadales ,the wood is loose , soft , scanty and not so compact and is therefore manoxylic. Secondary wood shows distinct annual rings.

(i) The roots are diarch to polyarch. Xylem of the root is formed of tracheids containing uniseriate or multiseriate bordered pits.

(j) The leaves invariably exhibit xerophytic characters in the form of thick cuticle, protection of stomata in pits, development of wax etc.

(k) The mesophyll of the leaf may be undifferentiated (e.g. Pinus, Cedrus) or differentiated into palisade and spongy parenchyma (e.g. Cycas)

(l) Most Gymnosperms leaves do not have lateral veins and the lateral translocation of nutrients takes place with the help of transfusion tissue.

(m) Sporophyte:-

The plant body represents a dominant and independent sporophyte. Mostly the cones are unisexual i.e. a cone may be either male (Microsporangiate) , or female (Megasporangiate) , rarely there are found bisporangiate cones (Picea excelsa , Abies alka). Except Gnetales the reproductive organs have no perianth.

(a) Male Cone:-

These are comparatively short lived and smaller in size than the female cones. The microsporohylls may be broad as in Cycas or peltate as in Dioon and Taxus.

The microsporangia (pollen sacs) may be arranged in soral groups of 3 to 5 (Cycas) or their number is reduced to only 2 (Pinus).

The microsporangia are always present on the lower surface of the microsporophylls. The development of the sporangium is of eusporangiate type (sporogenous tissue developing from a group of hypodermal cells, forming spore mother cells, each of which produces four microspores.).

(b) Female Cone:-

6. The ovules are naked. Hence the seeds are exposed and not enclosed in a closed ovary because the megasporophylls are not differentiated into a closed ovary, style and stigma.
7. Ovules are orthotropous as in Biota, Cycas etc. or anatropous as in Pinus and monotegmic (i.e. provided with only one integument) . Sometimes an additional outer envelope is present forming an aril as in Taxus or an outgrowth , epimatium as in Podocarpus.

8. The integument is differentiated into 3 layers—outer and fleshy layers and middle layer being stony in nature. The stony layer is usually strongly developed which in case of the members of Pinaceae form the outermost superficial layer, of the seed.
9. The integument encloses nucellus with a micropyle at the apex of the ovule. The ovule contains one or several sporogenous cells each developing into linear row of four potential megaspores.
10. Only the lowermost megaspore is functioning and forms embryo sac or prothallus which unlike Angiosperms lie deeply embedded in the nucellus in the chalazal region of the ovary.
11. Gametophyte:-

The plants are heterosporous and both Male and female gametophytes are very much reduced. The gametophyte is dependent and rudimentary.

12. Male Gametophyte:-

The male gametophyte develops from microspore after its germination. The microspores are liberated in various stages of the development of male gametophyte.

e.g.they are liberated at 3-celled stage in Cycas , 4-celled stage in Pinus and 5-celled stage in Ephedra.

The pollen tube may act mainly as haustorium (Cycas) growing and branching in the substance of nucellus , while in higher members (conifers) the pollen tube acts as a sperm carrier.

(c) FemaleGametophyte:-

The female gametophyte may have 2 to 8 archegonia though in advanced members e.g. Gnetum and Welwitschia , the archegonia are absent.

There are several archegonia in Cycas and only two in Pinus. The archegonium of Gnetum is represented by ovum like The archegonium has a single egg and a venter canal cell; Neck canal cells are absent.

13. Pollination :-

Pollination is direct i.e. pollen grains come in direct contact with the ovule. Pollens are deposited in the pollen chamber where they germinate. All Gymnosperms are anemophilous. (wind pollinated).

14. Fertilization is siphonogamic.

15. Endosperm:-

In contrast to Angiosperms , the endosperm in Gymnosperms develops before fertilization, as such it is a haploid tissue. The double fertilization and triple fusion as evident in Angiosperms is absent in Gymnosperms.

16. Embryo:-

In Gymnosperms, only a part of the oospore develops into an embryo. Thus in the whole plant kingdom, Gymnosperms afford the only example of meroblastic formation of embryo. The meroblastic phenomenon is of wide occurrence in Animal Kingdom.

In most of the members, except Gnetum and Welwitschia, there is a free nuclear period in the development of embryo. The proembryo gets differentiated

into three regions- upper haustorial , middle suspensor and basal embryonal cells. Cells of suspensor form long tubes.

Embryo is usually straight consisting of radical lying towards the micropyle and plumule towards the basal end.

The number of cotyledons may be two (Cycas) or many (Pinus). Cotyledons are usually green while still enclosed within the seeds .The embryo later gets differentiated into stem , leaves and roots.

(K) Polyembryony:-

(i) Since there is no ovary, there is no such organ as fruit as found in Angiosperms. The naked ovules develop only seeds.

(ii) The polyembryony may arise by the fertilization of more than one eggs or by the division of the zygote (Cleavage polyembryony). But due to physiological competition only one embryo attains maturity.

(L) Seed Germination:

Except in Cycas and Ginkgo , the seeds remain dormant for sometime and then germinate under favourable conditions. Germination is of epigeal type, the cotyledons forming the first leaves. On germination , the seed coat is ruptured and the embryo develops into a new sporophytic plant. The growth of plumule is limited in case of Welwitschia.

The seed represents three phases in the life cycle of Gymnosperms:

17. Integument and nucellus represent the mother sporophytic phase (first sporophytic phase)
18. Endosperm , the gametophytic phase and
19. Embryo, the next sporophytic phase (as it develops from the zygote).

(m) Alternation of Generations:-

The members of this group possess distinct phases in their life cycle – gametophytic and sporophytic which regularly alternate. The diploid sporophytic phase is dominant , whereas the haploid gametophyte phase is reduced. The gametophytic phase is dependent on the sporophytic phase.

Q.5 Describe the economic importance of Gymnosperms in detail.

Ans

Economic Importance of Gymnosperms:-

The Gymnosperms are an economically important group of plants spread all over the globe, primarily in the temperate regions and at higher elevations in the tropics. The trees are used for landscaping, timber , building construction, resin and for the manufacture of paper and board.

Wood:-

The wood of Abies alba , an important timber tree of Europe is used in general carpentry. It is white or yellowish white, light , soft with distinct annual rings. It finds use in the sound boards of musical instruments , carving , wood wool, boxes , paper pulp , planks and boards. After treatment with preservatives or copper sulphate , it can be used as telephone and telegraph poles.

A.balsamea is distributed mainly in North America and Canada. The wood is light , weak, knotty and is used for ordinary buildings and box-making . It is increasingly being used with spruce , as pulp –wood for paper making. A. amabilis (in Alaska) , A. grandis (Canada), A. concolor (Western N. America) and A. procera (America) wood is used for interior furnishing , box making , building purposes and general carpentry. Agathis australis , 'Kauri pine' the chief timber tree of New Zealand with its extremely tall , without taper cylindrical bole, ranks amongst the largest timber producing trees of the world. The wood is fine and even textured with a silky, lustrous surface. It is useful in building construction , boats , vats and wooden machinery. Araucaria angustifolia occurs mainly in Brazil yielding a non- durable , heavy and uniformly textured wood, useful in making doors , bus chassis , plywood and in joinery work. A. bidwillie and A cunninghamii are important timber trees for plywood manufacture in Australia. The wood is white or green colored and straight ; grained and easily worked. It is used for indoor finish, furniture, general house fittings, box wood , carving etc.

Cedrus atlantica (Algeria, Moroco) , C. deodara (India) and C. libani (Lebanon) are much valued among conifers. The wood of Cedrus is in great demand as it is very durable , oily sweet scented and generally without resin ducts. C . deodara , the deodar , is one of the most important timbers of North India. The seasonal wood is resistant to the insect attack due to the presence of oil. It is used for making doors , poles , furniture , beams , ceilings , columns , carriages , wagons , boats , flooring and wood carving. It was even used as battery separators and railway sleepers.

The wood of Chamaecyparis formosensis has a very smooth surface. It is used for making sound boards of musical instrumens. C. lawsoniana , widely distributed in America , furnishes timber that is light , fine and even textured, moderately strong , very durable with fragrant and spicy odour. It is mainly employed for ship building , railway sleepers and fence posts , match sticks , furniture , organ pipes and internal finish of houses and flooring. It keeps away moths and insects. The fragrant essential oil in the wood is a strong diuretic; so much so that workers in places where the wood is bawn had to change to other woods.

Cryptomeria japonica yields a coarse-grained , fragrant , strong , durable , easy to work wood. It is one of the most utilized timbers of Japan. The bark is carefully stripped from trees and is used for roofing of houses. The wood is employed for building construction , paneling , furniture and joinery.
The wood of Phyllocladus rhomboidalis (Tasmania) is used for making masts of small vessels, flooring and building purposes. P. trichomanoides in New Zealand yields a strong , dense , heavy wood that finds use in building work , mine , timbers , marine pebs and sleepers.

Resins:-

Resins are plant exudates which make the wood resistant to decay. Conifers are amongst the major resin yielders of the world. The resins are insoluble in water but soluble in organic solvents. The superior grade resin is used in paper sizing , varnishes , enamels , plasters , medicines and ointments.

Resin :-

The pine oleoresin was used to smear mummies by ancient Egyptians . An oleroresin (also called pine gum, pine pitch or turpentine) is the mixture of rosin and essential oil. A pine tree yields only oleoresins from which rosin could be separated by distillation. The residue after the distillation of oleoresin is called the gum rosin or colophony. Rosin is also obtained by solvent extraction of old stumps. Such rosin is called wood rosin.

Copal:-

Copal belongs to the group hard resins which contains only a little essential oil . These are much valued in the varnish industry because of their high melting point and hardness. Of the Copals , the most important and most valued is the kauri resin, also called ‘Kauri gum’ or ‘Kauri copal ‘ obtained from the kauri pine. (Agathis australis). It occurs underground in fossilized form. The copal resin is used for interior work and enamels and in preparation of spirit varnishes , lacquers , linoleum , plastics , oil cloth, water proofing compounds , printing inks and as sizing material.

Canada balsam:-

The resin obtained from Abies balsamea has a very high refractive index nearing that of glass. This makes Canada balsam as the most preferred mounting medium for microscopic objects and a cement for lenses in optical work.

Amber

It is a fossil resin secreted by the now extinct pine, Pinus succinifera. It occurs in blue earth near the eastern shore of the Baltic , Sicily, Madagascar and Myanmar (Burma).

It is used in medicine and x-ray therapy. It is reported that blood does not coagulate when kept in amber containers. It is also used for beads , carving and other ornaments , cigarette and cigar holders and mouth pieces of smoking pipes.

Essential oils:-

In Yugoslavia , Picea abies yields spruce oil , that is pleasant and refreshing and is used in room sprays , bath salts and deodorants. Abies sibirica, yields the Siberian fir needle oil, and is used in scenting of soaps (both toilet and shaving) , bath preparations , room sprays , deodorants and disinfectants.

In India , the oil extracted from Cedrus deodara is used in perfumery and scenting soaps. It is also recommended for clearing tissues in histological work and for use with oil immersion lens of the microscope. Cedrus atlantica yields an oil with medicinal properties. It is used against bronchitis , tuberculosis , skin diseases and gonorrhoea.

The Cedar wood oil, obtained from Juniperus mexicana, finds its use in scenting soaps , room sprays , deodorants , insecticides , moth proofing , floor polishes , lubricating greases etc.

Fatty oils :-

Many Gymnosperms seeds contain fatty oils. Tall oil (fatty acids : 20 to 60% , resin acid : 10 – 60 % unsaponifiable material : 5-24%) which is obtained as a by-product during sulphate process of cooking , confer wood for making craft paper, is used in paints , soaps , linoleum , emulsifiers , organic coaling industry etc. The fatty oil obtained from the seeds of Ceplatoaxus drupacea is used as an illuminant in Japan, whereas the oil from Pinus cembra seeds is used for food and paints.

Paper:-

Superior quality of writing and printing paper is manufactured from the wood of Picea , Tsuga and Abies. , whereas craft paper is obtained from Pinus . Most paper manufacturers consider that ' spruce is king.'

Food:-

In many parts of the world Cycads are used as a source of starch- either from the seed kernels or from stem pith. The stem starch is more popularly known as 'sago' and is mainly obtained from Cycas circinalis , C. rumphii and C. revoluta and also form Zamia and Macrozamia. The pith of Encephalartos stem is used in Africa to make 'Kaffir bread' . The young unfolded succulent leaves of Cycas circinalis , C. pectinata ,C. rumphii and Cycas siamensis are cooked and eaten in the Malay Peninsula , Phillipines , India , Indonesia etc.

Macrozamia spiralis and M reidlei are an important source of stem starch in Australia . M. reidlei starch has been used for laundry. M spiralis starch has been exploited for conversion into power alcohol. The cycads have long been known to be poisonous in nature. Eating seed kernels can be an acute irritant and an intake of cycad leaves can affect nerves. The poisonous principle is inactivated by heating. Pine seeds , have long been have been used as a food item for a long time. Pinus gerardiana , the Chilgoza pine, have long been marketed in India by Afghan traders. The tree grows in the Himalayas and its seeds are considered an important food item from Tibet to Afghanistan. The best known edible pine in Europe is P. pinea. The cones are exposed to sun to expand the scales. The seeds are mechanically released to expose the kernels. The nuts are mainly produced in Italy and Spain and are sold as far as America. In Italy , the nuts are used in soups, as dessert and in the preparation of a much valued sweetmeat.

Tannins:-

Small quantities of tannins are obtained from the bark of Tsuga canadensis , Sequoia sempervirens, Larix decidua, Picea alba , Phyllocladus trichomanoides, Araucaria and Dacrydium cupressinum. Tannins are mainly used in the leather and petroleum industry, in medicine and for dyeing purposes.

Drugs:-

The alkaloid ephedrine is extracted from the green branches of Ephedra sinica, E. equisetina and E. gerardiana . Ephedrine is an important ingredient in the cough mixtures because of its action in dilating the bronchial tube. It also contracts mucous membranes and is used in nasal drops and inhalents.

An extract of leaves of Ginkgo biloba is useful in the treatment of cerebral insufficiency and Vertigo. The leaves of Taxus baccata are used in asthma , bronchitis , hiccough, epilepsy and for indigestion. Taxol (from Taxus brevifolia) has been shown to be effective against ovarian cancer ; breast cancer , non-small – cell cancer , melanoma and colon cancer. The juice of young leaves of C. revoluta finds use for flatulence and vomiting blood.

Decoration :-

The one single item that heightens the beauty of any hill resort / forest is the Conifers , be it a pine , cedar , fir , spruce , juniper or hemlock. They are a pride possession of any horticulturist or garden lover. Picea and Abies are ceremoniously used as Christmas trees. Gymnosperms offer a good source material for developing 'Bonsai' plants. The art of dwarfing trees originated in Japan and is now fancied the world over. Juniperous chinensis, Pinus parviflora, Pinus thunbergii, Pinus densiflora , P. nigra and P mugo are some of the conifers used for this purpose. Cupressus junebris is generally planted around tombs and religious buildings. Taxus and Ginkgo plants are used as ornamentals.

Other uses :-

Wood wool and leaf wool are obtained by longitudinally cutting wood chips or leaves of conifers into small pieces. The wool is used for stuffing pillows, cushions etc. Wool from essential oil- yielding conifers is in demand as it emits a very faint and pleasant pine smell. The bark from several trees such as Picea abies. Pinus sylvestris, Pinus contorta , P. ponderosa and Tsuga heterophylla is added to wood in making commercial boards of standard quality. The bark and wood flour (saw mill waste) are used for making linoleum , plastics , artificial wood, composition flooring , insulating bricks and as an absorbent in the manufacture of dynamite . Sawdust is also subjected to aid hydrolysis in which the cellulose is broken down to 'sugars'. This sugar is then utilized in the propagation of yeast for use as stock feed or protein rich food for human consumption. Malco-pimaric acid , obtained from crude pine – pitch , is used in printers , ink, paper sizing and photographic chemicals.

Q.6 Describe about the development of male gametophyte and female gametophyte of Cycas in detail?

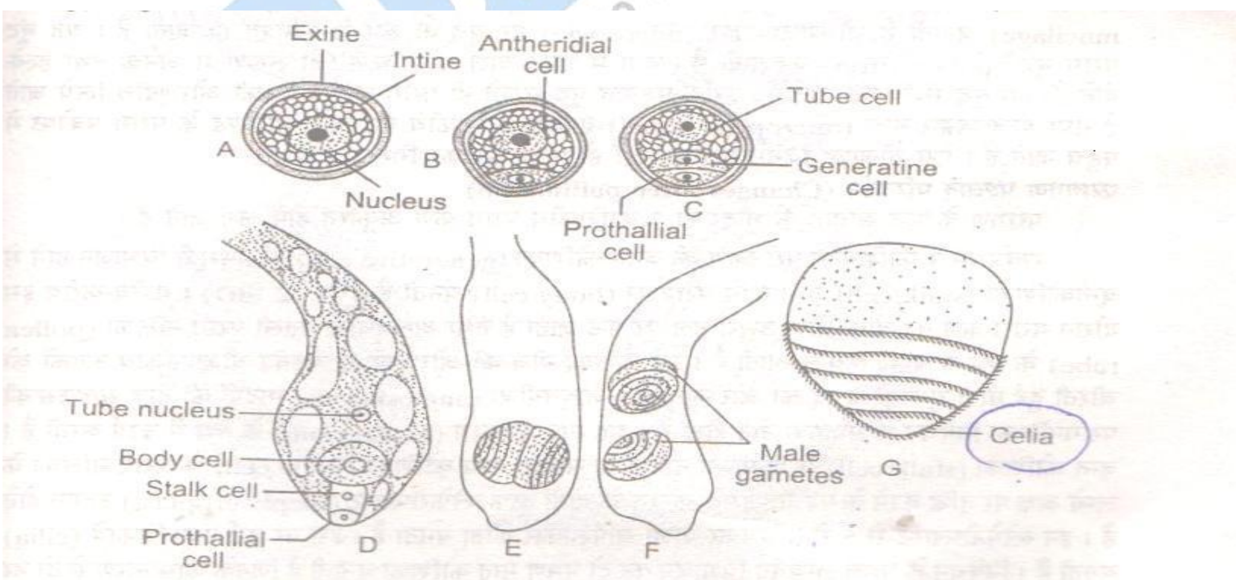
Ans

Cycas is heterosporous . It produces two types of spores – microspores and megaspores. The microspore develops into male gametophyte and megaspore develops into female gametophyte.

Male Gametophyte:-

The microspore is the first cell of the male gametophyte. Each microspore is boat shaped and has got two walls – outer thick exine and inner thin intine. It bears a longitudinal furrow or slit. During maturation , the starch grains disappear and a vacuole appears into cytoplasm on the 10Th day with the result that the nucleus is shifted to the other side. The microspore germinates while it is still enclosed within the microsporangium. Before the nucleus of microspore divides , the vacuole disappears.

The microspore divides mitotically by unequal wall and form a small persistent prothallial cell or vegetative cell and a large antheridial cell. The antheridial cell soon undergoes transverse division and forms a small generative cell which remains in the close contact with prothallial cell and a large tube cell. Thus the microspore becomes 3- celled . The dispersal of microspores takes place at the 3-celled stage. Further development occurs in the pollen chamber of the ovule after pollination.



Cycas : Stages of Developement of Male Gametophte

Pollination:-

Pollination in Cycas is direct and anemophilous . The pollen grains are carried to pollen chamber of the ovule by wind. The pollen grains being light and dry are easily blown away by the wind.

At the time of pollination , a large pollination drop or mucilage oozes off from the micropylar end of the ovule. In fact, the pollination drop develops as a result of disorganization of some of the cells of the nucellus.

Some of the microspores carried by air current are entangled in the pollination drop. As the pollination drop dries up, the microspores are sucked into the pollen chamber through the micropylar canal. After pollination the ovule increases in size. But pollinated ovules dry up and wither away.

Development of Male Gametophyte after Pollination:-

After about a period of 4 months , the microspores lying in the pollen chamber start further growth and division. The generative cell divides into a stalk cell and a body cell . The stalk cell does not divide further but increases in its size and accumulates cytoplasmic contents. In the meantime , the pollen tube acts both as a haustorium as well as a sperm carrier. Further development takes place when the archegonia get matured. On account of the growth, the pollen tube penetrates the nucellus by digesting and breaking down the tissue above the archegonial chamber.

The body cell divides to form two male gametes (antherozoids) just before fertilization . The antherozoids swim freely in the cytoplasm of the pollen tube. There is an interval of about 4 months between the pollination and fertilization.

The male gametes are naked , top- shaped structures , measuring 180 – 210 µm. The blepharoplast of the antherozoids elongates into a large spirally arranged structure with many cilia.

Microspore

(a) A small prothallial cell

(b) A large Antheridial cell

(a) a small generative Cell

(b) a large tube cell

(a) stalk cell → Does not divide further

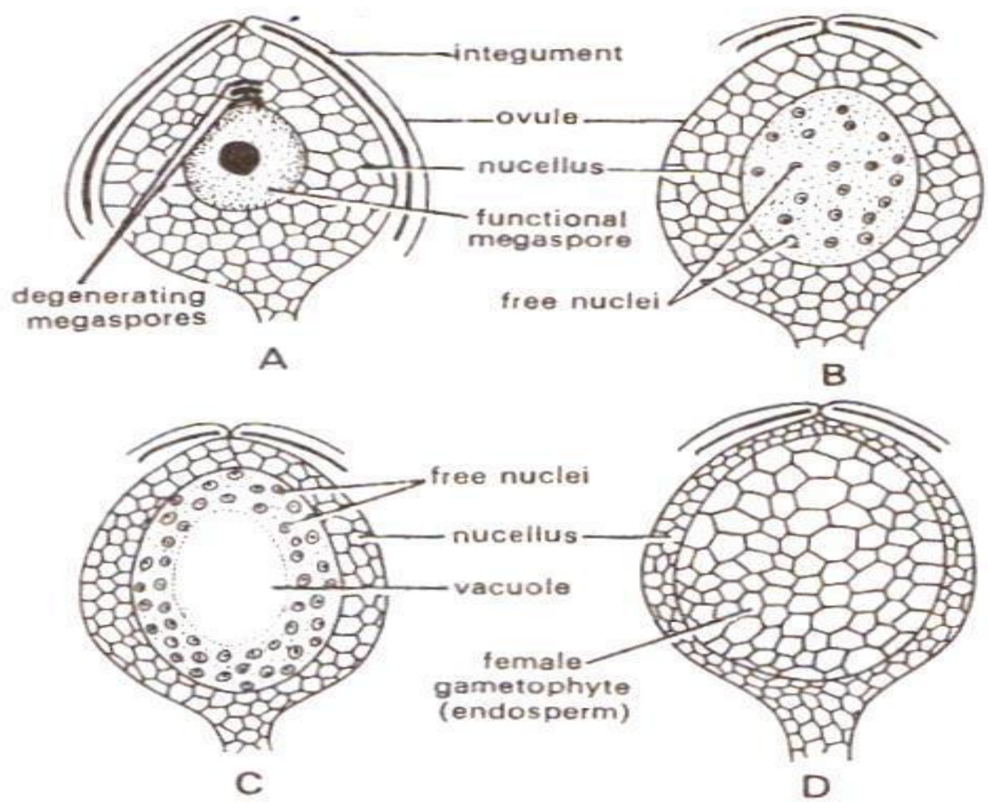
(b) Body cell → divides → 2 Male Gametes (Antherozoids)

Female Gametophyte:-

The female gametophyte develops from the functional megaspore which deeply situated in the ovule. The nucleus of megaspore divides by free nuclear divisions , till about 1.000 or more of nuclei are formed. These nuclei are found embedded in a thin layer of cytoplasm. The nuclei shift towards periphery along with the cytoplasm leaving a large vacuole in the centre. Thereafter , the wall formation is initiated at the periphery which proceeds in centripetal direction or towards the centre. Consequently , the vacuole is obliterated.

The wall formation continues until the entire female gametophyte becomes cellular. Such type of centripetal wall formation causes regular cell arrangement, along the radial rows. This cellular mass of the gametophyte is called female prothallus or endosperm. The cells of the endosperm are haploid.

Before the gametophyte becomes cellular , it gets differentiated into one or two celled thick layer called nutritive layer or endosperm jacket or spongy layer. This



A-D. *Cycas* : Stages in the development of female gametophyte.

layer remains in contact with the gametophytic tissue and bears a variable amount of starch grains. The number and size of the starch grains decreases from inner layer to outer layer gradually. The gametophytic tissue also possesses a considerable number of tannin cells.

Development of arhegonia:-

After the complete development of female gametophyte , a few cells at the micropylar end get fairly enlarged and act as archegonial initials. The nuclei of these initials migrate towards the periphery and simultaneously , the tissue situated over these cells soon disorganize. This causes the formation of small cavity called ' archegonial chamber' .

Each archegonial initial divides by a periclinal wall to form an outer primary neck cell and an inner central cell. Primary neck cell soon divides by anticlinal wall and forms two neck cells. These two cells fairly increase in size and project above the surface of the gametophyte. However , Swamy has reported formation of 4 neck cells due to a second vertical division. In Cycas , the neck is without any neck canal cells.

The central cell enlarges considerably in size and its nucleus divides to form a small venter canal nucleus and a large egg nucleus . The egg of Cycas is the largest amongst the living plants. Thus , the mature archegonium consists of 2- 4 neck cells and an egg. The venter is surrounded by a nutritive jacket of cells formed by the gametophyte cells. This jacket is called archegonial jacket. The nucellar tissue above the archegonial initials disintegrates to form an archegonial chamber.

Unit –IV

Palaeobotany

Q 1 Write in detail about Rhynia.

Ans. Rhynia, the type genus of family Rhyniaceae is derived from a Middle Devonian deposit from a place known as Rhyni in Scotland. Two species, namely R. Major and R. gwynne-vaughani were found by Kidston and Lang, at this station in a very well preserved condition.

<u>Sporophyte</u>:-

From the reconstructions, the sporophyte was distinguished as follows. The rhizome was horizontally creeping and its slender branches were turned upwards to become aerial leafless shoots. These were dichotomously branched, cylindrical and gradually tapering. They ended as vegetative apices or bore elongated sporangia at the tips of their ultimate dichotomies. There were no roots and the rhizome bore rhizoids on the underside, in patches. Among the two species, R. major was the large one and it was 50 cm in height, whereas R. gwynne-vaughiani grew only to a height of 20 cm.

In addition, to the usual structure R-gwynne – vaughiani bore on its stems, oval or hemispherical, parenchymatous outgrowths, some of them near the base, bore rhizoids.

<u>Anatomy</u>:

A transverse section of the aerial or substerranean part of the stem showed essentially the same structure. It was differentiated into epidermis, cortex and stele.

<u>Epidermis</u>:

The epidermis was single layered and it was provided with a conspicuous cuticle on the outer surface. The epidermis of the aerial portions showed stomata here and there. Each stoma was surrounded by two guard cells.

<u>Cortex</u>:-

The cortex, which was nearly ten times the stele, had distinction into outer and inner portions. The outer cortex was 1-3 layered, consisting of angular cells closely arranged without any intercellular spaces.

The inner cortex was more extensive and it was composed of spherical parenchymatous cells loosely arranged. It is thought that this part was the chief photosynthetic region of the plant.

The cortex sometimes showed hyphae which were either intracellular or intercellular. Whether this was a mycorrhizal association or it was due to the entrance of the fungus after the death of the plant is still not clear.

Stele:-

The stele, at the centre, showed a central mass of xylem surrounded by several layers of phloem. Thus, the stele was a simple protostele i.e. haplostele. The xylem was mainly constituted by tracheids which had most annular or rarely spiral thickenings. The tracheids were usually of the same diameter but sometimes peripheral ones, were larger than the central ones in diameter. The 3-4 layered phloem had elongated, thin walled cells with oblique end walls. Sieve plates were not found.

Sporangia:

The sporangia were borne at the ends of the ultimate aerial branches. They always occurred singly and it is doubtful whether they were borne on only a few or all the branches of the aerial portion.

The sporangia were very simple in structure. The sporangia had a sterile jacket of several layers of cells. This consisted of an outer layer, the epidermis consisting of thick-walled cells, provided with a thick cuticle, a middle region of thin-walled cells and an inner layer, probably constituting the tapetum.

The sporangia of R. major were nearly as long as 12 mm. The sporangium contained numerous spores which were all similar (homosporous) and in some cases, they were united into tetrads. There was no columella and liberation of spores took place by gradual decay of its wall and not by any special mechanism.

Gametophytes:

The spores had typical triradiate markings and was said to have produced a germ tube and a multicellular structure at its tip.

The cortex sometimes showed hyphae which were either intracellular or intercellular.

Q-2 Define fossilization and types of fossils?

Ans

Fossilization:-

The process of preservation of living beings or their parts in the form of fossils are known as fossilization.

Two theories have been proposed to explain the fossilization process in plants.

1. **Replacement theory:-**

   According to this theory, fossilization takes place by the replacement of the molecules of the original substances of the plant one by one by the molecules of minerals in soil solution. The replacement occurs due to hydrolysis or weathering of the organic substances present in the plant body.

2. **Infiltration theory:-**

According to infiltration theory, fossilization takes place as a result of infiltration and precipitation of minerals through the cell wall.

After burial, the plant body undergoes partial disintegration and the free carbon released in this process forms carbonates by reacting with infiltrated calcium, magnesium etc.

Types of Fossils:-

Fossils occur in a variety of farms. On the basis of the nature of fossilization, fossils may be classified into the following types:-

(I) Compression fossils:-

These fossils are formed as a result of burial of plants or its parts in sediments. The buried parts become flat due to compression or overlying pressure of the sediments. Sand stone, diatomaceous earth and volcanic ash are some of the materials that cause compression.

(II) Petrifaction fossils:-

Those fossils which preserve both external form and internal structure are called petrifactions. In this process, every cell of the plant tissue is preserved and perfectly distended as if it is living.

There is molecule by molecule replacement of plant parts by some 20 minerals (in the form of carbonates, sulphates, silicates, phosphates, etc.

For petrifaction, the organic part must be protected in some way from rapid decay while mineralization proceeds. In the past, this has been accomplished by exclusion of air (as in water saturated sediments), by low pH or by the specific physical and chemical conditions existing under a layer of volcanic dust. Petrifactions are rare but are most suitable for the study of structural details.

(III) Incrustation fossils:-

These are the commonest types of fossils, suitable for the study of morphology of fossil plants. In these fossils, external forms of the plant are preserved as a cast, but the internal structure is destroyed.

Here, deposition of sediments occurs in the form of a hard coat around the whole plant body or its parts. Incrustations are formed by precipitation of minerals like carbonates on the plant surfaces

(IV) Coal balls:-

Petrified plant organs of roughly spherical shape are known as coal balls. Coal balls are formed by infiltration of calcium carbonate, magnesium carbonate, iron sulphide etc. in buried plant parts. These substances prevent the conversion of plant organs into coal and result in petrifaction. Hence, these fossils occur in the form of coal balls.

(V) **Compactation or mummified plants**:-

These fossils are plants or plant parts, compressed by the vertical pressure of one against another. In such fossils, intervening matrix is not formed in between plant parts. Some plant structures like leathery leaves, hard fruits and seeds are preserved in mummified forms.

(VI) Amber:-

It is a resinous excretion of certain fossil coniferous trees which flowed due to injuries caused by boring insects or from the decaying branches. The exudates accumulated on the forest floor, gradually hardened to take the shape of amber.

(VII) Impression fossils:-

These fossils are just impressions of plants or plant parts on sediments. Hence, they do not contain organic materials.

They occur abundantly in clay deposits of Puryear in Western Tennessee. The plant material disorganizes and leaves impression, which gives a superficial resemblance of the plant part preserved when clay gets converted into a rock.

Impressions show clear details of venation and in some cases even cuticular details can also be seen.

(VIII) Leaf coal or paper coal:-

These fossils consist of thin dead leaves, dispersed in organic matrix. As the inner tissues of leaves are destroyed, there are layer after layer of cuticle.

(IX) Pseudofossils:-

Sometimes rocks take the shape of some plant part or animal during their formation and as such give an illusion of fossils. Their detailed studies, clearly reveal that they are not plants or animals but are mineral depositions mistaken for plant or animal remains .Such specimens are known as Pseudofossils.

Q.3 Write short notes on Lepidodendron and Calamites:-

Ans

Habit and Habitat:-

The genus Lepidodendron with its 100 species (approximately) appeared in the Late Devonian , flourished in the Carboniferous and then underwent degeneration most probably during the Late Permian . The plants were mostly tall trees.

The plant body (Sporophyte):-

The plant was large tree with a typical Stigmarian root system , a main trunk , which remained straight and unbranched for a considerable height and then showed a regular dichotomy in its branches. The stellar organization of the stem and branches of Lepidodendron was usually of a protostelic nature. The leaves named as the form genus Lepidophyllum, were circular to linear in shape and simple and they were borne spirally on the branches as well as in alternating whorls. The persistent leaf bases were pyramidal in outline and formed peculiar leaf cushions.

On either side of the solitary median vascular strand of the leaf base there was a strand of parenchyma cells giving rise to the parichnos , each of which ultimately lost its identity in the mesophyll tissue.

Lepidostrobus:-

The name of the form genus of the cone or strobilus of Lepidodendron is Lepidostrobus which is an elliptical or cylindrical body which contained both microsporophyll, each bearing one microsporangium with numerous microspores and megasporophylls bear one mega sporangium containing lesser number of megaspores. The former lie towards the apex and the later towards the strobilus.

Calamites

Habit and Habitat:-

Calamites possessed an arborescent habit . The genus appeared in the upper Carboniferous , flourished luxuriantly in the Devonian and then become extinct in the Early Triassic. The fossil remains are rather commonly found , though fragmentaty forms.

In the strict sense , the generic name Calamites should be applied only to pith casts of stems and branches.

The plant body :- (Sporophyte):-

Calamites was a tall tree , about 20 to 30 metres in height. Like the modern Equisetum , the plant had an underground horizontal rhizome, which gave rise to aerial branches ; the rhizomes were differentiated into nodes and internodes . The roots were adventitious and in whorl, developed from each node . The external surface of the stem of Calamites exhibited ribs and furrows , as are noted in Equisetum.

The leaves of Calamites, which were produced in whorls of 4 to 60 at each node of aerial branches were either free form one another or united along with lower margins. Internally , the stem of Calamites exhibit a stem remarkably similar to that of the present day Equisetum vallecular canals are, however , absent. The amount of primary wood scanty . Most of the wood being secondary in nature. The canals represented the protoxylem and the metaxylem . Centrifugal wood rays were also prominent.

The strobili or cones of Calamites showed wide arrangements , the majority of them , however, belonging to either of the two genera, Calamostachys and Palaeostachya. The sporangiophores in the former genus stood out at right angles to the axis of the strobilus , while in the later case , they stood out at an angle of near about 45^{o}. The sporangia may be either homosporous or heterosporous even in the different species of the same genus. Further in Calamostachys , the leaf bracts and sporangiophores appear in alternate whorl, while in Palaeostachya , the sporangiophores appear in the axils of the bracts.