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Evolutionary trends: From Bryophytes to Angiosperms

Partial-independence of sporophytic individuals in bryophytes:

The most important fact in the history of the sporophyte through the bryophytes, after the general fact of progressive sterilization, is that the sporophyte of **certain liverworts began to achieve independence**.

In most bryophytes the sporophyte is absolutely dependent upon the gametophyte, but the **sporophyte of liverworts referred to develop green tissue**, which means that, although they are anchored in the gametophyte and secure food from it, they are still able to manufacture food for themselves.

If these green sporophytes could establish connections with the soil they would become absolutely independent, and cease to belong to bryophytes.

The future of the sporophyte, therefore, was to achieve independence from the gametophyte, and **this independence was begun by this group of liverworts and established by the Pteridophytes**.

Position of sex organs in bryophytes:

In the more advanced liverworts and in mosses the **archegonia and antheridia are more or less stalked above the general surface of the body**. The advantage of this is seen when one remembers that the fertilized egg, thus carried up above the general surface, produces the sporophyte with its spore-case, and **the spores are thus in a very favorable position for dispersal by air**.

If this position favors the spores, however, it does not favor the sperms, which must swim, for they are carried up into a position of least moisture. It is a remarkable arrangement that favors spores by interfering with the very act (fertilization) that results in spores; but it works reasonably well for plants living in moist situations.

It is evident, however, that still larger and **more leafy plants would interfere with the swimming of sperms still more**.

The three things which enter the problem are:

i)**food manufacture** which means display of green tissue to light and air,

ii) **fertilization** which means water for swimming, and

iii) **spore-production** which means exposure for air dispersal.

Work distribution among gametophytic & sporophytic individuals in bryophytes:

In the bryophytes, food manufacturing and fertilization both belong to the gametophyte, and the condition that favors the one hinders the other. In other words, they are contradictory in their demands. On the other hand, food-manufacture and spore-dispersal make the same demands for exposure, and therefore they can be coupled together to advantage.

The further progress of plants, therefore, demanded that the spore-producing generation(sporophyte) should also become the food-manufacturing generation; and that the gametophyte, with its peculiar need for free water, should be restricted to fertilization.

In the higher plants, therefore, the sporophyte is the conspicuous, leafy, independent generation, and the gametophyte is so very inconspicuous that it is only seen by those who know where and how to look.

The sporophyte of **certain liverworts attains partial independence,** and the advancement of the **sporophyte of Pteridophytes is that its independence is complete**.

An independent sporophyte means one that can manufacture its own food, and this means that it is a green plant. This association of food-manufacture with spore-production combines functions that are favored by the same conditions of free exposure to the air. Correlated with the complete independence of the sporophyte, gametophyte is much more reduced. It no longer supports the sporophyte and is restricted to the function of gamete-production.

So inconspicuous has it become in pteridophytes that for a long time it escaped observation, and the sex organs of ferns were unknown. The older botanists felt that sex organs must exist, although undiscovered, and so they named the group “Cryptogams”means hidden sex organs.

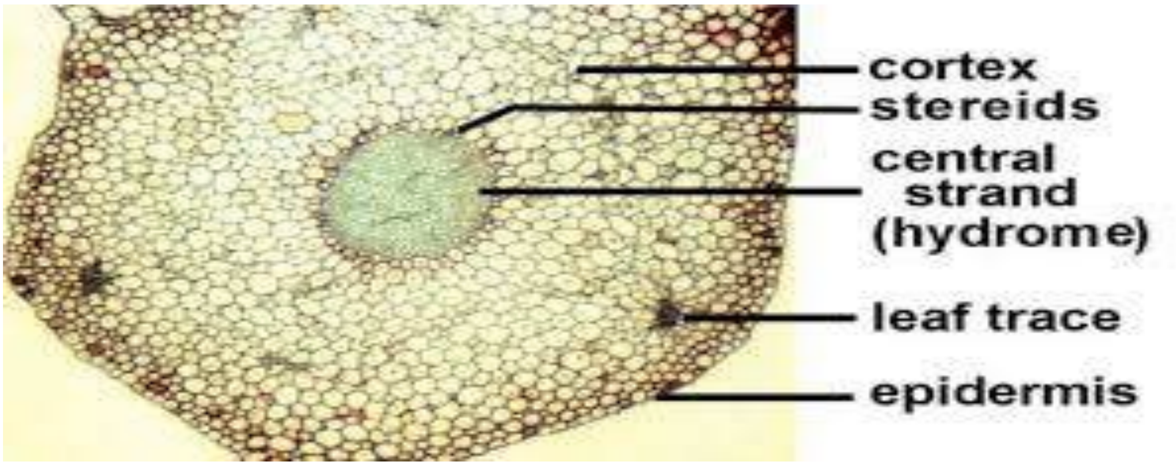
Water conducting cells: From moss to ferns

The independent sporophyte involves the appearance of three new structures. **The most significant new structure is the vascular system, a system of special water-conducting vessels**. The water-conducting vessels of plants are special cells arranged end to end to form strands, and in traversing them water must pass through innumerable partitions.

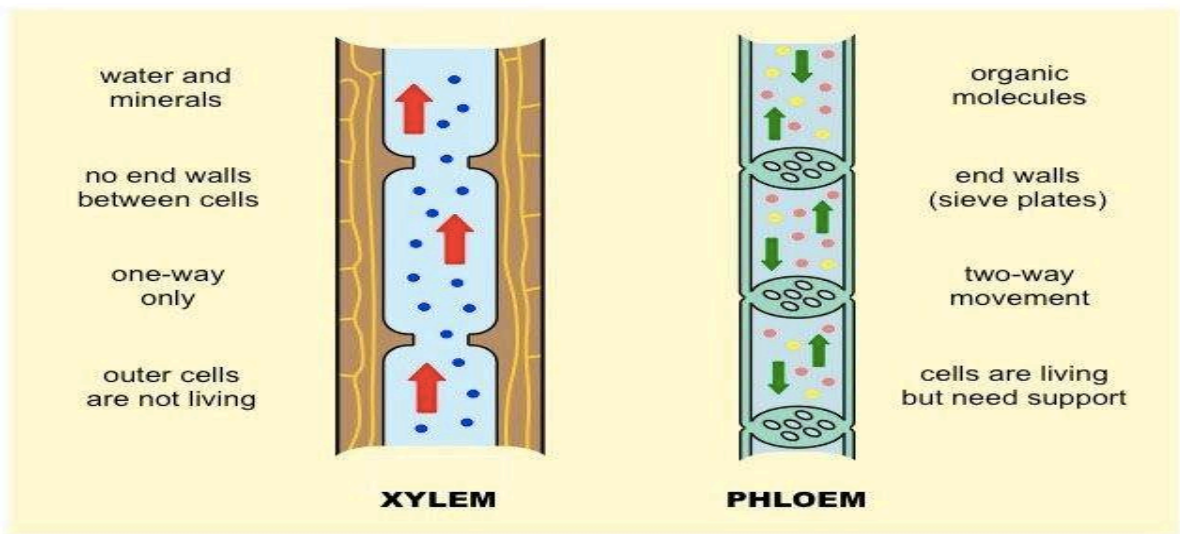
Of course, water moves through the body of a moss, although there are no vessels, but it is the ordinary movement that may occur from any living cell to an adjacent one. **The vascular system is a system of dead cells, through which water moves with greater rapidity and precision than through living cells**. The difference in the freedom of movement of water in the two cases may be compared to the difference between water working its way through a swamp and water flowing in a definite channel.

The chief significance of the vascular system, however, lies in the fact that **it makes larger plant bodies possible**. Probably the **larger mosses represent the extreme size of a plant body that is possible without a vascular system; but with a vascular system even large trees are possible**. It must be remembered that the plant body, to be in good working condition, must be kept saturated with water, and that the larger the plant body, the greater is the exposure to loss of water by evaporation. To meet all this loss and keep the body full of water necessitates a special water-carrying system.

In the stems of the larger mosses there are elongated cells which facilitate the movement of water, and this is the only hint we have as to the way in which the vascular system may have started in the sporophyte; it certainly never developed in the gametophyte.



In Moss plants



Vascular system

Roots & Leaves:

Two other new structures of pteridophytes are implied by the presence of the vascular system, namely, **roots to receive the water supply from the soil**, and **leaves to which the water supply is chiefly carried**. A vascular system would be meaningless without roots and leaves.

Leaves are not new structures in the plant kingdom, for mosses and many liverworts have leaves, but **among pteridophytes we meet the first leaves produced by a sporophyte**.

The sporophyte of bryophytes is a leafless, dependent plant, without vascular system or roots; while the sporophyte of pteridophytes is leafy, independent plant, well equipped with a vascular system and roots.

This means that when one **speaks of a fern he is referring to the sporophyte**; while in **speaking of a moss he is referring to the gametophyte.**

Later appearance of Sporogenous tissue:

This large and independent sporophyte involves a situation that concerns the evolution of the sextual individuals (gametophyte). Correlated with a larger vegetative body is the **later appearance of the sporogenous tissue**. This means that spores are formed at the period of waning vegetative activity, much as gametes were formed in the early history of sex. If spores appear in conditions relatively unfavorable to vegetative activity, they will either pass into the dormant stage, in which case they will germinate when favorable conditions are beginning to return, or they will germinate immediately. In either case the conditions for maximum vegetative activity are not present, and the result will be a relatively small body. For this reason the gametophyte of pteridophytes may be expected to be reduced, as compared with the more vigorous gametophyte of bryophytes.

In other words, the active and vigorous sporophyte has pushed spore-formation to the end of the growing season. On the other hand, **the fertilized egg functions after conditions for vegetative activity are present, and there is no inhibition of the development of a sporophyte with a vigorous body**. This tendency for the gametophyte to become more and more inconspicuous after the sporophyte has become independent is very marked throughout vascular plants.

Small gametophyte "Prothallium" with both sex organs:

In **pteridophytes when a spore germinates, it forms a very small gametophyte**, so inconspicuous that it long escaped discovery. This minute body, generally called **prothallium**, is green and independent, resembling a tiny flat liverwort.

Unlike the liverworts, however, the sex organs are not produced from the upper surface, but from the lower surface, against the substratum. The significance of this position is apparent when it is remembered that the **swimming sperms must find a water medium**.

There is no place in the land plant where a film of water is more likely to occur than between a prostrate body and its substratum.

The failure of bryophytes in this particular, **in carrying their sex organs up into the air, is thus avoided by the pteridophytes, so that fertilization in the latter is a much more constant feature** in the life history than in the bryophytes, especially the mosses.

The fertilized egg within the archegonium imbedded in the under surface of the gametophyte, germinates immediately and produces the strong sporophyte, which very soon becomes independent by the development of roots and leaves, emerging from beneath the gametophyte, and sending its shoot, or at least its leaves, upward.

At its maturity, the sporophyte produces spores, which in turn produce gametophytes, and the alternation is complete.

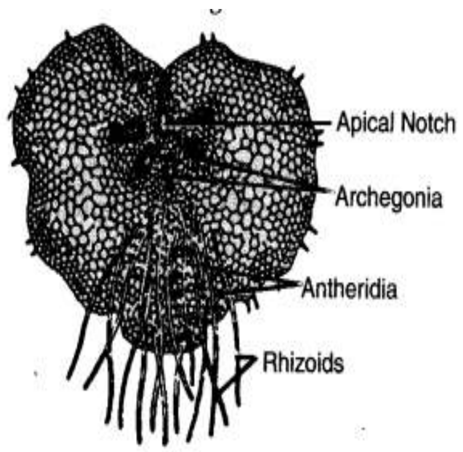
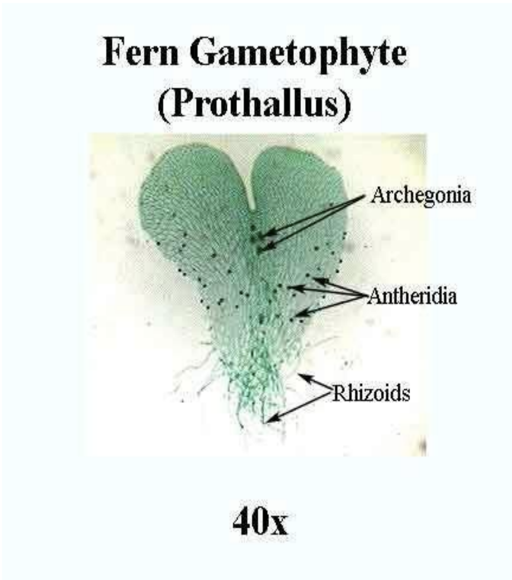


Fig. Fern prothallus bearing sex organs : antheridia and archegonia



Heterospory:

The next stage in the evolution of the two alternating generations is introduced by the **appearance of heterospory**, a situation developed by certain pteridophytes, notably by some of the club mosses.

Up to this point, all spores have been alike in their appearance and product, each one producing a gametophyte which bears both antheridia and archegonia.

Heterospory means that the spores are unlike, and this differentiation of spores should be understood. **A sporangium produces either a large number of small spores, or a small number of large spores.** Since the available material for spore-production is the same in both cases, the size of the spores depends upon the number produced.

Heterospory seems to have arisen by restricting the number of spores in certain sporangia, and as a consequence increasing their size. This restriction has been seen in a number of cases to consist in inhibiting all of the numerous sporogenous cells within a sporangium except one, which then grows at the expanse of the others, and forms **four large spores**. The small spores are called **microspores** and the larger ones **megaspores.**

Sexually differentiated individuals: Two gametophytes:

The important fact connected with heterospory is that **the megaspores produce female gametophytes and the microspores produce male gametophytes**.

With the appearance of heterospory, therefore, **gametophytes become sexually differentiated, so that two gametophytes are involved in the alternation of generations**.

The importance of this fact is indicated when it is known that **heterospory, although begun in pteridophytes, is characteristic of all seed plants**. In fact, heterospory made seed plants possible.

That large spores should produce female gametophytes and small ones male gametophytes is evident when the relation of the two gametes to food supply is remembered. Only a well-developed body can produce the highly nutritive egg, while a much smaller body can produce sperms. While a well-nourished gametophyte might produce sperms early in its development and eggs at its maturity, as is actually the case among ferns, a poorly nourished gametophyte could not produce eggs. Differentiation in the size of spores, therefore, naturally results in the sexual differentiation of individuals.

Reduced & Dependent gametophyte:

The effect of heterospory upon the gametophytes is seen not only in the sexual differentiation of individuals, but also in the dependence of the gametophytes. Up to this time, the gametophyte has been an independent plant, existing before the sporophyte appeared, nourishing the sporophyte among bryophytes, and maintaining its independent by the side of the large and independent sporophyte of pteridophytes.

But with the appearance of heterospory, the gametophyte becomes entirely dependent, a parasite upon the sporophyte. **When the two kinds of spores germinate, the gametophytes are so small that they remain within the spores that produce them**. Of course the female gametophyte makes much more tissue than does the male gametophyte, but it remains within the megaspore enclosure.

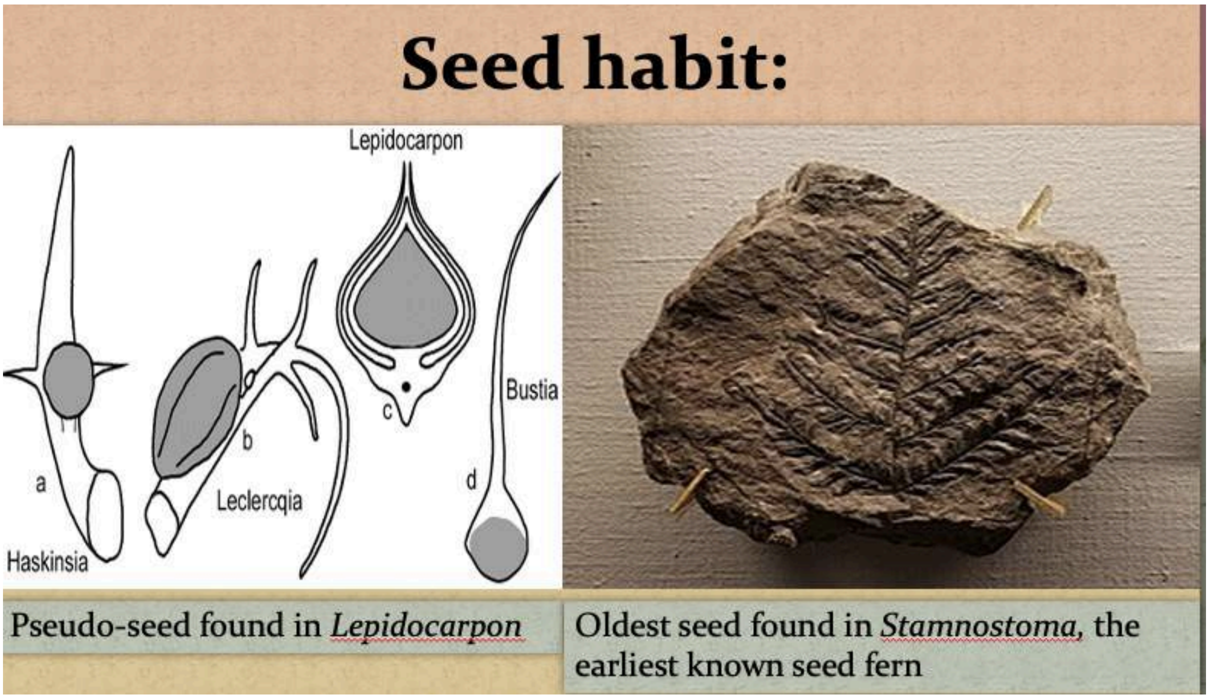
The gametophytes, therefore, have not only become much reduced and dependent, but they have disappeared from ordinary observation.

In heterosporous plants, therefore, the sex organs can only be discovered by the use of laboratory technique.

Sporophylls:

Heterospory not only differentiates spores, but also sporangia, so that those producing megaspores are called **megasporangia**, and those producing microspores are called **microsporangia**. The product of the two is so different that they soon become quite unlike in their appearance. Furthermore, the sporangia are usually produced by leaves, and such leaves gradually become more and more unlike ordinary leaves, until soon they do not resemble them at all. Such special sporangium-producing leaves are called sporophylls, and naturally those producing megasporangia are called megasporophylls, and those producing microsporangia are called microsporophylls.

Heterosporangiate heterospory in Selaginella



Gymnosperms: Formation of Cones

The gymnosperms are the primitive group of seed plants, their origin from ferns having been established. In fact, the luxuriant fernlike vegetation once thought to be a feature of the Coal Measures has turned out to have been fernlike gymnosperms. That these fernlike plants were gymnosperms and not ferns is shown by the fact that **they bore seeds**.

In the modern gymnosperms the sporophylls form the characteristic cones. There are two kinds of cones, the conspicuous ones being composed of megasporophylls. For example, it is this **megasporangiate cone** that is ordinarily observed on a pine tree, the much smaller microsporangiate cones usually escaping observation.

These cones are often spoken of as “male”and “female”cones, names which are obviously misapplied, since sporophylls are structures belonging to a sporophyte. Each megasporophyll (often called scale) of a cone bears one or more megasporangia. **These megasporangia were called ovules long before their real nature was known, and the megasporophyll was called a carpel or pistil**.

Endosperm:The female gametophyte within ovule:

Within each megasporangium (ovule) a large megaspore is developed. **This megaspore is never shed, but germinates within the ovule, forming the female gametophyte with its archegonia and their eggs**. The ovule (megasporangium), therefore, contains the **female gametophyte as an internal parasite**, and it is this relation that results in transforming such an ovule into a seed.

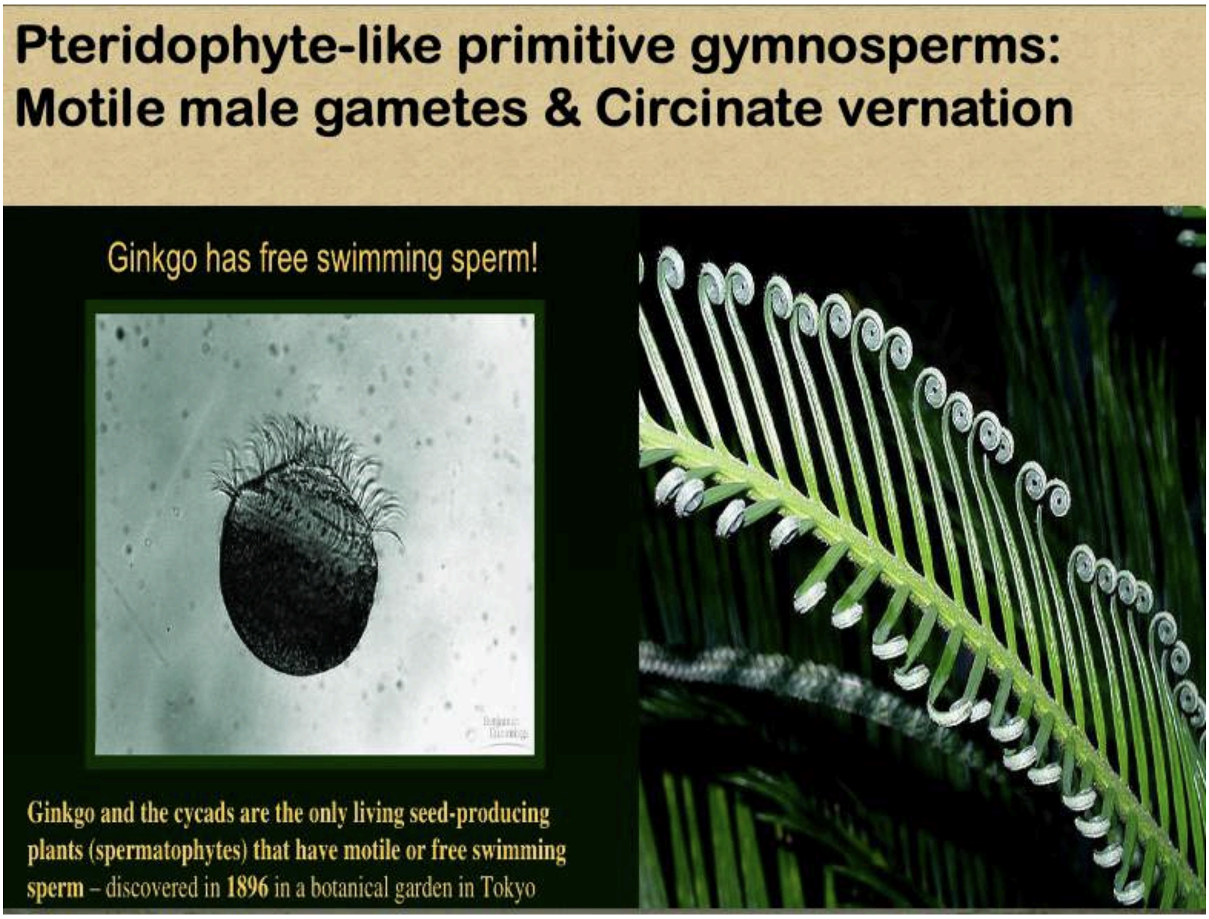
A seed, therefore, is a transformed megasporangium with its contents.

The female gametophyte was observed long ago embedded in the ovule as a tissue very distinct from the rest of the ovule, but **it was thought to be simply a special nutritive tissue of the seed, and it was called first albumen and later endosperm. The latter name is still used as more convenient than female gametophyte**.

Each microsporophyll of a cone bears several microsporangia, which contain microspores. Before the real nature of these structures was known, the microsporophyll was called a **stamen**; the region of the microsporophyll bearing sporangia was called an **anther**; the microsporangia, **pollen sacs**; and the microspores, **pollen grains**.

The abundant microspores (pollen grains) are shed and are scattered widely by the wind, the successful ones falling upon the megasporangiate cones. In germination, the microspore produces so small a male gametophyte that it consists of only a few cells which remain enclosed by the spore, until the sperms are discharged into the archegonium within the ovule.

It is no wonder that such gametophytes were not observed, and that **the sporophylls (stamen and pistils) should have been regarded as sex organs**. The name “ovule” suggests that it was thought to be an egg; it certainly did not suggest a sporangium to those who had not followed the history of the ovule. **It is evident that sporophylls produced by sporophytes cannot be sex organs**, but their behavior indicated that in some way they were connected with the sex act.



Angiosperms: the final fate of sex organs

In the true flowering plants (angiosperms), the great group of seed plants and the culminating group of the plant kingdom, the same conditions are carried forward to a greater extreme. **The two sporophylls (stamens and pistils) become so different from ordinary leaves** as hardly to suggest them, and **they become a part of a new structure called the flower**.

The flower is nothing but the cone of gymnosperms, composed of sporophylls, accompanied by new kinds of leaves (sepals and petals).

In angiosperms the male gametophyte is reduced to its lowest terms, being represented by only three cells, two of which are sperms, and the antheridium as a definite organ has disappeared. The passive sperms are carried to the egg, deep within the ovule, by a penetrating pollen tube.

The female gametophyte is also reduced to its lowest terms, being represented by only a few free cells at the time of fertilization, one of the cells being the egg. This gametophyte is so reduced, that is, so little developed, that there is no tissue for the development of archegonia, so that the **female sex organ is also eliminated**.

It is obvious that to regard a flower as a sex structure and its stamens and pistils as sex organs is to misapprehend the situation. They belong to the sporophyte, which does not produce sex organs. But the stamens and pistils contain the spores that in germination produce male and female gametophytes. To speak of male flowers and female flowers, as is so often done, is natural, but it is untrue.

History of gametophyte & sporophyte in land plants:

The general history of the two generations, sporophyte and gametophyte, may be summarized very briefly.

The gametophyte begins in the thallophytes as the only individual; it continues in the bryophytes as the conspicuous and independent individual; it appears in the pteridophytes as an inconspicuous but still an independent individual; while in the seed plants it disappears entirely from ordinary observation and becomes a dependent, internal parasite.

The history of the sporophyte exactly reverses this. **It appears in the bryophytes as a fully established individual, but relatively inconspicuous, and entirely dependent upon the gametophyte; in the pteridophytes it has become a conspicuous and independent individual; while among the seed plants it is the only individual seen**.

Separating male & female gametophytes: A physiological advantage

A situation is developed in the angiosperms that needs explanation in connection with the history of sex. The appearance of heterospory would seem to indicate that by the separation of sexes in the differentiation of the gametophytes, some physiological benefit was obtained. It is assumed in general that **the fusion of a sperm and an egg from two different individuals secures a more vigorous progeny than when the sperm and egg are from the same individual**. This means that, within limits, a difference in origin of sperm and egg is an advantage in reproduction. It is a notable fact that, in general, hybrids are likely to be more vigorous than either parent.

In angiosperms, however, while of course the two gametophytes are separate, they are brought together upon the same sporophyte in every flower containing both stamens and pistils. Whatever physiological benefit, therefore, came from their separation in the early history of heterospory is counteracted by bringing them together again to depend upon the same individual (sporophyte).

Cross-pollination:

In gymnosperms the gametophytes are separated by being developed in different cones, and these cones are often upon different plants.

There are also many angiosperms which have **pistillate flowers** on one plant and **staminate flowers** on another. Of course in these cases the physiological advantage of separating male and female gametophytes is maintained.

But in the majority of angiosperms the flowers contain both stamens and pistils, and therefore, the two gametophytes depend upon the same individual for their nutrition.

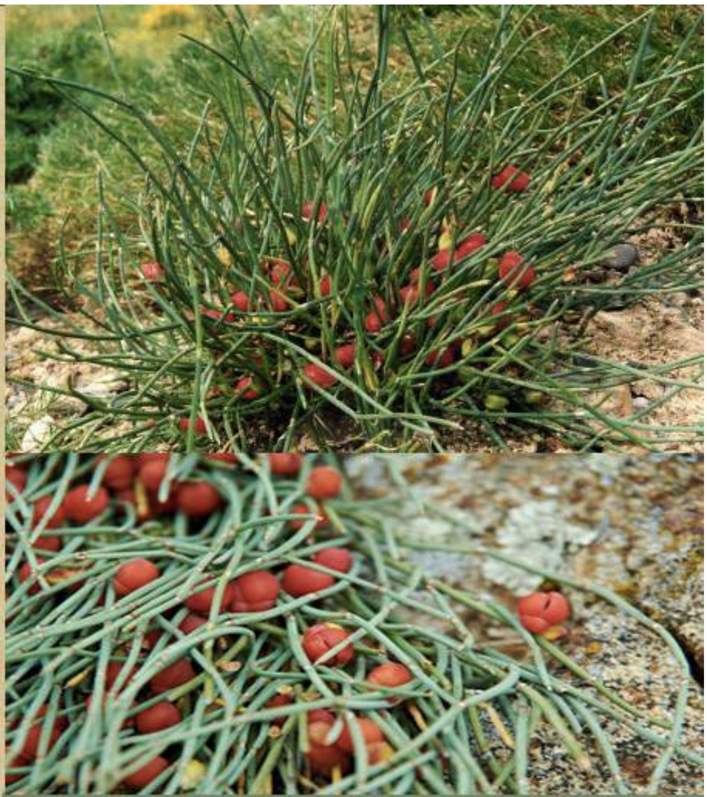
The advantage lost by the sexual separation is offset in this case by the elaboration of devices for **cross-pollination**.

It is among angiosperms that insect-pollination has reached so great a degree of development that **the female gametophyte developed within the ovule of one flower, seldom mates with a male gametophyte developed in a pollen grain of the same flower**.

In other words, the mating gametophytes are developed in connection with different sporophytes.

Angiospermic features of Ephedra

1. Double fertilization like angiosperms
2. Herbaceous habitat.
3. Vessels present in xylem tissue



Ephedra monosperma

Angiospermic features of Gnetum:

1. Archegonia absent
2. Tetrasporic type of embryo development
3. Vessels present in xylem tissue
4. 3-celled male gametophyte whereas in gymnosperms it is 5-celled & in angiosperms it is 2-celled.

Gnetum gnemon

Gymnosperms, Gnetum & Angiosperms:

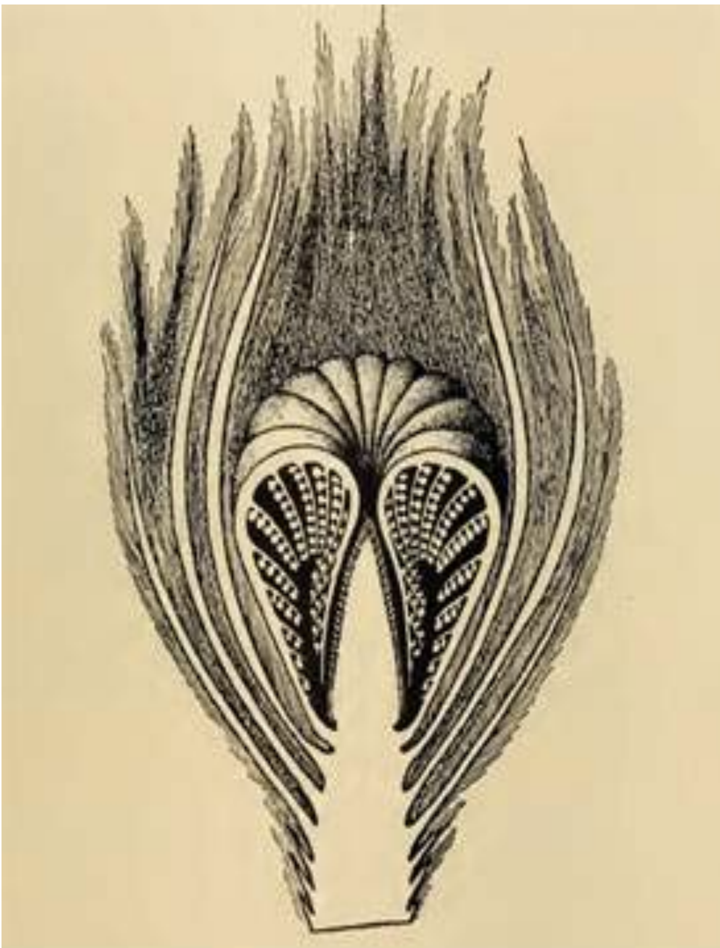
1. 5-celled male gametophyte in gymnosperms: Prothallial cell-I, Prothallial cell-II, Tube cell, Stalk cell & gamete/sperm
2. 3-celled male gametophyte in Gnetum: Prothallial cell, Tube nucleus & gamete/sperm
3. 2-celled male gametophyte in angiosperms: Tube nucleus & sperm

Cycadeoidea of Bennettitales:

The fructification in **Cycadeoidea** was bisporangiate. The **strobili** were developed in the upper part of the plant in large numbers. Each **strobilus** was made up of a number of heavy imbricate reduced leaves or bracts.

Angiospermous affinity:

Flowers are bisexual in strobili. The strobili can be compared with the flowers of *Magnolia*.



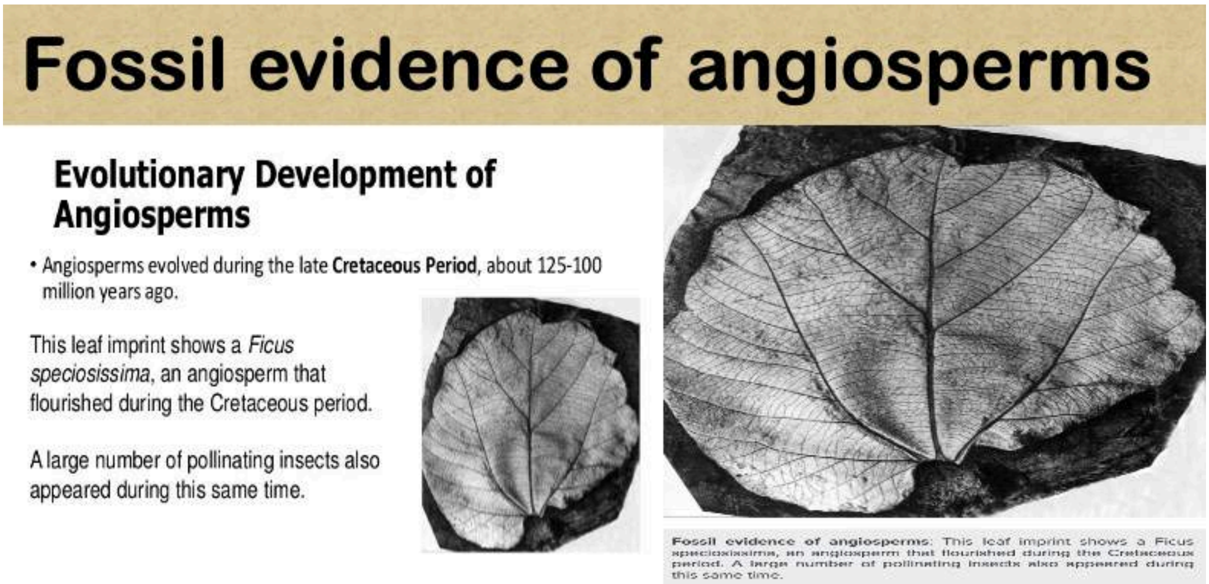
Cycadeoidea - Strobilus

Anthophytes:

The Euanthial hypothesis erected by Arber and Parking in 1907 posited that **angiosperms** arose from Bennettitales, as evidenced by the wood-like structures and rudimentary flowers. This theory placed them among the anthophytes, leading it to be known more commonly as the Anthophyte hypothesis.

The **anthophytes** were thought to be a clade comprising plants bearing flower-like structures.

The group contained the **angiosperms** - the extant flowering plants, such as roses and grasses - as well as the **Gnetales** (*Ephedra, Gnetum,* etc.) and the extinct **Bennettitales** (*Cycodeoidea* ,etc.).



Ficus speciosissima: A fossil angiosperm of Cretacetous period.

Nature of a seed:

In a certain sense a seed is a transformed megasporangium. Its transformation consists in changes that follow the act of fertilization. It will be remembered that the ovule (megasporangium) consists of the ordinary tissues of a sporangium, within which a megaspore is embedded; and within the megaspore is the female gametophyte with its egg. When this egg is fertilized by the sperm that has been discharged into the megaspore cavity, it begins to develop the embryo. At the same time, changes occur in the superficial tissues of the ovule, resulting in the development of a hard seed coat. When this coat has been completely organized, the development of the embryo is checked, and it passes into that dormant condition which is familiar in the case of a seed.

In fact, therefore, **the seed has locked up within its structure the representatives of three generations**. The **seed coat** and more or less of the tissues beneath it, which have been derived from structures of the sporangium, represent the old sporophyte; the **endosperm within represents the female gametophyte**; while the **embryo is the sporophyte of the next generation**.

Germination of a seed:

Nothing is more common than to speak of the "germination" of a seed, and not very far back in the history of botany seeds were contrasted with spores. In fact, the plant kingdom was divided into plants that reproduce by seeds and those that reproduce by spores. It was very natural to infer that, since spores germinate to produce new individuals, seeds are doing the same thing.

It is evident, from what has been said, that the germination that starts the new seed plant is the germination of the fertilized egg, which begins almost immediately after fertilization to form the embryo. This embryo passes into the dormant stage. When so-called "germination" of the seed occurs, therefore, **it is merely the arousing of this dormant embryo to activity and its escape from the seed coat.**

Seed germination does not result in the production of a new plant, for the new plant has already been produced and is within the seed.

It simply results in giving the new plant an opportunity to escape and continue its development.

…………..Thank You…………