NOTES

THE CORRELATION BETWEEN EMBRYO TYPE AND ENDOSPERM TYPE.—During critical and comparative studies of the life histories of plants which have been most commonly investigated, a striking correlation between types of embryo and of endosperm has been found. An explanation—in the real sense of the word—for this is not at present put forward, merely a statement of observed facts.

In those plants in which from the beginning the embryo grows very rapidly and is early differentiated, the endosperm developed in the embryo-sac is almost always non-cellular, cell formation taking place only very late. On the other hand, if the growth of the embryo is very slow or if the ripe seed contains only an undifferentiated embryo, then the endosperm is cellular either from the very beginning, or cell formation takes place very early.

Rapid differentiation of the embryo into cotyledons, plumule, and radicle necessitates rapid consumption of the endosperm, so that increase of non-cellular endosperm is the more economical. Cell formation in the endosperm begins when the embryo is nearing complete differentiation. In the case of slow-growing or undifferentiated embryos, where endosperm consumption occurs late, a more permanent type is formed.

Examples taken from published papers are quoted below: chambered embryo-sacs are chiefly found in saprophytic and parasitic plants, and most of these contain an undifferentiated embryo.

In *Peperomia pellucida*[1] even in oldest fruits, undifferentiated embryos are formed, which are completely surrounded by cellular endosperm.

In *Diospyros virginiana*[2] the embryo is very late in appearing and remains undifferentiated for a very long time. The endosperm is large and is cellular.

In *Magnolia*[3] the cotyledons are initiated after the embryo has enlarged considerably, and the endosperm is cellular from the beginning. The embryo is very small.

Thismia americana.[4] The seed has a very evident endosperm, with cells of relatively large diameter, and an inconspicuous embryo of a few cells.

Hedyosmum nutans.[5] The embryo is poorly developed and is simply an oval mass of cells. The endosperm is cellular from the outset.

Linaria vulgaris.[6] The endosperm is cellular from the beginning, and the majority of seeds are without embryos. The embryo is small and has two short unequal cotyledons.

[1] JOHNSON, D. S., 1900: On the Endosperm and Embryo of Peperomia pellucida. Bot. Gaz., xxx. 1–11.

[2] HAGUE, S. M., 1911: A Morphological Study of Diospyros virginiana. Bot. Gaz., lii. 34–44.

[3] MANEVAL, W. E., 1914: The Development of Magnolia and Liriodendron, including a Discussion of Primitiveness of the Magnoliaceae. Bot. Gaz., lvii. 1–31.

[4] PFEIFFER, N. E., 1914: Morphology of Thismia americana. Bot. Gaz., lvii. 122–35.

[5] EDWARDS, J. G., 1920: Flower and Seed of Hedyosmum nutans. Bot. Gaz., lxx. 409–25.

[6] COOK, M. T., 1924: Development of the Seed of Linaria vulgaris. Bot. Gaz., lxxvii. 225–7.

Embryology in Taxonomy

Embryology is the study of micro and mega sporogenesis, gametophyte development, fertilization development of endosperm, embryo and seed coats. embryological evidence has been used in solving the taxonomical problems at almost all levels. These evidences have resolved the doubtful systematic positions of several taxa. However, the role of embryology in solving taxonomical problems was first brought by a German embryologist, **Schnarf** in 1931.

According to **Maheswari**, **Bhojwani** and **Bhatnagar** and **Radford** some basic embryological characters which have proved to be of special basic embryological characters which have proved to be of special importance in taxonomic considerations include -

1. Presence and type of another tapetum.

2. Development of structure, position, and orientation of ovule.

3. Megasporogenesis and development of embryosac.

4. Form of embryosac.

5. Type of embryosac.

6. Type of embryogeny.

7. Fertilization.

8.Seedcoat.

<u>Role of Embryology :</u>

(1) <u>Dicots and Monocots:</u> Angiosperms are universally divided into dicotyledons and Monocotyledons. The primary classification of angiosperm is based on one major embryological character I.e; the number of cotyledons.

(2) <u>Helobiae:</u> This monocotyledonous order, treated as a subclass in some recent system of classification, is characterized by the presence of a helobial type of endosperm.

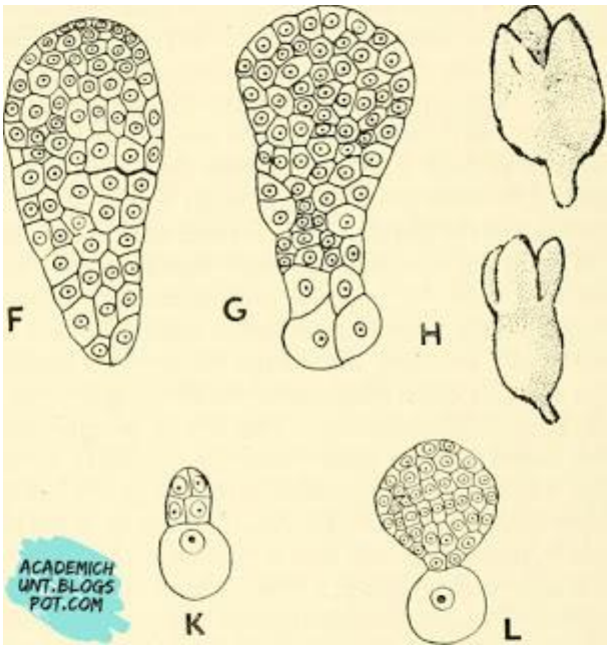
(3) <u>Orchidales:</u> The distinguishing embryological character of the members of this order is the presence of undifferentiated embryo and very little or no endosperm.

(4) <u>Podostemaceae:</u> Members of this family are recognized because of the formation of pseudo embryosac, which is formed by nucellar cells.

(5) <u>Lemnaceae:</u> Phylogenetic studies indicate that Lemnaceae have been derived either from the Helobiales or from the Araceae. But on the basis of the embryological studies, Maheswari suggested that Lamnaceae have been evolved from Araceae, not from Helobiales.

(6) <u>Crassulaceae:</u> Embryological studies of Crassulaceae suggest that it should be placed in the order Rosales.

All the above-mentioned examples confirm that embryology plays a definite and significant role in solving taxonomic problems.



Embryological Characters: Meaning, Significance and Application

Meaning of Embryological Characters:
Embryology is the study of micro- and mega-sporogenesis, gametophyte development, fertilization, and development of endosperm, embryo, and seed coats.

Although the possibility of utilizing embryological characters in taxonomy was indicated by some earlier botanists like Hofmeister and Strasburger, the role of embryology in solving taxonomic problems was first brought into prominence by a German embryologist, Schnarf in 1931.

Embryological characters, being less prone to adaptive stress, are relatively stable and have acquired great significance in plant taxonomy, especially when external morphological characters are inconclusive and misleading as a result of convergence.

Thus, embryological evidences have been used in solving taxonomical problems at almost all levels, and have helped resolve the doubtful systematic positions of several taxa.

However, according to Jones and Luchsinger, the embryological characters have proved to be of significant help in determining relationships within families, genera and species, but less useful at the rank of order, subclass, or class.

Maheshwari and John, on the basis of their extensive work on embryology, have provided lists of families, tribes, etc. where embryology has either supported earlier classifications or has proposed a new systematic position for the taxon concerned.

Embryological Characters: Meaning, Significance and Application

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In this article we will discuss about the Embryological Characters:- 1. Meaning of Embryological Characters 2. Basic Embryological Characters of Taxonomic Significance 3. Application of of Embryological Data in Taxonomy.

Meaning of Embryological Characters:

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These plant taxonomists have utilized embryological characters in various ways:

a. In the analysis of evolutionary trends.

b. In the circumscription and delimitation of taxa.

c. In making decisions on systematic position, etc.

Fig. 8.16 : Types of Embryo (After Martin & Barkley, 1961)

Basic Embryological Characters of Taxonomic Significance:

There are several embryological characters, which have proved to be of taxonomic significance.

According to Maheshwari, Bhojwani and Bhatnagar and Radford, some of these basic embryological characters, which have proved to be of special importance in taxonomic considerations include:

(i) Presence and type of anther tapetum, whether glandular or amoeboid.

(ii) Number and arrangement of anther loculi.

(iii) Type of anther endothecium i.e., structure and thickenings of endothecium and nature of tapetum.

(iv) Mode of quadripartition of microspore mother cell, i.e., whether it takes place by furrowing or by the formation of cell plates, whether the mode of division is simultaneous or successive, whether the arrangement of microspores is tetrahedral, isobilateral, linear, T-shaped or otherwise.

(v) Development and organization of the pollen grains i.e., number and position of germ pores, exine stratification, number of cells at the time of anthesis, etc.

(vi) Development, structure, position, vasculature of integuments, and orientation of ovule (Fig. 8.16).

(vii) Form and extent of the nucleus i.e., whether it is broad and massive (crassinucellate ovules) or ephemeral (tenuinucellate), presence or absence of hypostase, persistence or gradual disappearance of nucleus.

(viii) Origin and extent of the sporogenous tissue in ovule i.e., whether one-celled or many-celled, presence or absence of wall layers, type of division of nuclear epidermal cells.

(ix) Mega-sporogenesis, time of wall formation in mega-sporogenesis, arrangement of megaspores, position of the functioning megaspore, and development of embryo sac (Fig. 8.17) i.e., whether embryo sac is mono-, bi- or tetrasporic, number of divisions required for differentiation of mature egg.

(x) Form and organization of the mature embryo sac i.e., number and distribution of its nuclei and presence and absence of endosperm haustoria. Fertilization, pathway of pollen tube, the type of entry of the pollen tube into the ovule i.e., micropylar or chalazal and interval between pollination and fertilization.

(xi) Type of endosperm i.e., whether nuclear, cellular or helobial type, nature of food reserves, persistence or gradual disappearance in the mature seed.

(xii) Seed-coat.

(xiii) Certain abnormalities of development such as parthenogenesis, apogamy, adventive embryony and polyembryony.

Application of Embryological Data in Taxonomy:

The delimitation of angiosperms in the first instance has been largely based on embryological characters. They are characterized by enclosed ovules that are mostly anatropous, polygonum type of embryo sac in majority of flowering plants, double fertilization and triple fusion, and post-fertilization development of polyploid endosperm, which also support the probable monophyletic origin of angiosperms.

The further primary classification of the subdivision Angiospermae into two classes, namely, Monocotyledonae and Dictoyledonae is largely based on the characteristics of embryo, which are almost constant for the group. However, certain groups are well marked out by their embryological features that can be easily used to identify these members. These exceptions in particular are of taxonomic significance.

1. Above the Family Level:

There are a few orders of angiosperms, the members of which are morphologically well defined and also exhibit a set of uniform embryological features.

A few examples are given below:

a. Caryophyllales :

It is more widely known as Centrospermae and is embryo logically very distinct. This order is characterized by tri-nucleate pollen, bitegmic crassinucellate ovules, which are campylotropous or amphitropous, commonly with the inner integument longer than the outer and very often with a space between the integuments toward the chalazal end.

The seed has a curved, peripheral embryo, more or less surrounding the food storage tissue, which consists mainly of perisperm, with little or no endosperm.

b. Polygonales and Plumbaginales:

They are related to each other, and are also clearly related to Caryophyllales as they exhibit similar embryological features to a great extent.

c. Lecythidales :

This order, which was formerly considered, to be related to Myrtales, has been found to differ from the latter by the presence of alternate leaves, centrifugal stamens, lack of internal phloem and a series of embryological features in its various members.

d. Ericales :

This homogeneous group of sympetalous families includes members, most of which share several common embryological features including, notably, the production of pollen in tetrads.

e. Gentianales :

This order is characterized by mostly simple and opposite leaves, well developed internal phloem, lack of integumentary tapetum and a nuclear endosperm, which helps it to be distinguished from other sympetalous orders.

Some of the families like Buddlejaceae, Menyanthaceae and Oleaceae, which had been formerly placed under Gentianales, have been now removed from it, since they possess integumentary tapetum and cellular endosperm.

f. Helobiae :

This order under the monocotyledons (Engler), is characterized by the helobial type of endosperm. Although recent systems have raised the order to the level of subclass, the relationships of the constituent orders is scarcely disputed.

g. Orchidales :

This order is characterized by undifferentiated embryo and very little or no endosperm.

2. At and Below the Family Level:

Embryological evidences have strongly supported the proper placement of certain disputed families and genera, once regarded to have a doubtful systematic position.

A few examples are given below:

i. Onagraceae :

This family is characterized by the presence of peculiar monosporic four-nucleate Onagrad-type of embryo-sac in all its genera except Trapa. Such an embryo sac is derived from the micropylar megaspore of the tetrad. The lower three chalazal megaspores do not disintegrate. In this type of embryo sac, antipodals are absent.

Different systematists have placed the genus Trapa in several ways:

a. Some have placed it under Onagraceae

b. Some have placed it as an isolated member of Haloragaceae, and

c. Some have placed it as the only genus of the monotypic family Trapaceae.

Embryological evidence however strongly supports the last view. Trapa has a well- developed suspensor haustorium, in addition to the eight-nucleate embryo sac, which are absent in any other members of Onagraceae.

Further, in Trapa, the ovary is semi-inferior, bilocular with one ovule in each locule and the fruit is a large one-seeded drupe, while in other members of Onagraceae, the ovary is inferior and tetralocular with numerous ovules on axile placentation and fruit is generally a loculicidal capsule.

ii. Empetraceae:

This family, was considered, to be closely related to Euphorbiaceae and Celastraceae by Don. However, Bentham and Hooker treated them as an anomalous family under Monochlamydeae. Later, several taxonomists thought that they are related to Ericaceae on the basis of, several morphological features. This latter view, has been supported by Samuelsson on the basis of embryological data.

iii. Cyperaceae:

Earlier systematists considered the families of Cyperaceae and Poaceae to be closely associated. However morphological and anatomical features and the structure of the spikelet's reveal that the two families are quite distinct.

The Cyperaceae-Poaceae alliance is also contradicted by the embryological findings due to the following:

a. The micro-sporogenesis is of simultaneous type in Cyperaceae and the tetrad members do not separate (three degenerate and only one is functional), whereas in the Poaceae, micro-sporogenesis is of successive type and the tetrad members separate.

b. The parietal cell is present in the archesporium of the Cyperaceae, while it is absent in the Poaceae.

c. The antipodals are ephemeral in Cyperaceae, while they form a complex or become coenocytic in Poaceae.

d. The embryogeny is of Onagrad type with Juncus variation in Cyperaceae and it is variable in Poaceae.

e. The testa and pericarp are distinctly free in the Cyperaceae and the former comprises both the integuments, whereas in the Poaceae, testa and pericarp are fused and either both the integuments are obliterated or only the inner integument forms the testa.

Embryological evidence on the other hand, reveals a close relationship of Cyperaceae with Juncaceae, although the members of Juncaceae produce pollen grains in tetrads (which is actually a monad also containing the three non-functional nuclei of the other three microspores of the tetrad).

They are similar in the following aspects:

a. The pollen of the Cyperaceae is considered to be a reduced form of that of the Juncaceae.

b. Both the families resemble in the simultaneous cytokinesis, tenuinucellar ovules with obturator, Polygonum type of embryo sac with ephemeral antipodals, Onagrad type of embryogeny with Juncus variation and periclinal division of the cells of quadrat.

Cactaceae:

Different taxonomists have treated the family Cactaceae in different ways due to the presence of a large number of variable characters in the different members of this family.

Garryaceae:

There has been a long dispute regarding the systematic position of Garryaceae. Engler and Gilg and Engler and Diels have referred them to Amentiferae, while Bentham and Hooker and Wangerin included them high up in the polypetalous families near Cornaceae.

However, the latter placement is more natural, which has been confirmed by morphological and embryological studies of Hallock (1930). Comparative morphological and phylogenetic studies of the family also support the view of their inclusion in the Cornales.

Liliaceae:

There has also been a rearrangement of the tribes, and subfamilies within the Liliaceae based on embryological studies. A large number of genera also have been assigned their positions on morphological as well as embryological grounds.

The Liliaceae and Amaryllidaceae are considered as polyphyletic families, and certain groups of both these families are related to each other. Based on these resemblances, Hutchinson has united three tribes of the subfamily Dracaenoideae (family Liliaceae), Yucceae.

Nolineae and Dracaeneae (with the exception of two genera Astelia and Milligania) together with the subfamily Agavoideae (family Amaryllidaceae) and Phormium of the tribe Hemerocallideae into the Agavaceae. Accordingly he recognized six tribes in the Agavaceae viz. Yucceae, Dracaeneae, Phormieae, Nolineae, Agaveae and Polyantheae.

On the other hand on the basis of embryological data, Wunderlich has concluded that Hutchinson's Agavaceae is not an uniform family and the question whether these fairly heterogeneous groups should be united in one family remains open.

She has however suggested that Hutchinson's Agavaceae should be separated into four groups viz. Yucca-Agave, Nolineae, Dracaena-Sanseviera, and Cordyline, and the genera Phormium and Doryanthes should be excluded.

Lemnaceae:

The Lemnaceae are considered, to have been derived either from the Araceae or from the Helobiales. However, embryological studies of S.C. Maheshwari clearly indicate that the Lemnaceae have evolved from the Araceae, and they are not related to the Helobiales.

The resemblances between Lemnaceae and Araceae include:

a. The presence of bitegmic ovules with a micropylar cap of nucellus.

b. Cellular endosperm with a chalazal haustorium.

c. Irregular sequence of the divisions in the development of embryo.

d. Short and stocky suspensor and integumentary operculum in the seed.

On the other hand, the Helobiales are characterized by ovules that do not have any micropylar cap, helobial or nuclear endosperm, very regular sequence of divisions in the development of embryo and the hypertrophy of a prominent basal cell in the embryo.

The members of Lemnaceae, are also now considered to be related to Hydrophyllaceae and Boraginaceae, and Cronquist has placed them in Polemoniales somewhere near the point of origin of Lamiales.

Paeonia:

Many taxonomists have treated this genus as a member of the mono-generic tribe Paeonieae of the family Ranunculaceae.

But Paeonia differs from Ranunculaceae not only in its chromosome number, vascular anatomy, floral anatomy, but also in embryological details in the following ways:

i. Paeonia shows an unique embryogeny with its young zygote first becoming coenocytdc and then the cell formation begins from its periphery. The embryo initials develop from some of the peripheral cells. The coenocytic phase although common in the gymnosperms, is unknown elsewhere within the angiosperms.

ii. The seeds in Paeonia are arillate, and fruit, a follicle while in Ranunculaceae the seeds are non-arillate and the fruit is an achene.

iii. The embryological details thus suggests that Paeonia belongs to an independent fainily Paeoniaceae.

Butomus:

Butomus of the family Butomaceae is characterized by the presence of the Polygonum type of embryo sac, while all the other genera under this family have the Allium type of embryo sac. This suggests that only Butomus should be retained in Butomaceae.

The other genera of this family should be transferred either to Alismataceae or to Limnocharitaceae. Cronquist and Takhtajan also retained only Butomus under Butomaceae and transferred the remaining genera to Limnocharitaceae.

Exocarpus:

The genus Exocarpus was removed from Santalaceae of angiosperms and was treated as a member of the family Exocarpaceae near Taxaceae in gymnosperms, because of the presence of a naked ovule and pollen chamber.

But due to the presence of a typical angiospermic flower, Polygonum type of embryo sac, cellular endosperm and some other embryological characters, Ram confirmed that Exocarpus belongs to the family Santalaceae of angiosperms, and not with gymnosperms.

Peganum:

This genus has been variously treated as a member of Rutaceae or Zygophyllaceae. But its embryological details resemble those of Linaceae, and differs from those of Rutaceae and Zygophyllaceae. The recent embryological findings, therefore, suggest its inclusion in an independent family, Peganaceae near Linaceae.

Parnassia:

There has also been a dispute regarding the systematic position of this genus. It has generally been treated as a member of the family Saxifragaceae. But the total dissimilarity of its embryological details with the other genera of Saxifragaceae suggests its removal from Saxifragaceae and inclusion in a separate family Parnassiaceae.