to concentrate attention on the pathological aspects of the enquiry. As to the nature of the disease, Hartshorne writes, with commendable caution, "It is only possible to speculate at present. It is most probable that ague is a toxemic neurosis. The importance of the blood change attending it is shown by the disintegration of the blood corpuscles, and deposit of pigment in various organs." This destruction of the blood corpuscles was the critical point on which the investigation turned. About 1880, Laveran, a French army surgeon, discovered the destructive agency in a minute parasite, one of the protozoa, which takes up its residence in, and then, ungratefully enough, destroys, our red blood corpuscles. What a splendid problem was presented by the facts thus brought to light! The exquisite refinement of the researches which followed may be inferred when we reflect on the minuteness of an organism which can work out a part of its life history within blood corpuscles so small that four to six millions of them find plenty of room in a cubic millimeter. But stranger still is the fact, established within the past year or two, that the mosquito plays the rôle of an intermediary host and transmits the parasites to us while feasting upon our blood. The details of this remarkable discovery need only be alluded to here, for they have been so recently explained by the experts participating in them that their essential features are a part of popular information. Suffice it to remark that they show how we may secure almost complete immunity from malarial fevers at no distant day.

Thus, in whatever direction we look for the sources of scientific progress, the same elementary methods of advancement are found to be effective. Whether we consider the dimensions of the solar system or the distances between the molecules of a gas; whether we seek the history of a star as revealed by its light or the history of the earth as recorded in its crust; whether we would learn the evolution of man or the development of a protozoon; whether we would study the physical and chemical properties of the sun or the corresponding properties of a grain of sand; in short, whether we turn to the macrocosm or to the microcosm for definite, verifiable, knowledge, it is found to originate in and to advance with observation and experiment.

R. S. WOODWARD.

ON THE HOMOLOGIES AND PROBABLE ORIGIN OF THE EMBRYO-SAC.*

THE problems connected with the origin and interpretation of the embryo-sac have been of great interest to the student of plant morphology, from the time that they began to inquire into the relation of the ovule to the formation of the embryo plant. It is now a matter only of historical interest that Morland (1702), Geoffrey (1714) and others contended so seriously that the embryo-sac of the angiosperms was a sort of incubator where the embryo, brought in by the pollen tube, was hatched out into the young plantlet. While great advances have been made in our knowledge of the development and function of the embryo-sac, there are still unsettled problems of its origin and homology upon which we speculate, perhaps with no nearer approach to the truth than were the speculations by the founders of the science of plant morphology.

The first important contribution to the morphology of the embryo-sac was made by Hofmeister during the middle of the present (19th) century, extending over a period from 1849 (Die Entstehung des Embryo der Phanerogamen) to 1861 (Neue Beiträge zur Kenntniss der Phanerogamen). In the

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embryo-sac when ready for fertilization he recognized two groups of nuclei lying respectively at the poles, which we now regard as the egg apparatus and the antipodals. At the micropylar end of the embryo-sac Hofmeister found usually two nuclei which he called 'germinal vesicles,' or 'embryonal vesicles,' one of which developed the embryo after the entrance of the pollen tube. In the opposite end he found a variable number of antipodal cells. The embryo-sac was by him considered homologous with the macrospore of the higher Pteridophytes. The germinal vesicles corresponded to the corpuscula (archegonia) and the accompanying rosette of cells (neck) in the gymnosperms.

Schacht (*Jahrb. f. wiss. Bot.*, 1857–8) believed that one of the germinal vesicles received the pollen tube and conveyed it later to the other, or that in some cases a third was present when two germinal vesicles seemed to convey the pollen tube to it. The germinal vesicles were sometimes marked on their surface by parallel folds, or in other cases there were parallel striæ in their contents. These striæ or folds formed his 'filiform apparatus,' which came later to be recognized by Strasburger, Pringsheim and others as homologous with the ventral canal cell of the pteridophytes. This gave rise to a further conception of the embryo-sac which was held by some down to a late period, and even appeared in some of the earlier editions of Sach's *Lehrbuch der Botanik.* In addition to the embryo-sac being a macrospore, it represented a prothallium in which the germinal vesicles formed the archegonia, while the antipodals formed the sterile remnant of the prothallium which was homologous with the endosperm of the gymnosperms.

In 1877–78 there appeared three works, by Strasburger, Warming and Vesque, which mark another important epoch in our knowledge of the embryo-sac. These were concerned with the development of the embryo-sac, and led to new and quite divergent views that have been presented from time to time since that period.

Strasburger (*Ueber Befruchtung und Zelltheilung*, 1877) gave the more complete account of the development of the embryo-sac and the origin of the endosperm, while Warming (De L'Ovule, *Ann. d. Sci. Nat. Bot.*, 6 ser., **5**) and Vesque (Développement du sac embryonnaire des phanerogames angiospermes, *Ibid.*, 6 series, bot. **6**, 1878) were more concerned with determining the origin of the embryo-sac in relation to its homologies with the pollen mother cells. It is not my intention to outline the history of the studies of the embryo-sac further, since it becomes very complex and would be filled with tedious detail. It is my purpose, however, to call attention to the principal theories that have been put forward in the interpretation of the homologies of the embryo-sac.

It should be borne in mind that in reviewing some of these theories of the embryo-sac which have been proposed from time to time, it is done in no spirit of criticism, nor for the purpose of holding up to view, at the present time, interpretations of morphological structures which the authors themselves may not now hold. Undoubtedly they were proposed by the authors as working hypotheses upon which to build further investigations, and it is certain that they all have been very useful in stimulating renewed and more profound researches, with improved methods of technique, and out of it all shall come in the future a clearer insight into the true meaning of these obscure plant structures. It is the history of all progressive science, that theories are proposed as working hypotheses, upon which to build further investigations into the nature of truth. When these have fallen new ones are formulated, for without some formulated idea in the mind, as a working basis, not as something which we are striving to prove at all hazards, progress in investigation is impossible.

1. The first theory as we have seen was that proposed by Hofmeister who regarded the synergids and eggs as 'embryonal vesicles' or 'germinal vesicles,' and therefore the equivalent of eggs. The supposed variable number of antipodals when they were present represented the prothallium. It is interesting to note that at the present time a number of botanists are coming to recognize the synergids as potential eggs, thus confirming Hofmeister's interpretation of the egg apparatus.

2. The proposal by Schacht (1857–8) of a 'filiform apparatus' suggested by certain folds or striæ on the synergids, which were supposed to act as a conductor of the pollen tube to the egg, led Strasburger (Bef., p. 73, 1877), Pringsheim and others to recognize in this the ventral canal cell. The egg apparatus thus came to be recognized as the archegonium, with the synergids as neck cells, while the antipodals represented the prothallium. This was the prevailing view at that time, and was adopted by Sachs in the earlier editions of his text-book. A very similar view of the embryo-sac has recently been stated by Tretjakow.

3. The third view of the homology of the embryo-sac was the outgrowth of the studies of Warming and Vesque, in which the eight nuclei of the embryo-sac were interpreted as spores, the egg apparatus representing one tetrad, and the antipodals a second tetrad of spores, each spore homologous with the pollen grain. This had its origin in the endeavor of Warming to homologize the processes of cell division in the ovule with those in the anther, both of which were looked upon as sporangia. The larger cell which gives rise to the so-called axile row in the nucellus, and which is either the subepidermal cell, or a derivative of it when a 'tapetum' is present, he called the primordial mother cell of the embryo-sac, and it is so termed by some at the present day. This cell Warming recognized as the young archesporium, comparable with the tetrahedral cell in the young fern sporangium. This primordial mother cell, as is well known, divides into an axile row of several cells, 2, 3, 4, etc. This axile row Warming considered the mature archesporium, each cell being homologous with a pollen mother cell, and he termed them special mother cells. The lower one only developed into the embryo-sac, forming two tetrads, one at either pole, while the other special mother cells disappeared. The egg nucleus is then called the privileged spore. His conclusions here do not appear quite consistent with his hypothesis, since he derives two tetrads (8 spores) from a single special mother cell.

4. Vesque (1879), however, accepting in the main Warming's views, attempts to show that the two tetrads are derived from two special mother cells. The cells of the axile row he regards as the mature cells of the archesporium, that is, special mother cells, and numbers them 1, 2, 3, 4, 5, etc., according to the number present in different species, beginning with the uppermost cell (the one at the micropylar end). No. 1, then, the uppermost cell, divides to form a tetrad, the egg apparatus; while No. 2 forms one or several antipodals, and makes up the larger portion of the embryo-sac. The wall between 1 and 2 dissolves and disappears, so that the embryo-sac is supposed to form by the fusion of these two cells. It is not necessary to dwell further upon Vesque's view, since he gives such an imperfect account of the processes of development which take place here, and since subsequent studies show that in a very large majority of cases it is the lower cell of the axile row which gives rise to the embryo-sac. But it is of interest to note his attempt to harmonize Warming's view

of the relation of the special mother cells to the subsequent tetrads in the embryo-sac, the figure of the tetrad suggesting that each nucleus corresponds to a spore or pollen grain.

5. A fifth view, and one which was also influenced to some extent by Warming, was proposed by Marshall-Ward (*Jour. Micr. Soc.*, **20**, 1880; also, *Jour. Linn. Soc.*, 7, 1880). According to this view the embryo-sac consists of two prothallia, derived from two spores, the egg apparatus representing one, and the antipodals representing the second. The upper one consists of one vegetative cell (the upper polar nucleus) and the rudimentary archegonium, the two synergids being suggested as neck cells. The origin of the embryo-sac according to this view, was as follows: The primary mother cell of the embryo-sac, either a subepidermal cell, or the lower derivative of this, when a tapetum is formed, divides once and forms two cells. The lower one divides again, thus forming three cells in the axile row, separated by cell walls. These three cells correspond to the special mother cells which Warming believed to be homologous with the pollen mother cells. The lower cell now develops the embryo-sac. Its nucleus divides in the same direction as the division walls arising in the formation of the three cells of the axile row. These two nuclei at opposite poles of the young embryo-sac he believed represent cells in the axile row, thus making four cells in all. The two lower cells are not separated by cell walls, due, he believes, to the extraordinary rapidity of growth from this time onward. Each of these two lower cells, represented by the two-nucleated stage of the embryo-sac, he interpreted as a spore, one to give rise to the upper prothallium, and the other to the lower prothallium of the embryo-sac. It is possible to draw the inference that he regards the primary mother cell of the embryo-sac as a mother cell of four spores, since the axile row, as he interprets it, consists of four cells. The two lower ones he distinctly interprets as spores. The primary mother cell could not, however, be a cell homologous with the mother cell of spores according to this interpretation, since three successive divisions occur before these two spores are developed which are to form the embryo-sac; while the tetrad of real spores is developed by two successive divisions.

6. A sixth theory of the homology of the embryo-sac was proposed by Mann. (The embryo-sac of *Myosurus minimus* L., *Trans. & Proc. Bot. Soc.*, Edinburgh, **29**, 35; 1892. The embryo-sac of angiosperms is a sporocyte and not a macrospore, *Ann. Rep. B. A. A. S.*, 782, 1892.) He made an attempt to draw a direct homology between the embryo-sac and the pollen mother cell in origin, and also in the number of nuclei developed as a result of the division of the mother cell or sporocyte. For him each cell of the axile row is a sporocyte, and homologous with the pollen mother cell. Since from the pollen mother cell the four spores (pollen grains) are formed, and each pollen grain at maturity contains two nuclei, making eight in all, he traced a direct and parallel homology in the origin of the eight nuclei of the embryo-sac. The four-celled stage of the embryo-sac represents the four spores which are homologous with the four pollen grains. Each nucleus now divides again into a vegetative nucleus and a sexual nucleus, which correspond to the vegetative nucleus and generative nucleus of each pollen grain. In thus tracing the homology of the eight nuclei of the embryo-sac with the eight nuclei in the four pollen grains, Mann overlooks the fact that prior to fertilization, when the embryo-sac is still in the eight-nucleated stage, the generative cell in the pollen tube has divided again, *or in some cases it divides by the time the pollen is*

ripe, forming twelve nuclei for each pollen mother cell, instead of eight; and thus the homology falls.

7. Another view is that the embryo-sac, at the eight-nucleated stage, is homologous with the endosperm of the gymnosperms or, in other words, that the eight free cells are homologous with the endosperm of the gymnosperms. This was proposed by Strasburger as early as 1879. One of the cells of the endosperm forms the archegonium which here is very much more reduced than in the gymnosperms, being reduced to a single cell. A suggestion of such a reduced archegonium is found in Welwitschia, etc., where a single endosperm cell without division elongates to form the simple archegonium. Guinard ('81, *Ann. d. Sci. Nat. Bot.*) upholds this view.

8. Very closely allied to this view is the one which interprets all the cells at the eight-nuclear stage of the embryo-sac as potential eggs. Dodel ('91) found in *Iris siberica* that the synergids were sometimes fertilized, and developed embryos. He suggests that the synergids are potential eggs. Chamberlain, '95, suggests that one of the antipodals has all the appearance of an egg ready for fertilization. Strasburger (*Ang. und Gyn.*, '79) states that while in *Santalum* the normal number of eggs is two, there are sometimes three, and one of these may be the upper polar nucleus, when the endosperm is developed from the lower polar nucleus. Overton ('92) records a case of fertilization of one of the synergids of *Lilium martagon;* Guinard ('81) the development of embryos from two synergids in *Mimosa denhartii*, and Tretjakow ('95, *Ber. deut. Bot. Ges.*), the development of embryos from the antipodals of *Allium odorum*. Tretjakow interprets this as a case of apogamy, since he regards the antipodal cells as representing the vegetative portion of the prothallium.

In view of all the facts, Strasburger's hypothesis that the eight cells of the embryo-sac are homologous with the endosperm of the gymnosperms, seems the more reasonable one. If the synergids, then, can be fertilized and produce embryos, they too represent archegonia reduced to a single cell each. This would confirm the view first proposed by Hofmeister that the synergids and egg are 'germinal,' or 'embryonal vesicles.' Tretjakow holds that the antipodals represent the vegetative part of the prothallium, while the synergids and egg represent archegonia, which is very like the earlier views held by Strasburger, Pringsheim and others.

But if the eight cells of the embryo-sac are homologous with the endosperm of the gymnosperms, and the egg is an archegonium reduced to a single cell, it would seem that all the cells of the embryo-sac are potential eggs or potential archegonia.

It is probable that all the peripheral cells of the endosperm in the Abietineæ, for example, at a certain stage of development, a short time prior to fertilization, are potential archegonia. While the archegonia are usually developed from superficial cells at the micropylar end of the endosperm, they are frequently formed from superficial cells down on the side some distance from the end, giving to the endosperm in longitudinal section the appearance of a comb. Archegonia are in some cases developed at the opposite end of the endosperm which would correspond in position to the antipodals of then agiosperm-embryo-sac. Furthermore, archegonia are rarely developed from internal cells of the endosperm. This would indicate that prior to the time for fertilization all the cells of the endosperm are potential archegonia.

And this too seems reasonable since up to this time the course of development in all parts of the gymnosperm embryo-sac have been the same, all parts bear the same nutritive relation to the surrounding nucellus. No part functions particularly as the vegetative part, or protonema, as is the case with most of the pteridophytes. The true vegetative function of the endosperm appears later. The fact that the archegonia do usually arise at the micropylar end of the endosperm is probably acquired or hereditary, since archegonia there are more certain to be fertilized.

If, therefore, the eight-celled stage of the angiosperm embryo-sac is homologous with the endosperm of the gymnosperms, then all the cells are potential eggs. The functional egg is at the micropylar end of the embryo-sac, because the chances for its being fertilized here are greater. This is true of the synergids also when they become functional eggs. The antipodals probably appear in this rôle very rarely. Nevertheless, potentially they are eggs, or greatly reduced archegonia. If this be so, then an embryo developing from an unfertilized antipodal cell would fall in the category of parthenogenesis, instead of apogamy.

This, however, may be drawing the line very fine, and I am not so much concerned with that fine distinction as I am with the *probable origin* of the embryo-sac. Since the embryo-sac has been recognized as the female prothallium of angiosperms, it is natural that there should be an effort to interpret it as a derivative from a macrospore. It is derived, according to the different interpretations of its homologies, from a different number of macrospores.

According to the Vesque theory, it consists of eight macrospores derived from two cells of the axile row, a fusion of two-spore mother cells. According to the theory proposed by Mann it consists of four macrospores and is derived from a single cell of the axile row, regarded as a spore mother cell (sporocyte). According to the theory suggested by Marshall Ward, it consists of two macrospores, each representing a prothallium of four nuclei, the two spores derived from the third cell in the axile row by a division in which no cross wall is formed. This cell of the axile row then would represent a *one-half spore mother cell*, or if the *number of divisions from the primary mother cell be taken into account it would represent a single spore.*

The theory that it consisted of eight spores was shown long ago by Guinard ('81) to be untenable. It necessitated the fusion of two spore mother cells. Vesque had little in support of his theory, since he considered the embryo-sac to be formed by a fusion of the two upper cells of the axile row, while as a matter of fact the embryo-sac arises from the lower cell in all except a very few cases. Although Marshall Ward found no evidence of a cell wall separating the two nuclei in the first division of the embryo-sac mother cell, he regarded these as representing two cells of the axile row.

There have been recent attempts to show that the embryo-sac in some cases is derived by a fusion of two cells of the axile row, where a weak or temporary cell wall is formed after the division of the nucleus (Wiegand, '98, in *Convallaria*). This, however, is more properly to be classed with the phenomenon so often exhibited in free-cell formation, where a temporary cell plate is laid down to be soon dissolved, and as often occurs in the first division of the pollen mother cell of different plants. Guinard ('81), in addition to citing this phenomenon as evidence that the embryo-sac is not formed by a fusion of two cells, adduces other strong evidence against it. In *Agraphis patula* (Mellink, '80) the axile row consists of two cells and the upper cell forms the embryo-sac, as Campbell ('99) has recently shown to be the case in *Peperomia pellucida*, while in Caltha, according to Mottier ('95), with a three-celled axile row, the upper one sometimes forms the embryo-sac. In *Narcissus tazetta* (Mellink, '80) there are two cells in the axile row.

The nucleus of the upper one undergoes repeated division without, however, forming the embryo-sac, which develops from the lower cell. Fischer ('80) reports a similar case in *Melica nutans* with an axile row of three cells ; the two upper ones each contain two nuclei, and yet the embryo-sac is developed from the lower. Similar cases Guinard ('80) found in *Cercis*, *Phaseolus*, *Erythrina*, Miss McKenney ('98) in *Scilla*, and Wiegand in *Convallaria* (1900). The cells of the axile row with several nuclei, Guinard points out, are undeveloped embryo-sacs. Their nuclei divide several times in adjacent cells, but the intervening walls do not dissolve and permit the fusion of the two cells of the axile row to form the embryo-sac, which is always developed from a single cell. Other examples are known, like that shown by Strasburger in *Rosa livida*, Benson in *Fagus* and *Carpinus*, where *several embryo-sacs side by side, or one above the other, begin to develop and attain considerable size, but do not fuse.*

The weight of evidence then goes to show that the embryo-sac is developed from a single cell of the axile row, though this row may consist of but a single subepidermal cell, as in *Lilium*, *Tulipa*, etc., or of two, three, or four cells, as in other types.

If this single cell, the mother cell of the embryo-sac, or macrospore, is the homologue of a spore in a strict morphological sense it would be necessary to show that it is derived by the same, or similar, processes of development. In those plants where the axile row consists of four cells, the cells might be regarded as tetrads, or spores, one of which develops the embryo-sac, while the others degenerate. But their axile arrangement, so constant in all spermaphytes, is against that supposition, and indicates that the course of development of these cells is more in keeping with the development of adjacent nucellar tissue. The axile arrangement itself, however, would not constitute a bar to their homology as spores. But in plants where the axile row consists of but two cells, or one cell, not even such a slight suggestion of their homology with spores is presented.

So far as investigation has been made, there is evidence that the development of spores in the bryophytes and pteridophytes, and in the development of the pollen in the spermaphytes, from a mother cell, is accompanied by nuclear phenomena known under the head of reduction of the chromosomes. It has been suggested that the reduction of the chromosomes in the formation of the embryo-sac might be employed as a criterion to determine what constitutes the spores. The facts, however, which have been obtained in the few cases investigated do not offer any more hopeful evidence as to the identity of the spores. In *Lilium*, and other observed cases, where the single cell develops directly into the embryo-sac, the reduction takes place in the first division. In other cases where an axile row of two, three or four cells is formed, the reduction of the chromosomes, so far as I know, always takes place in the primary mother cell of these, several cell divisions removed from the beginning of the embryo-sac. This is what we should expect, since this cell undergoes a maturation period prior to the formation of the axile row. So, whatever criterion we employ to determine the identity of the spores, we are led to irreconcilable confusion ; either that the embryo-sac just prior to fertilization consists of 1, 2, 4 or 8 spores, or that it is developed in some plants from a spore representing one-fourth of a mother cell or sporocyte ; in other plants from one-half of a mother cell, and in still others from the entire mother cell.

It is clear then that there do not exist here spores in the sense in which they are represented in the pteridophytes, or in the microspores of the spermaphytes ; neither in actual form, nor according to processes of development. How then does the embryo-sac of angiosperms arise? It arises directly from the nucellar (sporangial) tissues or from the archesporium, without the intervention of spores. In the pteridophytes such phenomena are classed under the head of *apospory*. The origin of the embryo-sac directly from sporangial tissue, considered only from the standpoint of the absence of spores, would also fall under the general category of apospory. But apospory merely does not indicate the real morphological significance of its derivation. It is to be interpreted as an adaptation of the plant in developmental processes under the influence of the changed and peculiar environment of the gametophyte, which has become so general in the angiosperms, and probably in the gymnosperms also.

There is no longer any need of spores, as such, in the development of the female prothallium of angiosperms. Where spores exist, as such, they exist for the purpose of distribution of the plants, as in the bryophytes and pteridophytes; in the spermaphytes for the distribution of the male prothallia, so that they may be lodged in a position where the sperm cells may reach the egg. There is a law in the evolution of organisms and organs, that when an organ or structure is no longer needed as such, it tends to disappear. Spores are not needed in the development of the embryo-sac. They are therefore cut out of the cycle of development, and the embryo-sac, or gametophyte arises directly from the tissue of the sporophyte.

In suggesting that the origin of the embryo-sac is a kind of apospory, we do not mean that it is phylogenetically connected with cases of apospory in earlier forms, nor that it is derived from them, nor that apospory as a phenomenon is continuous through groups. We simply mean that there has been a shortening in the process of development here, before the formation of the spores, just as there has been a shortening after the beginning of the gametophyte, and it has gone so far that the spore, *as such, i. e.*, a spore which is formed by the accompaniment of the same phenomena which we know to prevail universally where we can recognize a definite spore, is *wanting*.

There is no need that such a spore or cell should be formed, because the necessity for it has disappeared. A cell, however, is formed which is not the morphological equivalent of a spore, but is the physiological equivalent, and develops the embryo-sac. The process is shortened so that the spore is cut out, and perhaps the mother cell forms the embryo-sac directly, a new development of a prothallium, or body functioning as such, directly from sporogenous tissue.

If Vines' suggestion (Student's Text-Book of Botany) that in *Asclepias* each cell of the pollinium is a mother cell, is correct, we should have a similar shortening process in the development of the male gametophyte. But this suggestion may not, possibly, be supported by the facts when we know the course of development of the pollinium and sperm cells in *Asclepias*. But we can conceive of a hypothetical case where a mechanism might arise for transporting the archesporium from an anther to the pistil bodily, and that the reduction in the anther had consequently gone so far that the tetrad divisions of the mother cell to form spores had ceased, now that there is no need for the individual and separate spore. The cell of the archesporium might form the pollen tube or male prothallium *directly*, cutting out the spore. This would be apospory so far as the loss of the spore is concerned. Its significance, however, would be greater. It would represent a new attainment in the evolution of the male gametophyte, quite independent of any phylogenetic relation to processes of development in earlier gametophytes.

The condition of things, however, in the ovule is very different from what it is in the anther, because early in the evolution of the spermaphytes the necessity for a definite spore for distribution disappeared, as the ovule retained the gametophyte within its nucellar tissue. The time has been long enough for the complete elimination of the spore. But in the case of the anther or microsporangium, the process has perhaps only begun; or perhaps it would be better to say that the conditions are being ushered in, in some cases where pollinia are formed, which in time may result in the elimination of the microspore from some of these forms.

In the elimination of the spore from the macrosporangium of the spermaphytes, they have arrived at a new morphological attainment, the development of the embryosac or gametophyte, directly from the archesporium or nucellus. The gametophyte of the angiosperms is very simple and rudimentary compared with that even of the gymnosperms, a few free cells, perhaps all of them potential eggs. Being free and few of them, they are in intimate relation with each other and are more subject to the secondary influences of fertilization than the endosperm cells of gymnosperms are.

Perhaps, for this reason, the angiosperms have arrived at a second and more remarkable morphological attainment, in the development of the second endosperm subsequent to fertilization. The interpretation of this may lie partly in the results of 'double fertilization,' and related phenomena, when the second sperm sometimes unites with one of the potential eggs, or with the 'endosperm nucleus' to form the second endosperm, or may possibly itself sometimes form a separate endosperm. It is well known that in the pteridophytes and gymnosperms often several eggs are fertilized in one prothallium, and several embryos begin to develop. Finally one of them usually outstrips the others, which then atrophy. In the angiosperm embryosac the potential eggs are all free and so situated that they are immediately and profoundly influenced by fertilization of the 'privileged' egg.

The endosperm nucleus, or one of the other potential eggs, being fertilized by the second sperm, may be so immediately influenced that, instead of developing into an embryo which in a short time would be outgrown and destroyed, it is directed into a new channel of development, which has resulted in the evolution of a new plant generation to be utilized as a nutrition body by the privileged embryo. If the secondary influences of fertilization in angiosperms have acted somewhat in this way, it might account not only for the retarded development of the so-called 'endosperm' in the angiosperms, but also for some of the phenomena known under the expression *Xenia.*

GEO. F. ATKINSON.

NATURAL HISTORY WORK AT THE MARINE BIOLOGICAL LABORATORY, WOOD'S HOLL.

NATURAL history has been a growing element in the work of the Biological Laboratory at Wood's Holl. All departments represented at the Laboratory have made contributions in this field. Life histories have been studied principally in connection with embryological research, as, for example, in Conklin's work on 'Crepidula,' Lillie's on '*Unio*,' Mead's on 'Annelids,' Foot's on 'Allolobophora,' Clapp's on the 'Toad-fish,' Patten's on '*Limulus*,' Wheeler's on 'Insects,' Watasé's on the 'Fireflies,' etc. Within the last few years natural history studies have acquired wider and more independent interests with us. Animal behavior has engaged the attention of a number of investigators, led by Loeb, Wheeler, Thorndike and others. The demand for instruction followed the development of various lines of research, and the courses in general physiology and animal psy-