

# THE OHIO JOURNAL OF SCIENCE

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VOL. XXVIII

NOVEMBER, 1928

No. 6

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## THE GENERAL COURSE OF EVOLUTION IN THE PLANT KINGDOM.\*

### STUDIES IN DETERMINATE EVOLUTION, I.

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A study of the system of plant relationships inevitably leads to a consideration of the processes through which the system came into existence. Having spent many years in an attempt to learn something of the true phyletic relationships of plants, the writer desires to present, in a series of short papers, some of the remarkable phenomena which have come to light and which apparently have never been published heretofore in any adequate manner. These papers will bear the subtitle, "Studies in Determinate Evolution," so that they can easily be recognized as forming a part of a general presentation. The term, "Determinate Evolution" is used advisedly as expressing the actual condition of things in all evolutionary movements of a fundamental nature. All such primary movements attain a definite limit, sooner or later, beyond which no further movement in the given direction is possible. This broad generalization will be justified when some of the more important evidence has been submitted. All of the more fundamental taxonomic forms, therefore, fall into what will be called orthogenetic series, and these series are the result of progressive and perfective movements, which commonly are profoundly consistent in their development.

In general, evolutionary movements are either segregative or progressive. But the segregative mutations are determinative as well as the progressive mutations. Each segregative

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\* Papers from the Department of Botany, The Ohio State University, No. 218.

movement produces narrower limits within which further mutations are confined. Thus when class, order, family, or genus limits are once established all further movements are within the limits thus set up. It is this fact, together with the general principal of irreversibility, that is responsible for the taxonomic system of larger and smaller phyla. Furthermore, the different movements which may take place in an organism are largely independent of each other. There is a certain correlation of a general sort, nevertheless fundamental evolutions, as for example that of the flower, are not at all dependent on any special type of structure or function, nor on any definite degree of advancement in the series, nor on any special geological period or climatic cycle. The property or potentiality responsible for the development of flowers appears independently a large number of times at entirely different levels. Another important development which will make this principle evident is the evolution of the time of sex determination from the bisporangiate flower condition to the monocious and diecious conditions. This movement has taken place independently a very great number of times in the most diverse morphological systems and at every level of advancement from the very low gymnosperms to the very highest dicotyls. The more primitive movement of sex evolution in the gametophyte has proceeded in the same manner. The two evolutionary movements given above are characteristic of a very large number of cases which it is the intention to present as occasion permits.

As intimated, there is no correspondence between the general evolutionary movements and the environment. Evolution, from the beginning, has ploughed its way consistently through the environment. Evolution is kinetic and not static. It is progressive and orthogenetic; it is perfective and, as stated above, determinative. The movements in general have no special utilitarian import. The two older prominent hypotheses of evolution, namely Lamarck's utilitarian explanation on the basis of desires and of use and disuse, and Darwin's utilitarian selection are purely static conceptions and do not at all correspond to the actual systems of taxonomy which they are supposed to explain. Utilitarian and selective theories are anarchistic, depending on the circumstances or accident of the environment to bring about a movement. They are reasoning in a circle and a contradiction of the taxonomic system as it is actually evolved. If either Lamarckism or Darwinism were

true, we would have a fundamentally different taxonomic system and this system would be in harmony with the environment but would nevertheless be anarchistic if considered by itself, since the habitat itself is continually changing. If the changing habitat were the cause either of a direct utilitarian, evolutionary response or of a selective value, the organisms which had developed in it at a given time or had taken refuge in it in the first place would be subject to these cyclic changes and an anarchistic system would be the result. But nothing of the kind is present in the plant world. On the contrary there is a most remarkable cosmos. These older evolutionary hypotheses belong to the kindergarten period of causative biological science and are purely teleological in their implications. Evolution goes on without any reference to special teleological ends, except that we can say that the system developed has a general utility and fits into the environment in which it has taken place to a greater or less degree. Philosophically there is no contradiction but rather a confirmation of the principle of universal design. It is the principle of special design, or special teleological causation, that finds no basis of support in the taxonomic system. There is a general utility and a universal design plainly in evidence. The whole system does work admirably and has been successful for millions of years. But this universal principle of utility is something very different from the notions of special advantages and special utilities on which the older static theories are developed. Since any organism cannot be dissociated from an environment of some kind, the principle of general utility is always in evidence. But the same orthogenetic movements have taken place in environments diametrically opposite in nature, as for example, many exactly parallel movements of angiosperms into the water, on the one hand, and into mesophytic and xerophytic conditions, on the other. In the angiosperms as well as in many other groups, there is a profusion of parallelisms, yet since evolution is determinate, a species or a larger group of any kind when once lost can never be replaced or duplicated. This is the conclusive testimony of paleontology.

Leaving the consideration of the taxonomic system and its non-correspondence with environment, we find, nevertheless, that there is an abundance of ecological adaptation in details of form and function, but these ecological characters, in general, do not run parallel with the taxonomic system. And since the

taxonomic movements are known to be independent of specific environments, the ecological adaptations, because of a lack of evidence to the contrary, must be considered to be brought about in the same general way, namely, through intrinsic changes which take place in many environments but which are occasionally of such a nature that the environment exercises a decisive eliminative effect. This must be the scientific inference in regard to ecological adaptations until acquired characters can be shown to be induced in the phylogenetic line as readily as they are induced in the ontogenic cycle. Instead of having natural selection in the old sense of the term, we have natural or selective elimination. But this elimination is to be considered as operative only in very special physiological and morphological developments. The vast majority of forms, structures, and functions have an agreeable survival value in the same general environment. The same general environment, for example, will harbor members of the plant kingdom from one end of the series to the other as well as a miscellaneous assemblage of animals. Furthermore, structures of exactly opposite nature in homologous parts survive in the same environment, and sometimes these structures may have a fanciful utility and sometimes not. As stated before, evolution has been described as irreversible and this is true for all fundamental movements. It is only in the extremely minor details that reversibility seems possible and this, as the paleontological record shows, has never involved any of the general movements of the organism, whether plant or animal. It must be emphasized that, in a general sense, evolution is non-selective and non-utilitarian. Very frequently a utility evolves that is of absolutely no value to the possessor, when compared with a lower, related form that has not evolved the utility; and since evolution is orthogenetic and determinative, there are frequently also developments which pass far beyond the limits of practical utility to the realm of the so-called over-adaptations. In some cases also, the development is a positive disadvantage to the possessor.

Evolution and the taxonomic system which comes from it are, therefore, anything but anarchistic systems. Those who hold to an anarchistic system of philosophy, whether political or scientific, need not look for support of their views from a study of the phyletic taxonomic system found in the plant kingdom.

The first part of the problem of evolution is to find out exactly what the process is and what has been the result of its operation, and after we have discovered some of these things we may proceed to investigate the causes of the process. In the past, evolutionary science so-called has commonly proceeded in the opposite direction. A dogmatic hypothesis was formulated, based on some preconceived philosophical attitude and then isolated facts were assembled which appeared to give a plausible proof of the assumption. This procedure is not science and has in the past resulted in enormous reversals and repudiation of widely accepted theories. True inductive science demands that theory shall follow a certain foundation of ascertained phenomena. It also demands that there be no confusion of fact and assumption and that reasoning in a circle shall be tabooed.

#### THE EVOLUTION OF THE GENERAL SERIES.

Without going into the question of the origin of the protoplast, which would take us too far afield, we will begin with a consideration of the general nature of the lowest known organisms. These organisms have a definite protoplast or a definite unitary cell organization. Whatever its origin, the cell is established as the unit of the living reaction system. Life phenomena are manifested by cells. Thus the organized cell is the starting point and the basis on which a complicated reaction system is built up, proceeding step by step from the lowest to the highest stage attained in the evolutions of organisms. The building up or evolving of the fundamental reaction system has been attained by adding at each stage some new potentiality or potentialities which were not there before. The new fundamental properties are laid down on top of the old. The old is not destroyed nor even inhibited but the new simply makes the reaction system more complex. This general evolution is, therefore, also to be regarded as an orthogenetic progression, although this may not be so manifest at first thought as some of the remarkable movements which take place in some of the greater or smaller phyla. When one remembers, however, that these new properties are commonly introduced not simply in one line but into all the advancing lines, then their evolution becomes the most profoundly remarkable of all the serial, orthogenetic movements known.

In the lowest plants, the cell is not nearly so elaborately organized as it becomes a little farther up the scale. These lowest plants are properly called PROTOPHYTA and the very lowest are apparently the group of the *holophytic bacteria*. There is no sex potentiality but the general properties manifest are: (1) unitary nature and activity of the protoplast, (2) assimilative property or hereditary perpetuation of the system, (3) division of the protoplasts or cells, and (4) separation of the units after division. These properties are present in all higher organisms also but the separation of cells becomes greatly restricted. They are the first and fundamental potentialities of all living things whether plant or animal. There are a number of important physiological systems established which are of a segregative character as various types of metabolism resulting in holophytic, saprophytic and parasitic groups, flagellate and non-flagellate, chlorophyll-bearing and chlorophyllless groups, etc. This subkingdom, therefore, represents in itself a great period of evolution.

#### THE FIRST GREAT TRANSITION.

In passing from the lowest to the higher organisms, both animal and plant, we find that there are three fundamental and universal advances. (1) The development of the colony or multicellular condition, brought about by a delay and usually a restriction of the process of cell separation after division; (2) The development of the process of differentiation of cells and tissues in the body, and (3) the development of the sex-potentiality. For purposes of a definite taxonomy it becomes necessary to choose one of these three—multicellular condition, differentiation process, or sexuality—as a basis of segregation, since the appearance of the three characteristics are not coincident in the various primitive groups. The most suitable and definitely determinable characteristic is the sex-potentiality. Therefore, the Protophyta are made to include all the plants which are nonsexual as contrasted with those having sexuality, namely the METAPHYTA. As stated, some Protophyta are multicellular and differentiated while some of the lowest Metaphyta are unicellular or are undifferentiated. However, the evolution soon proceeds far enough that shortly all organisms, whether plant or animal, possess the three added characteristics, namely, multicellular condition, differentiation,

and sexuality. All the higher Metaphyta and all the Metazoa therefore possess the seven characteristics mentioned thus far.

With the evolution of the sex-potentiality there are possible, from time to time, three general states in the cell lineage: (1) the female state, (2) the neutral state, and (3) the male state. In some plants the neutral state is the prevailing condition in others the neutral condition may be rare or never properly developed. With the advent of sexuality also there is an entirely new mode of hereditary transmission. The two fundamental features are primary sexualization of the haploid gametes, resulting in fertilization, and primary sexualization of the chromosome sets in the diploid reproductive phase, resulting in the reduction division. These processes are responsible for Mendelian segregation of heredity and Mendelian interaction of dominant and recessive allelomorphs in the diploid cell. These new phenomena are also characteristic of all the higher plants and animals.

#### PROGRESS IN THE SECOND SUBKINGDOM.

The NEMATOPHYTA show the progressive acquirement of a number of very important general properties among which the most important are: (1) the attainment of dimorphic gametes, and (2) the evolution of secondary sexual states and characters. It is needless to say that these advances are universal when once attained and are shared also by the animals. The appearance of secondary sexual characters is brought about by a shifting back of the time of sex determination into an earlier stage of the ontogeny before gametogenesis. These secondary sexual states give rise to dimorphisms by influencing hereditary expression but the cells do not manifest the attractive properties which appear later in the gametes. Thus the higher plants have a five-fold manifestation of the sex-potentiality in the cell lineage: (1) neutral state, (2) secondary female state, (3) primary female state, (4) secondary male state, (5) primary male state.

#### TRANSITION TO THE METATHALLOPHYTA.

The transition from the THALLOPHYTA to the METATHALLOPHYTA represents the greatest break or hiatus in the plant series. The Metathallophyta are a monophylletic group when compared with the lower forms. There was a long period of

evolutionary advancement in which the ancestors of the group developed all the fundamental characteristics outlined above for the Thallophyta and in addition the Metathallophyta evolved a characteristic life cycle. All of the higher plants have a uniform type of life cycle namely, the typical, antithetic alternation of generations with a haploid gametophyte and a diploid parasitic sporophyte. In this cycle there are twelve characteristic stages. These stages are retained to the end of the plant series. In the Thallophyta there are several types of alternation of generations but none that corresponds to the typical antithetic cycle of the higher plants. In most cases the sporophyte is an independent plant, like the gametophyte. The nearest approach is in the red algæ where the zygote undergoes vegetative growth and produces a number of carpogones which are discharged and develop the independent sporophyte. The twelve stages of the typical antithetic alternation of generations cycle are as follows: (1) Haploid gametophyte, (2) dimorphic gametangia, (3) dimorphic gametes, (4) fertilization, (5) oospore or zygote, (6) germination in the ovary, (7) diploid sporophyte, completely parasitic or parasitic in its embryonic stage only; (8) sporangium, (9) sporocyte, (10) reduction division, (11) tetraspores, (12) germination.

#### BRYOPHYTE STAGE.

This transition leads up to the third subkingdom, or general evolutionary stage, called the BRYOPHYTA. The parasitism of the sporophyte is complete. The sporophyte is also completely determinate in its growth, since the production of its spores either involves the entire individual or its single terminal growing axis. Only in one group is there a peculiar type of intercalated indeterminate growth evolved and this is usually of short duration. There is a marked progression in the size and importance of the sporophyte as compared with the gametophyte, and in general this forward movement in the evolution of the sporophyte persists to the very summit of the plant kingdom. The sporophyte is entirely neutral, the sex potentiality never giving rise to sexual states in the normal conditions. The lowest species have a sporophyte that is nothing but a sporangium, representing a hollow sack of spores; the highest species have a fairly well organized body with foot, stalk,



photosynthetic organ with stomata (hypophysis), and sporangium, and in the *Anthocerotæ*, as intimated above, even a crude beginning of indeterminate growth. One of the most important progressions is in the continually smaller area of tissue involved in the spore reproductive process. In the lowest species the entire individual except the epidermal layer is transformed into spores; in the higher liverworts there is sterile tissue interspersed with the spores in the sporangium; while in the very highest the central part of the axis remains vegetative, thus shifting the reproductive process to the outer regions of the stem. This is of most profound significance from an evolutionary point of view as will appear below.

#### TRANSITION TO THE VASCULAR PLANTS.

The transition to the vascular plants is accomplished by the addition of heredity which causes a shifting of the reproductive process of the sporophyte from the terminal bud (cauline sporangia) over to the newly evolved lateral appendages of the stem, or the leaves, thus giving rise to sporophylls which with some modifications are characteristic of all vascular plants. The growing axis is now an indeterminate system. Thus the transition from bryophyte to homosporous pteridophyte is a change from a determinate sporophyte to an indeterminate sporophyte, and this leads over to a two-phased condition, the first phase of the sporophyte being parasitic and the later phase entirely independent. This two-phased life of the sporophyte, thus evolved, is characteristic of all higher plants. It is again a fundamental characteristic imposed on the one-phased condition of the bryophyte type of sporophyte. Of course, the whole morphological condition advances in complexity by the appearance in the sporophyte of potentialities for the development of a vascular system, leaves and roots. As stated above, the shifting of the point of spore production from the stem axis to a lateral appendage of the stem is not a sudden advance but shows in itself a definite orthogenetic advancement. It is evident that this shifting of the reproductive center from the region of the stem axis was well advanced before the appearance of a definite vascular system, so that with the appearance of lateral appendages the final step to sporophylly was but the culmination of a movement begun far down in the bryophyte stage.

Whether the lowest vascular plants originally produced nothing but sporophylls or whether from the beginning they developed alternating zones of foliage leaves and sporophylls is of no great consequence, and can probably never be proven one way or the other. Our living primitive vascular plants apparently all have such alternating zones. One thing is certain. The vascular plants did not originate from a strobilus-like sporophytic ancestor. The flower is a secondary determinate system evolved later from or in the earlier indeterminate system. The shifting of the point of spore production from the terminal bud to the lateral stem appendages was the primary condition for the development of indeterminateness. Now in the higher plants the lateral shifting of the reproductive function progresses still farther to the lateral organs of secondary axes as in cycads like *Macrozamia* where the cones are always lateral organs. In *Equisetum* and many conifers like spruces, firs, pines, etc., the terminal buds of all primary axes remain entirely vegetative and the flowers are developed on secondary or tertiary axes or on axes still more remote from the primary.

#### IMPORTANT ACQUISITIONS IN THE STAGE OF THE PTERIDOPHYTA HOMOSPORÆ.

Among the progressive movements developed in the homosporous pteridophytes is the evolution of dimorphism between foliage leaf and sporophyll. This condition is established in this fourth subkingdom and becomes more intense or extreme, in general, the farther one proceeds along the line of any of the higher phyla. The development of the flower or determinate, sporophyll-bearing axis, is also attained in some lines of homosporous pteridophytes and becomes characteristic and more pronounced and extreme as one reaches the highest phyla. The advancement in this respect is extremely definite and extremely orthogenetic. As in many of the bryophytes, some of the highest species have also shifted the time of sex determination in the gametophyte back in the ontogeny to the spore itself so that the gametophytes become unisexual.

#### TRANSITION TO THE HETEROSPOROUS PLANTS.

The transition between the fourth and fifth subkingdoms is again a fundamental one involving a definite condition of sexuality. It was just as important for the origin of the

peculiarities of the higher plants as the origin of sex itself was at the first transition in giving rise to a new type of hereditary phenomenon. In this transition a new potentiality is introduced which causes the time of sex determination to be shifted backward in the life cycle from the beginning of the gametophyte to the end of the sporophyte, from which point it proceeds in many groups back to the beginning of the sporophyte. This step was probably necessary for the evolution of any kind of seed habit. All the main lines of pteridophytes and, of course, all the lines that evolved the seed habit later took this extraordinary evolutionary step. It was a new potentiality which determines functional states or gradients of a certain type in the diploid sporophyte and these in turn cause secondary sexual states to arise. In the sporophytes of bryophytes and homosporous pteridophytes no such states appear normally although the cells have the sex potentiality. Thus the new heredity gives rise to trimorphisms and dimorphisms in the sporophyte, while as stated all sporophytes below, whether bryophytes or homosporous pteridophytes are normally homomorphic in respect to sex because they remain in a neutral state. The secondary sexual states which arise determine the character of the reduction spores and thus the sexual states of the gametophytes are pre-determined. All gametophytes of heterosporous plants are unisexual while those of the homosporous, whether bryophytes or pteridophytes, are more commonly hermaphroditic. Along with the development of secondary sexual states in the reduction spores goes the great reduction in size and importance of the gametophyte generation, especially the male gametophyte. This latter condition paves the way for the evolution to the seed habit. The orthogenetic and progressive character of this great movement, as well as the intrinsic nature of the evolutionary process, are clearly in evidence when one considers the numerous independent appearances of the condition.

#### TRANSITION TO THE SEED PLANTS.

As stated, the development of PTERIDOPHYTA HETEROSPORÆ, through the shifting of the time of sex determination, was a necessary step for the development of the fifth transition. This evolution adds a number of fundamental properties to the system, and a large number of almost simultaneous move-

ments take place which make the history of the transition to the seed plant condition appear almost like a fairy tale. The great central movement in this transition was the retention in the mature sporangium of the spores giving rise to the development of the parasitism of the gametophytes. This condition imposed upon the fundamental complex of properties already attained was a truly marvelous step in advance. The reduction spores are now in the same evolutionary stage as the zygote was from the liverworts on up. The female gametophyte is permanently parasitic and enclosed in the megasporangium (ovule). Thus the development of the parasitic relation between the two generations has reached the final limit possible. The telescoping has advanced as far as the conditions of life will permit. The orthogenetic movement of one generation depending on the other has reached its ultimate possibility. It is as though a short snake swallowed a long snake's tail and then the long snake turned around and swallowed the short snake along with its own tail. The seed of the GYMNOSPERMÆ is thus a triple organism representing two generations and a part of a third. The male gametophyte acquires a double-phased life. At first it is parasitic in the microsporangium and later it is parasitic in the ovule through the development of the pollentube. This two-phased condition is again carried through the last subkingdom, the ANGIOSPERMÆ. A remarkable addition is also made to the previous complement of fundamental potentialities of the sporophyte. The sporophyte is still a two-phased individual but with the intercalation of a resting condition or a greater or less degree of dormancy between the two phases. Several additional minor details of complexity are added at the fifth evolutionary transition to the hereditary equipment of the plant which need not be mentioned here. One however is very interesting. The parasitic sporophyte individual in the seed, which becomes the plant to struggle with the outer world is now protected to the extreme and supplied with food for use after its reawakening, by means of which it can establish itself promptly as an independent organism when opportunity is afforded. The higher plants no less than practically all the higher animals have taken their offspring out of the struggle for existence with the external world, and have provided a most advantageous condition of opportunity for survival and also for a favorable migration from the parent habitat. At the level of seed evolution nearly all phyletic

lines have also attained to the complexity of determinate reproductive shoots or flowers, only two of the lowest living genera of gymnosperms being flowerless, namely, the carpellate plant of the species of *Cycas* and both carpellate and staminate plants of *Ginkgo*. The acquisition of the flower is another striking example of multiple progressive movements attained in all but a few of the main lines of vascular plants. When once attained also the flower has never devoluted, although in the lower types proliferation, as one would expect from the establishment of any such fundamental potentiality, is common.

#### TRANSITION TO THE ANGIOSPERMÆ.

The sixth transition leads to the highest subkingdom, the present culmination, and probably the final one, in the fundamental progressive evolution of the plant kingdom. The important change is the closing of the megasporophyll around the ovules which necessitates the acquisition of a new organ of pollination, the stigma. The closing of the sporophyll was accomplished in some lines of ferns but, of course, no stigma is present in these. The presence of a stigma and closed ovulary in the carpel requires an additional development of the pollentube. The pollengrain now germinates, not in the micropyle of the ovule as heretofore, but on the stigma. Thus the pollentube has an extensive growth before it enters the micropyle or some other part of the ovule. The angiosperms also attain the limit in many lines of determinate, floral development in the epigynous condition and in the extreme development of zygomorphy. The first mentioned condition never being attained in any lower plants and the second only to a very slight degree.

Another, and really the most profound of the added potentialities in the evolution of the Angiospermæ is the process of triple (or sometimes multiple) fusion of two cells of the female gametophyte with a sperm to form the triploid, definitive nucleus from which a distinct generation, the endosperm or xeniophyte, develops. This process makes the life cycle and the genetics of the angiosperms much more complicated than those of any other organism, either plant or animal. The seed now contains structures representing four distinct generations, two diploid generations, a haploid generation, and a triploid or sometimes a polyploid generation.

THE ARRESTED LIMITS OF THE EVOLUTIONARY  
PROCESS.

There is another fundamental fact which stands out and demands solution which is just as remarkable as the evolutionary progression itself. Why did the various groups of plants remain on the several levels which they have attained? There is a principle of stability involved which makes living organisms the most enduring things that we know of. There is also no evidence that any of the members of any level will ever evolve beyond the general limits to which they have attained. There may be endless evolutions in a subordinate way but the whole taxonomic system and the whole paleontological history indicate that the general process has been accomplished. It is also very doubtful whether any very great advance could be possible out of the angiosperm condition which might give an eighth subkingdom of plants. All the fundamental possibilities, as complexity of life cycle, evolution of the time of sex determination, reproductive system, interactionary parasitism, limit of floral evolution, etc., seem to have reached the limit of possible fundamental advancement of the system. Paleontology and a study of the present taxonomic system is a sufficient answer to any such fantastic speculation. So all we can say at the present in answer as to why a bacterium never got beyond the nonsexual unicellular stage, why a *Platanus* or a *Sassafras* of the present day is the same as a *Platanus* or a *Sassafras* of the time of the beginning of the Cretaceous period, why a liverwort or a moss never got beyond the liverwort or moss condition while other things at the same time were advancing in a most remarkable manner, is that in all such cases something appeared in the system which apparently forever prohibited a mutative change in the given direction, forever inhibited the addition of the essential potentiality into the given protoplast. As stated, this problem is just as fundamental and demands just as much attention and investigation as the actual evolutionary advancement and change itself.

CONCLUSION.

Now anyone who will take the trouble to understand what the entire evolutionary process outlined above implies will readily see that we are dealing with a kinetic principle, with a principle of progressive and perfective movement, with a most

remarkable accumulative or building up process, with a system which proceeds in the same general way in many diverse morphological and physiological complexes, right through the diversity of environments which are now on the Earth or which have existed in past geological ages. It is also clearly evident to any one, who knows something about the taxonomic system of plants and the geological history of organisms, that the progressive movements, like the evolution of the flowers in the various phyla, for example, have not at all taken place at the same time but often in entirely different geological horizons. When one comprehends all of this, then it becomes evident that much of the speculation of the nature and cause of evolution, developed in the past and still held to a considerable extent in the present, are, to repeat the proposition stated in the introductory part of this paper, to be regarded as amateurish beliefs mostly supported by the common illogical devise of reasoning in a circle, from which biological science should have been freed long ago. In this category are to be placed such teleological hypotheses like Lamarack's use and disuse through the sudden acquirement of new desires, Darwin's natural selection, sexual selection, and selective mimicry, and especially all the teleological vagaries of the Neo-Darwinians, as well as the unsupported belief in a direct specific causal effect of environment and in the inheritance of acquired characters.

The general array of facts and phenomena presented in the outline of the general fundamental evolutionary movements thus indicate that: Evolution is intrinsic, kinetic, progressive, orthogenetic, perfective, and determinative.