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MODERN ZOOLOGY[1]

ZOOLOGY has far outgrown its early boundaries when it could be defined simply as a part of natural history, and at no period has its growth been more rapid or more productive in results of scientific and practical importance than in the interval since our last meeting in this city. It is, however, impossible, even if time permitted, for any one observer to survey the many lines of activity in zoology or to record its contributions to knowledge in this fruitful period. I have thought it might be profitable to endeavor to take in retrospective glance the broad outlines of development of zoology during the last two or three decades, and then to limit our further consideration more especially to some of the relations of zoology to human welfare. The period under review has witnessed a growth of our knowledge of the living organism of the same order of importance as the progress in our knowledge of the atom. Never have investigators probed so deeply or with so much insight into the fundamental problems of the living animal; the means for observation and recording have become more delicate, and technique of all kinds more perfect, so that we can perceive details of structure and follow manifestations of activity of the organism which escaped our predecessors.

At the time of the last Liverpool meeting and for some few years previously, a distrust of the morphological method as applied to the study of evolution had been expressed by a number of zoologists. At that meeting Professor MacBride put forward an able defense of morphology while recognizing that the morphological method had its limitations, which must be observed if the conclusions are to rest on safe ground. Through undue zeal of some of its devotees morphology had been pushed too far on arid and unproductive lines, and rash speculation based on unsound morphology brought discredit on this branch of our science. It is now fully recognized that the observed resemblances between animals are due, some of them to genetic relationships, and others to convergent evolution, and therefore that the conclusions drawn from the study of morphology are to be interpreted with the greatest circumspection. There are some groups of animals, *e.g.*, the earthworms, in regard to the evolutionary history of which we can

[1] From the address of the president of the Section of Zoology of the British Association for the Advancement of Science, Liverpool, September, 1923.

never hope to receive help from paleontology; we must perforce make the best use we can of the morphological method applied, be it understood, with wide knowledge and deep insight. That careful systematic work, coupled with the skilful application of sound morphological principles, is capable of yielding results of specific and general importance is well illustrated by the researches of Michaelsen and of Stephenson on Indian Oligochetes; these authors have been able to trace the lines of evolution of the members of the family Megascolecidae so completely that we know their history as well as we know that of the Equidae. Again, to take an example from a different category, the fine morphological work on the cell and on the nucleus and its chromosomes which we owe to Hertwig, Flemming, Boveri, van Beneden, Wilson and others, made possible the modern researches and conceptions in regard to inheritance and sex. The danger that morphology will be pushed to excess is long past; the peril seems to me to be rather in the opposite direction, *i.e.*, that some of our students before passing on to research receive too little of that training and discipline in exact morphology by which alone they can be brought to appreciate how the components of the living organism are related to one another and to those of allied species or genera, and how they afford, with proper handling, many data for the evolutionist. I plead, therefore, for the retention of a sound and adequate basis of morphology in our zoological courses.

No one who engages in the study of morphological problems can proceed far without meeting questions which stimulate inquiry of a physiological nature, and, where means are available, resort to experimental procedure is the natural mode of arriving at the answer. That morphology is detrimental to or excludes experimental or physiological methods is entirely contrary to present day experience, and indeed the fruitfulness of the combination of morphology and physiology could have been amply illustrated any time during the last eighty years simply by reference to the work of Johannes Müller. The structure of an organism must be known before its coordinated movements can be adequately appreciated—morphology must be the forerunner of physiology.

Another of the basal supports of our science an appreciation of which, or better still a training in some branch of which, we must encourage is the systematic or taxonomic aspect. The student or graduate who is proceeding to specialize in experimental zoology or in genetics particularly requires a sound appreciation of the fact that the accurate determination of the genus and species under investigation is a primary requisite for all critical work—it is part of the fundamental data of the experiment and is essential, if for nothing else, to permit subsequent observers to repeat and perhaps to extend any given series of observations. Moreover, the systematic position of an animal is an expression of the final summary of its morphology and its genetic relationships, and it is from such summaries that we have to attempt in many cases—as, for example, in the Oligochetes already cited—to discover in a restricted group or order the probable course of evolution, though the method of evolution may not be ascertainable. From these summaries prepared by systematists issue problems for the experimental evolutionist and the geneticist. As Mr. Bateson has pointed out, it is from the systematist who has never lost the longing for the truth about evolution that the raw materials for genetical researches are to be drawn, and the separation of the laboratory men from the systematists imperils the work and the outlook of both.

Among the notable features of zoological activity during the last twenty-five years the amount of work on the physiology of organisms other than mammals must attract early notice in any general survey of the period. Eighty years ago Johannes Müller's physiological work was largely from the comparative standpoint, but for some years after his death the comparative method fell into disuse, and the science of physiology was concerned chiefly with the mode of action of the organs of man or of animals closely related to man, the results of which have been of outstanding importance from their bearing on medicine. Interest in the more general applications of physiology was revived by Claude Bernard ("Leçons sur les phénomènes de la vie," 1878), and the appearance of Max Verworn's "General Physiology," in 1894, was in no inconsiderable measure responsible for the rapid extension of physiological methods of inquiry to the lower organisms—a development which has led to advances of fundamental importance. Many marine and freshwater organisms lend themselves more readily than the higher vertebrates to experimentation on the effects of alterations in the surrounding medium, on changes in metabolic activity, on the problems of fertilization and early development, on the chemistry of growth and decline, and to the direct observation of the functioning of the individual organs and of the effects thereon of different kinds of stimuli. The study of these phenomena has greatly modified our interpretation of the responses of animals and has given a new impetus to the investigation of the biology and habits of animals, *i.e.*, animal behavior. This line of work—represented in the past by notable contributions such as those by Darwin on earthworms, and by Lubbock on ants, bees and wasps—has assumed during the last two or three decades a more intensive form, and has afforded a more adequate idea of the living organism as a working entity, and revealed the delicacy of balance which exists between structure, activity and environment. This closer correlation of form, function and reaction is of the greatest value to the teacher of zoology, enabling him to emphasize in his teaching that for the adequate appreciation of animal structure a clear insight into the activities of the organism as a living thing is essential.

The penetrating light of modern investigation is being directed into the organism from its earliest stage. During the summer of 1897 Morgan discovered that the eggs of sea-urchins when placed in a two per cent. solution of sodium chloride in sea-water and then transferred to ordinary sea-water would undergo cleavage and give rise to larvae, and J. Loeb's investigations in this field are familiar to all students of zoology. Artificial parthenogenesis is not restricted to the eggs of invertebrates, for Loeb and others have shown that the eggs of frogs may be made to develop by pricking them with a needle, and from such eggs frogs have been reared until they were fourteen months old. The application of the methods of micro-dissection to the eggs of sea-urchins is leading to a fuller knowledge of the constitution of the egg, of the method of penetration of the sperm, and of the nuclear and cytoplasmic phenomena accompanying maturation and fertilization, and will no doubt be pursued with the object of arriving at a still closer analysis of the details of fertilization.

The desire for more minute examination of developing embryos led to the more careful study of the egg-cleavage, so that in cases suitable for this method of investigation each blastomere and its products were followed throughout development, and thus the individual share of the blastomere in the cellular genesis of the various parts of the body was traced. This method had been introduced by Whitman in his thesis on Clepsine (1878), but it was not until after the classical papers of Boveri on Ascaris (1892) and E. B. Wilson on Nereis (1892) that it came into extensive use. About the time of our last meeting here, and for the next twelve or fifteen years, elaborate studies on cell-lineage formed a feature of zoological literature and afforded precise evidence on the mode of origin of the organs and tissues, especially of worms, molluscs and ascidians. A further result of the intensive study of egg-cleavage has been to bring into prominence the distinction between soma-cells and germ-cells, which in some animals is recognizable at a very early stage, *e.g.*, in Miastor at the eight-cell stage. The evidence from this and other animals exhibiting early segregation of germ-cells supports the view that there is a germ-path and a continuity of germ-cells, but the advocates of this view are constrained to admit there are many cases in which up to the present an indication of the early differentiation of the germ-cells has not been forthcoming on investigation, and that the principle can not be held to be generally established.

A cognate line of progress which, during the period under review, has issued from the intensive study of the egg and its development is experimental embryology—devoted to the experimental investigation of the physical and chemical conditions which underlie the transformation of the egg into embryo and adult. By altering first one and then another condition our knowledge of development has been greatly extended, by artificial separation of the blastomeres the power of adjustment and regulation during development has been investigated, and by further exploration of the nature of the egg the presence of substances foreshadowing the relative proportions and positions of future organs has been revealed in certain cases, the most striking of which is the egg of the Ascidian *Cynthia partita* (Conklin, 1905). Still further intensive study of the cytoplasm and nuclei of eggs and cleavage stages is required to throw light on the many problems which remain unsolved in this domain.

Progress in investigation of the egg has been paralleled by increase in our knowledge of the germ-cells, especially during their maturation into eggs and sperms, the utmost refinements of technique and observation having been brought to bear on these and on other cells. During the last thirty years, and especially during the latter half of this period, cytology has developed so rapidly that it has become one of the most important branches of modern biology. One of the landmarks in its progress was the appearance, at the end of 1896, of E. B. Wilson's book on "The Cell," and we look forward with great expectations to the new edition which, it is understood, is in an advanced stage of preparation. A great stimulus to cytological work resulted from the rediscovery in 1900 of the principle of heredity published by Mendel in 1865, which showed that a relatively simple conception was sufficient to explain the method of inheritance in the examples chosen for his experiments, for in 1902 Sutton pointed out that an application of the facts then known as to the behavior of the chromosomes would provide an explanation of the observed facts of Mendelian inheritance. In the same year McClung suggested that the accessory chromosome in the male germ-cells is a sex-determinant. These two papers may be taken as the starting point of that vast series of researches which have gone far toward the elucidation of two of the great problems of biology—the structural basis of heredity and the nuclear mechanism correlated with sex. The evidence put forward by Morgan and his colleagues, resulting from their work on Drosophila, would seem to permit little possibility of doubt that factors or genes are carried in the chromosomes of the gametes, and that the behavior of the chromosomes during maturation of the germ-cells and in fertilization offers a valid explanation of the mode of inheritance of characters. The solution of this great riddle of biology has been arrived at through persistent observation and experiment and by critical analysis of the results from the point of view of the morphologist, the systematist, the cytologist, and the geneticist.

Among other important developments in the period reference may be made to the great activity in investigation of the finer structure of the nerve-cell and its processes. By 1891 the general anatomical relations of nerve-cells and nerve-fibers had been cleared up largely through the brilliant work of Golgi and Cajal on the brain and spinal cord, and of von Lenhossék, Retzius, and others on the nervous system of annelids and other invertebrates. In these latter had been recognized the receptor cells, the motor or effector cells, and intermediary or internunciary cells interpolated between the receptors and effectors. In June, 1891, Waldeyer put forward the neurone theory, the essence of which is that the nerve-cells are independent and that the processes of one cell, though coming into contiguous relation and interlacing with those of another cell, do not pass over into continuity. He founded his views partly upon evidence from embryological researches by His, but chiefly on results obtained from Golgi preparations and from anatomical investigations by Cajal. The neurone theory aroused sharp controversy, and this stimulus turned many acute observers—zoologists and histologists—to the intimate study of the nerve-cell. First among the able opponents of the theory was Apáthy, whose well-known paper, published in 1897, on the conducting element of the nervous system and its topographical relations to the cells, first made known to us the presence of the neurofibrillar network in the body of the nerve-cell and the neurofibrils in the cell-processes. Apáthy held that the neurofibrillar system formed a continuous network in the central nervous system, and he propounded a new theory of the constitution of the latter, and was supported in his opposition to the neurone theory by Bethe, Nissl and others. The controversy swung to and fro for some years, but the neurone theory—with certain modifications—seems now to have established itself as a working doctrine. The theory first enunciated as the result of morphological studies receives support from the experimental proof of a slight arrest of the nerve-impulse at the synapse between the two neurones, which causes a measurable delay in the transmission. The latest development in morphological work on nerve-elements is the investigation of the neuromotor system in the Protozoa. Sharp (1914), Yocom (1918), and Taylor (1920), working in Kofoid's laboratory, have examined this mechanism in the ciliates Diplodinium and Euplotes and they describe and figure a mass—the neuromotorium—from which fibrils pass to the motor organs, to the sensory lip, and, in Diplodinium, to a ring round the oesophagus. The function of the apparatus is apparently not supporting or contractile, but conducting. By the application of the finest methods of micro-dissection specimens of Euplotes have been operated upon while they were observed under an oil-immersion objective. Severance of the fibres destroyed coordination between the membranelles and the cirri, but other incisions of similar extent made without injuring the fibrillar apparatus did not impair coordination, and experiments on Paramaecium by Rees (1922) have yielded similar results. While the experimental evidence is as yet less conclusive than the morphological, it supports the latter in the view that the fibrils have a conducting, coordinating function. Progress in our knowledge of the nervous system is but one of many lines of advance in our understanding of the correlation and regulation of the component parts of the animal organism.

The ciliate protozoa have been the subject during the last twenty years of a series of investigations of great interest, conducted with the purpose of ascertaining whether decline and death depend on inherent factors or on external conditions. While these researches have been in progress we have come to realize more fully that ciliates are by no means simple cells, and that some of them are organisms of highly complex structure. Twenty years ago Calkins succeeded in maintaining a strain of Paramaecium for twenty-three months, during which there were 742 successive divisions or generations, but the strain, which had exhibited signs of depression at intervals of about three months, finally died out, apparently from exhaustion. From this work, and the previous work of Maupas and Hertwig, the opinion became general that ciliates are able to pass through only a limited number of divisions, after which the animals weaken, become abnormal and die, and it was believed that the only way by which death could be averted was by a process of mating or conjugation involving an interchange of nuclear material between the two conjugants and resulting in a complete reorganization of the nuclear apparatus. Jennings has shown that conjugation is not necessarily beneficial, that the ex-conjugants vary greatly in vitality and reproductive power, and that in most cases the division rate is less than before conjugation. Woodruff has since May 1, 1907, kept under constant conditions in culture a race of Paramaecium. During the sixteen years there have been some ten thousand generations, and there seems no likelihood of or reason for the death of the race so long as proper conditions are maintained. The possibility of conjugation has been precluded by isolation of the products of division in the main line of the culture, and the conclusion is justifiable that conjugation is not necessary for the continued life of the organism. The criticism that Woodruff's stock might be a non-conjugating race was met by placing the Paramaecia, left over from the direct line of culture, under other conditions when conjugation was found to occur. Later observations by Erdmann and Woodruff show that a reorganization of the nuclear apparatus of Paramaecium takes place about every twenty-five to thirty days (forty to fifty generations). This process, termed endomixis (in contrast to amphimixis), seems to be a normal event in the several races of Paramaecium which Erdmann and Woodruff have examined, and it is proved to coincide with the low points or depressions in the rhythm exhibited by Paramaecium. The occurrence of endomixis raises the question, to which at present there is no answer, as to whether this process is necessary for the continued health of the nuclear apparatus and of the cytoplasm of Paramaecium.

Enriques (1916) maintained a ciliate—*Glaucoma pyriformis*—through 2,701 generations without conjugation, and almost certainly without endomixis. From a single "wild" specimen he raised a large number and found that conjugating pairs were abundant, so that the objection could not be made that this was a non-conjugating race. Enriques then began his culture with one individual, and examined the descendants morning and evening, removing each time a specimen for the succeeding culture. The number of divisions per day varied from nine to thirteen, and as there was no break in the regularity and rapidity of division, and no sort of depression, Enriques concluded that neither endomixis nor conjugation could have occurred, for these processes take some time and would have considerably reduced the rate of division. These results, especially if they are confirmed by cytological study of preserved examples, show that for Glaucoma neither conjugation nor endomixis is necessary for continued healthy existence. Hartmann's observations (1917) on the flagellate *Eudorina elegans* extend the conclusion to another class of Protozoa. He followed this flagellate through 550 generations in two and a half years. The mode of reproduction was purely asexual, and there was no depression and no nuclear reorganization other than that following fission. The evidence seems sufficient to confirm the view that certain Protozoa, if kept under favorable conditions, can maintain their vigor and divide indefinitely, without either amphimixis or endomixis.

Child (1915) states as the result of his experiments that the rate of metabolism is highest in Paramaecium and other ciliates immediately after fission—"in other words, after fission the animals are physiologically younger than before fission." This view, that rejuvenescence occurs with each fission, derives support from the observations of Enriques and Hartmann, for no other process was found to be taking place and yet the vigor of their organisms in culture was unimpaired. If, then, fission is sufficiently frequent—that is, if the conditions for growth remain favorable—the protoplasm maintains its vigor. If through changes in the external conditions the division rate falls, the rejuvenescence at each fission may not be sufficient to balance the deterioration taking place between the less frequent divisions. Under such conditions endomixis or conjugation may occur with beneficial results in some cases, but if these processes are precluded there is apparently nothing to arrest the progressive decline or "ageing" observed by Maupas and others. But further investigations are required on the physiology and morphology of decline in the protozoan individual.

The culture of tissues outside the body is throwing new light on the conditions requisite for the multiplication and differentiation of cells. R. G. Harrison (1907) was the first to devise a successful method by which the growth of somatic cells in culture could be followed under the microscope, and he was able to demonstrate the outgrowth of nerve-fibers from the central nervous tissue of the frog. Burrows (1911), after modifying the technique, cultivated nervous tissue, heart-cells, and mesenchymatous tissue of the chick in blood-plasma and embryonic extract, and this method has become a well-established means of investigation of cell-growth, tissues from the dog, cat, rat, guinea-pig, and man having been successfully grown. One strain of connective tissue-cells (fibroblasts) from the chick has been maintained in culture in vigorous condition for more than ten years, that is for probably some years longer than would have been the normal length of life of the cells in the fowl. Heart-cells may be grown generation after generation—all traces of the original fragment of tissue having disappeared —the cells forming a thin, rapidly growing, pulsating sheet. Drew (1922) has recently used instead of coagulated plasma a fluid medium containing calcium salts in a colloidal condition, and has obtained successful growth of various tissues from the mouse. He finds that epithelial cells when growing alone remain undifferentiated, but on the addition of connective tissue differentiation soon sets in, squamous epithelium producing keratin, mammary epithelium giving rise to acinous branching structures, and when heart-cells grow in proximity to connective tissue they exhibit typical myofibrillae, but if the heart-cells grow apart from the connective tissue they form spindle-shaped cells without myofibrillae. This study of the conditions which determine the growth and differentiation of cells is only at the beginning, but it is evident that a new line of investigation of great promise has been opened up which should lead also to a knowledge of the factors which determine slowing down of the division-rate and the cessation of division, and finally the complete decline of the cell.

For many lines of work in modern zoology biochemical methods are obviously essential, and the applications of physics to biology are likewise highly important—*e.g.*, in studies of the form and development of organisms and of skeletal structures. Without entering into the vexed question as to whether all responses to stimuli are capable of explanation in terms of chemistry and physics, it is very evident that modern developments have led to the increasing application of chemical and physical methods to biological investigation, and consequently to a closer union between biology, chemistry and physics. It is clear also that the association of zoology with medicine is in more than one respect becoming progressively closer—comparative anatomy and embryology, cytology, neurology, genetics, entomology and parasitology, all have their bearing on human welfare.

J. H. ASHWORTH

BIOLOGICAL ABSTRACTS

ON April 22, 1922, a meeting was held of representatives of 18 national biological organizations to consider the advisability of forming a federation,[1] and a year later, on April 26, 1923, the Union of American Biological Societies was formally inaugurated by the organization of a Council composed of accredited representatives of 15 member societies.

At the 1922 meeting, a publication committee of four was appointed to function jointly with a similar committee of the Division of Biology and Agriculture of the National Research Council. This committee presented a report to the Council of the Union at the latter's organization meeting, April 26, 1923. The report was adopted and the Council of the Union took the following actions:

(1) The Council of the Union of American Biological Societies considers that a single comprehensive system of biological abstracts is urgently needed.

(2) That the present Publications Committee be continued and given power to add to its membership subject to the approval of the Executive Committee of the Union of American Biological Societies and of the Executive Committee of the Division of Biology and Agriculture of the National Research Council.

(3) That the Council empower the Publications Committee (a) to formulate detailed plans for putting into effect a comprehensive system of biological abstracts for presentation to the Executive Committee of the Council of the Union and to the Executive Committee of the Division of Biology and Agriculture of the National Research Council; (b) to cooperate with the National Research Council in the continuation of its efforts to gain support for publication, abstracting and bibliography.

(4) That the Executive Committee of the Union be empowered to pass, jointly with the Executive Committee of the Division of Biology and Agriculture of the National Research Council, finally upon such plans presented by the Joint Publications Committee, it being understood that such plans do not involve other than voluntary financial commitments of societies or constituent members thereof.

(5) That the Publications Committee be authorized to determine the probable support from members of constituent societies for a comprehensive system of biological abstracts.

The substance of the Joint Publication Committee's report, with some additions, follows.

While the Joint Committee is one on publication and bibliography, the discussions which led up to its appointment centered about the need and desire for abstracting and indexing services. So, while recognizing the fundamental need for improved publication facilities, the committee has up to the present confined its attention largely to the problem of a comprehensive integrated system of biological abstracts.

It is considered unnecessary to present extended evidence of, or arguments for, the importance of adequate informational aids to the investigator and teacher. Very early, even when the output of scientific literature was an insignificant fraction of its present volume, the need for aids was felt, and bibliographies, either unclassified or classified only as to certain major subdivisions, were developed. As the situation grew more complex, more detailed aids were needed, and there evolved from the relatively simple bibliographies the more highly classified and indexed ones which have reached a high state of development, though in different ways, in such agencies as the Concilium Bibliographicum, International Catalogue of Scientific Literature, etc.

Then, in the second half, and especially in the closing quarter of the last century, with natural science largely emancipated from traditional restraints, scientific publication increased by leaps and bounds, and the impossibility of thorough search of the original sources, because of limited library facilities and insufficient time, necessitated still more detailed aids. So, especially in the last two or three decades of the last century, began the conspicuous development of abstracts. These abstracts furnished at the same time classified bibliographies and brief accounts of current work. But the modern, detailed, searching subject index was not at first a feature of the abstracting journal, at least not of the biological ones; this indexing represents a still later development. Literature aids have thus undergone an extensive evolution, and are destined to develop still further to meet future changing conditions and demands.

There has probably never before been a time when

[1] SCIENCE, 56, 184–185, 1922.