TREND OF ZOOLOGICAL RESEARCH IN THE U. K. AND THE U.S.A.

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DURING the last twenty-five to thirty years there has been a complete transfer of interest in Biology, both in the U.K. and in the U.S.A., from the earlier predominantly morphological standpoints to the more analytical experimental methods. During the last century when the fauna of most countries was not adequately surveyed, taxonomy and comparative anatomy attracted a large number of workers but now-a-days taxonomic work is confined only to workers in museums, and the discovery of a new species or a genus is considered a very minor event in Biology. Till the earlier years of this century comparative anatomy, embryography and phylogeny occupied the stage, so to speak, and the triumph of the doctrine of Evolution has owed much to the study of the structure and development of animals. Subjects like metamerism, segmentation of the vertebrate head, the morphological interpretation of the cranial nerves, *Limulus* and the ancestry of the vertebrates, origin of land vertebrates, adaptive radiation in the Reptiles, cell-lineage and the determinative type of cleavage were some of the hghlights of morphological research. In spite of these notable advances Zoology remained almost wholly a descriptive science little concerned with the active processes of life. Although zoologists still have a high regard for the basic discipline of comparative anatomy, they have now realized that the method of comparative anatomy must increasingly embrace considerations of function: it is not enough to examine diverse animal forms, the significance of their diversity must also be properly appraised. In modern biological research, therefore, there is a growing reliance on the more exact techniques of physics, chemistry and even mathematics, so that experimental biology in its various aspects has now developed into many newer disciplines like general physiology, biochemistry, biophysics, genetics, experimental embryology and ecology. The purely vitalistic conceptions of earlier days as working hypotheses have largely given place to mechanistic conceptions of the processes of life—in fact for the proper understanding of the working of the animal machine, the working hypothesis of a modern biological research worker can only be the mechanistic view of life, however inadequate it may be in the present state of our knowledge.

This change of interest from morphology to physiology began on the European continent, and thence spread both to the U.S.A. and the U.K. In the U.S.A. the Woods Hole Marine Biological Laboratory has developed into a fine and important institution: it is not only a meeting and working place in summer for biologists from all over the counry but serves as an important clearing house both of biological research and biologists—it combines the advantages of a large scientific society in residence and a truly democratic social club. There are about 400 workers and their families in residence in summer taking advantage of the excellently equipped laboratory and a very well stocked scientific library. Here, as early as 1891, Whitman advocated the development of "biological physiology" as distinguished from mammalian physiology of the medical schools. He emphasised that "the association of morphological and physiological research enlarges the field of vision on both sides—converts half-views into whole views." Whitman's own work was largely morphological—his classical monograph on the "metamerism of *Clepsine*" is still a masterpiece—but he invited Jacques Loeb to lead the Department of General Physiology both for instruction and research. This laboratory continues to offer a very efficiently run course in general physiology—probably the best in the world. Jacques Loeb and his co-workers made Woods Hole the centre of general physiology and its influence spread throughout the country. Embryology has always been a favourite subject at Woods Hole, as in summer it is a veritable paradise for students of development because of the wealth of material available for study. Jacques Loeb and his collaborators made full use of these opportunities and gave an experimental turn to embryology as well. Loeb's experiments on the production of multiple embryos and his famous discovery of artificial parthenogenesis, Wilson's experimental analysis of cell-lineage in the eggs of *Dentalium* and *Patella*, Conklin's work on the ascidian egg and the "organ-forming substances", Lyon's suggestion of the use of centrifuge in experimental embryology, and Morgan and Lillie's demonstration of polarity and bilaterality of the egg are some of the well-known results of experimental embryology of the earlier days at Woods Hole. Jacques Loeb also gave an impetus to the study of regeneration and regulation and wrote a book *Regeneration from a Physico-Chemical View-point*, just before his death. T. H. Morghan of *Drosophila* fame worked for several years on the experimental analysis of regeneration, and C. M. Child furnished the ideas of axial gradients and physiological isolation. The mystery of fertilization was explained by the analytical and experimental work of Wilson, Mathews, Conklin and Lillie. Mead and Morgan carried the analysis a stage further till Loeb put the coping stone, so to speak, by his work on artificial parthenogenesis. In cytological studies the work of Wilson, Montgomery, Morgan and Muller is too well known to be repeated here. Wilson was the first to present the theory of sex-chromosomes: Morgan by his epoch-making work on *Drosophila* established a clear relation between cytology and genetics, while Muller of Indiana used X-rays on the genes to produce mutations.

During recent years Parker's work on the elementary nervous system, the micro-dissection apparatus of Robert Chambers and its use in the study of cellular physiology, Paul Weiss's work in experimental embryology and his demonstration of the distinction between *auto-*

nomous versus *reflexogenous* activity of the central nervous system, Heilbrunn's work on the colloid chemistry of protoplasm, Harvey's work on animal light, Brooks's work on the permeability of the cell-membrane, Willier's work on transplantation in chick embryos, and Uachmansohn, Welsh, Prosser and Bullock's work on the physiology of the nervous system are worth mentioning.

In U.K. this change of interest is markedly reflected in the universities and other research institutes. At Cambridge almost all the zoologists are experimental zoologists, and the older people with a morphological bias complain that there is no morphologist left, although morphology is the bed-rock of zoology. Even at other British universities the bulk of zoological work carried on now is experimental. The Society for Experimental Biology, founded in the early twenties is a very active body; it holds conferences three times a year and publishes the *Journal of Experimental Biology* every quarter. The famous Oxford morphological journal, the *Quarterly Journal of Microscopical Science*, edited by Lankester and Goodrich, both leading morphologists of their times, for over 75 years, has recently changed its original morphological character and is now publishing memoirs on Functional Morphology, Cellular Biology and Histo-Chemistry. On looking through the pages of *Proceedings of the Royal Society* (B), one cannot fail to discern that most biologists in U.K. are now physiologically minded. How much of importance is given to experimental zoology will be gauged from the fact that recently John Z. Young of Oxford, whose brilliant work on nerves is well known, has been appointed Professor of Anatomy at the University College London, even though he has had no formal medical education and had possibly never dissected the human body. It has been realized that classical anatomy has long since exhausted itself, and we need a new generation of anatomists like Young in whose hands morphology correlated with parallel biochemical and biophysical analyses with considerations of function will result in profitable advances in anatomy.

Great advances have been made in several directions during the last quarter of a century, and it is difficult even to catalogue them; but perhaps the best example of recent experimental trend in Zoology in U.K. and U.S.A. is the important advance in our knowledge and understanding of the nature of the nerve-substance and its conduction activities. Not many years ago (1934) John Z. Young discovered giant nerve-fibres, about 1 mm. in diameter, in the squid *Loligo*: these giant nerve-fibres have proved excellent material for a study of the structure and conduction activities of the nerve-fibres, about which we now have perhaps more information than about any other bodily function. They have not only allowed direct confirmation of previous deductions but have also made possible the investigation of many new aspects of the process. These nerve fibres have been studied with the help of various optical and other physical and chemical techniques as well as by histochemical methods and by the use of the Electron microscope.

It has long been known that when a nerve-message travels along a nerve fibre, the active region becomes electrically negative to all the neighbouring regions. In the resting condition there is a potential difference—the resting potential—between the inside and outside of the nerve-fibre: it has now been shown that potassium is present in much greater quantities (26-29 times) inside than outside, while sodium and chlorine are present in smaller amounts within the fibres than around them. During the passage of the nerve-impulse, the nerve membrane becomes freely permeable to all ions and an electric wave—the action current—flows between the active and neighbouring regions, and during this process, potassium leaks out of the nerve-fibres. The effect is compared to that of a membrane with selective permeability separating two electrolytes. Optical investigations of the nerve-fibre in ordinary and polarised light have shown the presence of longitudinal organization in the molecules composing the nerve-fibre.

The conduction velocity of the nerve-impulse is increased by (1) increasing the diameter of the nerve-fibres and thus reducing internal resistance and (2) by changing the characteristics of the membrane. The second method has been adopted in the vertebrates where each nerve fibre has a "myelin sheath", while the squid has adopted the first method of increasing the diameter of its nerve fibres. The conduction rate in the large fibres of the squid is about 25 metres per second—the same is the rate in the giant fibres of the earthworm which have a fatty sheath around them. In birds and mammals with a constant high temperature the speed may come to more than 100 metres per second. In mammals each nerve contains a spectrum of fibres of different diameters (in rabbit they vary from 1·8 to 18 μ) and conduction rates; the fastest fibres with a diameter of 18 μ (including a sheath of 5 μ) are those that go to muscles, the messages concerned with touch are carried at 25 metres per second, while fibres concerned with pain conduct only at 1 metre per second.

It has been found that when a nerve is severed, the nerve fibres of the peripheral part disappear leaving only the framework of the nerve composed of connective tissues and other elements, while the nerve fibres of the central stump remain in tact and put out new growths. Since each large nerve contains thousands of nerve fibres with different diameters as well as conduction rates and functional connexions, it is necessary for proper regeneration that appropriate connexions must take place between the central and peripheral stumps. Motor nerve fibres must join up with muscles and not with skin and so on. It has been found, however, that connexions are unfortunately made at random. Many wrong and some right connexions are made, and it is not surprising, therefore, that after severance of a nerve, the return of function is never completely satisfactory. There is poor co-ordination of muscle-movements and there are abnormal pains and unpleasant sensations. It is possible that there is some mechanism by which the incorrectly connected fibres are later removed, but this mechanism has not yet been demonstrated,