Survey of BIOLOGICAL PROGRESS

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BENTLEY GLASS

VOLUME IV

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Preface

Volume III of this series offered perspectives of modern biology which included the development of embryological concepts in the twentieth century; the trends in systematic botany which have brought into use a great variety of new developmental, biochemical and physiological, cytogenetic and genetic, morphological and paleobotanical characteristics; the relation of chromosomal alterations to animal evolution; insect chemoreception and its relation to behavior; and two surveys of regulatory processes, one of which dealt with the action of hormones on cells, the other with the regulation of respiration in plants. The current volume offers six quite different, yet in some respects related, views of important new areas in modern biology.

Parallel with Keck's review of "Trends in Systematic Botany" in Volume III is the first essay in Volume IV: Animal Taxonomy and the New Systematics. The author, Richard E. Blackwelder, is sharply critical of trends in the "new systematics" which to him appear to threaten the utilitarian function of taxonomy, that is, the unavoidable housekeeping activity of identifying and classifying species so that workers in all fields of biology will know their material. He would make a sharp distinction between taxonomy, a tool based simply on morphological distinctions, and the study of speciation, which is a part of the now dominating field of evolution. Whether many or few animal taxonomists will agree with the author that the application of conceptions of speciation to taxonomy has not been wholesome and has not been "universally accepted and not even widely practiced" I would not venture to say. That these ideas are provocative and worthy of the attention both of those who are taxonomists and of those who are primarily students of evolution, as well as of biologists in general, can be stated without fear of denial.

Roger Herriott has recently pointed out that we are now entering a new period in the annals of the understanding of disease, since we may now identify nucleic acid, in pure and isolated form as well as in the form of native viruses, as being itself an infective agent. H. Fraenkel-Conrat's separation of tobacco mosaic virus into its ribose nucleic acid and protein fractions and reconstitution of them, together with formation of hybrid virus particles from nucleic acid derived from one strain or species and protein derived from another, already constitute a modern classic of biology. In his essay he analyzes the properties of infectious nucleic acid, especially of the ribose variety.

C. H. Li's review, on the protein structure and biological activity of the pituitary hormones, bears a relation to the review contained in the last volume on the action of hormones upon cells. The outstanding recent work done by Li and his collaborators, and by a number of other groups, on the pituitary hormones constitutes another fascinating chapter of modern molecular biology. The presence in the polypeptide hormones, intermedin and ACTH, of a particular identical sequence of amino acids is a remarkable discovery, foreshadowed in Vincent du Vigneaud's discovery of the near-identity of the molecules of oxytocin and vasopressin isolated from the posterior pituitary gland. These common amino acid sequences remain unexplained in terms of protein and polypeptide synthesis under gene control, although they help us to see why different hormone molecules may have dual and overlapping activities. Also of special interest is the fact that the forms of a single protein hormone—for example, the pituitary growth hormone—when isolated from different species of animal, differ in molecular structure, although they are indistinguishable in activity. The relation of structure to function is being rapidly extended to the molecular level in current biology.

In the analysis of animal behavior few subjects assume greater significance than territoriality, dispersal from the point of birth, and the size of the home range. New methods are being evolved for the study of these aspects of life, particularly as they exist among small mammals. L. E. Brown not only surveys the methods, new and old, and points out their usefulness and their limitations, but also discusses the nature of the factors that affect the extent of the home range—factors such as climate, sex, preference for particular kinds of habitat, stresses, and periodic cycles of activity.

The exhaustive review of the biochemistry of energy transformations in photosynthesis, by André T. Jagendorf, covers some of the most important advances in all of recent biology. The work of Melvin Calvin on the path of carbon in photosynthesis, on quantum conversions, and on energy migration in the chloroplast has earned him a Nobel prize in chemistry this year. The work of Daniel Arnon, who with others established the possibility of conducting photosynthesis in isolated chloroplast systems and who demonstrated the occurrence of photosynthetic phosphorylation, is a towering achievement. The experiments of R. Hill and of Jagendorf have greatly clarified our understanding of portions of the photosynthetic system; and the studies of C. S. French, B. Kok, and others have thrown light on the puzzling roles of the accessory pigments which cooperate with chlorophyll *a*. The work with bacterial chromatophores, by a number of scientists, has afforded a simpler system for analysis and has illuminated the nature of electron flow and of photophosphorylation in photosynthesis. The extraordinary number of distinguished workers in this biological field and the rapidity with which new discoveries are made sufficiently account for the difficulty so widely felt by biologists of keeping abreast of new advances. Jagendorf's review should be of great service. Its very length and abundance of information testify to the growing wealth of knowledge about what is indubitably one of life's most significant processes. These pages delineate the rapid steps toward an ultimate understanding of the process whence flows all food. Artificially produced and controlled photosynthesis seems to lie within human grasp.

The final article in this volume is a chronicle of another magnificent biological achievement of this past quarter century: the discovery and application of antibiotics. Vernon Bryson treats the subject from a point of view usually slighted. Many practical uses of antibiotics exist, quite apart from their uses in therapy. They have transformed biological laboratory methods, stimulated the growth of animals, altered chromosome behavior, and illuminated scientific problems in such fields as immunity and genetics, where antigen-antibody relations and mutations to resistance are of basic importance.

Of the six reviews in this volume, four represent highly active fields of molecular biology, two come from other subdivisions of biology. One of these two deals with the fundamental problems of identifying and classifying living objects. The other represents the broad and increasingly experimental field that deals with organisms as wholes, and as subunits in populations, communities, and ecosystems. Except for the lack of any consideration of evolutionary studies, the six articles are a fair sample, a reasonably just representation of the activity going on in modern biology. Though heavily dominated today by the spectacular advances being made in molecular biology, biology is nevertheless not restricted to biophysics and biochemistry. Especially those parts of the science which deal with whole individuals and their relations in time and in space (evolutionary and ecological studies) stand apart. Together with the necessity of identifying the species in the stockpile of living organisms, they look at life from a different peak. There is evidence of a severe split among biologists along these lines. The molecular biologist draws closer and closer to the chemist and the physicist, sees less and less of the organism and its place in the sun. What is needed, perhaps, is an ecological viewpoint (relation of system to environment) at *every* level of organization: the molecular; the cellular; the tissue, organ, and organ system levels; the individual; the population; the community; the ecosystem. Into this let us weave the time dimension, again at each level, from chemical process to evolutionary change. We would then indeed secure a perspective of incomparable grandeur—a view of life in its fullest extent.

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Animal Taxonomy and the New Systematics

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I. TAXONOMISTS

From the earliest days of taxonomy, whether or not we take 1758 as the starting point, taxonomists have struggled to make known the kinds of animals that inhabit the earth. The number of people involved in this work over the span of 200 years runs into many thousands. Among them were carefully trained scientists, self-trained professionals, experienced amateurs, and dilettantes. Among these, and probably without much correlation of grouping, were men of wide biological knowledge and understanding, very one-sided men of strong opinion, and men with no interest in theories or anything except the building of collections. It would be completely unrealistic to believe that all these people held the same views on any aspect of systematics or even of science.

It would probably be impossible to determine for the entire group of taxonomists whether the professionals or the amateurs had done the best work in the long run. Certainly some excellent work has been done on both sides. But it is certain that in number of workers, the amateur group is far ahead. Of what interest this may be to modern taxonomy we shall presently see.

Taxonomists have doubtless had many motives for their studies. Some may have been trying merely to increase their own importance as authors of new species or owners of large collections. Some may have been trying to throw light on the disputed biological theories of their time. Only one thing seems certain, that most taxonomists have worked ahead on the describing of the kinds of animals and have taken no part whatever in discussions of principles, theories, or the meaning of the diversity they recorded.

In retrospect, it seems easy for the biologist of today to reason that in the early days there was no unifying theory to account for the diversity and that therefore the taxonomy was in effect without purpose. Those who believe this look upon Darwin's theory of evolution as the unifying concept which was to give meaning to classification. But these same persons sometimes marvel at the astonishing fact that we can now see that the theory had practically no effect upon taxonomy. It is impossible to tell by a man's taxonomic work whether he believed in evolution or even knew about it. Even today, wonder is expressed at this failure of taxonomists to be affected by the theory. Those who wonder do not seem to see that the reason is obvious.

For comparison, the related field of comparative anatomy was greatly affected by Darwin's ideas, and its subsequent history was different from that of taxonomy. Before Darwin, comparative anatomy, now often called morphology, primarily served to discover facts of the structure of animals for use by the taxonomists. In the theory of evolution the anatomists sensed an opportunity to do more than this; they saw the possibility that information on the structure and development of animals might give the basis for proof of the new theory or provide the data for showing the course of the phylogenies.

Accordingly, the morphologists experienced a revolution. Their work was given direction and a definite goal, and they spent nearly half a century trying to unravel evolution by means of structure. It has often been forgotten that this effort ended in failure. Anatomy and embryology were not able to explain or prove evolution, even after the fields became largely experimental, because they were trying to infer from static phenomena (the intimate structure of the body) the dynamic relations in a course of events (organic evolution). This was a hopeless task, as pointed out by Raymond Pearl, in spite of the fact that it was bolstered by certain plausible ideas that were mistaken for natural laws. Among these was the idea of ontogenetic recapitulation of phylogeny and the belief in an objective basis for homology. It would doubtless be more accurate to say that the search for morphological proof of evolutionary theory was the result of the belief in these things. As Pearl remarks (1922, p. 585), "at the best they were only imperfect expressions of certain inherent necessities of the philosophic principle of organization, and at the worst just plain buncombe."

This left anatomy in the place it had occupied before Darwin. It is still the major source of comparative data about animals, in spite of the growth of other data fields such as genetics, biochemistry, and ecology. It is doubtful if anatomists (and here we mean animal anatomists, not students of the human body) would admit this failure in their history, but recent writers on evolution leave little doubt about it. The field is still one of those with a large amount of work remaining to be done, although there will have to be a switch of interest from the vertebrates to the invertebrates.

Darwinism thus had a very great effect on comparative anatomy, because the latter attempted to find the explanation of the theory. Pearl does not claim that taxonomy also tried to explain evolution, but many other writers seem to feel that there should have been some such effect if taxonomists had been awake to the implications of the theory. The error in this reasoning is the assumption that taxonomy, too, set out to explain evolution. Although some persons grouped taxonomists with the anatomists in this, the fact is that taxonomy was practically unaffected by Darwin's theories or the later developments. This was actually inevitable, because taxonomy was and still is the study of the groups found among animals; it is not the study of how the groups came to be. Any knowledge of this latter subject will be of great interest to taxonomists and will add to the data available to them, but this knowledge of mechanisms is not the goal of the study of taxonomy.

More recently, the biologists who have concerned themselves with the mechanisms of evolution, building an important new field of speciation and population dynamics, have again expected the new ideas to have a revolutionary effect on taxonomy. They have, in fact, claimed that this has occurred. The truth is that there has been no revolution because taxonomy still studies the groups rather than the mechanisms by which they may have arisen.

The claim has been made in a manner reminiscent of modern propaganda methods. Although possibly unconsciously, it has involved authoritative repetition of catch phrases and derogatory labels, which have seemed to carry a great weight of opinion and modern thinking. Some people have had neither the inclination nor the time to probe beneath the surface for motives or inconsistencies.

One of the effects of these techniques, perhaps their principal effect on taxonomists, has been to place real taxonomists on the defensive among biologists even more than they were 20 years ago. The most authoritative recent pronouncements on the status of customary or classical taxonomy have given the clear impression that the subject is "worked out," a relic of a bygone era, that it is not a truly biological or even scientific pursuit, and that the failure of an individual taxonomist to espouse the new ideas marks him automatically as a mere "cataloger" and his work as "meaningless."

These imputations, no matter how often repeated, are nothing more than the result of limited experience among the million kinds of animals, combined with zeal for some pet ideas and a repeated failure to use language with sufficient care to avoid widespread misunderstanding. There is very little confusion in taxonomy—the confused groups are an insignificant part of the total—but the compounding of errors of language and meaning has brought real confusion to the arguments of those who condemn the work of the "classical" taxonomists.

It will be the purpose of the present discussion to point out these misleading labels, to question the validity of the catch phrases, and to suggest ways to clarify the current view of what systematics is and what it can accomplish.

In the meantime, careful and conscientious taxonomists have a heritage and a future to be proud of. They have accomplished much in the face of fantastic complexities. Their errors and failures are those of human beings, and one of their continuing chores is to correct their own errors whenever new evidence warrants. The work of every taxonomist will be judged by future generations. There is no single channel in which advances will be made and no single arbiter of what is good work.

II. THE GOALS OF TAXONOMY

In Linnaeus' time the few taxonomists that were working on animals faced the problem of distinguishing and "making known" the few thousand kinds that were available to them. As work progressed, more and more areas of the world were explored, more and yet more animals were discovered in a rapidly increasing number of very distinct groups. No matter how many species were described, there were always more awaiting treatment. It is doubtful if new species have ever been described as fast as they were collected, so that large museums often contain thousands of undescribed ones.

Some groups of animals were more available or more popular with taxonomists than others, with the result that the work of finding and describing the kinds from all over the world progressed more rapidly in these groups. It is believed that there are now few kinds of birds still to be discovered, whereas new kinds of nematodes and mites are being described in larger numbers now than ever before. Popularity has no fixed relation to biological importance, and it must be recognized that the job of making known the animals of the earth is so far from finished that we don't yet know even the general pattern of relative abundance of all the different major groups.

The recent pronouncement by Mainx (1955) that "this work has been completed" is so far from true that even his qualification, "at least for certain groups of the animal and plant kingdoms," is inadequate to justify such a statement. Probably the only such animal group is the class Aves, which is only one of about a hundred classes, not one of the largest and certainly not one of the most diverse.

It would be a mistake to leave the impression that recognition and description of new species is the only or even the primary purpose of taxonomy. This is only a prelude to the major job, which is classification. Classifying the kinds is generally recognized as part of the job of taxonomy, but it is often overlooked that the more important and vastly more difficult part of taxonomy is the job of keeping track of all the information discovered about each species. With at least a million kinds of animals to deal with, it is a colossal job to keep track of hundreds or thousands of facts about each kind, keep them available in a way that will permit extrapolation from them, and arrange them in a system that will permit addition of any amount of additional data at any time.

The first requirement for this is a system of classification by means of which the kinds can be kept in order. An alphabetical file would admirably serve this purpose, but taxonomists have found that a great deal of additional advantage can be obtained if animals with like features are grouped together into classes on various levels. This was no accidental discovery. It was one of the ways known to the ancients for handling and increasing knowledge. It is a normal part of the subject matter of Major Logic.

The logical devices of definition and classification have been used by biologists to great advantage. Classification not only simplifies the filing of multitudinous data, it also serves to indicate new correlations among the data. It provides the basis for most hypotheses about the phylogeny of animals. It forms the platform on which most theories of speciation and evolution are built. Without the existing classification, the study of evolution, genetics, ecology, and other fields would have been impossible. Without extensions and refinements of the present system, many fields of biology would be retarded in the future.

III. THE BROADER TAXONOMY

From the very beginning of modern biological classification, from the time of Linnaeus, animals were classified principally on the basis of visible structural features. Various methods were devised for assessing the relative usefulness of different structures for this purpose, and occasionally other sorts of attributes were also employed. It was found necessary to preserve specimens for later comparison, as verbal descriptions and even pictures were not always adequate. The only attributes that can be readily preserved are the structural ones, and it became nearly universal to rely on such structural characters in taxonomy.

When other attributes seemed to offer additional material for comparisons, it was usually found that these were correlated with structural features. This strengthened the taxonomists' view that structure is an effective key to most inherent attributes.

After the publication of Darwin's works, it was expected that taxonomy would be greatly changed by the new ideas. Again, in the decade after 1938, the publications on The New Systematics led to expectation of another revolution in the basis of taxonomy.

Long after the publication of Darwin's *Origin of Species*, astonishment was expressed at the fact that the classifications of the taxonomists were not much affected by the evolutionary ideas. More than 15 years after The New Systematics was announced, there is a great reticence to admit that the classifications of the taxonomists have again gone unchanged. Were the same factors responsible for these two unexpected developments? The answer has been overlooked by the evolutionists of both periods, and a different revolution in taxonomy and classification also has been overlooked by them. It occurred in the two decades before The New Systematics.

In the third and fourth decades of the present century an important trend was started in the study of the largest "groups" of taxonomic subjects, the insects and the invertebrate fossils, and was felt in other groups as well. As these two include over three-fourths of all known animals, the trend was of substantial importance. Unfortunately, it has seldom been referred to, because it was not immediately recognized as a successful trend and was pushed from the limelight by later developments.

Beginning in the 1920's, an increasing number of professors taught that taxonomy and classification should not be based on a few key characters but on all available information, of whatever sort. This did not mean that equal weight was to be given to every feature,