responds with the one expressed in the foregoing. I take the liberty of quoting:

> I should say that the elementary course or courses in botany should always be synthetic. Fundamental in the synthetic presentation of botany I should say is morphology, for I do not believe that any effective work can be done without some knowledge of the structures involved. Then I should say that the morphological thread that runs through the course should string together the most important physiological phenomena as explanations of morphological structure. In fact, I would not regard any morphology as significant that could not be explained in terms of physiology; and on the contrary, I would not regard any physiology as worth while that could not be fitted into morphological structure. In other words, I can not divorce the machine from its work. Naturally in this statement ecology becomes merely a form of physiology. This would be my general notion as to the content of an elementary course in botany.
>
> What should be given afterwards depends entirely upon the size of the botanical staff and its differentiation in interest. After the synthetic course, I think there should be opportunity to develop morphology, physiology, ecology, etc., independently. Of course, experimental morphology should come in as a hybrid between morphology and physiology. I should say that genetics would come after almost everything else.

M. A. CHRYSLER

UNIVERSITY OF MAINE,
ORONO, ME.

EXPERIMENTALISM IN ZOOLOGY

THE followers of science have shown at all times a marked disposition to readjust the style of their intellectual apparel to new conditions, and in this respect the zoologist is no exception. There are some among us who still prefer to appear in the ancient and respectable mental garb of the systematist, others who adorn themselves in the Empire costume of the comparative anatomist, and still others who have put on the Victorian attire of the embryologist. But he who wishes to be truly modern is content to clothe himself in only the scanty raiment of the experimentalist. A glance at this last class shows it to be made up of the young and the would-be-young. This latest style, unlike its predecessors, is not a creation from Paris or from London, but is largely a home-product, the result of what its inceptors would call internal factors, those conveniently vague things about which we know so little. Although we are not wholly clear as to the process by which we have come to be experimentalists, we are convinced that it depended upon something like an irreversible reaction and that we have come to stay.

The experiment, however, is by no means a modern invention. As early as the thirteenth century Roger Bacon was proclaiming to unsympathetic scholars its soundness as an instrument for the discovery of truth. In his opus majus he maintains that

> There are two modes of knowing; by argument and by experiment. Argument concludes a question; but it does not make us feel certain, or acquiesce in the contemplation of truth, except the truth be also found to be so by experience.

And still farther on in the same work he declares that

> Experimental science, the sole mistress of speculative sciences, has three great prerogatives among other parts of knowledge: First, she tests by experiment the noblest conclusions of all other sciences; next, she discovers respecting the notions which other sciences deal with, magnificent truths to which these sciences themselves can by no means attain; her third dignity is, that she by her own power and without respect of other sciences, investigates the secrets of nature.

Although Roger Bacon's utterances in favor of experimental science were made over three centuries before the days of his illustrious fellow countryman, Francis Bacon, and at a time when such utterances were dangerous, they were by no means the earliest expression of the experiment. Some sixteen centuries before Roger Bacon's time, Aristotle wrote in simple language an account of what is probably the earliest recorded biological experiment. It deals with the physiology of the senses and reads as follows:

> By crossing the fingers a single object under them appears to be two and yet we do not say there are two; for sight is more decisive than touch. If, however, touch were our only sense, our judgment would declare that the single object is two.

Thus Aristotle employed the experimental method for the discovery of truth. With all this history behind us it may seem strange that we have been so slow in appreciating the significance of this method. But it must be remembered that the biological sciences, unlike physics and chemistry, have had an enormous volume of descriptive material to handle, and that it was only after this task was well under way that really fundamental problems could be attacked. It is also to be kept in mind that such sciences as chemistry and physics have begun to yield only recently results and methods which have been of direct service to biology. Viewed from this standpoint the whole course of development of the methods employed in biological research is a natural one, and, though we may not fully appreciate all the steps by which we have reached this new road to discovery, we are persuaded that the course we have taken is the result of the untrammeled growth of our science.

With the acceptance of the experimental method as a part of the means of biological research comes the responsibility of training students in the new way of work. To those of us whose zoological apprenticeship centered round the paraffin bath and the microtome, this is no simple proposition. With little physics, less chemistry, and almost no mathematics we find ourselves poorly equipped to meet the new emergencies. One of my colleagues trained in this fashion seems never to appreciate the fact that there is a third dimension in space, and in my case mathematics is metamorphosed from one of the most exact forms of expression into one of the most inexact. Although we may take consolation in the fact that even so illustrious a physicist as Faraday was essentially unmathematical, we can not look upon the deficiencies that I have just pointed out without recognizing that they are real shortcomings. These defects in our early training can not be ascribed to lack of reasonable foresight on the part of our teachers or even to our own idleness. They are the natural result of the prodigious rate at which our science has been growing, a rate that made it impossible for even the best informed of a generation ago to predict the needs of to-day. This is true not only of the present, but also of the past. Darwin's early training was that of a physician, and Huxley actually went into medical practise. Both men in their early days never entered a biological laboratory, for the obvious reason that no such institution existed, and both regretted their educational deficiencies.

Inadequately trained ourselves, how are we to meet the problem of training others in the new directions? The situation seems to include to a certain degree the impossibility of lifting oneself by one's boot-straps. But I suggest that while tugging at the straps a slight jump will lift us a little, and the jump that seems to me to be advisable is to recommend that our students pay more attention to chemistry and physics, sciences in which the experimental method is well developed and which are yielding results that are applicable more and more to the fundamental problems of biology. Such a training, when rigorously pursued by a student with a clear understanding of its relations to biological work, is bound to be richly productive as soon as it is turned in the appropriate direction.

But physics and chemistry are, in my

opinion, only part of the preliminary scientific training for these new lines of work. The zoologist is continually confronted at least in his study of the higher animals with those complicated conditions that we recognize in our own mental states. That such conditions exist in varying degrees in the lower animals no one can deny. The questions that arise concerning them are what is their nature and to what extent are they present in the lower forms. These problems are psychological, and I should, therefore, regret to see a prospective zoologist omit from his preliminary training a reasonable grounding in this field of investigation. In one way, however, I regard psychology as less important for the beginner than physics and chemistry. In it the experimental method is less completely developed than in the two sciences just named. In truth, it is in this respect much like biology itself and in need of help especially from the side of chemistry. The genius of Helmholtz seems to have had such an overwhelming influence on most psychologists that they have been content to study almost exclusively the physics of sensory phenomena to the neglect of other psychological fields, such as the chemistry of the central nervous states. But though psychology may have its own difficulties, I nevertheless regard it as a field that should be included in the general training of every student who aspires to a broad-minded and productive scholarship in zoology. With the botanist it may be different. He sometimes counts himself fortunate to have escaped the problem of mind, but to my way of thinking this very problem is one of those elements which makes zoology so intensely interesting.

But the young zoologist trained in the experimental method by physics and chemistry, and heedful of the fact that the material of his investigation may exhibit among its characteristics some of the phenomena of intelligence, must still assume a very different attitude toward his work from that which most of us were accustomed to in the laboratories of twenty or thirty years ago. Those were the days of morphology, when the visible structure of the organism was all important and the problem of the homology of various parts, the integrity of the germ layers, and so forth were of foremost interest. The attitude of the average student of those days was essentially anatomical, and the anatomical conception of an organism was that of a standing motionless object. Immensely important as this view was, it lacked the really essential characteristic of the living thing, its incessant activity. The new view, on the other hand, includes just this feature. The student of thirty years ago was concerned with methods of preserving animals and he never felt safe until his catch was in the alcohol jar; the modern student is all alert to keep his stock alive and he consigns it to preservatives with funereal rites. This change in attitude is part and parcel of the new growth and is working a slow but steady revolution in the equipment of our laboratories.

With all this overturning and revolution going on in our advanced work, what can we say of our elementary instruction. Here we are supposed to keep to those aspects of the subject that are well established and that are not open to fundamental revision. Moreover, in this direction the procedure of lecture work and laboratory routine is well established in text-books and the like, and the instructor, in keeping in these well-worn paths, is on what seems to him to be safer grounds. But even the elementary courses, in my opinion, must not be devoid of promising outlook. They should include a reasonable amount of the new work. But to accomplish this without printed guide or previous training is not an easy task for the older teacher. Here is perhaps the point in the new work at which the young and the would-be-young are most clearly differentiated. To me the contemplation of this subject is embarrassing and I pass it by. But for the encouragement of those who are in my plight, I must add a word from my own experience.

I believe that some of us who are older teachers fail to appreciate, from our disinclination to give the matter a trial, how easy it is to arrange elementary courses, especially the laboratory exercises in such courses so as to illustrate animal activities by the experimental method. I know that in my own experience a laboratory course which I gave to high-school teachers a year or so ago was in this respect immensely illuminating. I had no idea that the new methods could be applied so directly. To give some notion of the nature of the work that can be carried on in such courses let me name some of the exercises that we found serviceable: the effects of light on the movements of planarians, earthworms, mealworms and the larvæ and adults of flesh-flies; the combined influences of gravity and light on the movements of fruit-flies; the effects of odorous substances on the movements of earthworms and on the gathering of fruit-flies; the feeding reactions of planarians, catfishes and toads; the means of locomotion in earthworms, mealworms and snails; the reactions to stimulation in paramæcium, and its rate of reproduction; regeneration in planarians and earthworms; heredity in fruit-flies. These and other like exercises were found surprisingly applicable to elementary work and have encouraged me to believe that practise in experimental work may well be introduced into elementary courses.

Such work, moreover, is not without its beneficial influence on the teacher. No two animals are ever alike in their reactions, and in this respect they differ vastly more than they do in their structure. Although each exercise can be made to lead to a general conclusion for all students concerned, the details of the work soon come to be individual. The instructor is called upon, therefore, rather as an adviser in method than an authority in facts, and from this standpoint his attitude toward his work is much more natural than what it often is in purely anatomical exercises. Woe be to him if he begins to tell what a given animal at a given moment will do! I know of no elementary biological exercises that are better adapted than these to develop independence and originality in the student and to reduce the instructor to his true position, that of a student of greater maturity than those about him. As a result of this experience, I look with great hope on the steady introduction of experimental exercises into our elementary work. Certainly the conception of an animal that is gained from work such as this is much nearer the truth than that which we have been instilling through alcoholic specimens.

But if these are the realities of the experimental method, what are its vanities? I think the chief pitfall that besets the experimentalist is apparatus. What a strange allurement this feature of the situation has for us! What can be more pleasant to the eye than beautiful apparatus in glass cases or a grand array of delicate contrivances built up upon a table! And they are always so interesting to the visitor! But I shall never forget the comment of a friend of mine who on looking over an extensive device of my own construction finally remarked that the justification of such work as biological did require a goodly supply of brass. But if apparatus is our pitfall, we must remember that many of the pioneers in the new movement have already demonstrated to us fundamental results by means as strikingly simple. To Loeb the problem of the universe is soluble in a finger-bowl; to Morgan in a milk-jar; and we must never forget that the importance of a result is often inversely proportional to the complication of the apparatus by which it was attained. With these examples before us, let us avoid the pitfall of bright glass and shining metal.

I have entitled this paper "Experimentalism in Zoology" and I have nowhere used the term experimental zoology. This has been intentional, for I do not believe in this term. The new movement does not mean a new province in zoology; it is a new method of attacking old problems. It will, of course, lead us to new fields, but it is method rather than matter. We are not exchanging old lamps for new but burning the old lamp in a new way. I therefore resist the term experimental zoology. We are all still zoologists and we have simply added to our equipment the experimental method. As each one, old or young, realizes the significance of this method and the great power that it puts in his hand, he will adopt it in proportion to his needs and abilities. In this way it is gradually pervading the whole fabric of biology from the realm of the systematist to that of the ultramodernist. Our times are full of such changes. To-day we men vote, to-morrow our women will vote. Let all such changes come as natural growths.

G. H. PARKER

HARVARD UNIVERSITY

THE PRODUCTION OF RADIUM, URANIUM AND VANADIUM ORES IN 1913

PROBABLY no other mineral is mined which has so large a hold on public attention and at the same time has so small a total monetary value as the uranium minerals. This interest is, of course, due not to the minerals as such, nor to the uranium they contain, but to the accompanying radium, which is found only with uranium. Hitherto the interest in radium, though lively, has been largely academic, on account of the marvelous qualities which it displays when compared with better-known elements. Toward the end of 1913, however, public interest became almost feverish, owing to the apparent cures of cancer wrought by the application of the gamma rays given off by radium.

Uranium minerals were produced in commercial quantity in the United States in 1913, as shown by preliminary statistics gathered by Frank L. Hess, of the United States Geological Survey, only in Colorado and Utah, and although during the year some pitchblende was mined in Colorado in the Belcher & Calhoun mines, only a few pounds were sold, though 50 dry tons of low-grade material carrying 1.49 per cent. uranium oxide (U_3O_8) was shipped to France from the Kirk mine. This had been mined a previous year. Carnotite, a yellow powdery or waxy mineral found in the sandstones of the high plateau between the Rocky Mountains of Colorado and the San Rafael Swell of Utah, south of the Book Cliffs, furnished the whole production.

Carnotite, as the word is ordinarily used, is a potash or lime uranium vanadate. Several vanadium minerals occur with the carnotite, so that in mining for uranium a great deal of vanadium is also obtained. At Newmire, San Miguel county, Colo., one of the vanadium minerals, roscoelite, occurs practically free from uranium and is worked for vanadium alone.

The total mine shipments of uranium and vanadium, as shown by preliminary figures, were equal to 2,140 tons of dry ore, carrying an equivalent of 38 tons of uranium oxide. The vanadium in carnotite ores shipped, together with that which is estimated to have been produced from the Newmire district, was equivalent to 914 tons of vanadium oxide. These quantities are equal to about 32.3 tons of metallic uranium and 412 tons of metallic vanadium.