SCIENCE

FRIDAY, JANUARY 14, 1898.

CONTENTS:

MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

SOME OF THE FUNCTIONS AND FEATURES OF A BIOLOGICAL STATION.*

I HAVE a few considerations to offer on a subject not quite new, but perhaps not without some interest, to a Society of Naturalists. The subject may be stated in the form of a question: What are some of the more essential functions and features to be represented in a biological station? This question is one that may fairly claim the attention of a society organized for 'the discussion of methods of investigation and instruction, and other topics of interest to investigators and teachers of Natural History; and for the adoption of such measures as shall tend to the advancement and diffusion of the knowledge of Natural History.'

I know of no other organization in this country in which the different sides of biology are more fully and widely represented, and no other in which the discussion of such a question as I have stated has been more explicitly invited.

The question before us, as you perceive, is one of ideals, something which we can construct without the aid of an endowment, and probably without any permanent loss of protoplasm. And yet, what I have in mind is not wholly imaginary, for it has

*Address of the President of the Society of American Naturalists prepared for the Ithaca meeting, 1897, but not delivered, owing to the unavoidable absence of the writer.

some basis in experience and in acquaintance with some of the best models.

Let us, first of all, try to get at some general principle which may serve to guide our judgment of ideals, and by the aid of which we may be able to formulate an answer to the question proposed.

As all will allow, ideals are absolutely indispensable to progress, and always safe provided they are kept growing. Like all biological things, live ideals originate by germination, and their growth is subject to no limit except in mental petrifaction. Growth and adaptability are as natural and necessary to them as to living organisms. Here we have, then, an unfailing test for the soundness or relative merit of ideals. Seeds may be kept for years without sensible change or loss of power to germinate. But it is because they are kept, not planted and cultivated. Once planted, they must grow or rot. So it is with ideals. The unchanged ideal that we sometimes hear boasted of is at best but a dormant germ, not a plant with roots and branches in functional activity. If an ideal stands for anything which is growing and developing, then it must also grow, or be supplanted by one that will grow. It is easy, of course, to conceive of ideals a hundred years or more ahead of possible realization; but such ideals could have no vital connection with present needs, and long before the time of possible realization they would cease to be the best, if the best conceivable at the start.

We are here, then, concerned only with ideals rooted in experience and continually expanding above and in advance of experience. The moment growth ceases, that moment the work of the ideal is done. Something fails at the roots and you have waste mental timber to be cleared away as soon as possible to make room for the new seed.

Let us here take warning of one danger to which we are all liable—the danger of adopting ideals and adhering to them as finalities, forgetting that progress in the model is not only possible, but essential to progress in achievement. The danger is all the greater in the case of ideals lying outside our special field of work, which we are unable to test and improve by our own efforts. The head may thus become stored with a lot of fixed mental furniture, and the possessor become the victim of an illusion, from the charms of which it is difficult to disenchant him. He falls into admiration of his furniture, taking most pride in its unchangeableness. It was, perhaps, the best to be found in the market at the time of installment, and he finds pleasure in the conceit that what *was* the best is and must remain the best. He sees new developments in the market, but his pride and inertia content him with the old. The illusion now takes full possession of him, and every departure from his own ideals seems like abandonment of the higher for the lower standard of excellence. His conceit grows instead of his ideals, and every annual ring added to its thickness renders it the more impervious.

Can any one say he has never met this illusion? Then a warning may have more pertinency than I should have ventured to claim for it.

To conclude these introductory remarks let me again emphasize the all-important qualification of the sound ideal and name the prime condition of its usefulness. The qualification is vitality and the capacity for unlimited growth and development. The condition is absolute freedom for growth in all directions compatible with the symmetrical development of the science as a whole. Please remember that the question of means does not now concern us. We must first get at principles, leaving details of execution to be worked out afterwards in harmony therewith. No one can foresee what means may be found, and it would be a waste of time to try to decide what should be done under this, that or the other set of conditions. If we know our ideal we know the direction of effort, and through the effort the means are eventually found.

It will help us in the formulation of our ideal if we glance for a moment at the ideals that have found most favor. The best models of marine laboratories ten years ago all agreed in making research the exclusive aim and in limiting the work to marine forms. In most cases the work was still further limited, embracing only marine zoology, and often only a small portion of that field. The idea of representing all branches of even marine biology was seriously entertained nowhere except at Naples. Remembering that marine laboratories were first introduced only about a quarter of a century ago, we are not surprised at these limitations. Even the narrowest limitations were extensions beyond what had been done before. The Naples Station itself began as a zoological station, and still bears the name *Stazione Zoologica.* But the earlier ideal was not long in expanding so as to include both physiology and botany. Will its growth stop there? I don't believe it will, but that remains to be seen.

Our own seaside schools, introduced by Louis Agassiz at Penikese and continued by Professor Hyatt at Annisquam, combined instruction with research, and this plan was adopted at Woods Holl in 1888. Instruction, however, was accepted more as a necessity than as a feature desirable in itself. The older ideal of research alone was still held to be the highest, and by many investigation was regarded as the only legitimate function of a marine laboratory. Poverty compelled us to go beyond that ideal and carry two functions instead of one. The result is that some of us have developed an ideal of still wider scope, while others stand as they began by their first choice.

We have, then, two distinct types of ideals, the one including, the other excluding instruction. One is preferred for being limited to investigation; the other is claimed to be both broader and higher for just the contrary reason, that it is not limited to investigation. At first sight, it might seem that we had exact contraries, but that is really not the case, for one type actually includes the other, and differs from it only by the more which it contains. The difference is, nevertheless, an important one, and as it divides opinion we must examine it.

To my mind, nothing but experience can settle such a question; but if reason and experience coincide, so much the better, so we may consider it from both points of view. On the basis of ten years' experience, and a previous intimate acquaintance with both types, I do not hesitate to say that I am fully converted to the type which links instruction with investigation; and I believe that many, if not most, of my colleagues in the work at Woods Holl, would now concur with me in the opinion that we could not wisely exclude instruction, even if made free to do so by an ample endowment. Some of you will probably feel that such a conclusion implies a step backward rather than forward. On which side is the illusion? Is it with those who have accepted their ideal second-hand and held to it unchanged from the time of its adoption, or with those who have been compelled to develop their own ideal from all that they could learn by actual experiment and study? Which is the broader ideal, and with which are the possibilities for progressive growth least limited?

In what consists the argument for limitation to research? I have yet to learn of a single important advantage which is necessarily dependent upon this limitation. Is instruction a burden to the investigator which interferes with his work? That objection is frequently raised, and it is about the only one that we need stop to consider here. That instruction interferes with investigation when it is so arranged as to absorb all, or the larger share, of one's time, no one will deny. But is it not easy to so divide the time that the investigator will find rest and improvement from the instruction he gives? Certainly it is possible, as we have fully demonstrated at Woods Holl, and that too with only the most limited means. With a laboratory open throughout the year, the investigators connected with it would scarcely feel a few weeks' instruction as an impediment. Not only have we shown that such an accommodation or adjustment of the functions is possible and tolerable even in our vacations, but we have also learned that there are some important advantages growing out of it which are impossible under limitation to research. To my mind these advantages far outweigh any and all objections.

The advantages I have in mind are not those of means for running the laboratory, which could be supplied by an endowment, but those which add directly to the progress of the investigator and to the advancement of his work. If important advantages exist in connection with instruction even where there is no endowment, which are not available even with an endowment, where instruction is excluded, we can readily make our choice of types.

I suppose no investigator, not even the most confirmed claustrophil, would deny that instruction compels thinking and improves ability to express ideas as well as to describe facts. So does writing, so does investigation itself. True, and if that is to their credit, it must be the same to instruction. But wherein is the advantage with instruction? Every teaching investigator can answer that; and the answer will be, that power of exposition can be acquired and perfected by class-work and lectures to an extent otherwise unattainable. In this we need no better example than Huxley. If rare powers of exposition are sometimes gained without teaching, as in the case of Darwin, that in no way weakens the position here taken, which is that teaching is the most effective method, not the only one, yet an essential one to the highest attainment.

One thing more on this point. Why do we place so high a value on investigation? Because it is the only way of advancing knowledge, and because it affords a most attractive field for the exercise of the mind. But if knowledge needs advancement, so does the investigator, and whatever contributes to the increase and improvement of his powers makes him the better investigator, and thus indirectly raises the quality and augments the quantity of his researches. Herein instruction plays a very important part, as becomes evident when we remember that with increase and specialization in science the investigator himself becomes more and more dependent upon the instruction which he draws not only from books and journals, but also directly from his colleagues and his pupils. Indeed, he may learn in this way much quicker and more thoroughly than by reading. and often a long time in advance of publication. That is an immense advantage realized in a variety of ways, as in lectures giving the more important results of work before publication; in seminar where the results of individual investigators are brought forward and discussed, while the work is still in progress; in journal clubs devoted to reviews and discussions; in direct intercourse with pupils, seeing with their eyes and working with their hands; in daily intercourse of thought and comparison of observations with fellow-workers, etc. Indeed, it may be truly said that no one stands in such close and pressing need of continual instruction as the investigator. No one else absorbs it more eagerly and copiously, and no one else can convert it so directly into the results of research.

Another advantage supplied by instruction must be mentioned here, for in it I see opportunities for development of far-reaching importance to research. It is lamentable to see so much energy available for research lost or ineffective for lack of proper directive coördination. The avalanche of modern biological literature consists too largely of scrappy, fragmentary, disconnected products of a multitude of investigators, all working as so many independent individuals, each snatching whatever and wherever he can, and then dumping his heterogeneous contributions into the common hodge-podge. How are we ever to extricate ourselves from such appalling confusion? The ambition to be prolific rather than sound is a peril against which we seem to have no protection at present. And yet, if I mistake not, there is a growing sentiment against such traffic in science, which will eventually make it plain that ambition in that direction spends itself in vain. A dozen or more dumps a year, with as many or more retractions, corrections and supplements, is only a modest-sized ambition. Conclusions are palmed upon the unsuspecting reader, and then, without compunction or apology, reversed from day to day or from month to month, or, worse still, in an appendix subjoined, so that it may be seen how little it costs to be prolific when one day's work cancels another.

It behooves us to find effective remedies as rapidly as possible. The correction would be complete if each worker could bridle his lust for notoriety and take the lesson of Darwin's industry and reservation into his laboratory and study. The outlook for such a millennial dispensation is not very hopeful, and our resources are few and very inadequate, but all the more deserving of attention. The great need is *long-continued, concentrated* and *coördinated* work. In a laboratory which draws beginners in investigation in considerable numbers it is possible to assign problems in such a way that the participants may work in coördinate groups, and the problems be carried on from year to year, and from worker to worker, each performing his mite in conjunction and relation with the others of his group. In this way energy would be utilized to the greatest advantage to science as well as to the individual. Even under the very imperfect conditions represented at Woods Holl, I have found it possible to put this idea into practice to some extent, and I have great faith in its efficacy. Herein we see another possibility of development realizable only through instruction.

But it is as important for independent investigators as for beginners to cultivate organic unity in their work. How shall the investigator hope to keep in touch with the multiplying specialities of his science? Here, again, I maintain that instruction is an indispensable means. Fill a laboratory with investigators and, if no instruction is provided, many of the more important avenues of acquisition will be closed and the opportunities for coördination of work will be of little or no avail. Investigators might work for months in adjoining rooms and never learn anything about each other's work, as every one knows who has worked in such a laboratory. How different in a laboratory, where instruction is so arranged as, without over-taxing any one, to bring the workers into active and mutually helpful relations, and enable them to draw from one another the best that each can give! Instruction in the various forms before indicated supplies just the conditions most favorable to interchange of thought and suggestion. It is just this feature of our work at Woods Holl to which we are most indebted for whatever success we have had.

I am aware that other points might be raised; but it is far from my purpose to run down all possible objections. It is enough to have indicated the grounds of my choice of types. It now remains to briefly sketch the general character and to emphasize some of the leading features to be represented in a biological station.

The first requisite is capacity for growth in all directions consistent with the symmetrical development of biology as a whole. The second requisite is the union of the two functions, research and instruction, in such relations as will best hold the work and the workers in the natural coördination essential to scientific progress and to individual development. It is on this basis that I would construct the ideal and test every practical issue.

A scheme that excludes all limitations except such as nature prescribes is just broad enough to take in the science, and that does not strike me as at all extravagant or even as exceeding by a hair's breadth the essentials. Whoever feels it an advantage to be fettered by self-imposed limitations will part company with us here. If any one is troubled with the question: Of what use is an ideal too large to be realized? I will answer at once. It is the merit of this ideal that it can be realized just as every sound ideal can be realized, only by gradual growth. An ideal that could be realized all at once would exclude growth and leave nothing to be done but to work on in grooves. That is precisely the danger we are seeking to avoid.

The two fundamental requisites which I have just defined scarcely need any amplification. Their implications, however, are far-reaching, and I may, therefore, point out a little more explicitly what is involved. I have made use of the term '*biological station*' in preference to those in more common use, for the reason that my ideal rejects every artificial limitation that might check growth or force a one-sided development. I have in mind, then, not a station devoted exclusively to zoology, or exclusively to botany, or exclusively to physiology; not a station limited to the study of marine plants and animals; not a lacustral station dealing only with land and fresh-water faunas and floras; not a station limited to experimental work, but a genuine biological station, embracing all these important divisions, absolutely free of every artificial restriction.

Now, that is a scheme that can grow just as fast as biology grows, and I am of the opinion that nothing short of it could ever adequately represent a national center of instruction and research in biology. Vast as the scheme is, at least in its possibilities, it is a true germ, all the principal parts of which could be realized in respectable beginnings in a very few years and at no enormous expense. With scarcely anything beyond our hands to work with, we have already succeeded in getting zoology and botany well started at Woods Holl, and physiology is ready to follow.

If, now, experimental biology could be started, even in a modest way, it would add immensely to the general attractions of our work; for it would open a field which is comparatively new and of rapidly growing importance. There are so many things now called 'experimental' that I must explain what I have in mind sufficiently to make the general purpose intelligible.

It is not the experimental embryology redundantly described as 'developmental mechanics' which is now in vogue; not laboratory physiology, even in its wider application to animals; not egg-shaking, heteromorphism, heliotropism and the like —not any of these things, but experimental natural history, or biology, in its more general and comprehensive sense. It is not the natural history of the tourist, or the museum collector, or the systematist, but the modern natural history, for which Darwin laid the foundation, and which Semper, Romanes, Galton, Weismann, Varigny, Lloyd Morgan and others have advocated and practiced to the extent of the meager means at their command. The plan which I should propose, however, has not, so far as I am aware, been definitely formulated by any one, although some of its features were indicated several years ago, when I proposed such a station in connection with the University of Chicago. The essentials of the plan were sketched as follows:

"Experimental biology represents not only an extension of physiological inquiry into all provinces of life, but also the application of its methods to morphological problems—in short, it covers the whole field in which physiology and morphology can work best hand in hand. * * *

"A lake biological station equipped for experimental work would mark a new departure for which science is now ripe. Such a station has nowhere been provided, but its need has been felt and acknowledged by the foremost biologists of to-day. There are no problems in the whole range of biology of higher scientific interest or deeper practical import to humanity than those which center in variation and heredity. For the solution of these problems, and a thousand others that turn upon them, facilities for *long-continued experimental study, under conditions that admit of perfect control, must be provided.* Such facilities imply, first of all, material for study, and that nature here supplies in rich abundance. Then a convenient observatory, with a scientific staff, is required. In addition, and this is all-important, there should be not only aquaria and plenty of running water, but also a number of ponds with a continuous supply of water, so arranged that the forms under observation could be bred and reared in isolation when necessary. Finally, there should be room for keeping land animals and plants under favorable conditions for cultivation and study. A station with such facilities as have been briefly indicated would furnish ideal conditions for the prosecution of research in nearly every department of biology, and especially in embryology and physiology." *

If such a station could be developed in immediate connection with the plant already under way at Woods Holl we might begin to realize what a biological station stands for.

We need to get more deeply saturated with the meaning of the word 'biological,' and to keep renewing our faith in it as a governing conception. Our centrifugal specialties have no justification except in the *ensemble*, and each one of them is prolific in grotesque absurdities, for which there is no correction in disconnection with the organic whole. But why talk of an organic whole which no man can grasp or make any pretension to mastering? Precisely that makes it necessary to talk and act as if we knew the fact, and as if our inability had not rendered us insensible to our need. Physiology is meaningless without morphology, and morphology equally so without physiology. Both find their meaning in biology, and in nothing less. What an absurdity was human anatomy without comparative anatomy, and comparative anatomy was only a much bigger absurdity until the general connection of things began to dawn in the conceptions of biology. Just think of a physiologist seriously proclaiming to the world that instinct reduces itself in the last analysis to heliotropism, stereotropism and the like. The whole course of evolution drops out of sight altogether, and things are explained as if the organic world were a chemical creation only a few hours old. The absurdity is no greater than for a geologist to

* Program of Courses in Biology, Chicago, 1892.

try to explain the earth without reference to its past history.

Think of a young morphologist, with all the advantages of the Naples Station at hand—yes, within the walls of that grand station—loudly sneering at Darwinism, and spending his wit in derisive caricatures of general truths beyond the horizon of his special work and thought. And shall we forget the physiologist whose philosopher's stone is the search for his ancestry among the Arachnids? Or the anatomist who reverses his telescope to discover that his science begins and ends in terminology? And could we, much as we might yearn for such a benediction, forget the omnipresent and omniscient systematist whose creed is summed up in priority?

The catholicon for crankiness has not yet been found, but in science there is but one cure where cure is possible ; it is exposure to the full and direct rays of the system as a whole. The application to the subject in hand is patent. The one great charm of a biological station must be the fullness with which it represents the biological system. Its power and efficacy diminish in geometrical ratio with every source of light excluded.

My plea, then, is for a biological station, and I believe that experimental biology would be the most important element in such a station. It is now possible to procure a favorable site, with land and fresh-water privileges, in close proximity with the Marine Biological Laboratory ; and with a moderate foundation to start with, the work could begin at any moment.

The project is certainly one of preëminent importance, and for a successful undertaking of that magnitude we need the coöperation of American naturalists. I bring the suggestion before you in the hope that it will enlist your interest and support.

C. O. WHITMAN.

RECENT PROGRESS IN AGRICULTURAL CHEMISTRY.

II.

THE methods of the chemical changes produced in the growth of plants have recently received an admirable study at the hands of Green. (Journal of the Royal Agricultural Society of England, Vol. 6, third series, part 4, pp. 635 *et seq.*) The chief object of Green's study is the reserve food materials of plants, but in conducting these investigations he studies carefully the chemical action on which the plant metabolism is based. The apparatus of the plant, which is active in vegetable metabolism, was studied microscopically and fully illustrated by drawings.

The source of chemical activity in plants is confined to certain small bodies which are imbedded in the layer of protoplasm or living substance which lines the cells of the plants. These small bodies are called chloroplastids or chlorophyll corpuscles, and it is to them that we must look for the actual constructive activity. These are comprised essentially of small masses of protoplasm which have a loose or spongy arrangement of particles forming a complicated mesh work. In the meshes of this spongy mass the green color known as chlorophyll is found. It exists principally in solution. The work which is done by the chloroplastid is very complex, but it is possible to distinguish to a considerable extent between the part played by the green coloring matter itself and that which is discharged by its protoplasmic framework. On account of the character of this material the air has ready access to the interior tissues of the leaf. It enters at the stomata and fills the intercellular spaces. This air contains the small quantity of carbon dioxid which is the fundamental material of plant metabolism. The water which is taken in by the rootlets of the plant contains various mineral and nitrogenous matters in solu-