It would be impossible in this all too brief review to fairly distribute credit and rightly award the laurel crowns to the long line of explorers, geologists and paleontologists who have wandered from the banks of the Ohio and Hudson to the great deserts of America, of Africa and of Asia, from the pioneer period of Jefferson to the present flourishing period of the U. S. Geological Survey under its fourth director, George Otis Smith, and the Geological and Paleontological Societies of America.

Let it be said that throughout its entire history, our survey rightly crowded and pressed as it has been with the demands for economical surveys, researches and publications, has held aloft the torch of pure science and generously sustained the closely interweaving sister sciences of paleontology and geology.

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THE POTENTIALITIES OF ENTOMOLOGY[1]

WHAT came to your minds as the most important potentialities of entomology when you first read this title, I do not know. If I belonged to the new school of educational psychologists, I would find this out by giving you questionnaires to fill out. But I have such an aversion for this parasitic method of absorbing information that I prefer to commit the crime of guessing rather than steal your time. I will guess that the economic potentialities were among the first to present themselves.

The economic potentialities of entomology have certainly impressed the public. Give us a few more insect outbreaks and importations and we will be as respectable in the eyes of the public as a steel corporation. The man of the street who used to question the advisability of letting men interested in bugs enjoy the same freedom as normal individuals is becoming rare. In fact if one of the public were to ask an entomologist for an excuse for his existence to-day he would soon find himself so embarrassed by the economic arguments that he would feel it necessary to apologize for intruding upon the earth during the age of insects and would have to end his interview by thanking the entomologist for permitting him to continue his existence. From present tendencies the day may come when entomologists will be more in the class of diplomats than scientists. They may be ministers biopotentiary who will arrange for the coexistence of man and insects and will take the necessary steps to see that the movement of man and his articles of commerce from one geographic region to another will not be attended by any serious biological embarrassment.

Some time ago I was called upon to give an account of myself to determine whether I was entitled to certain advantages that I had asked for. After making a case for my project and its scientific significance as best I could, I mention a by-product of the work which involved no real scientific ability at all, but which incidentally saved seventy thousand dollars worth of goods and a million dollars worth of business for a corporation that really didn't need either. This one reference to economic importance trumped all the rest of the case. Even though the judges themselves were scholars, they reacted more quickly to the language of our economic age than to the logic of science.

I realize very well the value of the economic card, and I know that it is usually the trump, but I am not going to play it this time. I take it for granted that we are all aware of the economic potentialities of entomology, but I wonder if we give enough thought to certain other potentialities? Do we consider the potentialities for scholarship and culture?

I have a friend who is a business man of ability, and it happens that entomology has considerable economic importance in his field. In discussing research in entomology he once made the statement to me that he could not conceive of any one doing research work in entomology who did not have, directly or indirectly, as his ultimate aim some economic application of his work. This is not an unusual attitude, not only toward entomology but toward any branch of science. There seems to be a general feeling on the part of the public that a scientist must justify his time in the laboratory on the basis of the economic importance of the results that are to come from the work he is doing.

The public has come to have the attitude of the professional beggar—it expects something from everything that a scientific man does. But the public isn't entirely responsible for this view-point. We have schooled it in this attitude. We apologize for work that is undertaken from the standpoint of original scholarship by saying that no one knows what economic importance the results may have at some future time. Why not justify such work on the grounds that the results sought after are significant in the realm of knowledge, rather than try to make an economic case out of it by some stretch of imagination? I am of course ruling out all work that is designedly economic. Society is rightly entitled to economic benefits from such work, and I may add,

[1] The annual public address by invitation of the Entomological Society of America, delivered on December 28, at New York.

parenthetically, that it usually does receive them from all scientific research. I am simply making a case for scholarly scientific research on the basis of scholarship itself.

Society does not require an artist to justify a great painting on the grounds that those who look at it will thereby be able to earn more money or that they can save money by looking at it. If the artist can execute a masterful depiction of some beauty of nature, some great human emotion, or some great conception of the mind, society accepts his contribution as such. Poetry is not judged as to whether its lines are applicable to sales talk or whether the study of it will make or save money. There are at least a few people who can find time to look at pictures and read poetry for the satisfaction they can get out of them—because it makes their lives richer than they were before.

What economic justification is called for when a research program is carried out to prove significant facts that open up a new world to human thought? A problem is well conceived, a working hypothesis is formulated that calls for the determination of certain unknown quantities in an obscure field. The experiments are executed with ingenious and painstaking skill, overcoming the greatest technical difficulties which hitherto shut these unknowns from the human mind. All the resulting data are arranged in logical order and with perfect intellectual honesty. The conclusions are logically drawn and are presented in a masterly fashion, leading to a whole sequence of new conceptions and appreciations. The conception of a great hypothesis is a noble flight of imagination guided by an unfailing logic, its substantiation, an example of intellectual strategy; and its results open up an avenue by which the excursions of the mind may escape from the universe that formerly confined them. Surely research of this order stands on its own as intellectual achievement and should be accorded no less of the rights and recognition of culture than go to art, music or literature.

We must make certain reservations with regard to the cultural value of entomology. It is not contended that all the factual knowledge of entomology is of cultural significance. But in so far as the study contributes to intellectual refinement and enlightens man as to his place in nature, it certainly is of cultural significance. And in all nature there are no more available opportunities for cultural development than in the study of insects with their diverse forms and highly developed social habits. Unlike museums and libraries they are to be found everywhere.

Let us now turn our attention to the present status of entomology with respect to scholarship and culture. If science rises above the economic strife to enter the field of intellectual achievement, where does entomology stand in this realm? If we answer the question honestly, and we can not do otherwise, we must say that it does not rank very high. In hardly any country save America is it deemed worthy of a professorial chair in a university. England has one such professorship. Germany has none—and what is more, if a young zoologist were to devote himself to a study of insects he could not even hope to occupy a chair of zoology in a university. It is true that there are professors of applied zoology in forestry schools who are essentially entomologists, but they are nevertheless professors of applied zoology. Even at the University of Rostock, where a special course of study in entomology is outlined, the man in charge is a professor of applied zoology.

France has no entomology taught as such in the universities which are under the Ministry of Public Instruction. Entomology is taught in the agricultural institutes under the Ministry of Agriculture, but there are no professors of entomology. Dr. Marchal is director of the Entomological Station but his title is professor of applied zoology, and the entomology which is taught in his institute is not officially recognized by the universities of France because they are under a different ministry.

This general condition in Europe is not due entirely to the recognition of the fact that entomology is but a special branch of zoology, which is a perfectly correct view. It is due to a judgment that entomology is not on the same scholastic plane with the general field of zoology, and this view-point is not confined to Europe. It exists in America. I hold two part-time professorships in a university, and from my superior plane as professor of zoology I can look down upon myself as a professor of entomology with mingled feelings of scorn and pity. I can also reverse the process and look up with real envy to my superior position as professor of zoology. So long as my interests are as they are, it is fortunate for me that I am in this dual position. If I were in almost any country other than America and were to occupy a professorial chair at all, I would have to be a professor of zoology and "bootleg" the entomology or else leave it alone.

With regard to culture, the situation is almost worse in America but better in Europe. One of my colleagues recently surprised me by questioning whether even certain phases of general zoology could be considered as cultural, and some of my literary friends shudder at the thought of admitting science in any form into the realm of culture. Europe will probably concede us more from the standpoint of culture but possibly less from the standpoint of scholarship.

Now this is the situation and we may as well face it honestly. I have thought about it a great deal as I have visited universities and attended scientific meetings in various parts of America and Europe. Incidentally, it may occur to some of you that I have personally an easy way out of the dilemma, at least so far as scholarship is concerned, by ascending to my zoological chair. But this does not let me out of it entirely, for confidentially, I am not all there in the field of zoology, as an essential part of me is inextricably fixed in the field of entomology. This is a real, though fine, distinction, for you recognize the fact that a zoologist may study the genetics of Drosophila and not be an entomologist. In the zoologist's study of animals he may accidentally study insects, but the entomologist studies insects by purposeful preference.

It is not going to do any good to complain about the verdict that has been rendered in the field of science or culture. Let us put aside all feelings of injustice and accept the verdict as it stands. Let us examine the situation and see what has led to the present condition and then not ask that standards be lowered because of special conditions surrounding our situation, but look to the future and see to it that our achievements are such that any standard of recognition will have to accept us, not in the questionable lower levels, but fully abreast of any other branch of science.

It has been the history of the various branches of science that they have begun with qualitative observations and pure descriptions. Later, they have developed methods of technique for quantitative work and experimentation. Hypotheses have been built up and principles established that are based upon calculations involving highly technical quantitative methods. In the biological sciences the work began with description of species, habits and life histories. Later on, the development of the microscope and other technical equipment made possible the examination of more minute structures. During the Darwinian period, observations tending to uphold the theory of evolution so dominated everything in the field of biology that experimental work was almost forgotten. Quantitative experimental work in physiology, biochemistry and biophysics, which deals with the energy relations of organisms, constitutes one of the important recent developments that have found application in the fields of agriculture, industry and medicine. At the present time we have new methods, new theories and new principles rushing into literature at such a rate that most of us wonder how we are ever going to keep up with the trend of the times. It is true that many of these are fads and fashions, but many are of fundamental importance.

The mere fact that there are more species of insects than of all other animals together has resulted in more systematic work in entomology than in all other branches of zoology taken together. This great task of distinguishing and describing the vast numbers of species of insects, many of which are even now unknown, has proven not only time-consuming but fascinating. Consequently while the entomologists have been absorbed in this great task of pure description, workers in other branches of zoology have forged ahead into a more advanced field, involving experimental and quantitative methods. The great resources of entomology have proven a handicap. Lost in the wealth of material of which other branches of zoology might well be envious, it has not been able to keep pace with the progress of the day. Vast numbers of amateur workers have flocked to the field, attracted by the wealth of material. Some of these, it is true, have been actuated by the same stimulus that prompts the school-boy to collect stamps, but many others have come with true cultural desire, and they have been stimulated by the intellectual activities involved in the describing of species and the study of the habits of groups of insects. These constitute a very important element in society. They acquire a certain intellectual refinement that is difficult to get in any other way than by close contact with the facts of nature. They are a stable element in many of the European countries. It is difficult to conceive of such a group being swept off its feet by any anti-evolution propaganda. They know too well the facts of nature learned at first hand.

While entomology has made a very important cultural contribution in this way, it has, at the same time, done it at the expense of its own scholastic standing. The result is that zoologists have considered entomologists as nothing more than describers of species and habits. They have pointed out in many cases that some of the more important contributions in this line have been made by amateurs who have had no adequate schooling to qualify them to rank as scientists.

A second great resource to which entomology has fallen heir has proven not only a benefit but a handicap, that is, its economic importance. I have eliminated this from direct consideration, but we must introduce it here indirectly as an important factor in impeding the progress of scholastic work in entomology. We are in somewhat the same position as the newly rich with considerable economic prestige but not enough culture to get into the best society. An enormous army of entomologists has been called for to combat insect pests. Outbreaks have occurred that have amounted to catastrophies. Unfortunately from the scientific standpoint, there has been little correla-

tion between the type of scientific work involved and the economic results obtained in combating insects. Some of the most serious insect outbreaks were often successfully controlled by methods that would suggest themselves to any high-school boy. Entomology is not the only branch of science that has suffered in this way. The same thing has been true in medicine. Some of the earlier remedies were arrived at in a perfectly obvious way.

The fact that many untrained entomologists have been able to make marked strides in combating insects, yielding good economic returns to the public and attracting considerable attention to themselves, has caused the other branches of science to look down, possibly partly with envy but certainly partly with a feeling of scorn, at a field in which progress was made without any training in the fundamental sciences. However, as the more obvious problems have been solved and cleared away, we are approaching the time when we, like medical men, will be face to face with some difficult and involved problems which will demand the very best that our next generation can produce in the way of keen intellect, sound training in the fundamental sciences and the development of the most advanced technique for experimentation and the most refined biometrical methods for interpretation.

So it appears that entomology is behind the times, that her professionals are so indistinguishably mixed up with her amateurs that they have lost caste with the men of science. But these qualities are not altogether bad. Any large object gets under motion slowly, offers considerable resistance to the change in its course, but in the end may go farther than the smaller ones. Last summer Dr. Wheeler remarked, as we sat watching the entomologists assemble for one of the meetings of the International Congress, that he had always been interested in entomologists as such, that they seemed to have a conservative attitude that was quite a contrast to the fads and fancies that seem to dominate the zoologists, who are interested in one thing one year and in another the next. This remark was intended as a compliment to the entomologists rather than a reflection on the zoologists. But before I have finished you may have me classified as one of the erratic radicals if you have not already put me there.

The situation that confronts us is not a calamity but a great opportunity. I might have used the title "From Stumbling-blocks to Stepping-stones." The characteristics of entomology that have made its progress slow in the past are the greatest potentialities for its future. A fellow entomologist once remarked to me that he wished that he had lived in the time of Linnaeus when every species he got hold of could be given a new name. But I don't. If I were to live in any other generation than this I would rather that it would be the next one. I wish all the species were described and the keys fitted to a slide-rule that always worked.

Let us now consider the cultural potentialities which may come out of the amateur's interest in entomology. A year ago I was on leave of absence for fifteen months and had the first opportunity to think that I have had since I was promoted to be the head of a department. I saw professional and amateur entomologists in various countries and reflected upon the conditions in America, from a distance. It was my privilege to come in contact with some of the amateur entomologists of Europe. I visited them personally and saw them collectively in the meetings of their societies. I was greatly impressed with their interests and was convinced that most of them went beyond the mere collecting of insects or the mere observing of insects' habits. They reflected upon their observations. They built up a philosophy of life far above that of the average person. Some of the professionals who attended these meetings with me were inclined to treat lightly some of the questions asked and the subjects discussed by these laymen. But I took them rather seriously. I think they have a great stabilizing influence on society, and with many their interests in entomology dominated their lives. In southern France I came in contact with the late Mr. Powell, an amateur entomologist, interested in Lepidoptera. He adjusted his vocation to his avocation. He was greatly interested in the fauna of Morocco and he later moved his family there, establishing himself there for the main purpose of being close to the things he was interested in, and he died there. The story of Fabre is too well known to us all to require repeating. His influence will live for generations.

In an age that is so marked by material progress, I think we can do well to consider the cultural progress at the same time. We are told that the rapid increase in the use of machinery in industry is going to free men for greater leisure. But what are they going to do with their free time? From the appearance of our parks, boulevards and trunk highways, most of them spend their time in driving around, and about as many are going in one direction as in the other. Dr. Friederichs tells me that the interest in the study of nature and other cultural activities in Germany is giving way to an interest in athletic sports. I was much impressed by Germany's interest in athletics for personal physique but I think it would be a mistake for this to develop to the exclusion of an interest in cultural activities.

In America I believe that this situation is serious. We have, in general, the material well-being that is necessary as a foundation in culture, for culture does not thrive with want and suffering. But as we are being freed from our physical worries are we becoming interested in cultural subjects? In entomology, with its wealth of available material, there is a great opportunity to stimulate our citizens to study nature for the sake of its cultural values. Our local, state and national parks can become something more than areas to race through in automobiles, and our own back-yards can become fascinating places in which we can spend delightful and profitable hours in studying the nature of which we ourselves are a part. The small entomological societies composed of amateurs are a very stimulating factor in this connection. Their contributions to science may not amount to much, but their contributions to the human welfare and culture may amount to a great deal. It is true that there will be a certain strain upon professional entomologists by way of answering questions or lecturing. But I think we need not worry about losing caste by contact with them any more than the teacher may be dragged down by his pupils. They may be a stimulus rather than a hindrance. It is not ours to forsake society and withdraw into a hermitage. If we believe as much in democracy as we say we do we shall have to indicate it by our acts.

Now let us consider the potentialities of entomology in the realm of scholarship. We find ourselves classified as in a descriptive science for reasons that I have already given. Perhaps we will never be through with the describing and perhaps we should never be through with it. One of the fundamental questions before us in the field of biology to-day has to do with how new species arise, and we probably have derived as much information, or more, from the study of insects as from any other group of organisms, in making progress on this question. You may say that the entomologists are not the ones who made the contributions. Zoologists borrow the insects for the purpose of genetical study. Many important problems of the more advanced type have resolved themselves out of the field of entomology and more will follow in the future. If an investigator studies the physiology of insects he comes into closer contact with other physiologists than with other entomologists, and he soon finds himself a physiologist. Similarly, one who is devoted to the study of the genetics of insects soon finds himself in closer relationship with other geneticists than with other entomologists. This will probably always be true; probably it should always be true. If, out of the great army of describers, there come forward only a few individuals who become leaders in making contributions to our knowledge of the origin of new species, whether they later become geneticists or physiologists or biophysicists, entomology will have made a contribution of which it may be justly proud.

Turning our attention now to the hosts of people who are describing life histories, we find an ever-increasing number of students coming for graduate work who say that they are principally interested in life history studies. This is an appealing type of work and its elementary stages require very few prerequisites. But if one goes far in this field he comes up against some of the most fundamental problems, which rest basically upon the fundamental sciences. I believe it is safe to say that one of the greatest perils our modern students face is that they build their pinnacle of information so high that it begins to topple for the want of a solid basic foundation. When I was making up my program as a freshman in college, I took it to my adviser, and he called my attention to the fact that the mathematics I had included was not necessary, as I was going to major in biology. And now I would be willing to trade forty-five credits of any of several spare subjects to any one who would deliver to me the equivalent in mathematics.

The field of ecology in which I am personally interested is rapidly becoming complicated. On the one hand, we are pushing into the field of physiology for information on physiological effects and responses, a field that has been altogether too much neglected by entomologists—one that is almost unlimited in its possibilities but that demands good training in the fundamental sciences in order to make significant contributions. On the other hand, we are pushing into a newer and no less significant field of biocenosis, which deals with the systems of populations and the effects and the responses involved with physical and biotic factors. In this field we stand in the same relative position occupied by physical chemistry before Willard Gibbs made his great mathematical contribution that forms the basis of that branch of science. Entomology has the natural resources for making the greatest and most leading contributions in this field of ecology. Here, again, I fear that there is a tendency for the economic importance of the subject to run away from the scientific importance. We have for a considerable time realized the importance of parasites in controlling insect populations, but we have no fundamental information as to the trend of the populations of hosts and parasites, prey and predators, or as to the effect of physical factors on the trends of these populations. Fortunately, Dr. Vito Volterra, professor of mathematics at Rome, has

become interested in biological fluctuations and has issued a series of publications, outlining from the standpoint of a mathematician the trend of populations beginning with simple cases where two species contend for the same food, and then adding a factor at a time until a complicated association is built up, including the possibilities of forcing and damping the fluctuations by physical factors. From these calculations he has deduced certain laws that govern the cases where certain assigned coefficients apply. This work, I believe, is destined to take its place along with that of Willard Gibbs so far as significance in the field of science is concerned. Here, then, is a great opportunity to show that these mathematical theorems do or do not apply in the field of nature. It is a wonderful opportunity and I wonder if we are equal to it. We are dealing with populations in which organisms are units just as the physiologist deals with organisms in which organs, tissues and cells are units and as the physical chemist deals in systems in which colloidal particles, molecules, atoms and electrons are units. It is infinitely complicated and infinitely fascinating.

To summarize, we have in entomology a wealth of material and it has taken us a long time to get over some of the more elementary stages in our progress, but the great extent of the field is one of the most promising things in our science. The character of much of this material is such that it is destined to aid greatly in bringing to the public in general an appreciation of nature, thereby making a great contribution to our cultural life. But our age is moving pretty rapidly and, if we are going to get this before the public and see that our society maintains its well-balanced poise, we must all of us be active. Those to whom entomology is an avocation must take the obligation seriously to see to it that society, in its enthusiasm for material progress, does not forget some of the finer things of life.

In the field of scholarship our future is bright. No one can deny the wealth of material at our command, and I believe we have no reason to feel ashamed of the records of the past. Let us not spend any time in denouncing the verdict as to the scholastic position of entomology at the present time. Let us see to our own attitudes rather than decry the attitudes of others. It is difficult to maintain our scientific poise against the enormous economic pressure that comes upon us, but let us do it at all costs, knowing full well that it is in scholarship that our ultimate salvation lies.

Let us look to our scientific spirit. It has been my conclusion, after visiting many of the entomological laboratories of Europe and America, that the one most important factor for scientific progress is the spirit of the research man himself. Given a certain threshold value of material laboratory equipment, beyond this there is nothing that determines the significance of results more than the spirit of the man who is doing the work. And how costly is the petty administrative dictation which dampens such spirits and thereby deprives science of the most precious acquisitions of a laboratory! If this is true of individuals, it is certainly true of groups.

Even scientists themselves become enemies of progress when there is strife between them. One of the most discouraging tendencies of scientific progress is that of the crowd to down the man who steps out in advance, regardless of who or where he is. This does not imply the exclusion of friendly rivalry or the suppression of criticisms of questionable hypotheses. It is a plea for both individualism and cooperation in research and, above all, intellectual honesty in the spirit of research. Remember that when facts are accumulating for or against a hypothesis they are not accumulating for or against its author. If he is intellectually honest, his hypothesis is a tool for progress which is gained by proving or disproving it.

So in this day of organization and super-organization, of budgets of money and budgets of time, of teaching loads and weighted credit hours, of research project statements and reports, and even of achievement tests, I still say that the most important thing in scientific progress is the spirit of science itself. My recommendation for the progress of entomology is to turn absolutely free in the field all such great spirits that can be found, unburdened by the regulations of organizations, with no dictation as to the form of the final report, but with infinite trust in the spirit of research.

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SCIENTIFIC EVENTS

THE NEW HARVARD CHEMICAL LABORATORIES

THE formal opening of the Mallinckrodt and Converse laboratories was held last week, when the donors were entertained at a reception and dinner. Among those present was Mrs. Edmund C. Converse, widow of the late president of the Bankers Trust Company. Mrs. Converse and her family gave the Converse Memorial Laboratory in memory of her husband. Mr. Edward Mallinckrodt, Jr., represented his father, the late Edward Mallinckrodt, of St. Louis, who gave the first large sum, which made the new laboratories possible.