is rather of economic importance than of pure science, since it has to do with the transfer of the plant-food elements from one place to another, and their loss, in so far as our own country is concerned. It is a problem which has been but lightly touched upon, though many have recognized its significance. We are exporting in whole grains, and in waste materials from our oil and starch factories, enormous quantities of human and animal foods, for which we receive a return only in proportion to nutritive values, whereas these products carry enormous quantities of constituents from our country. The problem here, as already stated, is not a problem so much of investigation as it is an exploitation of the facts, and the education of the people as to the possible ultimate effect. The agricultural chemist must stand as the conservator of the nation's wealth; he is the one whom others seek for definite information, and for guidance, and it is his business to so direct the attention of the people as to prevent an undue loss of our fertility elements.

There is no doubt but that by careful adjustments of trade conditions it will be possible to obtain quite as much money for our surplus products as is obtained at the present time, without having the practise result in so great an annual loss of our plant-food constituents. The problem is not an easy one to solve, though I am sure that with the earnest study and support of our agricultural chemists, it will be solved in a manner that will result in the best good to all. It is an important question, and one which I hope our chemists will regard as worthy of their study.

I am well aware that in this brief paper, which was purposely made general in its character, I have done little more than to point out some of the reasons why the conditions have not been favorable thus far for such work as seems now to be needed, and to suggest lines of investigation, without being specific as to the methods by which they should be carried out. Nevertheless, the few facts stated are patent to all who have given the subject thought, and are sufficient to indicate the importance of a broad and detailed study of the whole question of soil fertility. The field is now largely unoccupied, and there is a growing demand for broadly trained investigators, and there is no field of investigation more promising of fruitful results for the investigator and the country at large. Our professors of chemistry and our colleges and universities should cooperate in providing such opportunities for study as shall fit them to pursue this attractive and important line of investigation.

E. B. Voorhees.
New Jersey Agricultural Experiment Station.

THE TEACHING OF SCIENCE IN COLLEGE.[1]

I wish to call attention to a situation which seems to me unnatural and unfortunate. It is unnecessary to present it in statistical form. No one will question that science in the colleges of this and other universities has not the importance and popularity that it should have, that this element of our modern education is by no means represented in the results of education in accordance with its importance.

It is not, however, to the failure to elect scientific courses as they are to-day or to enroll themselves for science degrees on the part of our students that I think especial attention should be directed. Nor do I think that we can explain this and other evidences of the deficiencies in this regard by the traditional prestige of the so-called humanities, or the prejudicing of the stu-

[1] Address delivered before the Chicago Chapter Sigma Chi, March, 1906.

dents' minds by preparatory courses inimical to scientific interest.

Scientific courses have not become popular as the old requirements in the languages have been decreased. It is rather the other courses such as the Ph.B. that have profited by the greater freedom of election. With considerable freedom of election in the preparatory schools the scientific courses are not sought out there by the children at a period when the concrete subject-matter of science properly presented should be immensely more attractive than the languages and many more abstract objects of study. The science courses in the high school are not at the present time popular, nor is the money spent upon them, either in equipment or in teaching force, comparable with their educational importance.

The result of this is that the majority of our students leave our colleges and universities, without being able to grasp the most important achievements in modern thought, without being able to take the point of view of those thinkers who are reconstructing our views of the physical universe and its constituent parts, and without being able to interpret what they see and hear and feel by means of the profoundest and most magnificent generalizations which the world has ever known.

I wish to present two reasons for this condition which seem to me more fundamental than those usually presented, and to discuss in connection with them the possibility of removing them or at least to invite discussion on the subject.

It is natural to compare the sciences so-called with the humanities. And yet in one respect the distinction between them has much decreased of late years and promises to continue to decrease. The method of study of the languages, history, literature and the so-called social sciences has become to a large degree that of the natural sciences. There is certainly no fundamental distinction between the researches of the historian, the philologist, the social statistician and those of the biologist, the geologist or even the physicist and chemist, in point of method. Each is approaching problems which must be solved, and to be solved must be presented in the form of carefully gathered data. For their solution hypotheses must be constructed and tested by means of experiment or observation. With the complexity of the phenomena, of course, the application of the scientific methods will vary. The processes of observation, for example, will vary enormously in the study of a historical problem in the ancient world, and in the study of the problem of variation where the material is immediately at hand. The methods of historical criticism—lower and higher—are nothing but methods of observations under conditions which are peculiarly difficult of access.

While it is true that in literature and other arts we do not go back of the esthetic reaction in the judgment of beauty, or the study of this reaction in others as presented in literary criticism; outside this field of appreciation and criticism, the methods of study in the field of the humanities is just as scientific as the subject matter with which it deals allows.

This means for one thing that we no longer regard the acquirement of information as the legitimate object or method of education. The ideal of modern education is the solution of problems, the research method. And this research method is no less dominant in the humanities than it is in the natural sciences so far as the subject matter permits.

The ground for the difference in attractive power of the natural sciences and the humanities can not be laid up, therefore, to a difference in method. And if it could the prospect would be discouraging indeed

and the judgment upon the students most unflattering, for the research method is, after all, nothing but the elaboration of the simple processes of perceiving and conceiving the world, elaborated in such a way that it can be applied to the complex and subtle problems of the physicist, the geologist, the biologist, etc. If the scientific method were the cause of unpopularity we should have to assume that the process of knowledge itself, the very function of cognition, was disagreeable to the average student.

If, however, we examine these two types of studies we do meet a distinction which holds for many if not for all. In the physical sciences the process of investigation involves the analysis of the objects, which are studied, into elements which are not present to immediate experience and which are with difficulty conceived and presented to the mind. The resolution of nature into atoms and molecules or corpuscles is an undertaking presenting itself at the beginning of scientific investigation, that is not forced upon the social sciences. Here the elements into which analysis reduces its objects are at bottom, but more or less reproducible states of our own consciousness, or still more direct objects of possible sense-perception. This was a difficulty that did not inhere in the old-time natural history. There the problem that aroused investigation was stated in terms of everyday experience, and for this very reason natural history was a more successful subject in the curriculum than our physics and chemistry. Its problems were real problems in the minds of the students. They were not located in a field as yet foreign to their acquaintance and, therefore, artificial and unmeaning.

The problems of biology and geology do not suffer as much from this remoteness, for to a large degree they can be stated in terms of a possible immediate experience of the student, and it is true that they make a more immediate appeal to the student than do the physical sciences. But it must not be forgotten that these biological and geological sciences are to no small degree applied physics and chemistry, and that this tendency is steadily increasing. That is, it is increasingly difficult to state the problems of these sciences in terms of immediate experience; their problems do not arise of themselves in the consciousness of the student, in other words, he is not immediately interested in the study.

We can generalize this in the following form: the result of the development of our sciences has been that their problems are no longer within the immediate experience of the student, nor are they always statable in terms of that experience. He has to be introduced to the science before he can reach the source of interest, *i. e.*, problems which are his own and which he wants to solve by the process of his own thinking.

On the whole, the problems of the social sciences have a meaning to the student when he meets them, *i. e.*, they can be his own problems from the start, and they do not have to be translated into terms which must be somewhat painfully acquired before they can be used.

In a certain sense mathematics has become the language of the physical sciences, and the student must have a command of this vernacular before he can read with interest that which is writ in the sciences, before he can attack their problems. But even where the vernacular of the science is not that of mathematics, it is still true, to a large extent, that the field of the real problems in the science lies outside of the direct experience of the student.

It hangs together with this, in the second place, that the natural sciences are not interconnected in the minds of the students, that they exist in water-tight compartments. There is no common field out of which they all spring. It seems to me that

in this lies the great advantage which the humanities so-called have over the natural sciences in the curriculum. They all of them belong to one piece of human experience, and it remains true *nil humanum mihi alienum est,* not simply because of the immediate human sympathy which unites men and women who are distant not only in space, but also in time, not only in speech, but also in state of civilization; there is a still more important hold which the social sciences and humanities have upon the interest of the student. It is that human history, human development, human institutions, its arts, its literature, its achievements, are so bound up together with each other, with the languages in which thought has been expressed, with the literature in which achievements have been recorded, with the movements of trade, commerce, colonization and discovery which have motived historic changes, that wherever one begins, problems of all sorts arise at once, interlacing with each other, so that the pursuit of one subject reinforces the interest in another, and *vice versa.* The whole group represents one social world which can not be picked up piecemeal nor divided up into separate compartments, but is bound to exist in the mind as a whole.

This is not simply an advantage of an external sort. The logician tells us that, if we would expand it, the subject of every judgment would be found to be the universe itself, individualized in some immediate experience, but implying the whole world in its implicit relations. If we express this somewhat more modestly it would run, in educational terms, that it is only the implicit relation to other things that makes any subject teachable or learnable, and that the more evident and more pregnant these relations are the more readily is it assimilated. In a certain sense the more complex a thing is the more readily it is acquired, while its simplicity leaves it bare, without lines of connection, without retaining points. Of course this would not be the case if education were merely a process of storing away, a process of piling learning into the mind. But as the theory of science instruction, as well as scientific advance, is that of research, it is evident that the richer an object is in relation to other things the more suggestive it will be of solutions for problems, the more fertile it will be in arousing associations of kindred data. To bring out a problem then in a field which is already rich in interest is to insure not only its immediate attractiveness, but to provide the ideas and connections through which the problem may be studied and a solution reached.

It is this wealth of associations, this complex interrelation with a mass of other things, which the student fails to secure when he is introduced to modern science, through one door at a time, and that door leading into a specialized subject-matter whose relations with immediate experience are of the slightest character. A new subject should not be presented by itself, but in its relation to other things. It must grow in some fashion out of the student's present world.

The problem of college science is, therefore, very intimately connected with science in the secondary school. If the child were introduced to it in the proper way there the situation, which has just been described, would not exist in the college. He would come up into the college with the world of science already in existence, and that world as a field of his own experience. He would find problems arising there for whose solution he must look to the more specialized sciences. But the opposite of this is the case. Science in the high school, at the present time, is in a more parlous condition than it is in the college, because the child is farther away from the field of exact science

than in the later college years. He finds fewer points of connection. His sciences remain for him located between impassable barriers. The college, therefore, at least until a reform can be wrought in the secondary school, is forced to face the problem within its own walls.

Its solution calls for introductory courses which will lead the student into the field of science, which will show the problems of his own experience in terms of this new field, and show them there capable of solution. There are two points of view from which such courses could be naturally presented; that of history, and that of a survey of the world analogous to what is given in introductory courses in sociology or social institutions.

The peculiar appropriateness of a course in the history of science for the junior college students, lies in the fact that the special character of modern science would grow out of the conditions that made it natural and necessary. There would be in it the inspiration of the personalities of the great scientific men, and the romance of their struggle with difficulties which beset their sciences from within and without. The conceptions of to-day would be found motived in the struggles of yesterday. But still more important the relations which have subsisted between scientific investigation and the whole field of human endeavor would appear—its relation to commerce, industry, the geographical distribution of men, their interconnection with each other, and the other sides of their intellectual life. Science would be interwoven with the whole human world of which it is actually a part. It is true that something of this is found in general history. It is there, however, presented not to lead up to further study of science, but to merely fill out the entire picture—a picture which is so crowded that many features are bound to be slighted, and among those which are slighted, science, just because it is a subject somewhat apart, is sure to be found.

We have of course the evidence of the import which such a course would have in the biographies of our scientific men—such as Darwin, Huxley, Pasteur, von Helmholtz. But few of our students in that period read them, and taken by themselves they do not have the educative power which the story of their efforts would have when presented in a course on the history of science. It is not, however, principally the personal note, which comes from the account of the men who have been the heroes of science, that would be found in such study. It is rather the form in which the scientific problem arose and the methods used for its solution which will carry the most valuable instruction. One scientific theory swallows up into itself what has preceded it, and the traces of the situation out of which the later doctrine arose are washed away. While our historical atlases present us in flaring colors the political situations out of which sprang present political conformations, the young student of science must pick up, as best he may, without assistance or interpretation, the explanation and historical interpretation of the conceptions he is forced to use. If an adequate comprehension of the powers of the American executive can not be gained without a knowledge of the situation which preceded the formation of the constitution, no more can the uninstructed student comprehend the value of such terms as forces, energies, variations, atoms or molecules without understanding what the problems were which brought forth these hypotheses and scientific conceptions.

And there is no study like that of history to bring out the solidarity of human thought. The interdependence of scientific effort and achievement, and the interrelationship which exists between all science in presenting its world as a whole, can be

brought out vividly only when its history is being presented, while in the midst of the arduous struggle with a single science these profound connections are quite overlooked. It is a fact that science is, from an important point of view, a single body of knowledge, whose different parts determine each other mutually, though this mutual influence is often overlooked. When the historian comes forward with the picture of a past age, such as Gompertz has given us in his 'Grieschische Denker,' we recognize these interconnections and see that what has been done in one line has been now advanced because of the achievement of another, and now has been thwarted by the backwardness in still another. The Weltanshauung of any age is at once the result of all its scientific achievements and a cause of each, by itself. We can not finally understand any one without the comprehension of the whole, and it is the whole which is more comprehensible than any single science. It is a great deal easier to present the problem of evolution in the world as a whole than it is in the specific instance. It is easier to recognize the problem of matter, as it is presented in the book entitled 'The New Knowledge,' than it is to present the specific problem with which the physicist or chemist must wrestle. It may be a Hegelism, but it is good educational doctrine that the whole is more concrete than the part. A student who has first followed out the results of scientific evolution through the preceding centuries in their interconnection with each other, and meets then the problems of modern science as the growing points of the past, who understands somewhat what the controlling meanings are behind scientific concepts and terminology, who feels that he is entering into a battle that is going on, whose field he has surveyed before he has lost himself in the particular brigade, such a student is bound to enter into his study with both a comprehension and an interest which his brother will lack —his brother who must get the parts before he can have an inkling of the whole.

I am aware that, in the minds of a great many of you, there has arisen a spirit of contradiction to what has been presented, a spirit of contradiction which arises out of the very competency and exactness of the scientist. Such a type of instruction as that suggested above is felt to be superficial, inexact, and bound to be misleading to the person who is not scientifically trained. It would be information in a word, and the scientist does not hold it to be his position to impart information, nor can he promise any valuable educational result from a course whose content is one of information.

I wish to bring out the point because it seems to me fundamental to the question which has been broached. We need, in the first place, a definition of what information is and what knowledge is, as distinguished from it. I would suggest toward such a definition that nothing is information which helps any one to understand better a question he is trying to answer, a problem he is trying to solve. Whatever bridges over a gap in a student's mind, enabling him to present concretely what otherwise would have been an abstract symbol, is knowledge and not mere information. Whatever is stored up, without immediate need, for some later occasion, for display or to pass examinations is mere information, and has no enduring place in the mind. From this standpoint nothing is superficial or inexact which gives concreteness and meaning to the problem before the student. Truth is a relative thing. We none of us have exact knowledge in the sense that our knowledge is exhaustive, and we none of us know the full import of what we do grasp. There can be no objection to the young student having a broad if seemingly superficial view of the scientific world, if it helps him to approach with

more understanding the particular science he has before him. It is also certainly the pedagogic duty of the instructor in science to get far enough into the consciousness of the student to present the part to him by means of the whole.

The second point of view suggested for approach to the specialized study of science was that of the survey of the present field. If we can find the counterparts of the historical course in the biographies of great scientists, we can find that of the survey course in such treatises as the popular lectures of eminent scientists, such as those of Tyndall on 'Sound,' or many of the popular lectures of men like von Helmholtz, du Bois Reymond and a score of others. We highly approve of such lectures when they appear on the lyceum or the university extension platform. We encourage the reading of such books, considering them distinctly educative, but we deny that they have a place in the university curriculum. The prevailing assumption is that when one can not follow out the scientific process by which the results are reached, it is indeed better that he should have the result presented in a form which he can understand than not to have them at all, though it is not the place of the university to perform this function, except through its extension department. This statement, however, overlooks the fact that such acquaintance with the results of scientific research is also the source of interest in the research itself. What is merely keeping up with the progress of the world on the part of the business man is preparation for the student who has to approach a new field. I presume that no one would question that those who had listened with intense interest and enthusiasm to an extension lecture upon the solar system would be better prepared for the study of astronomy. Indeed, we assume that university extension will serve in this fashion as a feeder of the university, but for some reason we feel that this same sort of preparatory work has no place inside of the university itself. From the point of view of education we are mistaken, for nothing is out of place which makes the approach of the students to the subject-matter a normal one. And until the student feels the problem of the science he undertakes to be a problem of his own, springing out of his own thought and experience, his approach is not a normal one.

One or two courses, then, from the standpoint of the history of science, and from that of the survey of the scientific field of to-day in the junior college, would organize the vague information of the student, would correlate it with the political and literary history with which he is familiar, would give him the sense of growth and vitality, would state the problems of science in his own terms, and awaken in him the passion to carry on the investigation himself which might otherwise remain dormant. They would be feeders to the specialized scientific courses that follow. They would break down the prejudice which most students bring against science from the high school. But not least, they would be as educative as any course in history could possibly be. They would serve as valuable a function as those courses which aim to acquaint the student with the social and political forces which dominate the world into which he is to enter.

What has been said so far has borne directly upon introductory courses in the junior college. It is only in the last remark that I have touched upon the demands which the university may make upon its scientists for the interpretation of the world for those who do not follow its special courses. If in the present day, under the sign of science in nature and society, any one leaves an institution of higher learning without a comprehension of the results of science, which he can grasp

in their relationship to the rest of human history and endeavor, he is certainly cheated out of one of the most valuable of the endowments which he has a right to demand from that institution. As I have already indicated, scientific method is dominant not only in the study of nature, but in the study of all the social subject-matters, in religion, politics, in all social institutions. Scientific discoveries have made over the answer even to the fundamental question of who is my neighbor. Science is responsible for the view of the universe as a whole which must be the background of our theology as well as our philosophy and much that is finest in our literature. Science has changed sentiment to intelligence in divine charity, and has substituted the virtue of reformation of evil for that of resignation thereto in religion. And yet a large percentage of our students leave the university without having any better opportunity of coming to close quarters with this science than those who are outside the university. They are compelled to get their science from the extension platform, or from the popular magazine. There should be unspecialized science for those who do not specialize in science, because they have the right to demand it of an educational institution.

There is still another demand that should be made upon the science faculties of the university, and that is that they should so organize the courses which their students take, that they will get the unity which every college course ought to give.

That unity of the social sciences which is given in subject-matter and human nature itself, is, as has been pointed out, absent from modern sciences which have become largely what Professor Wundt calls conceptual sciences. The interconnections are not apparent to the students who are in the special groups. Their attention is fixed within too narrow boundaries, the demands of their own subject is so great that they have no time to go beyond. They have a wealth which they can not realize because they can not put it into circulation.

Through the history of science, especially of the other sciences which they do not specialize in, through lecture courses which give them the results of these other sciences they should be able to get the unity of Weltanschauung, which is requisite for any college course.

It is requisite at the end as at the beginning that the student should see his world as a whole, should take up into it what he has acquired, and should get the mutual interpretation which the relation of his subject-matter has to what lies beyond it.

There is certainly no agent that can carry more profound culture than the sciences, but our science curriculum is poor in what may be called culture courses in the sciences, and the import of science for culture has been but slightly recognized and but parsimoniously fostered.

GEORGE H. MEAD.

SCIENTIFIC BOOKS.

An Introduction to Astronomy. By FOREST RAY MOULTON, Ph.D., Assistant Professor of Astronomy in the University of Chicago. New York, The Macmillan Co. 1906. 8vo. Pp. xiii + 557; 201 figures, including 50 photographic illustrations. $1.25.

This book is an elementary, descriptive text, suited to those who are approaching the subject for the first time, and from this point of view the selection of material is quite satisfactory, though not always presented in logical order. At the outset Professor Moulton gives a preliminary outline of the entire subject, followed by chapters which treat in greater detail of the topics usually considered in elementary works, such as systems of coordinates, the constellations, the classes and uses of astronomical instruments, and the leading facts and theories relating to the various bodies composing the solar and sidereal systems.